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Public skies: telescopes and the popularization of astronomy in the twentieth century

Gary Leonard Cameron
Iowa State University

Public skies: telescopes and the popularization of astronomy in the twentieth century

by

Gary Leonard Cameron

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Program of study committee:
Amy S. Bix, Major Professor
James T. Andrews
David B. Wilson
John Monroe
Steven Kawaler

Iowa State University

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Forward and Acknowledgements

My first telescope was a Christmas present in 1974: an imported 2.4-inch refracting telescope. Within a few years, I became an active member (the youngest at the time, I believe – age 14) of the Des Moines Astronomical Society. I never lost my interests in astronomy, but there has been a certain 'evolution' in them. I took astronomical observing fairly seriously from an early age: I still have a number of sketch-drawings of the moon, planets, nebulae, and galaxies as seen through the assortment of telescopes I've owned over the years. I was a frequent attendee of amateur astronomy conventions held all over the United States, and got to know a number of leaders in the American amateur astronomical community, as well as commercial telescope manufacturers, vending their wares in the convention exhibit halls. I even participated in the hobby of amateur telescope making, and produced a number of good instruments. Thus, the subject of this dissertation, the role of telescopes in the popularization of astronomy, is very much something I personally experienced.

I would like to thank my major professor, Amy Bix, as well as my committee members, James Andrews, David Wilson, John Monroe, and Steve Kawaler. I would also like to thank the staff at the Smithsonian, particularly those at the National Museum of American History Archives and Library, and all the members of the Antique Telescope Society, Tom Williams in particular. Finally, I would like to thank my friends Allison, Lori, Mike, Kaya, and Sara, my sister Viki, brother Randy (who bought me my first 'Christmas telescope'), and my mother Ruth, whose patience and encouragement meant so much, and whom I greatly miss.

Dissertation Abstract

Sputnik and the 'Space Age' have been cited as major factors in the growth of amateur astronomy in the 20th century. However, although the growth of popular astronomy magazines, public planetaria, and the popularity of science fiction contributed to the popularization of astronomy, I contend that the greatest growth in amateur astronomy coincides more with the availability of inexpensive telescopes after World War II.

Circa 1900, the average purchaser of an amateur-grade astronomical telescope was a wealthy doctor, lawyer, or the like. Hand-crafted refracting telescopes made by such firms as Alvan Clark & Sons, maker of telescopes for professional astronomical observatories, were the ideal. Even relatively small instruments, of only 3-inch aperture, cost the equivalent of $3,000 today.

A series of articles appeared in *Scientific American* in 1926 providing detailed instructions on making Newtonian reflecting telescopes. The articles, the work of two 'technological cheerleaders', Russell Porter and Albert Ingalls, proved popular. The resulting home-made telescopes were effective instruments, but cost a fraction the price of a commercial telescope of similar size. By 1940 there were at least 30,000 active amateur astronomers and 'ATMs' (amateur telescope makers), of diverse social classes, in America.

The Second World War created an opportunity for ATMs. Modern war requires all kinds of optical instruments, and the government was eager to find skilled workers to produce them. World War II became an 'advanced school' of telescope making where ATMs learned mass-production methods. ATMs founded a host of new telescope making

companies in the 1950s using mass-production techniques to produce modestly-priced astronomical telescopes: Newtonian telescopes in the 3 to 4-inch range sold for as little as $25 ($150 today). These telescopes were marketed in the same way as automobiles, TVs, and other consumer products. Countries outside the United States never experienced the 'ATM movement' in any major way, nor shared American production techniques. Only Japan adopted the same methods as American commercial telescope manufacturers in the 1950s. Huge numbers of small, mass-produced telescopes were being exported from Japan by the late 1950s, and hundreds of thousands of average Americans were involved in amateur astronomy by 1960.

Chapter I: Introduction

1. General introduction

The year 1910 saw one of the most high-profile events in modern astronomy to that point: the much heralded return of Halley's Comet. Newspapers and magazines across America and elsewhere contributed a good deal of 'hype' to the event, not all positive and some of which caused panic among the public. Much the same thing would occur 76 years later on the next visit of Halley's Comet, but with a significant difference. The mid-1980s event saw a major sales campaign among commercial telescope manufacturers tied to Halley's return that was totally lacking in 1910. The reasons for this difference have to do with tremendous changes, not so much in efforts at astronomy popularization in the mass-media, but in the nature of the hobby of astronomy and in telescope manufacturing and sales technique. The typical amateur astronomer of 1910 was a member of the well-to-do professional elite of American society, and telescope manufacturers were there to cater to them. No crude and utilitarian instruments for these lovers of science: only the finest in precision, hand-crafted, brass, steel, and glass would do. In 1910 astronomy was either one of two things: a profession for trained scientists or a hobby for the educated well-to-do. The general public did have an interest in astronomy. Popular-level books on astronomy were many, and went through many editions and reprints. British astronomy popularizer Richard A. Proctor's *The Expanse of Heaven* went through three editions by 1879 and American astronomer Simon Newcomb's book, *Astronomy for Everybody*, first printed in 1902, was still in print in 1926. Books do not stay in print if no one is interested in the subject-matter. Most people had to be content to read books, articles in encyclopedias, popular mass-market magazines such as *Collier's*, or newspapers, to get their astronomy 'fix'. There was a latent interest though, even a yearning, for first-hand knowledge and experience. 'Open-houses' at college and public observatories were well attended and itinerant Victorian 'sidewalk astronomers' did considerable business letting working-class people look through telescopes 'for a penny a peep'. However, the economic realities of telescope ownership restricted the numbers who could participate directly in astronomy to at most a few thousand across the globe.

By 1960, the hobby of astronomy had changed significantly. Although still more than pleased to hear public lectures or read articles and books by famous professional astronomers, amateur astronomers were doing more than just passively participating in astronomy. Amateur astronomers were directly involved in observational, telescopic astronomy to an extent not seen before. Some were doing research, making observations of the planets and variable stars. Others were educating school children and the general public. Amateur astronomers were heavily engaged in activities that seem similar to those their predecessors had done earlier. The great difference lay in who was doing astronomy and how many were involved. Ordinary people of modest means were now actively involved in observing in the tens of thousands, perhaps hundreds of thousands. It is true that there were larger numbers of outlets for astronomy popularization in 1960 than in 1910 such as more astronomy-specific magazines and books, TV and radio, and public planetariums and observatories. Sputnik had been launched, and man had entered the 'Space Age'. However, the key change for Americans was the vastly greater availability after the Second World War of inexpensive, but high-quality, telescopes.

Prior to about 1950, telescopes were individually hand-crafted, precision instruments of great expense. They were thus something only a member of the professional, educated middle-class could hope to own, and the few exceptions tend to prove the rule. The period between 1910 and 1960 was a crucial transitional period in the history of amateur astronomy where the 'sub-hobby' of amateur telescope-making became a rage in the United States. The 'amateur telescope makers' of the 1920s and 1930s (self-titled 'ATMs') provided a bridge for those passive proto-hobbyists of 1910, those with an interest but not the means, to those of 1960 who now had the means as well, thanks to the amateur telescope-makers themselves. It was the ATMs of America who would found a whole new group of telescope making companies in the wake of World War II using mass-production and mass-marketing techniques to make possible a telescope under every Christmas tree.

Amateur astronomy prior to the 20th century was a rich man's hobby. Around 1910, the average purchaser of an amateur-grade astronomical telescope in America was a middle-aged, successful businessman, doctor, lawyer, or the like, in other words someone with time on their hands and money in their pockets. By 1960 however, practically anyone could afford to buy a telescope. This change coincides with a dramatic increase in the numbers of organized astronomy clubs in America, growing from perhaps two dozen in 1910 to over two hundred by 1960. Changes occurred in the types of telescopes being made, as well as production methods, advertising, and sales techniques. Although there were many reasons for the growth of astronomy as a hobby in America, the increasing availability of inexpensive astronomical telescopes over a half century is particularly important.

My object is to show that the shift in commercially-made instruments from expensive, individually hand-crafted telescopes to inexpensive, mass-produced (or at least quantity-produced) telescopes created a major opportunity in America for the conversion of amateur astronomy into a mass-hobby. There were without doubt a number of contributing factors to the popularization of astronomy in the twentieth century. Popularizing science was increasingly important for scientists increasingly dependent on public funds for research. Science was fascinating to many in the general public as demonstrated by increasing readership of books and magazines on science, technology, and even science fiction. Although factors such as the growth of astronomy magazines like *Sky and Telescope* and the establishment of public planetaria certainly contributed, I contend that the greatest increase in growth of amateur astronomy coincides more with the availability of inexpensive yet reasonably good quality commercially produced telescopes after the Second World War.

Another issue is how amateur astronomy itself changed because of the very availability of telescopes. In 1910 the amateur astronomer almost *had* to be a 'serious' research oriented individual; the economic investment in a telescope was so huge as to demand it. Certainly there must have been "the idle rich" who could afford a telescope for watching yacht races, but such persons were generally *not* amateur astronomers. By 1960 a huge economically-based demographic shift had occurred. Amateur astronomy had become in great part 'recreational' and far more egalitarian, to the point that many professional astronomers began to dismiss amateurs as 'amateurish'.[1] An additional

[1] This is a change also noted by astronomy historian Thomas Williams. See, Thomas R. Williams, "Getting Organized: A Survey of Amateur Astronomy in the United States," (Doctoral dissertation, Rice University, 2000): 1–3.

demographic shift occurred in terms of age and sex. The vast majority of those calling themselves 'amateur astronomers' in 1910 were adult males (indeed, white males). By 1960, increasing numbers of women and children were getting involved; a survey conducted in 1957 found that fully half of amateurs belonging to a regional astronomical society in the Midwest were either junior high-school, high-school, or college students.[2] The new crop of telescope manufacturers following World War II increasingly targeted families as customers.

How was amateur astronomy in America different during this time than elsewhere in the world? To a certain extent, it was a difference more of degree than kind. That being said, American amateur astronomers have tended to be far more independent-minded than their counterparts elsewhere, for instance waiting until 1941 to establish a nation-wide astronomy organization, 50 years or so after similar groups were formed in Europe. Having one's own telescope was an important part of the American amateur astronomer's hobby and was a reflection of American attitudes, much like the importance of possessing one's own house or car.

Telescopes underwent a long period of technological development prior to the 20th century. Different types of telescopes were designed, tried out, and improved upon. Different materials and means of fabrication and testing were experimented with. Each improvement made to telescopes was due in part to amateur astronomers and amateur telescope-makers. The sum-total of these complicated technological improvements led to the perfection of techniques later utilized by ATMs in the 1920s and 30s. However,

[2]James E. King, *Resource materials for teaching astronomy in general science classes and science clubs with emphasis on the study of astronomy as a hobby*, (Master's thesis, Iowa State Teacher's College, 1957)

communicating this accumulated knowledge was problematic prior to the 20th century. The art of telescope making remained arcane knowledge for a considerable time.

Changes in amateur astronomy occurred in three distinct phases. First was the initial stage, one might think of it as the 'base-line' stage, to about 1920, dominated by the previously mentioned handful of well-off, serious, middle-class amateurs. The second period, from about 1920 to 1945, saw an explosive growth in the hobby of amateur telescope-making, a growth so comparatively massive as to really be the start of an entirely new hobby. The third and final period, from 1945 to 1960, is the one in which the most dramatic changes occurred; inexpensive telescopes, easily available for purchase by anyone resulted in tremendous growth of amateur astronomy, numbers of astronomy clubs, and the broadening of amateur astronomy into a more recreational hobby. These three periods also saw changes in locations where astronomy popularization was done and to a certain extent, the individuals involved. As stated earlier, astronomy popularization in America did differ to a certain extent from that going on elsewhere in the world at the same time, generally by being less centralized, and with essentially no state support until after 1960 when what might be called 'the Sputnik effect' brought massive Federal support for science education.

A study of amateur astronomy in America between 1910 and 1960 is significant to the history of science and technology as a whole for several reasons. First is the direct contribution to professional astronomy by amateur observers. Members of such organizations as the American Association of Variable Star Observers (AAVSO – established in 1911) and the Association of Lunar and Planetary Observers (ALPO – established in 1947) contributed large quantities of useful observations that professional astronomers could not make due to time and facility constraints.[3] Although guided by the advice of professionals, amateur observers could work on their own with their back-yard telescopes gathering useful observational data.

Another important contribution by amateurs, particularly since the end of World War II, has been in public education and popularization. Local amateurs were (and continue to be) called on frequently by schools, civic groups, and the like for informal talks and public 'star parties' where members of the general public could view the heavens through the local astronomer's telescope. Astronomy clubs increasingly took part in educational outreach after the Second World War and greatly supplemented the efforts of planetaria, museums, and public observatories. Indeed, many amateur astronomy clubs were permitted to meet at such facilities in exchange for volunteer public education work. By 1960 amateur astronomy clubs were beginning to establish their own club observatories equipped with a whole new class of telescopes but with the same educational mission of professional astronomy educators. In any case, little research or education by amateur astronomers could have taken place without the availability of large numbers of more affordable telescopes. American amateur astronomy would still have been a hobby only for those wealthy enough to afford it or as an occasional diversion for members of the general public lucky enough to visit the relatively few public observatories in or near larger cities.[4]

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[3] A description of amateur vs. professional observing programs could easily take up an entire book. Suffice to say that professional research and teaching observatories tended to carry out more restricted and difficult astrophysical observations, observations of distant galaxies, spectroscopy, and the like. This left no time for routine observations of objects like variable stars, the Moon, and planets. However, continuous observations of such celestial objects were an ideal pursuit for amateurs.

[4] The Drake Municipal Observatory was constructed in Des Moines, Iowa in the 1920s as a facility for public education as well as for teaching Drake University students. At the time of its completion, it was

2. Research methodology

In part, this study is an analysis of the economics of amateur astronomy. The dramatic drop in the cost of high-quality telescopes from 1910 to 1960 (by a factor of 20:1 or so) is the key to explaining the explosive growth of amateur astronomy, particularly after World War II. Fortunately, there are significant numbers of surviving sales brochures, product catalogues, and advertisements in magazines such that measuring the changes in relative cost of telescopes and related equipment is easy. Documenting the numbers of telescopes sold is a bit more problematic, as few companies have either kept or released such information.

Measuring the total growth of amateur astronomy is more difficult than determining changes in telescope prices. However, the expansion of astronomy clubs in the United States was remarkably, and fortuitously, well-covered at the time by such magazines as *Sky & Telescope*, which, as a service to readers, regularly published lists of astronomy clubs and announcements of new clubs.

This study is also heavily dependent on case studies of individual amateur astronomers (a surprising number of whom have left some biographical traces) as well as astronomy clubs. Enough in the way of astronomy club histories, reminiscences of club members, correspondence, and club newsletters remains to constitute a reasonable body of documentation for what is also a sociological history of amateur astronomy.

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touted as one of the first such publicly-owned facilities in the United States. (D. W. Morehouse, "Drake University Municipal Observatory," *Popular Astronomy,* 30 (February, 1922): 60–65) Aside from Twentieth Century examples, historian Trudy Bell lists 258 observatories established in America during the nineteenth century, but of these many were private observatories, college observatories, or research facilities and not all were in continuous operation. These would have had only limited access by the public and almost none were truly "public" facilities. Trudy E. Bell, *19th-Century American Astronomical Observatories*, (Lakewood, OH: privately published, 2001).

3. <u>Historiography</u>

Although a good deal of work has been done on amateur science in the Victorian period by the likes of Bernard Lightman and Allan Chapman, relatively little exists for the 20th century in general and amateur astronomy in particular. This is a view that has been noted over the past several years by a number of historians of science.

During the summer of 2009, the journal *ISIS* featured a "Focus" series on the historiography of "Popular Science". The authors noted a number of problems encountered with the historiography of science popularization, largely having to do with what James Secord spoke of as "British parochialism". This refers to the emphasis of historians of science on British amateur science, and even to the nineteenth century, to the neglect of other national contexts and periods.[5]

Jonathan R. Topham states that the topic of popular science has been marginalized among historians of science in favor of the intellectual history of professional scientists.[6] Topham also feels, similarly to Secord, that the term "science popularization" is a loaded term that has generally come to mean only the transfer of knowledge from professional scientists to the public rather than production of new knowledge by 'the public,' i.e., amateur scientists.

Andreas W. Daum notes that the historiography of science popularization has been marked by a good deal of uncertainty on quite basic ideas. The primary problem, which I will subsequently address myself, is the definition of science popularization and popular science. Part of this has to do with the division of science, from the nineteenth

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[5] James A. Secord, "Knowledge in Transit", *ISIS*, 95:654-672.
[6] Jonathan R. Topham, "Introduction", *ISIS*, 100: 310-318

century onward, into professional and amateur (or at least popular) realms. Beyond this, Daum addresses the whole issue of what I might call ‘coverage’. Given the uncertain definition of ‘popular science’, is it in fact worthy of study by historians of science? To Daum, the answer is at least a somewhat qualified ‘no’. There have been studies made of popular science and popularization of science, but in a fairly restricted sense. Historians *have* addressed both popular science and popularization of science, but have restricted themselves to fairly narrow foci, similar to those Secord suggests. These foci are: the transmission of scientific knowledge to the public by scientists, the overwhelming emphasis on Britain or English-speaking sources, and a chronological fixation on the nineteenth century.[7]

One of the few books not focused on Victorian Britain is James T. Andrews’, *Science for the Masses* (2003). Andrews primarily examines the role of science popularization in general during the late-Imperial and early-Soviet period in Russian history. Astronomy and amateur astronomy had a role to play during these periods as will be illustrated later.[8]

A number of historians of science have written on the whole problem of ‘national context’ in the history of science popularization. This is a legitimate issue for a study such as this one. One can take national context too far, particularly over the issue of ‘exceptionalism’. For instance, although amateur astronomy in the United States was

[7] Andreas W. Daum, “Varieties of Popular Science and the Transformation of Public Knowledge: Some Historical Perspectives”, *ISIS*, 100: 319-332.

[8] James T. Andrews, *Science for the Masses: The Bolshevik State, Public Science, and the Popular Imagination in Soviet Russia, 1917-1934*, (College Station, TX: Texas A & M University Press, 2003). Although science popularization and public education began in late-Imperial Russia, it was in Bolshevik Russia, particularly the 1920s, that science really became a mass-movement. This was in great part (especially after 1930) driven by needs of the state, but there was also public desire for such knowledge.

given a great boost by the amateur telescope-making movement of the 1920s and 1930s that does not mean that Americans were the only ones pursuing such a hobby; amateur telescope-making had a long history in Britain and Germany, and even the Soviet Union.[9] The difference is rather one of degree in this case.

This study seeks to escape from the cited Victorian Britain bias to explore different territory both geographically and temporally. Twentieth century America was an increasingly scientifically oriented culture and science popularization was an important issue. The history of the contribution to the science of astronomy by amateur astronomers during this period is a relatively untouched field. There were plenty of examples in Britain and elsewhere of amateur telescope-makers, William Herschel being the most notable of those in the 18th century and Andrew Ainslie Common a key figure of the 19th century[10]. However, these individuals must be seen as differing from those in the 20th century American context in part because of social and cultural differences in time and space. This study is in part a case study of several individual amateur astronomers and groups, but is also very much a statistical analysis based on economic issues.

The historiography on amateur astronomy is comparatively sparse to say the least. Likely the most in-depth study of amateur astronomy currently in print indeed concerns Victorian Britain. Allan Chapman's, *The Victorian Amateur Astronomer: Independent Astronomical Research in Britain 1820–1920* (1998), is an extremely important work on

[9] The journal *The English Mechanic* had long been a source of information on telescope making, but was virtually unavailable in the United States. For a description of amateur telescope-making in late Imperial Russia and the Soviet Union, see Sergey Maslikov, "Amateur Astronomy in Russia: Past, Present, and Future", *Sky & Telescope*, 102, (September, 2001): 66–73.

[10] Common seems to have actually worked on only a few large mirrors of an experimental nature; most of the telescope mirrors he actually used were purchased from other makers. See, H. H. Turner, "Andrew Ainslie Common", *The Observatory*, July 1903: 304-308, and F. W. Drower, "Andrew Ainslie Common", *Report of the Council to the Eighty-fourth Annual Meeting*, Royal Astronomical Society (February 1904): 274-278.

the subject, and touches briefly on 19th Century American amateur astronomy. Chapman's primary purpose is to examine the lives of key individuals who contributed most to astronomical research in 19th century Britain, most of whom were amateurs. As will be seen presently, the word 'amateur' had much different connotations prior to the 20th century; the amateur astronomers of Britain included many serious, though un-paid, scientists. Chapman focuses primarily on the work of 'Grand Amateurs', phenomenally well-off individuals who could afford telescopes better than 'professional' astronomers were using. Though one might quibble with some of Chapman's final conclusions about 20th century astronomy popularization, his account of 19th century astronomy in Britain is very useful.

John Langford touches on the subject briefly in *American Astronomy: Community, Careers, and Power, 1859–1940* (1997).[11] Thomas R. Williams' dissertation, "Getting Organized: A Survey of Amateur Astronomy in the United States" (2000), focuses primarily on how amateur astronomy groups were organized during this period, largely at the national level, and barely addresses the economics of the hobby.[12] Williams has also written some material on the amateur telescope making movement such as his biographical article "Albert Ingalls and the ATM Movement" (1991).[13] Williams' work presents a good deal of needed background on the organizations and people whose activities were affected by the economics of the hobby of amateur

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[11] John Lankford, *American Astronomy: Community, Careers, and Power, 1859-1940*, (Chicago and London: The University of Chicago Press, 1997). See also, Lankford, "Amateurs and Astrophysics: A Neglected Aspect in the Development of a Scientific Specialty", *Social Studies of Science*, 11 (1981): 275-303. Lankford primarily concentrates on professional astronomers and their development from a sociological standpoint
[12] Thomas R. Williams, "Getting Organized": 331.
[13] Thomas R. Williams, "Albert Ingalls and the ATM Movement", *Sky & Telescope,* 81, (February 1991): 140–142.

astronomy. W. Patrick McCray's study of "Project Moonwatch", *Keep Watching the Skies!* (2008) is quite useful for this present study, and in particular addresses amateur-professional relations during the 1950s.[14] All of these works offer some theoretical insights on social organization of amateur astronomy, to be discussed presently. None have taken the approach that I am presenting here, that of the effect of an innovation in technology and technical knowledge on social groups within popular science.

Although a good deal of material has been written about the history of scientific instruments by antiquarians, collectors, and the like, practically all of this has involved identification, cataloguing, and valuation of instruments. Gerard L'Estrange Turner is perhaps the best-known writer of books on historical scientific instruments, but his works are largely descriptive and designed for collectors and museum staff. Turner wrote or edited a dozen books and over one hundred articles on the history of scientific instruments, but the vast majority is on general topics and pre-20th century instruments.[15] Henry C. King's *History of the Telescope* (1955) has remained the standard work on the development of astronomical telescopes, but has never been up-dated and also fails to address the whole notion of commercial telescope manufacturing. Historians of commercially made telescopes are limited almost exclusively to collectors such as members of the Antique Telescope Society, though their *Journal* does provide a good deal of technical information and corporate history.[16] There have been a few corporate

[14] W. Patrick McCray, *Keep Watching the Skies! The Story of Operation Moonwatch & the Dawn of the Space Age*, (Princeton and Oxford: Princeton University Press, 2008).
[15] *Making Instruments Count: Essays on Historical Scientific Instruments presented to Gerard L'Estrange Turner*, R. G. W. Anderson, J. A. Bennett, and W. F. Ryan, editors (Aldershot, England: VARIORUM, Ashgate Publishing Limited, 1993); xi-xix.
[16] Among the more useful examples of articles from the *Journal of the Antique Telescope Society* is Thomas R. Williams', "John Edward Mellish and the Origins of The Amateur Telescope Making

histories of telescope manufacturers published, the most important undoubtedly being Deborah Jean Warner and Robert B. Ariail's, *Alvan Clark and Sons: Artists in Optics* (1995). This work is considered a classic of this type and includes a good deal of information on production, sales, and the like.[17]

Unfortunately, academic historians have largely ignored the history of scientific instruments, a point noted by Albert Van Helden and Thomas L. Hankins.[18] The relative lack of scientific instrument studies by academic historians until the last couple of decades seems to bear out this contention. The 400th anniversary of the invention of the telescope (2008-2009) has seen a bit more attention paid to the subject. As a result, there have been many works on Galileo and other early makers and users of telescopes published of late. Of particular note is Richard Dunn, whose *The Telescope: A Short History* (2009), unlike King's, takes a far more sociological-historical view of the development of the telescope, and in particular the public's reaction to such a revolutionary scientific instrument. Apart from a simple history of technological development, Dunn examines a topic largely ignored to this time by other historians of the telescope, the rise of mass-production and commercialized optics. Although Dunn does not explore the subject in the same depth that I shall, he does agree that the late 19th through 20th centuries saw a dramatic increase in the availability of inexpensive, yet reasonably high quality, optical instruments for both the military and the general public:

Movement in North America", *JATS*, 13, (Summer 1997): 15–19, and Gary Pike's, "The Lohmann Legacy: Turn of the Century Telescope Makers of the Heartland", JATS, 4, (Spring/Summer, 1993): 4–7.

[17] Deborah Jean Warner and Robert B. Ariail, *Alvan Clark and Sons: Artists in Optics, Second Edition*. Richmond, VA (Willmann-Bell, Inc. 1995). A similar work is Ian S. Glass', *Victorian Telescope Makers: The Lives and Letters of Thomas and Howard Grubb*, (Bristol, England and Philadelphia, PA: Institute of Physics Publishing Publishing, Ltd., 1997).

[18] Albert Van Helden and Thomas L. Hankins, "Introduction: Instruments in the History of Science", *Instruments, Osiris*, Second Series, Vol. 9, (1994): 1–3.

mass-production of optics gave a boost to such hobbies as ornithology and amateur astronomy.[19]

Although not directly related to the history of the telescope, Jordan D. Marché's *Theaters of Time and Space: American Planetaria, 1930-1970* (2005) is important for the overall context of astronomy popularization during the mid 20th century. Marche examines the motivations for financing and building public planetaria in America, the technology behind the projection planetarium (including the simplified "pin-hole" type developed after World War II), and the impact on American science education and culture, particularly in the wake of Sputnik.[20] As I will discuss later, public planetaria (and observatories) would provide a center with which many amateur astronomy clubs would form cooperative relationships.

More has been written recently concerning science popularization. In *Making Science Our Own: Public Images of Science, 1910–1955*, Marcel LaFollette contends that, in terms of the popularization of science, a primary route for learning about science was mass-media outlets such as *Harper's*, *Atlantic Monthly*, and *The Saturday Evening Post*.[21] There is no doubt that popular media assisted the growth of astronomy popularization. As I will touch on later, the growth of popular astronomy magazines such as *Sky & Telescope* would likely not have occurred without the increased accessibility to commercial telescopes for amateur astronomers, *and* the telescopes would not have had the commercial exposure without the magazines. They thus grew together as a "team".

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[19] Richard Dunn, *The Telescope: A Short History* (Greenwich, England: National Maritime Museum, 2009).
[20] Jordan D. Marché II, *Theaters of Time and Space: American Planetaria, 1930–1970* (New Brunswick, NJ & London: Rutgers University Press, 2005).
[21] Marcel LaFollette, *Making Science Our Own: Public Images of Science, 1910–1955* (Chicago and London: The University of Chicago Press, 1990).

4. Popularization – definitions

Popularization of science is a somewhat less tricky subject than the idea of 'amateur science'. Science popularization might best be defined as re-packaging scientific knowledge, generally by professional scientists or science writers/lecturers, for consumption by the general public. Science popularization c.1910 in America was still very much in the enlightenment tradition; public lectures by experts, and writing by experts to a popular audience. By the post-WWII era, at least in America, popular science was a far more participatory pursuit. Amateur astronomers, even those who were very casual and never became engaged in serious studies, wanted a first-hand experience on their own terms.

Ralph O'Connor has recently considered a number of issues that are important in understanding the labels "popular science" and "popularization". Some historians (Secord and Topham) have argued for eliminating such terms from historians' usage as being so diverse and changeable as to be useless[22]. O'Connor disagrees and considers the terms useful as "umbrella" labels that are convenient as shorthand descriptions. O'Connor states that historians in general define "popular science" as "science of or for the people": science designed for people outside of the scientific 'elite', the use put to by the public of the knowledge, and 'non-elite' scientific practices. A problem with this, as O'Connor points out, is – what is 'elite'? This is a definition that remains rather nebulous and really depends on the subject under examination. Whatever the exact definitions are, O'Connor

[22] Ralph O'Connor, "Reflections on Popular Science in Britain: Genres, Categories, and Historians", *ISIS*, *ISIS*, 100, (June 2009): 340. An enlightening work from the period under examination is Benjamin C. Gruenberg's, *Science and the Public Mind* (1935). Gruenberg voices a number of concerns including the kinds of 'science popularization' common at the time, contrasting German popular science journals such as *Kosmos*, with more flighty, topically-related American magazines as *Popular Science Monthly*; the latter is viewed as appealing largely to men and boys interested in the latest technology, rather than science, *per se*.

sees two different models for describing the relationships between 'elite science' (whoever the actors are that that description might entail) and 'popular science'. "Model A" sees a one-way flow of knowledge from a separate realm of "the elite" to a separate realm of "the public", whereas "Model B" shows an overlap between the two realms and a two-way flow of knowledge.[23]

In the particular case of astronomy, it would be more useful to introduce a third model. This "Model C", developed by me, is rather more a continuum and includes the category of "amateur astronomer" as an *intervening* actor between the scientific elite and the public.[24] A hallmark of amateur astronomers throughout the period examined here is the willingness, or even the urge, to themselves serve as transmitters of scientific knowledge to the general public. Though perhaps not making exactly the same point as I do, Secord considers it improper to have too sharply defined boundaries between elite (complex, "esoteric") knowledge and public (simplified for popular consumption by experts) knowledge.[25] The amateur astronomers in this study definitely occupy a middle ground between these extremes. Even finer distinctions can be made on such a continuum within the broad category of "amateur astronomy". Amateurs themselves frequently distinguished between "serious" amateurs, those who actually engaged in observational

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[23] O'Connor; 340–343

[24] As far as I know, mine is an original graphical depiction based on what I have read of others' ideas. It is similar to the ideas of Nathan Reingold and Robert A. Stebbins, as well as Mark Barrow. All argue against a too rigid distinction between amateurs and professionals. See Nathan Reingold, "Definitions and Speculations: The Professionalization of Science in America in the Nineteenth Century", *The Pursuit of Knowledge in the Early American Republic: American Scientific and Learned Societies from the Colonial Times to the Civil War*, Alexandra Oleson and Sanborn C. Brown (Baltimore, MD: Johns Hopkins University Press, 1976), and Robert A. Stebbins, *Amateurs: On the Margins between Work and Leisure*, (Beverly Hills, CA: SAGE Publications, 1972).

[25] Secord, "Knowledge in Transit"; 670-671, and Rodger Cooter and Stephen Pumfrey, "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture," *History of Science*, 32 (1994): 237–267, on 253–254.

research or popularization via writing or public lectures, to “arm-chair” astronomers who might occasionally get a telescope out to look at the moon, but otherwise mostly enjoyed reading about the subject on quiet evenings.[26]

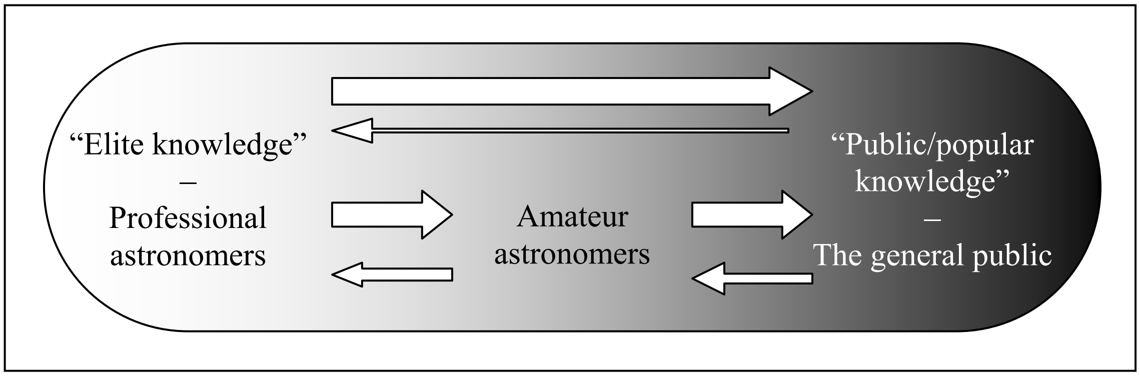

Fig. 1 – “Model C”: Continuum from expert knowledge to public knowledge. Arrows denote both direct and indirect routes of knowledge transfer from “elite” to “public”.

The arrows in this model are of some considerable significance in that they illustrate not only *routes* of communications, but also *quantities* or *volumes*. The producers and holders of scientific knowledge, the professional astronomers in this case, are primarily transmitters of knowledge. One route is direct to the general public via popular books, articles in mass-media magazines and newspapers, as well as radio, television, and even the occasional live lecture. The general public’s reciprocal communications with the scientific elite is comparatively slight, perhaps the odd letter or phone-call to the local university (which might or might not be answered) or letters to the editor of a magazine or newspaper; it can also be indirect communication (sales of popular books that answer their questions as opposed to those that don’t). Communications between amateur and professional astronomers, while still largely one-way, is far less so. Amateur astronomers did contribute data after all, some of low quality

[26] One might even ask whether a planetarium employee, who does no observing or research, is ‘a professional astronomer’.

but also some of very high quality, that professionals used. In turn, the professional astronomers (at least some of them) guided and encouraged amateurs in their efforts. Professional astronomers communicated with amateurs primarily via specialist astronomy or science-related magazines such as *Sky & Telescope* and *Scientific American*, more sophisticated books constituting observing manuals and texts, and, perhaps most crucial, participation in amateur organizations such as the American Association of Variable Star Observers (AAVSO), or the American Meteor Society[27]. Finally, amateur astronomers communicated with the general public; indeed, in most cases the nearest 'expert' on astronomy in 'Anytown, USA' was an amateur astronomer. For the general public, out of whose ranks would often emerge new amateur astronomers, the amateurs were far more approachable than the professionals.

5. What is an amateur astronomer?

One of the most problematic aspects of any study of amateur astronomy, or any other amateur science for that matter, is trying to come to grips with what an 'amateur scientist' is. Prior to the late 19th century, terms such as amateur and professional are somewhat meaningless when it comes to science, and a number of historians of science, including Allan Chapman, use both terms with considerable flexibility.[28] Up until that time, other than a handful of university and college faculty as well as an even smaller number of persons in government employ (the British Astronomer Royal, for example), all scientists might be considered 'amateurs' in that they were self-supporting, could study what they liked, and often study how they liked.

[27] See Marc Rothenberg, "Organization and Control: Professionals and Amateurs in American Astronomy, 1899–1918," *Social Studies of Science*, 11 (1981): 305–325.
[28] Chapman, for instance, uses the term 'amateur' when others might prefer 'gentleman philosopher'.

Thomas Williams noted in “Getting Organized” that the word amateur often has negative connotations today; this negative aspect makes it difficult to distinguish between genuine un-paid but valuable contributors to science and those who are ‘amateurish’. There is the further problem that many historians of science have blurred the line between amateurs and professionals by applying professional or pseudo-professional status to particularly noteworthy, but un-paid, astronomers such as William Huggins. Williams also makes a rather interesting suggestion, one that seems quite valid, that modern astronomy itself requires a whole support staff, maintenance technicians, secretaries, and the like, who are paid to assist in producing scientific results, but are certainly not ‘astronomers’. [29]

Roy Porter, in common with other historians, sees the use of ‘amateur’ as an outgrowth of professionalization within the sciences.[30] In other words, one cannot have amateurs without professionals. However, Porter also notes that science as a profession cannot be treated in the same way as medicine or law; regulation (or perhaps disciplinization?) of science is a relatively new concept. This being the case, amateur astronomy is not so much a new development as an outgrowth of a broader social organization of science.

Of some considerable interest is the fact that a significant number of professional astronomers, including a number cited in this study, began their astronomical ‘careers’ as young amateurs in something one might call the ‘ontological’ development of a scientist. Some eventually develop fully (professional astronomers), others did not (amateur

[29] Williams, “Getting Organized”: 3–6.
[30] Roy Porter, “Gentlemen and Geology: The Emergence of a Scientific Career, 1660–1920”, *The Historical Journal*, 21, (1978): 809–812.

astronomers – to carry the metaphor further, the development of a scientific profession might be ‘phylogeny’). Indeed, the youthfulness of amateur astronomy by 1960, including many college students preparing to enter the professional ranks, was one of its hallmarks.

As stated previously, amateur astronomers act as intermediary between the elite and the public, as ‘adjunct instructors’ for the scientific elite, and public outreach was therefore a major role for amateurs. One of the most important tools for this was the telescope. From sidewalks, to backyards, to school-grounds, to the lawns outside public planetariums and observatories, public ‘star parties’ hosted by amateur astronomers were a vital service in public education. Here, children and adults could catch a glimpse of the moon or the planet Saturn through a telescope for the first time in what was sometimes a life-changing moment. Finally, astronomy clubs in America, particularly after 1920, were almost always open to the general public

The significant feature of the period 1910 to 1960 was a change in the demographics of amateur astronomy. W. Patrick McCray notes that many amateur astronomers who contributed to ‘Project Moonwatch’ were involved in some kind of profession, such as engineers, and were not merely dabblers. McCray finds that the one universal characteristic of amateur astronomers involved in Project Moonwatch was that they were unpaid.[31] However, there were also increasing numbers of non-professionals becoming interested in astronomy by the 1950s. Another fact that will be expanded upon later is that the amateur astronomers of the late 1950s were young.

[31] McCray; 12–13.

To a great extent amateur astronomers were self-labeled; they quite willingly distinguished themselves as amateurs. The naming of amateur astronomical organizations could be significant. The astronomical society that developed in Los Angeles from 1925 onward (there had been a short-lived one a decade earlier) passed through a series of name changes, from "The Los Angeles Telescope Making and Astronomical Society" to "The Los Angeles Amateur Astronomical Society", and finally to "The Los Angeles Astronomical Society" sometime in the 1930s; this final change was made in order to attract both professional astronomers as well as amateurs to the organization.[32] The introduction to J. B. Sidgwick's, *Amateur Astronomer's Handbook* (1971), is worth quoting in part as it gives a very plain self-definition:

> "A large proportion of these amateurs [members of the British Astronomical Association – BAA] are active, in the sense that they possess telescopes of some sort and engage in more than desultory observation; of these, a hard core of 'specialists' take a regular part in the organized [observational research] programmes of the various Observing Sections [of the BAA]."[33]

The period at which this study begins is exactly when the division between amateurs and professionals had been made, and made consciously. The American Astronomical Society had been established in 1899 as the organization for professionals, those whose vocation was astronomy. These individuals were largely employed by colleges and universities, with a few working for the government at institutions such as the U. S. Naval Observatory. Although a very few talented amateurs were allowed membership in the AAS, it was a largely professional group. This move corresponds to

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[32] George W. Bunton, "The Past, Present, and Future of the Los Angeles Astronomical Society," *The Griffith Observer*, May, 1946: 50–53, 57–58, on 50.
[33] J. B. Sidgwick, *Amateur Astronomer's Handbook*, *Second Edition* (New York, NY: Dover Publications, Inc., 1971); 15.

those in other fields, such as engineering, to not only 'professionalize' but also 'disciplinize' their field. Requirements were increasingly being made in terms of education, methods, and employment. There is much to be said for the fact that without professionalization, there would be no amateurs.

The amateur-professional dichotomy continued to grow into the 20^{th} century. Although some amateur groups, such as the American Association of Variable Star Observers (AAVSO), had good reputations among professionals, most amateurs were treated with varying amounts of disdain by at least some professional astronomers. The fact that the AAVSO had been established at the suggestion of, and largely under the watchful eye of, Professor William Pickering (director of Harvard College Observatory – HCO), goes some way to explaining its respectable status. The AAVSO was in fact based at HCO for the first forty years or so of its existence and professional astronomers were able to exercise a good deal of influence over, and even supervision of, its activities. As Marc Rothenberg pointed out in his 1981 study, the organization of such groups as the AAVSO and the American Meteor Society was as much at the urging of professional astronomers as it was of amateurs. At more or less the same time, other professionalizing fields, such as geology and anthropology, generally barred membership to amateurs.[34]

The text of a letter from Dale P. Cruikshank, originally a young amateur astronomer from Des Moines, IA, laments the treatment of amateur observers by professional astronomers. Cruikshank was at the time a student at Iowa State University and was spending the summer as an intern at the University of Chicago's Yerkes

[34] Rothenberg, "Organization and Control"; 305–306. Astronomy was a notable exception for Rothenberg due to the separate nature of data collection and data interpretation in astronomy. This is not unlike the situation with ornithology, as will be seen.

Observatory in Williams Bay, Wisconsin. His contact with professional astronomers seems to have gone some way towards souring his disposition towards the possibility of amateur-professional cooperation. However, Cruikshank states that his "anti-amateur virus" was not just the result of contact with professionals, but something that had been gestating for some time. Cruikshank seems to be criticizing the 'amateurishness' that Thomas Williams commented on in his study of amateur astronomy.[35] Cruikshank also reflected the frustrations of many amateur astronomers with the general public; for instance, after a 'star party' at the Drake Municipal Observatory in Des Moines:

> ". . . a man upon returning from the [telescope] eyepiece after a look at Saturn noticed the spinning weights on the governor [of the] telescope [clock] drive. Turning to me, he asked, "Is that the generator that makes the little light [Saturn] that I saw?"[36]

A series of letters were published in the newsletter of the Great Plains Astronomical Society (of which Cruikshank was a leading member), over the course of about a year concerning the roles and 'duties' of amateur astronomers.[37] Cruikshank, himself primarily interested in planetary observing at the time, was particularly critical of his fellow amateurs' planetary observations for what might most charitably be called 'observational naïveté'. Amateur planetary observers often insisted on depicting features on the planets seen with their small, back-yard telescopes that were clearly not visible in large observatory instruments.[38] An example of what Cruikshank was likely talking about

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[35] Dale P. Cruikshank, "Letter to [editor] Bill Bailey", *Thru-the-Eyepiece*, XII (November, 1959): 4–6.
[36] Cruikshank, "Letter to [editor] Bill Bailey": 5.
[37] Dale P. Cruikshank, "Letter to Bill Bailey", January 8, 1959. Cruikshank wrote, "Amateur astronomy in this country [the United States] is in <u>terrible</u> shape! It is true that the ALPO contains about 450 members (1957) but of the estimated 175 observers, the work of only four or five is considered seriously by [professional] astronomers."
[38] The vast majority of these observations were in the form of pencil drawings. Only a few amateurs attempted to photograph the planets. The photographic technology of that time did not permit detailed photographs of the planets to be made with small telescopes. Even photographs with the largest telescopes

can even be seen in the Mars observations of Thomas Cave, a well-known and respected Southern California amateur who was a major player in the commercial telescope industry from the 1950s onward. For the 1958 apparition of Mars, Cave employed a very good 12½-inch Newtonian reflector to make drawings of the red planet – each drawing however featuring "canals" crisscrossing the planet, features that professional astronomers like Gerard P. Kuiper of Yerkes Observatory had long since proven were spurious artifacts of blurred atmosphere.[39]

Cruikshank was not the only critic of 'amateurishness' in amateur astronomy. Charles Martens asked "who would fill the gap" between amateurs and professionals, implying that there needed to be closer supervision and guidance of existing amateurs by professionals (or perhaps more advanced, or 'semi-professional' amateurs). Too much misinformation on the part of some amateur astronomers was getting through to beginning amateurs and the general public. Martens further states that amateur astronomers *cannot* bring astronomy to the public; they can only bring *amateur* astronomy to the public.[40] The crux of the matter was that amateur astronomers needed to be better educated about the *science* of astronomy, not just the *practice*.

It seems rather ironic that at the very time that amateur astronomers were getting their hands on large numbers of near-professional-grade equipment, large reflecting

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were relatively poor in terms of detail, mostly due to the relative insensitivity of photographic emulsions that in turn required exposures of 1 to 10 seconds, during which time atmospheric turbulence would distort and blur the image. This problem was not really solved until the advent of highly light-sensitive electronic CCD imaging cameras and image processing soft-wear in the 1980s.

[39] Such drawings were published in the Association of Lunar and Planetary Observers (ALPO) Journal, *The Strolling Astronomer*, as well as the catalogues of Cave Optical Company.

[40] Charles F. Martens, "Letter to [editor] Bill Bailey", *Thru-the-Eyepiece*, XII (December, 1959): 22–25. Others writing on the same subject had differing opinions, some stating that amateur astronomy only needed to be fun. See, Kathryn Hotovec, "Astronomy as I Like It", *Thru-the-Eyepiece*, XII (December, 1958): 17–18.

telescopes in the 10-inch (25cm)-plus aperture class, their perceived usefulness as observational-research adjuncts to the professionals had just about reached nadir. Yerkes astronomer George van Biesbroeck even stated to Cruikshank on one occasion that he thought there were *too many* telescopes available to amateurs and that there was a "vast amount of work that an amateur *might* [emphasis added] do with only a moderate instrument".[41] The implications of such a remarkable statement by a professional astronomer was that by 1958 there were so many telescopes available in the United States that the quality of amateur astronomy, as an adjunct to professional work, had plummeted in favor of quantity.

For my own purposes, I choose to include in this study a fairly broad definition of amateur astronomers as those who are more than just casually interested (i.e., not just someone who once or twice visits a planetarium, looks through a friend's telescope, reads an article or two in a newspaper); but someone who devotes some time and resources to the hobby, reads fairly steadily on the subject, might buy or make some equipment, but does not have to be 'serious' in terms of contributing observations to science. Indeed, one begins to realize that the period from 1900 to around 1950 is as much about changes in the definition of what it meant to be 'an amateur astronomer' as it did about changing demographics and economics.

6. Technical definitions – telescope types

A few technical terms need to be defined at this point. By commercial telescope manufacturers, I mean those makers who produced astronomical telescopes primarily for

[41] Cruikshank, "Letter to [editor] Bill Bailey": 4–6.

sale to the general public. This therefore does generally not include a number of manufacturers who produced optics for government or research institutions, surveying instruments, microscopes, or camera manufacturers who might have produced a few small telescopes as a side-line. Common features of all astronomical telescopes are a fairly large 'aperture' (the aperture, or diameter, of the objective lens or primary mirror governs what can be seen), an inverted image (objects appear rotated to an upside-down orientation – not a problem for astronomical observing), and the ability to exchange one eyepiece for another or for other equipment such as cameras and spectroscopes.

Optical telescopes fall into two broad categories: refractors (using lenses) and reflectors (using mirrors). The typical "starter" telescope in 1910 was a 3-inch refracting telescope and in fact this was still considered a good beginner's instrument in 1960.[42] The "objective lens" at the top of a refracting telescope gathers light and brings it to a focus at the bottom of the instrument. Here, a lens called an "eyepiece" (or "ocular") is used to view the image created by the objective. The objective lens of a refracting telescope is complex to make and mount properly. The objective must be made of expensive optical glass, of very specific optical characteristics, and extremely high quality.[43] Other parts of these telescopes required high levels of machining as well. For instance, the 'cells' for holding the lenses were usually carefully made of metal and fabricated to high tolerances. The lens had to fit the cell exactly, be held firmly in place,

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[42] This was an almost universally suggested size throughout the period under examination and beyond. See Rev. T. W. Webb, *Celestial Objects for Common Telescopes, Vol. I*, Edited and Revised by Margaret W. Mayall (New York, NY: Dover Publications, Inc., 1962). William Tyler Olcott, *In Starland with a Three-Inch Telescope*, (New York and London: G. P. Putnam's Sons, 1909), specifically designates the "three-inch telescope" of his book's title as one suitable for a beginner. See also James Muirden, *The Amateur Astronomer's Handbook, 3rd Edition*, (New York, NY: Harper & Row, Publishers, 1987), and Henry Paul, *Telescopes for Skygazing*, (Garden City, NY: American Photographic Book Publishing Co., Inc.,1976).

[43] The modern refractor objective is a two-lens type referred to as an "achromat" (meaning "free of color"). More will be said concerning the details of the development of this type of lens in Chapter II.

yet not be physically pinched by the cell. Cells even had to be designed to allow for expansion and contraction of the metal due to changes in temperature. Refractors tend to be very long in relation to their aperture. Astronomers and opticians refer to the ratio between the aperture and focal-length (distance from the optical center of the lens to the focus) as the focal ratio, or “f-ratio”. Refracting telescopes generally have f-ratios of f/10 to f/15 (focal-lengths 10 to 15-times the aperture).

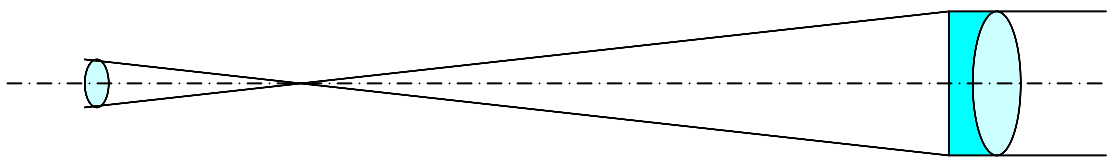

Fig. 2 - Optical lay-out of a **Refracting telescope**

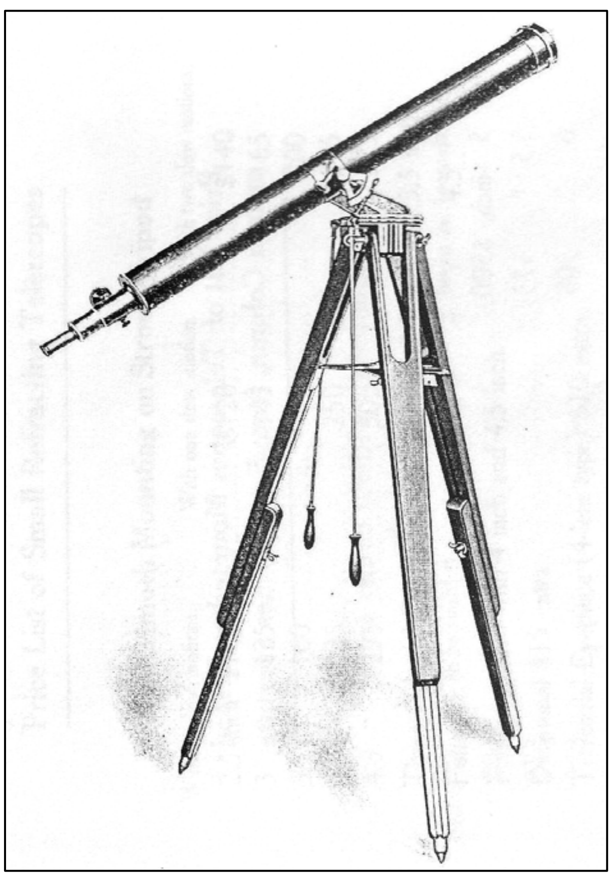

Fig. 3 - A 3-inch Refracting telescope on alt-azimuth mount and tripod by the John A. Brashear Company, from the 1906 company catalogue; price, $125.

The Newtonian reflecting telescope was a much simpler design, could be made from cheaper materials (mirrors could be ordinary plate glass), and was thus originally the telescope of choice for the amateur telescope maker of the early to mid 20th century. The reflecting telescope replaces the objective lens of the refractor with a concave “primary mirror” located at the bottom of the telescope tube. Light is then reflected up to a small “flat”, or “secondary mirror”, at the top of the tube, tilted to reflect the light out the side of the telescope, and then to the focus. The optics of a Newtonian reflecting telescope are thus far simpler than a refractor; only a single surface must be generated on the primary mirror and the quality of glass is far less critical.[44] Other parts of the telescope could be rather crudely made; wood was often used not only for tubes, but also for the mirror cells and other key parts. Newtonian reflectors are also more compact than refractors, having f-ratios of f/8 or even f/4.

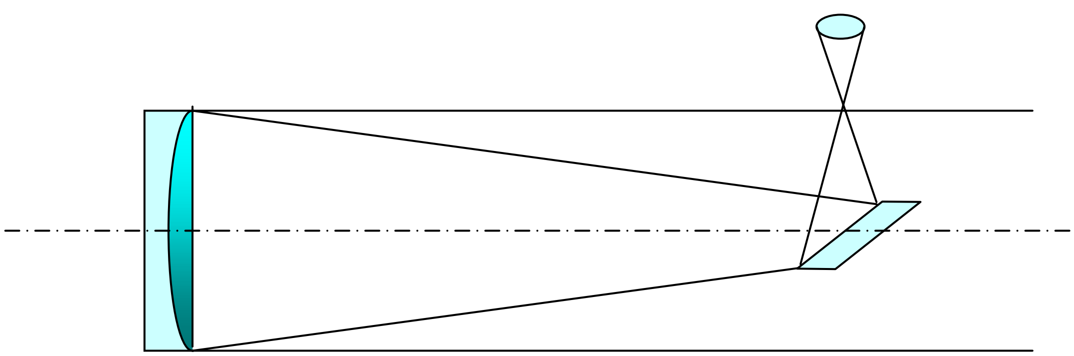

Fig. 4 - Optical lay-out of a **Newtonian reflecting telescope**

[44] The first reflecting telescopes (through the mid-19th century) used metal mirrors, but after the technique of depositing silver on glass was developed by Leon Foucault and others around 1855-60, glass mirrors became standard. Until the 1930s, ordinary plate-glass was used (and was still frequently used even as late as the 1990s), though it began to be superseded by Pyrex™ glass; the advantage of the latter was that it was more thermally stable and would therefore not distort as easily during night-time observing as the telescope cooled to outside temperatures. For the relatively small refractors, such thermal instability was relatively unimportant, but for the increasingly large reflecting telescopes, the Pyrex™ glass mirrors were a boon (the Palomar 200-inch mirror was the largest piece of Pyrex™ produced when it was cast in 1935).

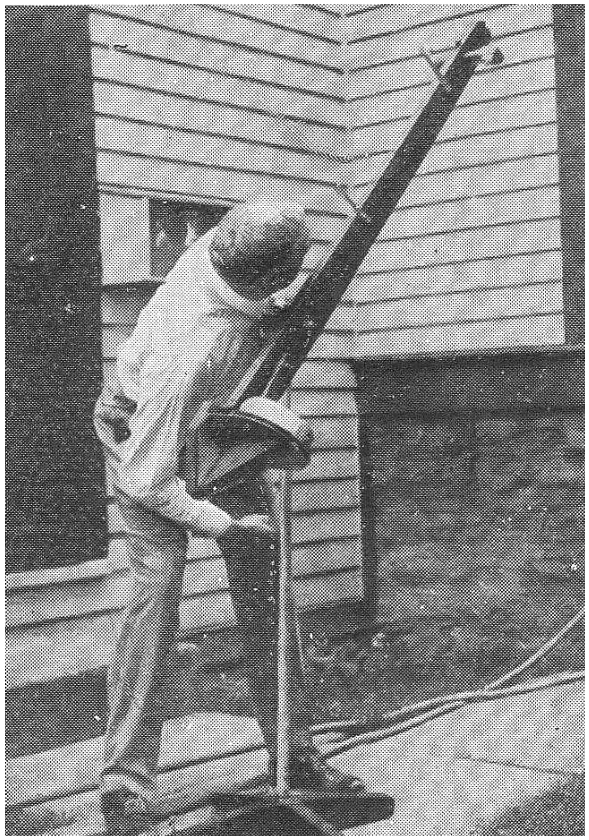

Fig. 5 – This is an amateur-made Newtonian reflecting telescope (c.1930) of 6-inch aperture and featuring an extremely bare-bones structure. The maker is demonstrating how the telescope is aimed by means of a simple peep-hole sight. The primary mirror is clearly visible at the bottom of the 'tube' (above the owner's right hand) as is the secondary mirror at the top (attached to a short stalk projecting from the side of the board holding it). Cost of materials for this telescope was said to be "around $15". From *Amateur Telescope Making, Book 1.*

A related reflecting telescope design is the Cassegrain, invented in 1672 by Sieur Guillaume Cassegrain; instead of directing light out the side of the telescope, the un-tilted convex secondary mirror directs the image back towards the primary mirror through which a hole has been bored, and then to the focus.[45] The Cassegrain shares many of the technical advantages of the Newtonian reflector but requires considerably greater precision in its manufacture, and thus relatively few were home-made. The Cassegrain was a far more common design for professional observatory telescopes, though a few

[45] King; 75–77. The actual identity of Cassegrain is somewhat disputed.

more advanced amateurs did succeed in making a few and some were available commercially. However, a few more manufacturers were making Cassegrain and the related 'Maksutov-Cassegrain' by 1960, albeit at higher prices than other telescope designs. The future held more promise for such designs.[46] An earlier but somewhat similar design to the Cassegrain was the Gregorian, conceived by James Gregory in 1663 (thus preceding Newton's reflector design by about 5 years).[47] The Gregorian uses a concave primary mirror, but also includes a concave secondary placed at a point past the focus of the primary. The main advantage of the Gregorian is that the resulting image is erect as opposed to being inverted as is the case with both Refractors and Newtonian and Cassegrain reflectors. Objects on the Earth could be viewed with a Gregorian telescope without any additional 'erecting lenses' to make them appear upright. The fairly compact Gregorian achieved its greatest popularity in the 18th century as a multi-purpose telescope for both celestial and terrestrial observing; little interest has been shown in the Gregorian since.

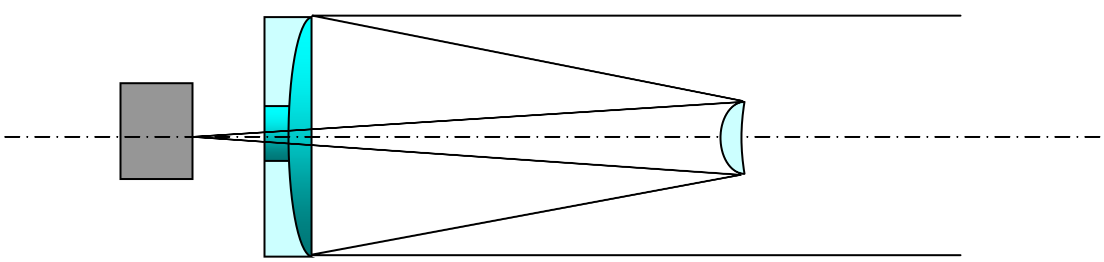

Fig. 6 - Optical lay-out of a **Cassegrain reflecting telescope**

[46] The 'Questar' 3½-inch Maksutov-Cassegrain telescope appeared on the market in 1958 and the 'Celestron' brand of Schmidt-Cassegrain telescopes followed in the early 1960s. Of the two, the Questar was by far the most expensive, retailing for around $900. It was, however, exceedingly compact (with it's mounting and all accessories, the Questar came in a leather carrying case measuring about 18" high x 8" square) and well-made. The Celestron appeared in sizes ranging from 4-inch to 22-inch, but the 8-inch was by far the most popular. They were marketed primarily to those amateurs interested in astrophotography.
[47] King; 70–77.

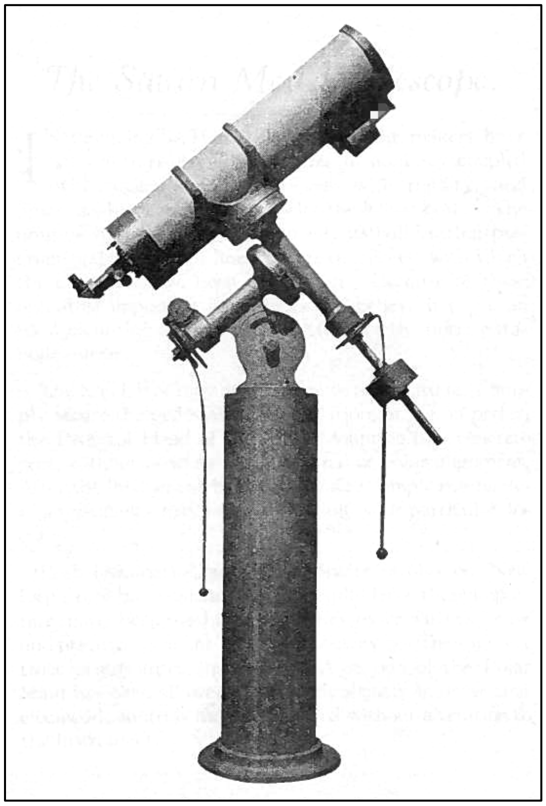

Fig. 7 – A photograph of a 12-inch Cassegrain telescope on an equatorial mounting and hollow steel pier from the *Tinsley Laboratories Catalogue*, c.1935; listed price: $1,150

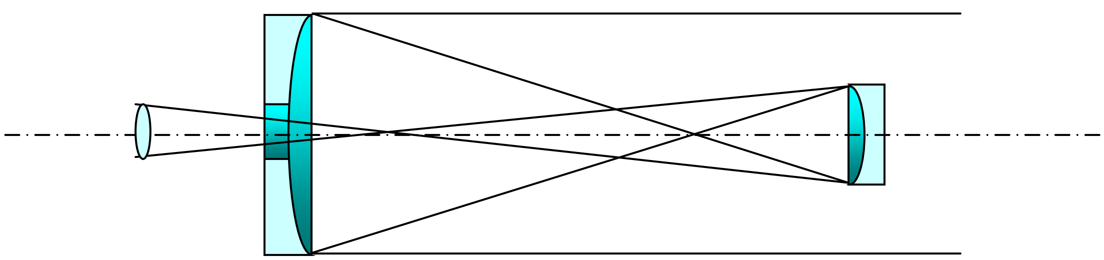

Fig. 8 - Optical layout of a **Gregorian reflecting telescope**

Final mention should be made of telescope mountings. The mounting consists of the stand (this could be a tripod or a single solid pier) and the 'head' of the mounting, the mechanism that permits pointing of the telescope in different directions. The two major types of mounting are the "alt-azimuth" and "equatorial"; the latter is considered more sophisticated and, until recently, necessary for astronomical photography. The alt-azimuth mounting simply move the telescope up-down and around the horizon; this is the least expensive type of mounting and is common for multi-purpose, day-night telescopes. Being more complicated, the equatorial mount is usually significantly more expensive and difficult to make.[48] Telescopes featuring equatorial mounts are frequently supplied with "slow-motion controls", devices for precise pointing of the telescope, "setting circles", two circular metal discs with graduated markings of astronomical coordinates and also used in precise pointing, and "clock drives", either mechanical or electro-mechanical devices used to compensate for the Earth's diurnal (daily) motion. As might be expected, all of these accessories contribute to the cost of telescopes and manufacturers frequently offer such equipment as options.

7. Comparison with other science & technology related hobbies

There are many hobbies that contain scientific and/or technological aspects, ham radio, model rocketry, 'rock hounds', archeology, bird-watching, but not all are of course equal in either the extent or kind of content. These hobbies can be grouped into two major categories: science hobbies and technological hobbies. Science hobbies are those, like astronomy, archeology, and ornithology, where there is at least a possibility for contributing to science. Furthermore, science hobbies can, but do not have to, include a technological aspect in terms of equipment. Finally, science hobbies have a strong educational aspect to them; aside from being fun, one can learn something of intrinsic value.

[48] The alt-azimuth mounting is designed to move the telescope up and down (altitude) and around the horizon (azimuth); this is the type of mounting commonly found on telescopes designed for terrestrial and general-purpose observing. The equatorial mounting is designed to move the telescope in equatorial, or celestial, coordinates (Right Ascension and Declination) and is purpose-built for astronomical use only.

Amateur ornithology is perhaps the nearest parallel to amateur astronomy. There are some enthusiasts who only casually observe birds in their backyards, while other, more serious, amateur ornithologists seek to make actual contributions to science. The nature of birds being what it is, the existence of a large number of observers and collectors was (and still is) a necessity for acquiring data on such highly mobile creatures; this in turn requires the presence of amateurs. The profile of the average amateur ornithologist in America c.1900 (and there were very few professionals) was remarkably like that of amateur astronomers of the same period; middle- and upper-class persons with a passion for nature and science. Natural history, broadly speaking, was considered a worthwhile pastime for personal education and enrichment. Like amateur astronomers, these individuals also formed clubs (various local Audubon societies) with their field-guide books, educational programs on record-keeping, and the like. As with astronomy, professional ornithologists formed their organization (the American Ornithological Union – AOU – 1883) in the process of disciplinization. Despite increasing professionalization though, ornithology was what Mark Barrow calls "a classic example of an inclusive scientific field".[49] A major difference between ornithology and astronomy, at least in the 19th century, was that ornithology became a market of sorts. 'Amateur' ornithological collectors and taxidermists were themselves creating a 'profession' based on the sale of specimens in increasingly large numbers. The professional collector and the professional biologist were increasingly at odds over issues of science versus profit.[50] This aspect aside, ornithology had, by the 20th century, developed into a scientific pursuit of scattered

[49] Mark V. Barrow, Jr., *A Passion for Birds: American Ornithology After Audubon*, (Princeton, NJ, Princeton University Press, 1998); 3-5.
[50] Barrow; 17-19. The only possible comparison to these entrepreneurs in astronomy, for obvious reasons, would be the work of meteorite collectors and sellers.

professionals supported by a vast network of amateurs who provided observations and specimens for research in a “social network”; quite similar to astronomy.[51]

As for equipment, the most important item for birders was an illustrated field-book, increasingly available from the 1880s onwards, that provided key identification information.[52] Beyond this, binoculars were used in bird-watching from the 1860s onwards and photography a decade later. There were considerable differences though in instrumentational needs *vis a vis* astronomy and ornithology. Bird-watching requires low magnification (3 to 5 power), a wide field of view, and light weight equipment for use in following fast-moving birds in the bush. As a result, simple (and relatively crude) Galilean-type opera glasses were perfectly suitable for ornithological studies. Although more sophisticated prismatic binoculars became available from around 1900, they were not essential and had more or less the same characteristics of earlier opera glasses.[53] These new prismatic binoculars did have one overwhelming trait: high price. Catalogues from various department stores featured both types of binocular in the early 20th century and the prismatic type (generally imported and of German make) were as much as ten-times as expensive as the Galilean-type field and opera glasses and would continue to be

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[51] Barrow; 6.

[52] Florence Merriam’s *Birds through an Opera Glass* (1889) is recognized as the first such work in America. See Barrow; 156–158. Merriam’s title is remarkably similar to Gerrett P. Serviss’ later book *Astronomy with an Opera Glass* (1888). It is just possible that Merriam was inspired by Serviss as both books were published in New York. It should be pointed out that Serviss’ book was intended for the most basically equipped amateur just starting in the hobby.

[53] Barrow; 158–161. The essential difference in opera glasses versus prismatic binoculars is their optical lay-out. The opera glass uses the original optical system of Galileo’s telescopes with a convex objective lens, but using a *concave* eyepiece lens. This results in an instrument with an erect image (something required for terrestrial observing, including bird-watching, but not for astronomy), but a rather narrow field of view of about 20°. The prismatic binocular is far more sophisticated and contains exactly the same optical lay-out of the refracting telescope described earlier, but with the addition of a prism assembly between the objective and eyepiece that rotates the ‘normal’ inverted image of the refractor to a more convenient erect image, generally with a field of view of 45-60°.

so until the 1950s.[54] The demands placed upon photography as related to ornithology was likewise different, and more forgiving, than for astronomy in that complicated mountings for very long-exposure photographs (up to an hour for stellar photography) were not required. In other words, equipment for bird-watching was both relatively cheap and not vital for either personal appreciation or contribution to science.

Likewise, amateur astronomy involves many casual back-yard astronomers who occasionally get out their telescope or binoculars for some "gee-whiz" views of the moon, planets, and a few of the brighter nebulae and star clusters, but with no serious intent. At the other extreme are amateurs engaged in serious observation, with data carefully recorded, and then sent to such semi-professional clearing-house organizations as the American Association of Variable Star Observers or the Association of Lunar and Planetary Observers (ALPO). In between the two extremes are a range of observers; some enjoy the hunt for faint nebulae, star clusters, and galaxies presented in "Messier Marathons"[55] or in simply trying to repeat the observations of William Herschel.

Likely the greatest difference between amateur ornithology and amateur astronomy lies in the need (whether perceived or actual) for equipment. As stated previously, at most all the bird-watcher needs is a reference book or two, a note-book, and perhaps a pair of binoculars or a camera. The naked eye and ear are often enough to make a positive identification of a species. The amateur astronomer is far more likely to

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[54] For example, see, *Sears, Roebuck & Co., Consumer's Guide, Catalogue No. 117*, (Chicago, IL: Sears, Roebuck & Co., 1908).

[55] The "Messier Marathons" are a common amateur observing program, usually done rather casually, but formalized by the Astronomical League in the United States in the 1970s. The goal is to observe as many of the objects in Charles Messier's catalogue of non-stellar objects as possible in one night. The list contains 106 star clusters, nebulae, and galaxies, all of which are visible in the Northern Hemisphere, and can be seen with telescopes no larger than 6-inches in aperture. Numerous books have been written as guides to this pursuit since the 1960s. The Messier Marathon is not unlike competitions among bird-watchers to spot and identify as many bird species in one day as possible.

desire a telescope, frequently as large as they can afford, as well as a host of accessories. These would include a full set of eyepieces giving a range of magnifications (typically 3 or 4 eyepieces magnifying from 50 to 300 times or so), usually a sun-filter of some kind for solar observing, and a camera adaptor and camera (usually a 35mm single-reflex type).[56] Many amateurs have had two or more telescopes, each for specific purposes (e.g., one for photographic or wide-field visual observing and one for lunar and planetary observing) plus binoculars.[57] Amateur astronomy is therefore a highly technology-dependent science hobby; ornithology is not.

On the other hand, technological hobbies such as ham radio are on the fringes of science. Although ham radio depends on in-depth technical knowledge, it really offers little contribution to science. Admittedly, there are some exceptions: a handful of ham radio enthusiasts contributed to early developments in radio astronomy and assisted in the space program. However, ham radio operators tended to be rather closed in terms of their public face. Although some leaders in the ham radio hobby tried to promote ideas of service to the community and government (particularly during war and instances of natural disasters) most individual ham radio enthusiasts have been content to work alone. Ham radio clubs were formed, but membership was more tightly controlled: one generally had to have equipment and training prior to becoming a member. There was also relatively little in the way of outreach programming on the part of ham radio operators or clubs in the same sense that amateur astronomers did.[58] Of course it could be

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[56] Most of these items are considered vital accessories, though electronic CCD cameras have replaced to film-type.
[57] This list is in part based on personal experience but also repeats what any number of the previously cited astronomical reference books state; in particular Muirden, Paul, and Sidgwick.
[58] See, Kristen Haring, *Ham Radio's Technical Culture*, (Cambridge, MA: MIT Press, 2006).

argued that some amateur telescope makers were too wrapped-up in technical details of telescope making to become involved in observational astronomy. However, those amateur astronomers and amateur telescope makers who *were* observers very frequently did so with the intent of contributing something to science.

Astronomers, both amateur and professional, depend greatly on telescopes for their studies. The invention of the telescope was truly a revolution that revealed previously unseen phenomena. The evolution of telescope technology from the crude instruments of Galileo's day to the sophisticated giant telescopes used by Edwin Hubble took a great deal of time and effort. Amateur telescope makers, as well as professional craftsmen, were part of that evolutionary process. By the end of the 19th century, amateur astronomers had at their call highly sophisticated, precision instruments. However, these 'amateur' telescopes came at a very high price indeed.

Chapter II: Perfecting ‘A Sharper Image’: the Manufacture and Marketing of Telescopes to the Early 20th Century

1. Introduction

Amateur astronomy in 1910 was substantially different than it was in 1960. The majority of amateur astronomers in the early 20th century were using commercially-made refracting telescopes of great expense. As a result of the high-cost of a telescope, amateurs had to be fairly serious about observing for scientific goals, fairly wealthy, or both. By 1960, the predominant telescope used by amateurs were relatively inexpensive Newtonian reflectors, some home-made, and just about anyone could afford one. Many could buy telescopes just for ‘recreational’ observing. Major changes occurred in both telescope making and the demographics of amateur astronomy in the 1920s. However, an examination of the making of telescopes and the amateur astronomers who used them prior to the 20th century is warranted as it establishes a ‘base-line’ by which later changes can be measured. One cannot say where one is without knowing something of the starting point. Fortunately, enough biographical information exists on representative amateur astronomers active prior to 1920 to establish the required baseline.

The year 1910 saw one of the most high-profile events in modern astronomy to that point: the much heralded return of Halley’s Comet. Newspapers and magazines across America and elsewhere contributed a good deal of ‘hype’ to the event, not all positive and some of which caused panic among the public. Much the same thing would occur 76 years later on the next visit of Halley’s Comet, but with a significant difference. The mid-1980s event saw a major sales campaign among commercial telescope manufacturers tied to Halley’s return that was totally lacking in 1910. The reasons for this difference have to do with tremendous changes, not so much in efforts at astronomy popularization in the mass-media, but in the nature of the telescope manufacturing and sales technique. The typical amateur astronomer of 1910 was a member of the well-to-do professional elite of American society, and telescope manufacturers were there to cater to such customers. No crude and utilitarian instruments for these lovers of science: only the finest in precision, hand-crafted, brass, steel, and glass would do.

There were several key steps involved in the perfection of the telescope and the transmission of knowledge concerning optical fabrication and testing. While the fundamental processes of making telescope lenses and mirror changed little, drastic changes occurred in the materials used, and most especially, the methods of testing optics. Assorted experiments and experiences in telescope making resulted in a considerable body of knowledge, but the successful transmission of such knowledge remained problematic. By the early 20th century, the results of all these developments were commercially-made telescopes of great quality, but equally great cost.

2. Early telescope making: artisans, 'gentleman-scientists', & basic principles

Telescope making prior to 1910 was dominated by two classes of telescope-maker: the professional artisan and the 'gentleman-scientist'. The professional artisan, men such as James Short, John & Peter Dolland, Merz, Secrétan, and Alvan Clark, were members of a larger class of scientific and mathematical instrument-makers who were in business to sell their wares. In a world where patent law was difficult to enforce, they tended to keep manufacturing methods a close secret, and relatively little can be learned from their surviving records concerning how they produced their instruments. Though

American telescope makers of the 19th century were free of the traditional European guild system, those in Europe were not, and the influence of guild secrecy was felt into the early 20th century, even after the guilds had ceased to exist as such. The art and science of optical fabrication were passed down from master to apprentice, and there was neither formal training nor textbooks as such on the subject until the 20th century. The 'gentleman-scientist' was not bound by secrecy as were the artisans; it was in fact their duty to expand the knowledge of all concerning science and scientific instruments. Some gentleman-scientists were professionals (university and government employees), others were amateurs (wealthy individuals with philosophical/scientific aspirations). It is from this latter group that most can be learned of optical production methods prior to 1910. It was also the gentleman-scientist who made these methods known to a wider audience in their own day.

A complete, detailed history of the telescope is not the purpose here. The subject has already been covered elsewhere, particularly by Henry King in *The History of the Telescope* (1955). However, in order to understand the changes that occurred in telescope-making between the late 19th and the middle 20th century and the impact of such changes on the hobby of astronomy, one must first understand something of the history of telescopes and telescope making. Once one understands the fundamental methods of fabrication and testing, the significance of later changes becomes apparent.

Scientific instrument-makers from the 17th to 19th centuries were a diverse group and produced diverse products, including telescopes. London was the center of both the scientific instrument and telescope making world during much of the 18th and 19th centuries. British census records through 1851 do not indicate exactly how many "opticians" and "philosophical instrument makers" actually made telescopes, but surviving examples of telescopes and advertisements suggest that at any one time there might have been several dozen instrument-makers who produced telescopes in England, Scotland, and Ireland, most concentrated in London.[59] Guilds to which they belonged were diverse and sometimes unexpected. Robert Bancks (or Banks, who worked in London from 1796-1831), a known maker of both telescopes and microscopes, was a member of the Joiners Guild, and Francis Hauksbee (d.1765) belonged to the Drapers Guild.[60] In truth, the whole subject of scientific instrument makers, as opposed to the instruments they made, is a remarkably little-studied field in the history of science and technology, limited to a famous few such as Jesse Ramsden. As a result, most of what is known of their work is limited to examination of extant instruments, and these have little to say about how they were made.

Although some written accounts of the details of lens and mirror making prior to the 18th century were made known publicly, these were very few and, in many cases, intentionally vague. Isaac Newton described some details of his own methods for fabricating his reflecting telescope in the *Opticks* (1704); his techniques seem basically similar to those of other lens makers of his era, but even he gave few details.[61] In the days before effective enforcement of patent law, fabrication methods were a closely-guarded

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[59] See, Gloria Clifton, *Directory of British Scientific Instrument Makers, 1550-1851*, (London: The National Maritime Museum, 1995), T. N. Clarke, A. D. Morrison-Low, and A. D. C. Simpson, *Brass & Glass: Scientific Instrument Making Workshops in Scotland as illustrated by instruments from the Arthur Frank Collection at the Royal Museum of Scotland*. (Edinburgh: National Museums of Scotland, 1989), and J. E. Burnett & A. D. Morrison-Low, *"Vulgar and Mechanick": The Scientific Instrument Trade in Ireland, 1650-1921*, (Dublin: Royal Dublin Society, 1989).
[60] Clifton; 16 & 128.
[61] Isaac Newton, *Opticks: Or A Treatise of the Reflections, Refractions, Inflections & Colours of Light, Reprinted from the Fourth Edition*, (London: G. Bell & Sons, Ltd., 1931), 102-107.

secret among members of the various craft guilds, a state of affairs that existed well into the 19th century. As a result, little is known, either then or now, of the details of the early lens and mirror making craft. Among the first widely disseminated works on optical fabrication, as opposed to theory, was Robert Smith's *A Compleat System of Opticks* (1738).[62] Besides contributing his own theoretical and mathematical knowledge, Smith compiled material on telescope-making from a number of well-known individuals including the Dutch natural philosopher and astronomer Christian Huygens and the British astronomers Samuel Molyneux and John Hadley, among others, and it was Smith's book that later acted as a guide for the astronomer and telescope-maker William Herschel. Smith sought to put together a work that would expand on all previous ones, and would be useful to a wide range of readers. The "popular" introductory section was non-mathematical and was "for the use of those who would know something of Opticks, but want the preparatory learning that is necessary for a thorough acquaintance with that Science."[63] More importantly, Smith intended the introduction to be sound enough to permit readers to understand the later books in his work, "especially if their heads be a little turned towards mechanical matters."[64] It is worth exploring the details of Smith's "Book III", as it describes the fundamental techniques involved in grinding and polishing lenses and mirrors. Smith acquired much of his knowledge of practical optics and lens

[62] Robert Smith, *A Compleat System of Opticks, In Four Books, viz., A Popular, a Mathematical, a Mechanical, and a Philosophical Treatise, To which are added, Remarks upon the Whole* (Cambridge, England: Cornelius Crownfield, 1738). Smith was Professor of Astronomy and Experimental Philosophy at Cambridge.
[63] Smith, *A Compleat System of Optics*; i.
[64] Smith, *A Compleat System of Optics*; i.

production via his friend Samuel Molyneux.[65] Smith himself apparently knew little concerning the actual techniques of fabricating lenses and mirrors; what he presents in Book III is largely the work of others. As a result of Smith's unfamiliarity with fabricating technique, it is a somewhat confusing account at times, demonstrating some of the problems with popularizing science and technology.

The section on lens production is based almost entirely on the work of Christian Huygens, which Smith considered "the best of any yet extant". Huygens produced a number of the largest and best refracting telescopes made in the late 17th century and used them to make a number of important discoveries including the nature of Saturn's rings, and he worked out a number of fabrication techniques for lenses.[66] The objective lenses of all refracting telescopes up to about 1750 were made from a single piece of ordinary glass, referred to as 'crown-glass'. As a result, such simple lenses suffered from a number of problems (to be discussed later) cured only by making them of very long focal-length, over a hundred feet in some cases. Smith's description of Huygens' methods take the reader step-by-step through all aspects of lens production including how to make the brass grinding tool, how to choose quality glass, the rough and fine grinding process, and polishing.[67] An aspect of telescope-making that was, and continues to be, of crucial

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[65] Smith, *A Compleat System of Optics*; 281. Molyneux served as a Lord Commissioner of the British Admiralty and as such was no doubt interested, both personally and publicly, in passing on everything learned concerning astronomical and navigational instrumentation.

[66] Galileo had first noted "ears" seemingly attached to Saturn in his own early observations, and later observers also remarked on the peculiar appearance of Saturn viewed with a telescope. The relatively poor quality of telescopes prior to Huygens' instruments (12-foot and 23-foot focal length and about 2-inch aperture) in fact drove Huygens and his brother to construct their own. King; 51.

[67] Smith, *A Compleat System of Optics*; 282–301. Although Huygens' methods would be familiar to telescope-makers today, there are some differences; for instance, the concave grinding and polishing tool (described by Smith as a "plate" or "dish") is made considerably larger in diameter than the finished lens, rather than the same size. Polishing appeared to be the problematic aspect of lens-making for Smith and Molynaux, as at least three different methods, or variations of methods, are described.

importance, is the quality of the glass required for lenses; this proved to be a major stumbling block to improvement of refracting telescopes for many years.[68] Grinding the curved surface of lenses then as now involved the use of an abrasive slurry, usually consisting of powdered emery (natural corundum, an aluminum oxide) and water. Once the curve had been generated by grinding with a coarse grit, finer and finer grades of emery were used to remove the large pits in the glass created by coarser stages of grinding.[69]

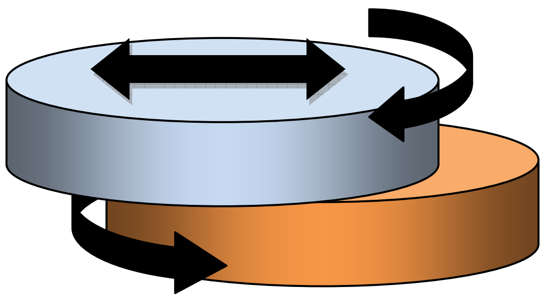

Fig. 9 – The basic motions involved in lens and mirror grinding and polishing. Two discs, often but not always of the same diameter, are rubbed against one another with an abrasive mixed with water in-between. To ensure uniform and symmetrical concave and convex surfaces, the two discs must frequently be rotated in reference to one another so that the grinding action can be done along different axes. If this is not done, the optic will suffer astigmatism.

Polishing the lens to remove all traces of grinding, so making the lens completely transparent and free of pits and scratches, was generally done with an extremely fine abrasive such as jeweler's rouge (ferric oxide, Fe_2O_3), or "tripoly" (decomposed silicaceous limestone), on a yielding surface. Huygens is quoted by Smith as using tripoly

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[68] Smith, *A Compleat System of Optics*; 287–288. Optical glass for lenses must be of high purity and free from an assortment of flaws. Huygens considered glass with a slight greenish, yellowish, or reddish tint to be superior to pure white glass as the latter often had "veins" likely caused by variations in density and composition. Whatever the details were, it is quite clear that telescope-makers of the early 18th century understood the problems of optical-glass manufacturing, though the solution would not come until the early 19th century.

[69] "Large pits" is a relative term as those generated in coarse grinding are only about 1/100th of an inch across; these are quite noticeable and give the lens a frosted appearance. By the last stage of fine grinding the pits will have been reduced to less than 1/10,000th of an inch and the lens will be nearly transparent.

directly on a copper tool, while others used linen, leather, paper, or other soft surfaces.[70] The majority of grinding work was done by hand, but polishing was considered by most workers to require considerable pressure, and so machines of one kind or another were used.[71] The last stage of lens production involved *centering* the lens; that is, making sure both faces of the lens had coinciding foci along the same optical axis. The centering process would often result in significant portions of the lens being cut away.[72] This last step seems to be the end of the process and nothing is really said about *testing* the final lens beyond the assessment involved in the centering process.

Smith then goes on to describe the method for making "specula", or telescope mirrors, as described by Samuel Molyneux and John Hadley. It is this section of Smith's book that gave William Herschel, and no doubt others, important clues to many details of telescope making. Reflecting telescopes had been theorized about since the early 17th century, but it was Isaac Newton who produced the first working models of such telescopes in 1668–70 using a mirror made of 'speculum metal', an alloy of copper and tin. After the experiments of Newton and a few others, little more was done concerning

[70] Smith must have misinterpreted Huygens, since polishing directly on the metal tool would have left numerous fine scratches. Smith's narrative of the process admits some confusion, using the phrase "if I understand Mr. Huygens right [the linen cloth is removed after using it to wipe the lens with tripoli]" (Smith; 293–294). Smith's confusion helps demonstrate how little was generally known about the craft of lens-making at the time. King, in *The History of the Telescope*, takes a less literal reading of this passage by Molyneux (or Smith quoting Molyneux) and suggests Huygens did in fact use a cloth adhered to the tool with wax and/or pitch as a polishing surface. This would seem to be far more likely.

[71] Smith; 297–301. The machines in question were of various types, and are illustrated in Smith's book, and could be said to be variations on the lathe and bear a remarkable resemblance to modern lens and mirror grinding and polishing machines (see Smith, figure 563). All such machines combine a rotary motion of one disc with a reciprocating motion of the other. Isaac Newton was one of the few who did not feel that high pressure was required and only used hand-pressure.

[72] Smith; 312–317, figures 568–574. If the lens were un-centered, it would have given the lens a wedge-shaped cross-section and resulted in it behaving more like a prism, giving rise to a whole host of optical defects. Today centering is usually accomplished by using a micrometer to measure the relative thicknesses of the lens edge from start to finish during the grinding process; micrometers of sufficient accuracy were not available in Smith's day.

the fabrication of reflecting telescopes until John Hadley applied his knowledge and abilities to the problem.

John Hadley (1682–1744), a mathematician and instrument maker from Essex, was notable for producing the first "large" Newtonian telescope, large being a comparative term as Newton's original had an aperture of less than two inches while Hadley's was a 6-inch. Hadley's reflecting telescope of 1719–1720 caused a sensation. The telescope worked well, as can be attested by the drawing of Saturn appearing with Hadley's description of his telescope in the *Philosophical Transactions*.[73] Hadley's letter had little to say concerning how he made either the optics or mechanical parts of his telescope; fortunately, later correspondence with Smith provided many answers. *A Compleat System of Opticks* supplied details of making the speculum metal disc from which the mirror was made, through rough grinding, fine grinding, and polishing.[74] The fabrication methods used were very similar to those for lenses at the time, aside from the different material used for the mirror itself.[75]

Of particular note, however, is that Hadley not only describes his method of *making* mirrors, but also of *testing* them. Optical theory, then as now, shows that, in order

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[73] Smith; p.301–312. John Hadley, "An Account of a Catadioptrick Telescope, made by John Hadley, Esq; F.R.S. With the Description of a Machine contriv'd by him for the applying it to use", *Philosophical Transactions*, XXXII, 376 (March & April, 1723); 303–312. Hadley's description concentrates on the physical lay-out of the tube and the mounting: his telescope was of about 6 inches in diameter and had a focal length of 62⅛ inches. In lay-out and accessories, Hadley's telescope is essentially the same as a modern Newtonian telescope: it had a "Slider" for adjusting the focus, a "common Dioptrick [refracting] Telescope" with cross-hairs as a finder, and three eyepieces magnifying 188 or 190x (1/3-inch FL), 208x (3/10-inch FL), and 228-230x (12/40-inch FL). The eyepieces were apparently of a single-lens convex type.

[74] The correct proportion of metals used was a matter of considerable argument and experimentation well into the 19th century. Hadley, with the assistance of Bradley, tried 150 different formulae for speculum metal before they came across the one that worked best, a combination of two alloys, the first of "Three parts of copper and one part and a quarter of tin" and added to the second of "six parts of good [plate] brass and one part of tin" (Smith, 304–305). Telescope-makers continued to fiddle with the details of these proportions, but speculum metal was essentially the same copper-tin alloy.

[75] Smith: 306.

to form a good image of an object at infinity, the cross-section of the surface of a reflecting telescope's mirror must be a paraboloid. This is a very difficult surface to produce for a number of reasons. First, the method of making mirrors is like that of making lenses; two discs are ground against one another, one convex the other concave. The natural shape produced by the grinding process (and later, the polishing) is a sphere. It requires somewhat different motions to produce an aspherical surface on either a lens or mirror and the special techniques for this are quite demanding. A second reason for difficulty is that the difference between the required spherical and paraboloidal surfaces of a telescope's mirror is very tiny, on the order of a millionth of an inch.[76] As a result, the difference between the two surfaces is impossible to detect by any normal means. Indeed, the testing of telescope optics was one of the major stumbling blocks to advances in telescope technology until the mid-19th century. Hadley's method, as described in *The Compleat System of Opticks*, continued to be used into the 19th century. Hadley well understood the basic geometry of optics and how light-rays behaved after being reflected from a concave mirror.[77] The correct paraboloidal surface is slightly deeper in the middle than a spherical mirror of the same focal-length. Hadley's test took advantage of his theoretical knowledge and he developed a simple, graphical, and qualitative test for different surfaces.[78]

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[76] The generally accepted maximum surface error for a telescope mirror is ¼ of a wavelength of green light, or about ±135 nanometers (±0.00000532 inches). The difference between a spherical surface and the correct parabolic one varies with both the diameter and the focal length of the mirror according to the formula $r^4/8R^3$, where r = the radius of the mirror (1/2 of the diameter) and R = the radius of curvature (twice the focal length) of the mirror.
[77] Book I of Smith includes numerous detailed diagrams concerning what is now referred to as "ray-tracing". For examples, see Smith, *A Compleat System of Opticks*; 6–27. For a brief description of both old and new optical testing methods, see Rolf Willach, "James Short and the Development of the Reflecting Telescope", *JATS*, 20 (Winter 2001): 3–18.
[78] Smith, *A Compleat System of Opticks*; 309–312.

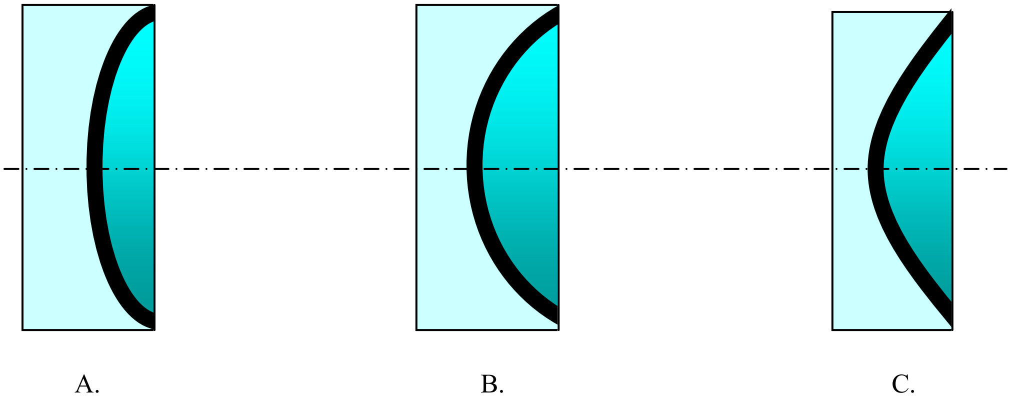

Fig. 10 – Profiles of different conic-projection surfaces: “A” the oblate sphere (ellipsoid), “B” spheroid, and “C” paraboloid.

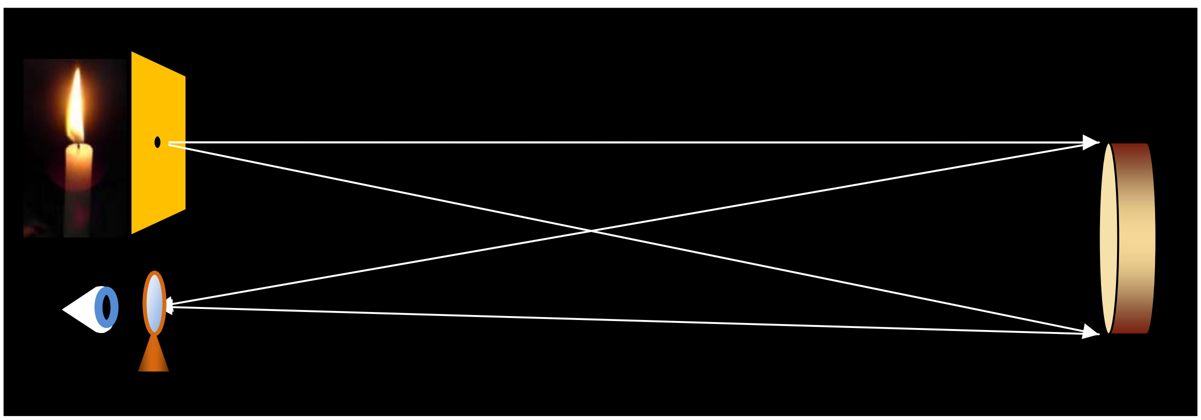

Fig. 11 – Hadley’s arrangement for testing mirrors at the center of curvature.

Hadley’s test was quite simple. Light from a candle was allowed to shine through a very small hole, commonly the size of a pin-point, in an opaque screen. The light would then reflect off the surface of the polished mirror, and the observer then examined the reflected image of the pin-hole by using a magnifying lens. Both the pinhole/light-source and the lens were located at the center of curvature of the mirror (twice the focal length), and the pin-hole served as an artificial star. Hadley clearly understood the test process in the same way as modern opticians: light-rays from the object reflect off the mirror’s surface and are brought to a single focal point, or not, depending on any flaws in the mirror's surface that might be present. The appearance of the artificial star's image at the focus as seen magnified by a lens could thus be used to interpret the mirror surface:

> "If the light, just before it comes to a point, have a brighter circle round the circumference [edge], and a greater darkness near the center, than after it has crossed and is parting again; the surface is more curve[d] towards the circumference and flatter about the center, like that of a prolate spheroid [ellipsoid] round the extremities of its axis; and the ill effects of this figure will be more sensible when it comes to be used in the telescope. But if the light appears more hazy and undefined near the edges, and brighter in the middle before its meeting than afterwards, the metal is then more curve[d] at its center and less towards the circumference; and if it be in a proper degree, may probably come near the true parabolick figure. *But the skill to judge well of this must be acquired by observation* [emphasis added]."[79]

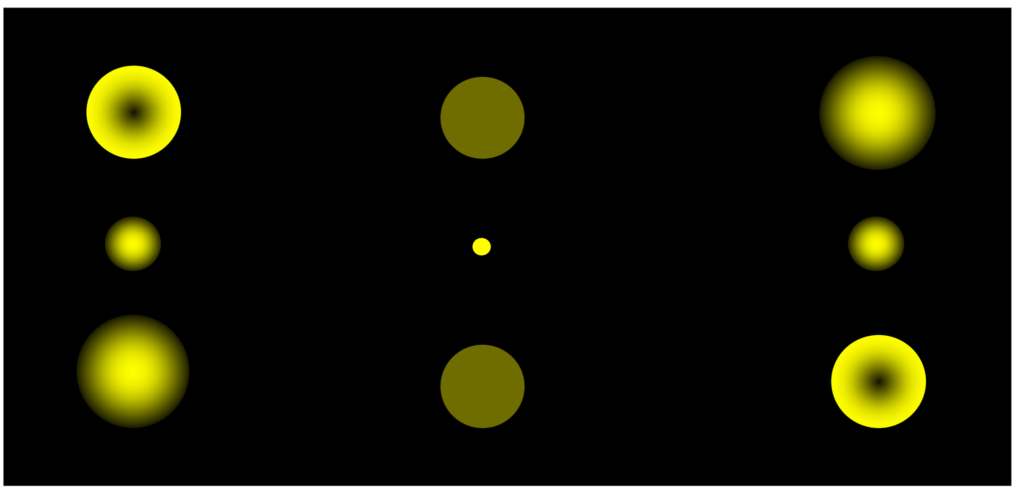

Fig. 12 – Hadley's testing method – images of artificial stars as seen with a magnifying lens at the center of curvature of a mirror. In each case, the upper image is what is observed just inside the focus (intra-focal), the middle image is at focus, and the lower is just outside the focus (extra-focal).

Note that a spherical mirror tested at the center of curvature gives a perfectly sharp image at the focus and symmetrical intra- and extra-focal images. The importance of such a test as Hadley's cannot be over-emphasized; this is *the* most critical portion of the entire telescope manufacturing process. Without it, fabrication of the telescope speculum was

[79] Smith; 310.

more guess-work than anything else, and resulting telescope performance could be mediocre at best. The problem with Hadley's test, as he clearly admitted, was that it is *qualitative*, rather than *quantitative*; the determination of whether the surface under examination was a *true* paraboloid or not was a matter of judgment requiring some considerable practice. As will be seen, modern tests of 18th century telescopes indicate that even the best makers of the day produced mirrors of somewhat variable quality.

A few opticians in London made small reflecting telescopes after Hadley, but relatively little is known of these.[80] It was James Short (1710–1768), a Scot who later moved to the center of the scientific instruments trade in London, who would dominate the manufacture of reflecting telescopes in Britain during much of the 18th century. Short was university educated and became interested in telescopes in the 1730s. Short met mathematician Colin Maclaurin at the University of Edinburgh during one of the latter's popular lectures on astronomy and the two worked together for a time, Short being allowed use of a room at the university for experiments in telescope-making.[81] Short produced a few Newtonian telescopes, but the vast majority of instruments he made were Gregorian reflectors. Short had a long career as a telescope maker and was considered one of the best in his day.[82] Prices are known for his telescopes and ranged from 3 guineas for a diminutive "3-inch focus" telescope of 12-power magnification, to a "144-inch focus", of 24-inch aperture and 1200-power, for 800 guineas.[83] The vast majority of

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[80] See, King; 84.
[81] King; 84. "Maclaurin, Colin", *The Biographical Dictionary of Scientists*, Roy Porter and Marilyn Ogilvie, Consultant Editors, (New York: Oxford University Press, 2000); 646–647.
[82] Willach, "James Short": 16. 1,342 telescopes is the generally recognized total made by Short.
[83] Clarke, Morrison-Low, and Simpson: 2. A full list of prices (date unknown, but likely c.1760) includes all known models of Short telescopes. These were listed by "Number" and by the focal length, as was typical for all telescopes of the 17th and 18th centuries. Short and other makers of Gregorian telescopes

telescopes produced by Short were in the smaller 7 to 18-inch focal length (1.9 to 3.8-inch aperture) range. Most of Short's telescopes actually sold were quite small; of 1,342 made, only about 380 were of an aperture greater than 3-inches, the 2½-inch size being most popular. Such small telescopes would have been of limited astronomical use and were equivalent in light-gathering power to refracting telescopes of half their aperture.[84] This, plus what little anecdotal information there is on Short's customers, would suggest that the vast majority of persons buying these telescopes were interested mostly in something for casual viewing of terrestrial objects and perhaps a glimpse of the moon.

A modern analysis by Rolf Willach of several James Short telescope mirrors shows that, while a few primary mirrors (about 20%) are good even by modern standards,

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gauged "focal length" by that of the primary mirror rather than the overall focal length of the telescope. Secondary mirrors of Gregorian and Cassegrain telescopes magnify the image several times; thus the "effective focal length" of the complete telescope would be much longer. My own analysis of data from some of Short's telescopes (described by Willach) gives a secondary mirror magnification of about 6 times on average.

The table below is a combination of data from Short's original price list cited above (columns 1, 3, 5, and 6), combined with the aperture, overall focal length, and price in U. S. Dollars as of 2001 calculated by myself (columns 2, 4, & 7).

No.	Aperture in inches	**Focal Length of Primary in Inches**	Overall FL in inches	**Magnifying Powers**	**Price (guineas)**	Price (US$)
1	*1*	***3***	*18*	***12 (terrestrial use only)***	***3***	*546*
2	*1.3*	***4½***	*27*	***25 (")***	***4***	*726*
3	*1.9*	***7***	*42*	***40 (")***	***6***	*1,092*
4	*2.5*	***9½***	*57*	***40 and 60***	***8***	*1,452*
5	*2.95*	***12***	*72*	***55 and 85***	***10***	*1,820*
6	2.95	**12**	72	**35. 55, 85, and 110**	**14**	2,548
7	3.8	**18**	108	**55, 95, 130, and 200**	**20**	3,640
8	4.4	**24**	144	**90, 150, 230, and 300**	**35**	6,364
9	6.5	**36**	216	**100, 200, 300, and 400**	**75**	13,650
10	9.25	**48**	288	**120, 260, 380, and 500**	**100**	18,200
11	12	**72**	432	**200, 400, 600, and 800**	**300**	54,600
12	24	**144**	864	**300, 600, 900, and 1200**	**800**	145,600

[84] The lesser light-gathering power of early reflecting telescopes was due largely to the relatively low reflectivity of speculum metal. Even when freshly polished, a speculum metal mirror only reflected about 60% of the light falling on it; with two mirrors, as is the case with most reflecting telescopes, the total reflectivity would be 60% of 60% or only 36%. A reflecting telescope had only 25% the light-gathering power of a refractor of equal size.

the majority show considerable under-correction; many are in fact nearly spherical in cross-section. The small secondary mirrors of Short's telescopes are likewise far from the theoretical shape required. Views through the under-corrected Short telescopes have a somewhat 'soft' appearance as a result of 'spherical aberration' when viewing various objects.[85] Short was highly secretive about his manufacturing methods, so the tests he used remain a mystery. Based on the variable quality of his mirrors, it is likely that he used Hadley's 'in-shop' method or some variation. Although Short was one of the most celebrated telescope makers of the mid-18th century, many of his instruments were far from perfect. The shock therefore felt by those who observed with the vastly superior telescopes made by William Herschel only a few years after Short's death can therefore be understood by comparison.

In terms of both size and quality, reflecting telescopes of the late-18th and early-19th centuries reached their zenith with those of William Herschel (1738-1822). Herschel, originally a musician by profession, took up astronomy as a hobby after his move to England from Hanover, though he had been exposed to mathematics, astronomy, and natural philosophy since boyhood.[86] Herschel had long maintained an interest in the sky, but this increased in the 1770s. His diary entries during 1773 repeatedly mention not only purchases of books on astronomy, but also the "hiring" of several small reflecting telescopes. Herschel also records the purchase of object glasses, tubes, and eyepieces for small refracting telescopes, and "tools for making a reflector. Had a metal [mirror blank]

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[85] Willach; 8-14. Spherical aberration is the term used when all light rays do not come to a single point. Tests were performed on 16 different Short telescope mirrors ranging in size from 40mm to 235mm in aperture. Though Willach considered Short's mirrors to be fairly good, some would have suffered from as much as a 1 wave of spherical aberration, about 4 times the amount generally found acceptable.

[86] J. B. Sidgewick, *William Herschel, Explorer of the Heavens*, (London: Faber and Faber Limited, 1953); 17-20. William received lessons in philosophy, logic, and ethics from one "Hofschläger".

cast."[87] Among the books William Herschel read was the *Compleat System of Opticks* by Smith.[88]

Herschel became greatly interested in the relative compactness of the various types of reflecting telescopes, both Gregorians and Newtonians. But, as with many future amateur astronomers, Herschel found the cost of commercially available telescopes to be prohibitive; he then decided to attempt making his own "with the assistance of Dr. Smith's popular treatise on Optics."[89] One of Herschel's neighbors in Bath was an amateur telescope maker who had given up the hobby; William quickly purchased all of his tools and unfinished mirrors. The purchase of additional speculum metal discs for more telescopes soon followed, and Herschel became totally immersed in telescope-making in his spare time. By 1791, Herschel claimed to have produced 200 mirrors of 7-foot focus (6–6½-inch aperture), 150 of 10-foot focus (8–10-inch), and 80 of 20-foot focus (12–18-inch). Most of the telescopes Herschel made were of the Newtonian type, but, in an effort to reduce light-loss from multiple reflections, the larger sizes were of a single-mirror design of Herschel's own devising now referred to as a "Herschellian". [90]

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[87] Sidgwick, *William Herschel*; 47–55. The objective glasses were of 10-feet (purchased May 24, 1773), and 20-feet focal-length (purchased from "Emerson's Optics" October 2), and were simple non-achromatic lenses having apertures probably of only 1½ to 2½ inches. Herschel had bought several other telescopes, the smallest being of 4-feet focus, magnifying 40-times, and longest of 30-foot focus. William's sister Caroline recalled that while they passed through London on one journey in 1773, virtually the only shops they stopped at were those of opticians'.

[88] *The Herschel Chronicle: The Life-History of William Herschel and his Sister Caroline Herschel*, Constance A. Lubbock, editor, (Cambridge, England: Cambridge, at the University Press, 1933); 65–66. Sidgwick, *William Herschel*; 49.

[89] Sidgwick, *William Herschel*; 55–56.

[90] Sidgwick, *William Herschel*; 56–61. The large number of mirrors made for use by Herschel likely included a large number of duplicates and failed experiments. Speculum metal is a difficult material to make and work with. There are many instances of speculum discs that shattered or became warped, possibly due to poor annealing. Besides this, makers of speculum-metal reflecting telescopes generally made pairs of mirrors for each telescope so that as a mirror became tarnished by exposure to the air, its twin could swapped into the telescope while the first was re-polished.

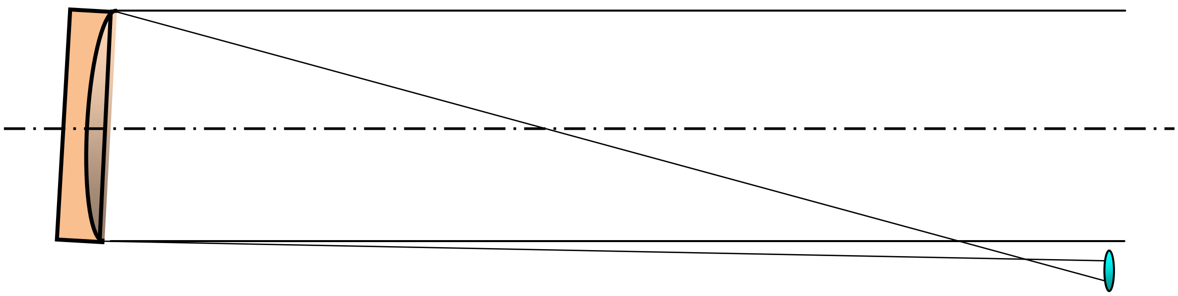

Fig. 13 – The Herschellian telescope.

Herschel seems to have preferred testing his telescopes on the stars, rather than in the shop; however, the test he used was really a variation of Hadley's method, substituting an actual star for the illuminated pin-hole. The crucial modification Herschel made to Hadley's test was that, when observing a star at infinity, the correct parabolic 'figure' of the mirror would produce the same symmetrical series of intra- and extra-focal images as produced by a spherical mirror tested at its center of curvature. Thus for Herschel, there would be no question of judgment as to whether the figure of the mirror was elliptical, parabolic, or some other figure as in Hadley's test; if one observed a good, symmetrical series of images, the mirror *had* to be perfectly parabolic.[91]

Herschel's efforts at producing ever larger, ever improved telescopes, was driven by his observational interests. Unlike most observational astronomers of the 18th and early 19th century who were interested chiefly in the positions of stars and motions of the planets, Herschel wanted to know something of the nature of the stars and nebulae. This study required a different type of telescope than in positional astronomy, as done at the Royal Greenwich Observatory in England, for example. Positional astronomy requires

[91] Sidgwick, *William Herschel*; 63–64. It is likely that other telescope-makers also did a final star-test of a telescope; but the need to wait for a clear night, mount the mirror in a telescope tube, test, then dismount the mirror in order to work on polishing it further, would have been very time-consuming. While this would not have been much of an issue for an amateur telescope-maker such as Herschel, it would have been a great annoyance for a professional optician struggling to meet orders.

very sturdy mountings, finely graduated scales for measuring small angles, and the ability only to see relatively bright stars. For such a purpose, the then standard, small aperture, long focal-length, refractor was perfectly adequate. Herschel's work on the other hand required aperture and light-gathering power. In addition, his telescopes' relatively crude wooden mountings were perfectly adequate for his purposes.[92]

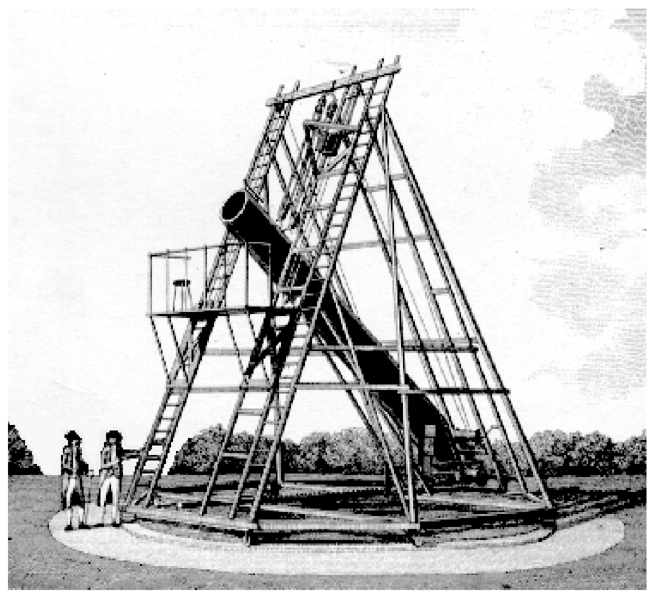

Fig. 14 – A Quadrant telescope (about 2-inch aperture, 8-feet focus – the telescope itself indicated by the oval) at the Royal Greenwich Observatory and Herschel's 20-foot (18-inch aperture) reflector.

Besides producing telescopes for his own observational program, Herschel also made telescopes for sale. Herschel was making the best large reflecting telescopes in the world around 1800, and the notoriety created by his discovery of the planet Uranus in 1781 without doubt encouraged many to purchase his instruments. Herschel could by no means be considered a mass-marketer of astronomical telescopes, even by the standards of his day, but he did offer more or less standard sizes at fixed prices. Records exist confirming the construction of at least 33 complete telescopes for sale, ranging in size

[92] *The Herschel Chronicle*; 64–65.

from 5½-inch to 24-inch aperture. The most common size was the very convenient 7-foot focus telescope, which varied in aperture from 5½-inch to 8.7-inch, though 6¼-inch was most typical; 21 7-foot telescopes were made and sold between 1788 and 1812. The 10-foot focus telescopes were the next most popular (9 produced) and had specula from 8.3-inch to 24-inch diameter. The 14-foot, 20-foot, and 25-foot focus telescopes were each one-off items.[93] Herschel stated in a letter on March 10, 1794 that his prices, which appear to have held steady for over a decade, for complete telescopes ranged from 100 guineas (£105 c.1800, $7,500 in 2001) for the "small 7-foot" (6¼-inch mirror) to 8,000 guineas ($600,000) for a 40-foot (48-inch mirror).[94] Purchasers of these telescopes were, to say the least, the elite of Europe. One of Herschel's best customers was none other than King George III, whose interest in astronomy led to royal patronage of Herschel's research work; the King purchased several instruments as gifts for loyal subjects. Other buyers included King Carlos IV of Spain, Kaiser Franz I of Austria, Catherine the Great of Russia, Lucien Bonaparte, and the Grand Duke of Tuscany. How these telescopes were actually used is debatable, but they certainly served as "showpieces".[95] Seven telescopes were purchased for use at various university and government observatories around Britain and the rest of Europe. Individuals, such as Italian astronomer Giuseppe Piazzi, purchased the balance (generally the smaller sizes) for use in private observatories.

Although the reflecting telescopes of William Herschel represented a very high level for such instruments, a level of both quality and size not surpassed until the 1840s, it should be realized that they were not entirely unique. Other astronomers were also

[93] Andreas Maurer, "A Compendium of All Known William Herschel Telescopes", *Journal of the Antique Telescope Society*, 14: 4–15.
[94] Maurer: 15. Herschel only produced a single 48-inch telescope, for himself, financed by King George III.
[95] Maurer: 4.

involved in making reflecting telescopes for themselves in the early 19th century. One of these, the Reverend James Little, wrote a tract, published in the *Journal of Natural Philosophy, Chemistry, and the Arts,* in 1807.[96] Little's article provides considerable details of his own methods of casting specula, grinding, polishing, and 'figuring' the mirror to the correct curve, as well as extremely detailed theoretical analyses of problems of telescope design and fabrication. Considering the seeming value of Little's treatise, it is remarkable that it remained obscure; later telescope-makers make no mention of it. There were, in fact, a number of tracts available to those interested in making reflecting telescopes into the early 19th century, but failed to turn it into the popular hobby it became in the 20th century. However, the effectiveness of such texts at transmitting knowledge is questionable. The fact that few seem to have read them suggests that these texts were not widely distributed.

However, the mid-19th century did see several large speculum-metal reflectors constructed by amateurs, primarily in Britain and Ireland. These telescopes and their users made significant contributions to science, in particular the 6-foot diameter "Leviathan of Parsonstown" (1845) constructed by the wealthy William Parsons, 3rd Earl of Rosse. Parsons conducted many experiments on producing large telescopes, but his improvements were quite gradual. While Rosse's giant telescope was spectacular in appearance, its construction did not greatly advance reflecting telescope technology. The test methods of Hadley and Herschel had been important in improving the reflecting

[96] Rev. James Little, "Observations on the Metallic Composition for the Specula of reflecting Telescopes, and the manner of casting them: also, a Method of communicating to them any particular Conoidial Figure & with an Attempt to explain on scientific Principles, the grounds of each Process: and occasional Remarks on the Construction of Telescopes", *A Journal of Natural Philosophy, Chemistry, and the Arts*, XVI, (1807): 30–59, 84–100. Little's work is not mentioned in any later tracts on telescope-making, nor in King's *History of the Telescope*.

telescope, but were still a bit clumsy and inexact. Texts on telescope-making by Smith, Little, and others, had been produced, but not widely read. However, while builders were slowly making advances in reflecting telescope technology, more radical changes were made in refracting telescopes that allowed those instruments to compete with, and to surpass, speculum-metal reflectors.

3. The refracting telescope: problems and solutions

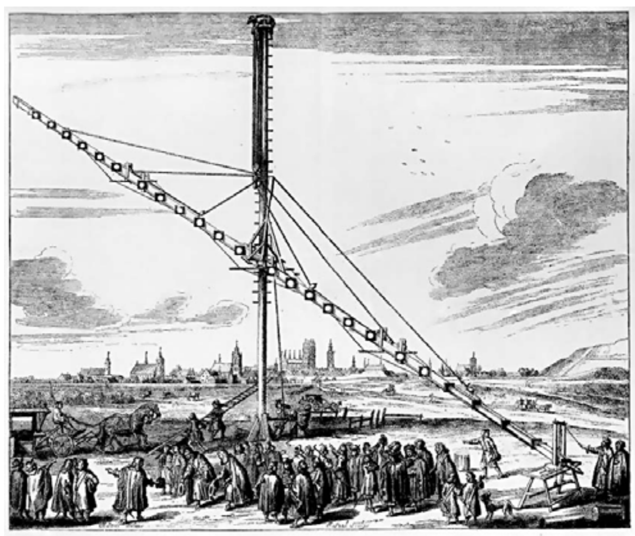

Fig. 15 – The 140-foot refractor of Hevelius (from Johannes Hevelius, *Machina coelestis, Part I*, 1673)

The very first telescopes were of the refracting type. The refracting telescope, invented in 1608, as used by Galileo, Johannes Hevelius, Huygens, and others, utilized a single-element objective lens. After the novelty of the early telescopes wore off, users discovered that these instruments had a number of flaws, chiefly chromatic and spherical aberration.[97] Instrument-makers found through trial and error that they could minimize these aberrations by making refracting telescopes with relatively small aperture and long,

[97] The first of these is caused by the fact that a single lens (or any other medium) refracts different colors of light by different amounts: thus the red and blue light rays from an object come to different foci. Spherical aberration in lenses is like that in mirrors and is caused by all light rays traveling through the lens not coming to the same focus. This creates a fuzzy image and difficulty in focusing.

sometimes ridiculously long, focal length. Huygens, Johannes Hevelius, and other late-17th century astronomers regularly used refracting telescopes with focal lengths measured in dozens or even hundreds of feet, but with apertures no larger than 6 or 7 inches. It was these difficulties with refracting telescopes that encouraged Isaac Newton and others to develop reflecting telescopes. For the type of positional astronomy work being done by many astronomers in the 18th century, refracting telescopes were only partially eclipsed by reflectors. Considerable useful work was done even by the optically imperfect refracting telescope.

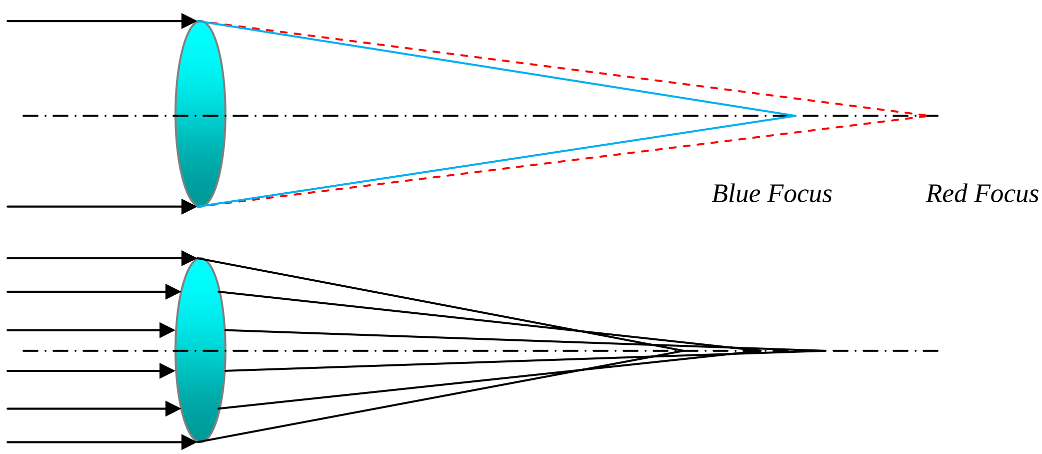

Fig. 16 – Chromatic aberration (top) and spherical aberration (bottom)

Fig.17 – The effects of chromatic and spherical aberration can be seen in these photographs taken through a small (1-inch aperture) non-achromatic telescope. Note the red and blue color fringes around bright objects, due to chromatic aberration, and the blurring, caused by spherical aberration (photographs by author)

The early difficulties encountered with refracting telescopes were largely overcome by the work of John Dollond (1706–1761) and son Peter (1730–1820) and the development of the achromatic ('color-free') lens. Though the Dollonds were not the inventors of the achromatic lens, they were the ones who first produced and marketed the achromatic refractor. The key to perfecting the refracting telescope was to make the objective lens out of not one piece of glass, but of two (or even more). The two lenses, one placed behind the other, sometimes in contact, sometimes with a small air-space between them, were made of different types of glass called 'crown' and 'flint' (see Fig. 2, Chapter 1). Crown glass was more or less standard window glass, as had been used for many years. Flint glass, however, was of a higher density made possible by including a small amount of lead in the mix; this gave it distinctly different optical characteristics. The result of combining the two types of glass was that, given a proper combination of glass characteristics and radii of curvature, the flint lens largely corrected the aberrations of the crown.[98] John Dollond learned of various experiments in producing achromatic lens sets around the year 1750; these experiments had not gone far however, and no professional instrument makers seem to have tried producing achromatic refractors for retail sale prior to Dollond.[99] John and his son Peter, who were both as talented as businessmen as they were as opticians, established a reputation in the London scientific instruments trade that spread far beyond the city and endured for many decades.

[98] It is generally conceded that the achromatic lens was first successfully produced by Englishman Chester Moor Hall around the year 1740, but a number of others including Leonhard Euler and Samuel Klingenstierna had concluded that such a design was possible.

[99] For details of the development of the achromatic lens, see King; 144–150

Reputation and quality came at a cost: a Dollond telescope of around 3½-inch aperture, alt-azimuth-mounted on a mahogany tripod, cost £70 in the 1780s ($7,950 today).[100]

An alliance between the Dollonds and instrument maker Jesse Ramsden (1735–1800) basically cornered the market on precision refracting telescopes in late 18th century Europe.[101] With optics made by the Dollond firm and precision mountings made by Ramsden, many of the major observatories of Europe featured Dollond-Ramsden telescopes.[102] Not a great deal is known of the work-habits, work-forces, or work-places of most scientific instrument-makers of the 18th century, largely for reasons of secrecy previously cited. Some enlightening information is available for Jesse Ramsden's shop. In common with many, though not all, scientific and 'mathematical' instrument-makers of the 18th and 19th centuries, Ramsden did not make the optical components for his telescopes and surveying instruments. He also apparently 'jobbed-out' manufacture of many other components to outside shops. Still, at the pinnacle of his profession, it is rather surprising how small Ramsden's workshop actually was. British Inland Revenue records include the ground plan of Ramsden's shop at 199 Piccadilly for the year 1799; the shop, workshop, and storage rooms were enclosed in a building measuring about 77 feet long and just under 20 feet wide. These were hardly shops for quantity production, let alone mass-production.[103]

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[100] King; 161.
[101] Some of the earliest American observatory-grade instruments were refractors by Dollond.
[102] King; 162–172.
[103] Anita McConnell, *Jesse Ramsden (1735-1800): London's Leading Scientific Instrument Maker*, (Aldershot, England and Burlington, VT: Ashgate Publishing Limited, 2007); 17–23, 53–58. According to the plan drawing, Ramsden's shop in 1799 was also divided into many small rooms, the largest measuring less than 20 feet square. Earlier drawings of Ramsden's shop (c.1776) exist, but are far less accurate; McConnell cites dimensions of 25 feet for width and 71 feet, 10 inches for depth, but it was an "irregular" structure and was rebuilt on at least one occasion. At any rate, Ramsden's shop was quite small.

Although the achromatic refractor was a distinct advance on the earlier single-lens telescope, the development of refracting telescopes was restricted by the availability of optical glass of sufficient quality. There were ordinary glass-makers in many countries in the 18th century, but few were able to make glass that was free enough from bubbles, ‘striae’, ‘seeds’, and various other flaws to make anything other than crude lenses of small size for spectacles. The best glass in the late 18th century came from Britain and France, but even the best makers were unable to produce usable pieces of optical glass much larger than 3 or 4 inches in diameter. In addition to problems with the available materials, the practical opticians of the 18th and early 19th centuries tended to use trial and error methods in designing and fabricating their lenses, despite the work of theoreticians such as Leonhard Euler and Alexis Clairaut. As a result, they wasted much work in producing lenses that might or might not be of sufficient quality for use in an astronomical telescope.

The solution to these problems came from two individuals who successfully combined practical knowledge of optical fabrication, diligent experiment, and mathematical rigor: Pierre Louis Guinand (1748–1824) and Joseph von Fraunhofer (1787–1826). Guinand’s early life is not well known, but he entered the business of clock-case and cabinet-making in les Brenets, Switzerland around 1790. As with so many others involved in innovation in the history of the telescope, Guinand’s interest in telescope-making began as an avocation after he had seen an acquaintance’s telescope, likely made by Short. Guinand made several attempts at making various types of telescopes, but increasingly turned his thoughts towards refractors. Being dissatisfied with the quality of available optical glass, Guinand began a long series of experiments in producing a higher quality optical glass. Guinand found that the secret to creating large batches of optical glass free of flaws involved careful choice of pure ingredients, careful annealing of the glass, and, most importantly, careful stirring of the molten glass to rid it of bubbles and inhomogeneities. From the late 1790s onward, Guinand was able to produce excellent flint-glass discs of 4-inch, 6-inch, and even larger diameters.[104] Joseph von Fraunhofer was important in conducting extensive experiments to determine the physical and optical characteristics of different types of optical glass. Fraunhofer was also a skilled lens and instrument-maker and produced some of the most innovative telescope-mounting designs at the time. Guinand and Fraunhofer joined the "Mathematical-Mechanical Institute Reichenbach, Utzschneider and Liebherr", a rather odd hybrid business-research facility for the time, in the first decades of the 19th century. With Guinand's vastly improved glass-making techniques and Fraunhofer's expertise in mathematically-based lens design, the center of telescope making began to shift from Britain to Central Europe. Guinand left Utzschneider and Fraunhofer around 1815 (not an amicable separation) and founded a very important dynasty of optical glass-makers in France that was to dominate the field through the end of the 19th century. Many commercial telescope makers in Britain and the United States depended on French, Swiss, and German glass-makers well into the early 20th century, who derived much of their knowledge from Guinand's work.[105]

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[104] King; 177. It would seem that the heavy flint-glass was more prone to problems than crown-glass, though the latter suffered from flaws as well.

[105] See, *1901-1902 L'Industrie Français des Instruments de Précision, Catalogue*, (Paris: Syndicat des Constructuers en Instruments d'Optique et De Précision, 1902); 180–184. Pierre-Louis Guinand was succeeded in business by his son Henry who became glass-maker to Bontemps et Lerebours in 1827 and later formed the firm of Guinand et Bontemps in 1839. In 1851 Charles Feil, Pierre-Louis Guinand's grand-son, took over the firm and, with M. E. Mantois, led the firm through its glory years from 1851 to 1900.

The problem of chromatic aberration was solved by the invention of the achromatic lens. Also solved were the problems of glass-quality and proper lens design. By the 1820s, the achromatic refractor had been perfected to the point that it became the instrument of choice for most amateur and professional astronomers around the world through the end of the 19th century.

4. <u>Telescopes in early 19th century America</u>

Little mention has so far has been made of astronomy and telescopes in the United States for the very good reason that little astronomical work was done here prior to the 19th century. There were of course a handful of individuals in colonial America who concerned themselves with observation of the heavens, but such astronomical interest that did exist tended towards the practical arts of navigation and surveying, subjects that, at the most, required telescopes of very modest size. Even by 1845 the number of astronomical telescopes being used in the United States likely numbered only a few dozen, nearly all being imported. The earliest known permanent observatory in the United States was that established at Yale University in 1833; its main telescope was a 5-inch Dollond achromatic refractor, the largest such telescope in the nation at the time.[106] Harvard possessed a small portable Gregorian reflector made by Short (18-inch focus), originally acquired to observe the transits of Venus in the 1760s. The Hudson

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During this period Feil et Mantois produced glass discs for nearly all of the large refracting telescopes in the world including the 36-inch Lick and 40-inch Yerkes telescope objectives made by Alvan Clark & Sons of Cambridge, Massachusetts. Of 72 large (30cm/12-inch aperture and larger) telescope objective lenses produced to 1902 for which Feil-Mantois provided glass, nearly half were non-French made instruments: 8 telescopes by Alvan Clark & Sons, 10 by John Brashear (Allegheny, PA), 2 by Steinheil and 1 by Merz (Germany), and 14 by Howard Grubb (Dublin, Ireland).The amount of glass Feil-Mantois might have produced for small telescopes is unknown, but was likely considerable.

[106] King; 247. The Dollond 5-inch was purchased for $1200 ($22,800 in 2001) in 1830.

Observatory (1838) at the Western Reserve College was placed in the hands of Elias Loomis, one of 19th century America's most prominent astronomers. Loomis was likely the leader who chose to equip the facility with a 4-inch refractor on a very substantial mounting made by the London firm of Troughton & Simms.[107] One of the most important early astronomical facilities in the United States was the Cincinnati Observatory (1842), built by public subscription, and equipped with one of the largest achromatic refracting telescopes in the world at the time, an 11-inch by the Munich firm of Merz und Mahler.[108] Soon after the Cincinnati Observatory was established, the Harvard College Observatory, likewise paid for by public subscription, was completed and opened for observing in 1845; it too had a Merz und Mahler telescope, a 15-inch twin to one at Pulkovo Observatory in St. Petersburg, Russia. Such instruments, brought in pieces from Europe, were of course quite expensive. The Harvard College Observatory was first conceived of around 1815, but required funds did not exist. It was only in the

[107] See, *Catalogue of Instruments, Made by Troughton and Simms, Optical, and Mathematical Instrument Makers to the Honourable Board of Ordnance*, (London: Troughton and Simms, 1844); 5; a 4-inch achromatic, equatorially mounted, with all accessories was priced at £230 ($24,800 in 2001).

Troughton & Simms produced the following telescopes in 1844:

Aperture	**Focal-length**	**Type of Mounting**	**Price (Br.£ 1844)**	**Price ($US 2001)**
Small "draw-telescopes"	1 to 3-feet	Hand-held	1.5.0 to 6.6.0	135 to 680
2¼-inch	30-inch	Alt-azimuth, table-top stand	10.10.0	1,130
2¾-inch	45-inch	"	23.2.0	2,490
3¼-inch	45-inch	"	42.0.0	4,530
3¼-inch	45-inch	Equatorial, tripod	73.10.0	7,925
3¾-inch	5-feet	Equatorial, w/clock-drive, etc.	200	21,565
4-inch	5-feet	"	230	24,800
5½-inch	8-feet	"	400	43,130
6-inch	10-feet	"	600	64,700

[108] King; 248. Merz und Mahler were successors to Fraunhofer und Utzschneider. The objective alone cost $9,000 in 1842 ($193,860 in 2001).

1840s that the then enormous sum of $25,730 ($602,000 in 2001) was raised for the 15-inch refractor and ancillary equipment.

Although antebellum astronomers in America depended largely on foreign instruments, three talented American telescope-makers began producing instruments for sale from the 1830s, and after the Civil War, American observatories large and small were provided mostly with American-made telescopes. Amasa Holcomb (1787–1875) was the first significant maker of telescopes in the United States. Born to a family of modest Yankee farmers on the Connecticut-Massachusetts border, Holcomb was fairly well educated at the local common school, enough so that he was able to pass the state teacher's examination. Holcomb was self-taught in the rudiments of surveying, navigation, and astronomy from reading books on these subjects left to him by his uncle. In addition to teaching, Holcomb also worked as a surveyor. At some point and from unknown sources, Holcomb learned the various skills needed to start a business in scientific instrument-making in order to supplement his teaching and surveying work. Between 1825 and 1830 Holcomb began to shift his interests from teaching and surveying to telescope-making, successfully completing an achromatic telescope of sufficiently good quality that he was willing to let Yale professor Benjamin Silliman examine and comment on it. Silliman was impressed with Holcomb's work to the extent of publishing a notice in the *American Journal of Science*. Details of this telescope are lost, but the reaction to it was sufficiently favorable to launch Holcomb's telescope-making business.[109] In the early 1830s Holcomb was making spyglasses, "achromatic

[109] Amasa Holcomb, "Autobiographical Sketch," in *Holcomb, Fitz, and Peate: Three 19th Century American Telescope Makers*, Robert P. Multhof, editor. *Contributions From The Museum Of History And Technology, Paper 26*. (Washington, DC: Smithsonian Institution, 1962); 160–164.

telescopes of forty eight inches focal length, which will give a distinct view of Jupiter's belts, and of the eclipses of his satellites, as well as of the principle double stars", and Herschellian reflecting telescopes, all made to order and warranted to surpass imported telescopes of equal price.[110]

Holcomb gained a good reputation, and most of those astronomers in America who had a chance to test his telescopes agreed on their quality. Yale astronomer Denison Olmstead reported that, during tests over the summer of 1834, views of the moon and various double-stars were quite distinct at magnifications varying from 40 to 350, though the eyepieces were of too narrow a field of view for his taste. On the whole, however, Olmstead was able to highly recommend Holcomb's work. A committee appointed by the Franklin Institute likewise had good things to say, having tested a small 3-inch, 6-foot focus Holcomb telescope in direct comparison to a 4-inch Dollond achromatic telescope owned by the University of Pennsylvania, a 3½-inch Dollond achromatic, and a 4-inch Gregorian of unknown make. After exhaustive examination of features on the moon, as well as a host of double-stars, the Franklin Institute experts judged Holcomb's telescope to be only slightly inferior to the two somewhat larger Dollond telescopes.[111]

Holcomb primarily made reflecting telescopes of the Herschellian type, ranging from 4 to 10 inches in aperture and up to 14-foot focus. The price of Holcomb's reflecting telescopes in the 1830s ranged from \$100 (\$1,900 in 2001) for a 4-inch to \$600

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[110] "Manufacture of Telescopes, &c", *The American Journal of Science*, 23 (1833): 403.

[111] William Hamilton, "Telescopes", *The American Journal of Science*, 27 (1835); 185–189. Double-stars, particularly those with a very small separation, were almost universally used as test-subjects for telescopes in the 19th century. Telescope manufacturers' catalogues often listed examples of double-stars for such testing and the ability to 'split' a particular double-star was considered a mark of excellence. Holcomb's reflector and both Dollond refractors were considered vastly superior to the Gregorian "which was probably not a very fine instrument of its kind." See also, Elias Loomis, *The Recent Progress of Astronomy, Especially the United States*, (New York, NY: Harper & Brothers, 1856).

($11,400 in 2001) for a 10-inch.[112] An 8½-inch aperture (9-foot 4-inch focus) reflector evaluated by the Franklin Institute in 1835 was for a time the largest telescope of any type in America. Holcomb was fully involved in the telescope-making business from 1839 to 1845, when business slacked off. There is little indication of how many telescopes Holcomb produced, though it is doubtful that the total number was much greater than a few dozen. However, Holcomb's importance is that he set an example: native-born Americans, self-taught in instrument-making and optics, could produce telescopes comparable to the best Europe had to offer.

About the time Holcomb's business was declining, a new manufacturer appeared who dominated the telescope market in America from the late 1840s to the Civil War. Henry Fitz (1808–1863) was born in Newburyport, Massachusetts into a lower middle-class family. The family later moved to New York City in 1819 where young Henry (aged 11) entered the printing trade as an apprentice. Fitz proved to have a talent for things mechanical and worked as a lock-smith from 1830 to 1839, apparently a lucrative enough trade to enable him to pursue astronomy as a hobby. Fitz made his first telescope in 1838, a reflector of unknown size.[113] Fitz managed to save enough money to travel to Europe the following year and there learned more about optics and the new technology of photography, just being developed by Daguerre and others.[114] On his return, Fitz displayed a 6-inch refracting telescope at the Fair of the American Institute in New York

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[112] Nicholas Der Bagdasarian, "Amasa Holcomb: Yankee Telescope Maker," *Sky & Telescope*, 72 (June, 1986): 620–622, on 621. Holcomb also sold a 6-inch, priced at $250 and an 8-inch for $400 ($4,750 and $7,600 in 2001).
[113] Julia Fitz Howell, "Henry Fitz (1808–1863)," in *Holcomb, Fitz, and Peate: Three 19th Century American Telescope Makers*, Robert P. Multhof, editor. *Contributions From The Museum Of History And Technology, Paper 26*. Washington, DC (Smithsonian Institution, 1962); 164 – 166.
[114] Fitz Howell; 168.

City during the summer of 1845; it was immediately awarded a gold medal. This marked the beginning of Fitz's commercial telescope-making profession. Fitz experimented on developing his own lens-making techniques and passed on his knowledge to two others; his son Henry Giles (Harry), who took over the business on his father's death in 1863, and John Byrne, who started his own business in the 1870s.[115]

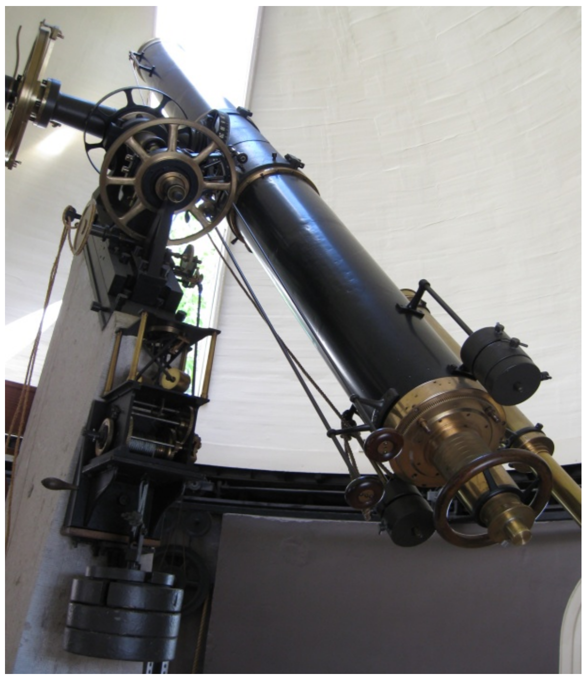

Fig. 18 – 12⅝-inch Fitz equatorial refractor, University of Michigan, Ann Arbor (photograph by author)

Fitz deliberately sought to out-bid European telescope-makers by repeatedly offering telescopes of equal size to those ordered by American astronomers overseas, but at a lower price. Fitz gained a considerable reputation for larger instruments constructed for prestigious customers. In 1849 Fitz produced a 6¾-inch refractor for an official United States Navy expedition to Chile, a 13-inch for the Allegheny Observatory (Pittsburg) in 1861, and several for private observatories, including that of Lewis

[115] Fitz Howell; 170. For the Byrne connection, see, *Description and Price List of John Byrne's Astronomical and Terrestrial Object Glasses and Telescopes, Manufactured by Gall & Lembke, Opticians* (New York: Gall & Lembke, 1892); 2–3;

Rutherfurd, to be described in greater detail later.[116] In addition to these, Fitz supplied telescopes to the University of Michigan, Ann Arbor (12⅝-inch), Vassar College (12-inch), and many small portable instruments including "a small equatorial" (likely a 4-inch) for the University of Iowa.[117] Prices of Fitz telescopes in an 1850 advertisement were as follows:

Aperture	Price for Alt-azimuth-mounted telescope	Price for Equatorially-mounted telescope
3-inch	\$100 (\$2,245)	\$300 (\$6,750)
4-inch	\$200 (\$4,500)	\$600 (\$13,500)
5-inch	\$350 (\$7,860)	\$750 (\$16,850)
6-inch	\$600 (\$13,500)	\$1,000 (\$22,450)
8-inch	\$1,200 (\$27,000)	\$2,100 (\$47,150)

(Price in 1850 Dollars followed by today's equivalent, in parentheses)

Harry Fitz continued his father's work until the mid-1880s, but never achieved the same market dominance, partly because of his own disinclination towards business, but also due to new competitors.

The firm of Alvan Clark and Sons was without doubt the premier commercial telescope manufacturer in America from 1860 to 1900, producing the optics for the world's largest refracting telescope, the 40-inch Yerkes Observatory (University of Chicago) in 1895. Clark produced many other large refracting telescopes for colleges and professional astronomical observatories such as the 26-inch refractor for the United States Naval Observatory in Washington, D. C., and the 36-inch telescope at Lick Observatory (Mount Hamilton, California). Each of these refracting telescopes were the world's largest when first completed.

Alvan Clark (1804-1887), like Holcomb and Fitz, entered the telescope-making business as an outgrowth of an amateur interest in astronomy, rather than by inheriting a

[116] Fitz Howell; 170.

[117] *Catalogue of the Iowa State University at Iowa City, for 1872-73,* (Chicago: Cushing, Parsons, & Thomas, 1873); 40.

business as was the case for most European makers.[118] Clark was originally a portrait-painter, specializing in miniatures; his visual acuity was noteworthy, and his artistic background likely helped in his later optical work. Alvan Clark's first telescope, made with the assistance of his son George, was a small speculum-metal reflector made in 1844, followed by several others. Not quite satisfied with the results of speculum-metal reflectors, Clark determined to try his hand at making refracting telescopes and completed the first, a 5-inch made for William Harvey Wells, in 1848.[119] Opinions as to the quality of early Clark objectives varied at the time, William and George Bond of Harvard Observatory being rather negative, but Elias Loomis of Yale and Charles A. Young, later of Princeton University, were more positive.[120] Relatively few advertisements for Clark telescopes appeared early on, and sales promotion was primarily by word of mouth. Clark was fortunate that one of his early telescopes was purchased by the noted British amateur astronomer William Rutter Dawes (1799–1868). Dawes was one of the leaders in the discovery and observation of double stars, objects regularly used by Clark and other telescope-makers to gauge the perfection of their lenses. In 1851, Clark wrote Dawes asking for assistance in identifying several very closely-separated doubles he had seen while testing objective lenses, as they were not listed in any books Clark had available. Dawes realized that Clark's visual acuity and telescope quality must be very high; Dawes ended up purchasing a total of five Clark lenses of 7 to 8-inch

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[118] For a concise family history, see, Gary L. Cameron, "Clark Family", *Biographical Encyclopedia of Astronomy, Volume I*, Thomas Hockey, Editor-in-Chief (New York: Springer Scientific Publishers, 2007); 237–238.

[119] Warner and Ariail; 10–11.

[120] Warner and Ariail mention that Alvan Clark identified several flaws in the 15-inch Merz und Mahler objective, which alone had cost $12,000 in 1844; I should think this would not have endeared the upstart Clark in the eyes of the Bonds, who were rather defensive of Harvard Observatory's investment.

aperture and found them so superior that he soon recommended them to other astronomers (both professional and amateur) in Britain and America.[121]

Although Clark made, and occasionally sold, a number of telescopes from the 1840s onward, "Alvan Clark & Sons, Manufacturer of Achromatic Telescopes" was not really established as a full-time business until 1857, with Alvan and younger son Alvan Graham (1832-1897) working on the optics, and George Basset (1827-1891) the mechanical parts. The company employed few others outside the family until the 1870s. The Clark factory was remarkably small (about 5,000 square feet) and working conditions were also crude; illustrations of the factory in an 1887 issue of *Scientific American* show workers mostly grinding and polishing lenses by hand.[122] The most significant early sale the Clarks made was an 18½-inch refractor, originally ordered by the University of Mississippi in 1860. Unfortunately for Mississippi, the Civil War broke out before the instrument could be completed, and it was instead sold to the University of Chicago in 1866.[123] The Chicago telescope secured the Clarks' reputation, and the company became the leading manufacturer of telescopes in the United States for the remainder of the 19th century. Alvan Clark died in 1887 soon after completing the 36-inch Lick objective, and both sons were gone by 1900. Thereafter, Alvan Clark & Sons, later to become the Clark Corporation, was run by others.

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[121] Warner and Ariail; 13–14, 83–87. Dawes, referred to as "the eagle-eyed Dawes", was regarded as one of the best astronomical observers in the world in the mid-nineteenth century.

[122] *Scientific American*, 57 (September 24, 1887): cover illustration; and "The Alvan Clark Establishment", *Scientific American*, 57 (September 24, 1887): 198–199. This article also shows how the Clarks tested lenses, using essentially a variation of the Hadley mirror test, but substituting the lens, backed by an optically flat mirror, in place of the concave speculum. An artificial star was provided in much the same way as in Hadley's test.

[123] Warner and Ariail; 19.

Small telescopes of 3 to 6-inch aperture were by far the most numerically important production for the Clarks. As is the case with other telescope manufacturers of the period (and indeed, later), corporate records are largely lacking and production numbers of telescopes made must be estimated based on existing examples, only some of which bear serial numbers. The total of 3 to 6-inch telescopes produced certainly numbered several hundred, but likely did not exceed four to five hundred by 1910.[124] The entire estimated production of 3 and 4-inch telescopes by Alvan Clark & Sons, those most likely to have been purchased by amateurs, were approximately three to four hundred instruments. Alvan Clark and Sons kept sufficiently detailed records to determine the customer-base of amateur astronomers purchasing their telescopes; the professions of buyers (when listed) include lawyers, college professors, bankers, engineers, businessmen, and the like.[125] Typical of the early generation of American telescope makers, Alvan Clark's methods of production and sales were highly traditional: each instrument was individually hand-crafted by a few highly skilled workers and frequently by the Clarks themselves. Most of Clark's early telescopes were made to order and only much later (1880s or 1890s) did the company produce "stock" telescopes, usually 3 or 4-inch aperture.[126] Alvan Clark & Sons were not particularly good self-promoters and issued neither catalogues nor price-lists until 1892, so sources for the cost of their telescopes are rather hard to come by. Dawes is known to have paid $950

[124]Warner and Ariail list the following surviving or known examples manufactured to 1910: 69 - 3 to 3.9-inch, 114 - 4 to 4.94-inch, 83 - 5 to 5¾-inch, 57 - 6 to 6.6-inch, 90 - 7 to 40-inch, a total of 413. Known serial numbers reach as high as #452 by 1910, but the application of serial numbers to Clark telescopes did not begin until the 20th century. Numbering began around 1904 after C. A. R. Lundin took over the company after the death of the Clarks but there is no known number lower than #353, leading to the conclusion that the serial numbers are meant to include all previous Clark telescopes. Warner and Ariail (p.211) consider the total production from 1948 to 1958 to have been 600 objective lenses.

[125] See "Part II: A Descriptive Catalogue of all Known Clark Instruments" in Warner and Ariail; 47–189.

[126] Warner and Ariail; 20 – 27.

($19,850 in 2001) for a superb 7½-inch objective in 1854. The University of Chicago purchased the 18½-inch Dearborn refractor (actually paid for by the wealthy members of the Chicago Astronomical Society), complete with equatorial mount, for $18,187 ($200,970 in 2001) in 1866.[127] Smaller complete equatorial refractors, c.1868, were priced at $160 ($1,975) for a 3-inch, $225 ($2,775) for a 3 ½-inch, and $300 ($3,700) for a 4-inch, each including a small finder telescope and several eyepieces. These prices stood fairly steady for a considerable time and around 1900 a standard 3-inch refracting telescope from Clark started at $175 ($3,620 in 2001). A few years earlier (1892), a 4-inch was priced at $325 ($6,295), a 4½-inch at $380 ($7,360), a 5-inch at $450 ($8,720) and a 6-inch at $650 ($12,590).[128] The Clarks continued to produce primarily the classic refracting telescope, and on the completion of the 40-inch Yerkes instrument, Alvan Graham Clark was sure that even larger refracting telescopes were in the future. Unfortunately for Clark, he had totally neglected advancements then being made in reflecting telescopes.[129]

5. <u>Resurrecting the reflector: silver-on-glass mirror technology</u>

The equatorially-mounted, achromatic refracting telescope as made by Fitz, Clark, and others, was the instrument of choice for most 19th century astronomers. It had excellent optical characteristics, was rugged, steady, and stable enough to make precise measurements of star positions. The speculum-metal reflector, on the other hand, was of variable optical quality (depending on the maker), generally mounted in a very

[127] Warner and Ariail; 88.
[128] Warner and Ariail; 32, 43, 255. Note that, though the Clarks' prices remained fairly steady, the value of the dollar did not, and in fact the same size telescope in 1901 actually cost nearly twice that of the one from 1868.
[129] Warner and Ariail; 29–30.

cumbersome style, and had the inherent flaw of metal tarnish. A few amateurs, the prime example being Lord Rosse, owner of the largest telescope built prior to the 20th century and discoverer of the 'spiral nebulae', demonstrated that the reflecting telescope *might* be more generally useful, if only the flaws could be eliminated.

In the late 1830s, a major technological advance in art and science was made with the introduction of photography. It is no surprise that a number of astronomers, largely amateurs, were immediately interested in the new technology for its potential in more accurately depicting the appearance of celestial objects. Many amateur astronomers, such as the Englishman Sir John Herschel, and the Americans Henry Fitz and John Draper, assumed a leadership role in the development of photography. Aside from the direct contributions of photography to astronomy, there was also an indirect one that historians have generally not remarked upon: the fact that photography trained many amateur astronomers to be practical chemists. The importance of the relationship between chemistry and telescope-making might seem slight, were it not for another revolutionary technology of the 1850s: the silver-on-glass telescope mirror. As already indicated, speculum metal was a physically hard material and difficult to work with, mirrors tarnished quickly, had to be re-polished, and, likely as not, had to be re-parabolized in the process of eliminating the tarnish. An excellent mirror could thus be ruined unless re-polished by a skilled optician, an expensive and time-consuming process. The development of silver-on-glass telescope mirror technology was a boon to astronomers. Glass was easier to work than speculum metal and much lighter in weight (about 70% less); glass telescope mirrors could also be made of relatively cheap plate glass. When innovators discovered the means of chemically depositing silver onto glass, they simultaneously solved the whole problem of mirror tarnish. When a telescope mirror's reflective silver coating tarnished, it could be easily removed and re-deposited in an afternoon with 10-cents-worth of chemicals (in 1860), without disturbing the optical surface. From about 1860 onwards, reflectors were increasingly common and competitive with achromatic refractors.

It is a fortuitous coincidence that many of the materials and methods used in depositing a silver coating on a glass surface are similar to those used in photography, the key ingredient in both cases being silver nitrate ($AgNO_3$). However, the leap that made silver-on-glass telescope mirrors possible had little to do with photography and everything to do with beauty – and death by mercury poisoning. The typical looking-glass mirror made prior to the 20th century was of glass coated on the rear side with an amalgam of silver and mercury, protected by paint. Although the reflectivity was good enough to satisfy most fashionable-ladies' tastes, working with the amalgam was highly hazardous to factory workers. Chemist Justus von Liebig developed a method for detecting aldehydes in 1835 that inadvertently ended up depositing metallic silver on the glass-ware used in his laboratory. A solution containing silver nitrate could be reduced using an agent such as aldehydes, sugar, or tartaric acid, thus leaving metallic silver as a precipitate. In 1843, Thomas Drayton, one of those searching for an alternative to the mercury amalgam for looking-glasses, patented an improved method of depositing silver based on Liebig's. Neither Liebig nor Drayton seems to have considered applying the new silvering method to telescope specula, but two optician-astronomers on the Continent did.

The basic idea of making a telescope mirror of glass coated with a highly reflective metal was not at all new, Isaac Newton having suggested it around 1700.[130] Karl August Steinheil (1801-1870) was born into a well-to-do family in Bavaria, attended both Göttingen and Königsberg universities and worked under the astronomer Friedrich Bessel at the latter, receiving a PhD in 1825. Steinheil's family wealth was such that he could pursue many of his astronomical and optical studies at the family estate near Munich, but he succeeded in gaining a professorship at the University of Munich in 1832. Steinheil was intimately concerned with practical technology including telegraphy and optics, serving as a technical consultant to the Bavarian government. In connection with this, Steinheil established an optical shop in 1855, a business continued by his son and grandson well into the 20th century.[131] Steinheil experimented with the idea of producing telescope mirrors of glass coated with chemically-deposited silver in the early 1850s and succeeded in producing a small (about 10cm diameter) silver-on-glass reflecting telescope in 1856; he began offering them for sale soon after.[132]

Jean Bernard Léon Foucault (1819–1868) is perhaps best remembered for the development of the Foucault pendulum. However, he also made two major contributions to telescope making. At the same time that Steinheil was experimenting with silver-solution coatings on mirrors, Foucault was working on the same idea independently. The invention of the Steinheil/Foucault glass-silvering method (later modified and improved

[130] Newton, *Opticks*; 105–111. Isaac Newton realized the fundamental faults of speculum metal soon after making the first reflecting telescope. His solution was to make a glass mirror that was to be coated on the rear side with a mercury amalgam. Newton attempted to make such a reflecting telescope around 1685, but failed to produce an instrument of sufficient optical quality due primarily to flaws in the glass disc.
[131] H. Christian Freiesleben, "Steinheil, Karl August", *Dictionary of Scientific Biography, Volume XIII*, Charles Coulston Gillispe, ed., (New York: Charles Scribner's Sons, 1976); 22–23.
[132] King; 262.

by others) was itself new and innovative. Foucault's greatest contribution was the development of a new test for mirrors that finally delivered to makers of reflecting telescopes an absolutely reliable and *quantitative* method of in-shop testing. The basic set-up was similar to Hadley's, but the lens used to examine the image of the pinhole was replaced by a thin opaque straight-edge, referred to later as a 'knife-edge'. The knife-edge is gradually introduced into the returning light-path, cutting-off part of the light-cone, and as it does so, the observer sees the reflected image of the pinhole gradually darken. If the mirror is spherical, this darkening occurs simultaneously and evenly. However, if the mirror is parabolic, the darkening will be symmetrical, but uneven. Portions of the mirror that are of a longer focal-length (the edges) will come to a focus farther out than the shorter focal-length portions (the center). The result is a "pseudo-shadow", as if light were being projected from the side onto a dome-shaped surface. This alone did not make the test quantitative: what did is that Foucault calculated the correct image- and object-distances for a series of ever-enlarging ellipses that approached a parabola. Foucault then observed for the evenly shaded darkening at each of these successive positions. The test was picked-up on by other telescope makers after it was publicly announced in 1857, and it became the standard test for telescope-makers well into the 20th century; it was also a test that required little in the way of special equipment. Within a few years, small telescopes made under Foucault's direction were soon being marketed in France by the Paris optician Secrétan to amateur astronomers, and large Foucault telescopes were being made for the Paris Observatory.[133]

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[133] See William Tobin, *The Life and Science of Leon Foucault, The Man Who Proved the Earth Rotates*, (Cambridge, England: Cambridge University Press, 2003); 199–226.

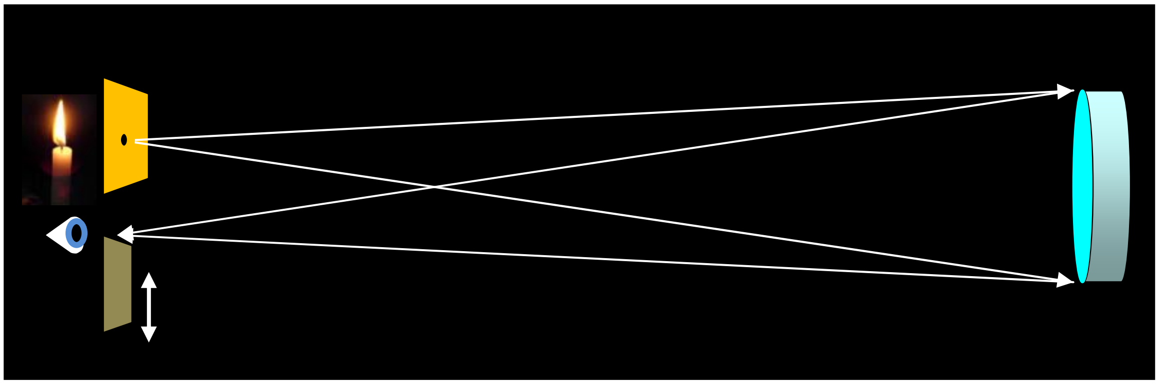

Fig. 19 – The Foucault Test was similar to Hadley's, but substituting a "knife-edge" inserted into the light-path for the lens previously used.

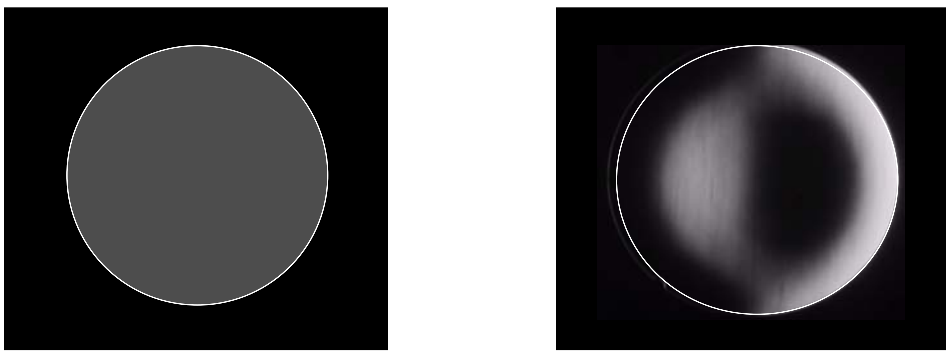

Fig. 20 – Appearance of a spherical mirror (left) and a parabolic mirror (right) tested at the center of curvature as seen in the Foucault test. An object at infinity (a star) as seen reflected in a parabolic mirror would also produce an effect like that of a sphere.

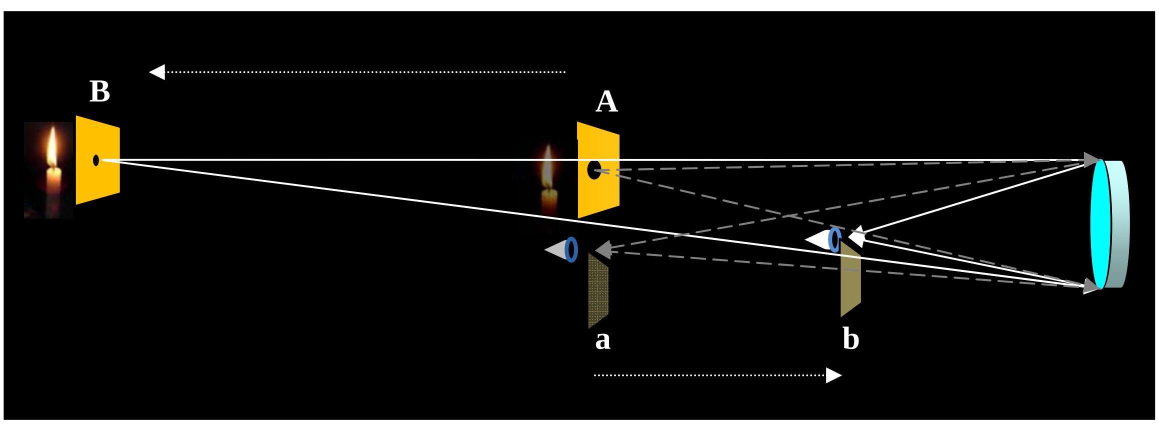

Fig. 21 – Foucault's method for testing at successive positions. "A/a" is the initial position when testing a spherical mirror; "B/b" is point where the "null" appearance is seen with an ellipsoidal mirror, half-way between a sphere and a parabola. Eventually, the knife-edge would be positioned at the mirror's focus and the light-source would be a star.

Fig. 22 – A Secrétan-Foucault telescope with wooden tube and mount made around 1865 on display at the London Science Museum. The aperture is 10 cm (3.9 inches). The cylindrical brass object in the foreground is an eyepiece from Lord Rosse's 6-foot speculum-metal reflector (photograph by author).

Foucault's method of testing did have flaws, however. The process of testing at successive positions was cumbersome, especially for larger mirrors. As the mirror was polished closer and closer to a parabola, the object distance increased considerably, to the point, in fact, of being too large for Foucault's lab. The final stage was really only an approximation of a parabola; though close to perfection, it was not quite 'there'.[134] Still, Foucault's method had promise for easy and accurate testing of optics in the controlled environment of the shop, and it was dramatically improved upon by an American.

More will be said later of Henry Draper (1837–1882) as an amateur astronomer, but aside from being one of the founders of astrophotography, he also made a noteworthy contribution to popularizing the silver-on-glass reflecting telescope in America. After journeying to Europe and seeing first-hand Lord Rosse's telescope, Draper determined to

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[134] Tobin; 207–211. In producing a 24cm (9.4-inch) mirror, Foucault placed the knife-edge at a distance of 1.10m and the light-source at 9.00m; this was as large a distance as he could fit into his laboratory-workshop. By my calculation, the actual focal length of this mirror would thus have been about 1m; it would have been under-corrected by about 10% – acceptable, but not as good as it might have been.

construct a reflecting telescope for himself. After failing with a speculum-metal mirror, Draper heard from John Herschel about Foucault's development, received copies of the pertinent papers on silvering mirrors and the Foucault test, and went to work on a series of 15½-inch mirrors, completed in 1861. Evaluation of the mirrors was interrupted by the outbreak of the Civil War, but by 1863 Draper had completed a telescope that gave good images at magnifications as high as 1,000.[135] Being the first American to construct a silver-on-glass reflector was one thing; Draper did much more by publishing a detailed account in the *Smithsonian Contributions to Knowledge* for 1865. This 55-page paper describes Draper's methods of grinding, polishing, parabolizing, and silvering mirrors. But Draper did not simply transmit knowledge, he innovated as well.

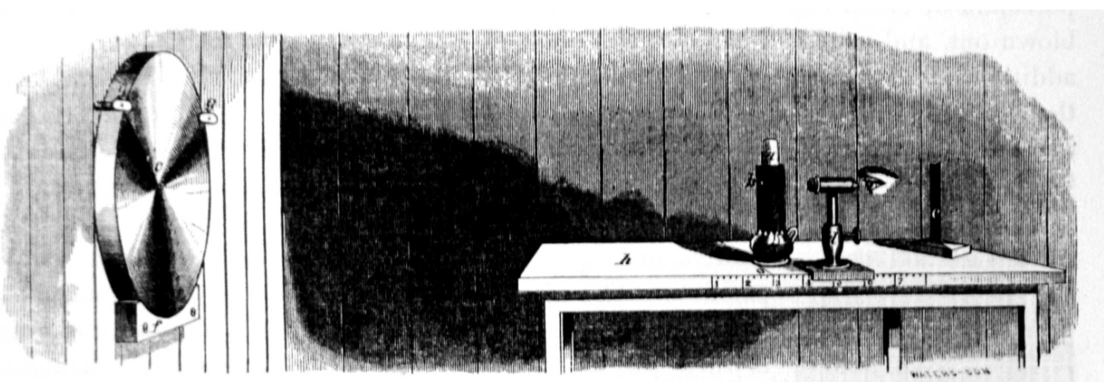

Fig. 23 – Draper's depiction of his modified Foucault test (from, "On the Construction of a Silvered Glass Telescope" - 1865). Note the ruled scale on the table-edge near the observing position; this allowed for accurately measuring the distances to the various zones on the mirror.

Draper noted the difficulties inherent in Foucault's procedure of successively testing a mirror at varying image/object distances, culminating in a final outdoors star-test in telescope. In Draper's opinion, "I do not think that anything more is learned of the

[135] Henry Draper, "On the Construction of a Silvered Glass Telescope, Fifteen and a Half Inches in Aperture and its Use in Celestial Photography," *Smithsonian Contributions to Knowledge, Volume XIV* (Washington, DC: Smithsonian Institution, 1865); 1–2.

telescope, even under favorable circumstances, than in the workshop."[136] Draper modified Foucault's test by only measuring at the center of curvature. He then calculated the focal-distances for various radial zones on the mirror at which the apparent 'peak' of the pseudo-shadows appeared, rather than using Foucault's technique of calculating successive positions to place the light-source and knife-edge. For each zone from the center to the edge, Draper calculated the difference between a spherical surface and the theoretically correct parabola; this corresponded to a slightly different image distance (the location of the knife-edge) that could be measured very accurately with a ruler. This was far easier to use in the workshop to evaluate the exact parabolic curve required, to a very small error. One could thus reliably produce a near perfect mirror in controlled conditions in the shop. The number of American astronomers who read Draper's article is not known, but it was the first such document to be repeatedly cited by later telescope-makers. It was in fact Draper's modification of the Foucault test that would be nearly universally used by amateur telescope makers in the 20th century. At least one reader of Draper's paper in the late 19th century was John A. Brashear, who would establish his own telescope-making company in 1880, as will be seen. At any rate, from the time of Draper's article, reflecting telescopes were increasingly popular in the United States, first among amateurs, then among the growing ranks of professional astrophysicists.

6. <u>Sources of telescopes in late-19th and early-20th century America</u>

Popular books on astronomy in the 19th century nearly always included some information on telescopes; a bit of their history, how they were designed and functioned,

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[136] Draper; 13.

and their application to astronomy, but hardly anything on how to acquire one. Simon Newcomb's, *Popular Astronomy* (1884), explained telescopes largely as part of an effort to describe *what* astronomers do, rather than *how to do* astronomy; for Newcomb, this was simply part of the science popularization process.[137] Newcomb's only 'advertising' for telescope makers was in his descriptions of "the world's great telescopes", mentioning manufacturers such as Alvan Clark & Sons, Thomas Cooke & Sons (York, England), and Merz und Mahler.[138] Newcomb does discuss some practical points that would have been of interest to amateurs, such as which telescope type is best but refers ~~to~~ mostly to large astronomical telescopes, rather than those of amateurs.[139]

Yale astronomer Elias Loomis was one of the leaders of astronomy in 19th century America and was the author of many astronomy textbooks. One of the most important, most used, and most reprinted of Loomis' texts was *Practical Astronomy* (1884). In this book, Loomis addresses the art and science of positional astronomy, time-keeping, and navigation, details of instrumentation forming an important part. Of great usefulness to astronomers of Loomis' day, and to the historian of the telescope today, is an appendix, "Catalogue of Astronomical Instruments by Several Different Makers, With Their Prices". Though hardly comprehensive, the catalogue certainly gives an idea of the prices

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[137] Simon Newcomb, *Popular Astronomy* (1884): 105–230. This includes sections on telescopic design and function as well as an appendix listing "The Principal Great Telescopes of the World". Most of what Newcomb wrote was a fairly typical description of basic optics, telescope design, design and function of telescope mountings, and special instruments such as spectroscopes and transit telescopes, but he does occasionally refer to amateur-grade instruments such as in his explication of magnification when he uses a telescope of "36 inches focal length" as an example (p.112), a telescope size definitely of the hobbyist range rather than the professional.
[138] Newcomb, *Popular Astronomy*: 138–141.
[139] Newcomb, *Popular Astronomy*: 145–146.

fetched for telescopes and related equipment in the late 19th century.[140] Although Loomis describes products largely of European manufacture, he begins with Alvan Clark & Sons. The largest telescope in America in 1884 was the Clark-built 26-inch equatorial refractor of the United States Naval Observatory, Washington, DC; it was also doubtless the most expensive bearing a price-tag of $38,000 ($679,440 in today's terms). Other observatory-grade telescopes, equatorially mounted, and with full accessories, were priced as follows:

12-inch: $6,000 ($107,280 in today's dollar)
8-inch: $2,700 ($48,275)
6-inch: $1,800 ($32,185)

The other American manufacturer mentioned by Loomis was Fauth and Company of Washington, DC, to be mentioned in more detail presently. Prices for Fauth telescopes, equipped similarly to those of Alvan Clark & Sons, are roughly comparable:

10-inch equatorial with 18 eyepieces, clock-drive, etc.: $5,500 ($98,340)
8-inch, with 12 eyepieces: $3,000 ($53,640)
6-inch, with 8 eyepieces: $1,800 ($32,185)
5-inch, with 6 eyepieces: $1,100 ($19,670)

Other telescope manufacturers mentioned by Loomis were European (British and German). The first of these is Thomas Cooke & Sons (York, England). As with Clark and Fauth, Cooke telescopes were very well-equipped equatorial refractors:

10-inch, with 8 eyepieces, clock-drive, etc.: £1,200 ($126,500)
8-inch, 7 eyepieces: £790 ($83,266)
6-inch: 6 eyepieces: £405 ($42,685)
4-inch: 4 eyepieces: £150 ($15,800)

Another maker of note for Loomis was Howard Grubb of Dublin, Ireland. At the time Grubb seemed more venturesome than Cooke in producing large telescopes offering one

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[140] Elias Loomis, *An Introduction to Practical Astronomy, With a Collection of Astronomical Tables, 7th Edition*, (New York, NY: Harper & Brothers, Publishers, 1884); 497–505. This book went through several editions from the 1850s onward, each of which seems to have included the "Catalogue".

of 27-inch aperture, equatorially mounted, for £6,000-7,000 ($632,400-737,800), depending on how elaborate the mounting. Smaller telescopes were priced as follows:

12-inch: £1,000-1,200 ($105,400-126,480)
10-inch: £750-950 ($79,050-100,130)
8-inch: £500-600 ($52,700-63,240)
7-inch: £420-500 ($44,270-52,700)

These British telescopes were roughly comparable to those of American manufacture in terms of their mountings and accessories, although somewhat more expensive.

Germany had of course long been a supplier of telescopes to America from the time that the newly-established Harvard College Observatory acquired its 15-inch Merz und Mahler equatorial in 1845. Of the eight manufacturers in Loomis' list, four are German with S. & G. Merz, successor to Merz und Mahler, still leading the list:

10½-inch equatorial: 45,000 marks ($193,320)
8-inch: 19,000 marks ($81,625)
6-inch: 11,000 marks ($47,255)
"52-line" (4.7-inch)[141], 4800 marks ($20,620)

Many other German manufacturers mentioned by Loomis produced specialized telescopes used in time-keeping and positional astronomy, meridian transit telescopes, for example. One thing is clear: German telescopes were on average much more expensive than either American or British instruments of comparable size and features. However, their reputation for precision made the specialized German optical instruments attractive for professional astronomers, as is indicated by the numbers of meridian transit instruments in use at American observatories.[142]

[141] The "line", was a unit of measure commonly used by European opticians, equal to 0.091 inches.
[142] See Trudy Bell, *List of American Observatories*.

About the time Loomis was compiling his list of telescope manufacturers, a new commercial operation was just getting underway in Pennsylvania. The John A. Brashear Company of Allegheny, Pennsylvania, became nearly as well-known and respected as Alvan Clark & Sons. Brashear had begun as an amateur telescope-maker in the 1870s, but went into business for himself in 1880. More will be said later about Brashear's life as an amateur astronomer and amateur telescope-maker, but suffice to say that Brashear continued a trend of American telescope makers who took up telescope-making first as a hobby, then as a secondary profession later in life. Brashear was a skilled machinist, having worked several years for a number of firms in the vicinity of Pittsburg.[143] After completing several telescopes for himself, and being assured of their quality by Professor Samuel P. Langley, then Director of the near-by Allegheny Observatory, Brashear placed an advertisement in Scientific American offering "Silvered-glass specula, diagonals and eye-pieces made for amateurs desiring to construct their own telescopes."[144]

A significant difference between Brashear and his predecessors Holcomb, Fitz, and Clark, is that, at least initially, he catered directly to amateur astronomers towards the lower end of the economic spectrum. Brashear was conscious that there were many like himself in America. There were some skilled, working-class individuals who were interested in astronomy, but lacked funds for a complete telescope. While they preferred leaving the difficult process of mirror-making to more expert hands, they could make

[143] John A. Brashear, *John A. Brashear: The Autobiography of a Man who Loved the Stars*, W. Lucien Scaife, Editor (New York: The American Society of Mechanical Engineers, 1924); 14–16, 22–25, 39–46.
[144] Brashear, *Autobiography*; 65. A common thread with American telescope-makers including Holcomb, Fitz, Clarke, and Brashear, was a combination of skills, interest, and luck. Part of that luck was the acquaintance of professional astronomers and physicists who were able to supply much-needed technical information and, even more important, connections with prospective customers. Charles Hastings, of Yale University's Sheffield Scientific School, was involved in lens design on behalf of Brashear and produced some of the best lens designs of the period, including a 'flint-forward' refracting lens design unique to Brashear's telescopes (see Brashear, *Catalogue, 1906*; 3).

many mechanical parts of the telescope. Brashear's sale of telescope mirrors, in addition to complete telescopes, satisfied the needs of the more mechanically-minded, but less affluent amateurs. Brashear was quickly swamped with orders, and by December of 1881, he had given up his work as a machinist and began optical work full-time in a small shop (12 by 20 feet) built behind his home. Brashear was extremely fortunate in having made the acquaintance of Professor Langley, who commissioned a number of items from Brashear's shop, and William Thaw, a wealthy Pittsburgh philanthropist who gave Brashear $3,000 as an outright gift to begin his new business.[145] Brashear moved to a larger factory building in 1886, a three-story brick structure measuring about 42 by 135 feet, very large compared to the shops of Fitz and the Clarks.[146]

A considerable amount of information is known of Brashear's customers. Over the years Brashear was in business (1880–1920), he produced the optics for a number of important telescopes for professional observatories including the 30-inch Thaw Refractor for the new Allegheny Observatory (1912), and the 72-inch Reflector for the Dominion Observatory in Canada (1918), Carleton College, Northfield, Minnesota (16-inch, 1890), University of Indiana, Bloomington (12-inch), and Drake University, Des Moines, Iowa (8¼-inch, 1895). The John A. Brashear Company Ltd. was a steady advertiser in the two magazines that catered to amateur astronomers in the late-19th and early-20th centuries, *Astronomy and Astro-Physics*, and *Popular Astronomy*.[147] Nearly every issue of

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[145] Brashear, *Autobiography*; 66–72.

[146] The Brashear factory and home were still standing in 2001 when the author visited Pittsburgh for the annual meeting of the Antique Telescope Society.

[147] Both of these magazines were largely the work of William W. Payne, director of Carleton College's Goodsell Observatory. *Popular Astronomy* (1893-1951) was an outgrowth of *Astronomy and Astro-Physics* (1892-94) when it was decided by Payne and George Ellery Hale, co-editor at *AAP*, to produce two journals, one for amateurs, the other for professionals; the latter became the *Astrophysical Journal*.

Astronomy and Astro-Physics included a full-page advertisement from "J. A. Brashear, Allegheny, PA., Manufacturer of Refracting Telescopes, Silvered Glass Reflecting Telescopes, and Specula."[148] Besides the usual advertisement for Brashear on the inside front cover, the November 1892 issue of *Astronomy and Astro-Physics* included a brief note concerning Brashear telescopes and objectives then being completed, or on order, the largest being a 15-inch refractor sold to Mr. Sommers N. Smith of Newport News, Virginia. Most of the telescopes mentioned were for amateurs, 15 out of 24.[149]

Smaller instruments were made entirely at the Brashear factory, but from the late 1880s equatorial mountings and many mechanical parts for the larger Brashear telescopes

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[148] "J. A. Brashear, Allegheny, PA." *Astronomy and Astro-Physics*, 11 (October, 1892): inside front cover.
[149] "Telescopes for Amateurs", *Astronomy and Astro-Physics*, 11 (November, 1892): 829. The full list, by aperture and type, consisted of:

Refracting telescopes:
- 15-inch, Sommers N. Smith, Newport News, VA
- 12-inch, for observatory at Beirut, Syria
- 6-inch, [for?], Lebanon, OH
- 4½-inch, F. G. Bennett, New Haven, CT
- 4½-inch, J. H. Wilson, Brooklyn, NY
- 4½-inch, D. H. Burrell, Little Falls, NY
- 4-inch, Park Painter, Pittsburgh, PA
- 4-inch, H. C. Frick, Pittsburgh, PA
- 4-inch, Oil City High School
- 3-inch, State Normal School, Farmville, VA
- 3-inch, Dr. A. C. Runion, Canonsburg, PA

Refractor Objectives:
- 12-inch with photographic corrector-lens, & 8¼-inch, Dudley Observatory, Albany, NY
- 12-inch, Kenwood Observatory (George E. Hale), Chicago, IL
- 6-inch, N. Johnson, Manistee, MI
- 6-inch, Warner & Swasey, Cleveland, OH
- 6-inch, Short-focus photographic, Georgetown College Observatory
- 6-inch, photographic doublet & 5-inch visual, Goodsell Observatory, Northfield, MN
- 6-inch, photographic objective, William Post, Bayport, NY
- 5⅝-inch photographic objective, Meudon Observatory, Paris, France
- 5-inch, Dayton C. Miller, Cleveland, OH
- 4-inch, A. S. Grant, Palistine, TX

Reflecting Telescopes:
- 6½-inch, J. A. Parkhurst, Marengo, IL
- 6½-inch, F. Dienelt, Loda, IL
- 8 ½-inch mirror, H. Bradford, North Ferrisburg, VT

were produced by the Warner & Swasey Company of Cleveland, Ohio. Worcester Warner and Ambrose Swasey were originally in the machine-tool business, but became interested in astronomy around 1880; their expertise as trained engineers enabled them to greatly improve the mechanical design of telescopes and telescope mountings. The special relationship between Warner, Swasey, and Brashear developed in part from real affection as fellow artists of precision instruments, but also through competition. Although Warner & Swasey produced the mountings for the two largest Alvan Clark & Sons objective lenses, the 36-inch for the Lick Observatory (1886) and the 40-inch Yerkes telescope (1895), Alvan Graham Clark, an extremely sensitive individual, did not at all get along with Warner & Swasey. As a result, Warner & Swasey effectively combined themselves with the John A. Brashear Company on all telescopes from 6-inch aperture on up, Warner & Swasey making the mountings, and Brashear the optics.[150]

John Brashear's advertisements in the 1890s mention a wide assortment of items for sale, but listed no prices; customers were apparently expected to write the company for details. The situation changed by the first decade of the 20th century, when fully illustrated Brashear catalogues appeared. The 1906 *Catalogue* includes a wide range of items including complete telescopes, objective lenses and mirrors, astro-graphic cameras, spectroscopes, position micrometers (used for measuring angular distances seen in a telescope), eyepieces, and an assortment of accessories for telescopes large and small.[151]

Prices for achromatic telescope objectives, ready to be mounted in a tube, began at $20 ($390 in 2001) for a 2-inch diameter, $50 ($975) for a 3-inch, and $325 ($6,350)

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[150] Edward Jay Pershey, "The Early Telescopes of Warner & Swasey," *Sky & Telescope*, 70 (April, 1984): 309-311.

[151] *Catalogue: Optical, Physical, Astrophysical and Astronomical Instruments, 1906* (Allegheny, PA: John A. Brashear Company, Ltd., 1906).

for a 6-inch; high prices, but in-line with other manufacturers of the time.[152] Brashear continued selling reflecting telescope mirrors intended to be mounted in a tube provided by the buyer. The smallest Newtonian mirror that Brashear sold, a 5-inch primary mirror of 4-feet focus, with a matching Newtonian secondary, could be had for as little as $38 ($743 in 2001). A 6-inch set of mirrors cost $48.50 ($950), somewhat pricey, but far less than a refractor objective of equal size.[153]

Brashear's complete telescopes came in several basic types, from simple alt-azimuth telescopes, to large, observatory-grade equatorials. The least expensive Brashear telescope in 1906 was a 2.5-inch, alt-azimuth telescope, complete with a wooden tripod and three eyepieces for $100 ($1,960). For the more advanced amateur, an equatorially-mounted 3-inch, with wooden tripod and three eyepieces went for $185 ($3,620) and a 6-inch equatorial on wood tripod for $700 ($13,720).[154] Equatorial telescopes of the

[152] Brashear, *Catalogue, 1906*; 4. Brashear offered achromatic objectives in 30 standard sizes; 2 to 10-inch in ½-inch increments, 10 to 16-inch in 1-inch increments, 16 to 26-inch in 2-inch increments, and 30 and 36-inch. The price for a 36-inch lens was listed as $40,000 ($782,000 in 2001), though the largest lens Brashear ever made was the 30-inch for the Thaw Memorial Telescope at Allegheny Observatory.

[153] Brashear, *Catalogue, 1906*; 6. Much larger mirror sets could be had as well ranging from 7-inch to 30-inch. A 12-inch Newtonian mirror with matching secondary, a fairly large mirror for an amateur telescope even by today's standards, cost $275 ($5,375 in 2001), compared to $2,000 ($39,000) for a Brashear refractor objective of the same size.

[154] Brashear, *Catalogue, 1906*; 8–9. Brashear offered a wide assortment of options with his telescopes. Smaller Brashear refracting telescopes are summarized thus:

	Alt-azimuth, no slow-motion controls	Alt-azimuth, with slow-motion controls	Equatorial on wooden tripod	Equatorial on plain iron column
2.5-inch	$100 ($1,960)	$140 ($2,740)	NA	NA
3-inch	$125 ($2,445)	$165 ($3,225)	$185 ($3,620)	NA
3.5-inch	$160 ($3,130)	$200 ($3,920)	$225 ($4,400)	NA
4-inch	$225 ($4,400)	$275 ($5,375)	$300 ($5,880)	NA
4.5-inch	$275 ($5,375)	$325 ($6,355)	$325 ($6,355)	NA
5-inch	$425 ($8,300)	$475 ($9,285)	$500 ($9,800)	$600 ($11,760)
5.5-inch	$500 ($9,800)	$550 ($10,752)	$575 ($11,240)	$675 ($13,200)
6-inch	$600 ($11,760)	$670 ($13,100)	$700 ($13,720)	$825 ($16,130)

"highest class" (on mountings made by Warner & Swasey) sold by Brashear began at $350 ($6,845) for a 4-inch with slow motion controls, five eyepieces, a 1.5-inch aperture finder telescope, and a 90° diagonal 'zenith-prism' (for comfortably observing objects directly overhead); with optional Right Ascension and declination setting circles and clock-work telescope drive, the price rose to $560 ($10,950).[155]

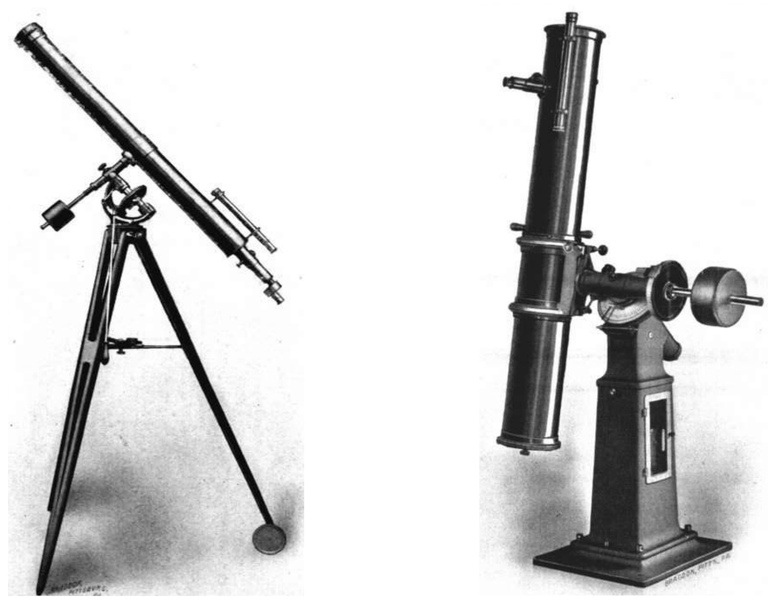

Fig. 24 – Brashear 4-inch equatorial refractor and 6-inch Newtonian reflector (from the 1906 Brashear Catalogue)

Since all of these telescopes were mounted either on alt-azimuth or equatorial mountings without clock-dive mechanisms or setting circles for accurate pointing, they would have been nearly useless for research work. These small Brashear telescopes can thus be considered purely amateur-grade instruments.

[155] Brashear, *Catalogue, 1906*, p. 12-15. The largest refracting telescope Brashear advertised as a standard model in 1906 was of 18-inch aperture selling for $15.175 ($296,670 in 2001). Such telescopes as these would have certainly been considered "research-grade" instruments in 1906, something for professionalized institutions or very serious amateurs:

	Cost of Objective alone	Equatorial, w/o circles or driving clock	Equatorial, complete
4-inch	$100 ($1,960)	$350 ($6,845)	$560 ($10,950)
6-inch	$325 ($6,355)	NA	$1,590 ($31,085)
8-inch	$700 ($13,720)	NA	$3,400 ($66,470)
9-inch	$900 ($17,640)	NA	$3,800 ($74,290)
10-inch	$1,125 ($22,000)	NA	$4,645 ($90,810)
12-inch	$2,000 ($38,800)	NA	$5,920 ($115,735)
15-inch	$3,800 ($74,290)	NA	$10,575 ($206,740)
18-inch	$6,900 ($134,895)	NA	$15,175 ($296,670)

Brashear also produced a range of Newtonian reflecting telescopes, all on equatorial mountings, but with varying accessories. In 1906, a 5-inch Newtonian reflector could be purchased for $225 ($4,390 today) on a plain equatorial mount, a 6-inch for $300 ($5,850), and an 8-inch for $500 ($9,750). Setting circles and a clock-work drive increased the cost by $350 ($6,825) for even these small Newtonian reflectors.[156]

Fitz, Clark, and Brashear constituted the "Big Three" telescope makers in the United States from 1845 to 1920, as evidenced by the number of their telescopes in use at American observatories. Of 258 observatories, public and private, constructed in the United States from 1823 to 1902, manufacturers of telescopes are known in 199 cases; of these, 79 telescopes were made by Alvan Clark & Sons, 39 by Henry and Henry G. Fitz, and 21 by Brashear, a total of 139 (69.8%).[157] However, there were also a number of sources for telescopes.

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[156] Brashear, *Catalogue, 1906*; 20.

[157] Bell, *19th Century American Observatories*; 6–13. Of the 199 primary-use telescopes (i.e., not including meridian transit telescopes or other auxiliary instruments) that were produced by a known manufacturer, the following is a list by me based on Bell's data:

	College, Public, & Professional Observatories	Private/Amateur Observatories	Total
American-made	**93**	**69**	**162**
Alvan Clark & Sons	55	24	79
Henry/ Henry Giles Fitz	17	22	39
John Brashear	9 (including 1 reflector)	12 (including 10 reflectors)	21
John Byrne	3	3	6
John Clacey	2	3	5
Charles S. Hastings	1	2	3
Petitdidier	1 (reflecting)	2 (reflecting)	3
A. Holcomb	2 (reflecting)	-	2
Fauth/Saegmuller	1	-	1
Warner & Swasey	1	-	1
Benjamin Pike	1	-	1
Queen & Co.	-	1	1
Foreign-made	**26**	**5**	**31**
Merz, Merz und Mahler	9	1	10
Troughton & Simms	4	-	4

John Byrne, a telescope manufacturer in New York City and pupil of Henry Fitz, was fairly well represented among 19th century American telescope-makers, but little is known about Byrne himself aside from the fact that, according to the catalogue of his distributor, Gall & Lembke, he was "acknowledged to be the most successful Constructor of Telescopic Object Glasses" in the 1890s.[158] Gall & Lembke were dealers in optical instruments in New York City in the late 19th century; they were regular advertisers in *Astronomy and Astro-Physics* directing their sales specifically to "Educational Institutions and Colleges".[159] Their only known catalogue, likely from 1892, exclusively marketed Byrne products. Byrne's telescopes were in-line with others of the period: a well-equipped 3-inch refractor, equatorially mounted with Right Ascension slow motion control and tripod stand, a set of 5 eyepieces (magnifying 50 to 350 times), a star-diagonal, and solar-viewing prism, cost only $175 ($3,390). Larger telescopes on fixed

T. Cooke & Sons	2	1	3
George Calver	1 (reflecting)	1 (reflecting)	2
Thomas Tully	2	-	2
Thomas Grubb	2	-	2
Dollond	2	-	2
Short	1 (Gregorian)	-	1
Wray	1	-	1
Adams	-	1	1
Stewart	1	-	1
Lerebours	1	-	1
Chevalier	-	1	1
Amateur-made	**-**	**6 (including 5 reflectors)**	**6**
Total	***119 (including 6 reflectors)***	***80 (including 18 reflectors)***	***199***

Note the relatively high proportion of reflecting telescopes in the hands of amateurs.

[158] *Description and Price List of John Byrne's Astronomical and Terrestrial Object Glasses and Telescopes*; 2–3. Though Byrne did have a fairly good reputation, some of the claims by Gall & Lemke must be considered hyperbole.
[159] "Telescopes of John Byrne," *Astronomy and Astro-Physics*, 11 (October, 1892): 7 of back matter.

equatorial mountings, setting circles, driving clock, and micrometer began at $1,800 ($34,870) for a 6-inch aperture.[160]

There was a trio of German-American instrument-makers of note who made considerable contributions to American telescope-making: William Wûrdemann, Camill Fauth, and George N. Saegmuller. Wûrdemann, trained at the University of Heidelberg, was brought to the United States in the 1830s for the specific purpose of constructing and maintaining instruments for the U. S. Coast Survey, finally going into work for himself in 1849. From 1849 to 1874, Wûrdemann conducted business from his shop in Washington, D. C., mostly constructing surveying instruments. However, in 1870 Wûrdemann recruited two young German instrument-makers, Camill Fauth and George Saegmuller. Fauth and Saegmuller went into business together in 1874 and operated as Fauth & Co. until 1892, when Saegmuller took over operations and the company became alternately known as both Fauth & Co., and George N. Saegmuller Co.[161] In 1905, Saegmuller

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160 *Description and Price List of John Byrne's Astronomical and Terrestrial Object Glasses and Telescopes*; 4. The small, portable telescopes ranged in size from 3 to 5½-inch aperture and the fixed, observatory-type from 6 to 9-inch:

3-inch, w/5 eyepieces,	$175 ($3,390)
3½-inch,	$250 ($4,850)
4-inch,	$300 ($5,820)
4½-inch,	$350 ($6,790)
5-inch, w/6 eyepieces,	$450 ($8,730)
5¼-inch,	$500 ($9,700)
5½-inch,	$550 ($10,670)
6-inch,	$1,800 ($34,870)
6¼-inch,	$1,900 ($36,860)
6½-inch,	$2,000 ($38,800)
8-inch,	$2,700 ($52,380)
9-inch,	$3,200 ($62,080)

161 Bart Fried, "The German-American Connection: William Wûrdemann, Camill Fauth, and George N. Saegmuller," *Journal of the Antique Telescope Society*, 7: 13–15. Fried states that the company changed names in 1892 when Saegmuller took over, but advertisements from 1892 to 1898 prove that the same company operated under both names.

merged with yet another German-American optical firm, Bausch & Lomb, becoming Bausch, Lomb, Saegmuller Company.

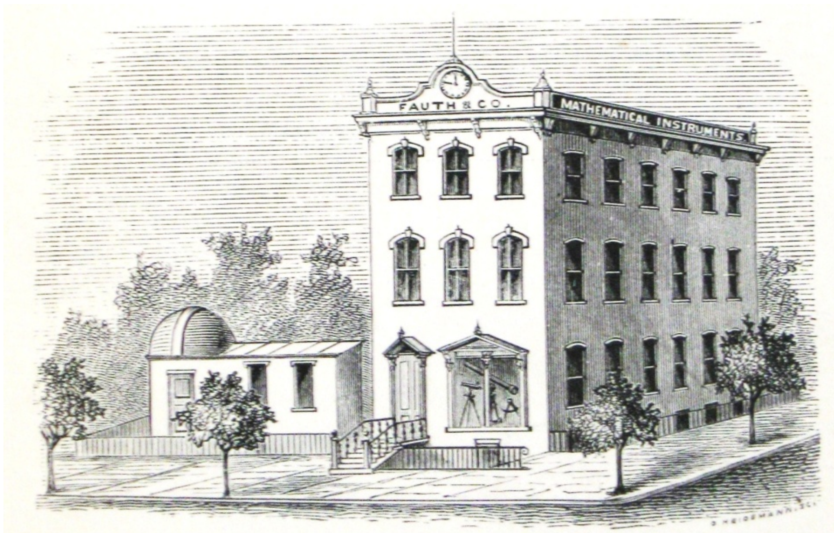

Fig.25 – The Fauth & Co. factory, sales shop, and demonstration observatory at 59 B Street, Washington, D.C., c.1877. Note the telescopes on display in the window at street-level.

Fauth and Saegmuller apparently used optical components produced by others, including Alvan Clark & Sons, rather than produce their own; this was a common practice with many of the smaller producers of telescopes in the United States.[162] Loomis' 1884 price-list of Fauth telescopes is identical with that in the 1877 Fauth catalogue, save that Loomis omitted the smallest and least expensive Fauth instruments. A 4-inch observatory equatorial with cast-iron stand, but without clock-work drive or micrometer, was priced at $550 ($9,210 in 2001).[163] Fauth & Co. did offer a range of smaller portable telescopes: the "Educational Astronomical Telescope" was a range of 2-inch to 3½-inch achromatic telescopes on table-top, alt-azimuth stands, supplied with "pancratic" eyepieces (an early type of variable-power, "zoom" eyepiece) for $230 to

[162] Fried; 14; Warner and Ariail; 191-192. See also, *Catalogue of Astronomical and Surveying Instruments Manufactured by Fauth & Co.*, (Washington, D. C.: Fauth & Co., 1877); v.
[163] *Catalogue . . . by Fauth & Co.* (1877); 10.

$380 ($3,850 to $6,365), a rather high price even for 1877.[164] Somewhat more affordable was the "Telescope on Light Extension Tripod", 2-inch to 2¾-inch aperture, primarily for terrestrial "reconnoitering" and listed at $125 to $175 ($2,095 to $2,930).[165] Small equatorial telescopes, tripod mounted and lacking clock-drive mechanisms and setting circles, could be had for $180 to $310 ($3,015 to $5,190) for 2-inch to 4-inch apertures.[166] Prices in the 1883 and 1885 Fauth & Co. catalogues were largely the same as in 1877 for the larger, observatory-grade telescopes (4-inch through 10-inch), but the number of smaller telescopes decreased dramatically; only the 3-inch and 4-inch equatorial refractors remained.[167] One curious aspect of the 1883 Fauth & Co. catalogue was mention of reflecting telescopes made by John A. Brashear; this was the only occasion when reflecting telescopes were mentioned in the Fauth/Saegmuller line of instruments and perhaps represents a failed attempt at combining forces.[168]

From 1892 to at least 1898, George Saegmuller offered a special "Cheap Astronomical Outfit" specifically for amateurs and students. The "Outfit" included a 4-inch equatorial refractor, a 2-inch meridian transit telescope, an astronomical clock, and a chronograph, the latter three items permitting observers to make and record their own local astronomical time. While marketed as "cheap", the combined price of these items was $850 ($17,900 in 2001), hardly "cheap" by most standards. The Fauth/Saegmuller 4-

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[164] *Catalogue . . . by Fauth & Co.* (1877); 13.
[165] *Catalogue . . . by Fauth & Co.* (1877); 14.
[166] *Catalogue . . . by Fauth & Co.* (1877); 12–13.
[167] *Catalogue of Astronomical and Surveying Instruments Manufactured by Fauth & Co.* (Washington, D.C.: Fauth & Co., 1883); 14–15.
[168] *Catalogue . . . by Fauth & Co.* (1883); x.; Brashear makes no mention of any sales of reflecting telescopes or optical components to Fauth & Co. in his autobiography, so it may be that it was only a proposed arrangement that fell through.

inch refractor was listed at $400 on its own, compared to $350 for the equivalent telescope from Brashear at nearly the same time.[169]

A number of new manufacturers replaced the older ones in the early 20th century. Beginning as a maker of camera lenses in New York City, William Mogey went into the telescope-making business in 1882, being joined by his brother David in 1888 and forming the W & D Mogey Company. The company later changed its name to William Mogey & Sons, Inc. after David's death in 1927. The brothers moved from New York City to Bayonne, New Jersey about 1894, and later (1908) to Plainfield, New Jersey, where the company remained until the 1940s.[170] The Mogeys produced a number of good refracting telescopes from 1882 to about 1940 and had frequent advertisements in *Scientific American*, *Astronomy & Astro-Physics*, and *Popular Astronomy*. In an unusual marketing technique for the times, Mogey sold telescopes and accessories on approval, only asking a small deposit: such sales techniques were to become an important aspect of the telescope business in America after World War II. The Mogeys purchased optical glass for their telescopes in large blocks from St. Gobain in France, and mostly ground their lenses by hand, since there were no electrical powered tools in the shop until 1915; production was quite slow. Other shops produced metal parts for Mogey telescope mountings, focusing mechanisms, and so forth. The mechanical parts of Mogey

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[169] *Description and Price-List of First-Class Engineering & Astronomical Instruments Manufactured by Fauth & Co. (Geo. N. Saegmuller, Prop.)* (Washington, D.C.: Fauth & Co., 1898); 34–35:

> "Numerous inquiries for small mounted telescopes and transit instruments, suitable for the use of the student or amateur, having been received by us, and appreciating the desire, now so popular, of many to acquire a knowledge of astronomy, we have manufactured a cheap, yet effective, instrumental outfit."

"Geo. N. Saegmuller", *Astronomy and Astro-Physics*, 11 (August, 1892): inside back cover.

[170] Peter A. Serrada, "Mogey Telescopes Rediscovered," *Sky & Telescope*, 76 (January, 1990): 98–104.

telescopes were not interchangeable as machining was done on an individual basis. Somewhere between 300 and 400 Mogey telescopes were made between 1882 and 1941.[171]

A notable feature of many of the new telescope manufacturers is a definite westward movement; three manufacturers that arose around 1900 were located in the Mid-west. William Gaertner & Co. was established in Chicago about the same time as the new University of Chicago. To a great extent, the two depended on one another: the University of Chicago needed scientific equipment, and Gaertner needed a steady customer. In addition to supplying specialized equipment for the University of Chicago (Gaertner supplied equipment to physicist A. A. Michelson, for one), Gaertner produced an extensive line of telescopes and accessories. Gaertner telescopes included 3 to 4-inch alt-azimuth telescopes, 3 to 4-inch portable equatorials, and permanently-mounted equatorials of 5 to 12-inch aperture. Unfortunately, the only known surviving catalogue fails to include prices (apparently, there was a separate price-list).[172] John Mellish was a Wisconsin telescope maker who, like many other American telescope makers, was at least somewhat self-taught. Mellish began selling telescopes in 1908, had some successes, but eventually went out of business in the 1930s due to a number of factors including the Depression and family problems. No catalogues are known to have survived, assuming Mellish even issued any; it is known that he manufactured both refracting and reflecting telescopes of fair quality. Mellish did, however, play an important part in sparking the amateur telescope making movement in America in the

[171] Serrada: 104. Scattered, but useful, company records survive: in 1925, W & D Mogey did $5,697.35 in sales (12 complete telescopes plus three lenses), spent $1,062.66 on supplies and overhead, and $960.00 on salaries to employees, all of whom were William Mogey's then teen-age sons.
[172] *Astronomical and Astrophysical Instruments,* (Chicago, IL: William Gaertner & Company, 1905).

1920s, as will be seen.[173] Another lesser known telescope-maker was Lohmann Brothers Manufacturing of Greenville, Ohio. Although they attained some notoriety selling telescopes to a few Midwestern colleges, the number produced between 1900 and 1940 were very few, and only about fifteen telescopes are known to have been made by them.

Aside from direct purchase overseas, there were a number of firms in late-19th and early-20th century America involved in importation and retail sale of telescopes. Likely the best known and most important of these importers was James W. Queen & Co. of Philadelphia. Queen & Co. were involved in many other markets besides astronomy and sold a wide variety of items including mathematical instruments, drawing instruments, microscopes, magic lanterns and slides, chemistry lab equipment, meteorological instruments, and photographic equipment.[174] James W. Queen established his company in Philadelphia in 1853, then formed a partnership with Samuel L. Fox in 1859. The firm subsequently grew to such an extent that by 1888 the main factory building measured 50 feet wide and extended along an entire city block.[175] By that time the company had come entirely under the management of Fox, Queen having retired in 1870, and was divided into six separate and specialized departments. “Department No. 5” was responsible for astronomical telescopes (and “magic lanterns”), but there is little indication that Queen & Co. actually made telescopes. Though the Queen & Co. catalogue fails to mention the source of their refracting telescopes, circumstantial evidence leads to the conclusion that

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[173] Thomas R. Williams, “John Edward Mellish and the Origins of The Amateur Telescope Making Movement in North America”, *JATS*, 13: 15–19.
[174] *Priced and Illustrated Catalogue of Astronomical Telescopes*, (Philadelphia, PA: James W. Queen & Co., 1884); 40. Queen & Co. was a fairly regular advertiser in *Scientific American*, for example, volume 42 (April 10, 1880): 236; 43 (November 30, 1880): 332.
[175] “The Manufacture of Scientific Apparatus”, *Scientific American*, 58 (April 28, 1888): 258-259. Queen & Co. also made it a point to acquire catalogues from scientific instrument companies in Europe

telescopes offered were of French and British manufacture. At least two illustrations in the 1884 *Queen & Co. Catalogue* are identical to those in other companies' catalogues, specifically those of Bardou et Cie (France) and T. Cook & Sons (Britain).[176] In addition, apertures are listed first in millimeters, a unit of measure not used by American telescope makers of the 19th century.[177]

The refracting telescopes sold by Queen & Co. were grouped in different classes depending on how they were mounted. The basic refracting telescope on a mahogany tripod and simple alt-azimuth mount ranged from 67mm (2.64-inch) priced at $75 ($1,340), to 102mm (4-inch) for $250 ($4,475); these were intended for both terrestrial and astronomical observing and were provided with two eyepieces and an attractive walnut case. A wider range of astronomical telescopes were sold, but not as complete systems; the telescope tube assemblies, complete with all optical components, were sold separate from the mountings. These ranged from 75mm (2.95-inch) for $75 ($1,340) to 128mm (5-inch) for $450 ($8,040); equatorial mountings could be purchased for an additional $40 to $550 ($715 to $9,825) depending on the size of telescope they could carry and various accessories and fittings accompanying them. A complete 5-inch

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[176] *Queen & Co. Catalogue*, cover & flyleaf; the cover illustration is identical to that in "Maison Bardou, J. Vial" in *1901-1902 L'Industrie Français des Instruments de Précision, Catalogue*. (Paris, France); 15; the flyleaf illustration is identical to that in *Illustrated Catalogue of Telescopes, Observatories, Transit Instruments, Spectroscopes, Theodolites, Levels, Levelling Staves, Clinometers, and other Astronomical and Scientific Instruments, Manufactured by T. Cooke & Sons, Buckingham Works, York, England.* York, England (Ben Johnson and Company, Printers, 1886); 8.

[177] *Queen & Co. Catalogue*; 13–14. A clue to these telescopes being of French manufacture is that the apertures given in millimeters do not match the size listed in inches. For example, the smallest astronomical telescope listed is a "67mm (2½-inch)" aperture; 67mm in fact is 2.64-inches. Contemporary American-made telescopes listed as being of 2½-inch aperture are known to have an aperture of 63.5mm. On the other hand, the French firm of Albert Bardou, Paris, is definitely known to have sold a 67mm aperture refractor around the year 1884, one being in this author's collection.

telescope from Queen & Co. could cost about $1,000 ($17,900), only marginally cheaper than one from Alvan Clark & Sons.[178]

Queen & Co. also sold silver-on-glass reflecting telescopes and these were definitely foreign imports, made by the noted British telescope-maker, George Calver. Queen & Co. only sold Calver's telescopes in two apertures, 6½-inch and 8½-inch: the "Educational Reflector" was provided with a plain equatorial mounting, two to three eyepieces, and a finder telescope for $250 ($4,475) to $375 ($6,700). The more sophisticated reflectors included various additional accessories for $375 ($6,700) to $600 ($10,735).[179] In addition to complete reflecting telescopes, Queen & Co. sold primary mirrors that the purchaser could mount in a tube of his own make.[180] For their aperture, the Calver-Queen reflectors would clearly have been less expensive than equivalent refractors.

The telescopes marketed by Queen & Co. were clearly aimed towards amateurs; the 1884 company catalogue includes basic information on types of telescopes and how they worked, how to test telescopes on celestial objects, how to care for telescopes, as well as other information useful to beginners. However, out of over 250 observatories (public, collegiate, and private) established in the United States between 1823 and 1900, only one is known to have possessed a telescope from Queen & Co.[181] The last known advertisements for Queen & Co. telescopes appeared in 1892 in *Astronomy and Astro-*

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[178] *Queen & Co. Catalogue*; 8-12. Mountings ranged from very simple "plain cast-iron" models on wooden tripods similar to what could have been made by an amateur, to very large and complex equatorials on cast-iron piers suitable for mounting in an observatory.
[179] *Queen & Co. Catalogue*; 29-30.
[180] Prices ranged from $50 for a 6½-inch to $325 for a 12½-inch.
[181] Camden Observatory, Camden Astronomical Society (NJ); See, Bell; 5.

Physics; it would seem that the company went out of business soon after, as no mention can be found of it after this date.[182]

Late 19th century America saw a revolution in mass-marketing of all kinds of products by way of mail-order catalogue companies. Such a marketing technique was made possible chiefly by the railroads, by which products could easily be shipped to nearly anywhere in the United States. Among the products sold were cameras, opera glasses and binoculars, and telescopes. The vast majority of the telescopes sold through the catalogues of Sears Roebuck & Co., Montgomery Wards & Co., and others, were small hand telescopes. Such "spy-glasses" were intended mostly for day-time use by bird-watchers, tourists, boaters, hunters, and others, but could also be used for limited astronomical observation. Entries in Ward's catalogues frequently suggested that the larger spy-glasses were suitable for investigating astronomical subjects:

> "Spy Glass, superior lenses, unequaled for definition; 5 sections, burnished brass draws, body of elegant polished mahogany wood, brass trimmings, sun glass to eyepiece. It affords excellent views of the sun, moon, satellites, etc., in addition to its terrestrial powers; 22-line [2-inch diameter objective lens] power, 30 diameters [magnification] . . ."[183]

Wards and other catalogue-sellers obtained the instruments they sold from foreign, not American sources. Although a few instruments, particularly prism-binoculars, were of various German make, the vast majority were French-made, including the well-known firms of Lamaire and Bardou. Bardou and Son did considerable business in the United States in the early 20th century with a number of importers. Sussfeld, Lorsch & Company

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182 "Queen & Co.", *Astronomy and Astro-Physics*, 11 (April, 1892): 5, rear matter.
183 *Montgomery Wards & Co., Fall & Winter 1894-95, Catalogue & Buyers Guide, No.56, Reprint*, Joseph J. Schroeder, ed. (New York, NY: Dover Publications, 1969); 200. The description is a little garbled, showing Wards' unfamiliarity with telescopes.

(New York) was a distributor for Bardou around 1910.[184] The 1911 Bardou catalogue suggests their telescopes be "For Institutional and Private Use, for Schools, for Country Houses and for Hotels, and for Astronomical Observation", and further emphasized the growing popular nature of astronomy.[185] The imported telescopes from France were undoubtedly the least expensive available: a 2¼-inch alt-azimuth refractor was priced at only $65 in 1911 ($1,200 in 2001) and a 3-inch at $80 ($1,480). However, the Bardou telescopes sold in the United States were only available as alt-azimuth telescopes; good for terrestrial use, but not so good for astronomy.[186]

7. Conclusion

By 1910, telescope-makers had made great advances in design and construction since the instrument's invention in the 17th century. Both refracting and reflecting telescopes had been considerably improved. The silver-on-glass telescope mirror, combined with the highly precise Foucault test, had advanced reflecting telescope technology to the point of near perfection. However, due largely to difficulties in effectively publicizing and transmitting knowledge, the Newtonian reflector remained of secondary importance among astronomers in America. The overwhelming telescope of choice for astronomers was the achromatic refractor. Equatorial refracting telescopes were what professional astronomers used, and amateurs sought to emulate professionals. Promoters also made significant developments in production methods and marketing of

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[184] *The Telescopes of Bardou & Son, Paris, France, Sussfeld, Lorsch & Company, Importers & Manufacturers Agents* (New York, NY: E. Schaefer, 1911).

[185] *The Telescopes of Bardou & Son*; title page, 5-6.

[186] The largest Bardou telescope sold was a 4¼-inch. A 3-inch Bardou refractor donated to Iowa State University around 1910 had been re-mounted on a small Alvan Clark & Sons equatorial prior to its donation. The telescope still exists in the Physics Department equipment collection.

telescopes, but such developments were more a slow evolution than a revolution. Telescope-making in the late-19th and early-20th centuries was largely what it had been in the 18th; a craft performed by a small handful of skilled workers in modest facilities. Despite increasing demand, astronomical telescopes were still individually hand-crafted and often made-to-order, rather than sold as stock items *en masse*.

A telescope catalogue from Bausch & Lomb, likely from the late-1920s, describes a number of telescopes then being marketed to the public for use by schools, clubs, and individuals. On the surface, this catalogue seems similar to those of firms like Brashear and Mogey. Prices for Bausch & Lomb instruments were rather higher than those of other companies of the time: an 80mm (3⅛-inch) alt-azimuth telescope was priced at $310, as compared to a similarly-equipped Mogey 3-inch for $230.[187] When one looks closer at the catalogue, a better idea of their market emerges. Although Bausch & Lomb were meeting "the growing demand" for American-made telescopes to schools, colleges, and individuals, the wording and imagery used in their catalogue gives a true idea of who their prospective market was. "A Telescope Will Make Yours a Popular Club." Was this an astronomy club? No, Bausch & Lomb was speaking of *country clubs*, where members could use a telescope to follow a golf match from the clubhouse veranda.[188] B &L telescopes were also "Ideal for Your Seashore Home" for following the yacht races.[189] The visuals are striking: men wearing dinner-jackets and bow ties, young ladies in their finest. These are not images of people of modest means.

[187] *Telescopes for Day and Night Use*, (Rochester, NY: Bausch & Lomb Optical Co., 1928); 16; *Astronomical and Terrestrial Telescopes*, (Plainfield, NJ: William Mogey & Sons, 1932); 17.
[188] *Telescopes for Day and Night Use*; 7.
[189] *Telescopes for Day and Night Use*; 4.

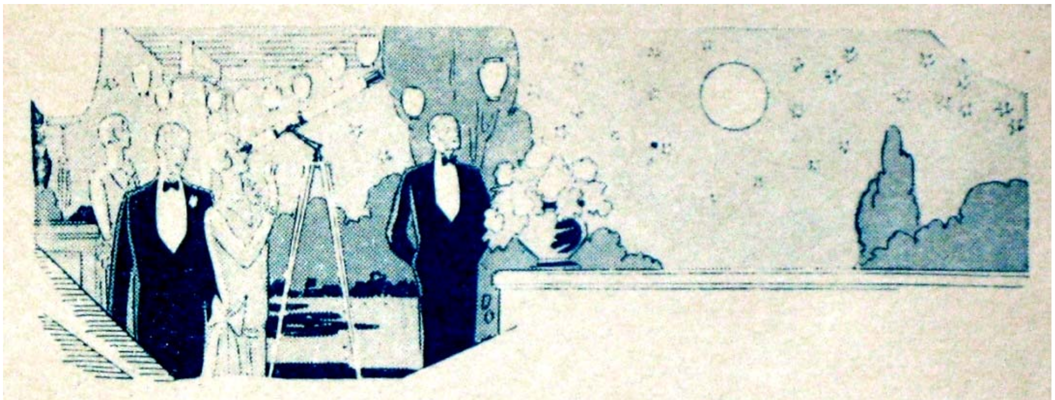

Fig. 25 – The customers of Bausch & Lomb telescopes, c.1930.

The only detailed account in print of the customers for any American telescope manufacturer is Deborah Jean Warner and Robert Ariail's, *Alvan Clark & Sons, Artists in Optics*. In discussing customers of the Clarks, Warner and Ariail note that the 19th century was one of increasing prosperity in the United States and that this created "a substantial number of people [who] were able to amass substantial amounts of disposable income."[190] While it might be true that the American economy was expanding, saying that it created "substantial numbers" of individuals who could buy telescopes is an exaggeration. When one examines the actual numbers of instruments sold by the Clarks, the leading manufacturers of telescopes in America, the results hardly demonstrate "substantial numbers". At the height of production for the Clarks, 1890-1920, the company produced about 240 complete telescopes. This might seem substantial, except that this amounts to an average production rate of only *8 telescopes per year*. Although many Clark instruments during this period were produced for colleges and professional observatories, including their culminating effort, the 40-inch Yerkes telescope, an analysis of sizes of telescopes sold and customers show that the majority (67.5%) were going to amateur astronomers, mostly 3-inch to 5-inch (about 150 telescopes). This is

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[190] Warner and Ariail; 211.

only 5 telescopes per year. One might think that the Bausch & Lomb catalogue was a freak, and fails to give a complete picture of commercial telescopes in the 1920s. This is not so: though higher in price than competitors, other companies were selling telescopes at nearly the same price to similar customers. These telescopes were expensive, as were those of other manufacturers. A Model T Ford automobile, c.1920, sold for around $400. A modest house might cost $2,000. The kind of people buying and using astronomical telescopes in the 19th and early 20th centuries were, for the most part, upper-middle-class, in some cases literally millionaires. As a result, around 1910 when Halley's Comet was causing such a public stir, the average amateur astronomer *had* to be someone with a large disposable income, and such people were few. But, who exactly were they?

Chapter III: Rich-man's Hobby:
The State of Amateur Astronomy Prior to 1920

Fig. 27 – Amateurs observe the 1900 solar eclipse in California (from *The Griffith Observer*, March, 1940).

1. Introduction

Amateurs had a considerable history of contributions to the science of astronomy by 1910. Indeed, some of the first workers in the new science of astrophysics were amateurs such as the Englishman William Huggins and the American Lewis Rutherfurd. There were a range of attitudes concerning the whole idea of 'amateur astronomer' in 1910. While it seems clear that a fair number of individuals were dilettantes in it for pleasure, others looked for some greater purpose. What might be more significant was the perceived self-image of amateur astronomers, and the image of amateurs that professionals had. In an article, written for *Scientific American* in 1910, on the subject of celestial photography by the amateur, Alfred Rordame wrote:

> "The amateur astronomer is usually looked upon by his friends and neighbors as a kind of harmless lunatic; and when he is seen busying himself around his telescope, he is usually pestered by an inquisitive individual with questions like the following: "What can you see, Mister?"

> or "What's the weather going to be like to-morrow?" He will have to bear these annoyances with resignation, *until he can make some discovery that will give him that prestige which scientific attainment of any kind always impresses on the lay mind* [emphasis added]."

But Rordame continues:

> "The real scientist, on the other hand, looks upon the amateur in quite another light; witness the following words by Prof. George Ellery Hale in a lecture delivered at the Royal Astronomical Society, London, June 26th, 1907: "According to my view, the amateur is the man who works in astronomy because he cannot help it, because he would rather do such work than anything in the world, and who therefore cares little for hampering traditions or for difficulties of any kind. The 'amateur' then, may be connected with a small observatory in the capacity of professional astronomer or be working by himself with very simple instrumental means."[191]

It is significant that someone of the stature of Mount Wilson Observatory's director George Ellery Hale should make such a comment concerning the amateur contribution. Other professional astronomers such as Harvard Observatory's director Edward C. Pickering also had positive views concerning amateurs in the early 20th century. Professionals did not exclude amateurs, they welcomed them. Participation in astronomy by amateurs was thus potentially open to many, but relatively few were actually involved, as is reflected by both the extreme sparseness of organized groups in America, and by the few telescopes in use. 'Amateur astronomers' were a widely varied lot in terms of interests, abilities, and social status. However, the vast majority who were willing and able to purchase an astronomical telescope, capable of making a useful contribution to knowledge, were men of means. The financial realities of the hobby of astronomy, from its beginnings to the early 20th century, were such that few could afford to participate in meaningful ways, even "with very simple instrumental means".

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[191] Alfred Rordame, "Celestial Photography for Amateurs", *Scientific American*, October 1, 1910, p. 261

2. The amateur astronomer to 1910: organizing amateurs

One indicator of participation in amateur astronomy in America is the number of organized groups of amateurs, and the activities of their members. Amateur astronomers were seen as an important adjunct to the professionals' work, and the most prominent hobbyists were considered part of the American astronomical community in general. The late 19th century was a time of growing professionalization in America, particularly in science and engineering. Historian John Lankford, among others, has pointed out that, at least prior to 1940, astronomy was a far less restrictive discipline in terms of educational and professional requirements than were others.[192] Astronomy, unlike many other scientific fields, continued to have a place for amateurs, as Hale's comment attests. Several amateurs were among the founding members of the American Astronomical Society (AAS), the chief organized body of astronomers in the nation: upon its foundation in 1899, the AAS membership was about 15% amateur. The only official requirement for admission to the AAS, at least in the early years, was that a member be able to present an acceptable scientific paper, a feat that a number of amateurs were indeed able to accomplish.[193] The AAS was for many years the only nationally-based, general astronomy organization in the United States, professional or amateur.

Although biographical information is available for a select few, the vast majority of amateur astronomers are nameless. Fortunately, amateur astronomers are, for the most part, gregarious and enjoy the company of others. Therefore, examining amateur astronomy organizations is one way of determining the overall numbers of people

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[192] John Lankford, *American Astronomy*; 75–77, 375–378.
[193] Marc Rothenberg and Thomas R. Williams, "Amateurs and the Society During the Formative Years", *The American Astronomical Society's First Century*, David H. DeVorkin, Editor (Washington, DC: The American Astronomical Society, 1999); 43–44.

involved in the hobby. Amateur astronomical organizations were few and far between in the United States in the early 20th century. A publication of the National Research Council (NRC), *Handbook of Scientific and Technical Societies*, lists 709 scientific and technical societies in the United States in 1927, some including amateurs in their membership. The list was compiled after 1,500 circulars were sent out in 1926 to all known scientific and technical organizations that were actively involved in scientific research in some form.[194] Astronomy-related organizations are very few; the *Handbook* lists only the American Association of Variable Star Observers (AAVSO - membership of 300 as of 1920), the American Astronomical Society (425 members), the Astronomical Society of the Pacific (ASP - organized in 1889 in San Francisco with branches in Chicago and Mexico; 700 members), and the Cincinnati Astronomical Society (associated with the Cincinnati Observatory - organized in 1911; 125 members). Notably omitted from this list are the Chicago Astronomical Society, organized in 1862 and the Los Angeles Astronomical Society organized in 1916. There are doubtless many reasons why the *Handbook of Scientific and Technical Societies* should only list four astronomy-related organizations in the United States and omit others, but it is quite obvious that such organizations were few. The *Handbook* lists a large number of bird-watching, gardening, and similar organizations that admitted amateurs to their ranks, the Vermont Bird Club, for example.[195] A number can be arrived at which gives at least some idea of the total

[194] Preface, "Handbook of Scientific and Technical Societies and Institutions of the United States and Canada", *Bulletin of the National Research Council, May, 1927, Number 58* (Washington, D.C., The National Academy of Sciences, 1927).
[195] *Handbook of Scientific and Technical Societies*, "Vermont Bird Club" (p. 245), "Vermont Botanical Club" (p. 246), and "The Radio Club of America" (p. 220), are the only organizations that specifically mention 'amateur' in their membership description; many others, such as the "Michigan Audubon Society", must have included amateurs.

number of active amateur astronomers in the United States, c. 1920-1925: assume that about 15% of the AAS members were amateur, and that the remaining groups were largely amateur (say 90%), then out of the total membership number cited in 1927 (1,550), there were only about 1,075 amateur astronomers belonging to major organizations. The number is even smaller if one assumes that some members of these groups (say 10%) held memberships in more than one organization (a number of AAVSO members were also members of the AAS and ASP, for example). Of course there may have been, and undoubtedly were, smaller, semi-organized or nascent groups around the country in the early 20th century, the total numbers of amateur astronomers in America was likely around 2,000, a number that agrees well with the known number of telescopes produced by commercial manufacturers in America up to 1920.

Although there were attempts to form a national amateur astronomical organization in the United States in the early 20th century, they were notable failures. One such was the Society for Practical Astronomy (1909–1911). Founded by a teen-age amateur from Chicago, Frederick C. Leonard, the SPA had only attracted a membership of 18 after two years.[196] The only such group that succeeded was the American Association of Variable Star Observers (AAVSO) founded in 1911. The AAVSO was, in a sense, a spin-off of Leonard's group. Suspicious of a purely amateur organization, Herbert Wilson, Director of Carleton College's Goodsell Observatory and Editor of *Popular Astronomy*, and Edward C. Pickering, Director of the Harvard College Observatory, wanted a group of amateurs to supply data, but be supervised by professionals. The AAVSO came into existence in 1911, headed by amateur astronomer

[196] Rothenberg and Williams; 46-47. Leonard owned a 3-inch refractor of unknown make.

and astronomical popularizer, William T. Olcott, but under the supervision of Harvard College Observatory.[197] Most members of the AAVSO would seem to have had some kind of instrumentation at their disposal. However, the nature of variable star observing is such that very modest means can produce scientifically useful results; binoculars or spy-glasses, for instance, could be used for brighter variable stars. A notable feature of the AAVSO was that it purchased a telescope for use by members who individually did not have sufficient instrumental/financial means; the group acquired a 5-inch Clark refractor in 1918.[198] Subsequently, members of the AAVSO who had themselves purchased telescopes donated them to the organization; for instance, J. J. Crane willed his 4-inch Clark refractor to the AAVSO, and, upon his death in 1927, the organization loaned it to Phoebe Waterman Haas (a computer at the Mount Wilson Observatory Pasadena Office) for a number of years.[199]

Other ‘astronomical societies’ were established, not so much by and for active observers, as for boosters supporting astronomical facilities. Although the Chicago Astronomical Society (CAS), founded in 1862, today touts itself as the oldest amateur astronomical society in the United States, the truth is a bit different. Until well into the 20th century, the CAS was made up largely of wealthy individuals who simply wanted Chicago to have a major astronomical observatory as a point of pride for the city. Few members appear to have had any real interest in astronomy, and their meetings are not mentioned in periodicals such as *Astronomy and Astro-Physics* or *Popular Astronomy*.[200]

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[197] Rothenberg and Williams; 47–49.
[198] Warner and Ariail; 61, It was purchased second-hand for $300 and loaned to Charles Y. McAteer, a railroad engineer from Pittsburgh for variable star observation.
[199] Warner and Ariail; 78. The telescope was originally purchased in 1893.
[200] Williams, “Getting Organized”; 86-133.

Far more active in astronomical research and observation were organizations like the Chicago Academy of Sciences; meetings of their Mathematical and Astronomical Section were regularly reported on in *A&AP* and *Popular Astronomy*. Formed in 1892, membership included a number of professional astronomers such as George E. Hale, but also included serious amateurs like S. W. Burnham. Other active groups included the Astronomical Society of the Pacific, the Astronomical Section of the New York Academy of Sciences, and the Camden Astronomical Society. Few other organized groups seem to have existed in the United States in the early 20th century. The reasons for this lack of amateur astronomy organizations might possibly be due to the individualistic spirit among Americans, particularly those of the 19th century. However, this idea simply does not hold up: when astronomical meetings were organized, such as that at the Columbian Exposition in 1893, amateurs did attend. The fact that there seem to have been so few groups of amateur astronomers, even at local levels, seems to indicate that there simply were not enough people involved in the hobby to warrant such organizations.

3. Example biographies of amateurs

What of the individual amateur astronomer c.1900? There are very few historical works concerning amateur astronomy. The only published book-length treatment of the subject currently available is Allan Chapman's *The Victorian Amateur Astronomer* (1998), which provides an excellent look at the role of amateur astronomers in Britain between 1820 and 1920. Chapman states that virtually no fundamental research was performed in Britain by those paid to do so; most work was done by "amateurs".

However, there were also many more amateurs who were mostly interested in astronomy simply for enjoyment. The Victorian Era, a designation Chapman uses in part for convenience for the years 1820–1920, was one marked by attitudes that emphasized "individual initiative and minimalist public provision."[201] Chapman's study depends to a great extent on biographical sources in an effort to come to terms with motives, means (financial and educational), philosophy, and even technology.

Chapman defines three major classes of 19th century British amateur astronomer: the "Grand Amateur", the "working-class amateur", and, towards the end of the century, the "middle-class amateur". Grand Amateurs include such wealthy individuals as Lord Rosse, William Huggins, and Warren de la Rue, men (and it seems that, outside of marriage, Grand Amateurs were exclusively male) of considerable financial means, education, and leisure. At the same time that astronomy in Britain was dominated by Grand Amateurs, there is considerable evidence that the lower social classes had considerable interest in astronomy as well. Though little in the way of primary source material exists, Chapman considers there is considerable evidence of broad latent interest among the general public of Victorian Britain. By the end of the 19th century, astronomical research had largely been transferred from amateur to professional hands, but the rising middle-class amateur astronomer more than replaced, at least numerically, the Grand Amateur. Chapman considers that these middle-class amateurs in Britain were the prototype of the modern amateur, and that it was they who "created a market for good-quality yet affordable instruments with which to study the Moon, or draw the

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[201] Allan Chapman, *The Victorian Amateur Astronomer: Independent Astronomical Research in Britain 1820–1920*; xii.

surface detail of the planets."[202] I would debate whether the telescopes available in 1900 were truly "affordable", but the basic classifications Chapman uses and his biographical method are quite useful.

While there are parallels between British and American amateur astronomers from 1820 to 1920, there are also considerable differences; for instance, there was no landed aristocracy in America, a social group that dominated much of 19th century British amateur astronomy. Although there is only a limited depth of biographical knowledge of American amateur astronomers (more being known of the few more famous amateurs, or those who eventually joined the ranks of professionals), there is considerable breadth. Biographical study, supplemented with what sales information exists for various telescope-makers, thus provides a good idea of the socio-economic nature of amateur astronomy in America.

4. Biographies of amateur astronomers: American 'Grand Amateurs'

Amateur astronomy in America c.1910 was, like that in Britain, largely dominated by the wealthier classes, but with certain exceptions, some uniquely American. The American equivalent of the British 'Grand Amateur' included those of the American upper-classes. The major difference is that the American 'Grand Amateurs' were economic aristocrats; the wealthy beneficiaries of the Industrial Revolution, rather than traditional landed aristocrats as existed in Europe. However, few of these Americans ever attained the same level of equipment as British amateurs, such as Lord Rosse, William

[202] Chapman; xiv.

Lassell, or Andrew Common, who were doing leading-edge research and whose telescopes far exceeded the size even of professional astronomers.

The nearest to Chapman's conception of 'Grand Amateur' was Percival Lowell (1855–1916). Although the founder of one of today's great professional observatories, Lowell established his observatory as a private, effectively 'amateur', effort. Lowell was born into one of America's wealthiest families, the Lowell's of Massachusetts textile-mill fame. Percival Lowell was educated at Harvard, then launched himself into a career as a financier. Lowell's interest in astronomy came rather late. It was not until 1892, at age 37, that he bought a 6-inch refractor from Alvan Clark & Sons. Lowell became fascinated with the planet Mars and determined to observe the particularly near approach of that planet in 1894; he thereupon decided to purchase a much larger telescope from Clark and establish his own private observatory under the clear skies of Flagstaff, Arizona.[203] The telescope was a 24-inch, one of the largest telescopes in America at the time, and by far the largest refractor ever privately purchased by an amateur astronomer in the nation's history.[204] 1909 saw an even larger telescope constructed for Lowell's observatory, a 42-inch Newtonian with optics by Clark optician Carl Lundin.[205] The 24-inch equatorial, regarded as qualitatively the best telescope the Clarks ever produced, cost $20,000 in 1894 ($410,000 in today's terms), and the mirror alone for the 42-inch cost $10,800 in 1909 ($209,200). Add to this the cost of auxiliary instruments, observatory buildings, support buildings, residences, a large library building, and a professional paid staff of

[203] David Strauss, "Lowell, Percival", *Biographical Encyclopedia of Astronomy*; 710–711.
[204] One could quibble with this, since James Lick and Charles T. Yerkes largely financed the observatories and telescopes bearing their names, but neither of them had any particular interest in astronomy, and so cannot be classed as 'amateur astronomers'.
[205] Warner and Ariail; 122–129.

astronomers and support personnel, and the scale of Lowell's investment in his hobby of astronomy becomes astounding, likely several million dollars in today's terms.[206] Lowell could certainly earn the title of 'America's Grandest Amateur'.

Lewis Morris Rutherfurd (1816–1892) was not just a leading American amateur astronomer of the 19th century; he was also a well-respected leader in the then emerging field of astrophysics. Rutherfurd was born into a well-to-do New York family and included as ancestors John Rutherfurd, a United States senator from New York (1791-1797) and Lewis Morris, a signer of the Declaration of Independence. Rutherfurd studied the natural sciences while a student at Williams College, Massachusetts, prior to entering the law profession in 1837. His avocational pursuits in science, particularly astronomy, were aided by his marriage to the wealthy Margaret Stuyvesant Chanler in 1849. Rutherfurd, free from having to make a living, embarked on a seven-year visit to Europe where he expanded his existing interests in astronomy and physics by contact with noted scientists such as Giovanni Battista Amici. On his return to New York, Rutherfurd constructed his own observatory where, from 1858 until his death in 1892, he made some of the earliest contributions to both astrophotography and stellar spectroscopy.[207]

Rutherfurd was a repeat customer of Henry and Harry Fitz (as well as the Clarks), purchasing a 4-inch Fitz refractor, possibly prior to his departure for Europe in 1849, and an 11¼-inch photographic refractor in 1864. Then in 1868, he purchased a 13-inch Fitz refractor, this being a special achromatic telescope with an additional third lens-element

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[206] William Lowell Putnam, *The Explorers of Mars Hill: A Centennial History of Lowell Observatory, 1894-1994*, (West Kennebunk, Maine: Phoenix Publishing, 1994); 25–26, 134–139.
[207] John K. Rees, "Lewis Morris Rutherfurd", *Astronomy and Astrophysics*, 11 (October, 1892): 689–697.

in order to form a better image for photography.[208] With these two instruments, Rutherfurd made some of the first extremely high-quality photographs of the sun, moon, and stars, regarded as unequalled until the 1890s. The total cost of Rutherfurd's observatory is not known, but must have been very substantial; both the 11¼-inch and 13-inch refractors were among the largest telescopes in America when built in the 1860s and must have cost an enormous sum. The 12⅝-inch equatorial made for the University of Michigan observatory in the late 1850s cost \$6,750 (\$135,675 in 2001).[209] Including the observatory building, the equatorial refractors, a transit telescope, clocks, cameras, dark-room equipment, and other miscellaneous items accumulated over the years, Rutherfurd must have spent the equivalent of around \$500,000 in today's terms on his hobby.

Though born in Virginia, Henry Draper spent most of his life in New York, like Rutherfurd. Henry Draper (1837–1882) was the son of John William Draper, a physician, chemist, and contributor to early photography.[210] Henry Draper benefited by his family's scientific interests, since they encouraged his mechanical and scientific talents. Draper was prepared to complete his medical degree in 1857, but was unable to graduate due to the fact that, at age 20, he was too young to be granted the doctorate of medicine at the University of the City of New York (Columbia). This was fortuitous as the family sent Henry on a European tour where he visited the observatory of Lord Rosse in Ireland, location of the great 72-inch speculum-metal reflector. On his return in 1858, Draper

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[208] Holcomb. Fitz, and Peate; 168. The exact date at which Rutherfurd purchased his first Fitz telescope is unclear, but seems to have been soon after Fitz exhibited his first telescope during the summer of 1844.

[209] Patricia S. Whitesell, *A Creation of His Own: Tappan's Detroit Observatory*, (Ann Arbor, MI: Bently Historical Library, The University of Michigan, 1998); 59–61.

[210] Donald Fleming, "Draper, John William", *Dictionary of Scientific Biography, Volume IV*, (1971); 181–183.

began both his medical and his astronomical career, starting work on a speculum metal reflector. Another fortuitous event took place when the metal mirror split after cold water spilled onto its surface; after receiving information from John Herschel on Steinheil and Foucault's work, Draper switched to making silver-on-glass mirrors.[211] Draper made over 100 mirrors in various experiments concerning polishing and testing methods, but his first large telescope was the 15½-inch Newtonian reflector constructed in 1861–64; this was followed later by a 28-inch Newtonian constructed in 1867–1872. Draper's private observatory was considered one of the best in the world at the time, and he made many contributions to early celestial photography and spectroscopy. Draper, also like Rutherfurd, married into additional wealth. Draper's wife, Anna Mary Palmer, became Henry's able assistant. Still, Draper never completely gave up medicine, became involved in teaching medicine and chemistry at New York University, and maintained a very full schedule outside of astronomy. Unlike Rutherfurd, Draper never made any major purchases of astronomical equipment, preferring to build his own; it is therefore difficult to equate the two on the basis of how much money they invested in their hobby. However, the amount of time Draper spent on observing and telescope-making was considerable and even the raw materials, work-spaces, and accessories were no doubt quite costly.

George Ellery Hale (1868–1938) is well-known as one of the great names in the history of professional astronomy and astrophysics. However, Hale can really be said to be one of the 'Grand Amateurs' early in his career. Before becoming director of the new

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[211] Steven J. Gibson, "Draper, Henry", *The Biographical Encyclopedia of Astronomy*; 310–311. Charles A. Whitney, "Draper, Henry", *DSB*, IV, (1971); 178–181.

University of Chicago's Yerkes Observatory in 1897, Hale did considerable leading-edge astrophysical research at the "Kenwood Physical Observatory" located on the grounds of his family home in Chicago. Hale's father, William Hale, was a wealthy businessman, owner of William E. Hale & Company, manufacturer of passenger elevators (a key component in the success of the new 'skyscrapers' then being built). George Hale's interest in astronomy came at a fairly early age, sparked by visiting various Chicago-area observatories, astronomers, and telescope-makers. Amateur-professional astronomer and double-star observer S. W. Burnham allowed young Hale to join him in his research and, the following year, informed his 'assistant' of an available telescope in the Chicago area. Hale's father purchased the second-hand 4-inch Alvan Clark & Sons refractor as a gift for George (aged 14) in 1882, just in time to observe the transit of the planet Venus. This telescope was mounted on a fixed pier in the garden of the Hale family's newly-built mansion, the attic of which was designed from the start as an astrophysical laboratory for George. A year after George graduated from MIT (BS, 1890) Hale's father financed a complete observatory with a 12.2-inch Brashear refractor on a Warner & Swasey mount, plus a large assortment of specialized equipment for observing the Sun and the Sun's spectrum.[212] William Hale estimated the cost of the substantial stone observatory building (designed by noted Chicago architects Burnham and Root), the 12.2-inch telescope, a spectrograph larger than that owned by Lick Observatory, and various other equipment, at $25,000 in 1891 ($484,000 in today's terms).[213] Although George Ellery Hale soon joined the ranks of full-time, professional astronomy, he definitely did his stint

[212] Ronald Florence, "Hale, George Ellery", *Biographical Encyclopedia of Astronomy*; 461–463. Warner & Ariail, p. 103.
[213] Donald E. Osterbrock, *Pauper and Prince: Ritchie, Hale, & Big American Telescopes*, (Tucson and London: The University of Arizona Press, 1993), p. 24-25.

as an amateur, a route travelled by many future professional astronomers, albeit far more modestly.

Fig. 28 – The Kenwood Physical Observatory used by the 22-year-old George Ellery Hale (photograph from the Emilio Segrè Visual Archives, American Institute of Physics).

There were somewhat lesser examples of 'Grand Amateurs' as well. For example, William Smith (1818-1912) of Geneva, NY (after whom William Smith College was named) established the "Smith Observatory" near his home in 1888, equipped with "instruments of the highest standard".[214] Smith, a wealthy nursery-man, employed amateur astronomer and noted comet-hunter William R. Brooks (1844-1921) as director. Brooks himself was from a modest back-ground and hunted for comets primarily with a home-made 5-inch Newtonian reflector from 1870 to 1888.[215] The telescope at the Smith Observatory was a specially-designed, short-focus, 10.1-inch aperture equatorial refractor (ideal for comet-hunting), with optics purchased from professional optician John Clacey

[214] "The Smith Observatory, Geneva, N. Y.", *Scientific American*, 58 (May 12, 1888): 288.
[215] William Sheehan, "Brooks, William Robert", *Biographical Encyclopedia of Astronomy, Volume I*; 171–172.

of Boston for $1,250 in 1886 ($23,375 in 2001), and a mounting by Warner & Swasey.[216] Brooks discovered 31 comets, more than any other American astronomer, amateur or professional, 11 of them while working at his own small 'observatory' in Phelps, New York, and 15 more while working for Smith. Smith is not known to have done any significant observing on his own, apparently being content to let Brooks do all the work.

5. Middle-class amateurs

As in Britain, aside from the 'Grand Amateurs', there were a large number of middle-class amateurs in America; they undoubtedly formed the single largest group of amateur astronomers in the nation. Joel Hastings Metcalf (1866-1925) had an extremely productive life as an amateur astronomer. As a young man, Metcalf read *Other Worlds*, one of many books written by the 19th century British astronomy popularizer Richard Proctor. Metcalf acquired his first telescope in 1882, a French-made spyglass, of 2-inch aperture. A few years after this, Metcalf bought a 3.6-inch Fitz equatorial refractor, likely second-hand. Metcalf attended divinity school, became ordained as a Unitarian minister in 1890, and continued his theological training at Harvard University and Allegheny College, Pennsylvania, receiving a PhD from the latter in 1892. He was an active minister in Massachusetts, Vermont, and Maine, being involved in a number of social reform movements around the turn of the century, but continued his work in astronomy. When the wealthy New York amateur astronomer Elisha Arnold passed away in 1901, Metcalf purchased Arnold's 7-inch Clark refractor (originally made in 1882). Although originally involved in traditional forms of observational astronomy, Metcalf became interested in

[216] John Clacey, "Agreement for lens construction", note to William Smith, November 24, 1886, Smith Observatory Collection. Bell: 9.

astrophotography, and, in 1905, constructed a second observatory at his home containing a 12-inch 'astrographic' telescope with an objective lens of his own construction. Telescope making was, in fact, yet another hobby for Metcalf. He produced several notable instruments, including a 16-inch astrographic camera lens for Harvard. However, he never gave up the ministry, nor was he ever employed as either an astronomer or telescope-maker. Although Metcalf was, as a noted church minister, a man of some means, the fact that the larger telescopes he owned were either second-hand or of his own make indicates his relatively restricted financial situation.[217]

Garrett Putnam Serviss (1851–1929) is the first of two American astronomy popularizers who took law degrees, yet preferred science-writing as a career. Serviss' parents were farmers, though they seemed to have been sufficiently well-educated and economically well-off to send their son Garrett to Cornell University, where he received a baccalaureate degree in science in 1872. Serviss chose to become a newspaper writer and editor, writing a series of science articles for the *New York Sun*. Serviss' *Astronomy With An Opera-Glass* (1888) was an immensely popular book, going through several editions through at least the 1920s.[218] Serviss was himself an amateur astronomer for reasons only of recreation and personal scientific enlightenment: the largest telescope he ever personally owned was a 3⅜-inch refractor of unknown make.[219]

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[217] Joel Hastings Metcalf, "An Amateur's Observatory", *Popular Astronomy* , 14 (1906): 211–217; Solon I. Bailey, "Joel Hastings Metcalf", *Popular Astronomy*, 33 (1925): 493–495; Rachel Metcalf Stoneham, "Joel H. Metcalf, Clergyman-Astronomer," *Popular Astronomy*, 47 (1939): 22–28.
[218] Garrett P. Serviss, *Astronomy With An Opera-Glass: A Popular Introduction to the Study of the Starry Heavens with the Simplest of Optical Instruments, Eighth Edition,* (New York and London: D. Appleton and Company, 1923).
[219] Leif J. Robinson, "Serviss, Garrett Putnam," *Biographical Encyclopedia of Astronomy*, *Volume II*; 1043.

William Tyler Olcott (1873–1936) followed in Serviss' footsteps to become one of the most important astronomy popularizers and organizers in early 20th century America. In addition to writing such popular books as *In Starland With a Three-inch Telescope* (1909) and *A Field Book of the Stars* (1907), Olcott was a key player in organizing the AAVSO in 1911. Olcott was college-educated, and was admitted to the bar in New York and Connecticut. Olcott later made his living as a writer of popular astronomy books; astronomy was of increasing interest to the American public and the books sold well. Olcott purchased a small refracting telescope (presumably a 3-inch) about 1905, and in 1921 constructed a small observatory on the roof of his house equipped with a 5-inch Lohmann equatorial refractor, likely costing around $2,000 (in 1921, $19,700 today).[220]

David E. Hadden (1866–1943) of Alta, Iowa was a particularly active amateur astronomer from 1890 to 1930. Hadden was particularly interested in solar observing and authored a number of articles printed in *Popular Astronomy*. Two of these articles are significant as they highlight his personal observatory, or rather *observatories*, and the instruments they contained. Hadden was by profession a pharmacist, having received a Bachelor of Science degree in chemistry and pharmacy from Morningside College (Sioux City, Iowa) in 1904 after working as a pharmacy clerk (and partner) at the C. E. Cameron and Company drug store in Alta since 1888.[221] His professional work as a pharmacist was preceded by his interest in astronomy; he was already doing some observing in the early 1890s and had his first telescope by 1895. This instrument, a 3-inch Brashear

[220] Edmund Fortier, "The Legacy of William Tyler Olcott", *Sky & Telescope*, 80 (November 1990): 536–539. A photograph of Olcott in his observatory exist in the AAVSO archives.
[221] C. H. Wegerslev and Thomas Walpole, *Past and Present of Buena Vista County, Iowa*, (Chicago: The S. J. Clarke Publishing Company, 1909); 155–156.

refractor, was eventually housed in a small observatory at his home in Alta. Subsequently, the 3-inch was replaced by a 4-inch by the same manufacturer. By 1909, Hadden had constructed a second, much larger observatory next to the original. This two-story structure housed a 5½-inch William Gaertner & Company refractor, equatorially mounted with clock-drive mechanism, a large-format camera he adapted to solar photography, a filar micrometer for measuring angular separations of double stars and other objects seen through the telescope, and various other equipment. In addition, the lower floor of his observatory was used to store a portable 9½-inch reflecting telescope that could be used in either the Cassegrain or Newtonian forms; although Hadden apparently made most of this telescope himself, the optics had been supplied by the John Brashear Company. This latter telescope was quite likely the largest instrument in the state owned by anyone, amateur or professional.[222] In addition to his own observing program, Hadden frequently opened his observatory to visitors and he was noted as an entertaining and informative public speaker.[223] Hadden's 5½-inch refractor was the fourth-largest permanently housed telescope in the state of Iowa at the time; only Drake University's 8¼-inch Brashear refractor, Grinnell College's 8-inch Clark, and a 6¼-inch refractor at Central College in Pella were larger. The University of Iowa's observatory only possessed a 5-inch refractor from the British firm of Grubb. In other words, Hadden was a decidedly well-equipped amateur astronomer.[224] An estimate of the cost of all this

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[222] David E. Hadden, "Photographing the Sun,", Popular Astronomy, XVII (January, 1909); 20–23. The camera was a very large, portrait-type (with bellows), and the spectroscope was a good-sized reflection-grating type. David E. Hadden, "An Amateur's Observatory", *Popular Astronomy*, XVIII (December, 1910): 597–600.
[223] Ben Hur Wilson, "Amateur Astronomer", *The Palimpsest*, (September 1944): 274.
[224] Photograph of observatory and equipment in, David E. Hadden, "An Amateur's Observatory": 598

equipment, plus the observatory structures, must have run to over $2,000 in 1909 ($40,000 today).[225]

Dr. Mars F. Baumgardt was not only the author of a history entitled, "Amateurs and Telescopes of Early Southern California," but was an active amateur astronomer in his own right.[226] According to Baumgardt, the first telescope known to have been used in California was a small spy-glass of 1⅜–inch aperture and 8-power magnification (Cutts & Co., London) said to have been owned by the last Mexican governor.[227] The first astronomical telescope however, arrived in Southern California in the late 1870s or early 1880s and was a 5¼-inch equatorial (of unknown make), owned by a "Senator Bliss" and placed in an observatory atop his home in Los Angeles. It is recounted that "Leading citizens were invited to look through his wonderful and powerful telescope," and many of these visitors later became amateur astronomers themselves.[228] In 1891, the Southern California Science Association (later the Southern California Academy of Sciences) was founded and an Astronomy Section formed. Bliss willed his telescope to the Astronomy Section, which frequently loaned it to others for use at their homes until about 1925.

B. R. Baumgardt (father of Mars Baumgardt) was a university educated publisher and writer and owned the next oldest California telescope, a 6-inch Clark refractor on a portable mount that he often set up at (then dark) street corners as a focus of activity for

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[225] About $150 for the optics of the reflector, $550 for the 4-inch refractor, and about $1,000 for the 5½-inch; add $200 for the micrometer, and $200 for assorted accessories = $1,920. The observatory buildings were fairly substantial and were professionally constructed by a local contractor.
[226] Mars F. Baumgardt, "Amateurs and telescopes of early Southern California", *The Griffith Observer*, (March, 1940): 26–38.
[227] The telescope was in the possession of the Los Angeles County Museum in 1940.
[228] Baumgardt, "Amateurs and telescopes of early Southern California": 27.

those interested in astronomy in 1890s Los Angeles.[229] Baumgardt was owner of Baumgardt & Co., a publishing house located in Los Angeles. Baumgardt frequently gave public lectures and viewing sessions with his telescope to the general public.[230] For many of these people, it was their first look through a telescope. Baumgardt was made a Fellow of the Royal Astronomical Society for his popularizing work and was well-known as a writer, publisher, and professional lecturer nation-wide.[231]

Thadeus Sobieski Constantine Lowe ("Professor Lowe") was yet another early astronomer of Southern California, who was a wealthy inventor and entrepreneur who had worked in such varied areas as ballooning during the American Civil War and railway refrigerator cars. It was Lowe's interest in astronomy that brought the Warner Observatory, complete with 16-inch refractor and director Lewis Swift, to California.[232] Operating as the Mount Lowe Observatory, the facility was largely operated as a place for public education and, though Lewis Swift did do some serious work there, the telescope was largely used during weekend expeditions by members of the Los Angeles Astronomical Society.

There were at least two groups that bore the title "Astronomical Society of Los Angeles". Though there was another group to be discussed later that bore the name from 1938, the first was organized in 1912. An existing bound copy of the society's newsletter sheds some further light on the activities of amateur astronomers prior to 1920. The only mention of personally owned telescopes among club members is a description of a home

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[229] Telescope not listed in Warner and Ariail.
[230] Baumgardt, "Amateurs and telescopes of early Southern California": 28–30.
[231] "The B. R. Baumgardt Lectures", brochure, un-dated, Brochure Collection, University of Iowa Library. The brochure quotes from "Who's Who?" to state that Baumgardt was educated in Sweden at Strengnas College in history, astronomy, and mathematics.
[232] Baumgardt, "Amateurs and telescopes of early Southern California": 30–32.

observatory that housed a 6-inch refractor in a 40-foot high brick tower with dome that would accommodate 12 to 15 persons. Members of the society tended to observe in groups, visiting established observatories. Expensive "Picnic Outings" to Mt. Lowe Observatory were popular pastimes for the ASLA amateur astronomers.[233] Members of the ASLA were each paying $1.75 ($28 today) just for a train ticket for their "Astronomical Excursion and Basket Picnic" to Mt. Lowe Observatory. This was for some time a regular monthly event for ASLA members.

As previously mentioned, enough sales information survives from the Alvan Clark & Sons Company to provide a further glimpse into the type of Americans who bought and owned telescopes in the late-19th and early-20th centuries. Robert Radford Beard, president of the National Bank in Pella, Iowa, purchased a 6¼-inch refractor in 1886, at that time the second-largest telescope in the state, which he later donated to Central College in Pella, c.1899. James Herbert Budd, a lawyer in Stockton, California (later elected governor), purchased a 5-inch equatorial in 1878. Gustavus Wayne Cook, owner of a steel plant in Philadelphia, purchased a 6-inch Clark telescope in 1905 that he later (1933) mounted as an auxiliary instrument on a 28½-inch Cassegrain built by Fecker (successor to Brashear); all this was part of an observatory complex later donated to the University of Pennsylvania. James Graham Fair was originally a mining engineer, but became a millionaire as one of the owners of the Comstock Lode; he purchased a 5-inch Clark telescope in 1878. John Jay Pierrepont, a Brooklyn, New York financier, purchased a 4½-inch equatorial in 1908. Though some of the purchasers of telescopes were of more

[233] Edgar Lucien Larkin, "The Lowe Observatory on Echo Mountain, California, U. S. A.", *Scientific American*, (February 12, 1910): 144-145. "History and Work of the Astronomical Society," *The Heavens, Monthly Record of the Stars, Planets, and Astronomical Events*, Newsletter of the Astronomical Society of Los Angeles, April, 1916: 4.

moderate middle-class status, others were wealthy, but all could be described as 'comfortably well off'.[234]

6. <u>'Working-class' amateurs</u>

There is, frankly, very little evidence of many 'Working-class' amateur astronomers in America prior to the 20th century. E. E. Barnard and John Brashear come closest, but Brashear's talents as an optician and machinist permitted him to found his own telescope-making company, which took him away from active observing, and Barnard's talents as an observer eventually led to a career as a professional astronomer. Lewis Swift and S. W. Burnham were on the lower-end of the economic spectrum, but were really lower middle-class: Swift was a shopkeeper, Burnham a court stenographer. Swift, Burnham, and the previously mentioned William R. Brooks were also lucky that, through diligent use of their own modest telescopic instruments, they gained notoriety enough that they were eventually either allowed free use of larger telescopes, or were hired by wealthy patrons to run private observatories.

Lewis Swift (1820–1913) was, like a number of serious amateurs of lesser means, both a comet-hunter and a hybrid amateur-professional. Swift's family were farmers in upstate New York; Lewis was injured in a farm accident as a boy, attended school instead, and became interested in astronomy. Swift became a small-town store-keeper in 1850, but maintained an interest in astronomy and constructed his own telescope using a purchased 3-inch lens. Around 1858, after hearing a public lecture by astronomer Ormsby McKight Mitchel, Swift purchased a 4½-inch Fitz refractor with which he co-discovered

[234] Warner and Ariail; 47–189.

Comet Swift-Tuttle in 1862. Swift continued to work as a shop-keeper, opening a hardware store in Rochester, New York, but also continued hunting comets and doing other types of astronomical observations near his home until 1882. Hulbert Harrington Warner was a well-to-do patent medicine seller from Rochester and knew of Swift's work; Warner, with the financial assistance of other Rochester residents, constructed an observatory featuring a 16-inch Clark refractor and hired Lewis Swift as astronomer. Observing conditions in Rochester were far from ideal, Warner lost his fortune in the Panic of 1893, and so, that same year. Swift took a position with Thadeus Lowe at his private observatory in the mountains just outside Los Angeles, California. Swift finally retired in 1904.[235]

The leading observer of double-stars in the 19th century was Sherburne Wesley Burnham (1838–1921), a man who only possessed a secondary-school education, yet was called on as an authority by many leading professional astronomers of his day. Burnham learned shorthand writing and spent much of his working life as a court stenographer in Chicago. His first telescope was a 3-inch refractor, of unknown make, acquired in England in 1861. Having read Elijah Burritt's popular book, *Geography of the Heavens*, Burnham began earnestly observing the sky in 1866, having traded the 3-inch telescope for a 3¾-inch Fitz equatorial. Burnham then purchased a copy of British amateur astronomer Thomas Webb's *Celestial Objects for Common Telescopes*, a very influential book among amateurs, which filled Burnham's need for better information on his chosen observational subject of double-stars. In 1869, Burnham bought the largest telescope he would personally own, a 6-inch Alvan Clark & Sons equatorial refractor. Though

[235] William Sheehan, "Swift, Lewis", *Biographical Encyclopedia of Astronomers, Volume II*; 1115–1116.

Burnham was at times able to use the 18½-inch Dearborn refractor at the old University of Chicago, much of his work, including the discovery of 451 double-stars, was done with his 6-inch Clark. Burnham did work for a time as a paid, professional astronomer, one year for the University of Wisconsin's Washburn Observatory (1881), later for the Lick Observatory, California (1888–1892), and lastly as, effectively, a part-time astronomer at Yerkes Observatory in Williams Bay, Wisconsin (1897-1914). The job at Lick paid less than his courtroom job in Chicago (and was far less comfortable), and Burnham continued working as a court reporter in Chicago while observing on weekends at Yerkes. Although not 'working-class' *per se*, Burnham was definitely not wealthy, and much of his observing work was effectively done with 'borrowed' equipment at the larger professional observatories he was associated with. Burnham was very much a hybrid amateur-professional.[236]

One of Burnham's great friends was also an amateur turned professional. Edward Emerson Barnard (1857–1923) was by 1910 a well-known and respected professional astronomer having worked at both Lick and Yerkes Observatories. However, he had begun his astronomical career as a dirt-poor young man in Nashville, Tennessee, but turned out to be extraordinarily lucky, talented, and persistent. Growing up in the war-ravaged, cholera-ravaged, and economically-depressed, city of Nashville, Tennessee, Barnard's early life was extremely difficult. Edward went to work at age 9 for a photographer, a job he held until age 25. Though Barnard was clearly interested in the sky and taught himself a considerable amount by reading second-hand books, his family's poverty did not permit him to buy a telescope at first. Fortunately, Barnard's

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[236] Edward Emerson Barnard, "Sherburne Wesley Burnham," *Popular Astronomy* 29 (1921): 309–324.

older friend, James W. Braid (chief photographer at the studio where Barnard worked), was mechanically talented and constructed for the boy a small 1-inch spyglass from parts scrounged off the streets of Nashville. With this unassuming instrument, Barnard began his career as an observational astronomer in 1870 at age 13. Braid and Barnard joined forces again in 1876 by combining a lens-less spyglass, bought as scrap for two dollars, with a 2¼-inch lens purchased from Queen & Co., and an old microscope eyepiece.[237] Immediately after completing the 2¼-inch telescope, Barnard began exploring other instrumental possibilities, first trying a second-hand telescope owned by a wealthy Nashville family, then a 3-inch refractor, neither of which was of particularly good quality. Barnard, again with the help of his friend Braid (who had relatives in New York City), discovered the existence of John Byrne's telescope company and decided to order a 5-inch, tripod-mounted, equatorial refractor. Byrne evidently knew Braid and, as a favor, sold Barnard the telescope for only $380, 30%-off the normal price. Still, this was an enormous sum for Barnard, who was only making $12.00 a week at the photographer's studio, and the 19-year old amateur astronomer actually had to borrow money for the purchase.[238] However, Barnard began observing with his new telescope in 1877 and soon gained notoriety as an astute observer who possessed the largest telescope in Nashville, save for the 6-inch Cooke equatorial refractor at Vanderbilt University. The same year as Barnard began observing with his powerful new telescope, the American Association for

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[237] William Sheehan, *The Immortal Fire Within: The Life and Work of Edward Emerson Barnard* (Cambridge: Cambridge University Press, 1995); 1-18. The 1884 Queen & Co. catalogue (from about 12 years after Baird and Barnard's telescope-making effort) does not include a 2 ¼-inch telescope objective, but does have a 2 ½-inch, priced at $15 ($268 in 2001); the smaller lens of Baird and Barnard's spyglass likely would have been a few dollars cheaper, say $10. Barnard had by then moved to a rooming house, at a cost of $4 per week (p. 12).

[238] Sheehan; 19-22. The two rejected telescopes were of unspecified make.

the Advancement of Science held their annual meeting in Nashville, a meeting the young Barnard attended. There, he met leading scientists from all over the country including the astronomer Simon Newcomb of the U. S. Naval Observatory, who suggested Barnard start a career as a comet-hunter and write S. W. Burnham for further advice on observing programs for amateurs.[239] Barnard did both and went on to discover a number of comets, winning several prestigious awards in the process. Barnard became close friends with S. W. Burnham, made numerous telescopic observations of the planets, many of which were published in journals such as *The Sidereal Messenger*, and finally, in 1883, became a paid astronomer at Vanderbilt University's observatory. From that point on, E. E. Barnard ceased to be an amateur and, though he held on to his 5-inch Byrne refractor for some years, had regular access to some of the largest telescopes in the world at the Lick and Yerkes Observatories. Barnard, though from a very poor background, managed to become an important observational astronomer, first as an amateur, then as a professional. However, his career as a "working-class astronomer" must be considered unusual; for every Barnard, there must have been dozens, even hundreds, of individuals whose astronomical appetites went un-satisfied.

Telescope-maker John Brashear began making telescopes due to his own interests in astronomy. Brashear was first permitted a glimpse through a telescope as a boy by a local Pennsylvania notable, one 'Squire Wampler', who had constructed his own telescope in the 1850s. Brashear never received much education beyond that afforded by the common schools, but he grew up in a family that respected learning, including science. John Brashear was apprenticed to a mechanic in the Pittsburgh area, and spent

[239] Sheehan; 23.

many years working as a mechanic and pattern-maker. Brashear was one of those who had great interest in astronomy, little means for buying a telescope, but great mechanical talent, and turned to making his own telescopes. He first constructed a 5-inch refractor, not knowing a great deal about the correct methods beyond what he could cull from the few articles available in periodicals like *Scientific American* and *The English Mechanic* (the latter to be examined in more detail in a later chapter). He was, however, immensely pleased with the results after observing the moon and Saturn; after his conversations with Langley at the Allegheny Observatory, Brashear produced his 12-inch silver-on-glass Newtonian. However, Brashear, like Fitz and Clark, soon gave up observing to concentrate on professional telescope-making, preferring to sell optics and complete telescopes to observers.

7. Economics of Victorian America: incomes, expenses, and hard facts of telescope ownership

Whatever the source, telescopes being sold commercially in the late 19th and early 20th centuries were expensive; the average cost of a modest 3-inch refractor on a simple alt-azimuth mount around 1910 was $110.[240] A Model T Ford in 1910 cost $950, though the price dropped to $290 by 1924 after mass-production kicked-in. However, the cost in real terms of commercially-made telescopes either remained steady or actually *increased* somewhat over the first quarter of the 20th century.[241] A two-story, three-bedroom house,

[240] 3-inch Brashear (1911), $125, Mogey (1910), $110, and Bardou (1911), $95.

[241] *Major Problems in the History of American Technology, Documents and Essays*, Merritt Roe Smith and Gregory Clancey, Editors, (Boston and New York: Houghton Mifflin Company, 1998); 312.

Continuous data is lacking for many telescope manufacturers, but it is known that the 3-inch Mogey refractor increased in price:

with fireplaces upstairs and down, featuring cypress-wood living room paneling, was built in a Chicago suburb in 1904 for $3,000.[242] Another two-story house, built in 1910, with four bedrooms, cost $3,300.[243] On the smaller end, single-story bungalows in Pasadena, California (within shouting distance of what would become Caltech), with three to five rooms, were being constructed for less than $1,000 in the first decade of the 20th century.[244] In 1914, flank steak cost $0.14-0.22 per pound, potatoes were $0.02 a pound, bread was about $0.05 per loaf, and a can of tomatoes cost $0.08.[245]

A number of historical studies have been written concerning the economics of workers, *The Five-Dollar Day* being one of the best known. Statistics are rather difficult to come by, as these are generally only available anecdotally prior to the establishment of the Bureau of Labor Statistics.[246] One individual who eventually became an important contributor to the amateur telescope making movement in America, Oscar Marshall, gives a fair idea of what most workers (skilled ones at that) were paid in Turn-of-the-Century America. Marshall wrote that he received $0.75 a day at the beginning of his apprenticeship for Gilman and Son Machine Shop in 1893; this increased to $0.90 per day after one year, $1.10 during the third year, and $2.00 a day upon completion of his

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Mogey 3-inch, on Class D mounting – (year, sale price, and cost in modern terms):
1910 - $110 ($2,037.20)
1927 - $200 ($2,029.80)
1932 - $230 ($2,978.50)
The 1932 price represents a real increase, not due to inflation. It seems amazing that Mogey raised prices so substantially during the Depression.

[242] Herrmann Valentin von Holst, *Country and Suburban Homes of the Prairie School Period, With 424 Photographs and Floor Plans*, (New York: Dover Publications, Inc., 1982), Plate 1.
[243] Von Holst, Plate 3.
[244] Von Holst, Plate 59.
[245] *Standards of Living: A Compilation of Budgetary Studies*, (Washington, DC: Bureau of Applied Economics, Incorporated, 1920); 126–128.
[246] See comments in Wayne G. Broehl, Jr., *Precision Valley: The Machine Tool Companies of Springfield, Vermont*, (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1959); 141.

apprenticeship. Marshall worked a six-day week, as did most workers at the time. On this basis, Marshall and machinists like him received \$230-335 annually as an apprentice and a little over \$600 annually as a skilled worker. Even the highest paid worker at Gilman and Son received only \$2.75 a day, or about \$850 annually.[247] From about 1903 until 1906, when he left the Gilman firm, Marshall was able to leverage his yearly pay, as the new senior shop foreman, to \$1,200.[248] Stephen Meyer's classic, *The Five Dollar Day*, states that workers in Detroit in the early 1890s earned from \$6.60 per week for unskilled laborers to \$12.58 per week for skilled mechanics; this equates to annual salaries of about \$342 to \$654. By 1910 wages had increased, somewhat unevenly, to \$390-\$1,622.[249] Even by the 1930s, the pay of skilled workers in the machine-tool industry hovered in the \$0.55-0.65 per hour (\$1,250-1,460 per year) range, and somewhat lesser amounts averaged over all manufacturing workers.[250] Studies compiled by the Bureau of Applied Economics provide further information on incomes in the United States from 1906 to 1920. In 1906, the average working-class family in New York City had an income of \$851.38.[251] Families of factory workers in 1914 Chicago were recommended to budget \$100 a year on clothing (for father, mother, and children), \$120 on rent, \$367 on food, \$22 on home furnishings, \$10 on health care, \$15 on education, including children's schoolbooks and newspapers, and nothing on recreation, Christmas gifts, or candy, a total

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[247] Oscar Seth Marshall, *Journeyman Machinist en Route to the Stars: Stellafane to Palomar, The Autobiography of Oscar Seth Marshall*, Eva Marshall Douglas, Editor, (Taunton, MA: Wm. S. Sullwold Publishing, Inc., 1979); 26–27.
[248] Marshall, *Journeyman Machinist*; 46. The increase in pay was during a period of worker unrest at Gilman and Son.
[249] Stephen Meyer III, *The Five Dollar Day: Labor Management and Social Control in the Ford Motor Company, 1908-1921*, (Albany, NY: State University of New York Press, 1981); 46–48.
[250] Broehl, *Precision Valley*; 141
[251] *Standards of Living*; 149.

of just over $730 of expenditures out of an average income of $801.49.[252] The average incomes cited were just that, averages; some laboring-class families had to exist on only $600 a year. The average American worker in 1910 could thus barely afford to subsist, let alone buy something as frivolous as a telescope, no matter what latent interest in astronomy might exist.

Even the members of the lower ranks of the American middle-class, clerks, teachers, and such, made relatively meager salaries. Professional astronomers, college and university educated middle-class individuals, are perhaps the most interesting group to examine. In 1902, Joel Stebbins (1878-1966) was just beginning his career, doing his graduate work at the universities of Wisconsin and Berkeley (after receiving his BS degree from the University of Nebraska, 1899). Stebbins was considering various possible university positions; one was indeed open at the University of Illinois in Urbana, which he accepted in 1903. The annual starting salary for the Illinois teaching/research position was $1,000.[253] By 1912, Stebbins was able to negotiate a raise with the University of Illinois to $3,000 per year (and with the title 'Observatory Director') after getting a tempting offer from the University of Virginia.[254] In 1910, pay at the Dudley Observatory in Albany, New York, ranged from $3,600 for a senior staff member, to $1,200-1,800 for an observer, and $655-875 for 'computers' (all female).[255] Ironically, many professional astronomers would have found it difficult to buy a decent telescope for

[252] *Standards of Living*; 142–144.
[253] Lankford, *American Astronomy*; 119–122.
[254] Lankford, *American Astronomy*; 163–164.
[255] Lankford, *American Astronomy*; 342. 'Computers' were persons, generally women, hired by observatories to do routine, and repetitious, computations connected with observational data reduction.

themselves in 1910. It is clear that the astronomical telescopes as were marketed in the late 19th and early 20th century were far beyond the means of the average American.

8. Astronomy's public face: popular books, magazines, and public observatories c.1900

The hobby of astronomy of course had to do with more than just telescopes: in becoming a popular hobby, knowledge must be communicated. There were several different routes for knowledge to take, some more effective than others. Newspapers helped, but, with the exception of those very few with knowledgeable editors like Garrett Serviss, newspapers as likely as not got scientific information wrong. Astronomy was a highly specialized science hobby even in 1910. Although ordinary Americans might have learned a few constellations by word of mouth, considerable confusion could result among the general public. Serviss recounts in one of his popular astronomy books the consternation felt by many citizens of New York City upon seeing the planet Venus in the evening skies in 1887. Opinions varied among people as to what it was: the final conclusion most appeared to come to was that it was an electrically illuminated balloon hoisted into the sky each evening by Thomas Edison.[256]

Books were of course a major route for transmitting knowledge in the 19th century, as they always had been. There were textbooks, but these for the most part would have been too advanced for general readers. The 19th century, particularly from mid-century onward, saw increasing numbers of affordable, popular-level books being written on science, including astronomy.[257] It is difficult to determine the level of latent interest among the general public in any subject; even today, with highly sophisticated

[256] Serviss, *Astronomy with an Opera-Glass*; 2.
[257] Average prices for hard-cover books, c.1900, ranged from $1 to $2 ($20 to $40 today).

polling methods, it is often hard to tell what the public is thinking. One way of at least getting some kind of grip on the issue is to examine not just the books being printed, but the number of copies printed, or failing that, the number of editions printed, the longevity of publication, and the number of surviving copies.

Ormsby MacKnight Mitchel (1809–1862) was a professional astronomer and teacher. Mitchel was also greatly responsible for the establishment of the Cincinnati Observatory in 1842 and utilized his ability as a public speaker to promote astronomy and raise funds for the new facility. Mitchel published several books, one, *Popular Astronomy* (1860) being based on his public lectures; though fact-filled, the writing style is rather dry and not particularly useful for anyone wanting to actually observe.[258] Simon Newcomb (1835–1909), mathematician and astronomer at the U. S. Naval Observatory, also wrote a number of popular-level astronomy books, the longest-lived being *Astronomy for Everybody* (1902) that, like Mitchel's book, was a collection of previously presented material. Newcomb gives more attention to the practical aspects of telescopes, but *Astronomy for Everybody* is still far from a truly useful observer's book.[259] A work written by a non-astronomer, that was nonetheless popular, was Henry White Warren's *Recreations in Astronomy* (1887). Warren's book was a mix of descriptive astronomy, rather simplified, and Christian philosophy; astronomy was for many Victorians, a morally appropriate study that demonstrated God's creation.[260]

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[258] O. M. Mitchel, *Popular Astronomy: A Concise Elementary Treatise on the Sun, Planets, Satellites and Comets* (New York: Phinney, Blakeman & Mason, 1860).
[259] Simon Newcomb, *Astronomy for Everybody: A Popular Exposition of the Wonders of the Heavens* (Garden City, NY: Garden City Publishing Company, 1926).
[260] Henry White Warren, *Recreations in Astronomy, with Directions for Practical Experiments and Telescopic Work,* (New York: Chautauqua Press, 1887). Despite the mention of "practical experiments and

The two authors who contributed most to observational astronomy by amateurs in the late 19th and early 20th centuries were amateur astronomers: Garrett P. Service and William Tyler Olcott. Serviss' *Astronomy with an Opera-Glass* (1888) has already been mentioned. The fact that Serviss' book has gone through numerous editions and reprints (and is still available today) gives some indication of its popularity. It is regarded as the first practical guide-book to observing written in the United States, and includes such useful information as how to select and test a good pair of binocular opera-glasses. Serviss was trying to encourage participation in astronomy by average people, and encourage readers to learn at least the basics of astronomy. Serviss noted in the book's introduction that many thought that astronomy required a powerful telescope. However, to Serviss, observing the heavens with an opera-glass was something that might spur readers on to later acquiring a telescope and make contributions to science.[261] Olcott wrote *A Field Book of the Stars* (1907) when he was just himself beginning to learn astronomy; this may be why it created such a positive impression on beginners. The book featured simple, clear and orderly, two-page presentations of each constellation and accompanying information on interesting objects accessible by small telescopes or the naked-eye. The previously cited, *In Starland with a Three-inch Telescope* (1909), is a slender, yet influential book. It had all the essentials the astronomical tyro needed, presented simply and succinctly. Although *Starland* has little to say concerning instrumentation, it is really the first 'modern' astronomy field-guide for amateurs with

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telescopic work" in the book's title, there is only minimal reference to telescopic observation, only 8 pages being devoted to astronomical instruments.

[261] Serviss, *Astronomy with an Opera-Glass*; iii–iv, 1–6.

modest telescopic aid, furnished like the *Field Book* with constellation diagrams and lists of celestial objects suitable for observing with a 3-inch telescope.

Beyond these relatively few American-produced works, most amateur astronomers in the late-19th and early-20th centuries depended on gaining knowledge of astronomy from foreign sources. Without doubt the most important book, unmatched until after the Second World War, was the Reverend Thomas William Webb's *Celestial Objects for Common Telescopes*. First published in Britain in 1859, Webb's book went through six editions by 1917 (and is still in print) and provided by far the most detailed practical description of telescopes, telescope accessories, and observing methods available at the time.[262]

Generalized descriptive astronomy books for the public far outnumbered specialized ones useful to amateur astronomers. The same can be said for periodicals. Only one magazine devoted to amateur astronomy was in circulation in 1910, *Popular Astronomy*. *Popular Astronomy* (1893–1951) was an outgrowth of *Astronomy and Astro-Physics* (1892–94), and that in turn from *The Sidereal Messenger* (1882–1891); all of these journals were largely the work of William Wallace Payne (1837–1928), director of Carleton College's Goodsell Observatory. Each issue of *A&AP* included a number of articles of general interest, but varying from 'entry-level' to extremely advanced, reports of observations, news notes, several pages-worth of information on planetary and celestial phenomena for the coming month, and advertisements, a format largely copied by *Popular Astronomy*. *Popular Astronomy* split off of *A&AP* in 1893 because many of

[262] Rev. T. W. Webb, *Celestial Objects for Common Telescopes*, edited and revised by Margaret W. Mayall, (New York: Dover Publications, Inc., 1961). Webb's advice on telescopes was so good, that the chapter concerning telescopes went largely unchanged in the Sixth Edition of 1917, and no changes at all were made when it was again reprinted in 1961.

the old *Sidereal Messenger's* amateur readership felt left out and overwhelmed by the professional, highly technical portions of *A&AP*. From its inception, editors W. W. Payne and H. C. Wilson advertised *Popular Astronomy* to be, "Designed for Amateurs, Teachers, Students of Astronomy, and Popular Readers; Plainly Worded and Largely Untechnical in Language," as well as amply illustrated.[263] However, despite the best intentions of Payne and Wilson, *Popular Astronomy* articles were a mix of quite technical reports, with a few more 'popular' articles and news notes. Some examples of the kind of material being published in *Popular Astronomy* in the early 20th century include astronomer T. J. J. See's article, "Doolittle's Observations with the Wharton Reflex Zenith Tube at Philadelphia", and Severinus J. Corrigan's, "An Astronomical Theory of the Molecule and an Electronic Theory of Matter: Solar and Terrestrial Physics Viewed in the Light Thereof".[264] Such a pattern remained fixed well into the 1930s and readership declined: *Popular Astronomy* was hardly a 'popular' astronomy magazine.

Ironically, an article written in 1909 for *Popular Astronomy* by W. T. Olcott bemoaned the state of amateur astronomy at the time. "Sidereal Astronomy, that uplifting and fascinating study, seems to find no place in this utilitarian age, and yet in the whole curriculum of knowledge there is no course more teeming with real interest and delight than the study of the heavens."[265] Olcott favorably compares astronomy to geology, botany, and ornithology. Astronomers do not have to travel 'far afield' for their studies as naturalists do. Even those with small instruments such as opera-glasses could make scientifically useful observations. Olcott actually considered astronomy to have been

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[263] "Popular Astronomy," *Astronomy and Astro-Physics*, 12 (November 1893): 1 of back matter.
[264] "Contents," *Popular Astronomy*, XVII, (January 1909).
[265] William T. Olcott, "Astronomy – A Plea for a Revival of Interest in the Subject", *Popular Astronomy*, XVII (January, 1909): 5–11.

much more popular than in 1909. However, ignorance and apathy among the general public towards astronomy was noted by Olcott. It was not taught, or at least, well taught, in public schools or colleges. There was confusion amongst the public of astronomy with astrology, and most people had the idea that astronomy was just too complex to understand. Sciences such as geology, botany, and ornithology were “making great strides in the direction of popular favor”, but that astronomy as a popular hobby lagged. Olcott in part blamed professional astronomers for writing tedious text-books, and argued instead for more emphasis on observation in teaching astronomy rather than rote memorization.

An examination of more generalized science and technology-related periodicals for the popular reader show that although there was interest in astronomy, it was superficial, rare, and aimed at general information on astronomy, rather than telescopes. *Scientific American* was one of the leading sources of information on science and technology in America from the magazine’s inception in the 1840s. Beginning as a weekly journal of news and correspondence, *Scientific American* contained a wide assortment of informative articles on nearly every subject imaginable. Though focused primarily on developments in technology until the mid-20th century, *Scientific American* did regularly direct attention to the pure sciences, including astronomy. By 1900, *Scientific American* had a number of respected scientists writing regular columns. Princeton University astronomer Henry Norris Russell had a well established relationship with *Scientific American* that lasted several decades. Russell’s most constant contribution to *Scientific American*’s astronomy popularization effort was his monthly column that typically included information of a theoretical nature, as well as positions of the moon and planets in the night sky, a monthly diagram of the night sky, and any news-worthy transient phenomena such as comets. Although Russell made occasional references to the telescopic appearance of celestial objects, the vast majority of observational references are to naked-eye viewing of the sky, such as identifying constellations.[266] This column was occasionally supplemented by others such as Frederick R. Honey's "Morning and Evening Stars for 1910".[267] The fame of Halley's Comet being what it was, it is not surprising that *Scientific American* featured articles concerning its 1910 return. However, as with most other astronomy-related articles in *Scientific American*, telescopic observation and telescopic equipment was rarely mentioned.[268]

Although *Scientific American* for 1910 included any number of how-to articles on overhauling cars, sighting a rifle, building a thermostatic alarm for house heaters, building a home-made wagon jack, and so forth, it published little technical discussion concerning telescopes, and that generally in reference to large, professional telescopes such as the Treptow Park telescope in Berlin.[269] Among the few applicable articles was

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[266] For example, see: Henry Norris Russell, "The Heavens in January," *Scientific American*, 102 (January 1, 1910): 12.

[267] Frederick R. Honey, "Morning and Evening Stars for 1910," *Scientific American,* 102 (February 12, 1910): 146.

[268] John C. Dean, "Relative Positions of Halley's Comet, The Earth, and the Sun", *Scientific American* 102 (January 8, 1910): 27. The same issue also included an advertisement "Halley and His Comet" (p.35), listing previous articles in Scientific American concerning everything from general information on comets and meteors, to a biography of Halley. A later issue does include some more practical observational advice; Rev. Buel W. Roberts, "How an Amateur May Find Halley's Comet" (January 29, 1910): 102, 113. Roberts' comments do cast some light on telescopes in use at the time, his own being a "3½-inch telescope", likely a refractor. Roberts' comments are particularly indicative of the state of most amateurs' equipment at the time in so far as he describes a method, now generally referred to as "star hopping" based on use of a star atlas, to locate the position of Halley's comet in reference to known, fixed stars. This method was required, so Roberts states, due to the fact that few amateur astronomers had telescopes with "setting circles", circular plates with graduated markings and a pointer, fixed to an equatorial mount, indicating the celestial coordinates of objects in the sky (Right Ascension and declination, roughly equivalent to latitude and longitude on the Earth). Such setting circles were generally found only on larger (5 or 6-inch), refracting telescopes on fixed equatorial mountings.

[269] Prof. S. A. Mitchell, "A Great Open-Air Telescope," *Scientific American*, 102 (January 29, 1910): 104.

one on silvering glass, though this could be used for more than just silvering telescope mirrors.[270] Every once in a while, *Scientific American* published useful, practical, articles concerning telescopes. "Telescope Lenses and how to Test Them", written by S. A. Mitchell (Columbia University) provided fundamental information on how to test telescope objectives using double-stars and the moon as test subjects. The 1910 article also sought to correct common misconceptions about the inner workings of telescopes, such as more lenses equaling more power. One interesting aspect of Mitchell's article was his attitude towards the 'appropriate' telescope for an amateur: the "moon presents a prettier picture in a three or four-inch telescope than it does in anything larger". Mitchell's implication seems to be that small refractors were for the 'pleasurable observing' suitable for amateurs and that serious astronomy was to be left to professionals.[271]

Perhaps not surprisingly, the best articles concerning telescopes, amateur astronomy, and practical observing, were penned not by professional astronomers, but by amateurs. An exceedingly important article on telescope building, penned by Wisconsin amateur astronomer and telescope-maker John Mellish, appeared in *Scientific American* in October 1910; it was this article that inspired Russell W. Porter to begin his own efforts at popularizing amateur telescope-making a decade later. Mellish gave a few details of his mirror-making procedures and included a drawing of his polishing tool and the Foucault knife-edge test set-up. His 16-inch telescope cost Mellish only $17 to build,

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[270] In fact, this article is about looking-glass mirrors, not those for telescopes. A. J. Jarman, "Silvering Glass at Home," *Scientific American*, 102 (Feb 19, 1910): 167–68.

[271] S. A. Mitchell, "Telescope Lenses and how to Test Them," *Scientific American*, 102 (April 30, 1910): 363.

gave good images, "but the tube and mounting are very poor".[272] Mellish's article was one of less than a half-dozen appearing in *Scientific American* during 1910; very few such articles were published until the 1920s when a new editorial staff 'spiced-up' the magazine with more 'do-it-yourself' articles.

Advertising was an increasing feature of periodicals in the late 19th and early 20th centuries. More general magazines of course had a wide-range of advertisements; not surprisingly, advertisements for optical goods were a rarity. Even the more scientifically-oriented periodicals like *Scientific American* had few ads for telescopes and related equipment. John Brashear only ever advertised once in *Scientific American*, and the Clarks, not at all. One fairly regular advertiser of scientific instruments in the 1880s and 1890s was Queen & Company; nearly every issue of *Scientific American* had one of their ads. But after that, commercial telescope-makers became even less visible to this audience of magazine-readers interested in science. During the first two decades of the 20th century, the only regular advertiser in *Scientific American* offering astronomical telescopes was W & D Mogey, who presented very small ads giving just the company name, address, and the words "astronomical telescopes".[273] There were of course fairly frequent advertisements for sportsmen's glasses, opera-glasses, and cheap spy-glass telescopes, but these would have been of little interest to serious amateurs. The only periodicals of the time to offer substantial advertising of astronomical telescopes were *Astronomy and Astro-Physics* and *Popular Astronomy*. The companies that advertised in *A&AP* hardly changed over the two-and-a-half years of the journal's run. J. A. Brashear,

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[272] John E. Mellish, "Construction of a 16-inch Reflecting Telescope," *Scientific American*, 102 (Oct 1, 1910): 260.
[273] "W & D Mogey," *Scientific American*, 102 (Feb 19, 1910): 175.

Warner & Swasey, Alvan Clark & Sons, George N. Saegmuller, and the Central Tennessee School of Mechanical Engineering, all took out full-page ads; Gall & Lembke (featuring telescopes by John Byrne), W & D Mogey, Queen & Company, and C. A. Steinheil Söhne of Munich, all had half-page ads.[274] One point about these advertisements that strikes the modern reader as odd is that they nowhere mention prices; this was just something not discussed. The reasons for this are not clear. The number of telescope advertisements appearing each month in *A&AP* was about 6 to 8, a completely trivial number compared to that found in new magazines like *Sky & Telescope* by 1960.

One additional point concerning telescopes and advertising is the presence of classified ads. A number of persons, mostly amateurs, occasionally posted advertisements either selling instruments or desiring them. J. Gledhill of Halifax, England, advertised in *A&AP* nearly every issue of the journal's run, attempting to sell the 3-foot mirror of British amateur astronomer and telescope-maker Andrew Ainslie Common (eventually purchased by Lick Observatory). Other ads for telescopes also appeared: John A. Daum of Canton, Ohio had "Two first-class telescopes" for sale (4⅝and 3⅛-inch refractors), and D. Appel of Cleveland, Ohio offered a 5½-inch achromatic objective for $165.[275]

The period from the American Civil War to about 1900 saw an unprecedented growth in the number of observatories in the United States. In 1845, America had only a handful of astronomical observatories, but by 1907 there were over 100, the vast majority being at the many new colleges and universities also being established during the

[274] *Astronomy & Astro-Physics*, August, 1892, March, 1893, and November, 1894. Sadly, all available copies of *Popular Astronomy* have been bound, and the covers and end-matter pages, where all advertising was placed, have largely been removed. It is likely that those companies that advertised in *A&AP* continued to do so in *Popular Astronomy*.

[275] "For Sale," *Astronomy and Astro-Physics*, March, 1893; 1 of end matter.

period.[276] Most of these college observatories were paid for by local subscription, such as the Goodenow Hall Observatory of Iowa College (Grinnell). Since locals had paid for them, it seemed appropriate for the general public to be able to use them. Most college observatories permitted at least some public use of their telescopes, frequently during monthly ‘open-houses’, featuring a lecture plus viewing. In his *Field Book of the Stars,* writing a description of the globular star-cluster Messier 13 in Hercules, William T. Olcott suggests that only a large telescope can really reveal the “inexpressibly wonderful sight”, and recommends that people lucky enough to live near a professional observatory should ask permission to view it through a large telescope. Olcott tells readers that “Astronomers are busy people but are always willing to oblige those interested when it is possible to do so”.[277] This gets at the crux of the matter: college astronomers and their telescopes existed primarily for teaching and research, not public education. Astronomers were in a quandary as to how to balance the needs of the college with the needs of the public, a public that very often supplied the sources of funding. With all the advances made in the establishment of excellent astronomical education and research facilities in the late 19th century, the United States still notably lacked even one observatory in the entire nation dedicated to the public. The situation would begin to change in the 1920s and 1930s, and new public facilities would be an important factor in the growth of astronomy clubs and astronomy education in America.

[276] Lankford, *American Astronomy*; 385.
[277] William Tyler Olcott and Edmund W. Putnam, *Field Book of the Stars: A Presentation of the Main Facts of Modern Astronomy and a Practical Field Book for the Observer* (New York and London, G. P. Putnam’s Sons, The Knickerbocker Press, 1934, first printing 1929); 212.

9. Conclusion

The processes of fabricating excellent optics and mountings for telescopes were well established in America by 1910. A number of manufactures were supplying a wide range of equipment for sale to both professional and amateur astronomers. However, the price demanded for such telescopes was extremely high, limiting participation in astronomy to professional astronomers at publicly or privately funded observatories, or financially well-off amateurs. A few talented amateur telescope makers such as Henry Draper, Joel Metcalf, and John Brashear produced fine instruments by their own hand; however, most telescopes were commercially made. The result was that, other than looking up and identifying constellations with the naked-eye or with opera-glasses, any kind of participatory, observational astronomy, was done by a very few, perhaps less than 2,000 out of a population of over 100,000,000. Considering that annual incomes for the middle-class ranged from \$1,000 to \$4,000 for the first two decades of the 20th century, even a modest 3-inch telescope costing \$100 to \$300 represented a huge investment. The working class was essentially left out of the hobby altogether.

But, if Draper, Metcalf, and Brashear could make their own telescopes, why couldn't others? The answer to this puzzle lies to a certain extent in both the social-demographics and social-psychology of amateur astronomers. First, even if the cost of constructing something like a 6-inch Newtonian reflecting telescope were within the means of the average worker in America c.1900 or 1910, one has to wonder if they would have had enough time to devote to such a hobby. Workers of late 19th and early 20th century America, as was generally the case during the Industrial Revolution, tended to work 10, 12, or more hours per day, 6 days per week. Add to time working at a factory the assorted other time required for basic needs of house and home, and there would have been precious little time for anything else. Workers in America, like their brethren elsewhere, were also likely not particularly literate, except for the elite craftsmen such as machinists and cabinet-makers. The fact is that, with a few exceptions such as E. E. Barnard and J. A. Brashear, the American working class simply did not have either the free-time or education required to make telescopes. This left only the relatively small middle class to try their hand at telescope-making, people who had leisure-time and sufficient education, as Henry Draper did. However, even if those middle class amateur astronomers who could have made telescopes existed, it is doubtful that many wanted to, or even *thought* they could.

Though extremely nuanced, an issue concerning 19th century popular astronomy books is the way they treat the subject of telescopes. Nearly every book of interest to amateur astronomers in the 19th century, including college-level textbooks, made mention of telescopes, describing how they worked and how they were used, some in considerable detail. However, almost none gave any but vague description of how telescopes, lenses, and mirrors were actually made. Indeed, the few that did describe this aspect tended to emphasize how difficult the work was. Simon Newcomb's *Astronomy for Everybody* (1902) is quite laudatory towards Alvan Clark as a master of his art, but strongly implies that his is a skill only a very few can even approach:

> "How great is the natural aptitude required [for making good lenses] may be judged from the fact that a generation ago there was but one man in the world in whose ability to make a perfect object-glass of the largest size astronomers everywhere would have felt confidence. This man was Alvan Clark . . . "[278]

[278] Newcomb, *Astronomy for Everybody*; 48.

Newcomb has little to say concerning small telescopes and considers reflecting telescopes much inferior to refractors. British amateur/professional astronomer Norman Lockyer's popular book on astronomy, *Stargazing: Past and Present* (1878), is, like Newcomb's book, based on a series of popular public lectures, and provides a considerable amount of information on lens and mirror design, fabrication, and testing, but emphasizes the work of leading 'Grand Amateurs' such as Rosse, Lassell, and Draper, as well as professional optical-designers and telescope-makers like Foucault and Grubb. In one passage, Lockyer states that lenses and mirrors were made by hand in the past, but that "today" (1878), telescope-makers use machines, and very complicated ones at that.[279] The idea seems likely to have stuck in the mind of many readers that special grinding and polishing machines were a must in making lenses and mirrors, whether true or not. The opinion of astronomers as noteworthy as Newcomb and Lockyer concerning the difficulty of making telescope optics must surely have dissuaded many would-be amateur telescope-makers from even making the attempt.

The amateur telescope-makers of the 18th and 19th century were few. Those amateur astronomers who might have made telescopes were limited by technical knowledge, the time they had available, and the disinclination to do some very hard work. Thus, prior to the 1920s, amateur astronomy in America (and elsewhere, for that matter) was largely limited to that small number of upper and middle-class individuals who could afford to buy telescopes from exclusive commercial makers. However, changes in conditions for the working classes began to appear early in the 20th century, and what it meant to be "middle-class" likewise began to change. More importantly, a

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[279] J. Norman Lockyer, *Stargazing: Past and Present*, (London: Macmillan and Co., 1878); 117–138.

few “technological cheerleaders” with loud voices started publicizing the message that it really was simple enough for non-experts to make their own telescopes and get rewarding results. That shift would completely revolutionize amateur astronomy, transforming it into a true mass-hobby of ordinary people working in basement optical shops and back-yard observatories.

Chapter IV: Poor-man's Solution: Amateur Telescope Making 1920–1940

Fig. 29 – "The Amateur at Work", a pencil sketch by Russell W. Porter from, "Mirror Making for Reflecting Telescopes", *Scientific American*, February, 1926.

1. Introduction

Amateur astronomy was largely a hobby of the well-to-do in 1910. Commercially available telescopes were expensive, and very few amateurs cared to attempt making one themselves. William Tyler Olcott, writing in 1909, considered that "The fact that there are so few telescopes in use, comparatively speaking, in a great measure accounts for the little interest in astronomy taken by the public."[280] Although many people were at least somewhat interested in astronomy, as indicated by a fairly large body of popular astronomy books, the organized, serious amateur astronomer, armed with a decent telescope, was fairly rare around 1910 when Halley's Comet appeared. Numbers of popular astronomy books assured readers that telescopes were precision instruments, the

[280] William Tyler Olcott, *In Starland With a Three-Inch Telescope*; iv.

making of which required expert knowledge, unique abilities, and specialized tools. A significantly different message appeared in the November, 1921 issue of *Popular Astronomy* with an article titled, “The Poor Man’s Telescope”, written by Russell W. Porter. This article itself did not immediately trigger changes in amateur astronomy, but it did initiate a chain of events that eventually had thousands, perhaps tens of thousands, of Americans, as well as many people elsewhere, making their own telescopes by 1940.

Russell W. Porter is frequently referred to as the “father of amateur telescope making.” There were of course many who had preceded Porter: Smith, Herschel, Foucault, and Draper, among others. However, it was Porter who was acknowledged by many followers to be the father of amateur telescope making, the respected and beloved authority for a vast new movement in popular-level science. But, if Porter was the “father”, then Albert G. Ingalls, an editor at *Scientific American* from 1925 to 1955, was the “god-father” of amateur telescope making. Modern historians try to avoid thinking in terms of “indispensable men”, but it is sometimes an irresistible temptation; it would be difficult to explain the rise of amateur telescope making without Porter and Ingalls. These two men, one a talented artist and technician, the other a talented writer, editor and promoter of truly “popular” science, worked as a team of “technological cheerleaders” who completely revolutionized amateur astronomy between 1920 and 1940.

2. Amateur telescope making in the early 20th century

There had been sources of information on telescope making available since 1738 detailed enough for individuals such as Herschel and John Brashear to produce excellent telescopes. This begs the question then of why amateur telescope-making as a hobby did not take off in a big way in either the 18th or 19th centuries. There are several factors that explain why amateur telescope making as a mass hobby had to wait until the 1920s. Despite the existence of Smith's excellent book (which did after all propel Herschel into a career as telescope-maker), would-be telescope-makers of the 18th century faced a number of practical difficulties. For those attempting to make refracting telescopes, there was the prime obstacle of glass; what was available was of generally poor quality, and the best would likely have been snapped up by professional opticians and telescope-makers. The refracting telescope had a whole host of inherent problems solved only after 1750, and the solution arrived at by Hall was largely monopolized as a closely-guarded secret by the Dollond family. For those attempting to make reflecting telescopes, the material used again created difficulties; speculum metal was a problematic material to work with, being physically hard, yet brittle, and easily tarnished.

Improvements in telescope technology were made in the 19th century, but were gradual. The development of new glass-making techniques by Guinand and his successors made larger pieces of higher-quality optical glass increasingly available and at some reduction in price. Advances made in scientific design of achromatic lenses by Fraunhofer, Steinheil, Hastings, and others, produced more perfect lenses for astronomical telescopes. Likewise, the exceedingly important development of silver-on-glass mirror technology at mid-century by Steinheil, Foucault, and Draper ushered in a revolution in telescope design and construction that would see the development of the biggest telescopes in the world in the early 20th century, such as the 100-inch telescope at Mt. Wilson (1918).

Still, for amateurs there was no rush to build hundreds or thousands of home-made reflecting telescopes as happened after 1926. The crucial problem comes down to communications, rather than materials, methods, or theory. Amateurs, or potential amateurs, could not easily acquire the knowledge to make telescopes, and likely did not think they themselves were capable of successfully making a telescope. What information was available was very difficult to get hold of. Albert G. Ingalls, a major player in the amateur telescope making movement of the 1920s and 30s, stated that when he went to the New York Public Library in 1925 in search of information on telescope making, he discovered that only a single book in English was available, and that had to be specially ordered from London.[281]

The British were indeed the leaders in amateur astronomy and amateur telescope making during much of the 19th and early 20th centuries. One British publication, *The English Mechanic & World of Science and Art*, was of particular importance in the history of amateur telescope making. Published from 1865 to 1926, *The English Mechanic* was very much the British version of *Scientific American*, offering news of science and technology, articles of a popular nature concerning scientific subjects, short notes and queries from readers, and advertising. Astronomy and telescope making were frequently appearing subjects in *The English Mechanic*, and contributors included many prominent British telescope makers. Even the American John Brashear wrote articles, particularly on making telescope specula and on his silvering process.

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[281] *Amateur Telescope Making, Book I*, Albert G. Ingalls, Editor (New York: Scientific America, Inc., 1935); vii.

The Reverend William Frederick Archendall Ellison (1864–1937) was among the most prominent writers on telescope making for *The English Mechanic* in the early 20th century. In particular, Ellison wrote a series of articles, which appeared in *The English Mechanic* from March to October, 1918, that gave point-by-point information on making both reflecting and refracting telescope optics, as well as eyepiece lenses and other components. In 1920, Ellison gathered his articles together and published them as a book, *The Amateur's Telescope*.[282] In the introduction of his little (112-page) book, Ellison noted that, despite much having been written concerning telescope making, sources were largely out of print or effectively lost in back-issues of magazines like *The English Mechanic*. The only other book known to Ellison available was Paul Hasluck's *Glass Working by Heat and Abrasion* (1899), a book that eventually fell into the hands of Russell Porter.[283] The problem with all these sources, as Ellison pointed out, was that they were out of date; new materials, such as the artificial abrasive silicon carbide, and new techniques had appeared, requiring an up-to-date treatment of the subject. Ellison's book was popular in Britain, but only made a splash in America in the 1930s when it was reprinted as a section in Albert Ingalls' *Amateur Telescope Making* book, of which much more will be heard. Suffice to say, then, that British and European sources on telescope making existed, but never made a significant direct impact on the hobby in America.

American amateur telescope makers existed and were trying to get the word out about the potentials of home-made Newtonian telescopes. C. J. Larson wrote a very

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[282] Rev. Wm. F. A. Ellison, *The Amateur's Telescope* (Belfast: R. Carswell & Son, Ltd., 1920).
[283] Paul Nooncree Hasluck (1854–1931) wrote a number of books on manufacturing including *Beehives and Bee keeper's Appliances* (1905), *Sewing Machines* (1905), and *Lathe-work* (1923), all available in the ISU Library collection. Hasluck is not known to have been an amateur astronomer, and likely collected information from other sources.

interesting and detailed series of articles that appeared in the *Scientific American Supplement* in October of 1917. The illustrations are good, and the information supplied is reasonably well-organized and detailed. Larson explained that his own interests in telescope-making were sparked by articles penned by Ritchey, Draper, and others; however, he thought none of these particularly complete.[284] Larson gets at the nub of the situation when stating that cost was an issue for him in acquiring a telescope; "when he [the amateur astronomer] learns that an instrument of not more than four inches costs hundreds of dollars fully mounted, he is inclined to think that astronomy, like some other amusements, is only for the rich. The reflecting telescope is his salvation."[285] The three articles by Larson give full details on grinding, polishing, testing, and silvering a reflecting telescope mirror, as well as constructing the mechanical parts of the tube and mounting. Many of Larson's clever ideas, such as using pipe fittings for parts of the equatorial mount, were repeated by later amateur telescope-makers. However, somehow, Larson's articles were 'lost'; there is no mention of them in later books on telescope-making. Of course, when Larson's articles were published in October of 1917, America was at war, the government of the Czar was falling, and most peoples' minds were on things non-astronomical; this must have lowered the impact of Larson's writings.

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[284] C. J. Larson, "The Making of a 6-inch Reflecting Telescope – I: Instructions for the Amateur Instrument Builder", *Scientific American Supplement*, 84 (October 6, 1917): 220-224. C. J. Larson, "The Making of a 6-inch Reflecting Telescope – II: Instructions for the Amateur Instrument Builder", *Scientific American Supplement*, 84 (October 13, 1917): 236-238. C. J. Larson, "The Making of a 6-inch Reflecting Telescope – III: Instructions for the Amateur Instrument Builder", *Scientific American Supplement*, 84 (October 20, 1917): 252-254.

[285] Larson, "The Making of a 6-inch Reflecting Telescope – I": 220.

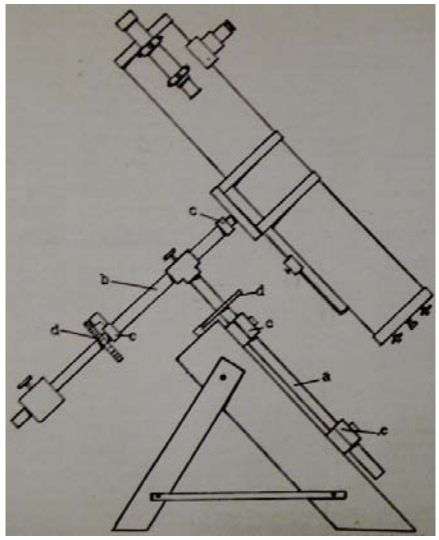

Fig. 30 – C. J. Larson's simple design for a 6-inch Newtonian telescope.

John Mellish (1886–1970) has been briefly mentioned as a commercial telescope maker of the early 20th century, but he was also a link in the chain leading to Porter, Ingalls, and the ATM movement in the 1920s. John Edward Mellish cannot be said to have come from either an auspicious or happy family; his father eventually abandoned him and his mother when John was a boy, and Mellish's own life was a series of professional and personal ups and downs.[286] Mellish only possessed a grade-school education and was self-taught in the sciences, including astronomy. While making a living as a farmer near Cottage Grove, Wisconsin, Mellish acquired a small refracting telescope in 1902, made by the French firm of Bardou & Sons, and soon decided to make a telescope after reading an article in *Harper's Monthly* by Yerkes Observatory optician George W. Ritchey.[287] Mellish soon completed a 6-inch Newtonian reflector, built for

[286] Thomas R. Williams, "John Edward Mellish and the Origins of the Amateur Telescope Making Movement in North America," *Journal of the Antique Telescope Society*, 13: 15-19. Thomas R. Williams, "Mellish, John Edward", *Biographical Encyclopedia of Astronomy, Volume II*; 766-767.

[287] There is some confusion as to where the Ritchey article appeared and which article it actually was. T. R. Williams thought it was a *Scientific American* article, but Ritchey never wrote one for that periodical in either 1902 or 1903. Ritchey did write several for *Harper's*; the most likely one being "Photographing the Moon" in *Harper's* for August, 1903.

$15, with which he began making observations of the moon, planets, and nebulae, and also began hunting comets, a popular ‘observing program’ among amateurs. Mellish discovered two comets by 1907 and sent a letter to *Popular Mechanics* describing his work and giving some information on how he built his telescope; the letter was published in October, 1907.[288] Mellish’s methods of optical work, as well as his skill as a writer, were rather crude. Nevertheless, his article generated considerable response, Mellish receiving over 300 letters from those interested in acquiring a telescope; it was at this time (1908) that Mellish began making telescopes for sale.

Mellish was of course not the only person making his own telescope at the time. A. R. Hassard, a Canadian amateur astronomer, wrote a 1908 article for *Popular Astronomy* that in part detailed his experiences as a telescope-maker.[289] Mellish read the article and the two began corresponding with one another. Both were interested in organizing amateur astronomers and telescope makers, but the group they formed never grew beyond about 20 members and disappeared after a few years. Mellish and Hassard were both interested in publicizing amateur telescope making, but were unsuccessful. Mellish sent a number of articles to *Scientific American* and *The English Mechanic*, but most were rejected. Mellish finally succeeded in getting a short article published in *Scientific American* concerning the building of his largest telescope to that date, a 16-inch Newtonian, which he had constructed for only $17. The telescope gave good-quality

[288] John E. Mellish, “Farmer’s Boy Builds a Telescope and Discovers a Comet,” *Popular Mechanics*, 9 (October, 1907): 1109-1110.
[289] Albert R. J. F. Hassard, “Occultations by the Moon in Præsepe,” *Popular Astronomy*, 16 (May, 1908): 328-329.

images, but had some problems with the mechanical parts, Mellish stating that, "the tube and mounting are very poor".[290]

Although Mellish and Hassard were trying to get an 'amateur telescope-making movement' going around 1910, they failed; both remained relatively obscure in American amateur astronomy, as did others who wrote articles around the same time. Historian Thomas Williams, in his biography of Mellish, points out that the telescope maker had an "unpolished and overly enthusiastic approach" to writing and that he was "petulant" when articles were rejected.[291] The problem that seems to have blocked the advance of amateur telescope making in the early 20th century was the conflict between the desires and communication abilities of the amateur telescope maker on the one hand, and popular science magazine editors on the other. Somehow, the two groups never 'clicked'; there were no amateur telescope makers who were really effective communicators, and there were no magazine editors who cared particularly about the subject.

The writings of individuals like Mellish and Hassard were not completely ignored, of course. Leo Holcomb was another rather obscure amateur telescope-maker of the early 20th century who passed on information on the subject.[292] Holcomb (apparently no relation to Amasa Holcomb) had read articles by both Mellish and Hassard, which inspired him to construct his own telescope and write an article for *Popular Astronomy* in 1910. As has been noted, *Popular Astronomy* was the only popular-level periodical at the time devoted entirely to astronomy; many of those people in America interested in the subject of astronomy of course subscribed to the magazine. One of those was James

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[290] John E. Mellish, "Construction of a 16-inch Reflecting Telescope": 260.
[291] Williams, "John Edward Mellish", *JATS*: 16.
[292] Leo Holcomb, "Speculum Making," *Popular Astronomy*, 18 (March, 1910): 169-171.

Hartness, wealthy senior manager of the Jones and Lamson Tool Company in Springfield, Vermont. Hartness, a fairly wealthy individual, already had considerable interest in astronomy and owned a 10-inch telescope (optics by Brashear) mounted at his home observatory, built around the time Halley's Comet appeared in 1910.[293] Hartness was quite willing to share his interests in astronomy, giving views through his telescope to his Springfield neighbors. One neighbor of Hartness shared his interest in astronomy and borrowed a stack of Hartness's *Popular Astronomy* magazines to read while recuperating from an illness; his name was Russell W. Porter.

3. Russell Porter, Albert Ingalls, and "The Poor Man's Telescope"

Russell Williams Porter (1871–1949) was born into a fairly prominent family in Springfield, Vermont, a small industrial town on the Connecticut River. Russell's father was handy with tools, became interested in photography, worked in the jewelry business, and finally set up a toy manufacturing company. Russell was fairly well educated for the times, but his course after entering college wavered; starting at Norwich University, he switched to the University of Vermont, and finally entered MIT in 1892 on his own dime after the collapse of his father's business. Porter was officially a student of architecture, but was repeatedly side-tracked, joining expeditions to the arctic, where his abilities as an artist and surveyor were put to use.[294] Porter spent the next several years alternately going to school, venturing to the arctic (where he nearly died), and doing what work he could as an architect. In 1907 Porter finally married and settled down in Port Clyde, Maine, where he dabbled in various projects over the course of several years.

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[293] Broehl; 77, 109

[294] Berton C. Willard, *Russell W. Porter: Arctic Explorer, Artist, Telescope Maker* (Freeport, ME: The Bond Wheelwright Company, Publishers, 1976); 1–17.

It was in 1910 that James Hartness, a long-time friend from Springfield, loaned Porter the stack of *Popular Astronomy* magazines. Porter read Holcomb's article on telescope mirrors, which actually had little to say on how to make them, and immediately began corresponding with the author. Holcomb sent Porter a copy of the previously mentioned book, *Glass Working*, by Hasluck. The artist and arctic explorer soon added telescope making to his interests, and Porter ordered the materials for making silver-on-glass mirrors. There is not much indication of immediate success, however, as Porter acquired a 6-inch refractor in 1911, for which he built an elegant observatory.[295] Though exactly how he managed it is not known, Porter dramatically improved on his abilities as an amateur optician and was producing excellent mirrors by 1912.

Hartness gave Porter considerable material aid, including gifts of money, and the two began cooperating on telescope projects, the largest being a 16-inch 'polar' telescope. This unusual instrument was a reflecting telescope that was essentially a modification of Newton's telescope. Porter altered the Newtonian system by adding a third mirror, as large as the primary, mounted at an angle in front of the primary mirror such that the third mirror fed light to the primary via the polar axis of the telescope's equatorial mounting. In other words, the added optically-flat mirror (called a 'coelestat') moved to track celestial objects, while the telescope itself remained motionless. While this type of telescope was not Porter's invention, the fact that he built the viewing-end into the study of his home (for observing comfort from indoors), and used parts scavenged off of Hartness' old Stevens Duryea car for the mounting, show his

[295] Willard; 102–114. Nothing is known about how Porter got the 6-inch refractor telescope, as he had meager funds at the time; Willard suspects Hartness gave the telescope to Porter, either as a gift or a loan.

imaginative abilities. Furthermore, Porter built the entire instrument for $150 ($2,600 in today's terms), far less than a refractor of equivalent size.[296] Porter wrote an article about the construction of his 16-inch telescope for *Popular Astronomy* that appeared in May of 1916, and was reproduced in *Scientific American Supplement* the following year.[297] Porter continued his work as an architect, as well as telescope-making, observing, and writing articles for *Popular Astronomy*, *Scientific American*, and even the professional astronomer's *Astrophysical Journal*, writing at least six articles in two years.[298] When the United States entered World War I, Porter became involved with work at the National Bureau of Standards designing optical equipment for testing machine-parts; it was just after the war in 1919 that Hartness offered Porter a job at the Jones and Lamson Machine Company, also to design optical test equipment.

Porter became the full-time optical designer for Jones and Lamson and so had considerable laboratory resources at hand. Porter also discovered that there were a number of talented machinists at the factory who had a latent interest in astronomy. There were other citizens of Springfield who also expressed an interest in astronomy and were intrigued with the idea of making a working astronomical telescope. One of these was John M. Pierce, teacher of manual arts at the Springfield High School; Pierce was likely the first who began learning telescope-making from Porter.[299] Soon, Porter had a group of sixteen people, including one woman, interested in making telescopes. On August 17,

[296] Willard; 110-113. Compare this price to that of a 15-inch Brashear refractor in 1911 of $10,575 ($195,600 in today's terms).
[297] Willard; 113. Russell Porter, "An Amateur's Observatory", *Popular Astronomy*, 23 (May 1916): 130–131 ; Russell Porter, "An Amateur's Observatory: An Attempt to Make Observation Comfortable in Cold Weather", *Scientific American Supplement*, 84 (August 4, 1917): 68–69.
[298] Willard; 114–117.
[299] Willard; 126–127.

1920, the group, led by Porter, met and agreed to begin a telescope-making class. Porter's students, largely made up of machinists, foundry-men, and others from various manufacturers in Springfield, began work in an unused room at the Jones and Lamson factory that fall with Porter giving hands-on instruction. Members worked on a variety of reflecting telescopes from 4-inch to 16-inch aperture.[300] Oscar S. Marshall, a highly-skilled machinist, was among the leading students of the group and had had an interest in astronomy for some time. Around 1910, while working for Jones and Lamson, Marshall began a new hobby of surveying and drawing maps. He apparently made some of his equipment himself, but one item was not: a 40-power refracting telescope he purchased for $11.00. Marshall provided few details in his autobiography of this small spyglass, but he likely used it for observing the sky, as well as the land.[301] Aside from Porter, Pierce, and Marshall, there was Mrs. Gladys M. Piper (the only woman in the group), Oscar P. Fullam, "an expert pattern maker", who assisted other telescope makers with fabricating metal parts for telescope mountings, Everett H. Redfield, who had previously made two grandfather clocks, Frank H. Whitney, "an exceptional mechanic", and Ernest N. Brookings, Raymond P. Fairbanks, Roy L. Lyon, Albert H. Herrick, Fred W. Barber, Guy E. Baker, F Eugene Lockwood, Clyde P. Baldwin, Charles N. Longe, and Carlton P. Damon, all Jones and Lamson employees. By the summer of 1921 most members had completed the grinding and polishing work on their mirrors.[302]

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[300] Willard; 131–137.
[301] Marshall; 69–70. Based on photographs in his autobiography, the telescope was about a 2-inch aperture, 3 feet long. Although Marshall does not indicate where he purchased the telescope, the 1908 Sears Roebuck & Company catalogue lists one very similar to that appearing in two photographs on p.70 of his autobiography. *Sears Roebuck & Co., Catalogue No. 112* (1908); 228.
[302] Marshall; 83–84.

It was at this time that Porter and Marshall devised the 'Springfield Mount', a modified equatorial that, like Porter's 16-inch polar telescope, permitted the observer to sit still in comfort while being able to sweep the entire sky. Marshall completed his telescope, an 8-inch Newtonian reflector, late in 1923 and placed it on a massive concrete pedestal in the backyard of his home in Springfield. The "Springfield Mount" was cleverly designed so that the light-path emerging from the side of the tube passed down the declination shaft of the telescope, reflected off a third mirror, and passed up along the polar axis; both the declination and polar shafts were hollow. The point of this was that the position of the eyepiece did not move as the telescope was pointed about the sky, providing a very convenient and comfortable situation for the observer. Though the Springfield Mount never achieved a huge success, a number of amateur telescope-makers later copied the Porter-Marshall design.[303] Marshall was not one to keep things to himself and, during the 1924 apparition of Mars, over 400 of Springfield's ordinary citizens were allowed glimpses of the Red Planet through his back-yard telescope.[304]

Porter taught his Springfield students everything he had learned concerning grinding and polishing mirrors, conducting the Foucault test (as modified by Draper), how to design the mechanical parts of the telescope, and finally, how to observe the night sky with their new telescopes. Members of the group completed their telescopes between 1921 and 1923, each adding their own personalities to the Newtonian design, and many displayed their telescopes at the 1922 County Fair in Springfield. The exhibit caused

[303] Marshall; 86–87.
[304] Marshall; 88. In 1930 Marshall followed Porter to California to take part in the 200-inch Mount Palomar observatory project where he applied his skills largely as a machinist, but one who was well-acquainted with telescopes. Most of the 200-inch Hale telescope's optical and mechanical parts were made in-house at Caltech's Instrument Shop.

something of a bewildered stir among the general populace as few people had seen *any* kind of telescope, and certainly not reflecting ones. Oscar Fullam's telescope, with a tube and mounting made largely of maple, caused considerable confusion and was misidentified as either a butter churn or a cream separator.[305]

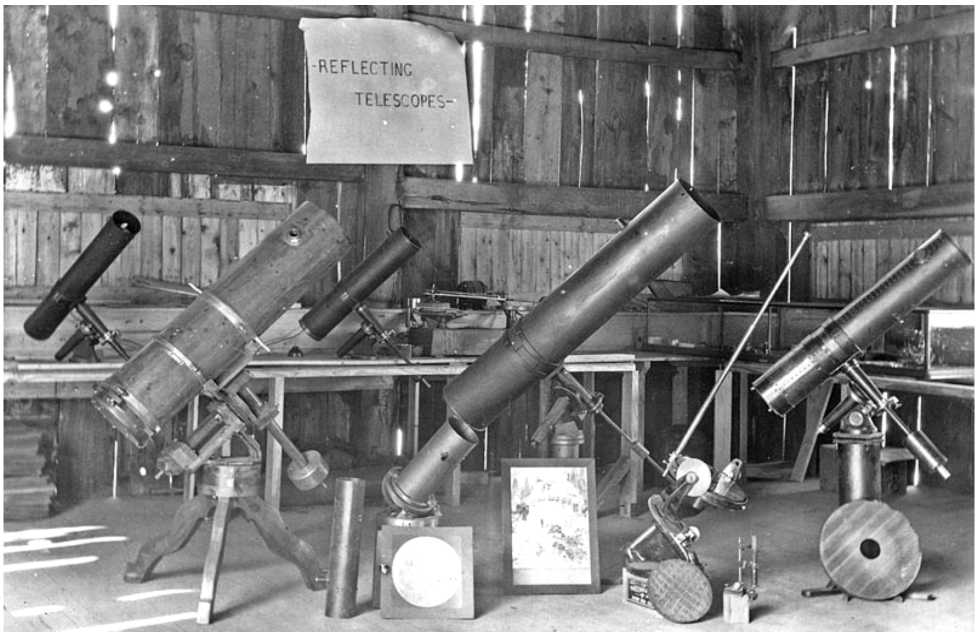

Fig. 31 – Telescopes and mirrors made by members of the Springfield Telescope Makers displayed at the 1922 county fair: Oscar Fullam's wooden telescope is on the left (from the photo collection at Stellafane).

An important aspect of Porter's method of making telescope mirrors, passed on to his students, one that differed greatly from that of previous experts, was his emphasis on grinding, polishing, and figuring mirrors entirely by hand. Although Porter later advocated the use of machines in optical fabrication in certain circumstances, he considered machines to be entirely superfluous for the hobbyist. This broke with a tradition stretching back to Huygens which emphasized a need for using machines at some point in the fabrication process; the great amateur telescope makers, Herschel, Lord Rosse, and Draper, all utilized machines in mirror-making. According to Porter, simple

[305] Marshall; 84.

materials and methods worked best. His students, many of them being highly-trained machinists, were astonished when told that the Foucault test could measure errors on a mirror's surface of only a few millionths of an inch.[306] This was even more amazing in that Porter's 'Foucault tester' consisted of an ordinary oil-lamp, wrapped in metal foil with a pin-hole in it, combined with an old razor-blade mounted on a wooden block; hardly the appearance of a 'precision' piece of equipment, yet it was, and it worked.

Members of Porter's group remained interested in telescope making, and astronomy in general, and in December, 1923, they officially organized themselves as the Springfield Telescope Makers (STM). This new club felt they needed a permanent facility for their activities, and Porter had inherited a piece of land that he thought ideal for a permanent 'club house.' The group constructed a large, comfortable 'cottage', with space for a workroom, a lounge, and even sleeping quarters upstairs for long nights of observing atop "Breezy Hill". The clubhouse, dubbed "Stellar Fane" ("Temple to the Stars") was completed in 1924 and would soon become an astronomical haven for telescope enthusiasts everywhere.[307]

Meanwhile, Porter had written additional articles for *Popular Astronomy*. Most notably, his November 1921 piece titled "The Poor Man's Telescope" gave a brief description of how one could grind and polish a highly accurate and extremely useful set of optics for a Newtonian reflecting telescope.[308] Porter followed up his 1921 *Popular Astronomy* article by another in 1923 for the same magazine describing the amateur telescope-making group in Springfield. The articles were relatively short, and do not

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[306] Willard; 135.
[307] Willard; 143–148.
[308] Porter was by profession an architect and was highly regarded enough to be asked to do design drawings of the Mount Palomar 200-inch telescope in the 1930s.

appear to have had much of an immediate impact. One must remember that, although *Popular Astronomy* was the only dedicated periodical devoted to amateur astronomy, it was not a magazine that appealed to a particularly 'popular' audience. The circulation of *Popular Astronomy* is not known, but, considering that there were likely only about 2,000 organized, 'serious', amateur astronomers in the United States around 1920, there could not have been many more readers than that. Also, many of *Popular Astronomy*'s readership were 'serious' amateurs and, as such, likely already possessed telescopes, and most likely refracting ones at that. Reflecting telescopes were not particularly common among existing amateur astronomers in early 20th century America. This lack of popularity may have had to do with technical problems, such as the tarnishing of metal mirror coatings, but also may have had something to do with aesthetics; it simply did not 'look' like a proper telescope. Add to this the fact that, up to around 1910, professional astronomers almost exclusively utilized equatorially-mounted refracting telescopes; similar refracting instruments became popular among serious amateurs, who were to an extent trying to copy professionals. However, professional astronomers were making a switch. George E. Hale established the Mount Wilson Observatory in 1905 and was soon equipping it with large reflecting telescopes, not refracting; first was the 60-inch (1908), then the 100-inch (1918), both of which were returning amazing results by the early 1920s.

Such was the situation telescopically in 1925 when Albert Graham Ingalls (1888-1958) went to the library. Ingalls was born in Elmira, New York and graduated from Cornell University in 1900, picking up odd jobs for a time after graduation, first as a telegraph operator, then in a logging camp, before returning home. Ingalls later worked at the Philadelphia city library before finally securing a job as an editor at *Scientific American* in 1925.[309] *Scientific American* was undergoing a change of image in the early 1920s, switching from a weekly to a monthly format in November, 1921. There was also a new editorial policy put in place where "If you [readers] don't see what you want, ask for it."[310] Although always having a certain amount of popular material, the style of *Scientific American* became more 'participatory' in nature about the time Ingalls joined the editorial staff. The 'old' *Scientific American* more or less just *reported* on science and technology; the 'new' *Scientific American* began presenting far more articles on *how* to do things, and Ingalls was one of those searching for writers of articles on 'how to do it'. The 'how to' articles began small; for instance, a brief article in the "Notes and Queries" column in March, 1925 showed the correct way to bend a 'bus bar' for use in building a radio set.[311] Ingalls was himself frequently responsible for monthly lead articles, often having an 'amateur scientist' theme; for example, how amateur geologists could hunt for fossils and prospect for mineral ores.[312] News and information on astronomy had long been a regular feature of *Scientific American*. Princeton astronomer Henry Norris Russell made an increasing numbers of contributions to *Scientific American*; aside from the monthly column on phenomena of the night sky, Russell wrote many feature articles on such things as eclipses, the discovery of the true distance to galaxies, theories of stellar

[309] Thomas R. Williams, "Albert Ingalls and the ATM Movement," *Sky & Telescope*, 81 (February, 1991): 140–143. Williams states that Ingalls began work at *Scientific American* in 1923. In fact, I have discovered that Williams was in error on when Ingalls joined the staff; it was in 1925, not 1923, as disclosed by the lists of editorial staff on the "Contents" pages of the magazine.

[310] "From the Editors," *Scientific American*, 125 (November, 1921): 3. The magazine announced the combination of *Scientific American Weekly* with *Scientific American Monthly* (formerly *Scientific American Supplement*), along with the new policy statement.

[311] "Correct Way to Bend Bus Bar for Radio," *Scientific American*, 132 (March, 1925): 212.

[312] Albert G. Ingalls, "Out of Doors with the Earth: With Simple Vacation Equipment, the Amateur May Easily Learn the Meaning of the Earth's Ever-varied Geological Features," *Scientific American*, 132 (June, 1925): 365–367.

evolution, and so forth. Readers of *Scientific American* were thus being exposed to a good deal of interesting material on the science of astronomy in the mid-1920s along with how-to articles by editors like Ingalls.

In the spring of 1925, while on his errand to the New York Public Library, Ingalls idly leafed through several issues of *Popular Astronomy* and discovered Porter's 1921 "Poor Man's Telescope" article. Ingalls was intrigued by the whole idea and soon contacted Porter for more information. Porter, sensing that something important was in the offing, arranged to meet Ingalls in New York City and the two met at a restaurant for six hours where, likely, much information was exchanged.[313] Ingalls was soon engaged in making his own telescope, coached via constant correspondence with Porter. Surviving letters between Porter and Ingalls are full of fascinating details, and some of Porter's abilities as a communicator are revealed, particularly in drawing cogent yet simple illustrations.[314] After an initial accident in which his first mirror fell on the floor and shattered, Ingalls succeeded in producing a good mirror as far as the polishing stage; however, he was having difficulties parabolizing his speculum. After Ingalls sent Porter a set of drawings of the mirror's appearance under the Foucault test, Porter explained that Ingalls's mirror was suffering from a "turned edge"; Porter coached him through the problem, and all was made good.[315]

[313] Williams, "Albert Ingalls and the ATM Movement"; 140.
[314] One example shows Porter's sketch of the Foucault test along with hints as to how to construct and use the tester. Correspondence, Russell Porter to Albert Ingalls, May, 1925, *Albert Ingalls Papers*, AC0175, Box 19, Folder 1, Archives Center, Smithsonian Institution National Museum of American History (AC, SINMAH).
[315] Correspondence Russell Porter to Albert Ingalls, late October, 1925, *Albert Ingalls Papers*, AC0175, Box 19, Folder 1, AC, SINMAH. A 'turned edge' is telescope-maker's jargon for a peripheral zone of a lens or mirror that has a much greater focal-length than desired, usually caused by the polishing tool being too small, resulting in most of the polishing action being concentrated at the lens' or mirror's center, deepening it.

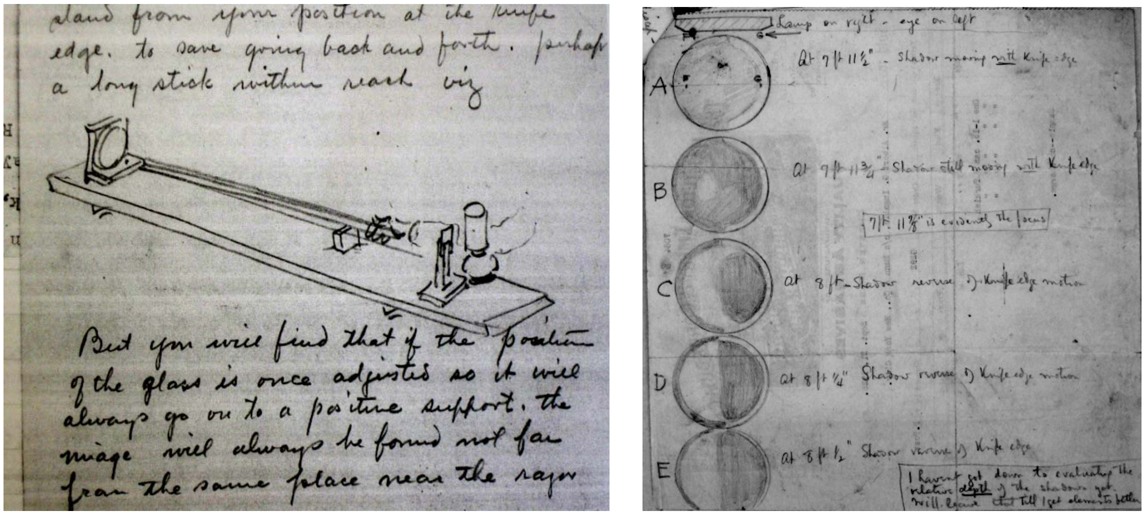

Fig. 32 – (Left) A sketch-drawing by Porter explaining the Foucault test to Ingalls. (Right) A sketch by Ingalls sent to Porter describing the problem in Ingalls' mirror under the Foucault test. Images courtesy of the Archives Center, Smithsonian Institution National Museum of American History.

Even early on in their friendship, Porter was addressing his letters to Ingalls with "My Dear Ingalls". It was no surprise when Porter invited Ingalls to visit Springfield in the early fall of 1925. Ingalls was enchanted by the colorful locale of the "Stellar Fane" clubhouse, as well as with the members of the STM he met. Ingalls knew the story of Porter and the Springfield group would make a good article, and likely had such in mind even before his visit. Ingalls wrote his piece for *Scientific American* on his return from Vermont, and had it ready for the next edition.

The article Ingalls wrote for the November, 1925 issue of *Scientific American* was the lead for that month. In it, Ingalls demonstrated his skills as a writer; the style is lucid, modern-sounding, and engaging. Ingalls, after only a year as an editor, knew his audience. The story "The Heavens Declare the Glory of God: How a Group of Enthusiasts Learned to Make Telescopes and Became Amateur Astronomers" reads like a popular travelogue; it is, frankly, a fascinating tale. Porter and the other members of the Springfield Telescope Makers come off as interesting, vibrant individuals, and their telescopes, described in word and picture, are also individuals. None of the STM group comes off as specially educated or experienced in science; they are for the most part, ordinary people. And this was the article's intent. Divided into three sections, the last part of the article announced, "You Can Make a Telescope". Ingalls, who by that time had personal experience of telescope-making, knew that it was possible for nearly anyone to do:

> "You must be handy, of course, but you do not have to be a genius. Patience is necessary, but no knowledge of mathematics, abstruse science or astronomy itself is required for telescope making. The tools are simply a barrel to work on, two inexpensive plate glass discs, a bit of common pitch, half a dollar's worth of optical rouge, a very few household tools, about four dollar's worth of abrasives, and your two hands to keep the upper disc moving back and forth over the lower one."[316]

This likely sounded quite 'do-able' for many of Ingalls' readers. A tag-line to Ingalls' article reads: "Provided enough of our readers write and request it—as some have already—we shall endeavor to publish an article telling how to go about the making of a reflecting telescope."

4. <u>1926: amateur telescope making takes off</u>

In the January, 1926 issue of *Scientific American*, there was a note 'from the editors' concerning the November, 1925 story about Porter and the Springfield ATM group. *Scientific American* had been flooded with requests for information on how to make a telescope; "Evidently, we have "started something"."[317] The February, 1926 issue contained the first of two Porter articles. "Mirror Making for Reflecting Telescopes" ran

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[316] Albert G. Ingalls, "The Heavens Declare the Glory of God: How a Group of Enthusiasts Learned to Make Telescopes and Became Amateur Astronomers," *Scientific American*, 133 (November, 1925): 293–295.
[317] "News Notes," *Scientific American*, 134 (January, 1926): 3.

only four pages, but featured wonderful artwork by Porter. His drawings readily explained the more confusing aspects of making a telescope mirror, and Porter used everyday analogies to explain things, such as likening the parabolic mirror of a telescope to an automobile headlight.[318] The remainder of the text is just detailed enough, the writing plain, but flowing, and Porter explains each procedure exactly in the order that it has to be done. The illustrations, though, are perhaps the key to the article.

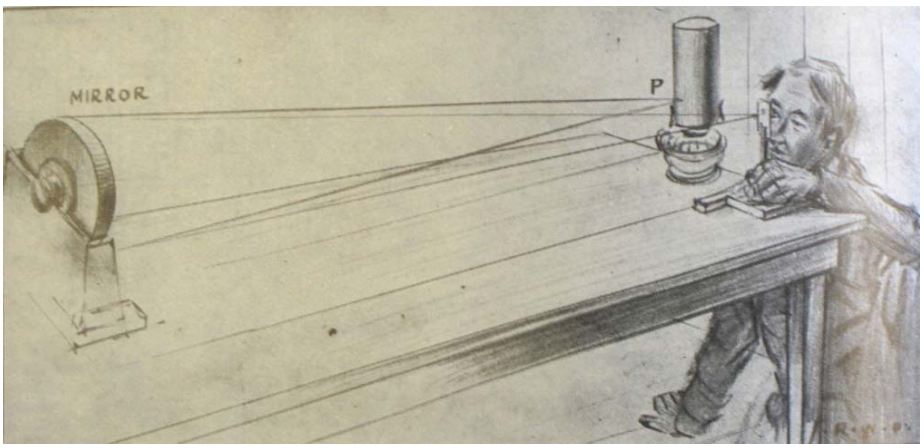

Fig. 33 – One of Porter's illustrations showing how to do the Foucault test.

Ingalls had a fairly good idea about how successful Porter's articles would be. In the same February issue of *Scientific American* that featured Porter's article on mirror making, there appeared a note by Ingalls in the "Scientific American Digest" column titled, "Our Telescope Makers".[319] Ingalls understood from the response to his November, 1925 article that there were large numbers of people interested in telescope making; 314 readers had written to Ingalls requesting the suggested articles by Porter. Ingalls further estimated that there was "several times this number", who were likely to read the articles on telescope making. The kinds of people asking for information on

[318] Russell W. Porter, "Mirror Making for Reflecting Telescopes," *Scientific American*, 134 (February, 1926): 86–89, on 86.
[319] Albert G. Ingalls, "Our Telescope Makers," *Scientific American*, 134 (February, 1926): 118.

telescope making suggested significant variety as well; young, old, professional men, business men, “a few women”, physicians, teachers, a college president, a pilot, a jeweler, a plumber, farmers, and a seaman. The geographical distribution is interesting, though perhaps somewhat predictable. The vast majority of persons interested in astronomy and telescope making were concentrated on the coasts, particularly in New York, New England, Pennsylvania, the Washington, DC area, and California. The next greatest concentration was in the Mid-West, mostly in Ohio, Michigan, Illinois, but also an unexpected number in Iowa, Kansas, Missouri, and eastern Nebraska. There were even seventeen requests from outside the United States.

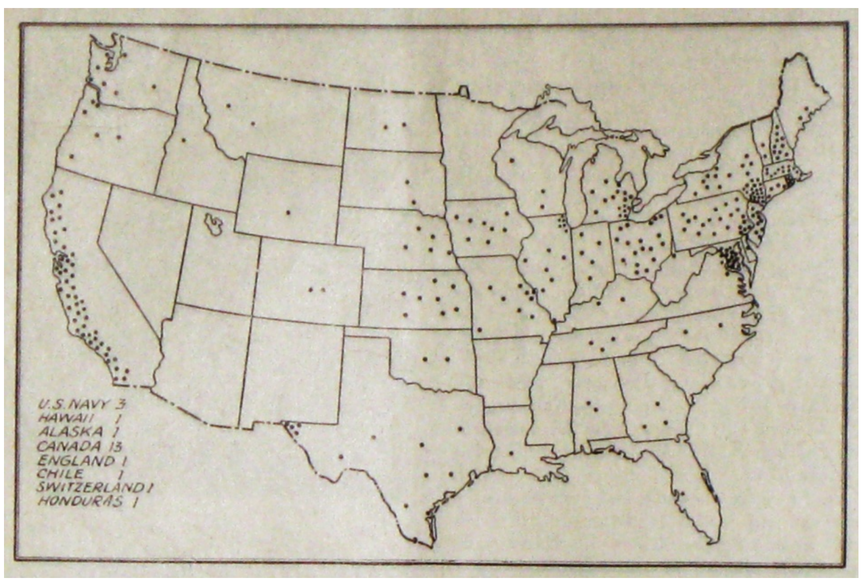

Fig. 34 – Map from *Scientific American* showing distribution of the 314 readers requesting information on telescope making

Porter’s February article was followed by one in the March, 1926 issue of *Scientific American* and concerned the construction of the mechanical parts of a telescope.[320] The second article, like the first, is well-written and features excellent

[320] Russell W. Porter, “Mountings for Reflecting Telescopes,” *Scientific American*, 134 (March, 1926): 164–167.

illustrations. Porter explains exactly how the telescope mounting should operate and why, for instance showing why the polar axis of an equatorial mounting must be inclined at different angles for different observer's latitudes on the Earth. Porter also explains that there are different types of equatorial mountings, each having its particular good and bad points. Finally, and perhaps most importantly, although Porter leads off his article with pictures of the magnificently machined, and complicated, 'Springfield mount', he finishes with a telescope that could not have been simpler. Porter explained that the mountings made by the members of the Springfield group illustrated in the November, 1925 article, were constructed by trained machinists. They were complex equatorial mountings made of brass and steel, which took weeks, if not months, of painstaking labor to produce. But Porter realized this was not within everyone's ability. As a result, Porter also presented to his readers likely the most simple, most basic, 'telescope' anyone had likely seen. The 'tube' was simply a board with a 'shelf' at one end to which the primary mirror was attached. The upper end included a 'focuser' that merely consisted of a large hole, bored through the longitudinal board, with a piece of brass tubing inserted that could be pulled out or pushed in to focus. The secondary mirror (actually a 90° prism) was mounted in the focusing tube. The 'equatorial mount' consisted of a 1-inch diameter iron rod, bent at the correct angle for the observer's latitude, with one end embedded in a concrete post in the ground, and the other passing through a wooden block attached to the plank 'tube' with a wing-nut and bolt. It was all there: the optical components were held securely, and one could point it at any part of the sky. It was, however, so basic that anyone with even moderate mechanical skills and tools could build it in a weekend. It was the most basic of telescopes, and it appealed to the most basic of telescope makers; it was the telescope "that anyone can make."

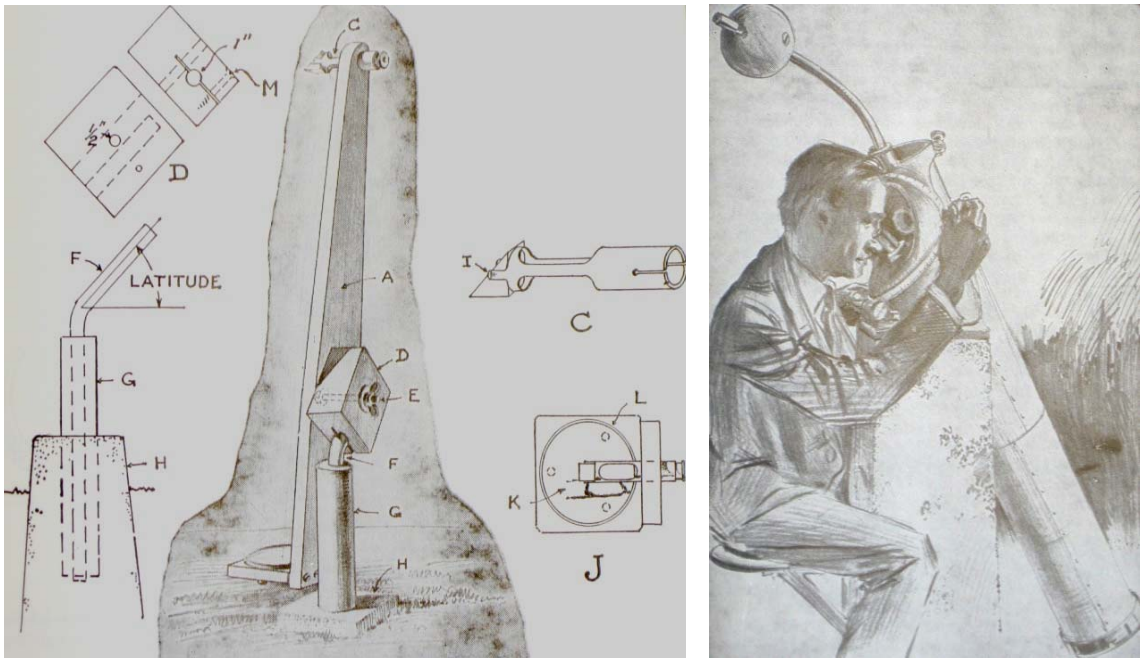

Fig. 35 – Simple and complex: the "Wooden equatorial mounting that anyone can make" (left), and the Springfield Mounting (right). The large object above the observer is a counter-weight balancing the telescope. Pencil sketches by Russell Porter from, "Mountings for Reflecting Telescopes", *Scientific American*, March, 1926.

The response, by way of letters from those who had successfully completed their own telescopes, began to come into *Scientific American*'s editorial offices a few months after the Porter articles appeared, first as a trickle, then a flood, until Ingalls began a separate column just for telescope makers. News of telescope makers' success stories first appeared in the "Editor's Mail" column, along with general news. May, 1928 saw the start of "The Back Yard Astronomer: A Department Devoted to Interests of the Amateur Telescope Maker"; the first entry in the column reported over 3,000 'A.T.M.s' all over the world. Victor H. Massey of Pasadena, California built an 8-inch reflector for $12 following Porter's simplified 'plank-tube' design. E. L. Worbois in Tanawanda, New

York built a similar 6-inch telescope, but modified it so that it would fold up; it only weighed 20 lbs and could be carried by his daughter.[321] By 1930, the column had changed names to "The Amateur Astronomer". ATMs were not simply copying Porter's designs: they were innovating with what came to hand. Most telescope makers had been using thick plate-glass (½-inch to 1½-inch thick, commonly in a 1:8 ratio, thickness to diameter), but George Steffa of Schenectady, New York, chose to use the recently developed heat-resistant glass called Pyrex; this new material had low-expansion characteristics that helped keep the optical surface stable under changing weather conditions.[322] The same material would be used a few years later for the mirror of the 200-inch Mount Palomar telescope. Ingalls' ATM-related column underwent a final name change in 1938 to "Telescoptics", a name retained until the mid 1950s, by which time Ingalls had retired from *Scientific American*.

Late in 1926, editors decided to combine the Porter articles, along with some added materials, into a small (102-page) book.[323] *Amateur Telescope Making* was an instant hit, selling out the entire first printing of 3,400 copies, by 1928. A second edition, now 285 pages long, was printed in 1928; its 5,400 copies were gone by 1932. A definitive third edition of nearly 600 pages was published in 1932 and has never been out of print since.[324] In 1937, a second volume was added, *Amateur Telescope Making – Advanced*. As the title suggests, the second volume of the *ATM* set addressed more complicated issues, including theoretical and mathematical ones, as well as new optical

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[321] "The Back Yard Astronomer," *Scientific American*, 138 (May, 1928): 448.
[322] "The Amateur Astronomer," *Scientific American*, 143 (July, 1930): 66–67.
[323] "Amateur Telescope Making [book advertisement]," *Scientific American*, 134 (April, 1926): 282.
[324] Ingalls, "Preface," *Amateur Telescope Making, Book I*; viii. A completely revised version of *ATM* is still available (2010).

designs such as the Schmidt camera, a newly invented system combining lenses and mirrors. The Schmidt was of particular interest to professional astronomers, but the first examples of this German design constructed in the United States were made by amateurs.

By the mid-1930s, the 'amateur telescope making movement' was maturing and its creators were well content. Ingalls and Porter had been the perfect 'parents'. Ingalls had the editorial experience and savvy, as well as some measure of control at the leading popular science magazine in North America. Porter had wonderful communications skills, including the ability to draw excellent illustrations, backed by expert knowledge of optical fabrication. However, the relationship between Ingalls and Porter soured at the end. Part of the reason had to do with Porter's departure for the new Mount Palomar telescope project in California in 1928. This was to be the largest telescope ever constructed, a 200-inch monster, and Porter found himself part of the design team. Ingalls began asking others to contribute to the *Scientific American* column, and by the mid-1930s, the ATM movement was really that of Ingalls, rather than Porter. In 1948, during the dedication of the 200-inch telescope, the two ceased their friendship, apparently because Porter felt slighted by Ingalls and others who, overwhelmed by the great telescope itself, had little to say about Porter as the architect of it all.[325]

5. ATMs and their telescopes

Some indications have already been given as to the new multitudes of ATMs and the telescopes they were building. Compiling a list of all the amateur-made telescopes appearing in the pages of *Scientific American* from 1926 onwards would be a

[325] Williams, "Albert Ingalls and the ATM Movement": 141–143. It has been noted that some commentators give Porter too much credit, while others too little (or none) for the 200-inch Palomar telescope. Porter did provide many of the basic ideas for the design, even if it was not his 'brainchild'.

monumental task. However, a few are worth looking at in more detail, as it gives one a better idea of the people and ideas of ATMs in the 1930s. Mr. Virl Davenport, of Quantico, Virginia, began working on his telescope before the Porter articles actually appeared in *Scientific American*, but finished with their help. Davenport scrounged parts from many sources including the scrap pile; he made the mirror 'cell', counter cell, and dust cover from "Aunt Het's Favorite Cake Pans", and the tube was made from a piece of stove pipe.[326] The June 1926, issue of *Scientific American* featured two telescopes with mountings made from Ford car parts; it was very common for these early telescopes to use axles & bearings from Ford chassis, especially the Model-T, as they were very cheap and readily available.[327] James Grant, a quarry-owner from Hall Quarry, Maine, reported in the December, 1926 *Scientific American* that he had completed a 6-inch telescope after reading the *Amateur Telescope Making* book, saying, "for years I had a desire to possess a telescope". Grant had made the mirror in the cellar of his house, sent the mirror to James M. Pierce in Springfield for evaluation, and the latter pronounced it, "a peach".[328]

As time went on, reports on more amateur made telescopes came into *Scientific American*; usually two or three such instruments were mentioned in the magazine every month. The April 1933 issue of *Scientific American* featured a two-page layout with twelve different telescopes with their makers' stories; one 9-inch Newtonian telescope was constructed for only $4.88 ($66.40 in today's terms), less than the cost of a single commercially-made eyepiece at the time.[329] Lynn Bloxom was a physics instructor at the Fort Dodge, Iowa, High School in the 1920s and 30s when he became interested in

[326] "An Ingenious Telescope Mounting," *Scientific American*, 134 (May 1926): 330–331.
[327] "Two Ford-Parts Telescopes," *Scientific American*, 134 (June, 1926): 404–406.
[328] "Scientific American Digest," *Scientific American*, 135 (December, 1926): 450.
[329] "More Amateur Telescopes," *Scientific American*, 148 (April, 1933): 224–225.

telescope making. Bloxom completed his first telescope in 1927, using the first edition of the *Amateur Telescope Making* book. The mirror was 4½ inches in diameter, and was mounted in a cardboard tube originally used for shipping rugs. Bloxom made the mounting from a disused music stand and items such as a laboratory clamp.[330]

Although many of these telescopes were made by scientists, engineers, doctors, and other members of the professional middle-class, those who had always maintained an interest in astronomy, others were being constructed by less well-off individuals. One was Clyde Tombaugh, later discoverer of Pluto in 1930, who, as the son of a Kansas farmer, constructed several reflecting telescopes between 1925 and 1928 with the assistance of Porter's *Scientific American* articles. Tombaugh's family was not financially well-off, but not entirely destitute. The first attempt Tombaugh made on a telescope mirror was a failure; the room in the house he was working in was too drafty to test the mirror accurately using his home-made Foucault tester. The teen-age Tombaugh then offered to build a cellar for the family to store food, provided he could make it long enough to test telescope mirrors in. The air in the completed cellar was perfectly steady, exactly what Tombaugh needed; he finished an excellent mirror soon after.[331] Some disciples of Porter in Vermont who were making telescopes of course included many working class individuals, such as Oscar Fullam, a pattern maker, and Frank Whitney, a machinist.[332] Other examples of working-class telescope makers include H. O.

[330] "Science Teacher Makes Home-Made Telescope," *Scientific American*, 137 (July, 1927): 87.
[331] David H. Levy, *Clyde Tombaugh: Discoverer of Planet Pluto*, (Tucson, AZ and London, UK: The University of Arizona Press, 1991); 21–26.
[332] Russell W. Porter, "The Telescope Makers of Springfield, Vermont: One Way of Absorbing Astronomy", *Popular Astronomy*, 31 (March, 1923): 154–156.

Bergstrom, a locomotive engineer from North Platte, Nebraska, whose photograph along with his new telescope, was featured in *Scientific American* in 1928.[333]

Some of the new breed of amateur telescope makers went on to establish businesses for themselves. John M. Pierce, Porter's original student, established a telescope-related business in the mid-1930s. He regularly advertised in *Scientific American* from 1936 onwards, offering mirror kits, parts (such as eyepieces), and services, including mirror testing and silvering.[334] Thomas Cave, Jr. was born in 1922 and lived much of his life in Long Beach, California. Cave was interested in astronomy from an early age and built his first telescope in 1934 after joining the Long Beach Telescope Maker's Club. This telescope was a 6-inch Newtonian reflector typical of many built at the time and was only the first of many he would build for himself. After learning production techniques during the Second World War, Cave would found his own telescope-making company in 1950.

6. Commercial telescope makers of the 1920s and 30s

Hundreds of amateur astronomers were making their own telescopes by the late 1920s and perhaps several thousand were at work in the 1930s. What of commercially made telescopes? It might be expected that the First World War would have changed the situation concerning the availability of telescopes; the demand for military and naval optical instruments must have created the means for greater numbers and less expensive commercial telescopes. In fact, this is not the case. The effect of increased war production for military optics on post war consumer optics was negligible and in some

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[333] "The Backyard Astronomer," *Scientific American*, 139 (July, 1928): 74.
[334] "Amateur Telescope Makers – John M. Pierce", *Scientific American*, 154 (January, 1936): 41.

sense negative. Production of small astronomical telescopes in Europe in the 1920's "almost completely stopped," according to one historian.[335] In Europe at least, supplies of surplus optical equipment were dumped on the market after the war but without much effect on prices of astronomical telescopes.[336] Although mass-production techniques were being employed for such items as camera lenses and binoculars, commercial telescope makers seemed to feel no need to change production techniques.[337]

The pages of science-related magazines like *Scientific American* contained remarkably few ads for telescopes in the 1920s and 1930s. The British firm of W. Ottway & Co. occasionally advertised "stalking and spotting telescopes".[338] W & D Mogey (Mogey & Sons after 1927) continued their usual advertising; prices for their telescopes, however, remained high. Bausch and Lomb seem to have entered the astronomical telescope market around 1920, but, as has already been seen, their prices were – astronomical. The old companies like Alvan Clark & Sons and John A. Brashear were still in existence, but had a much lower profile, at least among most amateurs. The members of the Clark family were long-gone and the Brashear firm had been taken over by J. W. Fecker in 1923 following Brashear's death. Fecker continued to produce high-quality, and high-priced, refracting and reflecting telescopes through the 1920s and 1930s.

Unlike *Scientific American*, *Popular Astronomy* maintained its rather stodgy format into the 1920s and 1930s. Under editors Curvin H. Gingrich and Edward A. Fath,

[335] Mari E. W. Williams, *The Precision Makers: A History of the Instruments Industry in Britain and France, 1870–1939*, (London and New York: Routledge, 1994); 159.
[336] Mari Williams; 134.
[337] F. Twyman, *Prism and Lens Making: A Textbook for Optical Glassworkers*, (London: Adam Hilger, Ltd., 1942); 41. Kodak was using mass-production techniques as early as 1913.
[338] "W. Ottway & Co., Orion Works, London," *Scientific American*, 133 (July 1925): 65.

Popular Astronomy still ran the same sorts of rather dull observational reports, reports of meetings (largely of professional groups), and even had a tendency to re-run old articles; the 1930 issue contains a repeat of an article concerning W. T. Olcott's observatory that first appeared in 1921.[339] The entire volume of *Popular Astronomy* for 1930 contains exactly two articles concerning telescope making, one of these simply being a news note concerning a telescope constructed at the University of Toronto.[340] The journal also contained advertising for the same old telescope manufacturers as it did two decades earlier. The December, 1938 *Popular Astronomy* advertiser's pages mention Robert Lundin, formerly of Alvan Clark & Sons, as selling custom optical equipment for professional astronomers, as was the Clark Corporation. The German firm of Carl Zeiss was an advertiser, as were Fecker, Mogey, and others; all were offering refracting telescopes, with the exception of large, observatory-grade reflectors from Zeiss and Fecker. By the late 1930s then, little had changed at *Popular Astronomy*: telescopes were still largely marketed to professional astronomers, colleges, and wealthy amateurs.

Only one really prominent new telescope manufacturer appeared in the 1930s: Tinsley Laboratories. Tinsley was established in Berkeley, California around 1930, and by the mid 1930s was advertising regularly in popular science magazines.[341] A surviving Tinsley catalogue, c.1935, shows that, while the company was in the business of selling high-end, precision telescopes, they were also aware of amateur telescope makers. A slogan, "Dedicated to the Amateur Telescope Makers", appears on the first page of the

[339] William T. Olcott, "An Amateur's Observatory," *Popular Astronomy*, 38 (January, 1930): 2–6.
[340] R. K. Young, "The Construction of a 19-inch Reflecting Telescope," *Popular Astronomy*, 38 (February, 1930): 99.
[341] "The Best in Telescopes and Supplies at Reasonable Prices – Tinsley Laboratories", *Scientific American*, 156 (January 1937): 185.

Tinsley catalogue, and the company was one of the few telescope manufacturers that supplied mirror-making kits, abrasives, component parts, and services for silvering and aluminizing.[342] This latter service was also something new. The late 1920s saw a number of experiments on deposition of thin metallic coatings on optical surfaces by means of evaporization in a vacuum chamber. A successful method was devised by John Strong around 1930: a mirror could be placed in a chamber, the air pumped out, then a sliver of metallic aluminum would be electrically heated and vaporized inside the chamber, the aluminum vapor condensing on the mirror. This was much faster and easier than the old silver-coating method, if one could afford the equipment.[343] By the end of the 1930s, firms such as Leroy M. E. Clausing of Chicago, Illinois, were advertising such services to amateur astronomers. Still, for the most part, the production of inexpensive telescopes was the work of amateurs; commercial makers continued to use tried and true methods and did not generally strive to cultivate any new mass market. In the 1930s then, commercial telescopes were still expensive, though there were some new sources.

7. <u>Growth of amateur and public astronomy in the 1930s</u>

The increase in availability of affordable, albeit home-made, telescopes in part created changes in the amateur astronomical community from the 1920’s onward. Now,

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[342] *Tinsley Laboratories: Supplies for the Amateur*, (Berkeley, CA: Tinsley Laboratories, 1935). Tinsley was offering the following complete telescopes around 1935:

10-inch Cassegrain Reflector - $636 ($8,200 in 2001)
12-inch “ “ - $1,150 ($14,835)
6 –inch Newtonian Reflector - $325 ($4,192)
8-inch “ “ - $400 ($5,160)
4-inch Newtonian on Alt-azimuth mounting and tripod - $165 ($2,128) – this was the least expensive Tinsley telescope

[343] See John Strong, “Aluminizing Mirrors”, *Amateur Telescope Making – Advanced*, (New York: Munn Publishing, 1937); 467–476. Strong was a fellow at the California Institute of Technology at the time.

anyone with a few simple tools could construct a high-quality astronomical telescope for a relatively trifling cost. Despite the economic stresses imposed by the Great Depression, more people from a variety of backgrounds could be a part of observational amateur astronomy; the growth of amateur astronomy clubs was one result. Organized amateur astronomy developed along somewhat different lines in the United States than it did elsewhere. As has been shown in the previous chapter, Americans formed national astronomy-related organizations quite late compared to Europeans. Many European nations had nation-wide organizations of amateur astronomers by 1900, for example, the British Astronomical Association (BAA) formed in 1890. One could speculate as to why this would be the case. Undoubtedly there was the issue of distance. The United States was a huge country, making associating with like-minded others a difficult prospect; parallels exist in the history of American professions such as engineering in the late 19th century, where organizing on the local level was favored over the national one, in part because of communications difficulties. Canadian amateur astronomers shared the dispersed population and distance problems of their neighbors to the south, yet organized the Royal Astronomical Society of Canada in 1903.[344] One may also suspect a native 'independence streak' among Americans; people in the United States valued local control, for example in running public schools. Also, Americans likely wanted the individualized control gained from having their own telescope. But as long as the cost of commercially-made instruments prevented many from acquiring telescopes, those people would stay out of the hobby. Therefore, likely the prime reason for the very few

[344] Denis Grey with contributions from Peter Broughton, "Going Royal: A History of Public Service," http://www.rasc.ca/history/index.shtml, retrieved on November 20, 2010.

organized amateur astronomical societies in America was numbers of participants. There simply were not very many active amateur astronomers in the United States, and this was in turn due to the scarcity of telescopes.

Prior to 1930, it was rare to read reports concerning the activities of amateur astronomy organizations. The March 1893 issue of *Astronomy and Astro-physics* mentions only four meetings of groups, three of which were professional or semi-professional organizations. However, by the early 1930s *Popular Astronomy* mentions amateur astronomy clubs being organized in Pittsburg, Los Angeles, Rhode Island, Washington state, and elsewhere. In addition to the growth of amateur astronomy clubs, amateur telescope makers also began to organize on their own. The Springfield Telescope Makers were only the first such group. Later, several other groups were formed including the Amateur Telescope Makers of Los Angeles (founded in 1926), the Amateur Telescope Makers of Chicago (1932), and the Amateur Telescope Makers of Boston (1934).

The Amateur Telescope Makers of Los Angeles (later re-named the Los Angeles Astronomical Society) formed as a direct result of the *Scientific American* articles by Porter. A few individuals located one another (perhaps having seen pictures of each other's telescopes in *Scientific American*), posted a notice at the Los Angeles Public Library calling for a meeting of interested people, and soon had their first meeting.[345] A workshop was set up in a rented building near downtown Los Angeles, and members started making telescopes, in addition to holding regular business meetings and lectures.

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[345] Mars F. Baumgardt, "The Los Angeles Astronomical Society," *The Griffith Observer* (June, 1949): 66–69, 75.

The group soon outgrew their original building and held lectures at the LA Public Library and moved their workshop to the old Los Angeles High School; by 1940, the Amateur Telescope Makers of Los Angeles likely had 100 members. Information on meetings and other activities of the ATMLA were frequently announced in *The Griffith Observer*, the newsletter of the Griffith Park Observatory in Los Angeles; the two organizations would be much more closely associated after World War II.

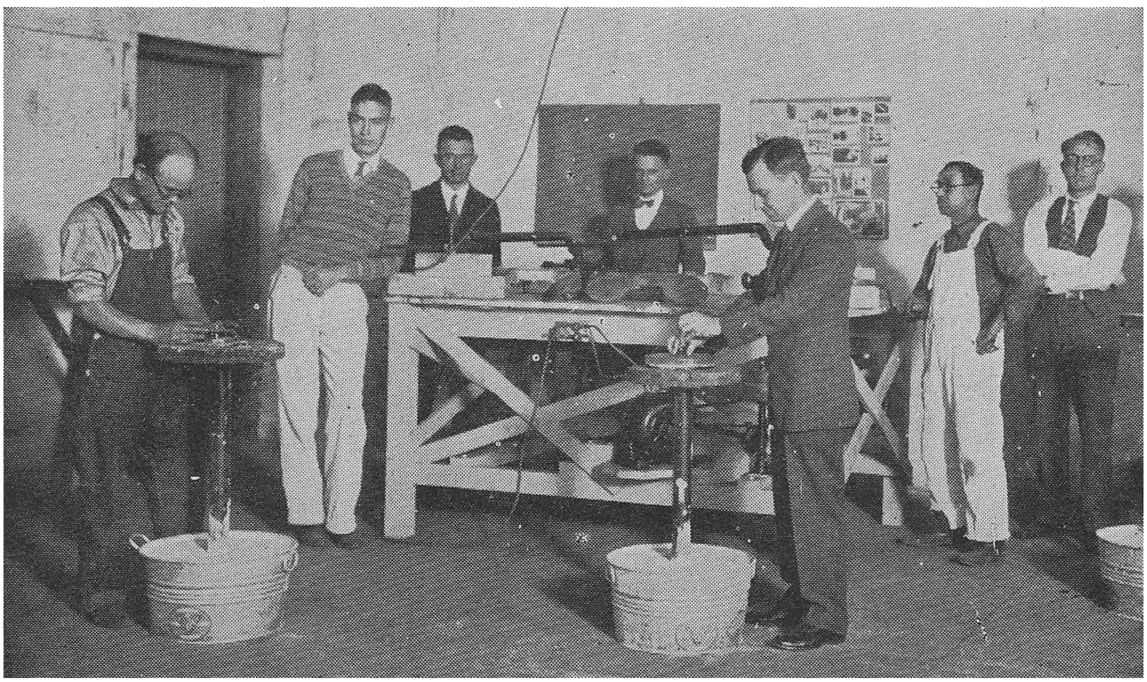

Fig. 36 – Amateur Telescope Makers of Los Angeles, hard at work sometime around 1930. In the background is a Hindle-type mirror grinding machine (electrically powered, but likely home-made) but the workers in the foreground are working by hand. (from *Amateur Telescope Making, Book 1*)

The Amateur Telescope Makers of Chicago were tied into an effort to revive the old Chicago Astronomical Society. After the Adler Planetarium was built in downtown Chicago, the then newly-formed ATMC were invited to move their headquarters to the Adler. The planetarium placed its machine and optical shops at the disposal of the amateur telescope makers. The ATMs and the director of the Adler, Philip Fox, apparently got on well, and saw that they could be of mutual assistance as the ATMs could bring their telescopes and assist the planetarium staff on public nights.[346] The members of the ATMC were quite ambitious and published a newsletter, made plans for standardized telescope designs for amateurs, and even supplied telescope-making kits "suitable for new ATM's, boy scouts or high school students."[347] Many other new amateur astronomy and amateur telescope making groups would associate themselves with colleges, libraries, and museums as venues for activities, but many smaller groups simply met in people's homes. By about 1942 there were over sixty amateur telescope making clubs in the United States, plus several groups in Europe.[348]

Amateur astronomers attended annual meetings of various astronomy-related groups such as the AAVSO, the Astronomical Society of the Pacific, and the American Astronomical Society. However, there were no national-level meetings just for amateur astronomers and telescope makers until after 1940, with one notable exception. After the members of the Springfield Telescope Makers constructed their Stellar Fane clubhouse, they proposed the idea for hosting some kind of special meeting. The group intended to invite telescope makers from outside the Springfield group for a day of talks concerning telescopes, followed by an evening of observing, scheduled for July 3 and 4 of 1926. Earlier that spring, members of the STM group mailed out cards to those they knew who might be interested. Their gathering promised talks, exhibits of telescopes, demonstrations of telescope making techniques, and "A night with the stars at

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[346] Williams, "Getting Organized": 178–179.
[347] L. I. Buttles, "Amateur Telescope Makers of Chicago," *Popular Astronomy*, 40 (November, 1932): 586.
[348] Marshall; 90.

Stellafane".[349] The September, 1926, *Scientific American* featured a report on the first Stellafane meeting.[350]

The meeting attracted 30 enthusiasts from several states. J. Watson Thompson, an attorney from Cambridge, Maryland, demonstrated how he used a frosted electric light bulb as the source of illumination for his Foucault tester in place of the oil lamps usually used. Other attendees included three un-named persons from the General Electric lab in Pittsburgh, and one United States Navy officer from Norfolk, Virginia, who had no telescope, but was interested in learning how to make one. Many attendees did bring telescopes to display to one another, and carried on informal networking.

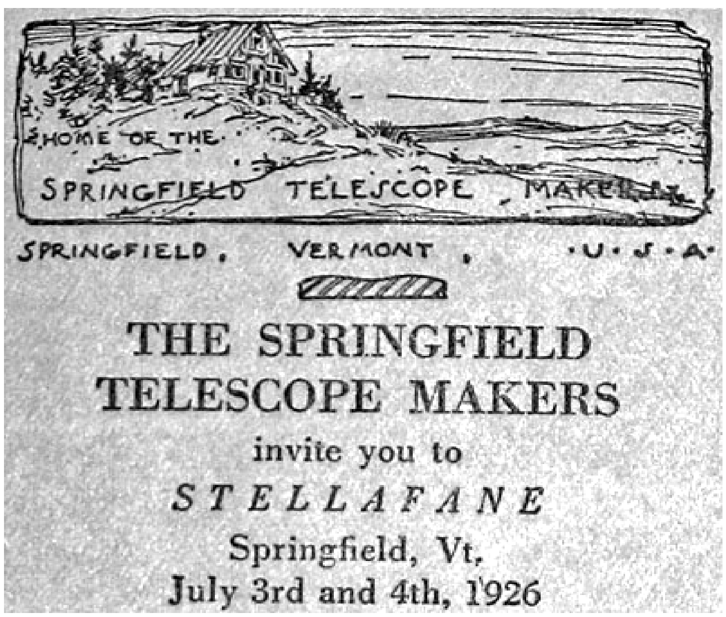

Fig. 37 – Invitation card, complete with Russell Porter artwork, for the first Stellafane meeting (from the Stellafane collections)

There were various hands-on sessions as well; Porter demonstrated how to silver a mirror, "an art which has long been regarded as secret", that could be done in only about

[349] "The Springfield Telescope Makers invite you to Stellafane", postcard (1926), Stellafane collections.
[350] "Amateur Telescope Makers Meet," *Scientific American*, 135 (September 1926): 212–214.

30 minutes. John M. Pierce gave a talk on making small lenses for eyepieces.[351] The day-time activities were followed by a late-night Saturday observing session with the home-made telescopes. A second Stellafane meeting was held the following year and has continued annually ever since then, barring a hiatus of a few years during and just after the Second World War. By the third meeting in 1928, visitors were coming from as far away as Kansas and Panama.[352] 'Stellafane' became the headquarters not only for the Springfield group of amateur telescope makers, but of the entire "Poor Man's Telescope Making Movement".

In 1910 there were no purely public facilities in America offering astronomy education to the average person, let alone a place like Stellafane where telescope makers could gather to work and exchange information. Existing observatories were either dedicated to research or to teaching at the college level. A few of these latter occasionally held 'public nights', perhaps once a month, but this was all. The situation changed considerably in the 1920s and 30s. New facilities were established for public education in astronomy that created places at which amateur astronomers could center their activities. The invention of the projection planetarium was of great importance to the increased popularization of astronomy. Developed by the Carl Zeiss firm in Germany in the early 1920s, the projection planetarium, an electro-optical device combining lights and lenses, was able to produce realistic images of the night sky to audiences indoors. The first

[351] The sources of telescope eyepieces varied considerably. A few ATMs likely made their own, though others likely purchased them from commercial telescope manufacturers; a Huygens or Ramsden eyepiece could be purchased for around $5 during the whole period from 1880 to 1940 (indicating that the actual cost declined over time). An additional source of eyepieces was those scavenged from other optical instruments. Though military surplus optics became a prime source after World War II, other sources were at hand earlier; recall that one of E. E. Barnard's first telescopes used an eyepiece scavenged from an old microscope.

[352] Marshall; 88-89.

public planetariums were established in Europe, but were being reported on in America in 1925.[353] Historian Jordan Marché has written a complete history of planetaria in the United States, *Theaters of Time and Space: American Planetaria, 1930–1970* (2005). The first projection planetarium to be established was the Adler Planetarium in Chicago, constructed in 1930. By 1940, planetaria, some with accompanying observatories, were established in Philadelphia (the Fels Planetarium – 1933), Los Angeles (Griffith Park Observatory – 1935), New York City (the Hayden Planetarium – 1935), and Pittsburgh (the Buhl Planetarium – 1939). American planetaria hosted hundreds of thousands of visitors each year; the Hayden Planetarium in New York hosted 850,000 visitors just in its first year.[354]

Public observatories also developed between 1920 and 1940. Drake University in Des Moines, Iowa, had an observatory atop its science building since 1895, housing an 8¼-inch Brashear refractor. Around 1920, the school decided that the region around the campus was becoming too congested and polluted for astronomy; lights, smoke, and even vibration from a nearby street-car line induced the faculty at Drake to ask to move the observatory to the edge of the city. Drake did not have sufficient funds to construct a new observatory, but fortunately, a number of public-spirited citizens in Des Moines gathered together and proposed a new, hybrid facility. Their plans called for the City of Des Moines to construct a building on the grounds of the new Waveland Municipal Golf Course, while Drake was to supply the scientific instruments and staffing. Things came together, and in November, 1921, the Drake Municipal Observatory was dedicated,

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[353] G. H. Morison, "Heavens Built of Concrete: Ingenious Optical Devices Installed in Concrete Dome Are Used to Show the Motions of the Stars," *Scientific American*, 132 (March, 1925): 170–171.
[354] Marché; 61.

acknowledged to be the first true public observatory in the United States.[355] Though observatories such as those at Cincinnati and Harvard had been previously established through public subscription, the Drake observatory was the first to be actually owned by a city and intended for use by the public. The facility hosted regular public lectures, with observing through the telescope, each week through the spring, summer, and fall. Though an astronomy club did not immediately form after the establishment of the observatory in the 1920s, a few amateur astronomers in central Iowa did use the telescope at Drake, and from the 1950s onward, the observatory would become the base for a new local astronomy club.

The Drake Municipal Observatory was only the first of many such educational facilities for public use. As already noted, Griffith Park Observatory was likely the most prominent public-use astronomical institution established in the 1930s; there would be many more built following World War II, numbers of which housed telescopes provided by amateurs as their main instrument. As was the case for the Adler Planetarium and the Amateur Telescope Makers of Chicago, these facilities, both public planetaria and observatories, became not just places for the general public to learn about the sky and outer-space, but also as centers of activity for organized groups of amateur astronomers and telescope makers. This trend, of scientific institutions providing material support and encouragement for local interests, started in the 1930s and significantly, continued to grow into the 1950s.

[355] D. W. Morehouse, "Drake University Municipal Observatory," *Popular Astronomy*, 30 (February, 1922): 61 – 65.

8. Conclusion

Although there had always been individual amateur astronomers who constructed their own telescopes, the numbers actually doing this were quite small prior to the 1920s, due in great part to a lack of easily accessible and up-to-date information on telescope making. There were no easily available books on the subject in America, and only a few articles scattered in various magazines. None of the authors or the articles they wrote had very high visibility, and they were effectively 'lost' to the amateur astronomical community. The accidental meeting of two 'technological cheerleaders', Albert G. Ingalls and Russell W. Porter in 1925, changed everything. From the first articles that Porter wrote for *Scientific American*, amateur telescope making as a mass hobby erupted almost overnight. Porter's talents as a largely self-taught optician, coupled with his innate talents as a visual and literary communicator, provided the first widely available and detailed instructions on how to make a reflecting telescope in 1926. Ingalls, as editor of *Scientific American*, had a great personal interest in astronomy and supported a continuing column on telescope making in that magazine that lasted from the late 1920s into the 1950s. Suddenly, hundreds, then thousands, of new amateur astronomers across the United States began making their own reflecting telescopes. The resulting increase in the availability of affordable telescopes helped create major changes in the demographics of the American amateur astronomical community between 1925 and 1940, trends that would continue after World War II.

The growth in amateur astronomy in the 1930s is particularly remarkable given the economic crisis created by the Great Depression; one could speculate that lack of work created more free-time for hobbies like telescope making. Besides an increase in sheer numbers, different kinds of people were getting involved in astronomy, in particular those people whose interests and abilities lay in ‘tinkering’. Amateur telescope making was just one of many new popular hobbies on the rise in the Inter-War period, ham radio and model airplane building being just two examples. New astronomy and telescope making clubs were organized throughout the 1920s and 1930s as more people became involved. However, the tone of the amateur astronomical community was also changing. Although organizations such as the AAVSO had been formed for the gathering of scientifically useful observations made by amateurs, such serious work was no longer the ultimate goal for many of the new generation of amateur astronomers. Rather, the challenge of building cleverly-designed and *potentially* useful scientific instrument was now a motivating factor for many.

The old-style telescope making firms like Alvan Clark & Sons Corporation, J. W. Fecker, and William Mogey & Sons, continued to produce old-style refracting telescopes of high-quality, but still very high price. These old-style companies would largely be gone by the end of World War II. The fact that firms like Clark were still producing telescopes at an estimated rate of only about 10 per year, while amateur telescope makers were producing hundreds per year, goes some small way to explaining the ultimate extinction of those conservative companies. The question for many amateur astronomers had become “why buy an expensive telescope when one can make their own?” The substantial (40%) decline in the real cost of the Newtonian reflecting telescopes sold by Tinsley (the only major new telescope-making firm established in the 1930s), versus those of Brashear and others c.1900, might be explained by the competitive market pressure generated by the ATM cadre. However, there was still a problem that limited participation in amateur astronomy. Potential participants still either had to have considerable money to buy an expensive commercial telescope *or* had to have the skills and tools to make a telescope, and not everyone had these latter, despite the coaching of Ingalls and Porter. While many were successful in making a good telescope, there were inevitably a number of failures.

Not everyone in the amateur community was completely enthused with the idea of the home-made reflecting telescope. William T. Olcott's book, *Field Book of the Skies* (1929), suggested that the commercially-made, 3-inch refractor should continue to be the telescope of choice for the amateur:

> Let us assume that you have purchased a three-inch refracting telescope of standard [well-known manufacturer's] make, as it should be, for the reason that you are never sure of an inferior glass, and a poor telescope is practically worthless. The glass is generally furnished with a simple tripod, and this whole outfit usually comes neatly boxed with a set of eyepieces.[356]

This all sounded quite nice and convenient; the admonition against buying a cheaper telescope from an unknown maker was well-founded, but also would likely dissuade many from the idea of making their own telescopes. Olcott continues with a comparison of refractors versus reflectors:

> What advantage has the refractor over the reflector, if any. Many amateurs have made their own reflectors and find them most satisfactory. The reflector has this advantage over the refractor in that it permits the observer to assume a comfortable observing position, and it is less expensive.
>
> Reflectors, on the contrary, are clumsier instruments than refractors, and are not as portable, but the chief difference between the two types lies in the mirror of the reflector which has to be resilvered every few months. Those who are familiar with the process of resilvering do not

[356] W. T. Olcott and Edmund W. Putnam, *Field Book of the Stars: A Presentation of the Main Facts of Modern Astronomy and a Practical Field Book for the Observer* (New York and London, G. P. Putnam's Sons, The Knickerbocker Press, 1934, first printing 1929): 440.

> regard this as a troublesome matter, *but the average amateur who knows nothing about telescopes* [emphasis added] finds the technique of resilvering difficult to master, and regards it as more or less of a nuisance. The refractor is always in order and ready for business. . . . For the simple needs of the average amateur a three-inch refractor, with Alt-Azimuth mounting, is ideal for his purposes.[357]

Olcott thus emphasized the potential difficulties facing amateurs not only in obtaining, but also in maintaining their own instruments in good condition. His was a conservative opinion, but it carried some weight coming as it did from one of his stature in the amateur community.

9. Postscript: the notable failure of the Porter Garden Telescope

At the same time Russell Porter became involved in promoting home-made telescopes with the Springfield group, he also created of one of the most elegant and artistically designed commercial telescopes in 20th century America. The "Porter Garden Telescope" was full of innovation and artistic touches and was meant as an affordable, easy to transport, and easy to use instrument that could interest a wider audience in astronomy. In addition, the Garden Telescope was to be an attractive ornament. Porter took great care in designing his telescope and convinced his employers at Jones and Lamson to produce it.[358]

Most of the mechanical parts for the Garden Telescope were made of cast bronze and made to resist weather: owners could simply leave the instrument in the garden as an ornament when not in use. Porter's greatest innovation was the type of equatorial

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[357] Olcott & Putnam: 446-447. Although Olcott mentions Scientific American as a periodical of note in his book's bibliography, he fails to mention anything about the telescope-making articles, only those of Dr. H. N. Russell, neither does he list Ingalls' *Amateur Telescope Making*, despite the fact it had been in print since 1926.
[358] *The Porter Garden Telescope, Built and sold by the Jones & Lamson Machine Company, Springfield, Vermont, U.S.A.* (New York: Bartlett Orr Press, 1923).

mounting he employed, now known as a ‘split-ring equatorial’. This same general type of mounting, patented by Jones and Lamson on behalf of Porter (patent number 1,468,973) would later be used for the 200-inch Mount Palomar telescope. The optical elements were largely produced at Jones and Lamson on a grinding and polishing machine, and the primary mirrors were hand figured by a man hired specifically for the job by Porter, one Wilbur Perry.[359]

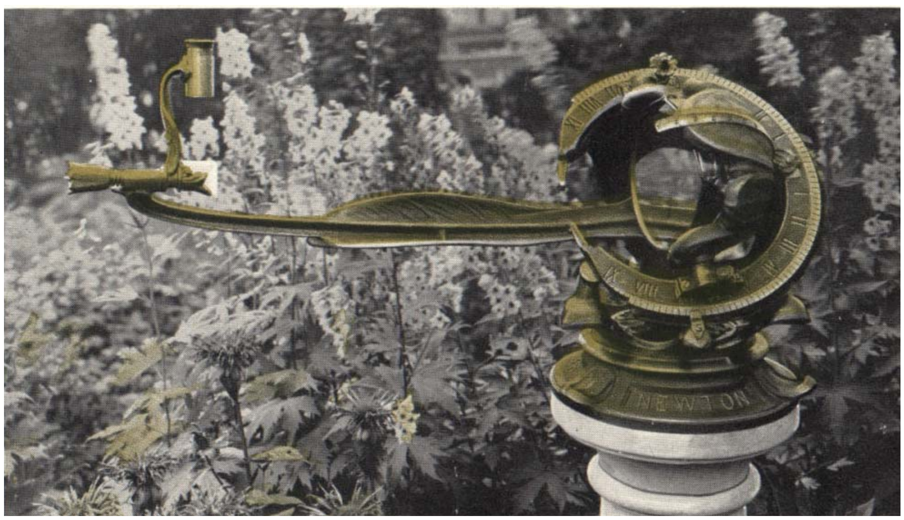

Fig. 39 – The Porter Garden Telescope (from the 1923 Jones & Lamson catalogue)

The Garden Telescope entered production during the summer of 1922, and by October about six telescopes were complete and ready for shipping. The initial price for the Garden Telescope was $250 complete and ready to use, but without a pedestal to set it upon. By June of 1923 the initial supply of telescopes was exhausted, and customers had to contend with a 6 to 8-week wait. Not long after this, Porter and others at Jones and Lamson realized that not all was well with the Garden Telescope. Most critically, they discovered that the retail price of $250 did not cover all the expenses in producing the

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[359] Berton C. Willard, “The Porter Garden Telescope,” *Journal of the Antique Telescope Society*, 29 (Fall 2007): 3–10, on 5. Eyepieces and the Newtonian diagonals were purchased from the John Brashear Company.

telescopes, and the firm had to increase the price to $400 late in 1923.[360] The company also soon found that there was a problem with many of the *purchasers* of Garden Telescopes: they had no idea how to use them. Despite the fact that printed instructions for use and care were included with each telescope prior to shipment, field reports from Jones and Lamson employees indicated that many purchasers were simply using the telescopes as garden ornaments or in fact never bothered to unpack them from their shipping crates. Oscar Marshall, one of those sent to follow up the sale of Garden Telescopes, found that Jones and Lamson had greatly misjudged the ability of people to use the instrument once they arrived.[361]

Only about 100 Garden Telescopes were produced from 1922 to 1924 and, though those instruments are now appreciated by collectors as a high-point of artistic telescope design, the venture proved a commercial failure of little value to amateur astronomy. The uniqueness of the Garden Telescope appealed to a certain number of well-off readers of magazines such as *House Beautiful* and *Country Life* where it was advertised, but these persons were not primarily interested in astronomy and merely wanted some unusual knick-knack for the garden. Artistic styles were changing: the Garden Telescope was an organic *art nouveau* object in a stream-lined *art deco* world. At any rate, for those who were more seriously interested in astronomical observing, the Porter Garden Telescope was simply too expensive and inappropriate. Much of the expense in production was likely due to the ornate castings employed in the mounting and by the relatively slow rate of production; Garden Telescopes were only produced in small batches of 10 or less.

[360] Willard, "The Porter Garden Telescope": 6.
[361] Marshall; 76.

Although designed by the creator of “The Poor Man’s Telescope”, the Porter Garden Telescope was appealing and affordable only to the wealthy and artistically-minded dilettante. Something was missing from the recipe that would put inexpensive, high-quality telescopes into the hands of everyone who had the ambition and interest to use one. It would take a war to supply that missing ingredient.

Chapter V: War and a Revolution: Commercial Telescopes for the Hobbyist 1940–1960

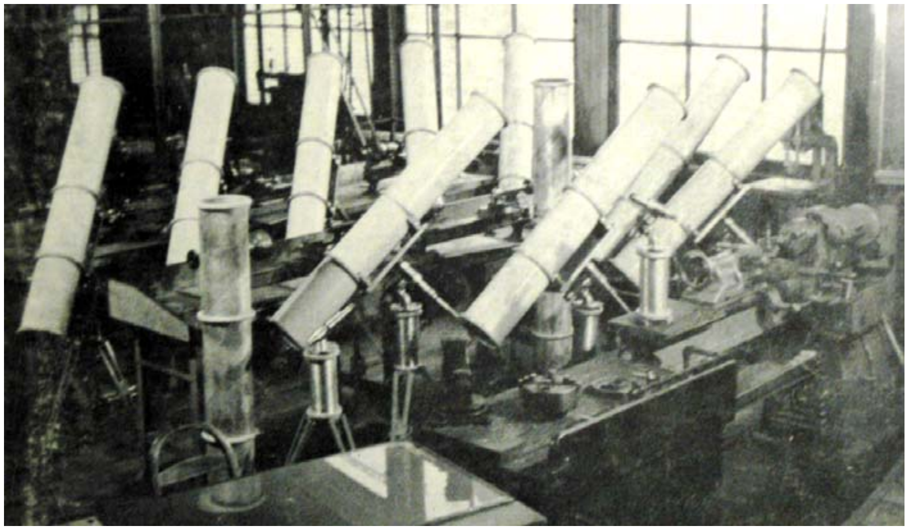

Fig. 40 – Thirteen identical 6-inch Newtonian reflecting telescopes built by members of a telescope making class held at the Stuyvesant High School, New York City, 1945-46. *Sky & Telescope*, December, 1947.

1. <u>Introduction</u>

1945 saw the publication of two exceedingly important books for both optical engineers and astronomers: George Z. Dimitroff and James G. Baker's *Telescopes and Accessories*, and Earle B. Brown's *Optical Instruments*. The latter of these works provides an excellent snap-shot of the American optical industry at the close of World War II. It is abundantly clear from Brown's comments that developments in the wartime years had changed something fundamental in how optical equipment was made in the United States:

> "No industrial processes have ever been so shrouded in mysteries as the processes of the optical industry. For two centuries the procedures for the manufacture of optical glass and for the fabrication of lenses and prisms have been passed on by the ancient practice of word of mouth and apprenticeship. In many cases, only a few individuals in a given company were in possession of the details of the procedures, the *tricks of the trade*.
>
> Until the start of the first World War, the optical glass-makers and most of the precision opticians of this country were foreign-born and

> foreign-trained. . . Then came the establishment of a substantial optical industry in this country, an industry which has expanded prodigiously since 1939.
>
> . . . An optical instrument is a product of extreme skill and painstaking work, and it is not a fit subject for mass production techniques. . . . Glass, and especially optical glass, is a very temperamental material; no specific and unalterable methods can be laid down for its fabrication. For these reasons, the optical industry can never adopt the automatic mass-production methods of the mechanical industries. . . .
>
> However, this attitude has been overdone. Optical men have been too certain that their industry was "different"; technological advances which would have been obvious to a mechanical engineer are only now being somewhat grudgingly adopted in optical plants.
>
> Accordingly, much that is written here will be obsolete within a very few years as the optical industry begins to realize that, although it can never be a mass-production industry, in the sense of the mechanical industries, it can nevertheless, adopt many major improvements in its present methods and techniques."[362]

Brown was largely referring to commercial optics such as binoculars, industrial testing equipment, cameras, and military equipment, but what he states can just as easily be applied to astronomical telescopes. Although large telescopes for professional astronomers were still custom made, those marketed to amateur astronomers after World War II differed greatly from those before. From 1945, certainly by 1950, commercially-made telescopes were being produced in large quantities of a limited number of models. As a result, telescopes could be purchased by amateurs at relatively low prices. Commercial telescope makers of the 19th century such as Alvan Clark & Sons had made perhaps a few hundred telescopes during their entire existence, many of them being one-off, custom examples. By contrast, those makers that emerged in the late 1940s and 1950s made telescopes by the thousands and tens of thousands. Moreover, the cost of these instruments plummeted to the point where nearly any family could enter the ranks

[362] Earle B. Brown, *Optical Instruments*, (Brooklyn, NY: Chemical Publishing Co., Inc., 1945); 379–380.

of amateur astronomy; even teenagers themselves could afford to purchase a decent telescope. The profusion of telescope making companies opened wide new technological options to amateur astronomers. Where once the choice had been between one maker's equatorially-mounted refracting telescope and another's, the choice by the 1950s covered a huge variety of types. Potential buyers had a choice of refractors, Newtonian reflectors, Cassegrain reflectors, new types like the 'Maksutov-Cassegrain', equatorial mounts, alt-azimuth mounts, and more. Price ranges, even for the same aperture of telescope could range enormously.

While Earle Brown was at work developing new production methods and training optical technicians during the war, he was also busy editing the "Gleanings for ATMs" column for the new popular astronomy magazine *Sky & Telescope*, thereby helping to pass on information to a wider readership. Quantity production, if not mass production, was an idea even adopted by amateur telescope makers who never intended to enter business; thousands would make near duplicates of one another's telescopes, in particular the 6-inch, f/8 Newtonian, the new "standard telescope" among beginning amateurs. The increasing numbers of inexpensive telescopes in the 1950s made it possible for more Americans to become involved in amateur astronomy. This increased participation is indicated by the dramatic growth in the numbers of amateur astronomy clubs in the United States. Between 1940 and 1960, the number of astronomy clubs in America quadrupled. The kinds of people who participated in amateur astronomy also broadened. Women, and especially children, participated in amateur astronomy in very large numbers in the 1950s. The world of amateur astronomy in post-war America was transformed as much as much as any other aspect of life after 1945.

2. Instruments of war: the military applications of optical equipment

Most Americans tried to ignore what was going on in Europe and Asia in the 1930s; aggressor-nations like Nazi Germany and Imperial Japan were far away, the nation had other things on its mind, and what went on outside America's borders was none of our business. Of course, all that changed with the attack on Pearl Harbor in December of 1941. The world of astronomy might seem remote from terrestrial strife, but astronomers in fact did their part in many ways. For instance, America's public planetaria and college observatories offered classes on celestial navigation for military personnel.[363] In 1941, both the American Astronomical Society and the American Association for the Advancement of Science appealed to astronomy clubs in the United States to recruit instructors in navigation.[364]Active amateur observers could also offer practical advice to the military on such vital issues as teaching navy and army observers night-vision techniques; astronomers had cultivated methods enabling them to see extremely faint stars and nebulae through a telescope, and such techniques could be usefully adapted to help spot enemy ships, aircraft, and other targets at night. Amateur telescope makers were equally useful to the military. The Second World War represents an important turning point in amateur astronomy and commercial telescope making history. In addition to the existing commercial optical manufacturers, amateur telescope makers (ATMs) were brought into the war effort between 1940 and 1945 to help produce the large numbers of optical components needed.

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363 "Celestial Navigation [Planetarium Program for March]," *The Griffith Observer*, March, 1943: 30–31. An earlier article announced that continuous free planetarium shows would be given in case of a blackout (air raid alert) and that the Griffith Observatory was a strong, fireproof building, and as safe as anywhere else during an air raid. See, "Revised Wartime Schedule of the Griffith Observatory", *The Griffith Observer*, May, 1942: 57.

364 Williams, "Getting Organized"; 189–190.

The military need for optical instruments was far greater in the 1939-45 war than in any previous conflict. Of course, military leaders had recognized the relevance of optical equipment for centuries. A year before Galileo began his telescopic observations of celestial objects late in 1609, Hans Lipperhey and other Dutch telescope makers were offering their small spy-glass telescopes to the military of Prince Maurice of Nassau. The ability to see an enemy from a distance was of obvious importance, but the introduction of gunpowder artillery made the use of scientific instruments even more valuable. Early cannon could fire up to a mile, and seeing the effects of solid shot against enemy troops and fortifications was nearly impossible without a telescope. Navies were also obvious users of scientific instruments; quadrants, sextants, and chronometers were needed for navigation, and telescopes were needed for identifying enemy ships and observing the fall of cannon fire.

Up to the time of the American Civil War, the smooth-bore cannon and muskets commonly used had relatively short ranges. Although these weapons could fire projectiles as far as a mile, effective range was much less, perhaps 1,000 yards for cannon and as little as 100 yards for muskets. At these ranges, 'firing over open sights' was perfectly adequate; gunners could simply sight down the top of the gun barrel, assisted by a front 'blade sight', perhaps assisted by a rear 'notched sight'. The introduction of rifled weapons greatly increased effective range. Still, use of telescopic sights on artillery pieces was deemed unnecessary until 1900, as the maximum range of field guns was 5,000 yards or less. Commanders of artillery units did use telescopes to observe targets and the fall of artillery shells.

Conditions changed rapidly for military applications of optical instruments around 1900. Navies were likely the first to implement the use of new optical instruments. The advent of steel-armored ships and large-caliber, high-velocity steel guns from the 1880s onward meant that battles could be fought at much longer ranges. The power-plants of ships were also becoming more capable. Naval vessels once limited in speed to 10 knots or less by wind-power, were by 1900 being driven by high-pressure reciprocating steam engines and steam turbines, propelling even the largest battleships through the water at over 20 knots. Ships could therefore move much farther in a given time, shrinking the relative battle-zone, but greatly expanding the real one. These technological changes, steel-armor, high-velocity guns, and steam power, meant that ranges of engagement increased dramatically from perhaps 1,000 yards in 1865 to 10,000 yards or more by 1914. The ability to see the target at such ranges absolutely required optical assistance.

Determining the range to targets was a difficulty. Guns had to be elevated at a precise angle (measured in fractions of a degree) in order to hit targets. Determining this elevation required gunners to know the exact distance to the target. By 1900, every naval combat vessel carried optical 'rangefinders.' These were very complicated devices working on the parallax principle. Operators viewed targets through a single system employing two telescopes with widely-spaced objective lenses, much the same as one would with a pair of binoculars. However, due to the effect of parallax (observing the same object from two different points of view), the images of the target would appear separated to the observer; dialing a knob to adjust the optical components would bring the images into 'coincidence' and let operators read the range figures off a dial. These rangefinders were incredibly complex instruments, containing not only telescope lenses, but an assortment of prisms, optical 'reticules', and other components, all of which needed to be precisely fabricated and aligned. A large optical rangefinder could include as many as 70 prisms and lenses.[365]

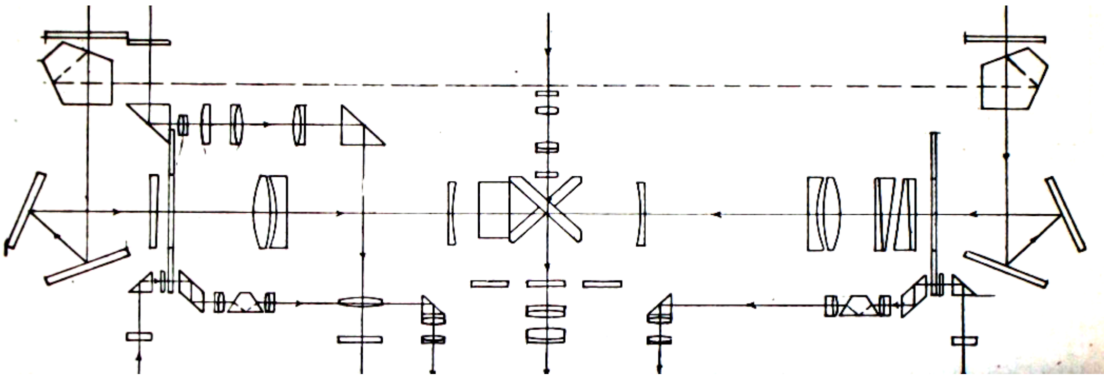

Fig. 41 – Optical components of a large parallax-coincidence range-finder (from Earle B. Brown, *Optical Instruments*).

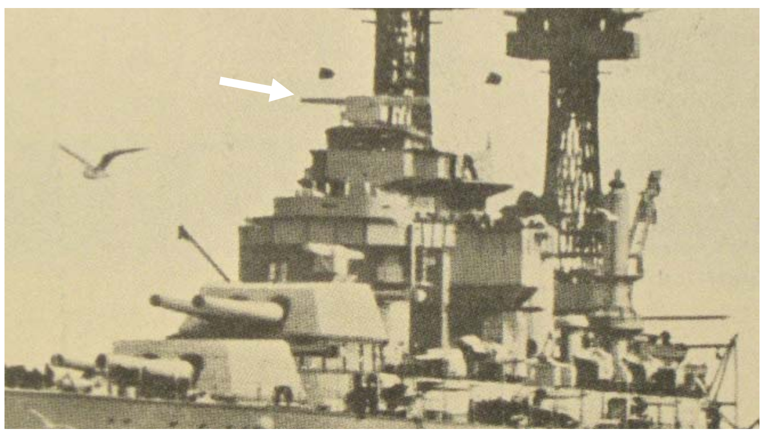

Fig. 42 – Main rangefinder of the battleship USS Maryland, arrowed (from *Jane's*, 1939)

Armies too required increasing numbers of sophisticated optical aids, as weapons grew more powerful and complex. Artillery early in the First World War could still be fired over open sights, but the requirements of trench warfare quickly made such tactics obsolete, as well as suicidal. Due to 'counter-battery fire', machine-guns, and so forth, armies had to place artillery in trenches, rather than in the open, where operating crews

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[365] Brown, *Optical Instruments*; 372. See also, *Jane's Fighting Ships, 1939,* Francis E. McMurtrie, Editor, (London: Sampson Low, Marston, & Co., Ltd, 1939); 477.

often could not see their targets. Maximum ranges to which ordinary field artillery could fire increased steadily; in 1914, the average field gun could fire out to 6,000 yards, increasing to 10,000 yards by 1918, and by 1940, a typical field artillery piece could fire to 15,000 yards or more. It was thus increasingly necessary to mount telescopic gun-sights directly onto artillery pieces to enable them to fire effectively at long ranges onto often un-seen targets. The 'panoramic' gun-sight was a combination instrument, mounted onto a field artillery piece just above the gun-aimer's position, that worked as either a telescopic sight on directly observable targets, or as a kind of 'surveyor's transit' using foreground features, such as hill-tops and buildings, as reference points for aiming at concealed targets. Uncommon during the early part of the First World War, the panoramic gun-sight became a regular feature of all artillery pieces made after 1918, from small trench-mortars used by infantry, to the largest field artillery pieces.

Artillery units of all armies increasingly required a whole assortment of auxiliary optical instruments to be effective; ordinary binoculars, periscope-binoculars (referred to in the United States Army as 'battery commander's telescopes'), engineer's theodolite-transits (for accurately positioning guns and mapping foreground reference objects), and range-finders. All of these optical instruments of course required numerous optical components. The numbers of such instruments required by armies in the Second World War were staggering. The German *Wehrmacht*, about as well-supplied in optical equipment as any other army in World War II, supplied the following optical equipment to an artillery battery: one battery commander's telescope, one range-finder, one theodolite, three pairs of binoculars (for unit officers), and four panoramic gun-sights (one for each gun in the battery). Each German army division fielded twelve such batteries, and there were about 180 divisions in the German army at its peak. This means that the German army would have required 2,160 battery commander's telescopes, the same number of range-finders and theodolites, 6,480 pairs of binoculars, and 8,640 gun-sights, just for divisional artillery units. A German army division also needed telescopic sights for anti-tank guns (72 per division), mortars (up to 142), infantry-support guns (24), and even medium machineguns (116). The crews of these weapons would also have had binoculars and small range-finders; most unit commanders within the division, from platoon level up (about 235), would have had binoculars for command and observation purposes. The total number of optical instruments for a single Germany army infantry division around 1941 would thus have been: 400 panoramic or telescopic gun-sights, 650 pairs of binoculars, 72 theodolite transits, battery commander's telescopes, and range-finders, a total of 1,122 optical instruments per infantry division.[366] There would have been over 200,000 such instruments used by German army infantry divisions in 1941.

As large a number as this is, it does not include artillery, engineer, anti-aircraft artillery, and other units attached to higher-level army units, nor does it include optical equipment used on tanks and armored cars. Medical units needed microscopes, construction engineers needed surveying transits. For all of these additional units, one might well add a further 150,000 optical instruments to the total. Even this does not give a complete picture; armies lose equipment, damaged either in accident or combat. Equipment also wears out or is superseded by new models. One could easily double the

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[366] Estimate based on information from, *War Department Technical Manual TM–E 30–451, Handbook on German Military Forces*, (Washington, DC: United States Government Printing Office, 1945). Optical equipment for artillery units would have been similar for most armies of the period: see also, Capt. Arthur R. Wilson, *Field Artillery Manual, Volume 1, Third Revised Edition*, (Menasha, WI: The Collegiate Press, George Banta Publishing Company, 1929), Chapter LVIII, "Fire Control Instruments and Their Use"; 1–56, and Chapter LIX, "Sighting an Laying Devices"; 1–20.

totals for all optical equipment used by the *Wehrmacht* to at least 700,000 instruments, perhaps 1,000,000. There is a certain amount of guess-work involved at arriving at these numbers, but they seem reasonable in light of available data for Allied armies: Research Enterprises Ltd., of Toronto, Canada, is known to have produced about 25,000 pairs of binoculars, just for the relatively small Canadian armed forces, from 1940 to 1945.[367]

The United States Army in 1940 stood at a strength of 7 active infantry divisions and 1 cavalry division; there were also about 18 National Guard infantry divisions, but these were at less than half-strength due to budgetary constraints. By 1945, the United States Army had mobilized about 100 divisions. This represented a vast increase in numbers of troops and equipment. The United States Army, like the German *Wehrmacht*, was fairly lavish in terms of supplying equipment, perhaps even more so. There was also the United States Navy, Marine Corps, and the Army Air Force, even allied armies on the Lend-Lease program, which had to be equipped. The American military in 1941 and 1942 were faced with going from practically nothing in terms of weapons and equipment, to filling out the requirements of one of the largest armies and navies of the world. There were many bottle-necks in production that cropped-up early on in the war. Optical equipment was needed in large quantities: suppliers of commercial optics such as American Optical, Bausch & Lomb, and Kodak began producing equipment for the United States Army and Navy, and telescope manufacturers like Alvan Clark, William Mogey, Tinsley, and others, also joined the war effort. However, it was still not enough. The sheer scale of the military's equipment demands promoted the wartime creation of

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[367] Richard Dunn, *The Telescope: A Short History*, (London: National Maritime Museum, 2009); 131.

new optical manufacturing companies, employing creative new methods of development and production.

3. ATMs to the rescue: the "Roof Prism Gang" & the Harvard College Observatory Optics Lab

As the United States entered the Second World War, the military became increasingly concerned with the shortage of optical instruments and optical components. The "roof prism" was a critical element in military optical equipment such as binoculars and gun-sights. A roof prism acts to optically rotate an image; since a telescope objective lens rotates the image of an object to an inverted position, objects viewed through a normal telescope are upside-down. This is not an issue for celestial objects, but it is inconvenient and confusing when observing terrestrial ones. A series of additional lenses or prisms can be introduced between the objective lens and eyepiece to give a 'correct' view; a roof prism accomplishes this in the most efficient and compact way possible, making roof prisms desirable in instruments where space is at a premium.

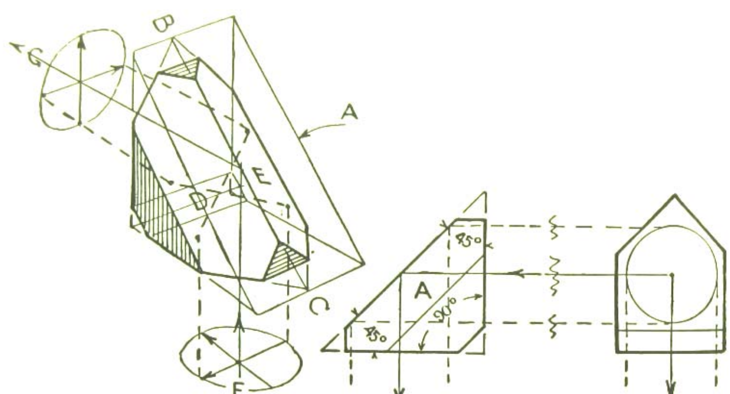

Fig. 43 – An Amici Roof Prism as drawn by Russell Porter (from *Amateur Telescope Making–Advanced)*

Prior to the outbreak of World War II, very few people in the United States, even among professional opticians, knew how to make roof prisms. The design is very complicated: instead of the 5-sides of a regular 60° or 90° prism, a roof prism has 9-sides, all of which must be very accurately aligned with one another. As early as 1937, Albert Ingalls was apparently worried that, should the United States enter a war, there would be a tremendous shortage of prisms for military equipment. He encouraged one particularly talented ATM, Fred B. Ferson, to begin learning how to make prisms.[368] In 1940, Bausch and Lomb were also aware of the problem, and Spencer Optical (primarily a manufacturer of microscopes) contracted Ferson to begin making roof prisms in his small garage shop. In 1941, Russell Porter, Albert Ingalls, and others contacted the US government, offering to involve the many thousands of amateur telescope makers in war-work. Porter began recruiting numbers of ATMs during 1941 and organized a list of those he thought capable of the work. Meanwhile, Porter and his group realized that there was little to no information available on making roof prisms. Porter, Ingalls, Ferson, and others began working on compiling an illustrated instruction manual (later reprinted in *Amateur Telescope Making – Advanced*) and began circulating copies among the 23 recruits for "The Roof Prism Gang". A significant feature included in these instructions was directions on the 'blocking' of prisms.

A technique that had been coming into more common use among commercial manufacturers of binoculars, microscopes, and camera lenses (but not of telescopes) was the blocking of optical elements during fabrication. Blocking involves the mounting of several items, lenses, mirrors, or prisms, onto a single tool (the 'block'). The 'blocking jig' permitted one to make a quantity of components, as long as they were identical. For instance, if one were making a set of seven convex lenses, all of the same radius of curvature, they could all be mounted on the same blocking jig and all ground

[368] Williams, "Getting Organized"; 163–164.

simultaneously. The same methods could be used for prisms, and Porter designed such jigs for The Roof Prism Gang. After a testing period, during which recruits were asked to successfully produce a single prism, 'graduates' were asked to produce prisms in batches of 25 or 50 at a time. There were eighty ATMs involved in the project by 1943, each working under identical instruction with optical glass supplied by the United States Army's Frankford Arsenal.[369] The prisms had to be rough-cut out of slabs of optical glass, were then mounted to a blocking jig, and then each face was ground and polished to very specific angles. Much of the final polishing work was done by hand.

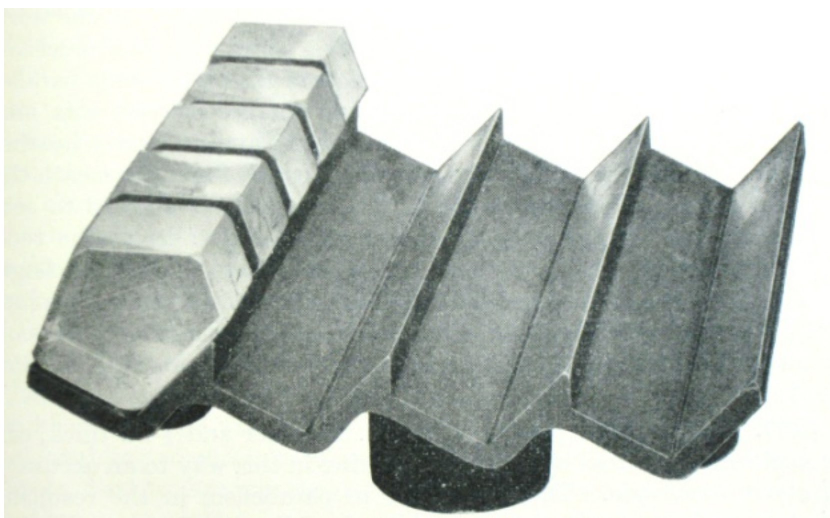

Fig. 44 – A metal blocking jig for prisms, which have just been attached after being sawn from a slab of optical glass, and so have rough edges; from Twyman, *Optical Glassworking* (1955).

There were some quality-control problems, but these were eventually ironed-out. The government was perhaps understandably reluctant to employ 'amateurs' in such critical work, but was pleasantly surprised by the results, both in terms of quantity and quality. The members of the Roof Prism Gang were pretty much an average cross-section of American ATMs: there were accountants, biologists, physicists, chemists, engineers,

[369] Williams, "Getting Organized"; 165.

cabinet workers, candy makers, dentists, a gravestone maker, and a steel worker.[370] Despite some problems, the Roof Prism Gang was able to produce about ten percent of the U. S. military's demand of this critical component, producing a total of 28,420 prisms. Ferson himself produced as many as 11,600 prisms with a better than 90% acceptance rate by the U. S. military. Ferson had in fact started his own small company in 1941 as the war began, and Ferson Optical would survive the war and last through the 1950s.[371]

ATMs made several other contributions to America's war effort between 1941 and 1945 beyond making roof prisms. James G. Baker operated the Harvard College Observatory Optics Lab (HCOOL) during the war, and produced a number of highly advanced photographic lenses for aerial reconnaissance cameras. Baker was a young member of the Harvard College Observatory staff who had received his doctoral degree from Harvard in 1942 (rushed through due to the war). Baker showed great talents as an optical designer as well as an astronomer and spent the majority of his career in designing telescope and photographic camera optics. Baker's interests in astronomy had been strengthened by his own efforts at telescope making while attending high school in the 1920s; he therefore had great respect for amateur telescope makers' abilities. As the war began, another critical shortage was revealed, aerial cameras for photographic reconnaissance. Aerial photography, sometimes from an altitude of 30,000 or even 40,000 feet, required lenses capable of extremely high resolution. The types of lenses with which cameras were normally equipped were not capable of showing the kind of

[370] Marshall; 89–90.
[371] Williams, "Getting Organized"; 163–166.

detail needed by the military, and so Baker was assigned the task of producing new optical systems. Although capable of designing and making a single set of lenses, Baker realized that he alone would never be able to design, fabricate, and test the required number of such lenses, even with an assistant. He therefore set about recruiting local ATMs for the task. The HCOOL utilized the services of a dozen or so members of the Amateur Telescope Makers of Boston between 1942 and 1945.[372] The personnel at the HCOOL were first engaged in developing prototypes for aerial camera lenses for military reconnaissance aircraft. After their designs were tried out, modified and improved, and finally approved for use, the HCOOL group turned to production work.

As the war went on, a few new sources of information concerning optical fabrication became available. As already mentioned, Baker and Dimitroff were working on their book concerning telescope optics, a project completed by 1945. Earle Brown too was working on his more generalized book on optical design, fabrication, and maintenance. Both Baker and Brown also contributed articles to later editions of Ingalls' *ATM* books, as well as to magazines such as *Sky & Telescope*. Both were intimately familiar with the world of amateur telescope makers and amateur astronomers; Brown was a regular attendee at annual Stellafane meetings and Baker encouraged a number of ATMs to try new telescope designs. Foreign sources of information on optics were making their way to America as well. In 1942, Frank Twyman (1876-1959), managing director of the British optical firm of Adam Hilger Ltd., wrote a book-length treatise titled, *Prism and Lens Making*. Twyman's book gives probably the best glimpse of state

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[372] Gary L. Cameron, "Baker, James Gilbert," *Biographical Encyclopedia of Astronomy, Vol. I*; 87–88. Also see, Williams, "Getting Organized"; 167.

of the art optical fabricating techniques during the Second World War, noting that, "optical firms are reticent about their methods." Twyman confirmed that there were really very few available sources concerning optical fabrication, a fact long-known to Porter, Ingalls, Ellison, and virtually every other ATM.[373] Twyman set out to remedy that problem by covering all aspects of the production of individual lenses, quantity production of lenses and prisms, testing, and so forth. By the 1940s, the technique of blocking lenses onto a single jig and grinding and polishing by machine had made quantity production possible. More than that, manufacturers could now produce hundreds of lenses by using banks of machines, running simultaneously, all managed by a single worker.[374] Manufacturers were also making increasing use of high-speed curve-generating machines, milling machines similar to those used in metal fabrication; such machines required the use of diamond or silicon-carbide abrasive wheels, cooled by a constant flow of liquid. Twyman later (1955) produced an updated version of his 1942 book, titled simply *Optical Glassworking*, which added chapters on making parabolic mirrors and telescope optics. The final chapter of *Optical Glassworking* is an annotated list of important works on practical optics: Caltech professor John Strong's *Modern Laboratory Practice*, Colonel Charles Dévé's *Le Travail des Verres d'Optique de Préscision*, and W. Ewald's *Die Optische Werkstalt*. Twyman added one last book to the list, a book "well worthy of a place on the bookshelves of those engaged in the optical instrument industry": Albert G. Ingalls' *Amateur Telescope Making – Advanced*.[375]

[373] F. Twyman, *Prism and Lens Making: A Text Book for Optical Glassworkers,* (London: Adam Hilger Ltd., 1942); preface.
[374] Twyman, *Prism and Lens Making*; 39–68.
[375] Twyman, *Prism and Lens Making*; 252–253.

Amateur and professional opticians were clearly learning from one another in the 1940s and 1950s.

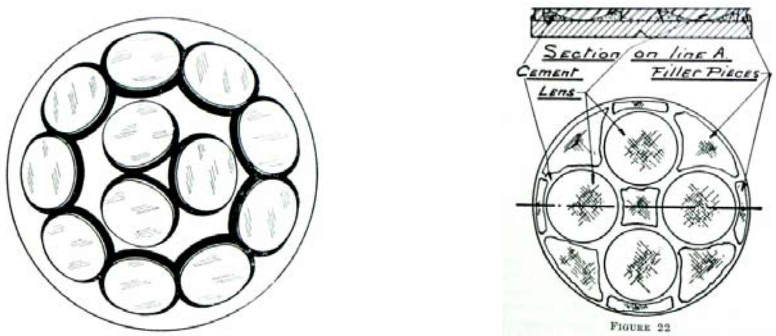

Fig. 45 – Blocks of lenses from Twyman, *Optical Glassworking* (left), and *Amateur Telescope Making – Advanced* (right).

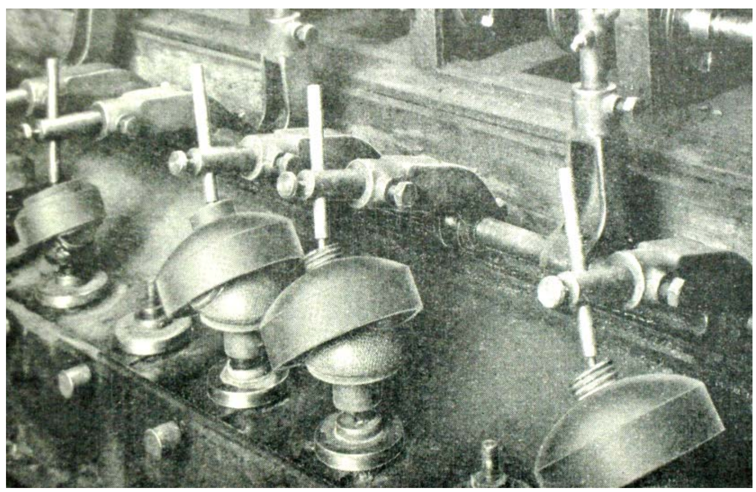

Fig. 46 – A bank of lens grinding machines at Adam Hilger Ltd.

4. The new telescope makers I: Post-War commercial telescope companies

Many of the old telescope manufacturers were gone by about 1950. Alvan Clark & Sons Corporation converted to producing military optics during the war, but is known to have produced only a handful of telescopes between 1945 and 1947; thereafter, the only advertisements seen refer to repair of old Clark telescopes. The assets and equipment of the Clark Corporation were finally bought out by American Optical in

1951. Another holdover from the 19th century was William Mogey & Sons. Mogey continued making telescopes through the 1920s and 1930s, but founder William Mogey passed away in 1938. The firm of Perkin, Elmer, & Moffitt, later Perkin-Elmer, Co., became sole distributor of Mogey telescopes during the 1930s. William's sons, Halley Mogey and Robert Kepler Mogey, continued the business until 1947, all work from 1942 to 1945 being for the United States government, for which the firm hired a significantly larger work-force. Halley Mogey became the chief optical engineer for Perkin-Elmer Co. in 1945, and his brother Robert K. Mogey founded a new company, Janan Instrument Co., also located in Plainfield, which operated from 1947 to 1953.[376]

Some older firms gained something of a new lease on life after World War II. Bausch & Lomb had already become one of the major makers of optical glass and optical equipment in the United States by 1945. However, except for the previously cited period following their absorption of Fauth-Saegmuller around 1920, B & L was never really in the business of selling astronomical telescopes. The introduction in 1953 of the Bausch & Lomb "BALscope Sr." provided an instrument that might appeal to amateur astronomers of modest means. The BALscope Sr. was a compact 60mm (2.4-inch) aperture refracting telescope. However, even at an initial price of $95 ($627 today), it did not come with its own tripod; buyers had to pay an extra $6.85 to get an adaptor enabling the telescope to be mounted on a camera tripod. Accessories included a set of four eyepieces, permitting magnifications from 15 to 60. Although marketed to amateur astronomers in *Sky & Telescope* magazine, the BALscope was in reality a type of 'spotting-scope' more

[376] Serrada: 104.

suitable for bird watching and hunting; the instrument had a built-in prism system providing an erect image, similar to binoculars.[377]

Tinsley Laboratories continued producing high-end telescopes from their factory in the Bay Area. Their larger reflecting telescopes, previously mentioned, were generally not advertised in magazines like *Sky & Telescope*. Instead, Tinsley continued to push refracting telescopes, nearly every issue of *Sky & Telescope* contained ads featuring the company's 3-inch and 4-inch refractors. These were not inexpensive products, even after the war; the 3-inch, on an alt-azimuth mount and wooden tripod, cost $199 in 1947-53 ($1,570-1,310 in today's terms), and the 4-inch, similarly mounted, was $249 ($1,970-1,645). However, the force of competition evidently made itself felt, and in 1954 Tinsley began marketing a much smaller telescope, a 44mm (1¾-inch) aperture refractor, with a fixed magnification of 60, alt-azimuth mounted on a wooden tripod, and with "no imported or surplus parts."[378] This $48 ($315) telescope was the sort of instrument that would appeal to many of the new amateur astronomers, specifically the young, at least as a beginner's instrument, and the firm's advertising reflected this. Tinsley did not completely abandon the amateur telescope makers after 1941. Though there was a considerable hiatus during and after the Second World War, Tinsley was again offering supplies and services to ATMs starting in 1954, including mirror-making kits and component parts.[379]

J. W. Fecker was still producing 6-inch and 8-inch observatory refractors and 24-inch to 60-inch reflecting telescopes for professional astronomers as the company had

[377] "Bausch & Lomb, BALscope Sr.", *Sky & Telescope*, 12 (June, 1953): 224.
[378] "Announcing A Junior, $48 Telescope, Tinsley Laboratories", *Sky & Telescope*, 13 (August, 1954): 355. "Precision Telescopes, As Low As $48, Tinsley Laboratories", *Sky & Telescope*, 13 (October, 1954): 439.
[379] "Telescope Kits and Supplies, Tinsley Laboratories", *Sky & Telescope*, 13 (August, 1954): 355.

been for years, but it also occasionally advertised smaller telescopes. "Precision Built for the Exacting Amateur," Fecker telescopes from the early 1950s sold for prices from $390 ($2,575) for a classic refractor of 4-inch aperture.[380] Fecker seemed to show relatively little interest in innovation and marketing of lower-end products until the end of 1956, when the company introduced the "Celestar", a 4-inch aperture, $198.50 ($1,250 today) 'catadioptric' telescope (an instrument combining mirrors with a correcting lens). But Fecker ended up only marketing the Celestar for a short time, since the product caused a legal dispute with another company, one of several such quarrels between Fecker and competitors at the time.[381]

Many ATMs returned to the hobby of telescope making after the war, some having gained production experience during the war, and began forming their own telescope making companies in the 1940s and 1950s. Of all the new commercial telescope makers to arise in the 1950s, one of the best known and respected was Cave Optical. Thomas Rolland Cave, III (1923-2003) and his company are perhaps the prototypical example of the new breed of commercial telescope makers in Post-War America. As has already been mentioned, Cave became interested in telescope making in the mid-1930s and built his own 6-inch Newtonian telescope, using it for observing the moon and planets from the back-yard of his parents' house in Long Beach, California. Cave later built larger telescopes for his own use, including 8-inch and 12½-inch Newtonians, placing both in a back-yard observatory constructed by Cave and his father. Cave graduated high school in 1941 and immediately went to work for James Herron at

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[380] "Fecker Telescopes," *Sky & Telescope*, 13 (November, 1953): 18.
[381] "The New Electrically Driven Celestar, by Fecker, A Fine Telescope of Advanced Design," *Sky & Telescope*, 16 (December, 1956): inside front cover.

the Herron Optical Company in Los Angeles. Cave enlisted in the United States Army, but returned to Herron Optical after the war where he worked part-time while attending the University of Southern California.

Having built a number of excellent telescopes for himself and learned quantity-production techniques for lenses, prisms, and mirrors at Herron during the war, Cave started his own company in 1952.[382] The Cave Optical Company began by supplying telescope mirrors alone, ranging in size from 6 to 16-inch aperture; Cave also offered to re-figure imperfect mirrors made by ATMs.[383] Being himself a lunar and planetary observer, an observational field demanding extremely high-resolution optics, Cave was a very critical telescope-maker; exacting optical performance was an obsession for him.[384]

Beginning in late 1954, Cave began selling complete telescopes under the "Astrola" name, from that point onward specializing in the production of complete Newtonian reflecting telescopes, just the kind of instruments that ATMs had been making since the 1920s. Knowing that his telescopes, "of superb quality, sturdy in construction, and unexcelled in optical performance", needed to be made available to a wide range of pocket-books, Cave offered his product in a range of models, differing somewhat in accessories and finish.[385] Prices for Cave telescopes in late 1954 were relatively modest, compared to pre-war instruments: the 6-inch "Model A", with fiber-glass tube, aluminum and steel equatorial mounting, and two highly-corrected 'orthoscopic' eyepieces (a newer design developed around 1900 by Germany optical-designer Ernst Abbe), cost only $240

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[382] Minami, Masatsugu, "Thomas R. Cave", in *Communications in Mars Observations,* 198 (25 December, 1997): 1–5. Thomas A. Dobbins, "Thomas R. Cave (1923-2003)," *Sky & Telescope* (July 23, 2003) www.skyandtelescope.com/news/3307721.html (retrieved October, 2009).

[383] "Telescope Mirrors, Cave Optical Company," *Sky & Telescope*, 13 (July, 1953): 245.

[384] O. Richard Norton, "Cave Optical Company," *Sky & Telescope*, 87 (August, 1994): 88–93.

[385] "Astrola Reflecting Telescopes, Cave Optical Company," *Sky & Telescope*, 15 (November, 1954): 24.

($1,584 today), a little less than a contemporary 4-inch alt-azimuth mounted Tinsley refractor. For those desiring a larger instrument to be housed in an observatory, Cave offered the 10-inch “Model C” and 12½-inch “Model D”; these were provided with scaled-up equatorial mountings, electric clock-drive tracking mechanisms, and sets of four orthoscopic eyepieces for $795 ($5,250) and $985 ($6,500), respectively. Cave also still offered mirrors and other component parts for those who wished to assemble their own telescopes, as well as mirror refiguring services.

By 1960, Cave was offering an even larger assortment of products. The least expensive telescope made by Cave Optical in 1960 was the 6-inch “Student” telescope. This was provided with an equatorial mount with a steel pedestal (supplied with legs to provide a steady, yet portable, base), three eyepieces giving magnifications of 50, 110, and 220, a low-power finder telescope, and rack-and-pinion focuser, all for only $194.50 ($1,160); there was no clock-drive, but one could be added.[386] Moving up from the “Student” model, Cave also had the “Model A Standard Astrola”; the equatorial mounting was more substantial than the “Student”, and the latter’s Kellner eyepieces were replaced by a set of the better orthoscopic ones. Finally, there was the “Astrola Deluxe” model; this came furnished and equipped the same as the “Standard Astrola” class, but with the addition of setting circles, electric clock-drive, and mounting rings for the tube that permitted users to rotate it to more comfortable observing positions. A 6-inch Standard Astrola telescope was priced at $350 ($2,085) and the 6-inch Deluxe Astrola was $500 ($2,980).[387] In addition to the 6-inch, Cave also offered 8-inch, 10-

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[386] *Astrola Reflecting Telescopes*, (Long Beach, CA: Cave Optical Company, 1960); 6.
[387] *Astrola Reflecting Telescopes*, (1960); 5.

inch, and 12½-inch telescopes, the latter also offered as an "Observatory Model", marketed in part to schools and colleges, with an extremely substantial equatorial mounting, large set of accessories, electric 'slow motion' controls for accurate pointing, and five orthoscopic eyepieces, priced at $1,780 ($10,610).[388]

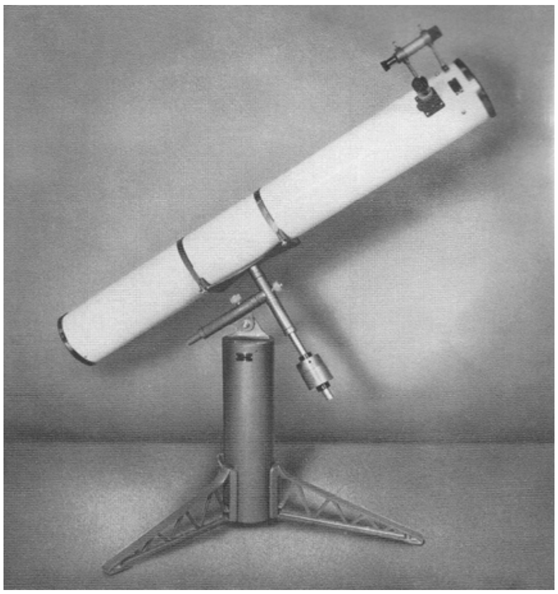

Fig. 47 – Small and large Cave Optical Company telescopes from their 1960 catalogue: the 6-inch Student model (left) and the 12½-inch Observatory Model (right) with Tom Cave at the controls.

Cave Optical began essentially as a simple, one-man operation, but rapidly grew. At its peak around 1960, Cave employed as many as 35 persons including machinists, assemblers, and up to eight opticians. One of the most notable opticians to work for Cave was Hawaiian amateur astronomer Alika K. Herring. Like Cave, Herring was an experienced lunar and planetary observer and telescope maker, and was hired in 1953 specifically to do the hand-figuring of mirrors. The original optical shop at Cave Optical was confined to a single room at first, but expanded to two, and by the 1960s to four.[389] Although the Cave Company's telescope mirrors were hand-figured during the critical,

[388] *Astrola Reflecting Telescopes*, (1960); 14.
[389] O. Richard Norton, "Master Optician, Master Observer", *Sky & Telescope*, 88 (May, 1995): 81–86.

final phase of parabolizing, photographs of the shop as seen in Cave's 1960 catalogue reveal, just behind Herring as he parabolized a mirror by hand, a bank of at least six polishing machines all hard at work. Such machines could polish a number of mirrors at once, far more than could be done by hand alone. Cave Optical Company's original machinery was crude, to say the least: O. R. Norton, another assistant in Cave's optical shop, recalled that some early machines were made from converted pottery-wheels.[390] However, the company later replaced these with modern, multi-spindle machines, similar to those used by larger optical firms. Over the course of only thirty years, Cave Optical produced at least 55,000 telescope mirrors and over 15,600 complete telescopes, far exceeding the output of all American telescope manufacturers from 1850–1940 put together.[391]

There were many other manufacturers of Newtonian reflecting telescopes in the years following World War II. C. C. Young of Hartford, Connecticut, had been in the telescope business for some time. Since the late 1930s, Young had been providing optical supplies to ATMs, as well as equatorial mountings, and complete telescopes.[392] Young's company was long-lived, still being around in the mid-1950s, but had a low-profile. Few details are available as to their exact products or pricing.[393] In 1956, the Garth Optical Company (Springfield, Massachusetts) was advertising 6-inch and 8-inch Newtonian reflecting telescopes, equatorially mounted on a folding tripod, three orthoscopic eyepieces, setting circles, and finder, for $310 ($2,015) and $400 ($2,600)

[390] Norton, "Cave Optical Company": 89.
[391] Norton, "Cave Optical Company": 93.
[392] "C. C. Young, Supplies for Amateur Telescope Makers," *Scientific American*, 162 (January, 1940): 59.
[393] "Complete Telescopes and Supplies, C. C. Young," *Sky & Telescope*, 13 (September, 1953): 299.

respectively.[394] There were a great many other small outfits that came and went, likely more than a dozen, between 1945 and 1960.

One that had more staying power was Coast Instruments, Inc., of Long Beach, California. Coast Instruments' advertising claimed they had been in the optics business since 1933, but there seems to be no evidence that they were producing telescopes prior to 1957.[395] However, the earliest Coast Instruments advertisements in *Sky & Telescope* magazine reveal a very well-developed product-line. Coast Instruments' "Treckerscope" line was somewhat similar to that of their near-neighbor Cave Optical, to the extent that Albert Ingalls considered the Treckerscope to be imitation Cave Astrolas.[396] Be that as it may, Coast Instruments actually had a somewhat larger selection of products, including Cassegrain reflectors, something Cave did not begin marketing until the 1960s. The Treckerscope line began with a 6-inch model for $295 ($1,915), an 8-inch cost $375 ($2,435), a 10-inch $675 ($4,385), and a 12 ½-inch $995 ($6,470), all very well equipped and well-built. The Treckerscope "Sky Giant" Cassegrain, one of the few Cassegrain telescopes marketed to amateurs in the mid-1950s, was a 10-inch aperture instrument, again mounted on a substantial equatorial mount, and sold at a premium price of $1,695 ($11,000 today), quite a high price for the time. One ameliorating factor in favor of Coast Instruments' pricing policies was that they were one of the first telescope making companies to offer an extended payment plan. The company also had a feature that likely helped its sales in Southern California, a storefront. Cave likewise had one, but Coast Instruments' store has all the appearance of a modern, slick, 1950s car dealership or

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[394] "The New Garthscope 6- or 8-inch Reflector," *Sky & Telescope*, 16 (April, 1956): 272.
[395] "Treckerscope, Coast Instrument, Inc.," *Sky & Telescope*, 18 (November, 1957): 44 – 45.
[396] Note attached by Ingalls to letter, "Larry Breymer to Albert Ingalls", December 12, 1956. AC, SINMAH, AC0175, Box 5, folder 6.

appliance store. Aside from Coast's own Treckerscope line, the store also sold binoculars, microscopes, telescopes, cameras, and various other items from other companies, as well as parts and supplies for ATMs, making Coast Instruments a virtual 'department store' for the amateur scientist. The Treckerscope brand was still going strong into the 1960s, but from the start there was some controversy concerning the name. J. W. Fecker was apparently outraged at the similarity between "Trecker" and "Fecker", thinking that it would draw away business; Fecker even appears to have taken some legal action, but this appears to have gotten them nowhere.[397]

Fig. 48 – Coast Instrument Company's Long Beach storefront with a full line-up of Treckerscopes (1958)

The Criterion Manufacturing Company of Hartford, Connecticut was another of the new companies to appear in America and came to dominate the market for a number of years. Criterion's early efforts included a number of small, cheap, and unspectacular refracting telescopes. These were quite small in aperture, only 1.4-inches, sold for only \$11.95 (\$80 today), but was really only effective for viewing the brightest celestial

[397] This was also mentioned by Ingalls in the previously cited correspondence with Breymer.

objects such as the Moon.[398] In 1957, Criterion offered a "New 1957 Geophysical Year" model, taking advantage of publicity over the International Geophysical Year; this telescope was a bit better mounted and was capable of magnifications up to 135, all for $18.95 ($120 today).[399] These were very likely telescopes imported from foreign sources and were far from perfect. However, as beginner's telescopes they enjoyed modest success, being sold by mail order and advertised in a number of popular magazines such as *Popular Mechanics*, and *Sky & Telescope*. A far more important, very popular, and more capable design was Criterion's "Dynascope" series of Newtonian Reflectors. The smallest was a 4-inch telescope on a simple alt-azimuth mounting and provided with only two eyepieces, selling for $49.95 in the mid-1950s ($325 today). A somewhat later version on a more sophisticated equatorial mounting and wood tripod, finder telescope, four eyepieces (one Huygens-type, two Ramsden, and one high-power orthoscopic, with magnifications of 65, 130, 167, and 300), and a tube made of Bakelite, was advertised at $79.95 ($500 today).[400] By 1958, Criterion Manufacturing was offering a whole series of larger Dynascope models consisting of 6-inch, 8-inch, 10-inch, 12-inch, and even 16-inch models. These "De Luxe Dynascope" models featured a very massive equatorial mounting (provided with a folding tripod hidden in the cast-iron pier for optional portability), fiberglass tube, electric clock-drive, and a set of five eyepieces, among many other accessories. Prices started at $265 ($1,670) for the 6-inch De Luxe. Likely the most important of Criterion's telescopes was the 6-inch Dynascope "RV-6", a very effective instrument that sold for $194.95 when it premiered in 1960. What was important about

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[398] "Criterion Mfg. Co.," *Popular Mechanics*, 105 (July 1956): 26 & 40.
[399] "New 1957 Geophysical Year Model, Criterion Mfg. Co.," *Popular Mechanics*, 106 (August, 1957): 28.
[400] "Now – The Deluxe 4" Dynascope Reflector, Criterion Manufacturing Company," *Sky & Telescope*, 18 (April 1958): 315.

this telescope other than its relatively low price was its completeness; it included several eyepieces and a motor-driven equatorial mount, something not found on similarly-priced telescopes such as Cave Optical's 6-inch Student model.[401] Particularly noteworthy for these reflecting telescopes was their value-for-money; one could get a 6-inch Newtonian reflector in 1960 for far less (in terms of real money) than a 3-inch refractor cost in 1910.

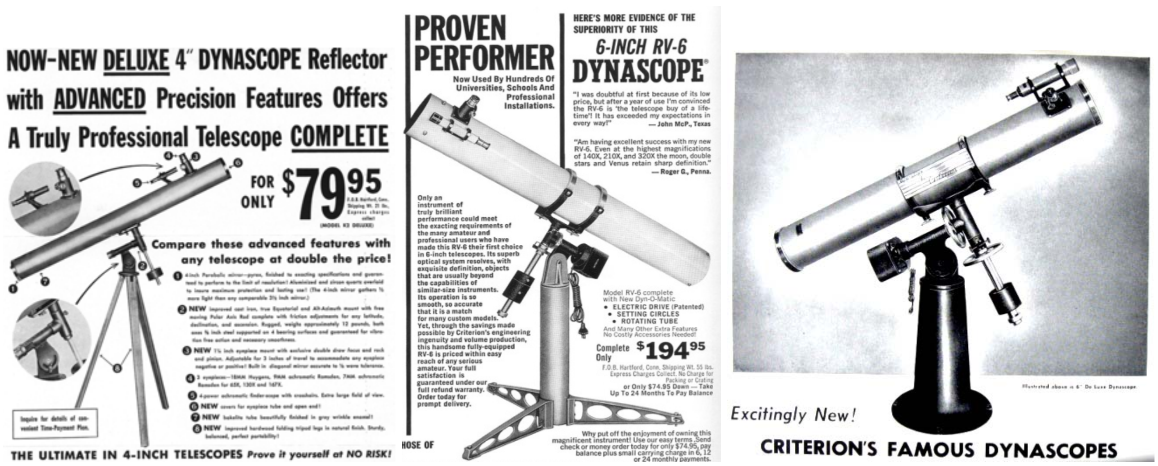

Fig. 49 – Advertisements featured in *Sky & Telescope* for Criterion's various "Dynascope" models.

In addition to these standard telescope types offered at varying prices, the postwar period also saw the introduction of a few more revolutionary examples of new commercial telescopes. Two 3½-inch reflecting telescopes appeared on the American telescope market within five years of one another; the design and marketing philosophies of their makers could not have been more different. The 'Sky-Scope' was an inexpensive starter-telescope designed for the young amateur and consisted of a 3½-inch Newtonian reflecting telescope on a simple tripod mounting. The very affordable Sky-Scope was introduced not long after the end of World War II for the extremely low price of $19.75 ($155 today), was made with a cardboard tube, a simple alt-azimuth mounting, and a

[401] Lloyd Mallan, *Amateur Astronomy Handbook*, (Greenwich, CT: Fawcett Publications, Inc., 1960); 16–19. Criterion also had full-page, often back cover, advertisements for the RV-6 in nearly every issue of *Sky & Telescope* from 1960 to the early 1980s when the company went out of business.

single Ramsden-type eyepiece giving a magnification of 60.[402] Its manufacturers gradually improved the Sky-Scope; by 1950, the mounting had been beefed-up and 35- and 100-power eyepieces were offered as optional accessories; it still retailed for only $25 ($182 today), good value for money compared to Criterion's much smaller-aperture 1.4-inch refractor.[403] Although nearly anyone could afford to purchase a Sky-Scope, they were clearly marketed to families and young astronomers. One owner of a Sky-Scope was David Levy, a now well-known amateur astronomer, discoverer of many comets, and an astronomy popularizer who has written many books and a long-running column for *Sky & Telescope*. Levy received a Sky-Scope, his first ever telescope, as a Christmas present in 1960 at age 12. While a modest instrument, it offered views of Saturn impressive enough to hook Levy on astronomy for life, as he later recalled.[404]

The second 3½-inch telescope appearing on the Post-War market could not have been more different from the Sky-Scope. In 1954, after eight years of development, the Questar Corporation presented its "Questar" 3½-inch Maksutov-Cassegrain telescope to the American public. The Questar was a very carefully-designed, precision instrument, intended for use as both a visual and photographic instrument.[405] The Maksutov design, which will be described in greater detail in the next chapter, was the brain-child of Soviet optical designer D. D. Maksutov. First revealed to the West in a 1944 article in the *Journal of the American Optical Society*, the Maksutov-Cassegrain design had several advantages. Unlike a Newtonian or standard Cassegrain, the mirrors of the Maksutov-Cassegrain could be left spherical, rather than having to be parabolized. This enabled

[402] "Sky-Scope," *Sky & Telescope*, 7 (November. 1947): 23.
[403] "Sky-Scope," *Sky & Telescope*, 9 (July, 1950): 225.
[404] David H. Levy, "Old Telescopes Should Never Die," *Sky & Telescope*, 113 (February 2007): 91–92.
[405] *Questar Catalogue* (New Hope, PA: Questar Corporation, 1960); 1.

makers to speed up the production of mirrors, within certain limits. Spherical aberration was corrected by a full-aperture correcting lens (the Maksutov design was therefore a 'catadiopteric' one). Also, the primary mirror of the Questar was made of very short focal-ratio: only an f/2. This made for an extremely compact and portable instrument. The mounting of the Questar could either be used in the alt-azimuth mode for terrestrial observing and photography, or, by inserting three adjustable legs, could be propped-up at the correct angle for use in the equatorial mode. The telescope and all accessories came in an attractive leather-covered case.

Questar Corporation's head, Lawrence Braymer, was interested in producing and marketing the best possible telescope to a diverse audience, of amateur astronomers, bird-watchers, and photographers. Braymer noted that astronomical telescopes, even with an erecting lens or prism system, were unsuitable for terrestrial observing, and that telescopes for terrestrial observing were unsuitable for celestial observing. Neither of these types of telescopes, as then marketed, was suitable for use in photography.[406] The Questar was meant from the beginning to serve as a terrestrial, celestial, and photographic telescope in one package. The marketing of the Questar reflects this multi-purpose-use philosophy. The Questar was equipped with two eyepieces of the highest-quality, a built-in amplifying lens that could double the magnification, if desired, and a rear 'port' that could accept an adaptor for an ordinary 35mm single-lens-reflex camera. The Questar was practically the only American-made telescope of the 1950s designed by an actual design team in the same way that automobiles were. The Questar was not only carefully designed from purely optical and engineering standpoints, but also from

[406] *Questar Catalogue* (1960); 2.

aesthetic ones; the Questar catalogue even emphasizes the attractive colors used. The price of the 3½-inch Questar was $995 ($6,475 today), or forty-times that of the Sky-Scope, definitely not a telescope for the beginner.[407] The Questar was primarily marketed towards advanced amateur astronomers, nature-enthusiasts, and photographers of some means. Questar Corporation was quite proud of its product; it was also very protective. When Fecker introduced its "Celestar" telescope in 1956, Questar quickly began legal proceedings against Fecker for intentionally using what seemed an obviously similar name to "Questar".[408]

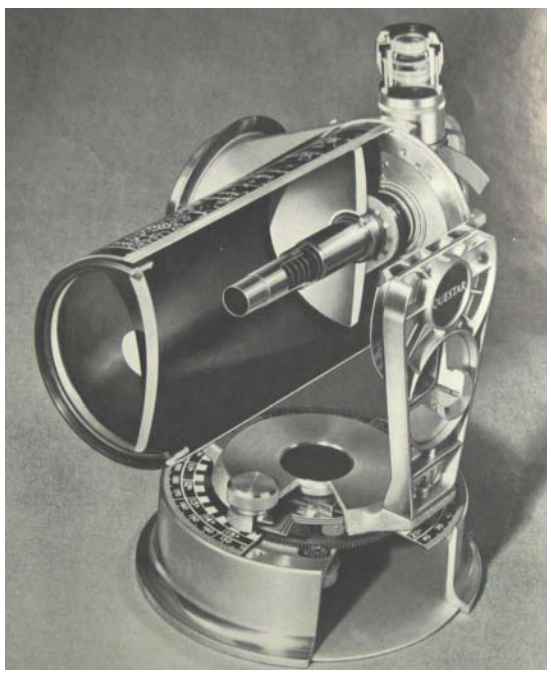

Fig. 50 – A cut-away model of the 3½-inch Questar telescope (1955)

Though Questar telescopes were relatively expensive, an incident from their early manufacture illustrates the limitations of quantity-production methods. The primary mirrors were made quite thin in order to save weight and permit them to fit within the

[407] *Questar Catalogue* (1960); 32.
[408] Letter and note attached by Ingalls to letter, Larry Breymer to Albert Ingalls, December 12, 1956, AC, SINMAH, AC0175, Box 5, folder 6.

compact tube-design. Braymer jobbed out fabrication of the mirrors to unnamed “large optical companies”. The results were surprisingly disappointing, as most of the mirrors turned out flawed by astigmatism.[409] What had happened is that the professional optical shops, unused to making high-precision telescope mirrors, had blocked numbers of the relatively thin 3½-inch mirrors onto a single tool, just as they would have with lenses. When the mirrors were released from the block, strains in the glass were released, resulting in astigmatic surfaces. Braymer happened to know Thomas Cave and the two were on friendly terms, so Braymer arranged to send the flawed mirrors to the Cave shop, where they were individually re-polished. The re-figured mirrors turned out perfect, and Braymer contracted with Cave Optical to produce about 1,000 Questar telescope mirrors. The clear lesson was that some methods suitable to mass-production of binocular and camera lenses were not so good for reflecting telescope mirrors, the latter requiring much higher tolerances than lenses (for various technical reasons). At any rate, most telescope mirrors were too large for blocking methods. Though various corporate approaches could somewhat increase the production-rate of reflecting telescopes, they could never be produced as rapidly as small refracting telescopes.

Although the post-World War II telescope manufacturers in America concentrated on producing Newtonian reflectors, there were a few noteworthy exceptions. Unitron Instrument Division of the United Scientific Company, Newton Highlands, Massachusetts, produced some excellent refracting telescopes ranging in size from 1.6-inch to 6-inch in aperture, starting in about 1952. These telescopes were relatively high-priced compared to reflectors of similar size but were noted for superb mechanical and

[409] Norton, “Cave Optical Company”: 90.

optical quality. The smallest Untron telescope was the 1.6-inch, alt-azimuth refractor; provided with three eyepieces (39 to 78 power), finder-scope, star-diagonal, and hardwood case, it sold for $75 ($485 today). The 2.4-inch and 3-inch Unitron telescopes were similarly-equipped to the 1.6-inch, but could be had on either alt-azimuth or equatorial mounts; they ranged from $125 to $435 ($815 to $2,830). Larger Unitron telescopes included 4-inch models, on alt-azimuth, equatorial, and observatory equatorial mounts, for $465 to $1,280 ($3,025 to $8,320 today).[410] Unitron added a 6-inch observatory equatorial to its line in 1958; provided with two cameras (one mounted to the side of the telescope tube for wide-field photography, the other for photographing objects through the telescope itself), a 4-inch auxiliary guiding telescope, 2.4-inch finder, and a huge assortment of accessories, the 6-inch sold for a whopping $6,075 ($38,270 today) when first introduced.

Even while new companies selling complete telescopes were being born in Post-War America, many others were still selling telescope parts and kits. It would be impossible to list all of these companies, but some more prominent ones include Harry Ross, Precision Optical Supply Co., De Palma Optical Co., all from New York City; David William Wolf, in Brooklyn, New York; Haines Scientific Instruments, Englewood, New Jersey; Telescopics, in Los Angeles; and E & L Optical, Minneapolis, Minnesota. One could easily purchase a 6 to 8-inch mirror grinding kit, containing all necessary materials (often including a Newtonian secondary mirror and lenses to be assembled into a simple eyepiece) for less than $10 around 1950 ($70 today). Aside from selling new telescopes, components, and kits, there was of course the military surplus market.

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[410] *Unitron Catalogue of Telescopes* (Newton Highlands, MA: Unitron Instrument Company, 1956).

Two new companies began operating in the late 1940s and early 1950s that directly benefited from World War II: Edmund Scientific and A. Jaegers. Edmund Scientific (Barrington, NJ) began originally as Edmund Salvage and was involved in the mass purchase and retail sale of military surplus optics. From this, the company grew to specialize in the manufacture, importation, and retail sale of scientific equipment to schools and hobbyists. Edmund advertisements were featured in nearly every issue of *Sky & Telescope* magazine and became well-known to every amateur astronomer. An item that Edmund began marketing at an early stage of the company's existence was telescope mirror making kits. These kits included a Pyrex mirror blank, a plate-glass tool, appropriate quantities of abrasives supplied in easy to use shaker containers, pitch for polishing, an optically flat mirror for use as a secondary, a pair of lenses that could be made into a 1-inch focal length eyepiece, and a larger magnifying lens for inspecting the surface of the mirror during grinding and polishing. Prices for these ready-to-go kits in 1952 varied from $7.00 for a 4¼-inch to $49.00 for a 12½-inch: the company continued selling these popular kits well into the 1970s.[411] Amateur telescope makers could purchase other components to complete their instruments locally at hardware stores and lumber-yards. After that, do-it-yourselfers needed only one more step to complete the telescope, to coat the completed mirror with the reflective surface of silver or aluminum.

Besides mirror making kits, Edmund also sold various components. Most of Edmund Scientific Company's eyepieces in the 1950s were military surplus from

[411] "Unusual Optical Bargains," *Sky & Telescope*, 11 (November, 1952): 19. The size range included: 4¼-inch, 6-inch, 8-inch, 10-inch, and 12½-inch. Prices for these kits remained quite low until they were discontinued sometime in the 1980s as the interest in home-made telescopes declined. The shaker containers were small (holding a few ounces of abrasive powder) and had a plastic top with a re-sealable cap nearly identical to those used for salt, spices, and other seasonings in the food industry, and it is not unlikely that Edmund went to manufacturers of such food containers for their supply.

binoculars and gun-sights. "We Have Literally Millions of WAR SURPLUS LENSES AND PRISMS FOR SALE AT BARGAIN PRICES" trumpets one ad, and indeed the company claimed to offer discounts of nearly 80% below US Government purchase prices.[412] Edmund sold vast quantities of military surplus equipment including gun-sight telescopes, range-finders, and panoramic gun-sights; ironically, all these items being sold as surplus equipment to ATMs contained roof prisms, which were quite possibly made by ATMs during the war.[413] In the 1960s, Edmund Scientific commissioned Sam Brown to write an illustrated, popular-level book: *All About Telescopes* included full instructions on making a whole series of telescopes from parts supplied by Edmund, ranging from simple Galilean hand-telescopes to 6-inch Newtonian telescopes on equatorial mountings.[414]

Edmund Scientific eventually entered the telescope market with complete instruments of their own make. By 1956, Edmund was offering a diminutive 3-inch Newtonian, similar to the Sky-Scope, for $29.50 ($185 today). Soon, Edmund began also selling larger, more sophisticated instruments for a wider market; these included a 4-inch refracting telescope, equatorially-mounted, for $247 ($1,530), a bargain compared to Unitron, and the 4¼-inch "Palomar Junior" Newtonian reflector, also equatorially-mounted, for $79.50, about the same price as Criterion's 4-inch Dynascope.[415]

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[412] "A. Jaegers," *Sky & Telescope*, 11 (January, 1953): 78. The particular eyepiece in question was a large, wide-angle "Erfle"-type originally used in gun-sights, having excellent optical characteristics, and was highly prized by amateur astronomers; it was claimed in the Edmund ad that the government paid $54.00 ($356 in 2001) for these eyepieces, but were sold for only $8.50 in 1953 ($56.10 in 2001).
[413] *Edmund Scientific Catalogue* (Barrington, NJ: Edmund Scientific Co., 1951).
[414] Sam Brown, *All About Telescopes* (Barrington, NJ: Edmund Scientific Co., 1967).
[415] *Edmund Scientific Catalogue* (Barrington, NJ: Edmund Scientific Co., 1960); 10–15.

A. Jaegers (of Ozone Park, later Lynbrook, New York), like Edmund Scientific, began business almost immediately following the end of the Second World War in the salvage business. Jaegers' general sales line was not greatly different from Edmund, but Jaegers did offer a much wider selection of large, surplus, achromatic lenses, suitable for telescope objectives. Prices for these lenses were reasonable, a 2⅛-inch cost as little as $9.75 and a 5-inch only $75 ($60 and $465 today). [416] Expanding beyond its sales of surplus, Jaegers eventually began contracting for the manufacture of new lenses to offer its customers, and the company began producing its own eyepieces, mirror-cells, focusers, and equatorial mounts. The important point concerning Edmund and Jaegers is not that the two firms offered greatly differing products, but that they competed for the same do-it-yourself amateur astronomers and ATMs who still, either through lack of money or just a desire to tinker, still wanted to make their own telescopes.

The postwar period's new availability of affordable commercial telescopes had not eliminated the community of hobbyists committed to building their own instruments. The market catering to them existed side-by-side with the market for readymade telescopes and even continued to expand. In 1947, *Sky & Telescope* magazine featured advertisements from twelve to fifteen sellers of telescopes, telescope parts, and services to ATMs. By 1960, there were at least thirty. Of the advertisers in 1947, four sold complete telescopes; in 1960 there were fifteen different manufacturers of commercial telescopes advertising in *Sky & Telescope*, all but one being American.

Another aspect of the new commercial telescopes involved materials and styling. While telescopes being sold in by makers such as Mogey and Fecker in the 1920s looked

[416] "A. Jaegers, the Glass House," *Sky & Telescope*, 17 (April, 1958): 308.

pretty much like those sold fifty years earlier, telescopes sold in the 1950s followed modern tastes in styling. Amateurs were increasingly accepting of new types of materials used in commercial telescopes. Telescopes were no longer made exclusively of brass and steel; for example, fiberglass, Bakelite, and even cardboard were increasingly utilized for telescope tubes. This acceptance, to a certain extent, was due to changing tastes in Post-war material culture. If plastic kitchen tile and fiberglass dining-room chairs were acceptable in the home, why not such materials in telescopes?

Commercial telescope making was now a comparatively major American business; it was also becoming somewhat more sophisticated in marketing techniques. American telescope manufacturers, unlike their Pre-War predecessors, were following the lead of other American businesses of the 1950s in developing a slickly modernized promotional pitch. These new companies were not afraid to employ flashy advertising and new sales techniques to sell telescopes in the same manner as cars, televisions, toasters, or any other consumer goods. Compared to the rather dull, minimalist advertisements typical of the decades prior to the Second World War, the new telescope manufacturers used numerous eye-catching pictures and bold statements:

> "BUILT FOR THE MOST BREATHTAKING VIEWS YOU'VE EVER EXPERIENCED. . . and completely equipped to deliver them! The Magnificent RV-6, Electric 6-inch Dynascope" [Criterion]
>
> "The Telescope That Lives Up To Its Name: 255X DELUXE SPACE CONQUERER 4¼" Astronomical Reflector Telescope" [Edmund Scientific Co.][417]

[417] Mallan, *Amateur Astronomy Handbook*; 1 and rear cover.

The catalogues of Cave Optical, Unitron, and other telescope makers frequently featured attractive, nicely dressed, young females either showing off the latest telescope model as they would a new car, or, rarely, looking through a telescope. Sellers embraced other modern sales techniques, such as the installment plans offered by Criterion and Unitron; this allowed consumers to purchase even premium telescopes for as little as 10% down. Although most of the new companies were strictly mail order, a few, such as Cave Optical and Coast Instrument Company, invested in building storefronts looking much like any appliance or car dealership in the 1950s, with large front windows to show off their latest models and entice window-shoppers.

Newly-created postwar companies used this new marketing approach to create a brand identity and to highlight the characteristics that made them different from older establishments. While men like Porter and Ingalls had spent years convincing amateurs that reflectors were as good as, or better than, refractors, Unitron's 1950s advertising tried just as hard to convince amateurs of the opposite view. Their catalogue is full, almost to absurd levels, with customers' testimonials, newspaper clippings, and even cartoons, all aimed at convincing potential customers to buy Unitron. "Choose UNITRON for UNIFORMLY High Quality", trumpets an ad showing rows of telescopes.[418] This single picture shows about three-dozen identical 2.4-inch refracting telescopes, about five times the annual output of Alvan Clark & Sons at that company's peak of production. Though Unitron obviously assembled this collection for an advertising photo-shoot, the fact is, they *had* three-dozen of just one of many sizes of

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[418] "Unitron", *Sky & Telescope*, 13 (October, 1954): rear cover.

telescope on hand, ready to ship. That modern scale of output would have been unheard-of just twenty years earlier, to say nothing of 1910.

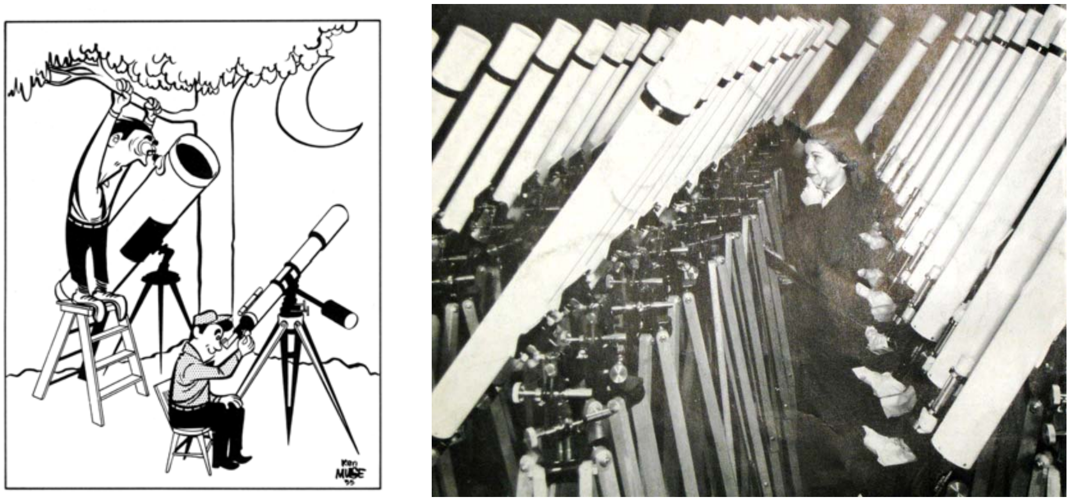

Fig. 51 – Why Unitron refracting telescopes are better than reflectors: viewing comfort, and perfect, uniform telescopes in large quantities. From the 1956 *Unitron Catalogue*.

Advertisers also used current events and newsworthy scientific advances as hooks to command consumers' attention. The Mount Palomar Observatory and its 200-inch reflecting telescope were officially opened in 1948 and aside from generating a good deal of general public interest in astronomy, also helped boost sales of Newtonian reflecting telescopes. Many advertisements included comments such as "just like the Mount Palomar telescope," while makers of the Edmund Scientific 4¼-inch reflecting telescope dubbed it the "Palomar Junior".[419]

As military optical equipment flooded onto the market after the war, ATMs, and amateur astronomers generally, snapped up huge quantities of surplus optics. In addition to American military surplus equipment, some former enemy equipment found its way into the hands of American astronomers. Henry Paul, in his book, *Telescopes for Skygazing*, recommends to readers that several large aperture binoculars, used originally

[419] "Edmund Scientific", *Scientific American*, 198 (January 1958): 108.

by the Germans and Japanese for artillery or naval observation, could be highly effective for postwar amateur astronomy. Paul touted the instruments made by well known German firms such as Zeiss, but he also suggested that Japanese “battleship” binoculars with lenses up to 5 inches in diameter were particularly effective in yielding “striking” views of the moon.[420] Brand-new astronomical telescopes from Japan also began to appear in America around 1952-54. While anyone in the market for buying a telescope after that time might notice the new availability of Japanese-made instruments, the internationalization of postwar telescope making also had other less obvious, but equally important aspects in the American market. What was not so apparent to Unitron customers, and was *never* mentioned in any Unitron advertising, was that the optical components of these superb telescopes, including both objective lenses and eyepieces, were in fact Japanese-made.[421]

5. The new telescope makers II: ‘the Japanese are coming!’

Japan had been a manufacturer of fine optics for decades. Nikon had produced binoculars as well as camera lenses since the early twentieth century. Japanese military and naval tactics emphasized fighting at night, and therefore the government required very good and very large binoculars for good vision under low-light conditions. Goto Optical Company was a manufacturer of exceptionally good telescopes from the 1920’s to the present day. Seizo Goto began making telescopes for sale in a small shop at his home near Tokyo in 1926. The first model was a small, inexpensive, very simple, but very popular refracting telescope with only a one-inch objective lens. After World War

[420] Henry Paul, *Telescopes for Skygazing*; 130–135.
[421] Norton, “Cave Optical Company”: 91. Cave Optical and many other American telescope manufacturers purchased Japanese-made eyepieces and other components starting in the 1950s.

II, Goto returned to production of telescopes and related optical instruments for astronomy.[422] It was in 1958 that an advertisement appeared in *A Guide to Astronomy* announcing that "Japan's Finest Telescopes and Accessories are now available to World Astronomers."[423] *Sky & Telescope* magazine also carried ads for Goto equipment around the same time. Although Goto never made a particularly deep direct impression on the American market, behind the scenes Goto and other optical manufacturers in Japan also did a big business in supplying optics and telescopes for export under different labels.

Many Japanese-made telescopes, mostly small refractors, were sold in America by the late 1950s under American import labels such as Tower, Mayflower, Jason-Empire, Tasco, and others. It was also in the early 1950s that Edmund Scientific began importing telescopes from Japan.[424] Although quality suffered in later years as the manufacturers tried to keep down prices, the first generation of these telescopes was of fine quality. Even many of the best American telescope manufacturers began offering inexpensive imported telescopes as a sideline. A price sheet from Cave Optical Company from 1960 offered nine different telescopes under the Mayflower and Tasco brand names, starting with an inexpensive 2.4-inch (60mm) refractor on an alt-azimuth mounting and with minimal accessories selling for $39.95. Such small, inexpensive telescopes, if purchased from a reputable distributor, were an excellent means for American telescope manufacturers to 'hook' new, young, customers.[425] Beyond the specialized distributors of telescopes, and of far more importance to the popularization of astronomy, America's

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[422] "Goto unpublished corporate history," found at GOTO World, www.goto.co.jp/company/heritage/goto_1926to2006-e.html (retrieved on May 12, 2010).
[423] Lloyd Mallan, *A Guide to Astronomy* (Greenwich, CT: Fawcett Publications, Inc., 1958); 141.
[424] "Edmund Scientific," *Sky & Telescope*, 10 (January1953): 78.
[425] "Small Telescopes for the Beginning Observer, Cave Optical Company," (Long Beach, CA: Cave Optical Company, 1960); 1.

department stores began selling these imported Japanese telescopes as well. Sears Roebuck had only a few cheap hand-held telescopes for sale in its catalogues from the 1920s to the 1940s. However, by 1961, Sears had a total of nine models of astronomical telescope for sale, all Japanese imports under the Tower label. These telescopes started with a modest but useful 2-inch (50mm) telescope for $24.94, up to a much more sophisticated 3-inch (80mm) equatorially-mounted telescope for $199.95 ($147 to $1,180), still quite affordable compared to telescopes sold earlier in the 20th century.[426] But while the Japanese influence helped expand the range of the American market, the international business pressure also produced some negative effects on American optical-goods manufacturers. In 1958, one Edmund Scientific advertisement declared that "due to Japanese competition we close these [American military surplus 7x50 monoculars] out at a bargain price".[427]

6. The new telescope makers III: innovative ATMs

Even with the vast increase in numbers of American telescope makers in Post-War America, as well as the new imported telescopes, amateur telescope makers continued to produce their own instruments. Although consumers could now buy a 6-inch Newtonian reflector for today's equivalent of about $1,300, ATMs of the 1950s found they could still make one of their own for less. Besides this, ATMs enjoyed doing things differently. They were constantly trying out and sharing new concepts in traditional telescope designs. At the 1954 Stellafane meeting, T. J. Ryan of Brooklyn, New York,

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426 *1961 Sears Roebuck Catalogue* (Chicago, IL: Sears Roebuck and Company, 1961); 748.

427 "Edmund Scientific," *Scientific American*, 198 (January 1958): 108. Monoculars are simply one-half of a pair of binoculars. Those mentioned in the advertisement were the United States Army and Navy standard 7 power, 50mm diameter size.

just one of about 250 attendees that year, brought a well-built 6-inch short-focus Newtonian telescope to display. The notable features of Ryan's telescope were its compact size, 'fast' focal-ratio (only f/5, as compared to the more usual f/8), and low-profile alt-azimuth mounting made of plywood in the shape of a simple box. Ryan's design was one of few at Stellafane that year that was centered on an alt-azimuth mounting; the vast majority of telescopes on display featured well-executed equatorial mounts made of steel and aluminum. Ryan's telescope design failed to catch on in the 1950s, but would be 'resurrected' around 1970 as the 'Dobsonian' telescope.[428]

Fig. 52 – T. J. Ryan (far right) and interested spectators view his simply-mounted 6-inch f/5 Newtonian telescope at the 1954 Stellafane meeting (from *Sky & Telescope*).

'Odd' telescope designs were a challenge and appealed to ATMs. The Schmidt camera was originally a purpose-built telescope for astrophotography. Designed by the German optician Bernhard Schmidt in 1932, the Schmidt camera was notable for its

[428] "Stellafane Convention – 1954," *Sky & Telescope*, 14 (November, 1954): 18–19.

extremely short focal ratio and wide field of view. Telescopes, and cameras, for that matter, of short focal ratio are extremely efficient at exposing photographic plates, vastly reducing the times of exposures. Photographs of stars and nebulae that took an hour or more to appear on film with conventional telescopes, took only minutes with a Schmidt camera. The camera itself is remarkably simple. A concave mirror collects light, in the same way as a normal reflecting telescope, bringing light to a focus. However, the mirror is spherical in cross-section: spherical aberration, as in the case of the Maksutov, is corrected by a large correcting lens placed ahead of both the mirror and the focus. The focal ratio is extremely 'fast' in a Schmidt camera, often f/1 to f/1.5. It is easy to produce such a steeply-curved spherical mirror, but the correcting lens is extremely difficult to make. Though American astronomers were quick to appreciate the Schmidt design's capabilities, few professional telescope makers were interested in the investment required to produce such a radically new telescope. Where professional telescope makers feared to tread, ATMs stepped in.

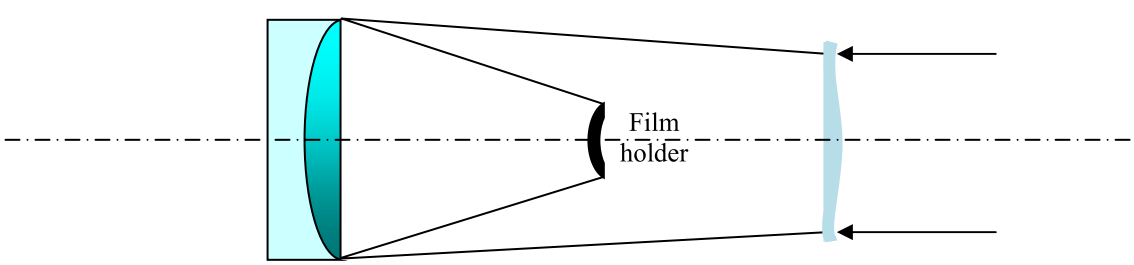

Fig. 53 – Optical layout of the Schmidt Camera

The first American to construct a Schmidt camera was H. Page Bailey, an ATM in Riverside, California, in 1932. Bailey's 8-inch aperture, f/2.4 Schmidt was followed a few years later by a camera of the same aperture, but a much faster f/1 focal ratio constructed by Charles A. and Harold A. Lower of San Diego, California; Harold Lower later contributed a chapter on making Schmidt cameras for *Amateur Telescope Making – Advanced*.[429] By 1941, 37 Schmidt cameras had been completed in the United States, all but 8 made by amateurs, including several in use by professional astronomers.[430]

At the same time that the Maksutov telescope was being developed into the commercially successful Questar, the promise of this unusual design also interested ATMs. In 1956, excitement about the concept even sparked the formation of an organized group of ATMs, the Maksutov Club. This new group hoped to promote the manufacture of the Maksutov telescope design among amateur telescope makers and provide its members with both technical assistance and financial support, via bulk purchases of materials. The creation of the group was prompted by James Baker, acting as yet another 'technological cheerleader', who gave a lecture at the annual Stellafane conference on August 11, 1956.[431] "Catadioptrics and an Off-axis Maksutov System" specifically concerned his own variation on this design, but *Sky and Telescope* noted that a broader "Amateur interest in Maksutov telescopes was very evident at the convention. During his afternoon talk, Dr. Baker urged that amateurs consider making Maksutov instruments."[432] In fact, Stellafane attendees could actually inspect a small Maksutov telescope at the meeting, one built by an amateur telescope maker named John Gregory, who would later, as a professional optician, go on to patent the Gregory-Maksutov design. Also delivering a paper at the 1956 meeting was Allan Mackintosh, a well

[429] Harold A. Lower, "Notes on the Construction of an F/1 Schmidt Camera", *Amateur Telescope Making – Advanced*; 410–416.
[430] James G. Baker, *Telescopes and Accessories*; 292–293.
[431] *Amateur Telescope Making, Book III*, Albert G. Ingalls, editor (Kingsport, TN: Scientific American, Inc., 1953); 615.
[432] "A Convention in Vermont", *Sky &Telescope*, 15 (October, 1956): 533.

respected amateur astronomer and telescope maker; Baker, Mackintosh, and others participated in a discussion that afternoon which spurred the birth of the Maksutov Club. Over subsequent years, amateur telescope makers played with variations of the basic Maksutov design, with the assistance of professional optical designers such as Baker.[433]

The Schmidt camera and the variations on the Maksutov are just two of many examples of unusual telescope designs that postwar ATMs took on, in what might be called the 'mature' or 'experimental' phase of the ATM movement. Although there were plenty of amateurs who just wanted an inexpensive Newtonian telescope, many others wanted something that pushed the creative envelope. Amateur telescope makers were bold in what they did. Baker recognized this when he said:

> "They know no defeat and, in the true spirit of the amateur, unhampered by professional reputation, by contracts, or time limits, they patiently polish away on their surfaces towards the desired optical perfection. . . . They have produced not only conventional surfaces of great excellence, but they have tackled with equal enthusiasm and success the odd and the unusual."[434]

7. <u>The changing faces of amateur astronomy: families, 'juniors', women, and minorities</u>

While specialist groups concentrated their attentions on narrow, technical subjects such as monitoring variable stars, lunar and planetary observing, or telescope making, the field of amateur astronomy as a whole was changing drastically. Families, women, children, and minorities were increasingly involved in the amateur astronomical community after World War II. As amateur astronomy clubs grew in number, members

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[433] James G. Baker, "Optical Systems for Astronomical Photography", *Amateur Telescope Making, Book III*; 1–8.
[434] Baker, *Telescopes and Accessories*; 223.

became more engaged in cooperative efforts with their communities, offering themselves as local 'experts' on astronomical questions to schools and newspapers. While many amateur astronomical societies in the United States began simply as efforts to gather together with like-minded individuals, to learn from others how to navigate the sky or make a telescope, many groups soon also adopted the self-imposed purpose of public outreach. Members of astronomy clubs opened their monthly meetings to visitors, gave public lectures at local libraries and schools, and set their telescopes up at public venues (school-grounds and parks) to give average people views of the night sky at "star parties". Some amateurs even started teaching more formal adult education classes in astronomy.

As astronomy clubs developed greater material and financial assets, many of them built club observatories, something nearly unheard-of prior to 1940. When club members were not using observatories, they often opened them to the public. Amateurs increasingly cooperated with schools and colleges, providing equipment too expensive to be purchased otherwise, including complete observatories. However, at the same time amateur astronomy was becoming more socially inclusive, it was also becoming less relevant to the professional astronomical community. Although more amateur astronomers were observing, the proportion who were serious observers declined. Astronomy was becoming a recreational hobby, albeit one that was scientifically and educationally-oriented.

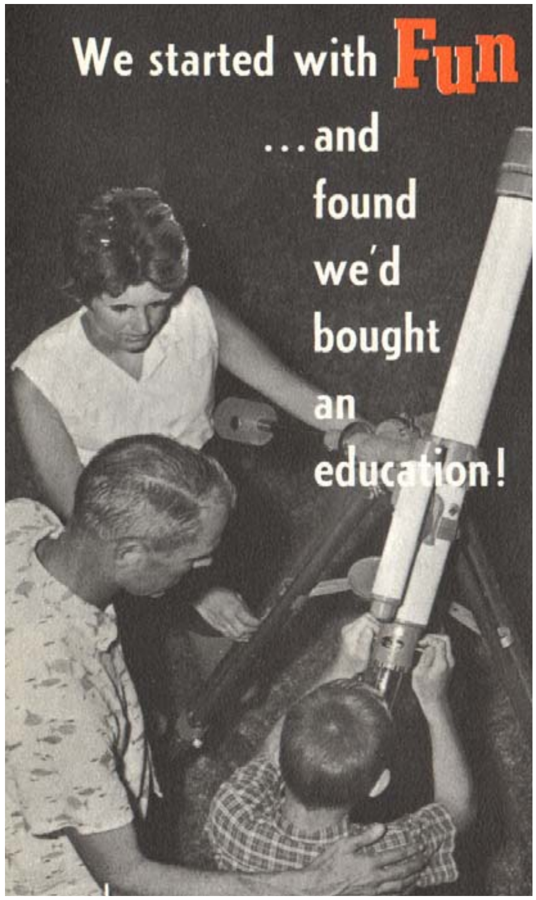

Fig. 54 – Cover for the November, 1961 sales brochure for Swift Instruments, Inc.

By the late 1950s, American amateur astronomy had visibly embraced a mission of contributing to the national education of children and families. This is not to say that there was no such aspect to amateur astronomy prior to this time, but the intensity had increased. Telescope manufacturers were more aware of the growing family-orientation of amateur astronomy, and adjusted their advertising appropriately. Telescopes were no longer marketed only to isolated, serious, male astronomers; companies promoted them as a purchase that the whole family could enjoy. The International Geophysical Year of 1957-58 also had an impact on amateur astronomy, though not as immediate as one might perhaps think. Amateur astronomers, and companies selling telescopes, had already been prepared for observing artificial satellites long before the launch of Sputnik in October, 1957. Project Moonwatch was a major effort on the part of a few professional scientists and science popularizers to organize amateur astronomers to contribute to a major international research effort. Moonwatch leaders recruited and trained thousands of amateur astronomers, students, and those simply interested in science, in techniques for observing artificial satellites.[435] While Project Moonwatch, the launch of Sputnik, and the new Space Age certainly had an impact on amateur astronomy and science education in America, such impact was actually surprisingly slow to build. In the 1950s, Dale P. Cruikshank, an amateur astronomer and President of the Des Moines Division of the Great Plains Astronomical Society (GPAS), noted that membership in the club had only increased by about 10% in the year following Sputnik's launch, far from a tidal wave of interest.[436] Of more impact was the United States government's Cold War effort at increasing funding for science education, including astronomy. From 1958 onwards, there was a massive flow of funding for new school, college, and public planetaria, observatories, and science museums. Many of these new facilities would serve as meeting places for both established and new amateur astronomy clubs.

The launch of Sputnik in 1957 did not cause a major change in the face of amateur astronomy in the United States, because the field was already in the process of changing. Compared to 1910, or even 1930, the demographics of amateur astronomy had altered drastically by the 1950s, not just in terms of economic classes involved, but in age groups as well. Teen-agers, and even younger children, were increasingly involved in

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[435] See, W. Patrick McCray, *Keep Watching the Skies: The Story of Operation Moonwatch & the Dawn of the Space Age*, (Princeton, NJ & Oxford, UK: Princeton University Press, 2008).
[436] Dale P. Cruikshank, "Dale P. Cruikshank to Bill Baily," June 4, 1958.

organized postwar amateur astronomy. While there had always been a few young people involved in amateur astronomy (young George E. Hale comes to mind), they were not really part of organized groups. Following World War II, enthusiasts organized a number of 'Junior' astronomy clubs, some as auxiliaries to existing clubs, others as independent efforts. While the launch of Sputnik might have had some impact on the growth of younger peoples' involvement in amateur astronomy, it seems clear from the evidence that 'Space Age' astronomy and 'Youth' astronomy simply had a co-developmental relation, rather than a causal one.[437]

Of 84 active astronomy clubs in 1949, only one, the Junior Astronomy Club of New York City, was primarily designed to attract and encourage younger astronomers. By 1958, there were a total of 220 astronomy clubs in the United States; of these, there were 'junior astronomical societies' in 10 cities in all parts of the country.[438] In addition to the ten-fold increase in organized astronomy clubs specifically for teen-agers and young-adults, the membership rosters of regular astronomy clubs were getting younger. A major driving force behind the Des Moines Division of the Great Plains Astronomical Society (GPAS) was Dale Cruikshank, who was only a high-school student at the same time he served as President of the club. One 1950s study found that fully one-half of the surveyed members of the GPAS were either junior high-school, senior high-school or college students.[439] They were full of enthusiasm and fascination with the "scientific"

[437] One might also credit the influence of science fiction, the 'UFO phenomenon', and other such factors, but science fiction, at least, had been around as a genre of popular fiction since the late 19th century.
[438] Pueblo, CO, Chicago, Madison, IN, Louisville, KY, Grand Rapids, MI, Minneapolis, Brooklyn, NY, Millvale, PA, Fort Worth, TX, and Richmond, VA. As a percentage, this would be: 1.2% in 1949, versus 4.5% in 1958.
[439] James E. King, "Results of Questionaire to Amateur Astronomers About Their Hobby – Chapter III of MA Thesis," reprinted in *Through-the-Eyepiece*, 7 (November, 1957): 5–14, on 6.

world around them. The Junior Astronomy Club of Cleveland was a particularly large and active group in the late 1940s. Meeting at the Cleveland Museum of Natural History, the JACC conducted telescope making classes involving as many as 145 local high-school aged members, boys and girls, supervised by instructors recruited from the Cleveland Astronomical Society. Other JACC activities reached out to even younger students, helping them assemble their own small refracting telescopes from military surplus parts.[440]

Fig, 55 – Students in class at the Cleveland Museum assemble telescopes (from *Sky & Telescope*, 1949)

Women played a relatively small role in astronomy prior to the 1940s. In the 19th century, one can find a few examples of professional astronomers such as Maria Mitchell and her students at Vassar. Although Mitchell was an active observer and well-known

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[440] "The Junior Astronomy Club of Cleveland," *Sky & Telescope*, 8 (May, 1949): 172. Frank Meyer, "Telescopes for Juniors," *Sky & Telescope*, 8 (September, 1949): 282–284.

comet-hunter, her main role was as a teacher training future teachers. By the turn of the century, there were a number of female astronomers involved in support activities at major American observatories. Edward Pickering, director of Harvard College Observatory, hired a number of women as 'computers' to do data-analysis. There were also a few women science-writers involved in popularizing astronomy and other sciences. However, female observational astronomers, amateur or professional, were extremely rare prior to the 20th century. The few prominent women observers were primarily working in support of their husbands' work, such as Anna Draper, wife of Henry Draper.

Women became much more involved in astronomy following World War II. It is admittedly difficult to determine real numbers of women involving themselves in amateur astronomy, as membership lists are not readily available. It is evident that outside of colleges, women were increasingly signing up for adult education classes in astronomy. In one case, 5 out of 8 students were women in an adult education astronomy class taught by an amateur in Pleasantville, New York.[441] Of course, many couples likely joined astronomy clubs together. Women on their own were also joining astronomy clubs. A news note in the June, 1956 Sky & Telescope, mentions that members of the Columbus Astronomical Society (Ohio) set up an exhibit of telescopes, including a 6-inch Newtonian owned by a Sylvia Lane.[442] Miss Mary Leshko, of Marshalltown, Iowa, was a long-time member of the Marshalltown chapter of the GPAS who served as secretary and treasurer for many years. Women officers are frequently mentioned in club reports in *Sky & Telescope* from the mid-1950s, onward. The Argonne Astronomy Club

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[441] George W. Michalec, "The Amateur Astronomer as a Community Teacher," *Sky & Telescope*, 9 (September, 1950): 267–268.
[442] "Amateur Astronomers," *Sky & Telescope*, 15 (June, 1956): 353.

included Marilyn Franzen as secretary-treasurer; Mrs. Charlotte Kelley served as vice-president and Mrs. Preston Nowlin as secretary of the Charlotte Amateur Astronomers Club in North Carolina.[443] Women were also becoming increasingly visible at the national levels of amateur astronomy. In 1955, two of the Astronomical League's newly-elected officers were women: Wilma Cherup as executive secretary, and Miss Grace C. Scholz president.[444]

If women were sparsely represented in American amateur astronomy prior to the 1940s, African-Americans and other minorities were effectively non-existent. Virtually the only prominent African-American astronomer of the 18th and 19th centuries was Benjamin Banneker (1731-1806). There were, of course, schools and colleges established for educating blacks in America, such as Howard University in Washington, DC. But there is little evidence that black Americans participated in amateur astronomy before World War II, and none were known to have been telescope-makers. William Calder was professor of physics and astronomy at Howard University in the 1940s when he started a telescope-making class for some of his students. Little is known about Calder's students, except that they were apparently very capable.[445] As a group, they successfully constructed seventeen identical 6-inch f/8 Newtonian reflecting telescopes in a workshop at Howard, making the mirrors and all mechanical parts.

[443] "Amateur Astronomers," *Sky & Telescope*, 16 (February, 1957): 178.
[444] "Amateurs Convene at Seattle," *Sky & Telescope*, 14 (September, 1955): 456–459.
[445] Maurice S. A. Delaney, "Operation ATM at Howard University," *Sky & Telescope*, 7 (February, 1948): 90.

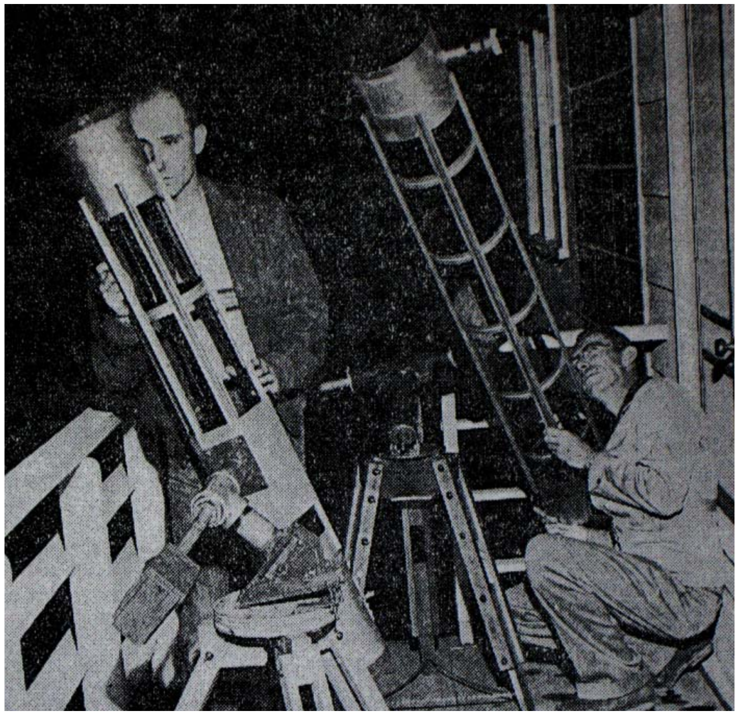

Fig. 56 – Great Plains Astronomical Society members Bill Banzhaf (left) and Donald Dean (right) observe with their $40, home-made, 6-inch reflecting telescopes (from the *Marshalltown Times-Republican*, May 31, 1957).

Still, the majority of amateur astronomers in the 1950s were white, middle-class, adult males. Even here, though, there were some changes. In the 1957 survey of the GPAS cited earlier, about half the membership were working adults. There were three mechanics, two professors of astronomy, two church ministers, a museum director, a lawyer, an optometrist, an osteopathic surgeon, a dentist, an office manager, a watchmaker, a teacher, and an engineer.[446] Two members of the Marshalltown, Iowa, branch of the GPAS, Donald Dean and Bill Banzhaff, worked at a roofing company when they became interested in telescope making in 1956; they completed nearly identical Newtonian telescopes a year later, and the two were featured in an article in their local newspaper. They explained that theirs had been a fairly long-term interest in astronomy,

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[446] J. King, "Results of Questionaire": 6.

but an interest frustrated for many years, since "you had to have a telescope and commercially built models ran $300 and more."[447] In 1960, a group of workers at the Union Carbide plant in Charleston, West Virginia, formed the "Questeers Amateur Astronomical Society".[448] The changing shape of this hobby reflected the fact that the American economy was changing. The United States was entering an "Age of Affluence" in 1950; Social Security, the GI Bill, and various other government policies and programs improved the economic picture for many families. The forced savings of Americans during World War II were released, following the end of the war. By 1950, real per capita GNP and real disposable income had both nearly doubled over what they were in 1935.[449] By 1950, half of all American laborers owned a car, and could spend 6.6% of their budget on recreation and education, as opposed to only 3.8% in 1918.[450] What it meant to be 'working class' or 'middle class' was becoming less well-defined, in terms of things like hobbies and interests. Leisure time was also increasing; the 40-hour work-week was largely in place by the mid-1930s and after World War II, ordinary American routinely expected to enjoy paid vacations.[451]

8. Cooperative ventures: Post-War astronomy clubs, observatories, & 'star parties'

As the American amateur astronomical community grew in size, increasing numbers of organized groups formed. By 1940, there were said to be around 60 amateur astronomy and amateur telescope making clubs in the United States. *Sky & Telescope*

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[447] Bill Baker, "City Men Spend Their Enjoyable Hours Studying Planets With Their Homemade Telescopes," *Marshalltown Times-Republican*, May 31, 1957: clipping, page not known.
[448] "Amateur Astronomers", *Sky & Telescope*, 19 (April, 1960): 350.
[449] Claire Brown, *American Standards of Living, 1918–1988*, (Oxford, UK & Cambridge, USA: Blackwell, 1994); 187–189.
[450] Brown; 105.
[451] Brown; 228–233.

regularly listed known astronomy clubs in America in the column, “Here and There with Amateurs”. In 1947, there were 74; by 1960, there were 220, in nearly every state of the Union. There were also new amateur astronomy organizations at the national level. The Astronomical League (AL) was formed in 1941, went on hiatus during the War, but returned afterwards. Unlike earlier attempts, the Astronomical League held together, and attracted large numbers of members, in part because it was both a federation of local astronomy groups (ensuring the local control that so many Americans hold dear) and allowed individual memberships from those not belonging to groups. The AL also survived in part because it divided itself into regions, each having its own ‘council’ and officers, and holding annual regional meetings. The AL national meetings were well-attended, and moved about from place to place each year, permitting nearly every member a chance to attend once every few years.[452] Another new national, in fact international, group of amateur astronomers formed in 1947: the Association of Lunar and Planetary Observers (ALPO). The ALPO was a highly specialized group dedicated to fairly serious observing in support of professional astronomers, as was the case with the AAVSO. ALPO had originated between 1938 and 1947 as an informal network of amateur planetary observers, led by Walter Haas (who, by 1947, had been awarded an MA degree in mathematics from Ohio State). Over the years, its ranks came to include a number of notable amateurs, including Tom Cave.[453]

Astronomy clubs met in a variety of venues; some at college and university observatories, others at schools, museums, and libraries, and still others met at members’

[452] See, Williams, “Getting Organized”; 305–350. Williams notes that the AL formed in 1947, but efforts actually began in 1941.
[453] Williams, “Getting Started”; 271–304.

homes. The Ann Arbor Amateur Astronomical Association met at the University of Michigan Observatory; the Amateur Telescope Makers of Boston met at the Harvard Observatory; and the Madison Astronomical Society met at the University of Wisconsin's Washburn Observatory. The Excelsior Telescope Club of Norwalk, California, met at the Excelsior Union High School. The Stamford Amateur Astronomers, Stamford, Connecticut, met at the Stamford Museum, which had just installed a planetarium in 1950, partly due to the efforts of the astronomy club. The Popular Astronomy Club in Moline, Illinois, met at the Sky Ridge Observatory, a small private observatory built by PAC member Carl Gamble. The St. Louis Amateur Astronomical Society met in members' homes, despite being located in a large city.[454] Of 84 active astronomy clubs in the United States in 1949, 15 met at college or public observatories, 4 at private or club-owned observatories, 16 at colleges and high schools, 14 at public planetaria and museums, 12 at public libraries and auditoriums, and 23 at members' homes.

"Star parties", informal gatherings of amateur astronomers and their telescopes for the purpose of recreational observing, became an increasingly prominent feature of Post-War amateur astronomy in the United States. Though sometimes hosted at a club or private observatory, such events were mostly set up in someone's backyard, using telescopes owned by individual club members. Star parties were important features of astronomy club life, a time when members could relax, socialize, talk about telescopes, try out each other's telescopic equipment, and simply observe the night sky. Star parties were also important for public outreach and recruitment of new club members. New

[454] "Here and There With Amateurs," *Sky & Telescope*, 8 (January, 1949): 79.

amateur astronomers were far more likely to become engaged by attending star parties and making friends with established amateur astronomers, rather than simply by learning about astronomy in school.[455]

Amateur astronomers and telescope makers frequently built telescopes, and even whole observatories, as part of cooperative ventures with schools, colleges, and other public educational facilities. One of the most spectacular early efforts at a cooperative venture was the Goethe Link Observatory, built in 1940 near Brooklyn, Indiana. Dr. Goethe Link was a surgeon from Indianapolis who noted the lack of any substantial astronomical facility for central Indiana's colleges and universities. Link financed the construction of a 36-inch reflecting telescope, with optical and mechanical components made by members of the Amateur Astronomers of Indianapolis. Fortunately, the AAI membership included a number of talented individuals, including professional mechanical engineer Carl Turner, and the group acquired a 36-inch Pyrex mirror blank and constructed a mirror-grinding machine. Local ATMs Charles Herman and V. E. Maier, successfully parabolized the mirror after 30 months' work, and it was mounted in the telescope in 1940. The observatory was opened to use by college and university students and faculty, as well as amateurs, and held regular public nights on Sundays.[456]

The Twin Ridge Observatory was a rather unique effort on the part of a Virginia amateur astronomer. Clyde Childress owned a drive-in movie theater just outside Richmond and between 1952 and 1956 constructed his observatory near the theater. Equipped with a 12½-inch reflecting telescope, Childress' observatory was open to

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[455] J. King, "Results of Questionaire": 7–8.

[456] Victor C. Maier, "Goethe Link Observatory: Built, With Its 36-Inch Telescope, by Amateur Astronomers of Indianapolis . . . Financed by Local Enlightenment . . . Presented to Science," *Scientific American*, 162 (June, 1940): 347.

members of the Richmond Astronomical Society, local school groups, Boy and Girl Scouts, and church groups, as many as 150 visitors at a time.[457] The Des Moines Division of the GPAS usually held its monthly meetings at the Drake Municipal Observatory. The members of the GPAS were fortunate in having a good relationship with Drake University astronomer, Dr. Phillip Riggs. In exchange for use of the observatory facilities for meetings and observing time, GPAS members assisted with weekend public nights. The amateurs would often bring their own telescopes to the Drake Observatory to help with 'over-flow' crowds for these public 'star parties'.

9. Conclusion

Amateur astronomy and the formation of organized astronomy groups grew at an astonishing rate between 1940 and 1960. Although some growth had occurred prior to 1940 and also continued after 1960, the rate of amateur astronomy's growth was greatest from 1940 to 1960, and particularly during the 1950s.[458] Although many factors were likely involved, the rapid increase in the popularity in amateur astronomy coincides so well with the development of inexpensive telescopes in America that it is difficult to believe the two are unrelated. Historian Thomas Williams concurs with this opinion in his dissertation on amateur astronomical organizations, but does not delve deeply into the detailed economic and technological factors involved.

The combination of new American manufactures and new sources of imported optics contributed to a rapid growth in amateur astronomy in America in the 1950s. Aside from a listing of new telescope companies after 1945, the trend toward telescope

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[457] "Twin Ridge Observatory in Virginia," *Sky & Telescope*, 15 (June, 1956): 353.
[458] Williams, "Getting Organized"; 329.

accessibility is also revealed by simply looking at the number and variety of advertising in such magazines as *Sky & Telescope*. The November, 1947 issue of Sky and Telescope included advertisements for only three manufacturers of complete telescopes, and eleven suppliers of either mechanical or optical components for telescopes, or military surplus optics.[459] By April 1958, there were fifteen ads alone for complete telescopes and sixteen more for components, accessories, and surplus optics.[460]

The new availability of instruments and do-it-yourself parts clearly made a difference to interested individuals. In 1958, *Thru-the-Eyepiece*, the newsletter of the Great Plains Astronomical Society, included a series of articles and reports on telescopes owned by members. Iowa members of the GPAS responding to a survey reported owning 29 telescopes ranging from 2-inch to 12½-inch aperture, the vast majority being Newtonian reflectors. These amateur astronomers were from all over the state of Iowa, only ten coming from major cities like Des Moines and Waterloo.[461] Out of eleven club members, ten amateur astronomers living in Marshalltown, Iowa owned a telescope of some kind, six of them owned home-made Newtonian reflectors of from 5 to 10-inches in aperture, and the remainder owned either small commercial telescopes (including a 4¼-inch Edmund Scientific Newtonian, a 2.4-inch and 3-inch refractors by Unitron), or only

[459] Sellers of complete telescopes were Sky-Scope (New York), W. Ottway & Co., Ltd. (England), and Tinsley Laboratories (California) and of these only Sky-Scope was new.

[460] Complete telescopes by Cave Optical Company (California), Treckerscope-Coast Instrument, Inc. (California), Stellar Scientific Instruments (CA), Cal-Astro Optical Laboratories (CA), O. Magnusson (Colorado), Questar Corporation (PA), Criterion Manufacturing Company – two separate ads (CT), Sky-Scope (New York), Goto Optical Manufacturing Company (Japan), Unitron – United Scientific Company – two separate ads (MA), Edmund Scientific Co. (NJ), Radio Shack (CT), and Tinsley (CA).

[461] James E. King, "Chapter IX, Jim King's Thesis – Appendices," *Thru-the-Eyepiece*, 7 (July, 1958): 5 – 11, on 7. 28 persons responded to the survey; Dale Cruikshank owned two telescopes (6-inch and 12-inch Newtonians), and the remainder amounted to 2 2-inch, 1 2.4-inch, and 3 3-inch refractors, 1 3-nch, 1 3½-inch, 3 4-inch, 1 4½-inch, 9 6-inch, 3 8-inch, 3 10-inch, 1 12-inch, and 1 12½-inch Newtonian reflectors.

binoculars or a spotting telescope. Some owned more than one telescope.[462] The fact that nearly everyone in a small-town astronomy club personally owned a telescope would have been unheard of fifty years earlier.

The launch of Sputnik in 1957 intensified American concern about science education. The Cold War's American vs. Soviet space race increased public consciousness of space, science, science literacy and threats to America. However, it is not apparent that Sputnik directly led to any immediate gains to amateur astronomy. In fact, evidence clearly suggests that the great increase in active participation in amateur astronomy pre-dates Sputnik's launch by several years. Astronomy was already a growing hobby by 1957. Amateurs frequently mentioned telescopes as an integral part of why they joined astronomy clubs. However, in many cases it was not that they joined astronomy clubs to acquire use of someone else's telescope; rather they joined to use their own. Reports of the activities of astronomy clubs appearing in magazines like *Sky & Telescope* constantly refer to how many telescopes the groups possessed. Individual ownership of a telescope was as important to these postwar ordinary Americans as was ownership of a car or a house.

The Second World War, not the launch of Sputnik, was the key event leading to the explosive growth in amateur astronomy in the 1950s. Military need for optical instruments during the war led to the employment of a number of pre-war ATMs in war production. Learning mass-production techniques, these ATMs then started their own telescope making companies after the war. Firms such as Cave Optical Company,

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[462] "Membership Roster, Central Iowa Division, Great Plains Astronomical Society, Marshalltown, Iowa", *Thru-the-Eyepiece*, 7 (July 1958): 11.

Criterion, and others, turned out extremely large numbers, compared to any previous era's production of telescopes. These new telescopes were of designs that benefited, to an extent, from quantity-production methods. Postwar manufacturers tried out new and often more affordable materials; telescope tubes for reflecting telescopes of the 1940s and 1950s were made of fiberglass, Bakelite, or even cardboard. Amateurs building their own telescopes had long used similarly simple materials, yet their telescopes worked fine. They saw no reason to immediately dismiss the cardboard-tube of the Sky-Scope and other budget models.

As a result of the availability of inexpensive telescopes, amateur astronomy became a hobby that appealed to a much wider cross-section of the American population. Families, and especially school-aged children, could participate to an extent not previously seen. The many new amateur astronomy clubs in the 1950s were more out-going than the old, elitist groups, such as the Chicago Astronomical Society, of 1862. Astronomy was no longer just for 'serious' amateur scientists. Everyone could find a place in the American amateur astronomy community of 1960.

Chapter VI: Other Modes and Models: Popularization of Astronomy in Europe & Japan

1. Introduction

Amateur astronomy was of course not restricted to the United States. If anything, the amateur traditions had been stronger in Britain and the rest of Western Europe than in the United States in the 19th century. Amateur telescope-making was likewise a hobby with foundations in Europe, as has already been noted. Although the origins of the American ATM movement of the 1920s was in both American and European traditions, its legacy subsequently spread to other countries as well, particularly Japan. Though it would be simplistic to say that the Japanese telescope-making industry owed its existence to American ATMs, there was certainly an influence.

However, countries outside the United States also had their own traditions and their own unique ways of doing things. American amateur astronomers and amateur telescope makers tended to organize in relatively small, independent groups. Despite a few early attempts to form a larger umbrella organization, the first real nationwide association of amateurs in the United States did not emerge until 1947. Amateur groups in other countries were far more highly centralized, if not for day-to-day operations, then certainly for organization, communication, and coordination. Economic realities that shaped the spread and practice of amateur astronomy were also different in America from the rest of the world. American workers and salaried employees were far better paid than those in Europe, even after the Second World War. In Post-War Europe, commercially-made telescopes were far less common and more expensive than those in America. Amateur astronomers outside America thus tended to depend to a far greater extent on shared telescopic equipment, as result of economic conditions and organizational traditions. University and purpose-built public observatories were more common and more important for astronomy popularization outside the United States and were more frequently the center of amateur activity.

2. Amateur astronomy in Britain, Western Europe, Russia, and Japan

Researching the history of amateur astronomy outside of Britain and the United States is problematic and frustrating. Very little serious historical research on amateur astronomy has been done until recently, and that focuses mostly on Victorian Britain. Secondary sources are almost totally lacking on the history of amateur astronomy in France, Germany, and elsewhere in continental Europe. This situation is just beginning to change, but much must be determined based on conjecture. The most extensive historical work on amateur astronomy is Allan Chapman's previously cited *The Victorian Amateur Astronomer* (1998). Historian Augusti Neito-Galan recently (October 2009) published a history of early 20th century amateur astronomy in Spain.[463] Beyond this are a few short biographical articles and some semi-popular histories. Developing a full picture of amateur astronomy outside of Britain and the United States requires far more effort than can be devoted to it here, but some conclusions suggest the value of an international comparative history.

The popularity of amateur astronomy in the 20th century outside the United States is rather difficult to gauge. However, considering that public observatories and planetaria in Europe were drawing crowds of hundreds of thousands each year gives some

[463] Agusti Nieto-Galan, "”… not fundamental in a state of full civilization”: The Sociedad Astronómica de Barcelona (1910-1921) and its Popularization Programme,” *Annals of Science*, 66: 4, 497–528.

indication at least of latent interest in astronomy. The economic realities for those interested in becoming amateur astronomers outside the United States were far more restrictive than those in America, even after World War II. Despite the Post-War economic recovery, incomes for Europeans were far below those in the United States. Wages for European workers increased after World War II, but remained considerably below those paid to Americans. In 1960, the average hourly wage for manufacturing workers in the United States was $2.28, but only $0.82 for German and British workers, and $0.51 for French.[464] Such low wages were somewhat compensated for by various types of government support, but were still far less than those paid to American workers. The actual standards of living in Europe compared to America gives a better idea of who might, or might not, have been able to afford their own telescope. As late as 1969 Europeans owned only about half as many telephones, passenger cars, and television sets as did Americans.[465] Differences in social class and education were far more marked in Europe than in America. Certain subjects were more 'elite' or 'proletarian' than others: the upper classes in Britain enjoyed tennis, whereas workers liked soccer.[466]Astronomy was no doubt of greater interest to the social elite of Europe well into the 20th century, but it is very difficult to say exactly what interest working-class individuals might have had. There are enough examples of working-class amateurs in Britain to show that there was at least some interest in the subject.

British amateur astronomy was both highly independent and highly organized. By this I mean that amateur astronomy in Britain had a long tradition of many independent,

[464] J. Robert Wegs and Robert Ladrech, *Europe Since 1945: A Concise History, Fourth Edition*, (New York: St. Martins Press, 1996); 161–163.
[465] Wegs and Ladrech; 169.
[466] Wegs and Ladrech; 200.

and largely independently wealthy, observational astronomers with their own private observatories and thus not tied to institutions. At the same time, these amateur scientists of means were quick to organize themselves into both formal and informal groups; the earliest astronomical organization in the world was the Royal Astronomical Society, organized in 1820, a group that included (and still includes) both amateurs and professionals. Another distinguishing feature of British astronomy was its observational nature. While astronomy in France, Germany, and Russia was slanted more towards theoretical-mathematical work, British astronomy was strongly oriented towards observation, and observation required telescopes.[467]

It is here worth reiterating that early generations of British amateur astronomers can be divided into the categories of notable 'Grand amateurs', middle-class amateurs, and working-class amateurs. One of the foremost 'Grand amateurs' of the 19th century was Irish aristocrat William Parsons, Third Earl of Rosse (1801-1867). Parsons received his higher education at Trinity and Magdalen Colleges, Oxford; despite doing his expected duty as a Member of Parliament from 1823 to 1834, Parsons also took time to pursue considerable interest in astronomy.[468] Parsons seems to have acquired a telescope around 1827 and was publishing results of his observations the following year; the origins of Parsons' first telescope are obscure, but what is definitely known is that he soon began experiments in telescope-making. Beginning with very little practical knowledge on the subject, Parsons began experiments in casting speculum metal reflectors of very large size almost from the first; his earliest known telescope had a 36-

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[467] Chapman; 296.
[468] Patrick Moore, *The Astronomy of Birr Castle*, (London: Mitchell Beazley, 1971); 7–13.

inch diameter mirror following the Newtonian pattern. Parsons seems to have been a natural engineer (he was, in fact, the founder of a family of engineers) and developed a steam-powered mirror grinding and polishing machine. The 36-inch mirror, completed in 1839, was soon employed in astronomical research, but Parsons himself was not the chief observer. Like other 'Grand amateurs', Parsons invited more experienced observational astronomers to use his telescope, including Dr. Thomas Romney Robinson of Armagh Observatory, and the English astronomer Sir James South.[469] Parsons soon determined to build an even bigger, 72-inch aperture, telescope and successfully completed the telescope and mounting by February of 1845. The "Leviathan of Parsonstown", as the 72-inch telescope was called, soon made its mark as a research tool when it revealed the spiral structure of the 'nebula' Messier 51 (now known to be a galaxy).[470] Lord Rosse's telescope continued to be used for several decades, up to at least 1900. However, though it made a number of useful contributions to astronomy, it was difficult to use, increasingly obsolete from a technological standpoint, and plagued by the poor weather conditions of Ireland.

There were many wealthy middle-class amateurs in Britain. There were many businessmen, doctors, ministers, and the like, who chose astronomy as a pastime. William Huggins, Warren de la Rue, and Andrew A. Common were contemporaries of the American amateurs Rutherfurd and Draper and, like their American counterparts, were leaders in the emerging sciences of astrophysics, spectroscopy, and astrophotography. Common was a telescope maker as well as an expert

[469] Moore; 14–17.
[470] Moore; 22–28, 39.

astrophotographer and constructed some of the largest silver-on-glass reflecting telescopes of the 19th century. The amount that such amateurs expended on astronomical equipment in Britain was at least as great as in the United States. When Common started work on a 60-inch telescope, he sold his 36-inch reflector to another wealthy British amateur in 1885 for £2,500 ($2,200,000 today).[471]

Working-class amateurs existed in Britain fairly early in the 19th century, but were small in number. One 'Mr. Tregent', a London tailor, became interested in astronomy as a boy, purchased his first telescope in trade for making five new suits of clothes, and by 1856 had a 4¼-inch refractor that had cost £80 ($7,100). Tregent then took his telescope on the road and made as much as £125 per year giving ordinary London street folk a view of astronomical objects for "a penny a peep".[472] Tregent thus financed his hobby by being an itinerant lecturer. Amateur astronomical societies became increasingly common in Britain after about 1860 and these groups were very beneficial to amateurs of lesser means. The Leeds Astronomical Society was established in 1859 and had its own observatory by 1863, equipped with a 3-inch refractor, which was used jointly by society members.[473] In the 1860s, Liverpool had a number of lower middle-class and working-class individuals interested in astronomy; they pooled their money, purchased *en masse* a number of 2-inch objective lenses and brass tubing, and assembled several small telescopes for use by members in a kind of 'borrowing library'. The group of telescope makers in Liverpool soon formed the Liverpool Astronomical Society and met regularly to hear lectures, in much the same way as did the local literary society and mechanics'

[471] Chapman; 137.
[472] Chapman; 174–175.
[473] Chapman; 245–246.

institute. The LAS was later (1889) given a 5-inch Cooke equatorial refractor which they placed in an observatory at the city-owned Liverpool Nautical College for use by college students, LAS members, and the public.[474] The groups in Leeds and Liverpool were just two of many local astronomical societies formed in Britain between 1860 and 1914. 1890 saw the founding of the British Astronomical Association (BAA), one of the largest, best organized amateur astronomy groups in the world in the early 20th century. The period from 1860 to 1914 was likely one of the greatest periods of growth in amateur astronomy in Britain.

Participation in amateur astronomy in Britain fell off a bit after the First World War. This is very different from the United States, which experienced a boom in amateur astronomy in the 1920s and 1930s. Observers were observing, well-known British amateurs like T. E. R. Phillips and W. H. Stevenson were writing popular books on astronomy, but somehow the inter-war period was not a vibrant one for amateur astronomy in Britain. Allan Chapman suggests that the Great Depression and the looming war had something to do with the comparative lack of enthusiasm for astronomy in Britain.[475] This does not explain why popular astronomy boomed in the United States. The Great Depression had just as much effect on Americans, yet there was a quadruple-growth in amateur astronomical societies in the 1930s. One thing that can definitely be said is that there was little sign of a mass wave of ATM work in Britain between 1920 and 1940 comparable to that which occurred in America.

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474 Chapman; 248, 254.
475 Chapman; 298–299.

British amateur astronomy grew in the years after the Second World War, but at a relatively slow rate compared to the United States. Records of the BAA show that from a low point of about 900 in 1940, membership had grown to 2,650 by 1960. However, BAA membership grew most rapidly between 1945 and 1950, as members drawn away by the war returned. In fact, while amateur astronomy was growing most quickly in America during the 1950s, it grew more slowly in Britain in the 1950s than it had in the 1940s. Membership in the BAA grew by only 80% between 1950 and 1960, as compared to 260% in the United States.[476] Economic stresses following World War II undoubtedly played a part in the relatively slow growth of membership in the BAA. Even the afternoon teas that were a regular part of BAA meetings had to be cut back in 1947: in October, sandwiches were no longer served, and in November, members had to bring their own milk due to rationing.[477] The BAA regularly increased its membership fees between 1945 and 1960.[478] As was the case in the United States, the launch of Sputnik had little effect on numbers of organized amateur astronomers in Britain. In fact, BAA membership actually dropped-off slightly between 1956 and 1958 and remained more or less steady for the next several years.[479] Sharing a telescope was still common practice for British amateur astronomers into the 20th century. Members of a small astronomy club formed in 1921 in the Llyfni Valley, Wales, were mostly miners, but managed to get hold of a 3½-inch Cooke refractor on long-term loan.[480] Such a large group of amateurs (50 members) sharing the use of a single, relatively small, telescope was something that was

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[476] "The British Astronomical Association: The Second Fifty Years", Richard McKim, Editor, *B.A.A. Memoirs*, 42, 2 (1990 December):122.
[477] "The BAA: The Second Fifty Years": 12.
[478] "The BAA: The Second Fifty Years": 13–22.
[479] "The BAA: The Second Fifty Years": 16, 122.
[480] Chapman; 266.

unheard of in America. The BAA Instruments Section maintained a collection of donated telescopes well into the 1960s to be loaned to active observers for research purposes. Individual telescope ownership in Britain only became common after 1960, due in considerable part to the increased availability of imported telescopes.

British amateur and professional astronomers maintained a close working relationship well into the 20th century and the distance between the two were "almost indefinable."[481] There were cases where the Royal Astronomic Society assisted the BAA financially and even allowed the amateurs to move into and share administrative space at the professional's headquarters at Burlington House, London. However, the British amateurs did not provide equipment for universities in the same way as their American counterparts did. There are few major examples of cooperative ventures in Britain, or anywhere else in Europe for that matter, comparable to the Goethe Link Observatory prior to the 1960s. When amateurs and professionals cooperated in Britain, it was often amateurs who used the professionals' telescopes. One of the few cases of amateurs giving equipment to professionals was in 1945 when BAA member Wilfred Hall donated his 15-inch refractor to the group; the BAA council subsequently determined they could not afford to house the instrument and it instead went to the Royal Astronomical Society.[482] Britain lagged behind both the United States and continental Europe in terms of public facilities for astronomy; the nation did not establish a public planetarium until 1958, which even then did not become much of a center for organized amateurs.[483]

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481 "The BAA: The Second Fifty Years": 9, 108.
482 "The BAA: The Second Fifty Years": 18–19.
483 "The BAA: The Second Fifty Years": 21.

Continental European amateur astronomy developed along somewhat different lines than it did in either America or Britain. Centralized, national amateur astronomical societies were first developed in France, created through the crucial contributions of Camille Flammarion (1842–1925). Flammarion's family origins were strictly middle-class, though economically stressed. Moving to Paris gave Flammarion a chance to learn a trade (engraving), and he learned something of science by attending lectures at the Polytechnic Association. Flammarion proved to be a talented observer and writer on astronomical subjects and became an apprentice observer at the Paris Observatory in 1858. Flammarion served as primarily a science popularizer, writer, and organizer. Flammarion's best-known work was *Astronomie Populaire* (1880), an exceedingly popular book subsequently translated into many languages. Flammarion founded the Juvisy Observatory in 1883 as a private venture, financed by a wealthy patron. Juvisy Observatory (about 20 miles outside Paris) was equipped with a 9½-inch (24-cm) Bardou equatorial refractor and was very much dedicated to lunar and planetary observing, Flammarion himself being fascinated with Mars.[484] Flammarion took the lead in founding the Société Astronomique de France (SAF) in 1887, a highly centralized group that served as a model for many other amateur astronomy organizations around the world.[485] The SAF was (and still is) made up of several provincial societies; in 1914 there were member societies in Amiens, Bordeaux, Le Havre, Lille, Marseille, Montpellier, Paris, Rouen, and Toulouse.[486] To a certain extent, the SAF mirrored many other organizations

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[484] Richard Baum, "Flammarion, Nicolas Camille," *Biographical Encyclopedia of Astronomy, Volume I*; 372–373.
[485] Roger Servajean, "Flammarion, Camille," *Dictionary of Scientific Biography, Vol. V*, (1972); 22.
[486] Nieto-Galan: 505.

in France, such as schools and universities, and even of the government in terms of its centralized structure.

Members of the SAF utilized both their own telescopes and those of others. Eugène Michael Antoniadi (1870–1944) was a teen-aged amateur astronomer when he began observing with a 3-inch refractor. Antoniadi submitted several exquisite drawings of the planets to the SAF and because of his observational skills began working as an assistant under Flammarion at Juvisy. After leaving the Juvisy Observatory in 1902, Antoniadi was lucky enough to marry a wealthy woman, and, as was the case with many an earlier amateur, her fortune financed his hobby. Antoniadi's personal telescope was an 8½-inch reflector (possibly of British make – Antoniadi was a member of the BAA and led its Mars observers' section for twenty years), but he was also able to observe with some of the largest professional telescopes in France including the 33-inch telescope at the Meudon Observatory, near Paris.[487] Antoniadi was, to a certain extent, the S. W. Burnham of France: an observer of such talent that even professional astronomers were willing to let him use their equipment.

The *Sociedad Astronómica de Barcelona* (SAB) was one of the many amateur astronomical societies that copied the SAF mold. The SAB was relatively short-lived (1910–1921) but was quite influential in its time, hosting the Exposición General de Estudios Lunares in 1912, a popular exhibit on lunar studies that drew crowds of 40,000 visitors per month.[488] Members of the SAB were involved in public education concerning astronomy, but also were active observers. Rafael Patxot (1862-1964) was the son of a

[487] William Sheehan, "Antoniadi, Eugène Michael," *Biographical Encyclopedia of Astronomy, Volume I*; 49–50.
[488] Nieto-Galan: 512–513.

wealthy Spanish businessman and became interested in astronomy after reading a number of popular works on the subject. Patxot owned a large equatorial telescope, a Mailhat refractor of 217mm (8.55-inch) aperture, which he eventually donated to the SAB.[489] A list of Jupiter observers during the 1910-1911 apparition of that planet shows that the majority of SAB's observers were equipped with small to medium-sized refractors, all of French or British make.[490] The SAB could not be considered an egalitarian group: members were all from the intellectual elite of Barcelona, including businessmen, doctors, artists, musicians, scientists, and teachers.

Though just south of the United States border, the Astronomical Society of Mexico (*Sociedad Astronomica de Mexico – SAM*), established in 1901, was organized very much on the same lines as the SAF and SAB. The SAM was formed largely due to the efforts of one man. Professor Luis G. Leon was a teacher of astronomy and an astronomy popularizer early in the 20th century, serving several terms as general-secretary of the SAM. The SAM operated a public observatory in Mexico City equipped with a 5-inch refractor made by the French firm of Mailhat; the observatory had over 12,000 visitors in 1908 alone. The SAM published a monthly bulletin and acted as a central clearinghouse for information and coordinator of activity. By 1913, there were

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489 Nieto-Galan: 502–503. Though Nieto-Galan did not state the maker of Patxot's telescope, a photograph clearly shows it is a Mailhat. In fact, the illustration in the French catalogue, *1901-1902 L'Industrie Français des Instruments de Précision,* for Mailhat (p.155) is *identical* to the photograph of Patxot's observatory, save that the Mailhat advertisement is a wood-cut with Patxot's image removed.
490 Nieto-Galan, p. 510. Telescopes included:

70mm (2.7-inch) refractor, maker unknown
80mm (3¼-inch) Dollond refractor
108mm (4¼-inch) Vion (Paris) refractor
108mm (4¼-inch) Mailhat (Paris) refractor
120mm (4.75-inch) Mailhat refractor
5-inch Grubb refractor
160mm (6.3-inch) Mailhat refractor

just over a dozen private amateur observatories in Mexico, most colleges had an observatory, and Mexico had established the Tonanzintla National Observatory. Total membership of the SAM is not known, but was likely over 100. The period from 1913 to 1938 was one of political and economic upheaval and the SAM entered a long hiatus. The SAM was revived in 1938 and established a brand-new central headquarters in 1946. The new SAM building in Mexico City, constructed in a city park, was a large, multi-story facility with 100 and 150-seat lecture halls, shops for amateur telescope making, administrative offices, and a roof-top observatory equipped with a 12-inch American-made (Fecker) Newtonian reflector on a massive equatorial mounting.[491] This was a major facility intended for public education by a centralized group. Though the SAM was an amateur organization, it received some public support and had several professional astronomers on its board of governors. Although the SAM conducted many of the same kinds of activities as astronomy clubs in the United States, including observing, telescope-making, public 'star parties', it did so on a much greater scale than any group in the United States.

German amateur astronomy was very much a bifurcated community in terms of where 'popular', or 'amateur', astronomy was actually conducted and who the managers were. Most astronomy popularization in Germany, as well as other Central European nations, was done via public observatories and planetaria controlled by a professional staff. Even small telescopes were fantastically expensive in Germany, even in good economic times. Independent amateur astronomers were a rarity in Germany prior to 1945, and amateur astronomy was frequently tied to university or public observatories.

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[491] Domingo Taboada, "Astronomical Society of Mexico," *Sky & Telescope*, 7 (July, 1948): 223–224, 229.

Dr. Friedrich Simon Archenhold (1861-1939) was an important astronomy popularizer in early 20th century Germany. Archenhold and Wilhelm Förster, director of the Berlin University Observatory, established the Urania Astronomical Society (*Astronomische Gesellschaft Urania*–AGU) in 1888. This early German popular astronomical society was dedicated to carefully supervising popular education programs and was tied directly to the Berlin Observatory. The AGU was thus not a truly independent, purely amateur effort.[492] However, there were also a number of individual amateurs working on their own, rather than in association with a club. Phillip Johann Heinrich Fauth (1868–1941) was a leader in German amateur lunar observation. Fauth's father owned a pottery works, but Fauth earned his own living as a schoolteacher. His income was evidently such that he was able to construct an observatory at his home in 1890; the telescope was a 162mm (6.4-inch) refractor of unknown make. Although Fauth produced some of the best-known lunar maps of the early 20th century, his was an individual pursuit.[493] There were evidently a number of local astronomical societies in major German cities, many associated with universities. An astronomical society was active in West Germany following World War II, and several German amateur astronomers, such as planetary observer Günther Roth, became well-known even in America. Aside from contributing planetary observations to organizations like the ALPO and BAA, Roth wrote a number of popular astronomy books, such as *The Amateur Astronomer and His Telescope* (1963). The Union of Amateur Astronomers (*Vereinigung der Sternfreunde*–VdS) was formed in the late 1950s and began having annual meetings in 1960. The VdS was a nation-wide

[492] Dieter B. Herrmann, "Archenhold, Friedrich Simon," *The Biographical Encyclopedia of Astronomy, Volume I*; 56.
[493] Thomas A. Dobbins, "Fauth, Philipp Johann Heinrich," *The Biographical Encyclopedia of Astronomy, Volume I*; 360–361.

Federation of amateur astronomers, something like the Astronomical League in the United States, and was very much involved in public astronomy education, as well as in private observational research.[494]

A blend of French (centralized) and German (public observatory-based) models of amateur astronomy can be found in Russia and the Soviet Union. Russian amateur astronomy owes its existence in part to the reforms of Peter the Great in the early 18th century. Mimicking the ruling classes of the west, Russian aristocrats followed the pattern of purchasing various scientific instruments, including telescopes, for personal enlightenment and show; members of the nobility even established private observatories.[495] Observational astronomy developed slowly in Russia, and though there was some activity among wealthy dilettantes, there was little done outside the official academies and universities.[496] In 1879, an attorney from Smolensk, Vasiliy Engelhardt, established his own private observatory in the city of Dresden, Saxony. Engelhardt was a proficient and dedicated observer of comets, asteroids, nebulae, and double stars, and upon his death left all of his equipment to the University of Kazan, a school that had an established record of distinction in math and science under the direction of Nikolai Ivanovich Lobachevsky.[497] A Russian Astronomical Society, as well as a number of provincial societies, 'circles', and like organizations, had been established by the early

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[494] Günter D. Roth, "German Amateur Astronomers Convention," *Sky & Telescope*, 35 (December, 1967): 377.
[495] Sergey Maslikov, "Amateur Astronomy in Russia: Past, Present, and Future," *Sky & Telescope*, 102 (September 2001): 66–67.
[496] There were, of course, a number of important scientific expeditions, such as Behring's, during which astronomical observations were made.
[497] Maslikov: 67. According to Ian Glass' book cited earlier, Engelhardt's was a 12-inch refractor made by Thomas Grubb in 1879 to replace an 8-inch Grubb purchased two years earlier; it was still in operation at the University of Kazan as of 2001. Glass; 251, 255.

20th century. The Russian Astronomical Society published a journal, *Mirovedenie*, and acted as a communications nexus, though it did not direct activities as such.

As with all aspects of life in Russia, amateur astronomy was greatly affected by the 1917 Revolution. Astronomy, both professional and amateur, came under Marxist-Leninist ideological examination and influence. Changes were relatively slight during the NEP period, but 1928 saw the dissolution of the Russian Astronomical Society and its replacement in 1932 by the All-Union Astronomical-Geodetical Society (VAGO) a massive organization of both amateur and professional astronomers. As with virtually all aspects of Stalinist Russia, VAGO was charged completely with coordination of amateur astronomers' activities. Amateurs were supervised by professional astronomers, and VAGO published numerous observing manuals, organized eclipse expeditions, and convened regular meetings and congresses.[498] *Mirovedenie* ceased publication in the late 1930s and a popular astronomy journal did not reappear until 1965.[499] The only major astronomy publication between these years was the *Astronomical Journal* of the Soviet Academy of Sciences (an English-language version being published beginning in 1957). Examination of the *AJSAC* in the late 1950s would have discouraged most amateur astronomers of the time, as articles were highly technical. There were a few exceptions to this rule, and these give some insight into the role of amateur astronomy in the USSR in the late 1950s. A very brief article published in May-June 1957 concerned observation of artificial satellites. As was the case with the American "Project Moonwatch" program, observing groups all over the Soviet Union were to be organized in teams of 10 to 20,

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[498] Maslikov: 69–70.

[499] Maslikov quotes the title of *Mirovedenie*'s final editorial as, "For the Full Eradication of Sabotage on the Astronomical Front". The popular magazine *Zomlya i Vselennaya* (*Earth and Sky*) began publication in 1965, but as of 2001 was nearly defunct.

"not necessarily professional astronomers" and using a standardized, wide-angle telescope.[500] The history of the activities of Soviet amateur astronomers is quite obscure during much of the Soviet period, though there was plenty of interest in public observatories and planetaria.

Amateur astronomy in Japan is essentially a 20th century phenomena. The hobby developed quickly from the 1920s onward, and the Oriental Astronomical Society was established at that time. The OAS was very much like the BAA in that it consisted of a number of observing sections, each devoted to study of a particular subject, such as the planet Mars, or comets. Popularizing astronomy in Japan must have been problematic until after 1960, as there were few public facilities for the purpose. Given post-World War II conditions, it is not surprising that the first public planetarium in Japan was not established until 1957 (Goto Planetarium, Tokyo), though a large number of such facilities were established in the 1960s.

3. Comparison of commercial telescope availability in Europe & Japan

British amateur astronomers after 1940 maintained several traditions of their predecessors. The 'Grand Amateurs' were gone, but the middle-class amateurs remained. Telescopes were available for sale from makers like Cooke, Troughton, and Simms, Broadhurst & Clarkson, and others. Many British made their own telescopes, as they had in the 19th century. Less well-off British amateur astronomers also shared telescopes. There were also significant numbers of 'hand-me-down' instruments in use by British amateurs. Telescopes produced by famous 19th century makers were still in regular use

[500] A. A. Mikhailov, "On The Observation of Artificial Satellites," *Soviet Astronomy AJ*, 1, 3 (1957): 309.

by British amateur astronomers well into the mid-20th century. F. M. Holborn and Alan W. Heath both used large (12 to 15-inch) Calver reflecting telescopes, the latter receiving his from T. E. R. Phillips and using it into the 1990s.[501] Although Americans did preserve older instruments, their tendency was to buy or build new telescopes whenever possible, as they did with other consumer goods such as cars.

A number of old telescope-making firms survived into the 20th century in Britain. Howard Grubb succeeded his father in business, but concentrated primarily on large astronomical telescopes for professional observatories, rather than making more accessible instruments for amateurs. By 1960, Grubb had been absorbed by Parsons Engineering to become Grubb-Parsons. Troughton and Simms were likewise absorbed by T. Cooke and Sons. Cooke was likely the most important maker of telescopes for amateurs in Britain during the inter-war years. Cooke sold a 3-inch alt-azimuth refractor in 1920 for £19s16 ($650), a relative bargain.[502] It was not, however, an astronomical telescope and appears to have had some problems. American amateur astronomer David W. Rosebrugh purchased a 3-inch Cooke refractor in 1923 and ended up replacing all parts except for the objective lens, due to problems with the telescope's mechanical components.[503] The British commercial telescope industry was in considerable decline in the 1920s and 1930s, which might help explain the popularity in Britain of preserving older instruments. The few commercial astronomical telescopes available between the

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[501] "The British Astronomical Association: The Second Fifty Years": plate 4. James Muirden, *The Amateur Astronomer's Handbook*, (New York: Thomas Y. Crowell, Company, 1974); 33. Julius L. Benton, "The 1987-88 Apparition of Saturn: Visual and Photographic Observations," *The Journal of the Association of Lunar and Planetary Observers*, 34: 49.
[502] "T. Cooke and Sons - A Universal Telescope" Pub. No. 525, June 1920.
[503] David W. Rosebrugh, Correspondence, "David W. Rosebrugh to Albert G. Ingalls," (April 24, 1948), *Albert Ingalls Papers*, AC0175, Box 3, Folder 2, AC, SINMAH.

wars also likely reflect the poor economy; why try to sell telescopes if no one can buy them? The Post-War period saw a resurgence of commercial telescope manufacturing in Britain, including new makers of Newtonian reflectors. However, the British astronomical telescope industry saw nothing like the expansion that occurred in the United States in the 1950s. By 1962 there were only 9 manufacturers of refracting and reflecting telescopes (including those for professional astronomers) in the UK.[504]

German telescopes produced in the 19th century were considerably more expensive than their American equivalents. Carl A. Steinheil Söhne Company was selling an assortment of telescopes in 1907. A small 75mm (2.95-inch) refractor on a table-top stand with 5 eyepieces was priced at 380 Reichs-Marks ($1,780 today); the same aperture telescope on a wooden tripod cost 475 RM ($2,245) with an alt-azimuth mount and 600 RM ($2,805) with an equatorial.[505] These prices are more or less in line with American makers, but a complete, slightly larger 81mm (3.2-inch) refractor, equatorially-mounted, with setting circles and driving clock cost 1,810 RM ($8,445 today), about 30% more than the equivalent American-made telescope of the time. Steinheil telescopes were becoming a bit dated in their design by 1907 and were no longer cutting-edge technology.

The German firm of Carl Zeiss Jena was without doubt the leader in optical equipment of all types in the early 20th century. Established in 1846 as a small shop by Carl Zeiss, a former toy maker, the company began as a supplier to the university in Jena. As with many scientific instrument makers of the period, Zeiss produced a wide range of products including microscopes, camera lenses, and telescopes. The real key to Carl

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[504] N. E. Howard, *Handbook for Telescope Making*, (London: Faber and Faber Limited, 1962); 298–299.
[505] *Price-List of Astronomical and Physical Instruments, C. A. Steinheil Söhne*, (Munich: C. A. Steinheil Söhne, 1907); 36–39.

Zeiss' success was the close association the firm maintained with Jena University and the world of academic research science. Carl Zeiss benefitted by sales to universities and by constantly improving his product line in consultation with professional scientists such as Ernst Abbe.[506]

In terms of scale, Carl Zeiss Jena was far beyond any commercial telescope making firm in the United States or Britain. By 1917, the factory itself was immense, a four- to six-story structure occupying several blocks in the city of Jena.[507] Supporting the Carl Zeiss works was the Jena Glass Works owned by the Schott family. This was yet another huge industrial operation. The glass works initiated a scientific research program in the late 1880s to develop new types of optical glass and glass-making methods, and these contributed greatly to Zeiss' production of advanced lens designs.

Fig. 57 – Photograph (c.1930) illustrates just one part of the vast factory of the Carl Zeiss Company, Jena.

[506] King; 346–350. Felix Auerbach, *Ernst Abbe: Sein Leben, sein Wirken, sein Persönliechkeit, Zweite Auflage*, Leipzig (Akademische Verlagsgesellschaft m.b.H., 1922).
[507] Auerbach: 331.

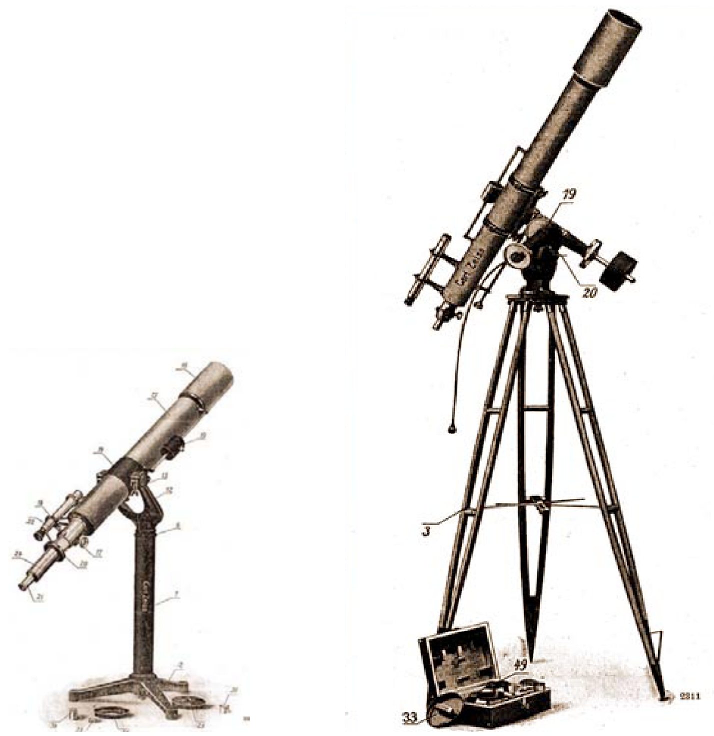

Fig. 58 – Zeiss refracting telescopes, from a catalogue c.1930: a 60mm alt-azimuth telescope (left), and an 80mm equatorial (right).

Telescopes produced by Carl Zeiss were of extremely high quality, but they were also extremely expensive. A 60mm (2.4-inch) refractor on a table-top alt-azimuth stand was the least expensive Zeiss telescope sold in 1936 at 680 RM ($275 in 1936, $3,490 today). An 80mm (3.1-inch) equatorial refractor on a field tripod cost 1250 RM ($505 in 1936, $6,415 today), and a similarly-mounted 110mm (4.4-inch) was priced at 3100 RM ($1,250 in 1936, $15,875 today).[508] These were extremely pricey telescopes, even by the standards of the time. Zeiss did produce Newtonian reflecting telescopes, but seemed to do so only on a custom basis.[509] Reflecting telescope mirrors could be had and were a bit more reasonably-priced, starting at 130 RM ($52 in 1936, $670 today) for a 110mm (4.4-

[508] *Carl Zeiss Jena, Preisliste uber Astronomische Instrumente. Astronomische Optik, Sternwarten-Kuppeln, Aussichts-Fernrohre*, (Jena, Germany: Carl Zeiss, Jena, 1936); 3.
[509] The 1936 *Preisliste* has a "300mm Spiegelteleskop nach Newton, Preis - Auf Anfrage" ("12-inch Newtonian reflecting telescope, price on inquiry"); 4. Earlier Zeiss catalogues do list complete Newtonian telescopes, but without prices.

inch) and 210 RM ($85 in 1936, $1,075 today) for a 150mm (5.9-inch).[510] Still, the economic realities of Germany before World War II would have made it extremely problematic for most individuals to acquire their own telescopes.

The situation for commercial telescope manufacturing in Germany was totally disrupted by the Second World War and its aftermath. Not only was the economy in a wrecked state, factories all over Germany had been flattened by bombing, then largely stripped by the victors. The Carl Zeiss works were particularly disrupted. The factory's location in Jena placed it squarely in the Soviet Zone of occupation; much equipment was removed to the Soviet Union, and Carl Zeiss Jena became an East German enterprise. Though limited amounts of advertising for Zeiss Jena products appeared during the Cold War years in Western magazines like *Sky & Telescope*, the number of Zeiss instruments released for export to the West in the 1950s and 1960s was miniscule. It is likely that very few in the Eastern Bloc would have been able to afford any kind of telescope either.

Information on telescopes professionally made in the Soviet Union in the post-war period is mainly limited to the larger instruments for professional observatories. However, several smaller telescopes that were exhibited at the Brussels International Fair in 1958 give some indication of instruments available to Russian amateurs, if not for direct sale then at least available for use at public facilities. For instance, the Soviet displaying included a "small" 5.1-inch (13cm) refractor intended for "training" but also suitable for variable star observations.[511] At the conclusion of the 'Great Patriotic War', Soviet authorities directed the removal to Russian territory of a good deal of German

[510] *Carl Zeiss Jena, Preisliste*; 10.
[511] "Telescopes at Brussels International Fair," *Soviet Astronomy AJ*, 2, 6 (1958): 634–635.

industry. During the Cold War period, East Germany also supplied many instruments to the Soviet Union. Telescopes from Zeiss, Jena were used to equip a number of university and public observatories in the East, and small Zeiss astronomical telescopes were likely available, but must have been phenomenally expensive.

Commercial telescope manufacturing was well underway in Japan prior to World War II. At least three major manufacturers of telescopes and other optical equipment had started production by 1930: Nihon Kogaku Kaisha, Ltd. (aka, Nikon) and S. Goto Optical Works, both located in the Tokyo area, and S. Nishimura & Sons, located in Kyoto. The instruments of Nihon Kogaku ("Japan Optical Company"), as was the case with most optics made in Japan at the time, were heavily influenced by German practices and practitioners. In 1921, the company had hired several German optical workers, veterans of the Zeiss works, to assist in both production and design. However, there was plenty of home-grown talent by the mid-1920s, and K. Nakamura of Kyoto University designed and produced a number of telescopes, mostly reflectors, for Nihon Kogaku.[512]

The Goto Optical Manufacturing Company is perhaps the most significant of the three early Japanese telescope manufacturers in that, while producing some very fine professional-grade instruments, company leaders still recognized the need for an affordable, but high-quality, telescope for the amateur and student market. Seizo Goto began producing telescopes in 1926 and had a considerable reputation in Japan by the

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[512] Y. Iba, "Amateur astronomy and telescope making in Japan," *Popular Astronomy*, 39 (1931): 290–292, on 290. Nikon had produced "hundreds" of refracting telescopes up to 8-inch in aperture by 1931 and Nakamura, in his time at the company, was responsible for the construction of a considerable number of Newtonian reflectors: 1 – 20-inch "fork type reflector on trial" (possibly a Cassegrain or Cassegrain-Newtonian), 1 – 10-inch f/3.8 photographic reflector, 3 – 8-inch, 3 – 6.5-inch, 25 – 6-inch, and over 200 – 5-inch and smaller.

mid-1930s. Most of Goto's sales brochures stress the use of telescopes by amateurs, as well as professionals.[513]

Fig. 59 – 63mm Goto telescope, c.1950.

Goto offered a wide range of telescopes beginning in the 1930s for amateur astronomers in Japan. The least expensive telescope was the "Kasutoru" ("Castor" – named after the star in Gemini) 42mm (1.65-inch) aperture refractor, alt-azimuth mounted with a tripod, and with three eyepieces and wooden case, which sold for 17,000 ¥ ($600 today). A 63mm (2.5-inch) on a small equatorial mount and wooden tripod sold for 52,000 ¥ ($1,800). A more substantial 78mm (3.1-inch) aperture refractor, equatorially-mounted, and with four eyepieces, cost 90,000 ¥ ($3,100).[514] Goto Optical recovered quickly after the war, and by 1950 had returned to selling telescopes. Many Japanese export telescopes appeared on the American market from 1950 onward, but

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[513] *Goto's Astronomical Telescope*, (Tokyo: Goto Optical Mfg. Co., ND, c.1950); 4.

[514] *Goto Telescopes*, (Tokyo: Goto Optical Mfg. Co., ND c.1950), cover. I have questions as to the correct dating of this catalogue, as the date of printing does not actually appear on it. The only clue is the date of a testimonial letter on the last page, dated December 6, 1936 (11th year of the Showa emperor, 12th month, 6th day). However, this does not mean that the catalogue was actually printed that year; the listed prices suggest a date around 1950.

most were retailed under importers' names. Goto was a notable exception and became a regular advertiser of Japanese-made and branded instruments in *Sky & Telescope* from about 1955.

4. Amateur telescope making in Europe & Japan

Amateur telescope making was a hobby likely practiced in most European countries to one extent or another in the twentieth century, if not earlier. However, as a major pastime, telescope making was by far most popular in Britain. The efforts of British ATMs like Common and Ellison have already been mentioned. Due to the economic realities that discouraged many from buying commercial instruments before recent decades, British amateur astronomers (like their American counterparts) appreciated the possibilities of home-made telescopes. The BAA had established an official 'Telescope making Section' in 1917 that remained quite active through World War II and beyond.[515] Horace Dall was a well-known British ATM in the 1940s and 1950s, making contributions of articles on both sides of the Atlantic. Dall was a trained professional engineer, but was an amateur astronomer and telescope maker from age 16, assembling a small telescope from spectacle lenses. In 1920, Dall acquired an 8½-inch Calver reflector, but soon began telescope making in earnest a few years later, having read Ellison's telescope-making book. Dall developed a number of clever telescope designs, including a 3½-inch Cassegrain telescope that could be folded-up and placed in a pocket.[516] Dall was very much a part of the small, but important, international ATM

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[515] "The British Astronomical Association: The Second Fifty Years": 107.
[516] Ingalls, *Amateur Telescope Making – Book III*; 619.

community and made a number of contributions to *Sky & Telescope* and the *Amateur Telescope Making* books, as well as the *Journal* of the BAA.

There was a very long history of telescope making in France. Many of the commercially telescopes of the 19th century sold world-wide were of French make. The manufacturers Secrétan and Bardou have already been noted. In addition, there were others including Vion (the successor to Bardou), Mailhat, Gautier, and Henry, all of whom made a variety of telescopes for amateurs and professionals. The vast majority of French telescope manufacturers produced refracting telescopes. Secrétan was one of the few French makers of reflecting telescopes, though Gauthier produced a few for professional observatories.[517] One hears little of amateur telescope making in France prior to the mid-20th century, although there must have been a few French ATMs. Jean Texereau was quite likely the most important optician in mid-20th century France. Texereau made his first telescope, a 10-inch Newtonian, in 1939 at age 20. Texereau was largely self-taught, but went to work for the Optical Laboratory of the Paris Observatory after the end of World War II.[518] Besides working on a number of important instruments for professional astronomers, Texereau also taught telescope making to French amateur astronomers and published *La Construction du Télescope d'Amateur* (*Making an Amateur Telescope*) in 1951. Texereau directed members of the Instrument Group of the Societe de Astronomique de France at the SAF's observatory workshop, producing a 'standard' Newtonian telescope, of 20cm (8-inch) aperture. They were simple

[517] *1901-1902 L'Industrie Français des Instruments de Précision*; 113.
[518] "A Short Biography of the Professional Work of Jean Texereau", in, Jean Texereau, *How to Make a Telescope, Second English Edition*, Translated and Adapted by Allen Strickler, (Richmond, VA: Willmann-Bell, 1984); 409–410.

instruments and, like those of ATMs in America, employed inexpensive, often recycled materials.[519]

Amateur telescope making was present in Germany before World War II, but information is sparse at best. It is known that Dr. F. S. Archenhold advocated the manufacture of inexpensive telescopes for schools, but exactly what became of this effort is a mystery.[520] Post-War Germany saw a number of German ATMs of note. Anton Kutter (1903-1985) became a well-known amateur telescope maker in the 1950s with the introduction of his 'Schiefspiegler' (oblique-reflector) design in the 1950s. Kutter had been an amateur astronomer since age 12, assembling a small telescope made from parts of a disused camera. Kutter became a disciple of German lunar and planetary astronomer Philip Fauth and experimented further with the design of telescopes specifically for planetary observing. Based on the earlier German/Austrian 'Brachyt' ('broken') design, the schiefspiegler was a purpose-built lunar and planetary telescope that was essentially an un-obstructed Cassegrain telescope.[521] In his spare time away from his profession of film-directing, Kutter perfected his design and published detailed construction plans in a book, *Der Schiefspiegler*, and in articles for *Sky & Telescope* magazine in America. Other West German (and possibly East German) amateurs were also building telescopes after

[519] Texereau; 14, 51, 251–255, 263. As Texereau's book concerns making telescopes rather than those who made them, I have inferred some information from photographs and captions. C. Gauthier, an amateur astronomer in Sanary, constructed a 13-inch reflecting telescope after the war and used salvaged auto parts for the mounting and military surplus parts (p. 251).
[520] Herrmann, "Archenhold, Friedrich Simon"; 56.
[521] Anton Kutter, "The Schiefspiegler (Oblique Reflector)", *Sky & Telescope, Bulletin A*, (Cambridge, MA: Sky Publishing Corporation, 1958). "Moon Photographs with an Off-Axis Reflector," *Sky & Telescope*, 18 (December, 1958): 64–67. R.W. Sinnott, "Optical Innovator Dies - Kutter, Anton," *Sky & Telescope*, 70 (October, 1985): 461. Earlier German telescope makers referred to such designs as 'broken' since they were comprised only of an off-axis section of a Cassegrain system.

World War II. Johann Kern constructed a 24-inch reflector to study nebulae and galaxies.[522]

Russians were at least somewhat active in amateur telescope making early in the 20th century. Aleksander Chikin's book, *Reflecting Telescopes: Making Reflectors by Means Available to Amateurs* (1915), became an important guide for Russian amateur astronomers and was similar to those written in America, but exerted no influence outside Russia as it was never translated into other languages. The 1930s saw an effort to popularize amateur telescope making that was similar to that in the United States; Mikhail Navashin wrote a popular book, *The Amateur Astronomer's Telescope*, and artist Mikhail Shemyakin published a journal entitled *Amateur Telescopes*, under supervision of VAGO. A uniquely Soviet approach permitted those interested in exploring the hobby of telescope making to gain access to materials and shop equipment free of charge simply by joining a telescope making club, present in most large cities.[523] The Newtonian telescopes made by Soviet ATMs were in the same 4 to 6-inch aperture range as were being made by their American counterparts. However, none of the Soviet ATMs pursued, or were permitted to pursue, telescope making as a for-profit business, as American ATMs did. It was not until the 1980s that commercial telescopes for amateur astronomers were produced in the Soviet Union. Dimitry D. Maksutov was without doubt the most influential Soviet optical designer. While working at the State Optical Institute (GOI) in Moscow, Maksutov developed his revolutionary telescope design in 1941. The catadioptric Maksutov design showed great promise as a telescope for both professional

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[522] Roth, "German Amateur Astronomers Convention": 377.
[523] Maslikov: 72.

and amateur astronomy. Maksutov specifically mentions use of his telescope by amateur astronomers, schools, etc., in the Soviet Union in his article released in 1944.[524]

Telescopes had been known in Japan since 1613 and were being manufactured there by the end of the 18th century.[525] However, amateur astronomy as such was a comparatively recent phenomena. Until the mid-1920s, astronomy had been "solely in the hands of professionals" and held little interest for the general public, in great part due to the "costly extravagance" of telescopes.[526] Such a statement is of obvious importance for the thesis that amateur astronomy in general shifted in demographics worldwide between 1910 and 1960. The fact that the real start of amateur astronomy in Japan can be traced to a 1922 article on telescope making in the Japanese popular journal *Astronomy Herald* by Yamazaki Masamitsu is of even more significance.[527] Yamazaki was visiting the United States at the time and described how to construct a Newtonian reflector; the idea that Yamazaki had read one of Porter's articles in *Popular Astronomy* is by no means unlikely. Urged on by some of Japan's professional astronomers, amateur telescope making quickly caught on among students and even attracted encouragement from the government. By 1931 there were about 200 amateur telescope makers in Japan, like their counterparts in America making 6 to 8-inch Newtonian reflectors. A number of these amateurs were students at various universities in Japan. Nakamura Kaname, a student assistant at the Kasan Astronomical Observatory, had his own shop in the observatory's

[524] D. D. Maksutov, "New Catadioptric Meniscus Systems," *Journal of the Optical Society of America*, 34 (1944): 270–284.
[525] Telescopes were first brought to Japan by European merchants. The first known was a gift to Tokugawa Ieyasu from the captain of *HMS Clove* in 1613. See, Peter Abrahams, *The History of the Telescope in Japan*, (privately published, 2001). The Louwman Collection of Historic Telescopes in the Netherlands includes a number of examples of telescopes manufactured in whole or in part in Japan as early as 1784 (marked "First Months of Year of Dragon").
[526] Iba: 290.
[527] Iba: 290.

basement and produced a number of optical components of his own design.[528] It is apparent that the vast majority of Japan's burgeoning amateur astronomical community in the 1920s and 1930s were given considerable support by professional astronomers at the universities and observatories, and most likely by indirect state support as well.

5. Public observatories & state support of astronomy popularization across Europe

Given the extremely high cost of astronomical telescopes available in Europe, it is not surprising that most public astronomy was done at public observatories and planetaria supported either by government funding, or private financing. The use of public facilities for public astronomy education has a much longer tradition in Continental Europe than in either the United States or Britain. A 1908 news note in *Popular Mechanics* describes the observatory in Zurich, Switzerland, as being "the only genuinely public observatory in the world."[529] The Zurich "Urania" Observatory was equipped with a 12-inch (30cm) Zeiss refractor, made in 1906, on an unusual mounting, unique to Zeiss, which placed the eye-end of the telescope close to the instrument's balance-point. The result of this unusual mounting system was that it was far more convenient for members of the public to look through.[530] Open every night with free admission, the Urania Observatory hosted around 25,000 visitors in a 6-month period in 1908.

The Treptow Park Observatory in Berlin was established in 1909 by Dr. F. S. Archenhold specifically for the purpose of providing a telescope for public enlightenment. Many observers at the time praised its radical design and relatively low

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[528] Iba: 291. Nakamura was also an observer and astro-photographer. From the context of Iba's article, it is not clear if Nakamura was a student or an employee, but the former seems to be suggested.
[529] "An Observatory for the Public," *Popular Mechanics*, 10 (October, 1908): 741.
[530] *Carl Zeiss Jena, Astronomische Instrumente, Astronomische Optik, Sternwartenkuppeln, Beobachtungsleitern, Hebebühnen*, (Jena, Germany: Carl Zeiss, Jena, ND, c.1920); 39.

cost; its design was in fact optimized for ease of use by the public, as the more or less fixed position of the eyepiece was more convenient than that of typical telescopes of the same size (27-inch aperture, 68.9-foot focal length).[531] The Treptow Park Observatory was built for the 'modest' sum of $62,500 ($1,200,000 today) and was financed by private donations.[532] This German observatory continued to host large numbers of visitors until World War II, when it was damaged in Allied bombing raids. The observatory was rebuilt after the war, renamed in honor of Archenhold, and remains in use today. The world's first projection planetarium was constructed by Carl Zeiss, Jena for the Deutsches Museum, Munich and officially opened to the public in 1925.[533] By 1930, there were 15 planetaria operating in Europe, all but three in Germany. The number of visitors to these facilities was significant even during economically-stressed times: the Deusches Museum had 80,000 visitors in two years, the planetarium in Jena hosted 100,000 in its first year of operation, the Berlin planetarium did the same.[534]

To a certain extent, Russia and the Soviet Union emulated Western ideas concerning institutions for the popularization of science. Scientific societies, both professional and amateur, were established in Russia in the 19th century. Like scientific societies in the West, many pre-Soviet Russian organizations were supported by wealthy

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[531] S. A. Mitchell, "A Great Open-Air Telescope," *Scientific American*, 102 (January 29, 1910): 104. The Treptow 27-inch is fairly unique in being mounted in the open (no observatory dome) and supported only at the lower end rather than in the middle of the tube; this was permitted by the use of large counter-weights low to the ground. Viewers could therefore simply walk up to the telescope, step onto the observing platform, take a look through the eyepiece, then step off the platform, never being more than a few feet above the ground no matter which way the telescope was pointed. The 'modest' cost of this telescope, about the 6th-largest refractor in the world in 1910, was quoted by Mitchell as $62,500. Funds were in part obtained via popular subscription among the people of Berlin. Zeiss later produced a series of moderate-sized refractors on a similar principle, generally for public observatories and planetaria. See also, Herrmann, "Archenhold, Friedrich Simon", *BEA*; 56.

[532] S. A. Marshall, "A Great Open-Air Telescope," *Popular Astronomy*, 18 (1910): 297, 296–299.

[533] Marché; 9–12.

[534] Marché; 20.

members, as well as patrons who simply wanted to support a worth-while cause that promised to propel the nation forward economically.[535] Public science museums, such as the Museum of Science and Industry in Moscow, were established in many cities in Russia, again following patterns found in the United States and Western Europe. However, there were differences; for example, S. G. Lepneva of the Iaroslavl□ Natural-History Society added a 'visitor's laboratory' where patrons had a chance for hands-on work with simplified scientific apparatus under expert guidance, something that rarely occurred in American museums of the time (c.1910).[536] Astronomy was one of the sciences which encouraged participation by amateurs. An aspect of Russian amateur astronomy that was considerably different from that in the United States was the Russians' routine joint use of telescopic equipment. For example, the director of the Tenishev School in St. Petersburg offered the use of the school's 6.9-inch (17.5cm) refracting telescope to members of the Russian Society of Amateur Investigators of the Natural World, a leading amateur astronomical group in St. Petersburg from 1909-1916. In exchange for use of the Tenishev School's telescope, the Russian Society of Amateur Investigators of the Natural World assisted with activities during public nights. This sort of cooperative venture would have been unheard-of in the United States in the early 20th century, but did become fairly common later in America by 1960.[537] There were some amateur astronomers, even in Stalin's Russia, who somehow borrowed or otherwise managed to use foreign-made instruments; a photograph of Leningrad amateur astronomers in 1933 shows them observing with a moderate-sized Zeiss refractor. It

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[535] James T. Andrews, *Science for the Masses: The Bolshevik State, Public Science, and the Popular Imagination in Soviet Russia, 1917–1934* (College Station, TX: Texas A & P University Press, 2005); 29.
[536] Andrews: 31–32.
[537] Andrews; 33–34.

seems doubtful that anyone in the Soviet Union could have purchased such a telescope, or even been permitted to own it.[538]

6. Japanese commercial telescopes: a success story

Why were the Japanese apparently able to seize the post-World War II market in small refracting telescopes in America? Part has to do with price and mass production. Japanese manufacturers were better able to turn out large numbers of telescopes of a more standardized type, due to the fact that the optical components were the same size as that of military optics. Japanese-made telescopes were made mostly in 50mm, 60mm, or 80mm apertures, exactly the same as many military binoculars. Japan had either no military or an extremely limited one in the 1950s, and unlike the United States, Japanese manufacturers produced optics for both the military and commercial market. Only simple changes in tooling would be required to produce either astronomical telescopes or military binoculars. Few if any American commercial telescope makers produced optics for the military outside of war-time emergency; in other words, the American optical industry was bifurcated into a limited amateur-commercial telescope industry and a larger industrial-research-military optical industry.

In discussing Japanese high technology manufacturing after World War II, historian Kenkichiro Koizumi suggests that Japan's defeat drastically altered that nation's views on the usefulness of technology. Prior to the war, the Japanese military felt that technology was useful but that Japan could not possibly match the industrial might of the

[538] Maslikov; 66. It appears to be a 110mm Zeiss on an equatorial mount and pyramid stand. In the photo, speaking to a boy who is looking through the telescope, is Alexander Soloviev, a professional astronomer. It might be that the telescope was a portable instrument from Pulkovo Observatory or some other official institution.

West. The solution was the concept of *wakon*, or spirit. Fighting spirit and moral superiority would succeed over technology. The total defeat of Japan by the United States and its allies led to a total abandonment of *wakon*, replaced by Japanese leaders' wholesale embrace of technology as an answer to economic problems. A further boost to this new view was the relative material wealth displayed by members of the United States military's occupation forces in Japan following the war. Scenes of ordinary soldiers and sailors having access to cars, refrigerators, washing-machines and other such consumer goods astonished the Japanese.[539] The postwar Japanese government directed massive support to the remaining prewar industries, including optical manufacturers like Nikon ant Goto. The result was a flood of innovative and increasingly affordable consumer goods, including electronics, cameras, and telescopes.[540]

7. Conclusion

Source material concerning amateur astronomy outside the United States is difficult to locate, to say the least. However, evidence supports the following conclusions. First, amateur astronomy was practiced in every industrialized, and industrializing, nation on earth. Classifications of amateur astronomers generally follow Chapman's categories: 'Grand amateurs' in the 19th century, middle-class and a few working-class amateurs in the 20th. The obvious exception to the rule is amateur astronomy in the Soviet Union.

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[539] Aside from tours of United States military bases in occupied Japan by government officials, Japanese civilians were often hired as workers on bases, (cleaning ladies, for instance) and were able to see such rare appliances as these at first hand. Keep in mind that prior to 1945, Japanese soldiers were expected to make do with very primitive conditions, meager rations, and minimal equipment. By contrast, the idea of even ordinary American soldiers having access to automatic washing-machines, refrigerators, and copious amounts of good food was therefore even more of a shock.

[540] Kenkichiro Koizumi, "In Search of *Wakon*, The Cultural Dynamics of the Rise of Manufacturing Technology in Postwar Japan", *Technology and Culture*, 43 (January, 2002): 29–49.

Second, access to participation in amateur astronomy around the globe was limited by the cost of telescopes, just as it was in the United States. If anything, the cost of astronomical equipment was even greater for those outside the United States, given relative levels of wealth and income. Amateurs both in America and elsewhere adopted do-it-yourself telescope making as a common solution to the problem of prohibitively-expensive commercial instruments, but not all countries embraced amateur telescope-making universally or at the same level. Third, outside the United States, amateurs tended to get around the problem of expensive equipment far more often by sharing their instruments. Especially in early twentieth-century Europe, groups of amateur astronomers formed centralized organizations, used borrowed equipment, and shared time at centralized observatories. Public observatories were quick to develop in Europe, particularly in Germany, and served large numbers of visitors. America did develop such facilities, but much later and on a strictly private or local-government basis. Finally, the route from amateur telescope making to commercial telescope making developed in very different ways outside the United States. In most of Europe, amateur telescope making never achieved the same levels of popularity as it did in America, nor did growth of the hobby lead skilled entrepreneurs into commercial telescope production until well after 1960. Japan was the only country that seemed to have followed the same path as in America, though with certain differences in detail.

Chapter VII: Conclusion

> "Aside from the obvious fact that all the older books are now very much out of date, there are a number of other reasons why a complete new Celestial Handbook is needed. To begin with, the earlier observing guides were written for the possessor of the standard telescope of about 1900, the classic 3" refractor. Today's average amateur telescope is a 6" to 12" instrument, and the increasing availability of good quality large reflectors has opened up a vast new world of deep-sky objects for the modern observer." (Robert Burnham, Jr., 1978)[541]

Robert Burnham, Jr. joined the staff of the Lowell Observatory in Flagstaff, Arizona in 1958. Between 1958 and 1965, Burnham compiled a near complete list of all "deep-sky" objects (nebulae, star-clusters, and galaxies) observable with amateur instruments. The fact that this catalogue ran to 2000 pages and was first published as a four-volume book in 1966 goes some way in indicating how far amateur astronomy had progressed in the United States since Olcott had written his little guidebook, *In Starland with a 3-Inch Telescope,* sixty years earlier.[542]

The 1960s and 1970s saw a continuation of growth in amateur astronomy in America and the rest of the world. Some of the telescope manufacturers established in the 1950s operated for many decades, others survived only a few years, but were replaced by others. Telescope companies in 1960 were producing a wide variety of products: refracting telescopes, Newtonian and Cassegrain reflectors, and even the then new Maksutov design. There were many companies also producing and marketing telescope objective lenses, mirrors, eyepieces, mountings, and assorted other parts. Still others continued to cater to ATMs, selling mirror making kits or aluminizing services. Finally,

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541 Robert Burnham, Jr., *Burnham's Celestial Handbook: An Observer's Guide to the Universe Beyond the Solar System, Revised and Enlarged Edition*. (New York: Dover Publications, Inc., 1978); 7.
542 Burnham; 7–11.

there remained a good deal of military surplus optics available well into the 1970s, thanks to the Korean and Vietnam conflicts.

Two new advances, one technological, the other philosophical, aided the continued growth of amateur astronomy in the United States. Although created several decades earlier, the Schmidt telescope underwent a drastic evolutionary change in the 1960s when a new company, Celestron Pacific, Inc. (later Celestron International), introduced the first commercially-produced and marketed Schmidt-Cassegrain telescopes. The Schmidt-Cassegrain was a design optimized for both photographic and visual observing, unlike the original Schmidt photographic-telescope system. The Celestron telescopes sacrificed the high photographic speed of the original Schmidt system (f/0.5 to 2.5) for improved usability as a visual telescope, the effective focal ratio being f/10. However, while making these compromises, Celestron succeeded in producing an extremely compact instrument that was highly portable, a factor of increasing importance with the growth of American cities and "light pollution". Originally built in a large range of apertures from 4-inch to 22-inch, the young company finally settled on production of just three sizes of telescope: 5-inch, 8-inch, and 14-inch. In 1969, the 10-inch Celestron sold for $2,000 ($9,600 today), but by 1981 an 8-inch "C-8" cost only $720 ($1,400) and a 5-inch "C-5" $570 ($1,100).[543] Criterion and other American manufacturers also began producing Schmidt-Cassegrain telescopes in the early 1970s, and the type became a standard one used by tens of thousands of amateur astronomers around the world.

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[543] "The world's only production manufacturer of Schmidt-Cassegrain Telescopes, Celestron Pacific, Inc.", *Sky & Telescope*, 37 (January, 1969): 52.

Fig. 60 – Telescopes, sophisticated and crude: the Celestron C-8 Schmidt-Cassegrain telescope (left) and a large home-made Dobsonian reflector (right)

The second advance was not so much technological as philosophical. John Dobson was, quite literally, a monk living in the San Francisco area in the late 1960s when he developed an interest in astronomy. As a monk, he was totally without the money to buy a telescope, and even the purchase of a standard Newtonian telescope-making kit was beyond his means. Instead, he searched junk-yards, scrounged materials, read what he could at the public library, and began grinding mirrors in a small shop allowed him at the monastery. For mirror blanks, he used old ship's portholes, made of ordinary plate-glass. For telescope tubes, Dobson scrounged cardboard tubes from various sources, and he constructed extremely crude alt-azimuth mountings of plywood. All of Dobson's methods and materials were at first scorned by experienced ATMs (and must have horrified professionals); but his telescopes worked. Dobson then began to take his telescopes onto the streets in the Bay Area and introduced the man-on-the-street to the wonders of the heavens. Thus began the San Francisco Sidewalk Astronomers.[544] The "Dobsonian" telescope was just another Newtonian telescope, but stripped-down to the bare essentials and made of everyday materials.

By the mid-1980s, when Halley's Comet returned for its second appearance in the 20th century, amateur astronomy had undergone many changes since 1910. Just about anyone could participate, since just about anyone could buy a telescope. Ordinary Americans could find a plethora of telescope retailers and manufacturers listed in numerous astronomy and science-related magazines. Telescopes were relatively easy to find, at inexpensive levels, at local department stores. Consumers could buy a small 2.4-inch refractor on an alt-azimuth mount and tripod for as little as $99 ($150 today) or a 3.1-inch equatorially-mounted refractor for $290 ($435).[545] Makers of Newtonian reflectors were still plentiful: Parks Optical was making reflectors similar to those of Cave Optical (Cave having gone out of business in 1980). And then there was Coulter Optical, makers of a commercial version of John Dobson's telescope: users could buy an 8-inch, alt-azimuth mounted telescope, with heavy-duty cardboard tube, for only $239.50 ($360 today). The United States continued to import immense numbers of telescopes from Japan, mostly the smaller 2.4-inch and 3.1-inch refractors, and 4.5-inch reflectors. Taking advantage of this wealth of equipment choices, hundreds of thousands of people observed the sky from their own back-yards.

The standard view explaining the tremendous growth of amateur astronomy seen in the 20th century is that the 'Space Race did it'. Comparatively few historians have

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[544] "Walden of the Sky". *Sky & Telescope*, 90 (September, 1995): 84–87.
[545] "Adorama," *Sky & Telescope*, 73 (March, 1987): 349; and, "Focus Camera Inc.," *Sky & Telescope*, 73 (March, 1987): 333.

studied the subject, but all seem to agree that the launch of Sputnik in 1957 was crucial to the popularization of astronomy. Allan Chapman is one who sees the beginning of the Space Race in 1957 as *the* crucial event that "brought amateur astronomy out of its comparative doldrums".[546] Chapman does qualify this a bit by adding the appearance of the spectacular Comet Arend-Roland and the debut of astronomy popularizer Patrick Moore's BBC TV program, *The Sky at Night*, both in 1957, to the spark that got amateur astronomy going as a hobby for the masses in Britain. However, statistics and other evidence show that the popularity of amateur astronomy, as measured by membership in the BAA, actually fell off a bit around the time of Sputnik. Also, if Sputnik and the Space Age were so important to the growth of amateur astronomy, how can one explain Williams' data clearly showing that the growth-rate of astronomy clubs in America was greatest in the decade *before* the launch of Sputnik?

In his conclusion to *The Victorian Amateur Astronomer*, Chapman does get round to mentioning the growing Post-War economic affluence as a factor in the growth of amateur astronomy. More Europeans were able to buy cars, afford holidays, TV sets – and Japanese-made telescopes.[547] In fact, amateur astronomy boomed from the 1960s onward for a whole host of reasons, but the availability of inexpensive telescopes was the major one. It is the technology of mass-produced telescopes, not space travel, which was the enabler that made astronomy available to nearly everyone.

Amateur astronomy, certainly that before 1920, was the pursuit of a tiny intellectual and economic elite. Traditions of amateur telescope making extend far back,

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[546] Chapman; 299.
[547] Chapman; 300.

essentially to the beginning of the history of telescopes: after all, neither Galileo nor Newton was a professional telescope maker. However, the knowledge of telescope making was a closely-guarded secret for decades, and gaining access to this knowledge was problematic. Professional telescope makers like the Dollands, Fraunhofer, Fitz, and the Clarks, benefited from years of slow progress in the development of new scientifically-based technologies of glass-making and lens-design. It took a number of experimentally-minded 'amateurs', Smith, Herschel, Rosse, Foucault, and Draper, among others, to gradually improve the making of reflecting telescopes to the point where makers could reliably produce a good-quality instrument. However, after many long decades of development, telescopes were still a very expensive product in the early 20th century. The knowledge of how to make telescopes, though publicized to a certain extent, remained largely obscure. As a result, very few persons were able to view Halley's Comet in 1910 with their own telescope, and the number of active amateur astronomers in the whole world was likely only a few thousand.

The advent of "The Poor Man's Telescope" article in the 1920s changed everything. Russell Porter and Albert Ingalls, two exceptionally good technological cheerleaders, for the first time effectively communicated the knowledge of telescope-making to a wide audience. Americans were especially primed for this by the post Great-War boom in such amateur science hobbies as ham radio, but it was likely the enthusiasm and communication abilities of Porter and Ingalls that really made the difference. By the 1930s, thanks to Porter and Ingalls' telescope making articles in *Scientific American* and the resulting *Amateur Telescope Making* books, tens of thousands of Americans were building and using quite respectable astronomical telescopes by 1940. Since commercially-made telescopes were still quite expensive, United States amateur astronomy in the 1930s belonged to the “ATMs”.

World War II and the years following were a major turning point in the history of amateur astronomy. The military required hundreds of thousands, even millions, of optical components for weapons systems, and it was America’s ATMs who helped provide at least some of these. Enthusiastic amateurs became professional opticians and applied the mass-production techniques to telescope-making after the war. The ‘professionalized ATMs’ then started their own telescope-making companies in the 1940s and 50s. The new telescopes ranged from sophisticated ones like the 3½-inch Questar Maksutov-Cassegrain to very humble, but still effective, telescopes like the cardboard-tubed “Sky-scope” Newtonian reflector. Telescopes such as the Sky-scope appealed to the tastes and pocketbooks of the vast new pool of young amateur astronomers, teenagers who would go on to build or buy more sophisticated instruments later on, or even to become professional astronomers. By 1960, astronomy had become a very popular hobby in America, with well over 200 astronomy clubs and 100,000 persons involved.

The ‘telescope revolution’ in America was largely confined there until after 1960. While a certain part of the population in Europe and elsewhere shared an interest in astronomy, the extremely high cost of telescopes kept many from developing individual participation in the hobby the way Americans did. However, amateur astronomers outside the United States often compensated by embracing other methods of access. Many Europeans formed amateur astronomical societies in part to share telescopes, enabling the less financially well-to-do to enjoy at least some use of high-quality instruments. In other cases, particularly Central Europe, public observatories and planetaria were established as centers of activity for amateur astronomers and the public. Relatively few amateur astronomers in Europe seem to have joined the American ATM movement of the 1920s and 1930s, for reasons that are obscure. The one place that did, and the one place that later perhaps came to outpace the United States in producing inexpensive Post-War telescopes, was Japan. Significant numbers of Japanese ATMs, at least several hundred, were hard at work making telescopes in the 1920s and 30s. While the Second World War greatly disrupted the production of astronomical telescopes, Japanese optical manufacturers like Goto recovered quickly after the war and by the 1950s were producing large numbers of high-quality telescopes for the expanding world market.

However, some segments of the telescope business ultimately proved willing to sacrifice quality in the rush to expansion. “Halley’s Comet Fever” was high in America in the 1980s, with publicity inspiring a desire among many families and individuals to view the famous comet with their own telescope; fortunately, there were plenty available. Exact production numbers are not known, but the quantity of commercial telescopes produced in America and Japan between 1985 and 1987 must have run on the order of a quarter-million. Telescopes poured out of the factories and were eagerly bought-up by enthusiastic amateur astronomers – who were frequently disappointed by the results of their observation attempts. Part of the disappointment was the naiveté normal to neophytes; beginners were expecting to see the same images in a 2.4-inch refractor as they saw in photos taken with large telescopes. But, something else was wrong. Experienced amateur astronomers of the mid-1980s who bought new, large-aperture telescopes often noted remarkably poor images in some instruments. I personally tested a 4.5-inch Newtonian reflector made in about 1985 and found that the optics had over 3-

waves of spherical aberration, 25-times the usual maximum error tolerance. The telescope's primary mirror was so poor that stars could not be made to come to a sharp focus, even at low magnification. What seems to have happened in the mid-1980s was that manufacturers were so behind on orders and were making telescopes so rapidly, that poor-quality optics were simply allowed to slip by inspection. This is a well-known trait of mass-production. Perfection is impossible, but a certain percentage of failure is economically viable given the ease of replacing flawed products that are produced in massive quantities. Today's amateur astronomers in the know generally shun "Comet Halley telescopes", those commercially-made instruments from the mid-1980s, which tend to exhibit such flaws. The 1980s brought a certain trade-off between accessibility and quality. While small, inexpensive telescopes were mass-marketed at department stores, those instruments were increasingly made with poorly-produced injection-molded plastic parts, wobbly tripods, and eyepieces so poorly made and designed as to be nearly useless.

Although the 'telescope revolution' beginning in the 1950s delivered large numbers of mass-produced telescopes into the hands of amateur astronomers, it did so at a price in overall quality. Though excellent telescopes could be had, amateur astronomers were also awash in a sea of mediocre 'department-store rubbish' telescopes. 'Amateur astronomy', and what it meant to be an amateur, had changed as well between the two apparitions of Halley's Comet. Most amateur astronomers in 1910 were fairly serious about it: though many sought personal enlightenment and pleasure, a significant number were amateur scientists hoping to make a real contribution. By the late 1950s however, most amateurs were in it for fun and recreation, to the point where the more serious amateurs like Dale Cruikshank despaired of the hobby.

Leif Robinson, a long-time editor for *Sky & Telescope*, recently suggested the effects that changes in telescope accessibility had on American amateur astronomy:

> "Just think of how it was in 1941 [when *Sky & Telescope* first began publishing]: commercial telescopes and accessories were practically nonexistent. Now, you only need to thumb through *Sky & Telescope* to see the vast array of retail telescopes and equipment available all over the world."[548]

The growth of commercial telescope manufacturers in America and the introduction of large quantities of Japanese imports from the 1950s onward enabled the tremendous growth of amateur astronomy over the same period. The origins of this enabling technology, inexpensive telescopes, begins with the amateur telescope making tradition, its massive expansion in the 1920s and 30s, its conversion to war-time use in the 1940s, and its reconversion into the new commercial telescope manufacturing of the 1950s. It was 'The Poor Man's Telescope' that put astronomy into the reach of the average person.

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[548] Leif J. Robinson, "A Brief History of *Sky & Telescope,*" (2009), www.skytonight.com/about/generalinfo/3305301.html (retrieved in June, 2010).

Appendix 1:
Beginner's Telescope Prices, 1850–1960

Small (2.25 to 3.1-inch) Refracting Telescopes

Year	Manufacturer and Size	Price	Price in 2001 dollars
1850	Fitz, 3-inch	$300.00	$6,750
1868	Clark, 3-inch	$160.00	$1,975
1892	Byrne, 3-inch	$175.00	$3,390
1900	Clark, 3-inch	$175.00	$3,620
1906	Brashear, 3-inch	$185.00	$2,088
1911	Bardou (French import), 3-inch Bardou, 2.75-inch Bardou, 2.25-inch	$80.00 $72.00 $65.00	$1,267 $1,140 $1,029
1927	Mogey, 3-inch Mogey, 2.5-inch (table-top)	$165.00 $110.00	$1,431 $954
1930	Bausch & Lomb, 3.1-inch	$310.00	$4,030
1932	Mogey, 3-inch	$230.00	$2,990
1936	Zeiss (German), 3.1-inch	$505.00	$6,415
1947	Tinsley, 3-inch	$265.00	$1,791
1950	Tinsley, 3-inch	$199.00	$1,247
1958	Edmund Scientific, 3-inch	$125.00	$653
1958	Unitron, 3-inch Unitron, 2.4-inch	$265.00 $125.00	$1,384 $653
1960	Mayflower (Japanese import), 3.1-inch (80mm)	$184.50	$941
1960	Tasco (Japanese import), 2.4-inch (60mm)	$39.95	$204

Small (3 to 6-inch) Newtonian Reflecting Telescopes

Year	Manufacturer and Size	Price	Price in 2001 dollars
1876	Browning, 6 ½-inch (British), equatorial (w/circles, no driving clock)	£88 ($450)	$7,400
1884	Calver, 6½-inch (British import), equatorial (w/circles, no driving clock)	$375	$6,540
1906	Brashear, 6-inch, equatorial	$300	$5,860
1906	Brashear, 6-inch, equatorial (w/ circles & driving clock)	$650	$12,700
1935	Tinsley, 4-inch alt-azimuth	$134	$1,725
1935	Tinsley, 4-inch equatorial (on metal tripod – no drive)	$175	$2,252
1935	Tinsley, 6-inch, equatorial (w/ circles & electric clock drive)	$375	$4,826
1947	Sky-Scope, 3.5-inch, alt-azimuth	$19.75	$158
1950	Sky-Scope, 3.5-inch - improved	$25.00	$182
1958	Edmund Scientific, 3-inch, alt-azimuth	$29.50	$180
1958	Edmund Scientific, 4.25-inch, equatorial	$74.50	$454
1958	Criterion, 4-inch "Dynascope", alt-azimuth	$49.95	$305
1958	Criterion, 4-inch "Dynascope" deluxe, equatorial	$79.95	$488
1958	Sky-Scope, 3.5-inch - improved	$29.75	$181
1960	Cave Optical, 6-inch "Student" equatorial	$194.50	$1,160
1960	Tasco (Japanese import), 4.5-inch, equatorial	$93.95	$560
1960	Criterion, 6-inch "RV-6 Dynascope" equatorial (w/ circles & drive)	$194.95	$1,162

Appendix 2:
Relative Values of the US Dollar and British Pound from 1800 to 2000

This is a table giving the relative value of the United States Dollar and the English Pound from 1850 to 2000. The data presented here is derived from a commodity-based index tables in McCusker's, *How Much Is That In Real Money, 2nd Edition* (p. 49–60 and p. 93–106). This provides a rough idea of the relative value of products historically, but there are of course nuances to values that cannot be understood simply on a commodity-based index, as the cost of commodities are inconsistent over long spans of history; grain, for instance, is far less expensive to produce today compared to 1900 largely due to mechanization of farming. Another aspect to consider is the simple fact that, with the coming of the consumer culture in the 20th century, workers were paid more relative to what they had made previously.

The table was created by taking the 2001 value of the U. S. Dollar (2111) and British Pound (4682) respectively, and dividing it by the commodity-based index value from McCusker:

Year	US Dollar Index Value	Relative value compared to 2001	British Pound Index Value	Relative value compared to 2001
2000	2059	1.025255	4559	1.02698
1999	1992	1.059739	4426	1.05784
1998	1949	1.08312	4360	1.073853
1997	1920	1.099479	4216	1.110531
1996	1876	1.125267	4089	1.145023
1995	1822	1.158617	3990	1.173434
1994	1773	1.190637	3859	1.213268
1993	1728	1.221644	3765	1.243559
1992	1678	1.258045	3707	1.263016
1991	1629	1.295887	3574	1.310017
1990	1563	1.350608	3376	1.386848

1989	1483	1.423466	3084	1.518158
1988	1415	1.491873	2862	1.635919
1987	1359	1.553348	2728	1.716276
1986	1311	1.610221	2619	1.787705
1985	1287	1.640249	2532	1.849131
1984	1243	1.698311	2387	1.961458
1983	1191	1.77246	2274	2.058927
1982	1154	1.829289	2174	2.153634
1981	1087	1.942042	2002	2.338661
1980	985	2.143147	1789	2.617105
1979	868	2.432028	1517	3.086355
1978	780	2.70641	1338	3.499253
1977	725	2.911724	1231	3.803412
1976	680	3.104412	1066	4.39212
1975	643	3.283048	915	5.11694
1974	590	3.577966	736	6.361413
1973	531	3.975518	635	7.373228
1972	500	4.222	582	8.044674
1971	484	4.36157	543	8.622468
1970	464	4.549569	496	9.439516
1969	438	4.819635	466	10.04721
1968	416	5.074519	442	10.59276
1967	399	5.290727	422	11.09479
1966	388	5.440722	412	11.36408
1965	377	5.599469	397	11.79345
1964	371	5.690027	379	12.35356
1963	366	5.76776	367	12.75749
1962	362	5.831492	360	13.00556
1961	358	5.896648	350	13.37714
1960	354	5.963277	339	13.81121
1959	348	6.066092	335	13.97612
1958	346	6.101156	333	14.06006
1957	336	6.282738	324	14.45062
1956	325	6.495385	312	15.00641
1955	320	6.596875	303	15.45215
1954	321	6.576324	291	16.08935
1953	320	6.596875	284	16.48592
1952	317	6.659306	303	15.45215
1951	310	6.809677	278	16.84173
1950	288	7.329861	240	19.50833

1949	285	7.407018	239	19.58996
1948	288	7.329861	212	22.08491
1947	267	7.906367	196	23.88776
1946	233	9.060086	180	26.01111
1945	215	9.818605	174	26.90805
1944	210	10.05238	169	27.70414
1943	207	10.19807	163	28.72393
1942	195	10.82564	162	28.90123
1941	176	11.99432	136	34.42647
1940	168	12.56548	120	39.01667
1939	166	12.71687	92	50.8913
1938	169	12.49112	97	48.26804
1937	172	12.27326	97	48.26804
1936	166	12.71687	92	50.8913
1935	164	12.87195	87	53.81609
1934	160	13.19375	83	56.40964
1933	155	13.61935	84	55.7381
1932	163	12.95092	81	57.80247
1931	182	11.5989	87	53.81609
1930	200	10.555	97	48.26804
1929	205	10.29756	115	40.71304
1928	205	10.29756	113	41.43363
1927	208	10.14904	114	41.07018
1926	211	10.00474	120	39.01667
1925	210	10.05238	130	36.01538
1924	204	10.34804	132	35.4697
1923	204	10.34804	131	35.74046
1922	200	10.555	127	36.86614
1921	214	9.864486	156	30.01282
1920	240	8.795833	197	23.7665
1919	207	10.19807	172	27.22093
1918	180	11.72778	190	24.64211
1917	153	13.79739	150	31.21333
1916	130	16.23846	126	37.15873
1915	121	17.44628	100	46.82
1914	120	17.59167	87	53.81609
1913	119	17.7395	78	60.02564
1912	117	18.04274	76	61.60526
1911	114	18.51754	75	62.42667
1910	114	18.51754	76	61.60526

1909	109	19.36697	81	57.80247
1908	111	19.01802	79	59.26582
1907	113	18.68142	78	60.02564
1906	108	19.5463	77	60.80519
1905	106	19.91509	75	62.42667
1904	107	19.72897	75	62.42667
1903	106	19.91509	76	61.60526
1902	103	20.49515	73	64.13699
1901	102	20.69608	75	62.42667
1900	101	20.90099	76	61.60526
1899	100	21.11	72	65.02778
1898	100	21.11	75	62.42667
1897	100	21.11	73	64.13699
1896	101	20.90099	72	65.02778
1895	101	20.90099	74	63.27027
1894	103	20.49515	75	62.42667
1893	108	19.5463	70	66.88571
1892	109	19.36697	76	61.60526
1891	109	19.36697	76	61.60526
1890	109	19.36697	72	65.02778
1889	111	19.01802	72	65.02778
1888	114	18.51754	72	65.02778
1887	114	18.51754	73	64.13699
1886	113	18.68142	71	65.94366
1885	116	18.19828	78	60.02564
1884	118	17.88983	82	57.09756
1883	121	17.44628	90	52.02222
1882	123	17.1626	87	53.81609
1881	123	17.1626	92	50.8913
1880	123	17.1626	89	52.60674
1879	120	17.59167	92	50.8913
1878	120	17.59167	97	48.26804
1877	126	16.75397	101	46.35644
1876	129	16.36434	104	45.01923
1875	132	15.99242	100	46.82
1874	137	15.40876	108	43.35185
1873	144	14.65972	109	42.95413
1872	147	14.36054	105	44.59048
1871	147	14.36054	100	46.82
1870	157	13.44586	94	49.80851

1869	164	12.87195	95	49.28421
1868	171	12.34503	98	47.77551
1867	178	11.85955	102	45.90196
1866	191	11.05236	99	47.29293
1865	196	10.77041	94	49.80851
1864	189	11.16931	91	51.45055
1863	151	13.98013	87	53.81609
1862	121	17.44628	98	47.77551
1861	106	19.91509	99	47.29293
1860	100	21.11	100	46.82
1859	100	21.11	92	50.8913
1858	99	21.32323	91	51.45055
1857	105	20.10476	98	47.77551
1856	102	20.69608	96	48.77083
1855	104	20.29808	97	48.26804
1854	101	20.90099	96	48.77083
1853	93	22.69892	86	54.44186
1852	93	22.69892	74	63.27027
1851	92	22.94565	73	64.13699
1850	94	22.45745	74	63.27027
1849	92	22.94565	79	59.26582
1848	95	22.22105	84	55.7381
1847	99	21.32323	96	48.77083
1846	92	22.94565	85	55.08235
1845	91	23.1978	82	57.09756
1844	90	23.45556	78	60.02564
1843	89	23.7191	78	60.02564
1842	98	21.54082	88	53.20455
1841	105	20.10476	96	48.77083
1840	104	20.29808	98	47.77551
1839	112	18.84821	96	48.77083
1838	112	18.84821	90	52.02222
1837	115	18.35652	89	52.60674
1836	112	18.84821	87	53.81609
1835	106	19.91509	78	60.02564
1834	103	20.49515	77	60.80519
1833	101	20.90099	83	56.40964
1832	103	20.49515	89	52.60674
1831	104	20.29808	96	48.77083
1830	111	19.01802	87	53.81609

1829	112	18.84821	90	52.02222
1828	114	18.51754	91	51.45055
1827	120	17.59167	94	49.80851
1826	119	17.7395	101	46.35644
1825	119	17.7395	107	43.75701
1824	116	18.19828	91	51.45055
1823	126	16.75397	84	55.7381
1822	141	14.97163	78	60.02564
1821	136	15.52206	91	51.45055
1820	141	14.97163	103	45.45631
1819	153	13.79739	114	41.07018
1818	153	13.79739	116	40.36207
1817	160	13.19375	116	40.36207
1816	169	12.49112	102	45.90196
1815	185	11.41081	112	41.80357
1814	211	10.00474	125	37.456
1813	192	10.99479	143	32.74126
1812	160	13.19375	140	33.44286
1811	158	13.36076	123	38.06504
1810	148	14.26351	127	36.86614
1809	148	14.26351	123	38.06504
1808	151	13.98013	112	41.80357
1807	139	15.18705	109	42.95413
1806	147	14.36054	111	42.18018
1805	141	14.97163	116	40.36207
1804	142	14.8662	100	46.82
1803	136	15.52206	96	48.77083
1802	129	16.36434	103	45.45631
1801	153	13.79739	133	35.20301
1800	151	13.98013	119	39.34454

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Appendix 3:
Currency Exchange Rates

The exact exchange rate for foreign currency is not always easy to come by. Fortunately, a number of primary sources used in my research have included just such information. From Loomis (1884), p. 503: 1 German mark = $0.24, 1 Austrian Florin = $0.417; From the Carl A. Steinheil catalogue (1907), p. 2: 1 German Mark = 1.25 French Francs = 1 British shilling (£0.05) = $0.25 US.

The following representative exchange rates are from R. L. Bidwell, *Currency Conversion Tables: A Hundred Years of Change*, (London: Rex Collings, 1970):

Country	**= £1**	**= $1**		**= £1**	**= $1**
United States:			**Austria** (florin):		
1913	4.87	-	1897	10.20	2.00
1920	3.70	-			
1925	4.74	-			
1930	4.87	-			
1935	4.93	-	**Germany** (marks):		
1940	4.03	-	1913	20.43	4.20
1945	4.03	-	1920	250.00	70.37
1950	2.80	-	1930	20.40	4.20
1955	2.79	-	1935	12.10	2.48
1960	2.81	-	1940	NA	2.50
1969	2.40	-	1950	11.76	4.20
France (francs):					
1870	25.10	4.98			
1914	25.30	5.19	**Japan** (Yen):		
1920	47.20	13.03	1930	10.00	2.00
1930	123.90	25.50	1935	17.00	3.40
1940	176.50	43.80	1940	17.00	4.26
1950	980.00	350.00	1950	1,010.00	360.00

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Note on archival sources

The main publicly available archival source consulted in this dissertation is that of Albert G. Ingalls, held at the Archives Center, Smithsonian Institution National Museum of American History under the catalogue designation "AC0175". I have used the abbreviated archival designation "AC, SINMAH, AC0175", followed by box and folder numbers, on all bibliographical entries from this source.

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