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THE FUTURE OF ASTRONOMY

BY PROFESSOR EDWARD C. PICKERING

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THE FUTURE OF ASTRONOMY[1]

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HARVARD COLLEGE OBSERVATORY

It is claimed by astronomers that their science is not only the oldest, but that it is the most highly developed of the sciences. Indeed it should be so, since no other science has ever received such support from royalty, from the state and from the private individual. However this may be, there is no doubt that in recent years astronomers have had granted to them greater opportunities for carrying on large pieces of work than have been entrusted to men in any other department of pure science. One might expect that the practical results of a science like physics would appeal to the man who has made a vast fortune through some of its applications. The telephone, the electric transmission of power, wireless telegraphy and the submarine cable are instances of immense financial returns derived from the most abstruse principles of physics. Yet there are scarcely any physical laboratories devoted to research, or endowed with independent funds for this object, except those supported by the government. The endowment of astronomical observatories devoted to research, and not including that given for teaching, is estimated to amount to half a million dollars annually. Several of the larger observatories have an annual income of fifty thousand dollars.

I once asked the wisest man I know, what was the reason for this difference. He said that it was probably because astronomy appealed to the imagination. A practical man, who has spent all his life in his counting room or mill, is sometimes deeply impressed with the vast distances and grandeur of the problems of astronomy, and the very remoteness and difficulty of studying the stars attract him.

My object in calling your attention to this matter is the hope that what I have to say of the organization of astronomy may prove of use to those interested in other branches of science, and that it may lead to placing them on the footing they should hold. My arguments apply with almost equal force to physics, to chemistry, and in fact to almost every branch of physical or natural science, in which knowledge may be advanced by observation or experiment.

The practical value of astronomy in the past is easily established. Without it, international commerce on a large scale would have been impossible. Without the aid of astronomy, accurate boundaries of large tracts of land could not have been defined and standard time would have been impossible. The work of the early astronomers was eminently practical, and appealed at once to every one. This work has now been finished. We can compute the positions of the stars for years, almost for centuries, with all the accuracy needed for navigation, for determining time or for approximate boundaries of countries. The investigations now in progress at the greatest observatories have little, if any, value in dollars and cents. They appeal, however, to the far higher sense, the desire of the intellectual human being to determine the laws of nature, the construction of the material universe, and the properties of the heavenly bodies of which those known to exist far outnumber those that can be seen.

Three great advances have been made in astronomy. First, the invention of the telescope, with which we commonly associate the name of Galileo, from the wonderful results he obtained with it. At that time there was practically no science in America, and for more than two centuries we failed to add materially to this invention. Half a century ago the genius of the members of one family, Alvan Clark and his two sons, placed America in the front rank not only in the construction, but in the possession, of the largest and most perfect telescopes ever made. It is not easy to secure the world's record in any subject. The Clarks constructed successively, the 18-inch lens for Chicago, the 26-inch for Washington, the 30-inch for Pulkowa, the 36-inch for Lick and the 40-inch for Yerkes. Each in turn was the largest yet made, and each time the Clarks were called upon to surpass the world's record, which they themselves had already established. Have we at length reached the limit in size? If we include reflectors, no, since we have mirrors of 60 inches aperture at Mt. Wilson and Cambridge, and a still larger one of 100 inches has been undertaken. It is more than doubtful, however, whether a further increase in size is a great advantage. Much more depends on other conditions, especially those of climate, the kind of work to be done and, more than all, the man behind the gun. The case is not unlike that of a battleship. Would a ship a thousand feet long always sink one of five hundred feet? It seems as if we had nearly reached the limit of size of telescopes, and as if we must hope for the next improvement in some other direction.

The second great advance in astronomy originated in America, and was in an entirely different direction, the application of photography to the study of the stars. The first photographic image of a star was obtained in 1850, by George P. Bond, with the assistance of Mr. J.A. Whipple, at the Harvard College Observatory. A daguerreotype plate was placed at the focus of the 15-inch equatorial, at that time one of the two largest refracting telescopes in the world. An image of α Lyræ was thus obtained, and for this Mr. Bond received a gold medal at the first international exhibition, that at the Crystal Palace, in London, in 1851. In 1857, Mr. Bond, then Professor Bond, director of the Harvard Observatory, again took up the matter with collodion wet plates, and in three masterly papers showed the advantages of photography in many ways. The lack of sensitiveness of the wet plate was perhaps the only reason why its use progressed but slowly. Quarter of a century later, with the introduction of the dry plate and the gelatine film, a new start was made. These photographic plates were very sensitive, were easily handled, and indefinitely long exposures could be made with them. As a result, photography has superseded visual observations, in many departments of astronomy, and is now carrying them far beyond the limits that would have been deemed possible a few years ago.

The third great advance in astronomy is in photographing the spectra of the stars. The first photograph showing the lines in a stellar spectrum was obtained by Dr. Henry Draper, of New York, in 1872. Sir William Huggins in 1863 had obtained an image of the spectrum of Sirius, on a photographic plate, but no lines were visible in it. In 1876 he again took up the subject, and, by an early publication, preceded Dr. Draper. When we consider the attention the photography of stellar spectra is receiving at the present time, in nearly all the great observatories in the world, it may well be regarded as the third great advance in astronomy.

What will be the fourth advance, and how will it be brought about? To answer this question we must consider the various ways in which astronomy, and for that matter any other science, may be advanced.

First, by educating astronomers. There are many observatories where excellent instruction in astronomy is given, either to the general student or to one who wishes to make it his profession. At almost any active observatory a student would be received as a volunteer assistant. Unfortunately, few young men can afford to accept an unpaid position, and the establishment of a number of fellowships each offering a small salary sufficient to support the student would enable him to acquire the necessary knowledge to fill a permanent position. The number of these scholarships should not be large, lest more students should undertake the work than would be required to fill the permanent paying positions in astronomy, as they become vacant.

In Europe, a favorite method of aiding science is to offer a prize for the best memoir on a specified subject. On theoretical grounds this is extremely objectionable. Since the papers presented are anonymous and confidential, no one but the judges know how great is the effort wasted in duplication. The larger the prize, the greater the injury to science, since the greater will be the energy diverted from untried fields. It would be much wiser to invite applications, select the man most likely to produce a useful memoir, and award the prize to him if he achieved success.

The award of a medal, if of great intrinsic value, would be an unwise expenditure. The Victoria Cross is an example of a successful foundation, highly prized, but of small intrinsic value. If made of gold, it would carry no greater honor, and would be more liable to be stolen, melted down or pawned.

Honorary membership in a famous society, or honorary degrees, have great value if wisely awarded. Both are highly prized, form an excellent stimulus to continued work, and as they are both priceless, and without price, they in no way diminish the capacity for work. I recently had occasion to compare the progress in various sciences of different countries, and found that the number of persons elected as foreign associates of the seven great national societies of the world was an excellent test. Eighty-seven persons were members of two or more of these societies. Only six are residents of the United States, while an equal number come from Saxony, which has only a twentieth of the population. Of the six residents here, only three were born in the United States. Not a single mathematician, or doctor, from this country appears on the list. Only in astronomy are we well represented. Out of a total of ten astronomers, four come from England, and three from the United States. Comparing the results for the last one hundred and fifty years, we find an extraordinary growth for the German races, an equally surprising diminution for the French and other Latin races, while the proportion of Englishmen has remained unchanged.

A popular method of expending money, both by countries and by individuals, is in sending expeditions to observe solar eclipses. These appeal both to donors and recipients. The former believe that they are making a great contribution to science, while the latter enjoy a long voyage to a distant country, and in case of clouds they are not expected to make any scientific return. If the sky is clear at the time of the eclipse, the newspapers of the next day report that great results have been secured, and after that nothing further is ever heard.

Exceptions should be made of the English Eclipse Committee and the Lick Observatory, which, by long continued study and observation, are gradually solving the difficult problems which can be reached in this way only.

The gift of a large telescope to a university is of very doubtful value, unless it is accompanied, first, by a sum much greater than its cost, necessary to keep it employed in useful work, and secondly, to require that it shall be erected, not on the university grounds, but in some region, probably mountainous or desert, where results of real value can be obtained.

Having thus considered, among others, some of the ways in which astronomy is not likely to be much advanced, we proceed to those which will secure the greatest scientific return for the outlay. One of the best of these is to create a fund to be used in advancing research, subject only to the condition that results of the greatest possible value to science shall be secured. One advantage of this method is that excellent results may be obtained at once from a sum, either large or small. Whatever is at first given may later be increased indefinitely, if the results justify it. One of the wisest as well as the greatest of donors has said: “Find the particular man,” but unfortunately, this plan has been actually tried only with some of the smaller funds. Any one who will read the list of researches aided by the Rumford Fund, the Elizabeth Thompson Fund or the Bruce Fund of 1890 will see that the returns are out of all proportion to the money expended. The trustees of such a fund as is here proposed should not regard themselves as patrons conferring a favor on those to whom grants are made, but as men seeking for the means of securing large scientific returns for the money entrusted to them. An astronomer who would aid them in this work, by properly expending a grant, would confer rather than receive a favor. They should search for astronomical bargains, and should try to purchase results where the money could be expended to the best advantage. They should make it their business to learn of the work of every astronomer engaged in original research. A young man who presented a paper of unusual importance at a scientific meeting, or published it in an astronomical journal, would receive a letter inviting him to submit plans to the trustees, if he desired aid in extending his work. In many cases, it would be found that, after working for years under most unfavorable conditions, he had developed a method of great value and had applied it to a few stars, but must now stop for want of means. A small appropriation would enable him to employ an assistant who, in a short time, could do equally good work. The application of this method to a hundred or a thousand stars would then be only a matter of time and money.

The American Astronomical Society met last August at a summer resort on Lake Erie. About thirty astronomers read papers, and in a large portion of the cases the appropriation of a few hundred dollars would have permitted a great extension in these researches. A sad case is that of a brilliant student who may graduate at a college, take a doctor’s degree in astronomy, and perhaps pass a year or two in study at a foreign observatory. He then returns to this country, enthusiastic and full of ideas, and considers himself fortunate in securing a position as astronomer in a little country college. He now finds himself overwhelmed with work as a teacher, without time or appliances for original work. What is worse, no one sympathizes with him in his aspirations, and after a few years he abandons hope and settles down to the dull routine of lectures, recitations and examinations. A little encouragement at the right time, aid by offering to pay for an assistant, for a suitable instrument, or for publishing results, and perhaps a word to the president of his college if the man showed real genius, might make a great astronomer, instead of a poor teacher. For several years, a small fund, yielding a few hundred dollars annually, has been disbursed at Harvard in this way, with very encouraging results.

A second method of aiding astronomy is through the large observatories. These institutions, if properly managed, have after years of careful study and trial developed elaborate systems of solving the great problems of the celestial universe. They are like great factories, which by taking elaborate precautions to save waste at every point, and by improving in every detail both processes and products, are at length obtaining results on a large scale with a perfection and economy far greater than is possible by individuals, or smaller institutions. The expenses of such an observatory are very large, and it has no pecuniary return, since astronomical products are not salable. A great portion of the original endowment has been spent on the plant, expensive buildings and instruments. Current expenditures, like library expenses, heating, lighting, etc., are independent of the output. It is like a man swimming up stream. He may struggle desperately, and yet make no progress. Any gain in power effects a real advance. This is the condition of nearly all the larger observatories. Their income is mainly used for current expenses, which would be nearly the same whatever their output. A relatively small increase in income can thus be spent to great advantage. The principal instruments are rarely used to their full capacities, and the methods employed could be greatly extended without any addition to the executive or other similar expenses. A man superintending the work of several assistants can often have their number doubled, and his output increased in nearly the same proportion, with no additional expense except the moderate one of their salaries. A single observatory could thus easily do double the work that could be accomplished if its resources were divided between two of half the size.

A third, and perhaps the best, method of making a real advance in astronomy is by securing the united work of the leading astronomers of the world. The best example of this is the work undertaken in 1870 by the Astronomische Gesellschaft, the great astronomical society of the world. The sky was divided into zones, and astronomers were invited to measure the positions of all the stars in these zones. The observation of two of the northern and two of the southern zones were undertaken by American observatories. The zone from +1° to +5° was undertaken by the Chicago Observatory, but was abandoned owing to the great fire of 1871, and the work was assumed and carried to completion by the Dudley Observatory at Albany. The zone from +50° to +55° was undertaken by Harvard. An observer and corps of assistants worked on this problem for a quarter of a century. The completed results now fill seven quarto volumes of our annals. Of the southern zones, that from -14° to -18° was undertaken by the Naval Observatory at Washington, and is now finished. The zone from -10° to -14° was undertaken at Harvard, and a second observer and corps of assistants have been working on it for twenty years. It is now nearly completed, and we hope to begin its publication this year. The other zones were taken by European astronomers. As a result of the whole, we have the precise positions of nearly a hundred and fifty thousand stars, which serve as a basis for the places of all the objects in the sky.

Another example of cooperative work is a plan proposed by the writer in 1906, at the celebration of the two-hundredth anniversary of the birth of Franklin. It was proposed, first to find the best place in the world for an astronomical observatory, which would probably be in South Africa, to erect there a telescope of the largest size, a reflector of seven feet aperture. This instrument should be kept at work throughout every clear night, taking photographs according to a plan recommended by an international committee of astronomers. The resulting plates should not be regarded as belonging to a single institution, but should be at the service of whoever could make the best use of them. Copies of any, or all, would be furnished at cost to any one who wished for them. As an example of their use, suppose that an astronomer at a little German University should discover a law regulating the stars in clusters. Perhaps he has only a small telescope, near the smoke and haze of a large city, and has no means of securing the photographs he needs. He would apply to the committee, and they would vote that ten photographs of twenty clusters, each with an exposure of an hour, should be taken with the large telescope. This would occupy about a tenth part of the time of the telescope for a year. After making copies, the photographs would be sent to the astronomer who would perhaps spend ten years in studying and measuring them. The committee would have funds at their disposal to furnish him, if necessary, with suitable measuring instruments, assistants for reducing the results, and means for publication. They would thus obtain the services of the most skilful living astronomers, each in his own special line of work, and the latter would obtain in their own homes material for study, the best that the world could supply. Undoubtedly, by such a combination if properly organized, results could be obtained far better than is now possible by the best individual work, and at a relatively small expense. Many years of preparation will evidently be needed to carry out such a plan, and to save time we have taken the first step and have sent a skilful and experienced observer to South Africa to study its climate and compare it with the experience he has gained during the last twenty years from a similar study of the climate of South America and the western portion of the United States.

The next question to be considered is in what direction we may expect the greatest advance in astronomy will be made. Fortunate indeed would be the astronomer who could answer this question correctly. When Ptolemy made the first catalogue of the stars, he little expected that his observations would have any value nearly two thousand years later. The alchemists had no reason to doubt that their results were as important as those of the chemists. The astrologers were respected as much as the astronomers. Although there is a certain amount of fashion in astronomy, yet perhaps the best test is the judgment of those who have devoted their lives to that science. Thirty years ago the field was narrow. It was the era of big telescopes. Every astronomer wanted a larger telescope than his neighbors, with which to measure double stars. If he could not get such an instrument, he measured the positions of the stars with a transit circle. Then came astrophysics, including photography, spectroscopy and photometry. The study of the motion of the stars along the line of sight, by means of photographs of their spectra, is now the favorite investigation at nearly all the great observatories of the world. The study of the surfaces of the planets, while the favorite subject with the public, next to the destruction of the earth by a comet, does not seem to appeal to astronomers. Undoubtedly, the only way to advance our knowledge in this direction is by the most powerful instruments, mounted in the best possible locations. Great astronomers are very conservative, and any sensational story in the newspapers is likely to have but little support from them. Instead of aiding, it greatly injures real progress in science.

There is no doubt that, during the next half century, much time and energy will be devoted to the study of the fixed stars. The study of their motions as indicated by their change in position was pursued with great care by the older astronomers. The apparent motions were so small that a long series of years was required and, in general, for want of early observations of the precise positions of the faint stars, this work was confined mainly to the bright stars. Photography is yearly adding a vast amount of material available for this study, but the minuteness of the quantities to be measured renders an accurate determination of their laws very difficult. Moreover, we can thus only determine the motions at right angles to the line of sight, the motion towards us or from us being entirely insensible in this way. Then came the discovery of the change in the spectrum when a body was in motion, but still this change was so small that visual observations of it proved of but little value. Attaching a carefully constructed spectroscope to one of the great telescopes of the world, photographing the spectrum of a star, and measuring it with the greatest care, provided a tool of wonderful efficiency. The motion, which sometimes amounts to several hundreds of miles a second could thus be measured to within a fraction of a mile. The discovery that the motion was variable, owing to the star's revolving around a great dark planet sometimes larger than the star, added greatly not only to the interest of these researches, but also to the labor involved. Instead of a single measure for each star, in the case of the so-called spectroscopic binaries, we must make enough measures to determine the dimensions of the orbit, its form and the period of revolution.

What has been said of the motions of the stars applies also, in general, to the determination of their distances. A vast amount of labor has been expended on this problem. When at length the distance of a single star was finally determined, the quantity to be measured was so small as to be nearly concealed by the unavoidable errors of measurement. The parallax, or one half of the change in the apparent position of the stars as the earth moves around the sun, has its largest value for the nearest stars. No case has yet been found in which this quantity is as large as a foot rule seen at a distance of fifty miles, and for comparatively few stars is it certainly appreciable. An extraordinary degree of precision has been attained in recent measures of this quantity, but for a really satisfactory solution of this problem, we must probably devise some new method, like the use of the spectroscope for determining motions. Two or three illustrations of the kind of methods which might be used to solve this problem may be of interest. There are certain indications of the presence of a selective absorbing medium in space. That is, a medium like red glass, for instance, which would cut off the blue light more than the red light. Such a medium would render the blue end of the spectrum of a distant star much fainter, as compared with the red end, than in the case of a near star. A measure of the relative intensity of the two rays would servo to measure the distance, or thickness of the absorbing medium. The effect would be the same for all stars of the same class of spectrum. It could be tested by the stars forming a cluster, like the Pleiades, which are doubtless all at nearly the same distance from us. The spectra of stars of the tenth magnitude, or fainter, can be photographed well enough to be measured in this way, so that the relative distances of nearly a million stars could be thus determined.

Another method which would have a more limited application, would depend on the velocity of light. It has been maintained that the velocity of light in space is not the same for different colors. Certain stars, called Algol stars, vary in light at regular intervals when partially eclipsed by the interposition of a large dark satellite. Recent observations of these eclipses, through glass of different colors, show variations in the time of obscuration. Apparently, some of the rays reach the earth sooner than others, although all leave the star at the same time. As the entire time may amount to several centuries, an excessively small difference in velocity would be recognizable. A more delicate test would be to measure the intensity of different portions of the spectrum at a time when the light is changing most rapidly. The effect should be opposite according as the light is increasing or diminishing. It should also show itself in the measures of all spectroscopic binaries.

A third method of great promise depends on a remarkable investigation carried on in the physical laboratory of the Case School of Applied Science. According to the undulatory theory of light, all space is filled with a medium called ether, like air, but as much more tenuous than air as air is more tenuous than the densest metals. As the earth is moving through space at the rate of several miles a second, we should expect to feel a breeze as we rush through the ether, like that of the air when in an automobile we are moving with but one thousandth part of this velocity. The problem is one of the greatest delicacy, but a former officer of the Case School, one of the most eminent of living physicists, devised a method of solving it. The extraordinary result was reached that no breeze was perceptible. This result appeared to be so improbable that it has been tested again and again, but every time, the more delicate the instrument employed, the more certainly is the law established. If we could determine our motion with reference to the ether, we should have a fixed line of reference to which all other motions could be referred. This would give us a line of ever-increasing length from which to measure stellar distances.

Still another method depends on the motion of the sun in space. There is some evidence that this motion is not straight, but along a curved line. We see the stars, not as they are now, but as they were when the light left them. In the case of the distant stars this may have occurred centuries ago. Accordingly, if we measure the motion of the sun from them, and from near stars, a comparison with its actual motion will give us a clue to their distances. Unfortunately, all the stars appear to have large motions whose law we do not know, and therefore we have no definite starting point unless we can refer all to the ether which may be assumed to be at rest.

If the views expressed to you this morning are correct, we may expect that the future of astronomy will take the following form: There will be at least one very large observatory employing one or two hundred assistants, and maintaining three stations. Two of these will be observing stations, one in the western part of the United States, not far from latitude +30°, the other similarly situated in the southern hemisphere, probably in South Africa, in latitude -30°. The locations will be selected wholly from their climatic conditions. They will be moderately high, from five to ten thousand feet, and in desert regions. The altitude will prevent extreme heat, and clouds or rain will be rare. The range of temperature and unsteadiness of the air will be diminished by placing them on hills a few hundred feet above the surrounding country. The equipment and work of the two stations will be substantially the same. Each will have telescopes and other instruments of the largest size, which will be kept at work throughout the whole of every clear night. The observers will do but little work in the daytime, except perhaps on the sun, and will not undertake much of the computation or reductions. This last work will be carried on at a third station, which will be near a large city where the cost of living and of intellectual labor is low. The photographs will be measured and stored at this station, and all the results will be prepared for publication, and printed there. The work of all three stations will be carefully organized so as to obtain the greatest result for a given expenditure. Every inducement will be offered to visiting astronomers who wish to do serious work at either of the stations and also to students who intend to make astronomy their profession. In the case of photographic investigations it will be best to send the photographs so that astronomers desiring them can work at home. The work of the young astronomers throughout the world will be watched carefully and large appropriations made to them if it appears that they can spend them to advantage. Similar aid will be rendered to astronomers engaged in teaching, and to any one, professional or amateur, capable of doing work of the highest grade. As a fundamental condition for success, no restrictions will be made that will interfere with the greatest scientific efficiency, and no personal or local prejudices that will restrict the work.

These plans may seem to you visionary, and too Utopian for the twentieth century. But they may be nearer fulfilment than we anticipate. The true astronomer of to-day is eminently a practical man. He does not accept plans of a sensational character. The same qualities are needed in directing a great observatory successfully, as in managing a railroad, or factory. Any one can propose a gigantic expenditure, but to prove to a shrewd man of affairs that it is feasible and advisable is a very different matter. It is much more difficult to give away money wisely than to earn it. Many men have made great fortunes, but few have learned how to expend money wisely in advancing science, or to give it away judiciously. Many persons have given large sums to astronomy, and some day we shall find the man with broad views who will decide to have the advice and aid of the astronomers of the world, in his plans for promoting science, and who will thus expend his money, as he made it, taking the greatest care that not one dollar is wasted. Again, let us consider the next great advance, which perhaps will be a method of determining the distances of the stars. Many of us are working on this problem, the solution of which may come to some one any day. The present field is a wide one, the prospects are now very bright, and we may look forward to as great an advance in the twentieth century, as in the nineteenth. May a portion of this come to the Case School and, with your support, may its enviable record, in the past, be surpassed by its future achievements.

[1] Commencement address at Case School of Applied Science, Cleveland, May 27, 1909.

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