News & views

Astronomy

Is it time for astronomers to reflect on "rapid" telescopes?

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Telescopes with glass lenses have dominated professional astronomy, but recent improvements to mirrored telescopes may suggest that a new era of observational astronomy is about to begin.

Humans, for millennia, have looked towards the heavens and attempted to make sense of what they can see. In the last few centuries, we have become more adept at this practice, constructing new instruments to aid our eyes in viewing the skies. In recent decades, we have even begun to replace the eye itself. Large telescopes have allowed those most curious to view far-away objects in greater detail than ever before and as these continue to improve, so does our knowledge of the stars.

The largest telescopes collect and focus starlight using glass lenses. These so-called 'refractors' are the pinnacle of astronomical technology. However, their dominion over the field of astronomy may be fleeting, suggests James Keeler - director of the Lick Observatory at the summit of Mt. Hamilton. In his recent paper,[1] Keeler remarks at the power and 'rapidity' of the Crossley reflecting telescope.

Telescopes collect light and focus it to a single point, in a similar way to the eye. A telescope observes the invisible by collecting a greater quantity of light than the human eye. The light-collecting area of a telescope is known as the aperture. This is such an important property that it is often quoted with the name of the instrument itself (such as the "thirty-six-inch Great Refractor" or the "Crossley three-foot reflector"[2]). As well as allowing us to see that which is too faint, we are also able to see that which is too small; miniscule objects can be magnified and inspected in great detail through the use of a telescope.

Refracting telescopes use a glass lens to focus light from a distant source to a point. The distance between this point and the lens is, rather intuitively, called the focal length. This is an important factor in two key properties of any telescope: its magnification and 'speed' (the time taken to collect light). A telescope with a large focal length will magnify greatly the object at which it is pointed. However, the ratio of the focal length to the aperture determines a telescope's speed. Thus, a highly magnifying telescope must be exposed to a source for a longer time to collect enough light.

The Great Lick Refractor is a 36-inch refracting telescope, second in size only to the brand-new 40-inch refractor in Chicago.[3] The telescope's frame is a lengthy 57 feet, so it requires very skilled craftsmanship to achieve the required performance, in spite of its enormous weight. As the glass lenses in telescopes become larger they also become heavier, which increases the strain on the frame of the telescope. Another issue with using lenses is a visual effect called chromatic aberration, where the red and blue light from a star appear separately, not as a single image.

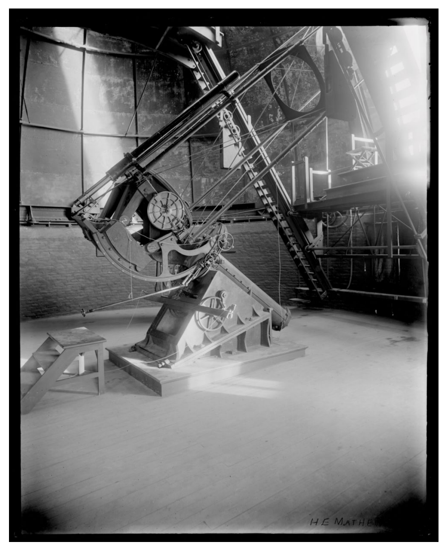

Figure 1: The 3-foot Crossley Reflector. In this image taken in November of last year, the reflector's small size and lightweight frame can be seen.

This effect is a consequence of the fact that the path of blue light is more severely altered by the glass lens than red. As a result, these two light beams come to focus at different points. Some amount of blue light is also absorbed by the glass lens, reducing the collecting power of the telescope.[4]

The reflecting telescope is no new concept. With such an instrument, William Herschel was able to catalogue various nebulae and discover the planet Uranus in 1781. These telescopes have the remarkable ability to see extremely faint objects in the sky. However, constructing and using large reflectors has historically been a tough challenge due to the heavy speculum metal mirrors and constant necessary attention. Fortunately, as noted by Keeler, in the last two decades vast improvements have been made in mirror technology.[5]

The 3-foot mirror of the Crossley reflector is made from glass, with a silver coating. The reflector was built by Andrew Common in 1879, around the same time as the Great Refractor. Having been acquired by the Lick Observatory in 1896, the presence of both a reflecting and refracting telescope of equal aperture has provided the opportunity to compare the two.

"To one who, like myself, has always worked with refracting telescopes, the photographic power of a large reflector is surprising."

- JE Keeler (Dec. 1899)[1]

The Crossley Reflector does not suffer from aberration, as all colours of light are reflected by the same angle.[6] Furthermore, the mirror provides much improved reflectivity compared to the the glass lens. Keeler notes that on nights with extremely clear weather, the reflector greatly outperforms its refracting counterpart by collecting the additional blue light that is usually absorbed by the atmosphere.

By reflecting collected light onto an eyepiece or photographic plate, reflectors can be made significantly shorter in length. Figure 1 shows that the Crossley reflector's length is significantly less than the Great Lick Refractor. Consequently, the speed of the telescope is greatly increased. Keeler lauds the rapidity of the Crossley reflector, citing observations of various small and faint nebulae which yielded distinct images in a matter of minutes or even seconds.[7]

Furthermore, the Crossley reflector is able to observe areas of highly varying brightness in great detail. In the great cluster of Hercules, there exist very bright stars in the centre. Surrounding these are thousands of fainter stars, which can be hard to detect given their proximity to the central stars. From observations with the reflector, 5,400 stars could be counted - which showcases the great detail the telescope is capable of capturing. These thousands of stars were observed in just two hours.

The Crossley Reflector is evidently an instrument of impressive power. Four hour exposures have revealed nebulae hidden from even the Great Refractor. However, beyond this time the capabilities of the refractor are unknown. In comparison with the exquisite mounting on which the Great Refractor is placed, the mounting of the reflector is crude. An upgrade would likely see discoveries of even fainter nebulae.

With Common's new 5-foot reflector reportedly in construction, large reflecting telescopes may be the future of astronomy. However, before declaring this the beginning of a new era, it should be noted that the reflecting telescopes come with their own challenges. Refractors have been so successful thanks to their reliability, as Common put it, their "readiness for work at all times".[4] In comparison, the mirrors on reflecting telescopes can lose their characteristic reflectivity quickly, particularly in adverse weather conditions. Keeler does note that in the summer months when the weather is pristine, the "silvered surfaces retain their brilliancy without any care on the part of the observer".

The Crossley Reflector is currently used to photograph faint nebulae which are invisible even to the largest reflecting telescopes. Chromatic aberration does not occur in the instrument and its smaller size, mass and light-collecting time are owed to its shorter focal length and improvements in mirror construction techniques. However, these mirrors require greater care from the observer to retain their reflectivity.

Keeler wrote this paper with the intention of informing the reader of the impressive yet underused power of reflectors, and given their rapidity and ever-improving ease of use, I am inclined to believe that these telescopes will become the new standard in observational astronomy. As we continue to gaze further into the cosmos, it appears that the reflecting telescope will be the tool to push horizons, and enable us to see the undetectable, incomprehensible and unimaginable.

References

[1] J. E. Keeler. The Crossley reflector. *The Observatory*, 22:437–440, December 1899.

[2] James E. Keeler. Scientific Work of the Lick Observatory Instruments and Scientific Work of the Observers. *Science*, 10(254):665–670, November 1899.

[3] E. E. Barnard. Measures of the satellite of Neptune with the 40-inch refractor of the Yerkes Observatory, with remarks on the great telescope. *The Astronomical Journal*, 19:25–29, May 1898.

[4] A. A. Common. Note on large telescopes, with suggestions for mounting reflectors. *Monthly Notices of the Royal Astronomical Society*, 39:382–386, April 1879.

[5] J. E. Keeler. ”An Improved Astronomical Mirror”. *Publications of the Astronomical Society of the Pacific*, 1:81, September 1889.

[6] James E. Keeler. On the Chromatic Aberration of the 36-inch Refractor of the Lick Observatory. *Publications of the Astronomical Society of the Pacific*, 2:160, July 1890.

[7] J. E. Keeler. Small nebulæ discovered with the Crossley reflecter of the Lick Observatory. *Monthly Notices of the Royal Astronomical Society*, 59:537, June 1899.