THE 36-INCH CROSSLEY REFLECTOR

PEDRO RÉ
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The 36-inch Crossley Reflector was used by James Edward Keeler (1857-1900) during the last two years of his short productive scientific life for a systematic and epoch making astrophotographic study of diffuse, planetary and "spiral" nebulae. Keeler became one of the first astronomers to successfully use large reflecting telescopes in the United States.

This telescope was built by Andrew Ainslie Common (1841-1903), a wealthy engineer and amateur astronomer of Ealing, London. Common commissioned a 36-inch silver-on-glass mirror from George Calver (1834 - 1927) and mounted it in 1879 as a newtonian with a fork mount. Common used this instrument mainly as a photographic telescope. Several photographs of the Orion nebulae were obtained with considerable success. In 1883, Common produced images that showed for the first time, stars that were not seen by visual observers (Figure 1).

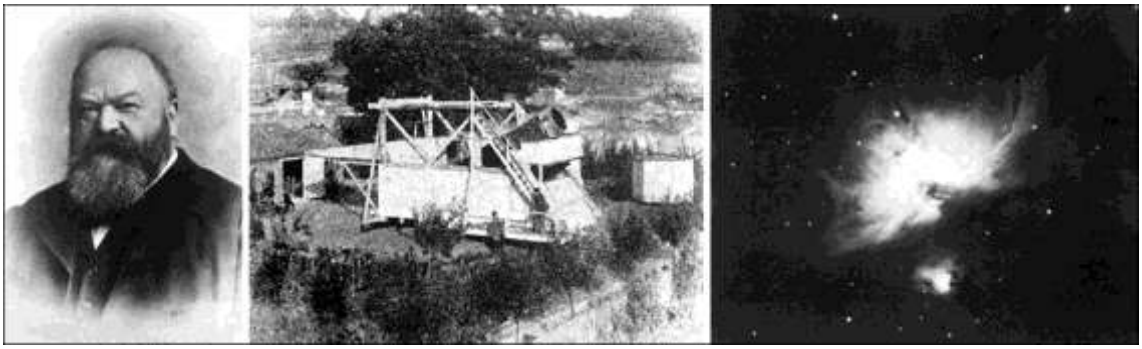

Figure 1- Andrew Ainslie Common (left), 36-inch reflector (center), M 42 photograph obtained in 1883 (right).

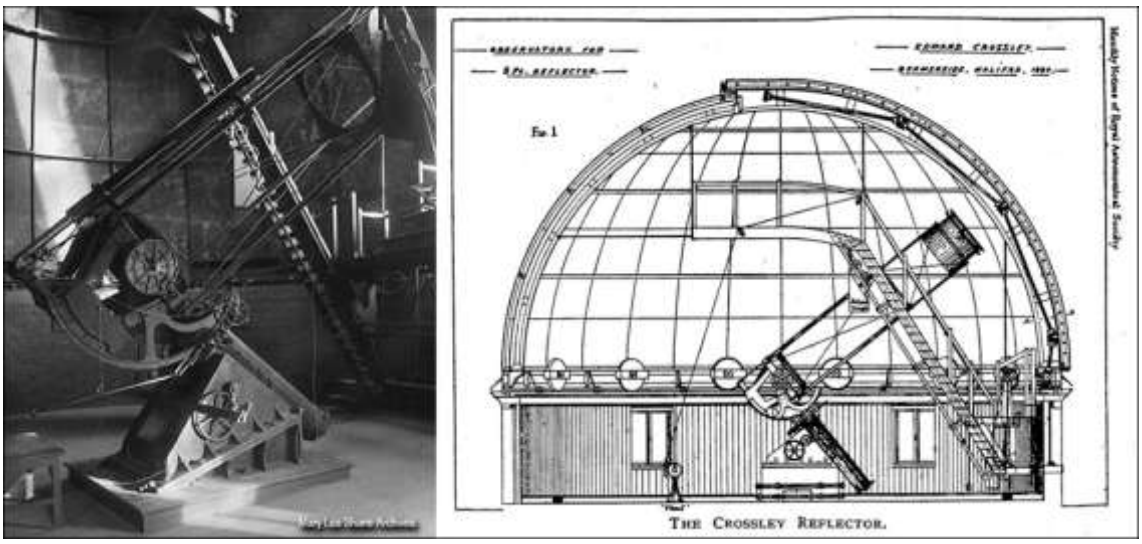

Figure 2- 36-inch Crossley reflector (left) and iron dome (right).

The telescope was sold to Edward Crossley (1841-1901) in 1885. Crossley, also a British amateur astronomer, installed it in Halifax (Yorkshire, England). Crossley designed and constructed a dome to house the telescope. This iron covered dome was almost 40 feet in diameter and weighted 15 tons. It was moved by a water engine (one full turn lasting 5 min). Heat exchange was minimized by a clever system of water pipes running on the ground of the observatory. There was also an elevated platform for the observer (Figure 2).

The Halifax climate was very unfavourable and in 1883 Crossley decided to sell the observatory and telescope. Edward Singleton Holden (1846-1914), director of the Lick Observatory in Mount Hamilton California, was very interested in acquiring this instrument. After an exchange of several letters, Crossley decided to donate his telescope and dome to the Lick Observatory. In 1895 the whole package was finally shipped to California. By June 1986 it was installed on Mount Hamilton (Figure 3). The dome was provided with a rope and pulley system instead of the native water engine. Calver built two mirrors for the Crossley telescope (A and B). When it was installed at Lick the B mirror was used (36-inch f/5.8) which proved to be of excellent quality. The equatorial mount was however not suitable for long exposure direct photographs.

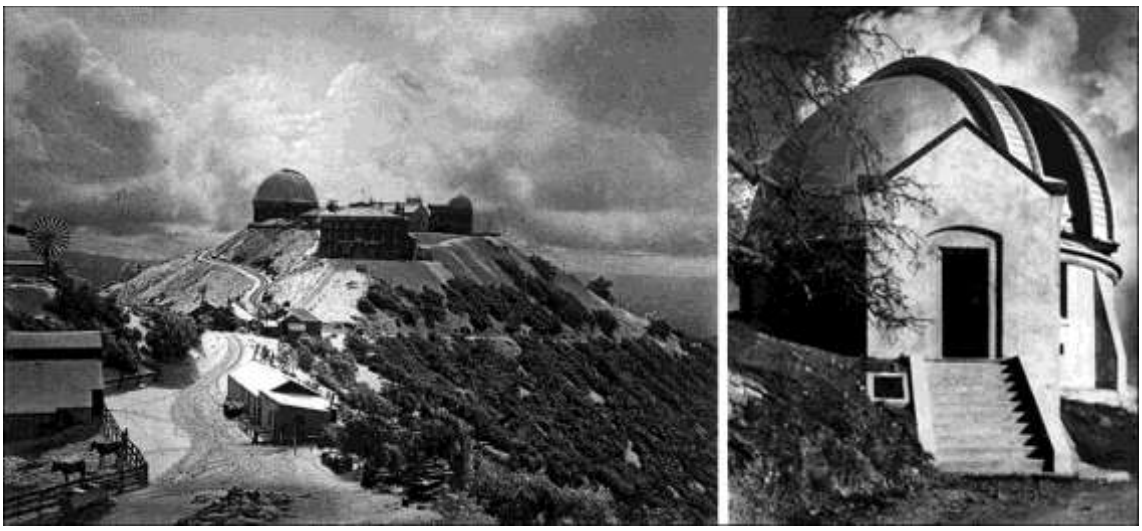

Figure 3- Lick observatory (left) and dome of the 36-inch Crossley reflector (right).

When the Crossley reflector was installed at Mount Hamilton in 1896 it was the largest reflector telescope in the United States. The telescope was first mounted by William Joseph Hussey (1862-1926). Progress was very slow and for Hussey it was a never-ending bad dream. When the telescope arrived at Lick it was a real mechanical nightmare. The open tube was not well designed and proper collimation of the optical components was very difficult. The drive clock was inefficient meaning that direct photography was very difficult.

James Edward Keeler assumed the directorship of Lick observatory on January 1, 1898. Keeler first job was to align the mount to the pole[1]. Keeler introduced many modifications in order to improve the operation of the Crossley reflector. The pier was cut down by two feet providing more clearance between it and the dome. Other modifications included the addition of a windscreen, a new drive clock and improvements to the double-sided plate holder. Keeler also adjusted the mirror so that its optical axis was accurately aligned with the center of the tube and added a new low-power finder telescope. Keeler was able to obtain long exposures of up to four hours by 1899 but the instrument still proved difficult to handle and inadequate for

[1] Hussey's previous alignment was incorrect by more than 2 degrees.

longer direct photographs. The major problem was the mount, which was inadequate in holding the telescope steady during high winds conditions and flexed excessively near the zenith. Adding to these problems was the occasional slippage of the mirror in its cell.

Keeler described in detail the adjustments he made to make the Crossley reflector operation in a 1900 publication of the Astrophysical Journal[2]:

(…) On taking charge of the Lick Observatory in 1898, I decided to devote my own observing time to the Crossley reflector, although the whole of my previous experience had been with refracting telescopes. I was particularly desirous of testing the reflector with my own hands, because such preliminary trials of it as had been made had given rise to somewhat conflicting opinions as to its merits (…).

Keeler also designed a spectrograph for the Crossley reflector (Figure 4). It consisted originally[3]:

(…) of a 50^{o} quartz prism with a circular aperture of 27 mm, placed directly in the converging beam of light of the main mirror, at a distance of 15 cm inside the focus; of a plate-holder suitably placed; and of a guiding eyepiece working in the same principle as that employed in ordinary nebular photograph (…) The instrument was completed on the day Professor Keeler left Mount Hamilton for the last time, about a fortnight before his death.

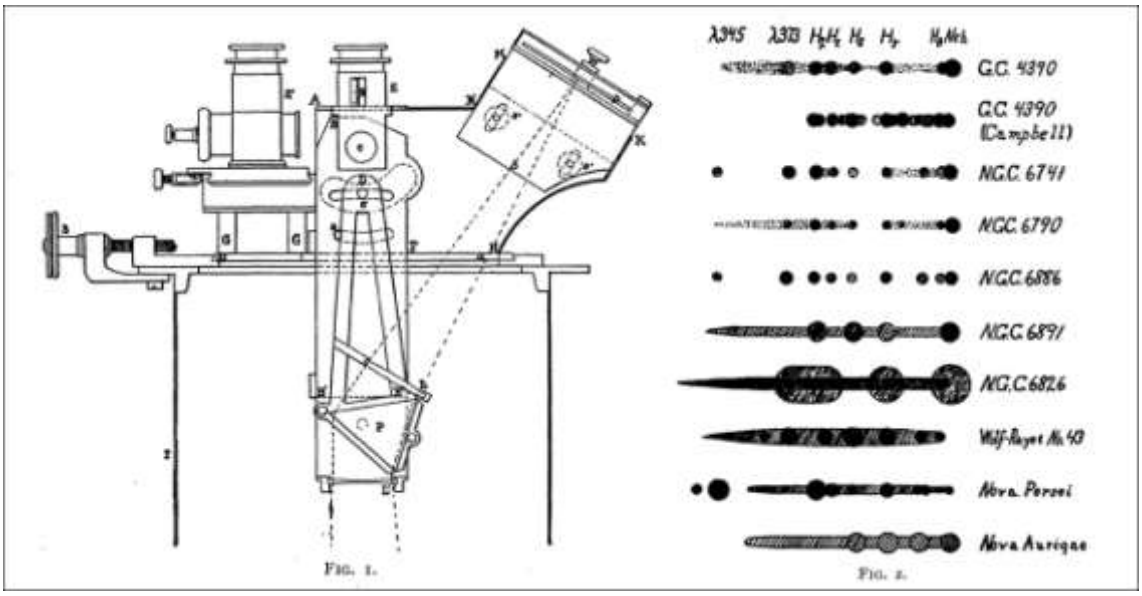

Figure 4- Spectrograph designed by E. Keeler for the Crossley reflector (left) and several spectra obtained with this instrument (right).

Keeler initiated an extended program of nebular photography showing for the first time that a great majority of these objects exhibited a spiral structure. After Keeler's death, Charles Dillon Perrine (1867-1951) completed the project and renewed the telescope completely between 1902 and 1904. Common original open tube and mount were replaced with a much more rigid closed tube on an English equatorial mount (Figure 5).

[2] Keeler, J. (1900). The Crossley refector of the Lick observatory. *Astrophysical Journal*, XI (5): 325-353.
[3] Palmer, H.K. (1903). An application of the Crossley reflector of the Lick observatory to the study of very faint spectra. *Lick Observatory Bulletin No. 35:218-235.*

Perrine improved the mount, mechanical drive and gears. He also removed the secondary mirror and mounted the plate-holder directly at the prime focus of the telescope. A clever system of prisms and lenses were also installed so that the observer could guide during the long exposures directly from an eyepiece outside the telescope tube. In this way the Crossley reflector became a much faster and efficient instrument for direct nebular photography.

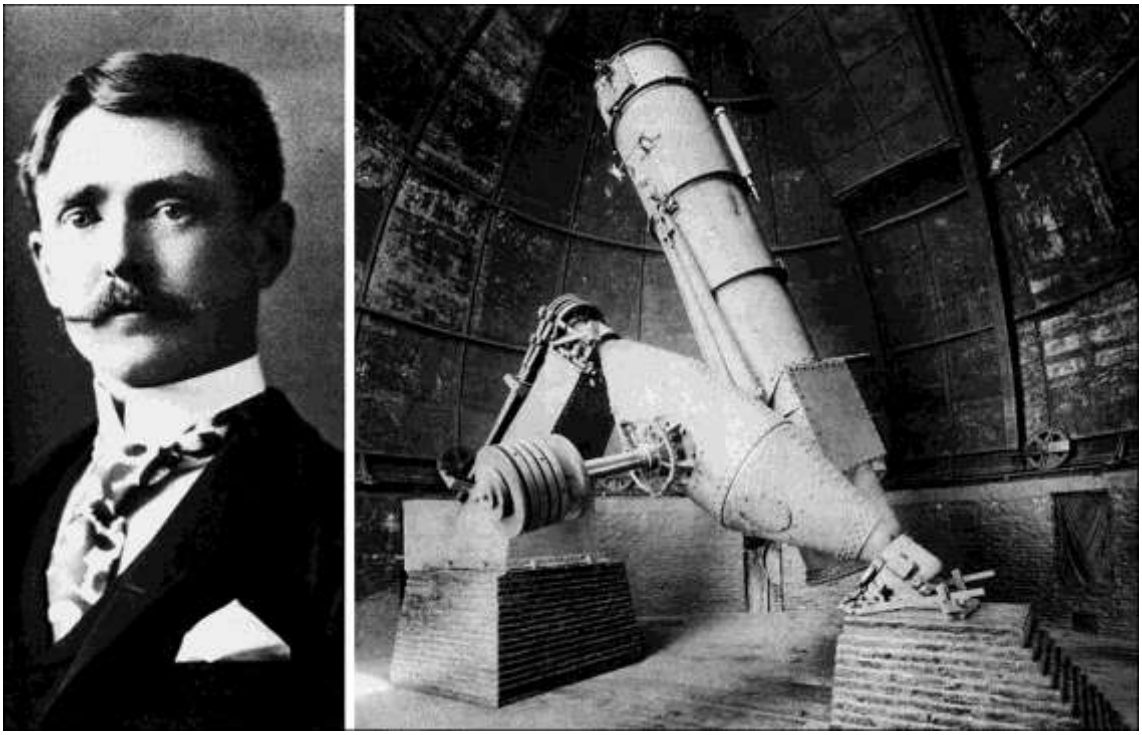

Figure 5- Charles Dillon Perrine (left) and the rebuilt Crossley reflector (right) (*ca.*1905).

These first successful photographic results obtained with this telescope helped to establish the reflector as the preferred observatory instrument.

After Keeler's death, his colleagues at Lick Observatory arranged for the publication of his and Perrine's photographs of nebulae and clusters in a special volume of the Lick Observatory publications[4] (Figure 6).

George Ellery Hale (1868-1938) wrote the following about the publication of the Crossley direct photographs:

The resulting photographs of nebulae surpass any similar photographs ever before obtained, and reveal new and unexpected features of the first importance (…). The remarkable success of his experiments with the Crossley reflector has impressed everyone who has seen the wonderful photographs of nebulae and star clusters made with this instrument.

The Crossley reflector was also used for many important studies of stellar evolution, planetary nebulae and spectral analyses of variable stars.

In 1908 Edward A. Fath (1880–1959) used the Crossley to obtain continuous spectra of spiral nebulae showing that these consisted of individual stars[5].

[4] Keeler, J. E. (1908). "Photographs of Nebulae and Clusters made with the Crossley reflector. *Publications of the Lick Observatory, Vol. 8*.

Between 1912 and 1923 Herber Doust Curtis (1872-1942) publishes a long list and descriptions of nebulae and clusters based on direct photographs obtained with the Crossley reflector. Curtis also observed many "new stars" (supernovae) in spiral nebulae leading to the conclusion that these systems were outside our own galaxy. Curtis was one of the first astronomers mentioning that spirals were island universes. His views were very different from those expressed by Harlow Shapley (1885-1972). The two astronomers held in 1920 a great debate, also known as Shapley/Curtis debate, concerned with the nature of spiral nebulae and the size of the universe, at the National Academy of Sciences (Washington, DC).

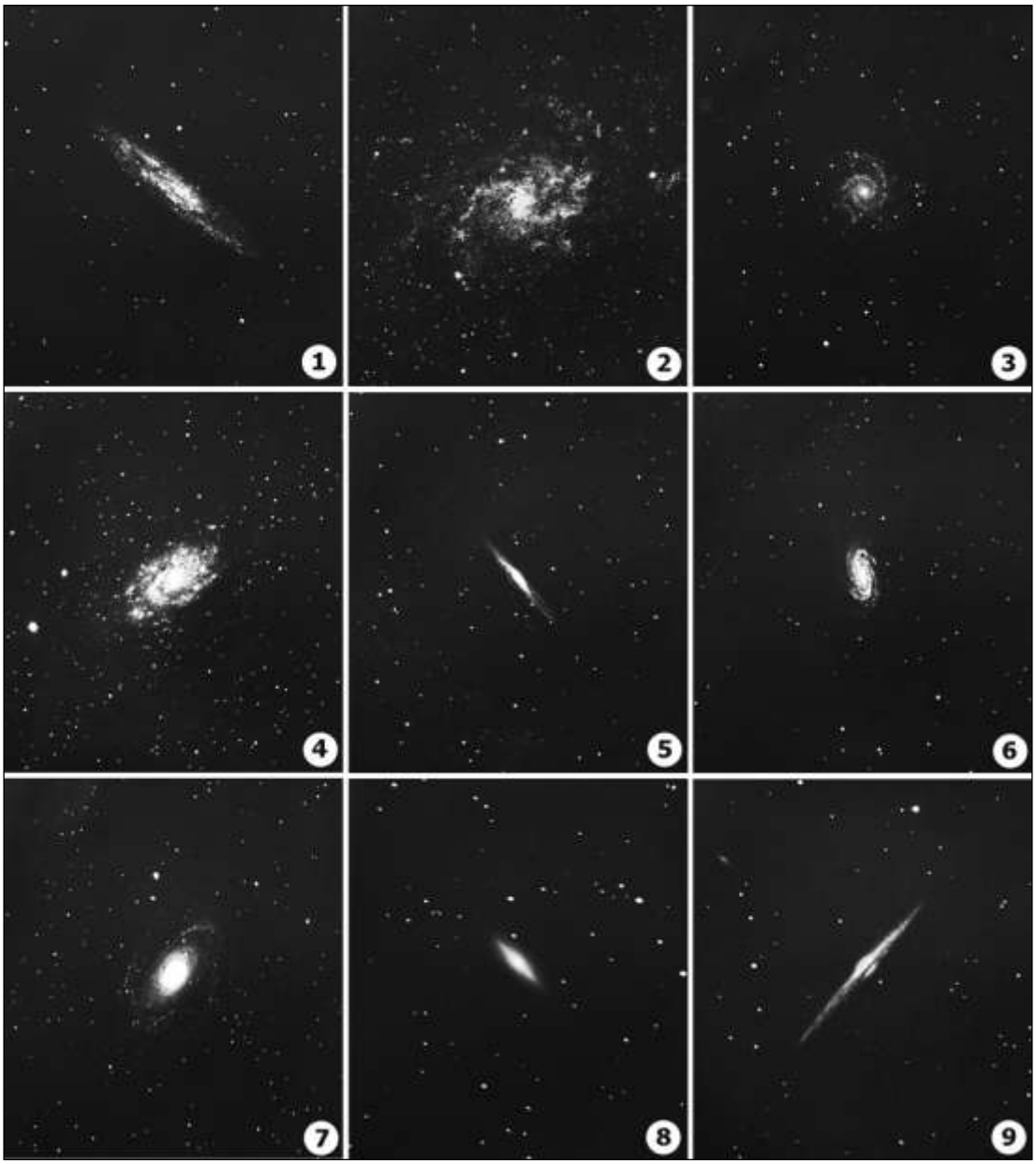

Figure 6- Selection of photographs obtained by Keeler and collaborators with the Crossley reflector: 1- NGC 253, 3h, November 18-20, 1902; 2- M 33, 3h30min, September, 12 1899; 3- M 74, 4h, October 31, 1899; 4- NGC 2403, 3h, February 27, 1900; 5- NGC 2683, 3h30min, February 23, 1900; 6- NGC 2903, 3h30min, February 24, 1900; 7- M 81, 3h55min, March 21, 1900; 8- NGC 3115, 2h30min, April 9, 1901; 9- NGC 4565, 3h, April 21, 1901.

[5] The physical nature of spirals was an unsolved puzzle at the time.

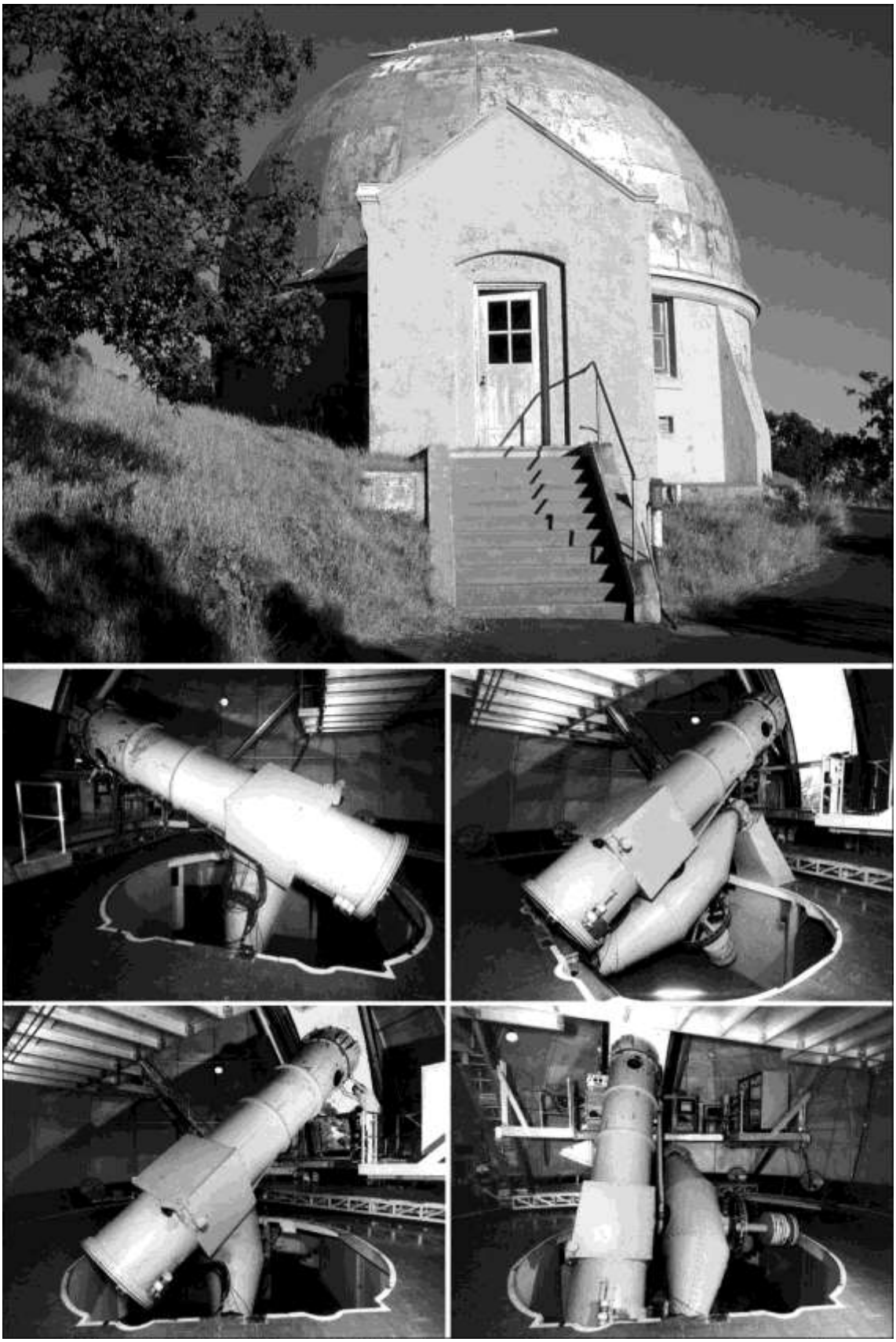

Figure 7- The Crossley reflector today.

Sources:

- Keeler, J. (1900). The Crossley refector of the Lick observatory. *Astrophysical Journal*, XI (5): 325-353.
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- *Stone, R.P.S.* (1979). The Crossley Reflector: A Centennial Review - II. Sky & Telescope Magazine, November 1979: 396-311.