The Kew Photoheliograph

Pedro Ré
http://pedroreastrophotography.com/

The Kew Photoheliograph (Figure 1) was the first telescope specifically designed for solar photography. It was commissioned in 1854 and named after the Kew Observatory where it has housed.

The Photoheliograph was designed by Warren De la Rue (1815-1889) (Figure 2) for the London Royal Society in 1857 and made by Andrew Ross (1798-1859). It was mainly used for daily photography of the Sun at the Kew Observatory and the Royal Observatory of Greenwich. It was also transported to Rivabellosa in Northern Spain where it was used to photograph the Total eclipse of the Sun on July 18th, 1860.

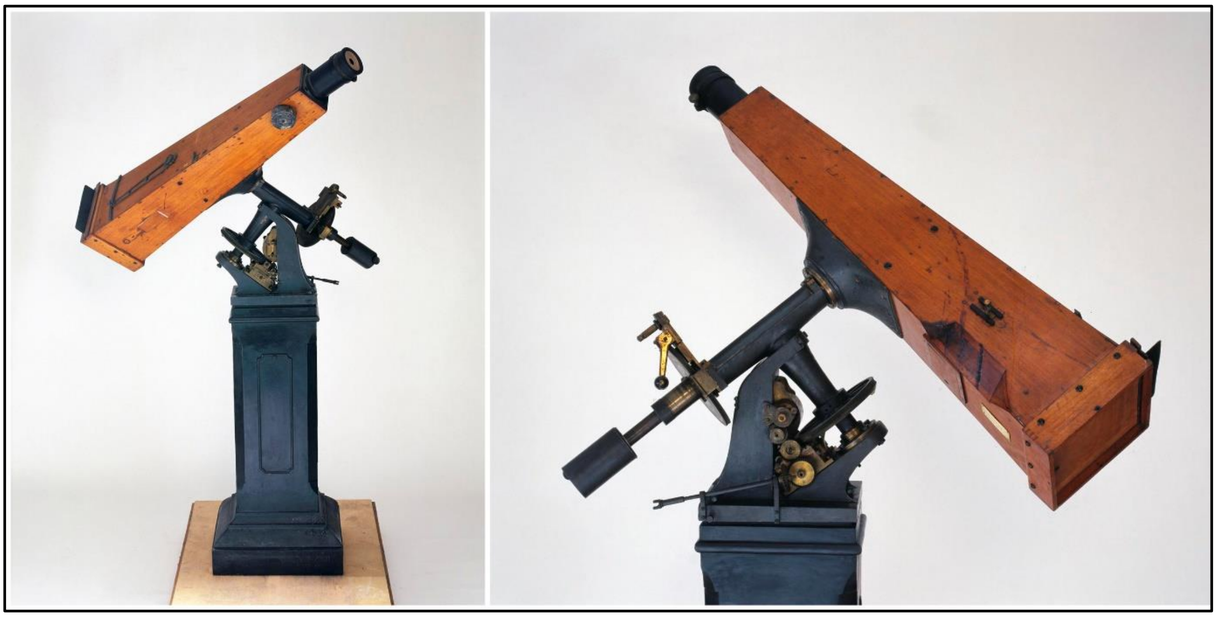

Figure 1- The Kew Photoheliograph.

The first solar photographs were obtained by Hippolyte Fizeau and Leon Focault in 1844. The first photographs of the partial phase of a total solar eclipse and of the solar spectrum were also obtained in the 1840s. In 1849 Hervé Faye made an important communication to the Frech Academy of Sciences proposing the continuous photographic survey of the Sun:

If a solar image is formed in the daguerrotype plate ... the same measurements can be repeated later on and compared with contemporaneous ones ... The same procedure may be applied to the determination of the heliocentric sunspot co-ordinates ...

On April 24, 1854 John Herschel wrote to Edward Sabine:

I consider it an object of very considerable importance to secure at some observatory, and indeed at more than one, in different localities, daily photographic representations of the sun, with a view to keep up a consecutive and perfectly faithful record of the history of the spots.

Herschel's idea was followed, and a grant was given to Warren de la Rue for the construction of the photoheliograph for the Kew Observatory. The telescope was operational in 1856[1] and it was initially referred as "the sun-spot photographic apparatus". It subsequently became know as the Kew Photoheliograph.

Figure 2 – Warren de la Rue.

[1] The photoheliograph did not become fully operational until March 1858. It was not used on a daily basis until several years later.

The Photoheliograph was described in an 1857 report (Kew Observatory):

The object-glass of this instrument is 3 $^{4}/_{10}$ inches aperture and 50 inches focal length; it is not corrected for achromatism in the ordinary manner, but so as to produce a coincidence of the visual and photogenic foci. The secondary objectives for magnifying the image produced by the principal object-glass are of the Huyghenian form. They are three in number, producing respectively images of the sun 3, 4, and 8 inches in diameter. Between the two lenses of each of these secondary object-glasses is inserted a diaphragm-plate carrying the fixed micrometer wires, which are of platinum; these wires are four in number, two at right angles to the other two. One of the wires of each pair is in such a position that they may both be made tangential to the sun's image, while the other two crosses at a point situated near the sun's centre. By means of these wires, the distance in arc between each pair having been once for all ascertained astronomically for each secondary object-glass, it will be easy to determine all the data necessary for ascertaining the relative magnitudes and positions of the sun's spots. These micrometer wires are under the influence of springs, to preserve a tension upon them when expanded by the sun's heat, and thus to keep them straight.

The principal and secondary object-glasses are not mounted in an ordinary cylindrical tube, but in a pyramidal trunk square in section, 5 inches in the side at the upper end, which carries the principal object-glass, and 12 inches in the side at the lower end, which carries the photographic plate-holder and the usual ground glass screen for focusing.

This trunk is firmly supported by a declination axis of hard gun-metal 2½ inches in diameter; it is furnished with a declination circle 10 inches in diameter, reading to one minute of arc, and has a clamp and screw motion for fine adjustment in declination.

The declination axis works in Y-bearings at the top of the polar axis, which is 12 inches long; it is 4 inches diameter at its upper end and I½ inch at its lower end. The lower end fits with a slight taper into a brass collar up to a shoulder, the friction being reduced by a steel spring plate pressing against a hardened steel hemisphere at the end of' the axis.

It will be seen by the above description, that every precaution has been taken to secure stiffness in the telescope combined with freedom in the motion of the polar axis. The polar axis is driven by a clock driver, which answers perfectly, and is easy of regulation to the greatest nicety, so that the sun's limb remains for a long period in contact with the tangential wires. Near the lower end of the polar axis is fixed the hour-circle, which, like the declination circle, is 10 inches in diameter; it is graduated to read to 2 seconds of time. An endless screw, making about two revolutions in one minute, gears into the hour-circle and connects it with the clock. As it is generally necessary to make small corrections in right ascension after the tangent screw has been geared with the driving clock, in order to bring the sun's image in position with respect to the micrometer wires, a sliding plate is provided which carries the bearings of the tangent screw; this is acted upon by a second fine screw parallel with the tangent screw; so that by rotating the second screw, the sliding plate and the tangent screw are moved through a small space, and the hour-circle thus caused to rotate to the extent necessary for bringing the sun's image in position.

The clock is driven by two weights, one pulling upwards over a pulley, the other downwards, thus suspending the barrel and equalizing the pull and avoiding friction on its bearings. By causing the click of the winding lever to abut on the ratchet-wheel of the going part of the clock during the period of winding, the clock goes at its normal speed while it is being wound.

The mode of regulating the clock is extremely simple and efficacious; it is effected by approaching to, or withdrawing from, a hollow cone over a small wheel, on which are attached, by means of flat *springs, two small weights, which expand by centrifugal force and come in contact with the inside of the hollow cone.*

The polar axis of the telescope is carried by a dial-plate which fits on the top of a hollow column of cast iron, the section of which is a parallelogram. This column is securely fastened to the stone foundation. The instrument is mounted within the rotating dome of the Kew Observatory, which has been repaired and put for that purpose. photographic dark room is at present too distant from the telescope, but it is contemplated to construct close to it, as serious inconvenience has been already experienced in the preliminary experiments in consequence thereof.

The telescope and its mechanical appliances may be said to be perfect so far as they go, but experience will undoubtedly suggest several minor alterations and additions before the telescope is brought practically to work. The photographing of such minute objects as the sun's spots will always require the utmost skill and care of an accomplished photographer, even when the telescope has been fairly started. The difficulties yet to be mastered must occupy some considerable time. The first attempts have been confined to the production of negative photographs, but in consequence of the imperfections always existing in the collodion film, it has been deemed advisable to make attempts to produce positive pictures, and recourse may ultimately have to be made to the Daguerreotype process.

Warren de la Rue also described how the instrument for photography:

It has been found, after repeated trials, that the best photographic definition is obtained when the sensitized plate is situated from 1/10th to 1/8th of an inch beyond the visual focus in the case of a 4-inch picture; and that when this adjustment is made, beautiful pictures are obtained of the sun 4 inches in diameter, which still bear magnifying with a lens of low power and show considerable detail on the sun's surfaces besides the spots, which are well defined.

The image is not received directly on the sensitive plate, as is the case in taking lunar and planetary photographs, but is enlarged before it reaches the plate, by means of a secondary lens, which magnifies the sun's image to about four inches in diameter. The time of exposure is so short, that there is a necessity for a special contrivance for regulating the time of exposure. This is effected by means of a sliding-plate placed just before the secondary lens. In this plate is a slit which is adjustable in width. The plate before taking the picture is held up by means of a thread. In this position the light is shut off from the sensitive plate. When the picture is about to be taken the retaining, thread is set fire to, and a spring pulls the plate rapidly across the secondary lens. The time of exposure depends on the rapidity of passage of the sliding-plate before the secondary lens.

In 1860 The Kew Photoheliograph was transported to Rivabelossa in Spain to photograph the Total Solar Eclipse (July 18) (Figure 3). A new Iron Pillar with the latitude of Rivabelossa was build and a portable observatory was also constructed (measuring 8.5 square feet and 7 feet high). The observatory was open at the top and included a photographic dark room[2].

In 1860 it was not known if the solar prominences were part of the sun or an atmospheric phenomenon. By comparing the photographs obtained with the Kew Photoheliograph with those obtained by Angelo Secchi (in Las Palmas 500 km away), Warred de la Rue proved that the prominences intrinsic to the Sun (Figure 4).

[2] *The Bakerian Lecture: On the Total Solar Eclipse of July 18th, 1860, Observed at Rivabellosa, Near Miranda de Ebro, in Spain*. Warren de la Rue, *Phil. Trans. R. Soc. Lond*. Vol. 152, pp. 333–416 (1862)

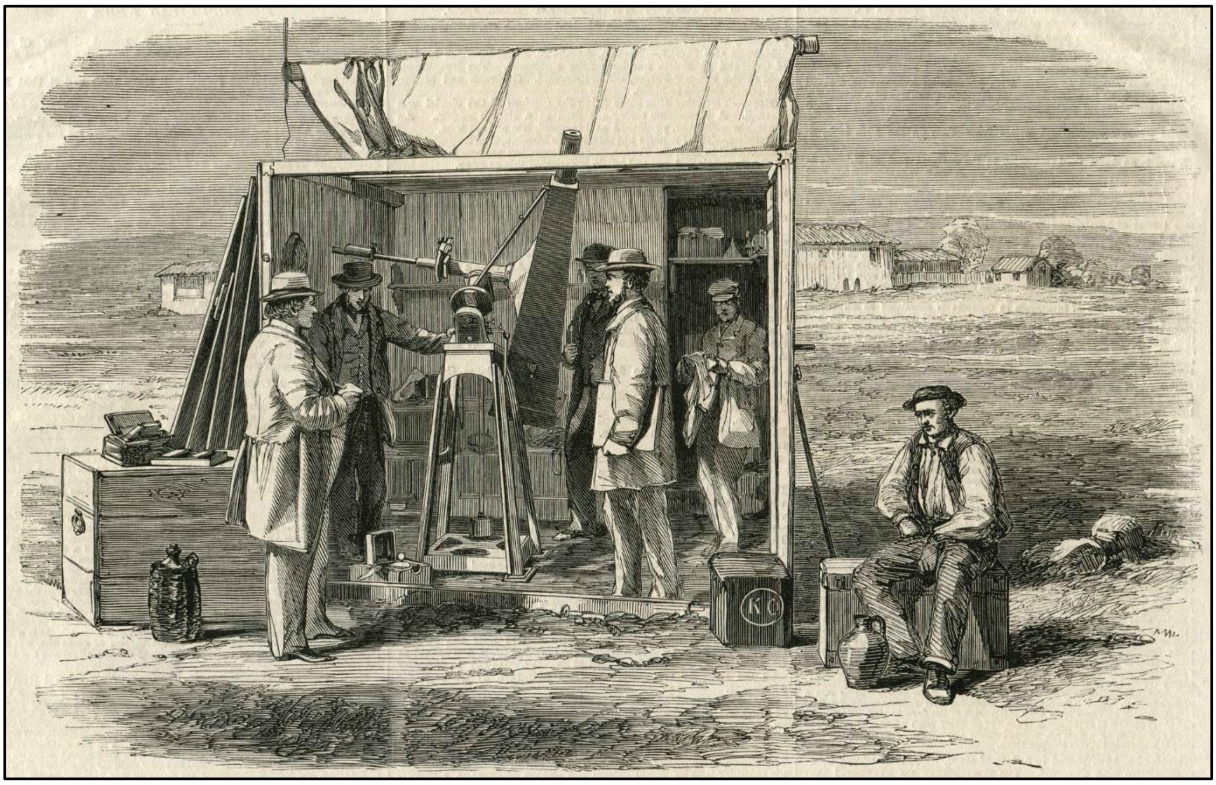

Figure 3- The Kew Photoheliograph at Rivabellosa, Spain.

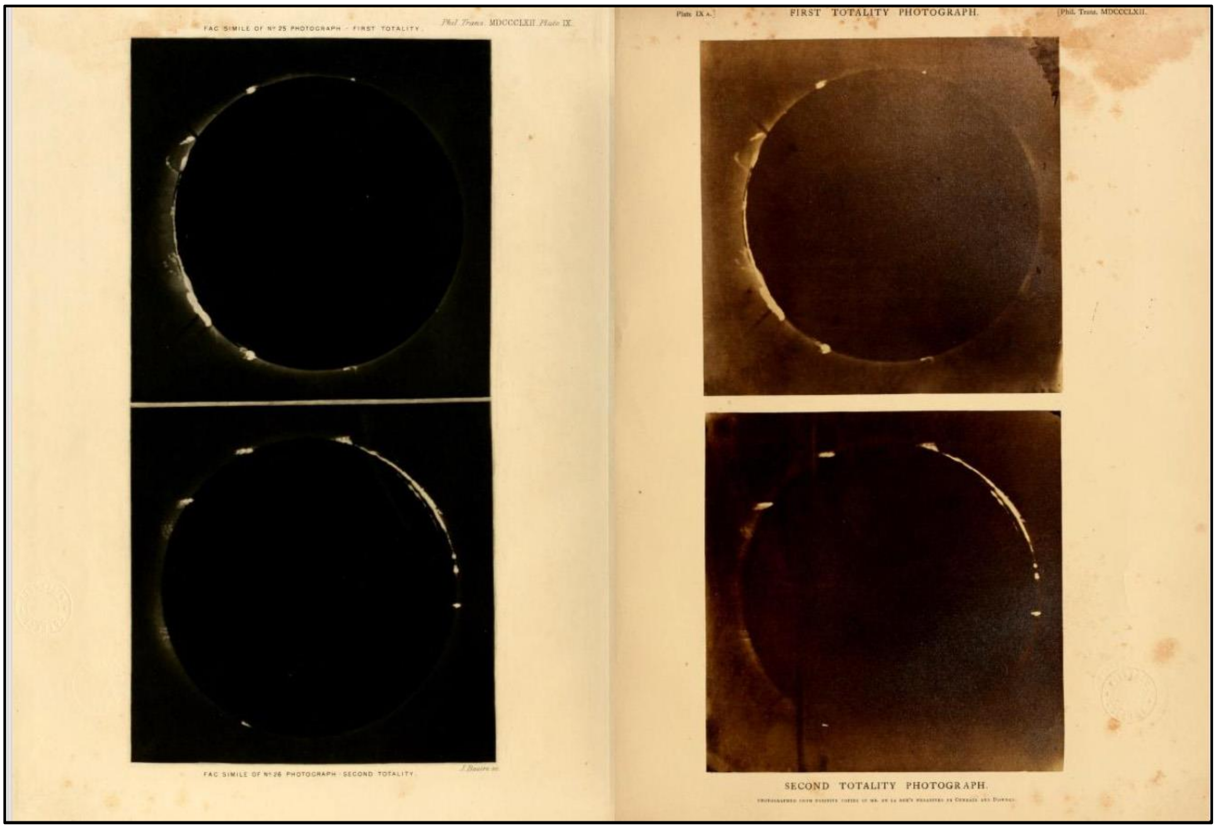

Figure 4- Photographs of the Total Solar Eclipse obtained with the Kew Photoheliograph.

After the Spain Eclipse, Warren de la Rue used the instrument in his private observatory in Cranford. The first photographs were obtained on February 7, 1862. After this the Photoheliograph was used in a daily basis ate Kew from 1863 onwards.

A ten-year solar photography programme was started at the Kew Observatory. From 1863 to 1872 the Photoheliograph was used regularly at Kew (Table 1) (Figure 5).

Table 1- number of days on which photographs were obtained at Cranford and Kew[3].

Year	Days	Comment
1862	163	Pictures taken at Cranford
1863	125	Instrument returned to Kew in Feb, pictures recommenced May
1864	164	
1865	159	
1866	157	
1867	131	No pictures taken during building works (9 Aug – 9 Sep)
1868	174	
1869	195	
1870	220	
1871	226	
1872	10	Figures relate to January only. The programme ceased a few weeks later
Total	**1724**	

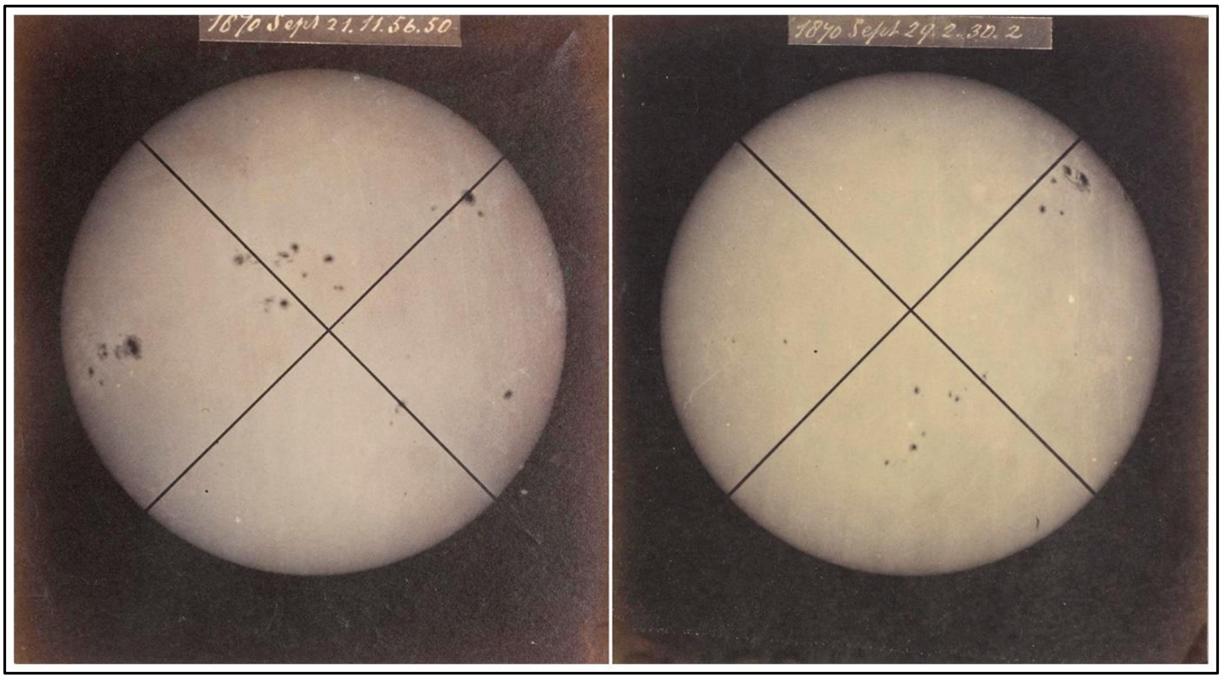

Figure 5- Solar Photographs taken by Elizabeth Beckley in 1870 with the Kew Photoheliograph[4].

[3] *Monthly Notices of the Royal Astronomical Society*, Feb 1872 (Vol. 32, p.156).

[4] Elizabeth Beckley, the teenage daughter of the observatory's mechanical engineer, was employed cheaply to take daily photographs of the Sun. She went on to work at Kew for over ten years and was one of the first female employees of an astronomical observatory. Warren De La Rue praised her ability to capture photographs 'even on very cloudy days, when it would be imagined that it was almost impossible'.

The 1874 Transit of Venus was also photographed with the Kew Photoheliograph. the observatory's Board of Visitors determined that:

Mr. Warren De la Rue be requested to confer with the Astronomer Royal with the view of organizing a plan for photographic observations of the Transit of Venus, and for preparing an approximate estimate of the probable expense.

And also:

Resolved, that as this Board deem it most important that Photographic be combined with eye observations at the approaching Transit of Venus, an opinion in which the Astronomer Royal fully concurs, the Chairman [Edward Sabine] apply to the Lords Commissioners of Her Majesty's Treasury to sanction a grant of Five Thousand Pounds (£5000) for the purpose, a sum which it is considered will cover the cost of photographic apparatus and observations for all stations.

The Photoheliographic programme of the Royal Observatory ran at Greenwich from 1873 until 1948 (Figure 6) and at Herstmonceux from 1948 until the end of 1976 when it was formally brought to an end by Richard Woolley. Given the importance of the work, it was taken up by the Heliosphysical Observatory, Debrecen, Hungary, where a programme of observations continues to this day.

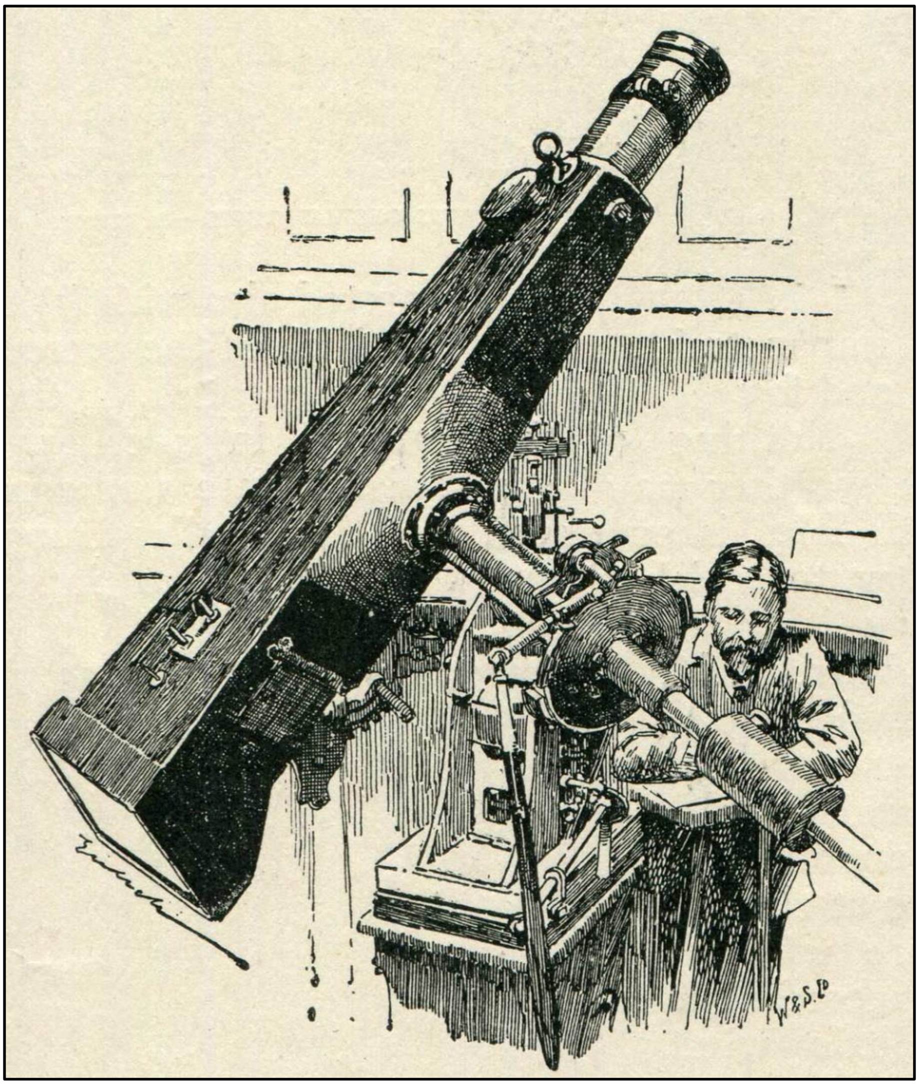

Figure 6- The Photoheliograph in its dome at Kew.
Weather Watchers and their Work, *The Strand Magazine*, Vol.3, London, 1892, p.185

In 1876 the Photoheliograph was installed in a dome and a few weeks later, it was dismounted and sent on Loan to and Exhibition at South Kensington. There it remained until 1882 when it was once again returned to Kew. It was used after 1882 to record sunspot positions visually as they appeared projected on to the focussing screen. The new programme with the Kew Photoheliograph continued for 15 years before being brought to a close at in 1897. Over this period, the average number of days in each year on which observations were made was about 170. This was considerably lower than the number of days each year on which good photographs were obtained at Greenwich.

Since 1927, the instrument has been in the care of the Science Museum in London (Figure 7).

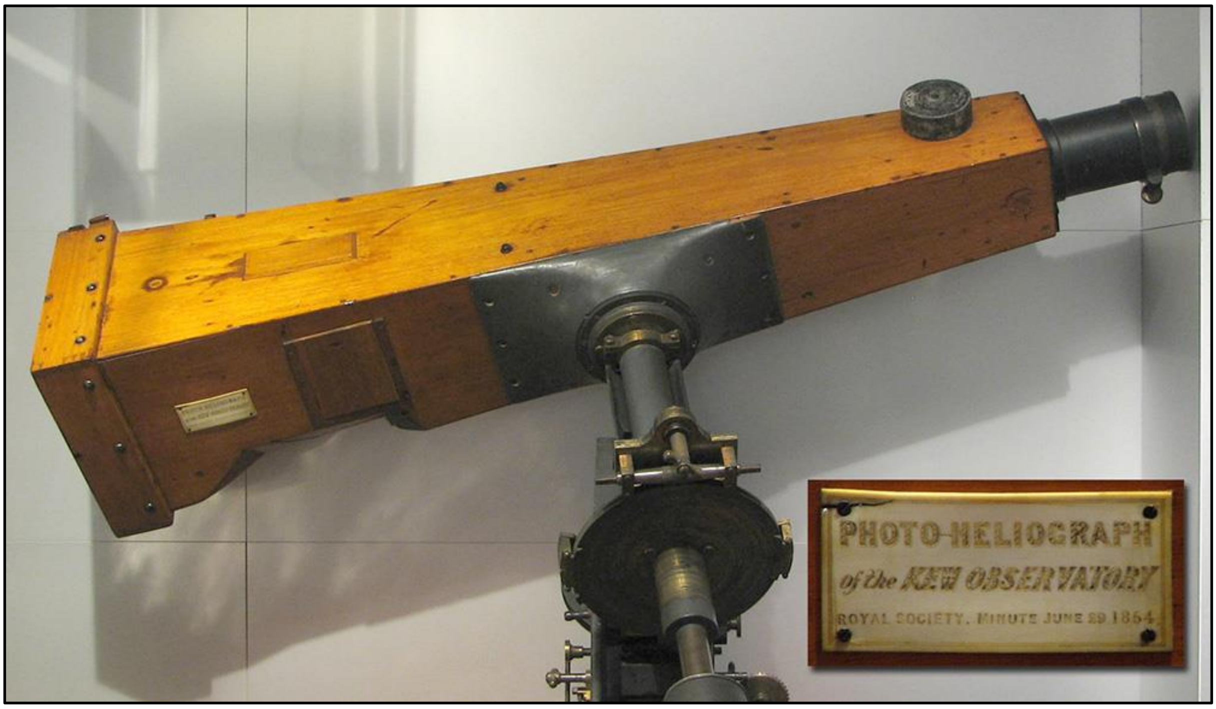

Figure 7- The Kew Photoheliograph on display in the Science Museum (2016)

Sources:

[The Bakerian Lecture: On the Total Solar Eclipse of July 18th, 1860, Observed at Rivabellosa, Near Miranda de Ebro, in Spain](). Warren de la Rue, *Phil. Trans. R. Soc. Lond*. Vol. 152, pp. 333–416 (1862).

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The Greenwich Photo-heliographic Results (1874 – 1885): Observing Telescopes, Photographic Processes, and Solar Images. D. M. Willis, M. N. Wild, G. M. Appleby & L. T. Macdonald. *Sol Phys* (2016).

http://www.royalobservatorygreenwich.org/