Carnegie Institution of Washington

CONTRIBUTIONS FROM THE SOLAR OBSERVATORY
MT. WILSON, CALIFORNIA
NO. 4.

SOME TESTS OF THE SNOW TELESCOPE

BY
GEORGE E. HALE

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SOME TESTS OF THE SNOW TELESCOPE[1]

BY GEORGE E. HALE

In *Contributions from the Solar Observatory*, No. 2, I have given a brief description of the Snow telescope and the house in which it is mounted on Mount Wilson. At the time that paper was written the telescope was not yet in working order, and it remained to be determined whether it would prove capable of giving the results expected from it. I am glad to say that it has since been completed and successfully used in a variety of work. It is believed that an account of the experience so far gained with this telescope may be of service to others who may intend to use similar instruments.

The cœlostat and second mirror are shown in Plate VI, a view taken from within the sliding shelter which covers these parts of the instrument when not in use. The cœlostat mirror is 30 inches (76 cm) in diameter, and the second (plane) mirror, which sends the beam from the cœlostat to the concave mirror in the north end of the telescope house, has a diameter of 24 inches (61 cm). The second mirror can be moved along rails, so as to receive the reflected beam from objects at different declinations. The cœlostat and second mirror stand on a stone pier 29 feet (8.8 m) high at its south end and 25 feet (7.6 m) high at its north end. A house, of steel construction covered with canvas louvres, surrounds the pier and affords space in the extension toward the north for the concave mirrors and the spectroheliographs and spectroscopes. The concave mirror, shown in Plate VII, has an aperture of 24 inches and a focal length of 60 feet (18.3 m). A second concave mirror of the same aperture and of 143 feet (43.6 m) focal length is under construction in our optical shop, and will soon be mounted in the long extension of the house which lies beyond the canvas partition now temporarily in place near the 60-foot mirror.[2]

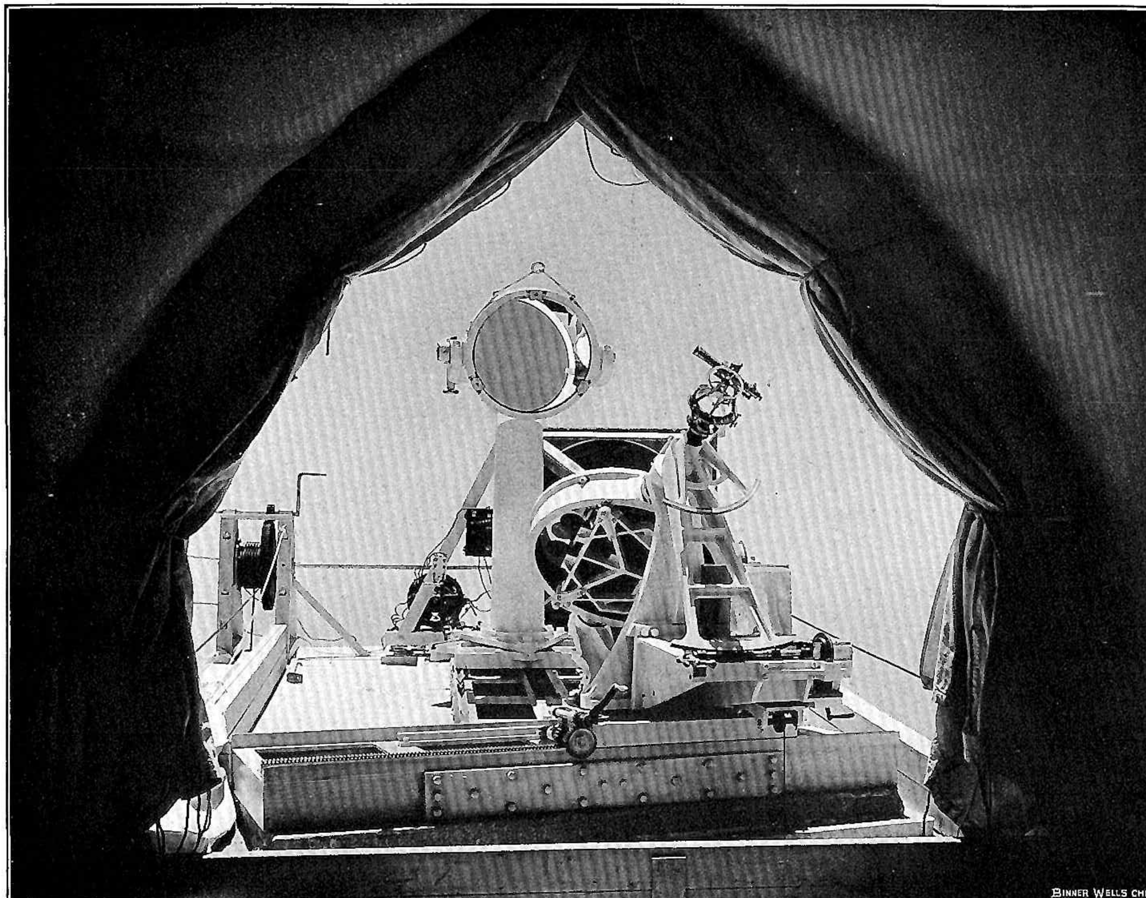
[1] *Contribution from the Solar Observatory*, No. 4.

[2] For a plan and elevation of the Snow telescope house, together with photographs showing its manner of construction, and a further account of the instrument, see *Contributions from the Solar Observatory*, No. 2, and the *Report of the Director of the Solar Observatory for the Year Ending September 30, 1905*.

In the preliminary tests of the Snow telescope at the Yerkes Observatory, the results were rather disappointing, though good images were occasionally obtained. It was evident that difficulty might be expected from the distortion of the mirrors by the Sun's heat, and in the first experiments on Mount Wilson this expectation was realized. Soon after the exposure of the mirrors to the Sun it was seen that the focal length was increasing, and, as the focus changed, evidence of the astigmatism of the mirrors made itself apparent in the appearance of the image inside and outside the focal plane. Since the change of focus amounted in some cases to as much as 12 inches (30.4 cm), and since the astigmatism under such circumstances was very marked, it was feared that great difficulty would be experienced in the use of the telescope, particularly as the focus at opposite limbs of the Sun on one occasion differed by as much as 3 inches (7.6 cm). The changes of focal length at different times did not seem to be the same, even for equal altitudes of the Sun. This was soon traced to the change in the amount of heat absorbed by the mirror as the silver film deteriorated in use. Another variable, as subsequent experiments proved, was introduced by the strength of the wind and the temperature of the air blown across the mirror surface. On a day with a cool breeze the focus changed less than on a day with no wind. Naturally enough, the height of the Sun above the horizon proved to be a very important factor, so that the focus changed much more rapidly near noon than early in the morning.

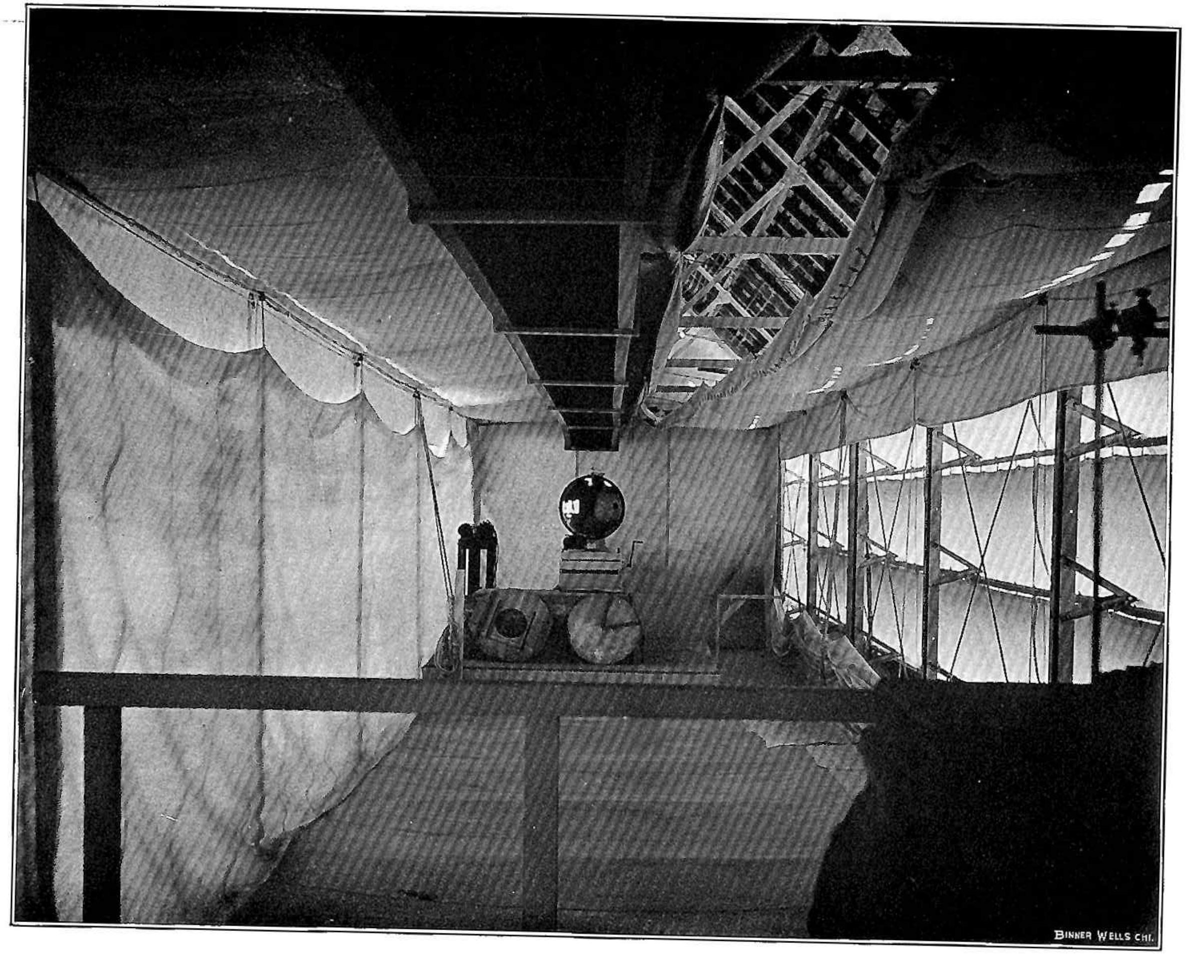
From the outset, the advantages of observing the Sun during the early morning hours had been apparent. In view of the difficulties that were being experienced, this point was again carefully investigated, and it was soon found that with the Snow telescope the finest definition is to be expected about one hour after sunrise. At this time the mountain is but little heated, and the atmospheric absorption reduces the intensity of the solar radiation to such a degree that the mirrors change their figure slowly. If the mirrors are shielded from sunlight between exposures of photographs, and if the exposure time is made as short as possible, excellent results can be obtained

PLATE VI



COELOSTAT AND SECOND MIRROR OF SNOW TELESCOPE

PLATE VII



Concave Mirror of Snow Telescope

during a period of about an hour in the early morning, and usually during a similar period not long before sunset.

It must be understood that the precautions mentioned are necessary only when it is desired to secure the finest possible definition of the solar image. When such precautions are used, the average photographs taken during the summer in the early morning with the Snow telescope and temporary spectroheliograph are but little inferior to the best photographs, secured on only a few days in the year, with the 40-inch Yerkes telescope and the Rumford spectroheliograph. The best photographs taken on Mount Wilson are distinctly superior to the best ever secured by Mr. Ellerman and myself with the 40-inch telescope. Unless these points were made clear, it might be supposed that no work could be done with the Snow telescope except under the conditions stated. As a matter of fact, however, very fair photographs can be obtained with the spectroheliograph at almost any time during a cool day, and in the early morning and late afternoon hours of a hot day without wind. It is only necessary to arrange the daily program of observations so that the spectroheliograph, which requires the finest definition, is used during the period when the seeing is best. Photographic work on the spectra of sun-spots follows, and after this is completed the conditions are entirely satisfactory for various other observations, such as bolographic work on the absorption of the solar atmosphere, etc.

The photographs reproduced in Plate VIII will give an idea of the results obtained with the Snow telescope. The spectroheliograph employed was put together for temporary use pending the completion of the permanent instrument. The only prisms available were some that had proved unsuitable (because of poor definition) for the Bruce spectrograph, and the slits were taken from old instruments. The optical train was mounted on a wooden platform, with cast-iron Λ-rails running on four steel balls resting on cast-iron V-rails attached to a wooden base. A small electric motor, belted to a pulley on the end of a long screw, provided the motive power. The screw was mounted on the wooden base, and passed through a nut attached to the platform. The numerous photographs obtained with this simple and inexpensive apparatus have served for a comparative study of the faculæ and the H_1 flocculi.

The ventilated house provided for the Snow telescope has proved so satisfactory that it has not seemed necessary to make further experiments on the use of Langley's method of stirring the air along the path of the beam. It is usually found best to lower the inner canvas wall on the side of the house away from the Sun, leaving the canvas wall on the opposite side of the house in place, so that the heated air under the louvres may pass upward and out through the ventilated roof, instead of entering the house and disturbing the beam (see Plate VII).

While fans have not been employed for stirring the air, they have nevertheless been used to advantage in blowing the mirrors, for the purpose of preventing a rapid change of figure. In the first experiments, a fan 4 feet in diameter, driven by an electric motor, was mounted at the south end of the cœlostat pier. Air from this fan was led to the cœlostat mirror and the second mirror through large canvas tubes. In these experiments the concave mirror did not receive a blast of air, as it was thought the effect could be detected sufficiently well if only the first and second mirrors were cooled in this way. As it was found that the focus could be varied through a considerable range by blowing the first two mirrors, arrangements have been made to cool all the mirrors in the same way. The small electric fans to be used for this purpose will be operated while the adjustments of the spectroheliograph are being made, and also between exposures, when the mirrors are also shielded from the Sun by an adjustable canvas screen.

Excellent definition is obtained at night with the Snow telescope, except when the mirrors have been exposed to the Sun for some hours during the afternoon. On such occasions the rapid change of figure during the early evening results in irregular distortions, as indicated by the multiple images sometimes observed. Without such previous exposure to the Sun, the images of the stars and of the Moon leave nothing to be desired. Nevertheless there is a considerable change of focal length during the night, but this would be inappreciable during short exposures, and during long exposures on stellar spectra it is only necessary to correct the focus by changing the position of the concave mirror from time to time.

PLATE VIII

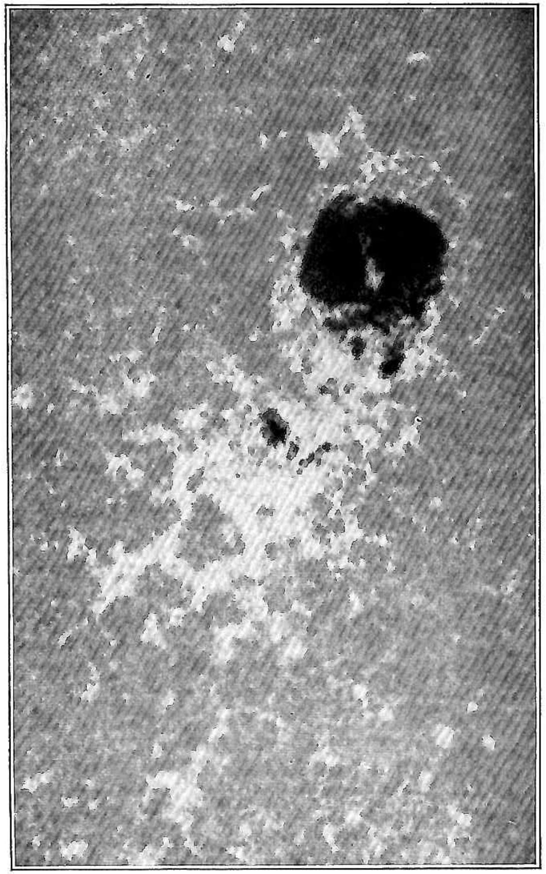


FIG. 1

July 17, 1905, 17^h 56^m. Low-Level Calcium Flocculi
Slit Set on H_1 (λ3966). Sun's Diameter =0.28 meter

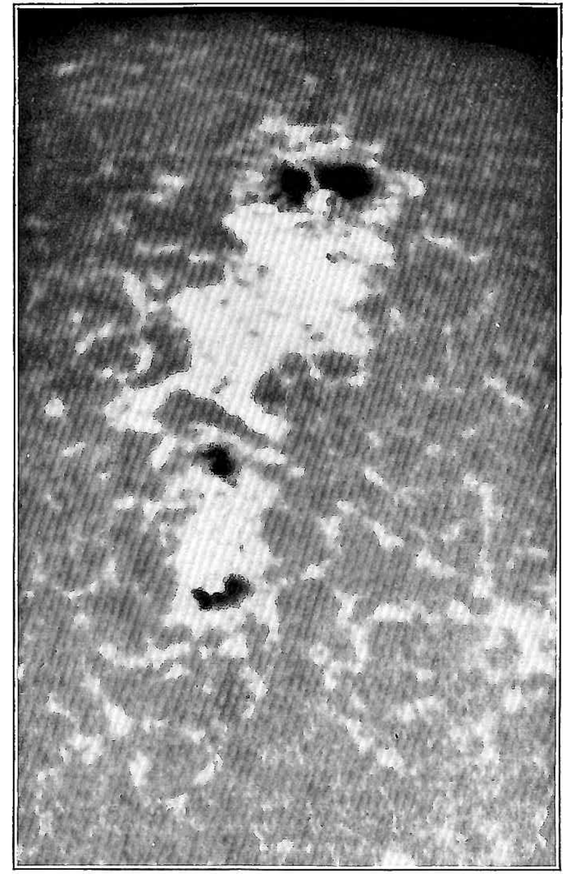


FIG. 2

July 20, 1905, 5^h 18^m. High-Level Calcium Flocculi
Slit set on H_2. Sun's Diameter=0.28 meter

It is to be hoped and expected that materials more suitable than glass can be obtained for the mirrors of telescopes which are to be used for solar work. Some preliminary tests of small mirrors of "Invar" (nickel-steel of the lowest coefficient of expansion), made by Hilger, indicate that this material can hardly be used, since it is too soft, in Professor Ritchey's opinion, to permit a large optical surface, even if once produced, to be kept well polished and free from scratches. It is probable that speculum metal could be used with a fair degree of success, since such a good conductor of heat would presumably act very differently from a poor conductor like glass. I am informed by Mr. Brashear that when speculum metal grating-plates are being figured, tests can be made very much sooner after polishing than is possible in the case of glass. This indicates that the figure is changed less by the heat produced by friction. Our attempts to produce disks of fused quartz have not yet been successful enough to demonstrate that mirrors can be made of this material.

From a mechanical standpoint the Snow telescope has proved to be completely successful. From an optical standpoint it has shown itself capable of giving results with the spectroheliograph superior to those obtained in our work with the 40-inch refractor. In view of the advantages it offers for many classes of astrophysical research, this telescope may now be considered to have passed the experimental stage, though the possibility of providing better material for the mirrors indicates that its optical performance will probably be considerably improved in the future.[1]

MOUNT WILSON, CALIFORNIA,
November 1905.

[1] For an account of recent work with the Snow telescope, see *Contributions*, Nos. 5, 6 and 7