ιAquilæ . . . . 19h31m.5—1° 31′ 4.28 B5

Spectroscopic variable of β *Canis Majoris* type. Six series of photometric measurements at Illinois in 1925 leave the question of its light variability still undecided.

55 Cygni . . . . 20h45m.5+45° 45′ 4.89 B2

Spectroscopic variable of very short period. Five series at Illinois in 1925 suggest that the light varies, but the period is undetermined.

9 Cephei . . . . 21h35m.2+61° 38′ 4.87 B2

Suspected β *Canis Majoris* type (*DO* **5**, 358, 1921). Light constant on two nights in 1925 at Illinois.

THE SPECTROHELIOSCOPE

By George E. Hale

The simple instrument for observing the Sun in monochromatic light, which I developed two years ago and tested then in a preliminary way,[1] has recently given me extraordinarily interesting views of the entire hydrogen atmosphere of the Sun. The optical parts of the spectroscope used in the earlier work are now rigidly mounted in a well beneath the low tower of my new Solar Laboratory in Pasadena. A beam of sunlight, reflected vertically downward from the second mirror of a coelostat mounted at the summit of the tower, falls on a 30 cm objective loaned me by the Yerkes Observatory. This forms a solar image 5 cm in diameter on the slit of the spectroscope in the laboratory at the base of the tower. A 15 cm concave mirror 3.96 m below the slit (in the spectrograph well which descends to a depth of about 24 m) sends a parallel beam nearly vertically upward to a large plane grating, ruled by Jacomini with 600 lines to the millimeter on the ruling machine of the Mount Wilson Observatory. From the grating the dispersed rays descend to a second 15 cm concave mirror, (also of 3.96 m focal length) mounted on the same support with the collimating mirror. The center of the image of the spectrum formed by this mirror is 26.7 cm from the center of the first slit, and in the same plane. I thus work out of the

[1] *Proceedings of the National Academy of Sciences,* **10,** 361, 1924. The principle of the spectrohelioscope dates from the earliest days of solar prominence observation without an eclipse, when it was suggested by Janssen, Lockyer, Zöllner, and others. A spectroscope embodying it, built for Young, is illustrated in Lockyer's *Solar Physics,* p. 167. Unfortunately it did not survive the introduction by Huggins of the wide slit method of observing prominences at the limb, and I find no record that it was ever used for observations of the disk.

axis of the mirrors, but the resulting astigmatism is inappreciable. The concave mirrors, (which lie in the same plane) can be moved up and down together by a screw for focussing, and the grating can also be rotated from the eye-end. An electric motor, of variable speed, can be used to cause the solar image to move across the first slit and a photographic plate across the second slit when the instrument is employed as a spectroheliograph. Its use as a spectrohelioscope, however, is the only point I wish to describe at present.

The long first and second slits of the spectroheliograph lie in the same line. Imagine them opened to a width of about 5 mm. A flat brass bar, mounted a short distance above these slits, and supported by a vertical bearing half way between their centers, carries two slits, each about 2.5 cm long and 0.08 mm wide. One of these stands directly above the wide first slit of the spectroheliograph, the other above the wide second slit. After the concave mirrors have been adjusted so that these slits lie in their principal foci, the bar is set central, and the grating rotated to bring the Hα line in the first order into coincidence with the second slit on the bar. The binocular body of my Spencer microscope, carrying a positive eyepiece magnifying 2½ diameters, is mounted above this slit. By means of a small electric motor the bar is set into oscillation, thus causing the first slit to move back and forth across a part of the solar image, and the second slit to move alternately toward red and violet through an equal amplitude (about 5 mm). The rate of oscillation is sufficiently rapid to give a persistent image of a portion of the Sun on the retina. As the second slit moves exactly with the Hα line, it is evident that a monochromatic image, in hydrogen light, will be seen by the observer. With the arrangement now used, the monochromatic window through which the Sun is seen is 5 mm wide and 12 mm long. Its length could easily be increased by the use of an eyepiece of larger field. The present arrangement, however, is very satisfactory, since all parts of the 5 cm solar image can be quickly examined with the aid of the electric slow motions of the coelostat and second mirror.

I have been surprised and delighted by the admriable performance of this simple device. When first tested two years ago, the temporary wooden mounting of the spectroscope, the absence of electric slow motions and accurate means of focusing, and the quiet condition of the Sun prevented its full merits from appearing. It is now evident that the spectrohelioscope will serve, not merely as a useful scouting auxiliary of the spectroheliograph, but as a powerful independent instrument of research.

The prominences around the limb are of course beautifully visible, though with a slit-width of 0.08 mm they are better seen with a smaller amplitude of oscillation. By means of the electric slow motions, the entire circumference of the Sun can be examined in a few moments and interesting objects selected for study. Prominences projecting on to the disk usually appear there as dark areas, and their steady increase in length, when advancing upon the disk from the east limb, is readily noticeable in the course of a day. The long dark prominences or "filaments," which often lie with their axes nearly east and west, are strikingly seen in transit over the limb. These are so conspicuous on the disk that I have frequently observed them through clouds dense enough to reduce very materially the brightness of the Sun.

The hydrogen vortices centering over sun-spots are also beautifully seen whenever a dark prominence is involved. Differences in the radial velocity of the absorbing hydrogen greatly affect the visibility of the vortex structure, and here is where the spectrohelioscope has a marked advantage over photographic methods restricted to a single setting of the second slit. The bearing which supports the oscillating bar is carried on a brass plate, which can be moved parallel to the spectrum by means of a micrometer screw. Thus during observation the second slit can be set on any part of the Hα line or far to the red or violet when great line distortions, due to the high radial velocities of ascending or descending gases, are in question. Thus by a quick turn of the screw one may pass from the observation of a brilliant eruption, seen on the violet side of the line, to a dark absorbing mass descending into the hydrogen vortex at a velocity of a hundred kilometers a second, seen when the slit is well to the red of Hα. Each of these could be photographed separately in turn by the spectroheliograph, or the ascending and descending gases could be photographed simultaneously, as Ellerman and I have done long since (see *Annual Reports of the Director of the Mount Wilson Observatory* for 1910 and 1911). But the multiplicity of forms seen at different slit positions, and the rapid changes which they undergo in active regions, render the spectrohelioscope extremely useful in observing them. It may also prove possible to record all these effects by the aid of a photographic attachment which, if feasible, should be capable of reproducing them for subsequent study in the form of moving pictures.

Among the many remarkable phenomena already observed with the spectrohelioscope a few may be mentioned. The most striking of these was a brilliant eruption seen on January 25 in the following part of the great sun-spot group,[2] which lasted throughout the morning and part of the afternoon and was followed by a great magnetic storm and aurora on January 26. The rapidly changing forms of prominences involved in hydrogen vortices, seen in cross section on either side of spots at or near the Sun's limb, are of great interest, especially as the spectrohelioscope reveals the related phenomena on the disk and permits the gaseous masses moving at different velocities in the line of sight to be observed separately. Thus (on February 26) a small bright "spike" prominence near one side of a spot was seen alone when the second slit was at the extreme edge of Hα, while a similar spike, on the opposite side of the spot, came into view when the slit was shifted to the center of the line, where an arch nearly uniting the two spikes was also visible. At the extreme violet edge of the line the arch and the first spike

[2]A large eruption, though less violent than that of January 25, was seen in the same region on January 24.

had disappeared, and only the second spike persisted. Similar phenomena were observed when the spot reached the west limb on the following day, and the influence of the hydrogen vortex in elongating toward the spot the upper parts of three neighboring prominences was strikingly seen. Another interesting sight on February 26 was the rapid descent toward the same spot of bright masses involved in the hydrogen vortex. Also the appearance near the spot for a few minutes of a small brilliant spike prominence giving a greatly widened Hα line, so that the spike could be seen when the second slit was well beyond the red and violet edges of the dark line. This object, because of its small size, brief duration, and great widening of Hα thus closely corresponds in character with the "bombs" occasionally observed on the Sun's disk with the 75-foot spectograph of the 150-foot tower telescope on Mount Wilson.

These phenomena and many others already seen suggest some of the various uses to which the spectrohelioscope can be put, when carefully designed for precise observations and equipped with index and scale showing the exact position of the second slit with reference to the center of the Hα line. Such an instrument is now under construction and will soon be ready for use. This will carry either a rotating disk bearing 180 slits or an oscillating disk provided with several sets of slits for special purposes. One of these, consisting of a pair of slits set on the red edge of Hα and a second pair set on the violet edge, operated like the "blink" eyepiece of a stereocomparator, will permit the quick and accurate comparison of the forms of the flocculi corresponding to wave-lengths exactly equidistant from the center of the line.

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