Solar Prominences by Daylight —A Classic of Science

Astronomy

PHOTOGRAPHIC INVESTIGATION OF SOLAR PROMINENCES AND THEIR SPECTRA; by George E. Hale. In American Journal of Science, 1891.

When Dr. Hale photographed the solar prominences through a spectroscope slit he allowed astronomers to learn by daily observation the life history of those strange "flames," sometimes many thousand miles in height, which shoot out from the surface of the sun. Before the spectroheliograph, momentary glimpses at times of total eclipse furnished our only information on these constantly shifting clouds of gaseous elements. Dr. Hale, now honorary director of the Mount Wilson Observatory, still studies the sun as seen from his private observatory at Pasadena.

IT is now many years since any important advance has been made in our knowledge of the solar prominences. With the exception of spectrum photographs made at the Siam and Egyptian eclipses, and the momentary glimpses of mysterious "white prominences" during totality, almost nothing has been added to the collection of facts gathered nearly twenty years ago. After Professor Young's vigorous attack upon the chromosphere and prominence lines at Mount Sherman and elsewhere, other investigators seem to have been impressed with the belief that no further additions could be made to the long catalogue of lines drawn up by our most skillful solar observer, and the spectroscopic side of the matter was allowed to rest, though a continuous record has been kept of the forms of chromosphere and prominences. While it is probably true that the most persistent watching would be required to increase the number of known lines in the visual spectrum, it is rather singular that the importance of photography in a study of the ultraviolet has been entirely overlooked. While the positions of spots on the sun's disc are daily recorded by photography, the same cannot be said of the chromosphere and prominences, and even in investigations of the extremely complicated spot spectra, photography has been but little employed, experiments with it not having proved very successful.

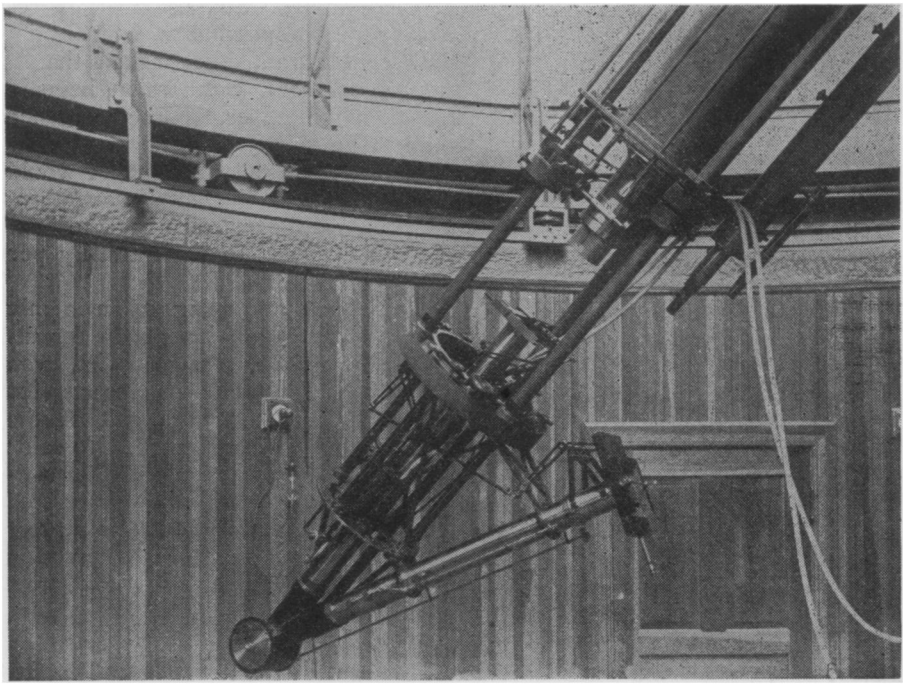
It is unnecessary here to urge the importance of using photographic processes to assist the eye in nearly all classes of solar investigation. What has been said for photography in other fields of astronomical or physical research will apply with equal force in the present instance, and the results of many years speak forcibly for themselves. It is of course very desirable that the ultraviolet should be studied, and for this purpose visual observations are of no service. Again, prominence forms as photographed through different lines should be compared, and the sequel will show that photography affords the only means of investigating the white prominences.

The history of attempts at solar prominence photography extends over twenty years, and it is remarkable that the earliest experiments were the only ones which gave any indications of possible success. In 1870 Professor C. A. Young made the first prominence photographs taken without an eclipse. Using the hydrogen gamma line (G'), and a wide tangential slit, a magnified image of the prominence was formed upon an ordinary collodion plate, and given an exposure of nearly four minutes. Professor Young has very kindly shown me silver prints from the best original negatives; in these only the general outline of the prominence can be faintly seen. This is due partly to a small displacement of the image during the exposure, as the polar axis of the telescope was slightly out of adjustment. The nebulous character of G' makes its use objectionable, but the serious difficulty with this line lies in the employment of a wide slit. The brilliancy of the background of atmospheric spectrum increases very rapidly when the slit is opened, while the prominence itself grows no brighter. Thus the contrast in a photograph is greatly decreased, and the general illumination of the field, due to diffused light from the grating, or fluorescence of the prisms or object glasses, conspires to hide all details of structure. For these reasons the method has never been employed in practice.

It is beyond the scope of the present paper to describe the various methods of prominence photography proposed by Braun in 1872, Lockyer and Seabroke in the same year, Lohse in 1874 and 1880, Zenger in 1879, and Janssen in 1881. Suffice it to say, that in no instance was any success attained sufficient to bring the method into practical use, and in 1889 it was impossible to see where any advance whatever had been made beyond the brief experiments of Professor Young with a simple open slit.

In undertaking an investigation of the subject in the summer of the year last named, the writer devised two methods of accomplishing the desired result with a narrow slit, for it was evident that with any line in the prominence spectrum as then known, the use of a wide slit could not have more than an extremely limited application. In the first method the rate of the driving clock of the equatorial is so changed that the sun's image drifts at right angles across the slit of a spectroscope of high dispersion. At the focus of the observing telescope (of equal focal length with the collimator) a photographic plate moves at the same speed, at right angles to the axis of the telescope, and in the direction of dispersion. A narrow slit just in front of the plate allows only the line in use to fall upon it, and thus prevents fogging. It will be easily seen that fresh portions of the plate will be uncovered as the prominence drifts across the slit, and the result will be a latent image upon the photographic plate.

The second method exactly reverses the operations of the first. The sun's image is held in a fixed position by the driving clock of the equatorial, while the plate at the focus of the observing telescope is also stationary. The slit of the spectroscope is caused to move steadily across the end of the collimator, while a corresponding slit before the plate moves at such a rate



The original Hale spectroheliograph attached to the 12-inch refractor at the Kenwood Observatory at Chicago.

that the line in use passes constantly through it.

Both of these methods, together with the experiments carried on with the first at the Harvard Observatory and more recently at the Kenwood Physical Observatory, have been already described, and in the present paper I wish to consider especially the results obtained in Chicago within the last few weeks.

In my earliest attempts at photographing the prominence spectrum I was much surprised to find narrow, sharp, bright lines running up through the center of the dark shades of both H and K, apparently to the very top of every prominence. At Mount Sherman in 1872 Professor Young, whose eyes are exceptionally sensitive to the shorter wave-lengths, had been able to see similar reversals of H and K, but the difficulties of observation were so great that he considered it probable that the whole width of each dark shade at H and K was reversed, the eye being able to perceive only the maximum of intensity at the center. Once or twice he noticed a bright line estimated to be about one division of Angström's scale below the central reversal of H, but with the utmost precautions the eye was incapable of any accurate determinations of position or appearance in this part of the spectrum. But with high dispersion and care in manipulation the photographic plate meets with no difficulties, and the lines are obtained with ease. . . .

The important variations in the relative intensities of prominence lines revealed in eclipse photographs have been partially confirmed by my photographs. So far only one prominence has appeared in which the ultra-violet hydrogen lines could be photographed, and this showed a corresponding increase of brilliancy in the visual spectrum. But the H and K reversals are invariably strong, and easily photographed. Preliminary measures show that both lines probably belong to calcium, but this is yet to be definitely determined, and the origin of the broad dark shades in the solar spectrum is decidedly uncertain. In spite of the constant presence of the H and K bright lines in prominences, it can hardly be supposed that the substance producing them can be ordinary hydrogen, for several reasons. In the first place there is no provision for K in Balmer's series, and H certainly does not fall in the position of the hydrogen line, as it is about 1-5 tenth-metre more refrangible. Again, H and K do not follow the hydrogen lines in their intensity variations, and in several cases I have photographed both H and K expanded and reversed over spots in which the C and F lines showed no signs of reversal. Some very recent photographs suggest the possibility that the substance producing the H and K bright lines occasionally ascends in prominences to a higher level than that reached by hydrogen itself (observed through C) in the same prominences, and the "white prominences" observed and photographed at several eclipses offer a most interesting case in point. At the Grenada eclipse of August 29, 1886, Prof. W. H. Pickering found in his photographs made during totality a spiral prominence 150,000 miles high, which had for the only lines in its spectrum H, K and a faint trace of an ultra-violet line about half-way between K and L. There was also a brilliant continuous spectrum in the visible region, but as the usual hydrogen lines were absent, Prof. Tacchini was unable to see the prominence by the usual spectroscopic method, either before or after totality. In his report Prof. Pickering adds: "It is highly probable that a great number of prominences pass by entirely unnoticed, because we rely solely upon visual instead of photographic methods of observation." . . . The various theories connecting sun-spots and prominences are based upon observations in the visual region, and the invisible prominences, which are shown by the Grenada photographs, to reach at times to great elevations, have been left entirely out of account. It will be seen shortly that this need no longer be the case, and we may hope soon to have a daily record of all classes of prominences, both visible and invisible.

When the sharp and brilliant reversals of H and K were discovered at the beginning of my investigations in prominence photography at the Kenwood Physical Observatory, it at once became evident that a considerable advance had been made, for the substitution of either of these lines for the less refrangible hydrogen lines removed the serious difficulty of photographing the longer waves of the C region with short exposure. But apart from their position in the spectrum, the distinctive peculiarity of H and K specially fits them for prominence photography. The narrow bright lines, instead of being superposed on a brilliant continuous spectrum as is the case with all of the other prominence lines, lie in the center of broad, dark bands, where the troublesome light of the atmosphere is missing. Thus both slits used in my apparatus for photographing the prominences could be much (*Turn to page* 46)

To Excavate Big Assyrian Mound

Archæology

Americans Will Search Palace of Biblical King

THE University of Pennsylvania Museum and the American School of Oriental Research in Bagdad have joined in equipping an archæological expedition which will carry on excavations in a hitherto little known section of Kurdistan, in northern Mesopotamia, Horace H. F. Jayne, director of the University Museum, has just announced.

"The site which has been chosen for excavation," Mr. Jayne states, "is known as Tell Billa, one of the largest and most imposing mounds in the land of ancient Assyria. It is situated about fifteen miles northeast of Mosul and about five miles east of the famous ruins of Khorsabad.

"Tell Billa first attracted the attention of Dr. Speiser in 1926 when he was making an archaeological survey of northern Iraq. A surface examination disclosed that the huge mound contained extensive remains of the prehistoric period, going back to the original inhabitants of Mesopotamia and the neighboring regions of the Near East. Furthermore, the historical period is also well represented.

"The site is of particular archæological interest in that a fragment of an inscribed brick picked up on the mound bore the seal of Sennacherib, the Assyrian king of biblical fame, making it clear that the Tell contains one of the summer palaces of the great ruler.

"Sennacherib reigned in Assyria from 705 B. C. to 681 B. C. He laid unsuccessful siege to Jerusalem, his army being decimated by a plague in 689 B. C. He razed Babylon to the ground. It is the fall of Sennacherib's army before Jerusalem that Byron celebrates in his poem 'The Destruction of Sennacherib.'

"Tell Billa was occupied from about 4000 B. C., till the fall of the Assyrian Empire in 606 B. C. It is likely, therefore, to yield sculptures from the Golden Age of Assyrian art as well as prehistoric remains of the aboriginal population of the land. In any case it is certain to furnish important scientific information relative to the early history of Mesopotamia."

The expedition, which will begin work in November of this year, will be headed by Dr. Ephraim A. Speiser, assistant professor of Semitics at the University of Pennsylvania, and the staff will include Dr. C. S. Fisher, who has been engaged in archæological research for the past thirty years, Dr. S. N. Kramer, who holds a fellowship from the American Council of Learned Societies, and A. H. Detweiler, an architect.

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Solar Prominences—*Continued*

more widely opened, without the difficulty of fogging and loss of contrast experienced with the other lines. The result was that the first photograph made in this way proved a success. The prominence drifted slowly across a narrow tangential slit, and behind the second slit, at the focus of the observing telescope, a small cylinder with its axis parallel to the slit, carried a strip of sensitive film at a speed equal to that of the moving solar image. A smooth and uniform motion of the cylinder was produced by a small clepsydra. The photograph showed the form of the prominence very well, and with considerable contrast. It was then concluded, on account of the great width of the dark shades at H and K, that for prominences of not too great size (the image of the sun on the slit plate is two inches in diameter) it would only be necessary to use a wide slit, and give a short exposure. . .

Although this method will serve to photograph the invisible prominences it is evident that there are two objections to it. In the first place it would be very troublesome to find invisible prominences, and to do so it would be necessary to take a large number of photographs with the slit tangent at various points on the limb. This could be remedied by using a curved or ring slit. Again, prominences surpassing a certain size could not be photographed, though for single narrow prominences reaching to a considerable elevation it would be desirable to make the direction of the slit coincide with the direction of the longest axis of the prominence, the direct light from the limb being excluded by a small strip of metal, sliding under the slit. To overcome all of these difficulties I have devised a new form of apparatus, which will much excel the rotating cylinder in ease of adjustment, and allow the use of ordinary glass plates, instead of the celluloid film, which decomposes if kept for any length of time. A new form of clepsydra, of much larger size and with an improved valve, will replace the smaller one before used. The equatorial is also to be supplied with a 12-inch photographic object glass, and a new tube parallel to the old one, so that by a suitable form of cell, either object glass may readily be used on either tube, as the spectroscope is too large and heavy to be easily moved.

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Soil Congress

PREPARATIONS are rapidly being completed for the meeting of the Second International Soil Science Congress in Leningrad and in Moscow, July 20 to 31. During the first six days the sessions will be held in Leningrad, and the rest of the time they will take place in the capital. In addition to the scientific papers and addresses, there will be a series of short excursions into the country around both cities, giving the delegates an opportunity to see various types of soil as they exist in Russia and to observe Russian methods of meeting the technical problems of soil utilization in forest, agricultural and grazing lands, and in the reclamation of marshes and other waste areas.

The Congress will meet under the presidency of one of the most noted of Russian soil scientists, Dr. C. C. Gedroiz. In addition to the large number of Russian workers who will be in attendance, about 200 foreign soil scientists, representing 33 European, Asiatic and American countries, will also be present.

After the adjournment of the formal sessions, there will be a 29-day excursion by rail and river boat and Black Sea steamer.

Soils Science

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