AN OPTICAL IMPROVEMENT IN THE SPECTROHELIOSCOPE

By Edison Pettit

In the construction of his various spectroheliographs Dr. Hale was guided by several optical considerations, discussions of which may be found in the literature.[1] One principle which has not been accorded the importance it deserves may be briefly described as follows. When the slits of a spectroheliograph are opened wide the instrument may be used visually as a wide-slit spectroscope to examine solar phenomena, particularly prominences. The side of the line on which the prominence appears to arise will obviously depend on the number of reflections in the spectroheliograph, whether odd or even. Now, if we narrow the slits down, we begin to observe strips across the image, which are simply sections of the prominence. When the spectroheliograph is set in motion to build up an image on the plate, it must be done so that each successive strip matches the adjacent strips and the complete image rises from the solar limb on the same side of the line as that on which it was seen with wide slits (Fig. 1*Aa*). This requirement we shall call the *correspondence condition*. If this condition is not fulfilled, an image will still be formed, but much blurred unless the slits are extremely narrow (Fig. 1*Ab*). To correct the defect an additional reflection must be introduced. It may be observed that any reflection which reverses the slit or spectral lines end for end will not affect the correspondence condition. Of course, the same principle applies to the spectrohelioscope.

When he designed the spectrohelioscope, Dr. Hale first constructed one with slits mounted radially on a rotating disk, but rejected it because of difficulties of adjustment.[2] The disk was replaced by oscillating slits mounted on the opposite and

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[1] *Pub. Yerkes Obs.*, Vol. **3**, Part I, 1903; *Mt. W. Contr.*, No. **7**; *Ap. J.*, **23**, 54, 1906; *Mt. W. Contr.*, No. 388; *Ap. J.* **70**, 265, 1929; *Encyc. Brit.*, 14th ed., **2**, 178, 1937.

[2] See, however, "A Simplified Spectrohelioscope" by G. A. Mitchell, *Mt. W. Contr.*, No. 599; *Ap. J.*, **88**, 542, 1938.

equal arms of a first-class lever, and the optical system of the spectrohelioscope was designed for this slit arrangement, which fulfills the correspondence condition.

Two disadvantages are found in the use of revolving or

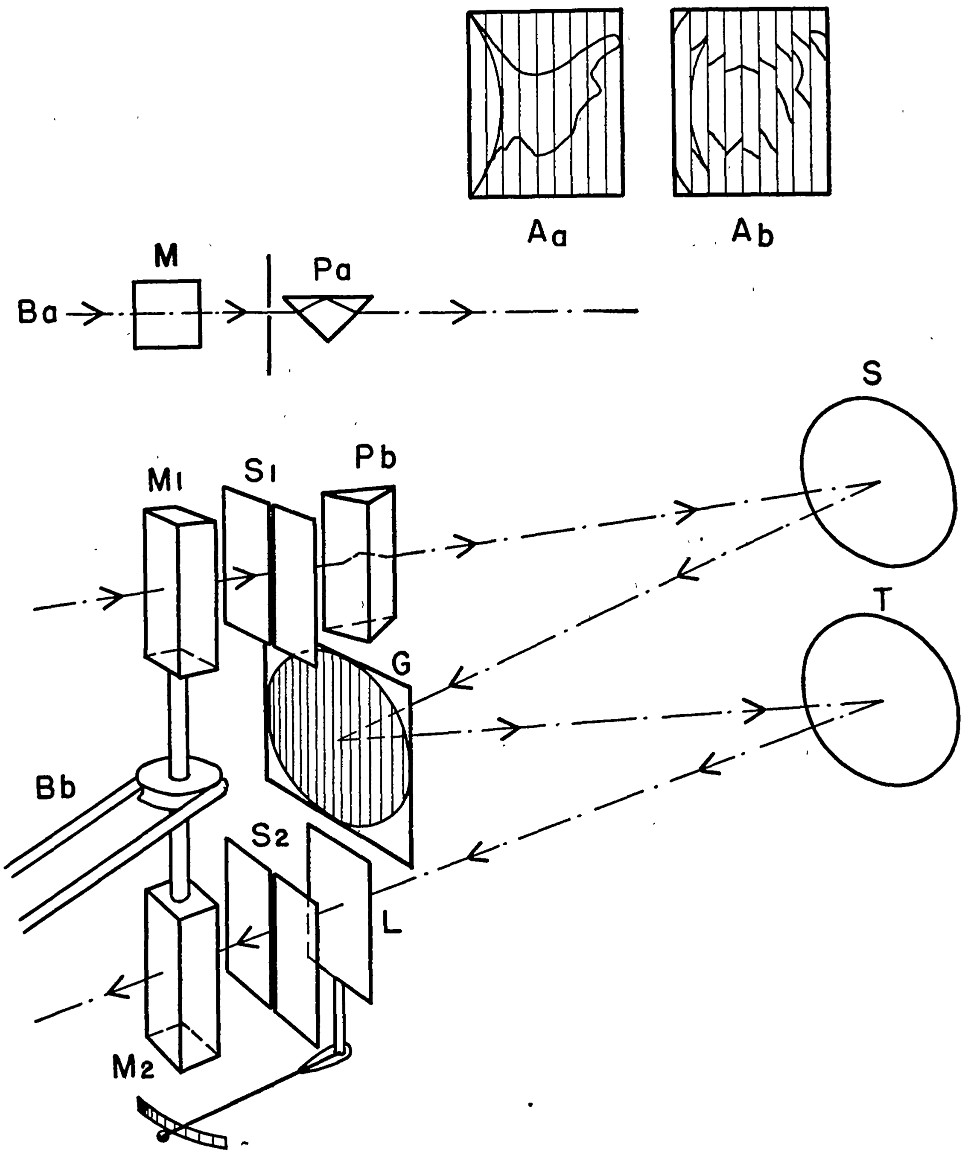

FIG. 1.—*A,* successive images of a prominence on the second slit; *Aa,* when the correspondence condition is satisfied, and *Ab,* when it is not satisfied. *Ba,* diagram showing use of right-angle prism *Pa* to change from condition *Ab* to *Aa*. *Bb,* optical system of spectroheliocope showing proper position of right-angle prism *Pb*. *M1–M2,* Anderson prisms; *S1–S2,* slits; *Pb,* reversing prism (right angle); *L,* line shifter; *G,* grating; *S,* collimation mirror; *T,* telescope mirror.

vibrating slits: (1) their widths cannot conveniently be changed relative to one another, (2) they rotate with respect to the grating rulings. It would be much better if the slits were fixed in position while the solar image on the first slit and the second slit-image in the eyepiece were made to oscillate optically, thereby producing the same result. This was accomplished by Dr. J. A. Anderson with a pair of square cross-section prisms. The oscillating slits were therefore removed, a pair of fixed slits attached, and the Anderson prisms added. This, then, became the standard Hale spectrohelioscope, many duplicates of which have been acquired by observatories over the world.

I recall that Dr. Hale once said he thought the oscillating slits gave much the best definition, but no importance was attached to the matter at that time. When, however, the author came to design the optical system for the new tower telescope of the McMath-Hulbert Observatory at Lake Angelus, Michigan, it was noted that if the correspondence condition was satisfied for the oscillating slits, with which that instrument was provided, it would not be satisfied for Anderson prisms, since in the first instance the slits move in opposite directions, while in the second the images are optically made to move in the same direction. In other words, one cannot change from oscillating slits (or revolving disk slits) to Anderson prisms without inserting or removing a reflecting surface. It follows that all the standard Hale spectrohelioscopes, as now used, should have a reflection added somewhere in the optical train between the first and second Anderson prisms.

If the spectrohelioscope does not have the standard optical train, the test of the correspondence condition can be made simply as follows. With the prism stationary, open the second slit wide and center Hα upon it; then open the first slit several divisions and bring the sun's limb into it, noting how the limb enters the Hα line. Usually, small prominences will be seen first, then the curved segment of the sun's limb. If the limb is convex in the same direction as that of the built-up image produced by the rotating prisms the correspondence condition is satisfied.

If the curvature of the two images is opposite, the condition may be fulfilled by introducing an additional reflection produced by a right-angle prism mounted just behind one of the slits, as shown in Fig. 1*Ba*. In practice the prism should be 1¼ inches long with sides ⅜ of an inch wide. Incident light parallel to the hypotenuse face will be reflected from that face (Fig. 1*Ba*). Since the width of the field of the prism is about one-half the distance from the rectangular edge to the reflecting face, a slit 1¼ inches by ⅛ inch may be used.

It seems preferable to place the prism just behind the first slit (Fig. 1, *Pa, Pb*), first, because this slit is seldom opened more than a millimeter, while the second slit must often be opened to examine the spectrum near Hα; and second, because the change in focus produced by this prism (about ⅛ inch) will then be partially compensated by the line-shifter *L* behind the second slit. In any case, adjusting screws are necessary on the prism mounting to direct the beam of light from the first slit S_1 upon the first collimating mirror *S* (or collimating lens if a Littrow form of spectroscope is used). A prism of the kind described was first added to the Hale spectrohelioscope on loan at the Lake Angelus Observatory in 1938, and the improvement in optical performance was such that slits from 1 to 2 mm wide could be used with little loss in definition of the prominences. Reversing prisms in the scout camera of the tower telescope at Lake Angelus and in the spectroheliokinematograph also greatly improved the definition of the photographs made with these instruments.

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