Technical Papers

On Projection as a Possible Source of Apparent Color in Sunspots

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That sunspots occasionally show definite colors is a fact attested by numerous observers dating back at least to Messier (*4*), who in 1759 reported a deep brown color in the notable sunspot of that year. Many competent observers, however, have not conceded the objectivity of the observed colors and have ascribed them to illusions or to the secondary spectrum of objectives (*5*). The difficulty has been to account for them within the framework of accepted physical theories of the sun's constitution.

However the reconciliation is to be accomplished, such colors may be seen with reflectors as easily as with refractors, which fact greatly weakens the argument that they arise through the effects of the secondary spectrum. Moreover, two facts seem to suggest most strongly that some, if not all, of the observed colors are truly objective: 1) they are seen chiefly during maximum sunspot periods and are generally confined to the largest and most active class of spots; and 2) they are comparatively rare. Thus, of 6,169 individual sunspots observed by the writer at Baltimore in 1948, only 22 were found to be colored. It is not easy to see why, if the colors are illusionary, they should not be seen much more frequently.

Hitherto, the writer has been inclined to regard sunspot colors as being due to radiation from the spot in selective wavelengths (*1*); but while this may account for umbral colors, it is not easy to assign such a cause when the color is in the penumbra.

D. H. Menzel, in a letter to the writer referred to by Bartlett (*2*), suggests that color may also be due to the projection of chromospheric eruptions. A recent observation by the writer tends to confirm this view very strongly.

August 21, 1949, at 17h 24m, the writer observed a very large, irregular sunspot of F-1 type (Waldemeier classification) close to the equator in the northern hemisphere and almost on the solar meridian. The time given here is the mean time of observation, i.e., the mean of the sum resulting from the addition of the time when the observation began to the time when it ended. Actual times are given as follows:

At 17h 10m the penumbra was found to be normally grayish with little contrast. The umbra was certainly black. At 17h 29m the penumbra was observed to be red-violet and the umbra appeared brown. At 17h 32m the penumbra suddenly became a bright red-violet, showing marked contrast with the photosphere. At 17h 36m the penumbra was again grayish with little contrast and the umbra again looked black. Between 17h 32m and 17h 36m color in the penumbra was observed to fade and brighten alternately several times.

Although the writer had never seen this particular phenomenon before, it had been previously reported to him by at least two other observers on the writer's granulation program; and Walter L. Moore, observing with the 12.5-in. Clark reflector of the University of Louisville, had also reported colored areas in penumbrae, though the color had not been observed to fluctuate.

While observing this phenomenon, it occurred to the writer that the appearances corresponded very well to what might be expected from the passage over the spot of a chromospheric area of varying density—hence the fluctuations—in brightness inferior to the photosphere but superior to the penumbra and umbra. Thus, Menzel's suggestion of color by chromospheric projection appears to receive observational support.

In this connection an observation recently made at Climax may perhaps be confirmatory. In October 1948, the writer observed rapid changes of color (not merely fadings and darkenings) and other phenomena in a large sunspot. A telegram was sent to Walter Orr Roberts in charge of the High Altitude Observatory of Harvard at Climax, urging spectroscopic examination of this spot. In a letter to the writer (*3*), Roberts reported marked phenomena "directly over the region of the sunspot" and presumably within the chromosphere. There was also observed a brilliant emission in the yellow at the coronal line 5694 A. Since this activity took place above the spot, and therefore had a relatively dark background for projection, it seems quite possible that color effects might have been noticed which seemed to be in the spot itself.

References

1. Bartlett, J. C. *Science*, 1946, **103**, 681.
2. ———. *Popular astronomy.* Northfield, Minnesota: Carleton College, February 1948.
3. Roberts, W. O. Letter, October 27, 1948.
4. Webb, T. W. *Celestial objects for common telescopes.* London: Longmans, Green, 1917. Vol. 1, p. 37, footnote.
5. Young, C. A. *The sun.* New York: A. L. Fowle, 1895. Revised ed., p. 118, footnote.

The Frequency of Beat of Sperm Tails

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Since Bidder (*1*) in 1895 estimated the vibrational frequency of choanocyte flagella, several methods of measuring the rate of ciliary beats have been devised, and a number of readings have been made on vibratile parts of protozoa, molluscs, vertebrates, and arthropods. Bidder's first approximation placed the rate at about 10 beats per sec, but he later (*2*) recorded 5 beats per sec in *Grantia*, giving at the same time the opinion that a healthy frequency ought to be closer to 20 beats per sec. Gray (*3*) measured beats of cilia and flagella, ranging