ON EMISSION LINES OF HYDROGEN, HELIUM AND IONIZED CALCIUM SEEN ON A CORONAL SPECTROGRAM OF THE MARCH 7, 1970 ECLIPSE

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(Received 14 March, 1972)

Abstract. Emission lines of the Balmer series, D_3 and H and K are reported present on a coronal spectrogram obtained at the March 7, 1970 eclipse. Arguments are presented to show that these could not have originated from scattering in the Earth's atmosphere and hence possibly have a coronal origin.

We obtained at the March 7, 1970 eclipse a single spectrogram of the solar corona covering nearly 90° in position angle, distributed over both the north–west and south–west quadrants about the solar centre, and covering a range of solar radii from 1.0 to $1.5\,R_{\odot}$. A horizontal 25-cm telescope, used in the Newtonian arrangement and fed by a two-mirror coelostat, provided a 22-mm diam. solar image on the slit of the spectrograph. A quartz optical flat of 1 cm thickness placed before the $130\,\mu$ wide slit permitted guiding of the solar image on the curved slit of the spectrograph. The spectrograph utilized an off-axis collimator of 76-cm focus, a 600 lines mm^{-1} grating blazed at 5000 Å in the first order and a spherical mirror camera of radius of curvature 112 cm. The dispersion of the spectrograph in the curved focal plane was 23 Å mm^{-1}. An unmounted red Wratten gelatin filter located close to the focal plane eliminated overlap of the second order spectrum. The spectral range covered 3400 Å to 7600 Å in the first order on Eastman Kodak I-N emulsion.

It was our plan to obtain a series of coronal spectra with the slit centered in position angle about the solar equator close to the west limb. An accidental movement of the guide plate, soon after commencement of totality, eliminated the possibility of execution of such a scheme. A single long exposure of 40 s was, therefore, obtained. Soon after totality, the relative locations of slit and emerging crescent were determined. The slit position during exposure, derived from such a measurement, is shown in Figure 1. The tracking of the coelostat was uniform and we have no reason to believe that a change could have taken place in its driving performance during the few minutes that lapsed between the mid-epoch of exposure of the spectrum and when we noted the position of the solar West limb with respect to the slit. The exposure of the spectrum was timed to have commenced nearly 45 s after second contact and is characteristic of conditions near midtotality.

The spectrogram is well exposed in the green, yellow and red regions and over-exposed in the blue from 4800 Å to 3900 Å. The sharpness of the focus could have been much better, a fact necessitated by the unexpected delays in arrival of the equipment in

Solar Physics **26** (1972) 366–369. *All Rights Reserved*

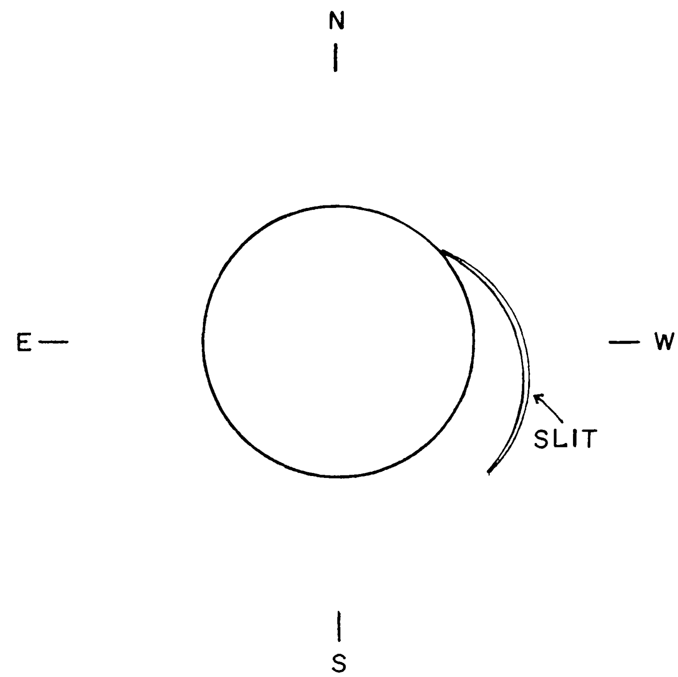

Fig. 1. Location of the spectrograph slit on the solar corona.

Mexico, that left little time for perfect adjustment of the instrument. Nevertheless the resolution is not seriously impaired and leaves ample scope for the certainty of wavelength identifications that we have made.

The most striking aspects of the spectrogram are the emission lines of He I 5876 and Hα. Also present in sufficient intensity is Hβ over the same range in position angle. The [Fe XIV] 5303 Å line is seen over that part of the spectrum which corresponds to a slit location close to the Moon's limb. The [Fe X] line at 6374 Å is weak but detectable on the spectrum and covers a larger length of the slit than 5303 Å. Over most of the slit length that intersects the outer parts of the corona the Fraunhofer absorption spectrum is seen in good intensity. The absorption lines weaken considerably in the region where the 5303 Å and 6374 Å lines are noticed. In the over-exposed part of the spectrum we can identify with certainty the Hγ line in emission as well as the H and K lines of ionized calcium, Hζ and Hη. Weak emission can also be seen at 3820 Å which we tentatively identify with He I

These results of observation are thus similar to those made at previous eclipses in the blue region of the spectrum by Colacevich (1953), Deutsch and Righini (1964), Migeotte and Rosen (1955) and Conway *et al.* (1967). Colacevich had seen H and K, 3908 Å, Hζ, 3765 Å on the spectrogram obtained with a radial slit. Some of the lines were seen out to 70′ from the Moon's limb. Deutsch and Righini (1964) used a radial slit at the 1963 eclipse and observed only the K line in emission up to almost $2R_\odot$. A maximum intensity of this emission feature, as seen on the reproduction of their spectrogram, is in the portion around 1.4 to 1.5 $R_\odot$. No H line was seen and presumably this may be due to the observation of the spectrum in a preferred plane of polarization.

Deutsch reports (Babcock, 1965) that at the eclipse of 1965 both H and K were seen in emission, thus confirming the reality of the 1963 observation. Migeotte and Rosen (1955) used a tangential slit and remark that they found knots of intensity distribution along the Ca^+ emission lines suggestive of condensations located in 'clouds' of ionized calcium. They infer the origin of this emission to be from diffusion in the Earth's atmosphere, of the light of the prominences that were incompletely occulted during the first 15 s of totality.

In speculating on the source of the emission of the kind we have observed, possibilities such as those suggested by Migeotte and Rosen (1955) must necessarily be considered, before one ascribes a coronal origin to the emission lines. The skies at Miahuatlan were superbly clear during the eclipse. Veteran eclipse observers claim that the exceptionally clear skies must have reduced the scattered light in the atmosphere to levels far lower than those typically present at most eclipses (Menzel, 1971). The possibility of terrestrial contribution could, therefore, be ruled out even though the west limb had a prominence of the quiescent type.

It is of interest to examine in this context the visual observations made at eclipses in the exciting period 1868–1874. Rayet at the eclipse of 1868 noticed that the D lines, 5303 Å and Hβ extended to greater heights than the other prominence lines. If such extension of these emission lines is the result of scattering by the Earth's atmosphere, the region of the slit that passes over the Moon's disc should show a similar feature. Rayet's observations are clear cut on this matter. Ranyard (1879) commenting on Rayet's findings points out that, "on the side of the spectrum corresponding to the Moon's limb all the lines were sharply cut off." At the 1871 eclipse Janssen traced the hydrogen spectrum to 10′ with a radial slit. His examination of the Moon's disc permitted the recognition of weak scattered light of telluric origin. But, this was insufficient in magnitude, to prevent him from ascribing the extension of the hydrogen lines seen beyond the prominences and into the corona, as indicative of genuine hydrogen emission from the corona. The condition of high transparency in which those observations were made facilitated also his discovery of the absorption lines in the outer corona which, as we recognize today, arise from the F-corona.

It is also of interest to note that the spectrum of the inner corona obtained by Aly (1955) and Aly *et al.* (1962), shows little spread of H and K beyond the location of the prominences.

By the fortuitous circumstances which led to the particular orientation of spectrograph slit, most of the slit length had a more limited 'exposure' to variation in $R_\odot$ than the more conventional radial and tangential settings used by numerous investigators at total eclipses of the Sun. If such emission is normally a maximum near 1.5 $R_\odot$, without much position angle dependence, our spectrogram should show it to the optimum, as indeed it does. Besides, if scattered prominence radiation is really the source, the spectrum should show many of the finer details normally characteristic of prominences. No emission is seen in the NaD lines or in Mg b, which the quiescent prominences usually dispaly. We also do not see any high excitation lines of He II seen in loop and active prominences. There is no trace of 6678 Å of the singlet series of helium.

Our spectrogram cannot indicate the presence of weak 4471 Å and 4026 Å and so little can be said of their presence.

If we now consider that the above arguments on sources of contamination do not indicate such a possibility, we must look for a coronal source of these emission lines. F corona scattering of chromospheric and prominence radiation is a possibility which we could rule out on our spectrogram from intensity considerations. A cooler columnar component in the outer corona is not unlikely. But further studies, substantiating these observations, would be necessary at forthcoming eclipses before we enter on such paths of conjecture. The evaluation of scattered light of telluric origin is best done by obtaining exposures during totality on the Moon's disc 4–5′ within the limb.

The observations of Conway *et al.* (1967) and those of Gnevyshev and Gnevysheva (1963) had stimulated Eakin (1971) to search with the aid of interference filters for emission in the corona in H and K and the D_3 lines. Considerable coronal structure in calcium emission was seen in both the He I and Ca II lines. Mogilevsky's observations, (1971) with a narrower bandpass filter, should be of interest when announced in detail.

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