Interferometric observations of emission features in the F-corona

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Abstract. We are solving the problem of detection of the resonance emissions of Ca II ions created by the interplanetary dust sublimation. To this end, a suitable technique was developed for interferometric observations of the eclipsed sky around the Sun. Successful observations have been carried out during the eclipse of February 26, 1998 in Guadeloupe. On the negative obtained, all the field is covered by an interference pattern adequate to a daytime sky interferogram. Such a pattern must be due to the double scattering of the sunlight in the Earth's atmosphere. There is a number of emission features on the above background. Unshifted K-line of Ca II is seen up to about 10 solar radii. This is consistent with other evidences on the occurrence of the H and K emission lines in the coronal spectrum. The most important features on the photograph are Doppler-shifted K-emissions in the SW-quadrant of the circumsolar space within the range of 5 to 20 solar radii. The sign of the Doppler shift corresponds to direction of the planetary orbital motions. That is why, we suppose that these features just represent the emission associated with the sublimating dust. If so, it will be said about the discovery of a new component of the solar corona, namely the 'S-corona' (from 'sublimation').

Key words: solar eclipse – solar corona – interplanetary dust

1. Introduction

The interplanetary dust is responsible for the phenomena of the zodiacal light and the F-corona. Dust particles forming the interplanetary zodiacal cloud move along Kepler orbits gradually approaching the Sun due to the Pointing-Robertson effect. Apparently, at a certain distance from the Sun, dust particles should suffer sublimation in consequence of heating by the solar radiation. As a result, the dust-free zone could exist around the Sun with the radius of ≈ 4 to > 10 solar radii according to various estimations.

Attempts to detect the boundary region of the zodiacal dust cloud have been taken up repeatedly, mostly during the total solar eclipses (Prasad, 1995; Gulyaev and Shcheglov, 1998a). Usually, observers tried to detect an excess of continuous radiation of the F-corona in the infrared spectrum (2 to 5 μm) which could be attributed to the thermal emission of the heated dust (so-called 'T-corona'). The results obtained are rather inconsistent. In particular, that gave grounds to suggest a variability of the T-corona due to solar activity variations (Prasad, 1995).

Another way of the study of the boundary zone under discussion appears to be more promising. As an indicator of this region, we can use an emission of resonance lines of metal atoms and low-charge ions expected to occur while the dust sublimating. Shestakova (1989, 1990) computed the expected intensities of a few resonance lines at a heliocentric distance of 6 solar radii. The H and K lines of the ionized calcium proved to be the most preferable for observations. According to results by Shestakova (1990), the brightness of the K-line can amount to the spectral intensity of the daytime-sky continuous spectrum around the above line. Successful observations of this line have been carried out during the eclipse of February 26, 1998. Preliminary results of these observations are presented in the following sections.

2. Equipment and first observations

For the eclipse observations of the sky around the Sun in the K-line, we have built a rather simple device consisting of a Fabry-Perot etalon, an interference filter and a lens of 50 millimeter focal length. The angular diameter of the field of view is equal to about 20°. The interference filter has the 60 Å(FWHM) passband centred with respect to the K-line ($\lambda = 3933.7$ Å). The H-line being away by 35 Åfrom the K-line passes through the wing of the filter passband with the marked attenuation. Figure 1 shows a photographic image of the daytime sky made with our interferometric camera.

While the interplanetary dust sublimating, released atoms and ions keep the orbital velocities of dust particles in an early stage of occurrence. So, emission features under search should have Doppler shifts consistent with the Kepler velocity along the line of sight. For instance, at the heliocentric distance of 10 solar radii, the Kepler velocity is equal to about 130 $km\ s^{-1}$ and respective Doppler shift of the K-line is equal to ≈ 2 Å. It is very important that Doppler shifts are opposite at alternate sides of the Sun: the red shift will be observed to the west from the Sun and the blue shift - to the east.

We were going to perform the first observations during the eclipse of October 24, 1995 in Viet-Nam. Unfortunately, observations did not take place by reason of heavy clouds during the totality. The second attempt has been realized during the eclipse of March 9, 1997 in Eastern Siberia. Some expositions were made according to the calculations by Shestakova (1990): exposure times ranged from 5 to 60 seconds. The resulting photographs do not show any evidence of the K-line: the solar corona alone is seen on the quite clear negatives (Gulyaev and Shcheglov, 1998a). This means that theoretical values of the K-line intensity are evidently overestimated.

For the following solar eclipses, we have prepared an improved version of the camera with a new high-power lens ($F/1.5$ instead of $F/3.5$ as was formerly). In addition, we came to use a very high sensitive negative film, namely Kodak TMax 3200 film. As a result, we succeeded in enhancing the sensitivity of our device of some 40 fold. By this, the third attempt of observations has proved very successful.

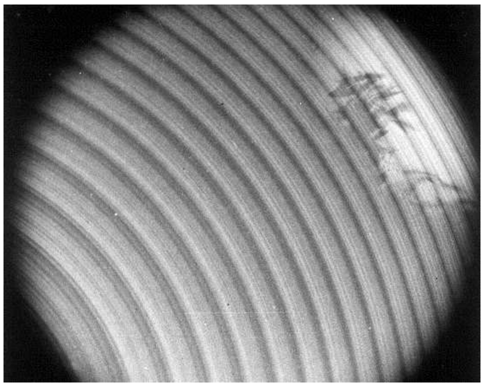

Figure 1. Interferogram of the daytime sky in the region of the Ca II H and K lines

3. Results of eclipse observations on February 26, 1998

One of the authors (R.G.) has observed the total solar eclipse of February 26, 1998 in Guadeloupe. Three expositions were made with exposure times of 3, 10, and 70 seconds. The latter photograph is the best. A suitable photographic print is presented in Figure 2. It is seen that the solar corona image is strongly overexposed. Below the corona, there is a patch of light formed in the instrument. All the field is covered with interference bands similar to those visible on the daytime-sky interferogram (Fig. 1). Such a picture is evidently due to the double scattering of the sunlight in the Earth's atmosphere: the sky was rather bright during the totality. On such a background, fine emission features are present as fragments of interference rings. These features are clearly seen on the original negative.

To extract the fine emission details, photographic grain has been smoothed by repeated superimposing the same original image with small successive shifting along the interference rings. Figure 3 shows a negative print of such a smoothed image. Analysis of the interference pattern has revealed the following.

Unshifted emission K-line is traced up to ≈ 10 solar radii from the Sun. The presence of this line is in accordance with reports by several authors concerning the observations of the H and K emission lines in the solar coronal spectrum (Dermendjiev, 1997). The origin of the unshifted K-line may be concerned with

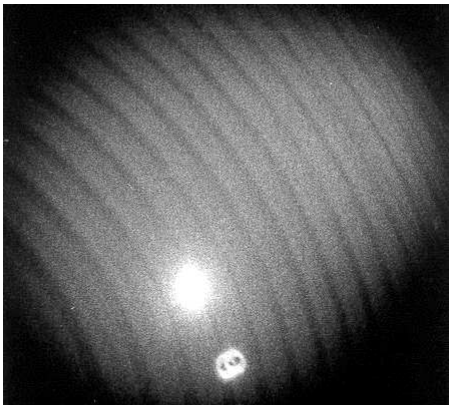

Figure 2. Interferogram of the sky around the Sun made during the total solar eclipse

the scattering of the chromospheric and/or prominence radiation in the Earth's atmosphere like to the aureole effect (Caccin et al., 1971).

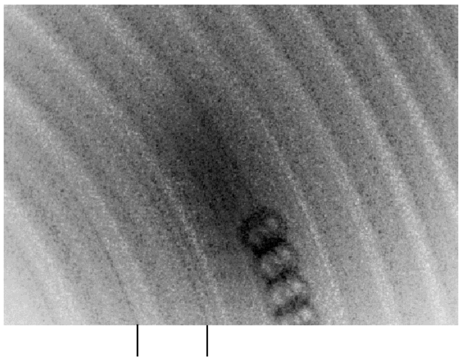

Figure 3. Negative print of a portion of the eclipse photograph (Fig. 2) being affected by smoothing. The lines below the image show two of Doppler-shifted K-emissions

The most important details on the interferogram are emission features (fragments of rings) consistent with the K-line shifted by the Doppler effect (Gulyaev and Shcheglov, 1998b). Such features are seen in the SW-quadrant of the circumsolar space in the heliocentic distance range of ≈ 5 to ≈ 20 solar radii. Two of those are marked in Figure 3. Figure 4 shows the situation of those features on the celestial sphere.

The Doppler shifts of above features in the SW-quadrant have the positive sign (red shift), which corresponds just to the direction of the orbital motion of planets in the Solar system. Such a circumstance is a strong argument for belonging the above spectral features just to emission associated with the sublimating dust. It will be noted that resulting Doppler velocities (from 200 to 300 $km\ s^{-1}$) are proved to be higher than Kepler velocities at heliocentric distances under consideration. The nature of such a discrepancy is yet under question. Analysis of the observational data is now in progress.

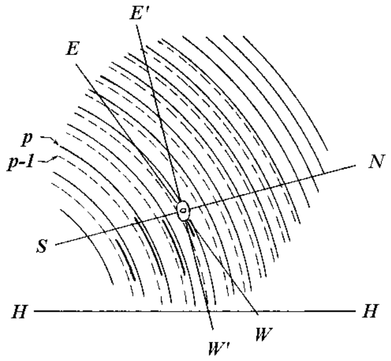

Figure 4. Situation of the most important details of the eclipse interferogram on the celestial sphere. An oval in the central region corresponds to the solar corona. Thin solid lines refer to the K-line in the scattered sky light; dashed lines refer to the H-line; p is an order of the interference. Short bold arcs represent the Doppler-shifted K-line. EW is the diurnal parallel; $E'W'$ is the ecliptic; NS is the axis of the Sun's rotation; HH is an almucantar (a line parallel to the horizon)

4. Conclusion

Such a photograph of the circumsolar space as presented in Figure 2 is obtained for the first time. We can state that the first successful experiment on detection of atomic emission in the far F-corona has been carried out. In so far as described emission features involve the Doppler-shifted K-line, it will be said about discovery of a new component of the solar corona in addition to well-known components such as K-, E-, F-, and T-corona. We propose to name this new component as S-corona (from 'sublimation').

During the forthcoming solar eclipses, we are planning to proceed the interferometric observations of the S-corona. Besides, it is very desirable to carry out fine spectrographic observations of the circumsolar space in addition to the interferometric study.

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