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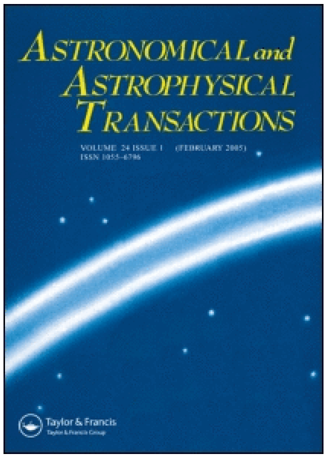

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RUSSIAN–BULGARIAN COLLABORATION ON STUDIES OF THE INTERPLANETARY MEDIUM

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On the initiative of Professor Shcheglov, the Sternberg Astronomical Institute and Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN) proceeded in 1995 to carry out joint investigations of the resonance emission of metal atoms released by the sublimation of solid material near the Sun. In 1998, Bulgarian colleagues joined our research. A search for resonance emissions in the circumsolar sky was made using the interferometric technique during total solar eclipses. At the eclipses of 1998 and 1999, the emission sought was finally detected, namely the resonance K line of Ca II ions with Doppler shift consistent with the Keplerian orbital motion of solid particles near the Sun. So, a new component of the solar corona radiation has been discovered. This contribution is dedicated to the memory of two outstanding scientists: Peter Shcheglov and Vladimir Dermendjiev.

Keywords: Solar corona, interplanetary medium, solar eclipses.

1 INTRODUCTION

The origin of our collaboration with Bulgarian colleagues is associated with the names of two outstanding scientists: Professor Peter Shcheglov and Professor Vladimir Dermendjiev. They both passed away in 2001. Our contribution is dedicated to the memory of these researchers.

In the 1940s, Allen (1946) and Van de Hulst (1947) have shown that the phenomenon of the Sun's F corona is due to diffraction of the sunlight on particles of 10–100 μm size located in the interplanetary space between the Sun and the Earth. The indicatrix of diffractional scattering on such particles involves a narrow beam strongly elongated in the direction of the incident light. As a result, only dust particles located far from the Sun, namely at heliocentric distances greater than about $20R_{Sun}$, can be involved in formation of the observed F corona. Hence, the very inner part of the interplanetary dust cloud (less than about $20R_{Sun}$ from the Sun) cannot be detected by conventional means, for example by photography of the white-light corona.

However, there are some specific possibilities for studying the innermost regions of the interplanetary dust cloud which do not depend on the mechanism of the sunlight scattering.

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First of all, there is the detection of thermal radiation of the heated dust in the infrared spectrum. Such observations have been successfully performed as early as the 1960s; thermal radiation of the dust was detected (Peterson, 1967; MacQuin, 1968).

Another way to study the inside regions of the interplanetary dust cloud appears to be very promising. This is detection of the resonance emission of metal atoms and low-charged ions expected to occur when the dust (and solid fragments) sublimates near the Sun. Only resonance lines should serve as the most reliable indicator of sublimation of the solid material close to the Sun. Dr L. Shestakova is probably the first scientist who has drawn attention to this fact. After graduation from the Moscow University, she works at the Fessenkov Astrophysical Institute at Alma-Ata.

According to Shestakova (1990), the H and K lines of ionized calcium proved to be the most preferable for pilot observations. Spectral lines associated with sublimation should have an appreciable Doppler shift (a few ångströms), if only because of orbital motion of sublimating particles. It is evident also that the most favourable conditions for detection of the above lines with ground-based observations arise during the total solar eclipses.

2 DISCOVERY OF THE RESONANCE EMISSION OF SUBLIMATION PRODUCTS NEAR THE SUN

Practical implementation of the task has been enthusiastic supported by Professor Shcheglov at the Sternberg Astronomical Institute of Moscow State University (Figure 1). Some time ago he was adviser to Shestakova during her post-graduate training. Shcheglov built a portable interferometric camera with a Fabry–Pérot etalon to search for Ca II resonance emissions under conditions of total solar eclipses. The camera allows a section of sky with an angular dimension of some 20° to be photographed in the region of the calcium K line. Figure 2 presents an interferogram of the daytime sky obtained with the above camera (Gulyaev and Shcheglov, 1999b).

Shcheglov proposed that I should take responsibility for the observational part of the project and, in particular, should make observations during the total solar eclipses. I agreed and in October 1995 went to Vietnam as a member of the eclipse expedition of the Russian Academy of Sciences. Unfortunately, observations of the eclipse on October 24, 1995, failed because of the weather.

The next eclipse on March 9, 1997, was observed in Siberia. This time the sky was clear and observations succeeded. However, in the photographs obtained with the interferometric camera, only the solar corona was seen but no sign of the sky emission. Evidently, the sensitivities of the equipment and the film were insufficient for our task.

Before the next eclipse on February 26, 1998, we succeeded in increasing these sensitivities by one and a half orders of magnitude. This has bornefruit. I made successful observations in Guadeloupe (Gulyaev and Shcheglov, 1999a). On the interferogram obtained, the total field of view is covered with interference bands similar to those visible on the interferogram of the daytime sky. Such a picture is evidently due to the scattering of the penumbral sunlight in the Earth’s atmosphere. On such a background, fine emission features are present as fragments of interference rings. The most important details are emission features consistent with the K line shifted by the Doppler effect. The values of the shift vary in the range from 2.2 to 3.7 Å, which corresponds to line-of-sight velocities from 170 to 280 $\mathrm{km\,s^{-1}}$. Figure 3 shows a portion of the contrasted negative print of the eclipse interferogram displaying clearly the emission details.

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FIGURE 1 Professor Peter Shcheglov (1932–2001).

The occurrence of large Doppler shifts is a strong argument for associating the above spectral features just with emission associated with the fast-moving sublimating particles. Such a phenomenon has been recorded for the first time. More details of the principal results of the 1998 eclipse observations have been published elsewhere (Gulyaev and Shcheglov, 1999a,b, 2001).

3 OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF 1999 IN BULGARIA

At the Solar Physics Euroconference (in Preveza, Greece, on October 7–11, 1997), one of the sessions was devoted to discussion of the programmes of observation of the fourthcoming total solar eclipse on August 11, 1999. The path of totality was to cross all Europe. Note that the preceding European total solar eclipse had been observed almost 40 years ago, on February 15, 1961. One of the participants of the meeting was Professor Vladimir Dermendjiev, the Head of the Solar Physics Group of the Institute of Astronomy of the Bulgarian Academy of Sciences. I presented a contribution on our task and plans for the 1999 eclipse. Professor Dermendjiev expressed his interest in our task and proposed collaboration. It was very important for all of us because the 1999 total eclipse passed through Bulgaria. So we accepted his proposal.

We made successful observations of the 1999 eclipse in Shabla, Bulgaria (Gulyaev et al., 1999). Photometric reduction of the negatives obtained was carried out at the Rozhen

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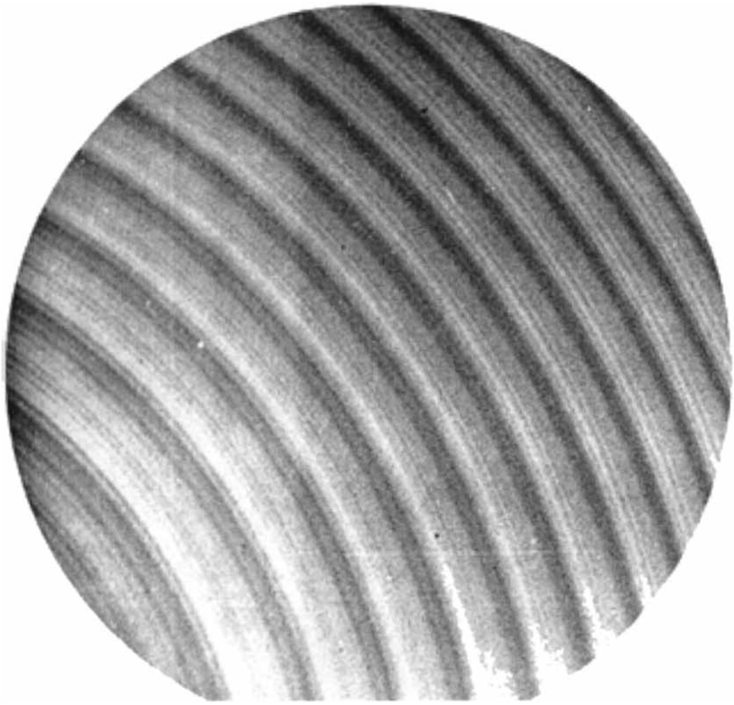

FIGURE 2 Interferogram of the daytime airglow in the region of the H and K lines of Ca II.

Observatory of the Bulgarian Academy of Sciences. Most of the photometric measurements

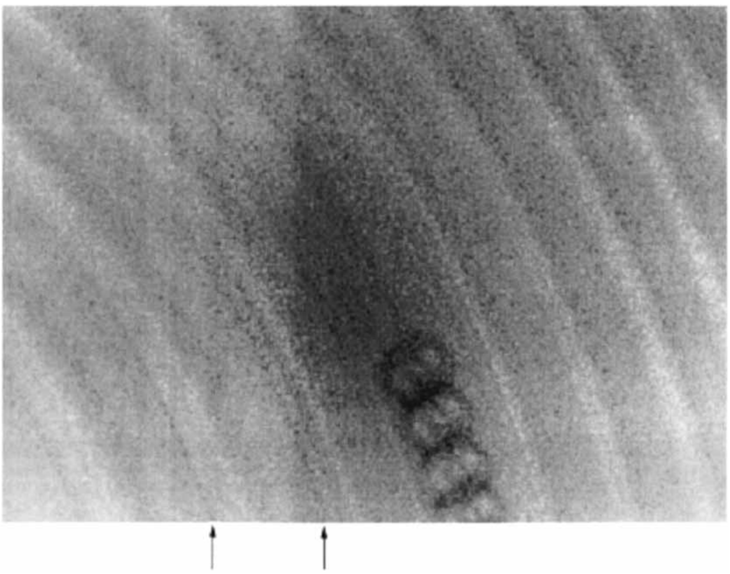

FIGURE 3 Contrasted negative print of a portion of the 1998 eclipse interferogram. The arrows below the image indicate two of Doppler-shifted K emission details.

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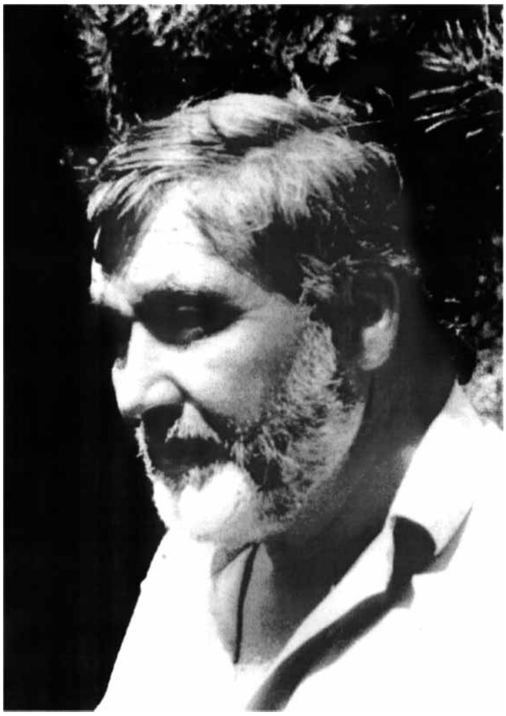

FIGURE 4 Professor Vladimir Dermendjiev (1943–2001).

with a Joice–Loeble microdensitometer were made by a worker at the Institute of Astronomy, Nikola Petrov, a post-graduate of Professor Dermendjiev. Observations of the 1999 eclipse confirmed our results obtained in 1998. This allowed us to formulate the final conclusions as follows.

(i) A new component of the solar corona radiation has been discovered, that is the component associated with sublimation of solid material close to the Sun.
(ii) Observations of the calcium-ion resonance emission with large Doppler shift imply that this emission is not distributed regularly around the Sun. Instead, it is located in separate, more or less compact regions. Perhaps, uniformly distributed dust is almost absent at heliocentric distances less than about $20R_{Sun}$. As an alternative, discrete sporadic formations may be present, which may be associated with meteoroid streams or Sun-grazing comets.

Recently Shestakova (1999) has proposed a theoretical model of motion of Ca II ions after their separation from the parent body on sublimation. According to the model, the most likely scenario appears to be as follows. Streams of stones and dust (meteoroids, comet remnants, etc.) moving on elongated orbits enter the near circumsolar space. In the sublimation region ($r < 9R_{Sun}$) a gaseous cloud is produced which detaches from the original orbit and moves rapidly from the Sun owing to the light pressure, leaving the sublimation region far behind. Consequences of the model are highly consistent with our observations.

Note that there are appreciable differences in the photographs of 1998 and 1999. In the interferogram of 1999, the whole sky within the field of view (at least up to $25R_{Sun}$ from the Sun) emits a very bright K line without a Doppler shift (Figure 5). Nothing of the

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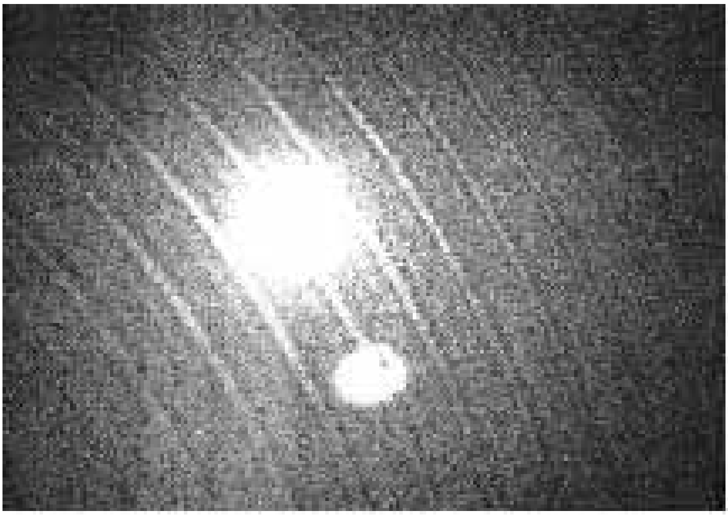

FIGURE 5 A portion of the 1999 eclipse interferogram. The strongly overexposed solar corona image is seen in the centre of the frame. Below the corona, there is a patch of light formed in the instrument.

kind was observed during the preceding eclipse in 1998. So, quite a new phenomenon is displayed, which is of great importance. The full emission of the sky in the calcium line must be evidently of atmospheric origin and of the twilight radiation type.

As long as 50 years ago, Vallance Jones (1956) made an assumption that the appearance of Ca II emission on the twilight sky is associated with meteor showers, primarily with the powerful stream of Perseids. Subsequent observations of many investigators have confirmed that suggestion. The eclipse of 1999 happened just at the period of peak activity of the Perseids. Because of these circumstances we could record the intense airglow in the Ca II line which was absent in February 1998. Detailed photometric analysis of this airglow has been presented in the paper by Gulyaev et al. (2002).

4 OUTLOOK FOR FURTHER COOPERATION

After the early death of Professor Dermendjiev, our cooperation with our Bulgarian colleagues was not terminated. Now the principal Bulgarian investigator is Nikola Petrov. For further progress of investigations carried out during recent years and to fulfil the ideas of the late Professor Shcheglov, we are going to direct our main attention to non-eclipse observations. First of all, we plan spectral observations of the twilight sky and zodiacal light with a high spectral resolution.

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