Observations of the total solar eclipse on 22 July 2009 in China

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(Conference poster. Accepted on 09.12.2009)

Abstract. The total solar eclipse on 22 July 2009 was observed by team of the Institute of Astronomy, Bulgarian Academy of Sciences, from the territory of China. The place for observations was situated at 300 km south-west of Shanghai, 900 m above the sea level, being close to the central line of totality. We used Fabry-Perot interferometer and CCD camera to obtain data for circumsolar dust sublimation. The interferograms of the sky during the eclipse were obtained in the line D of sodium. Using a B/W film and photo camera we also obtained images of the white-light solar corona for three polarized filter orientations and the degree of polarized corona was determined. The results are not consistent with other ones, obtained during the eclipses in the minimum of activity because of poor meteorological conditions and the observations through the dynamically changing cloudy layer.
Key words: Sun: eclipses, Sun: corona-polarization

Наблюдения на пълното слънчево затъмнение на 22 юли 2009 г. в Китай

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Пълното слънчево затъмнение на 22 юли 2009 г. бе наблюдавано от екип на Инстотута по астрономия при Българската академия на науките от територията на Китай. Мястото на наблюдението бе разположено на 300 км югозападно от Шанхай, с надморска височина 900 м и близо до централната линия на пътя на лунната сянка. Използван бе Фабри-Перо интерференчен филтър и CCD камера за регистрация на сублимация на прахови частици в околослънчевото пространство. Получени бяха интерферограми на небето по време на затъмнението в линията D на натрия. С помощта на фотокамера и черно-бял филм бяха получени изображения в бяла светлина на слънчевата корона при три ориентации на поляризационния филтър и бе определена степента на поляризация на короната. Резултатите не са съвместими с онези, получени по време на пълни слънчеви затъмнения в минимума на активност, поради лошите метеорологични условия и наблюденията през динамично променящ се облачен слой.

1 Introduction

The path of totality of 22 July 2009 solar eclipse crossed India, Bangladesh, Nepal, Bhutan, Burma, China, and part of the Pacific (Fig. 1).

The first observational task was the registration of the white-light polarized corona for study of its global electron density structure and brightness distribution. The eclipse gave the unique opportunity to measure the polarization of the solar corona larger than 1.3 solar radii ($R_\odot$) up to 5 $R_\odot$, i.e. in the middle and outer corona. When one uses different exposures, then it is possible to cover large scale of intensities from the most intensive inner corona (short exposure times) up to outer coronal layers where the intensity is rather faint and one has to use long exposure time.

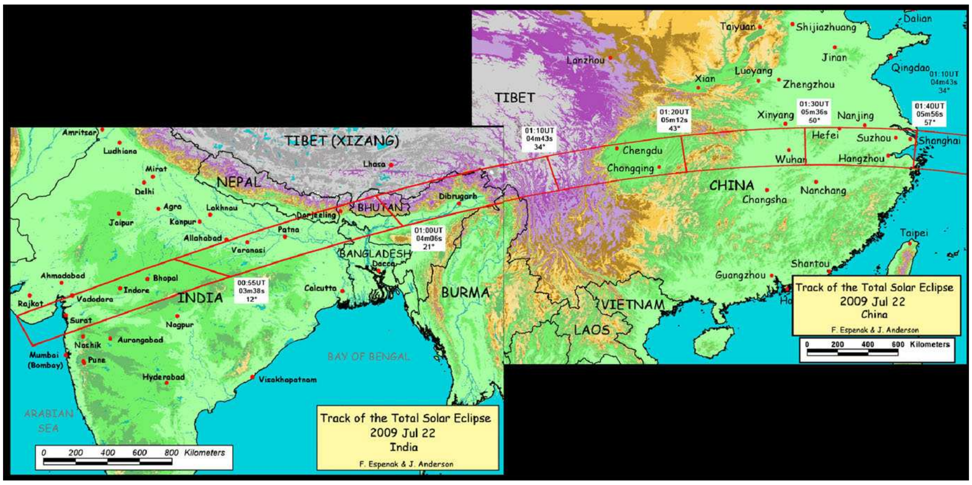

Fig. 1. Path of the lunar shadow through Asia

The second task in the research programme was observations and study of the sublimation processes of interplanetary dust close to the Sun. The circumsolar space is filled with cosmic dust. The well-known optical manifestations of the interplanetary dust material are zodiacal light and the F-corona. Because of the very elongated shape of the diffractional scattering indicatrix, only those dust particles are responsible for the F-corona phenomenon which is located at heliocentric distances more than about 20 solar radii. Observations of the innermost part of the circumsolar dust medium are impossible when using conventional ways. As an indicator of dust regions, we used the resonance emission of D Na I and low-charge ions, expected to occur by the dust sublimation near the Sun. It was used a Fabry-Perot etalon with interference filter centered in D Na ($\lambda = 5890.0 - 5895.9$ Å) lines.

Our team was located in Tianghuangping, about 300 km south-west of Shanghai (Fig. 2). The duration of the total phase of the eclipse at this place was 5 min and 41 s. The observations were performed under poor weather conditions with some low and fast moving clouds.

2 Observations of white-light corona polarization

Tele-objective 5.6/500, linear polarization filter and photographic camera Zenit with B/W negative film Ilford 100 ASA were used to receive images of the polarization solar corona. The images were taken with exposure 1/250, 1/125, 1/60, 1/30, 1/15 and 1 sec.

The polarization filter was placed in front of the objective lens and three positions of the filter at interval of 60 degrees were fixed according to every exposure time. Unfortunately, the bad weather conditions did not allow to carry out all planed exposures perfectly. It was impossible to get calibrated images by the solar disk with neutral density filter. In this case, for us was possible to calculate only relative degree of white-light solar corona polarization. The white-light corona images for three angle positions of polarizing filter, taken with tele-objective and 1 s exposure are shown in the Fig. 3.

Fig. 2. View from Tianghuangping, China, in the day of the eclipse on 22 July 2009

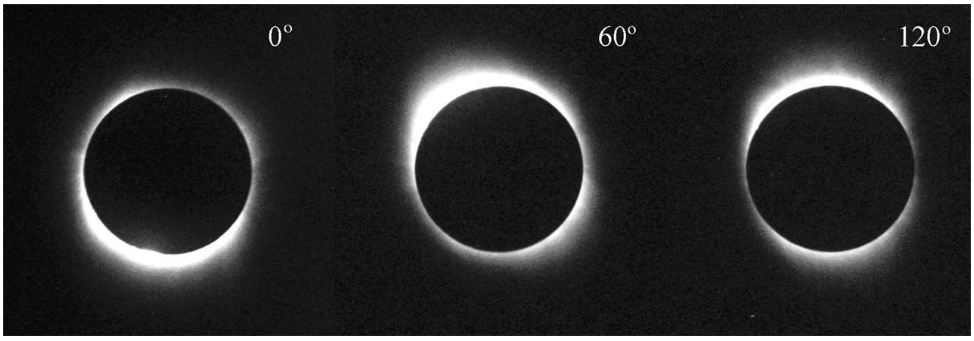

Fig. 3. Images of the white-light solar corona, taken on 22 July 2009 for three positions of polarizing filter

We used the method based on photographing of the solar corona by three positions (0°, 60° and 120°) of the linear polarization filter in order to determine the polarization of the solar corona. If $I_0 = I_A$, $I_{60} = I_B$ and $I_{120} = I_C$ are the intensities of radiation, corresponding to the three positions of the polaroid (Billings [1966]), then:

$$I_p = \frac{4}{3}[(I_A + I_B + I_C)^2 - 3(I_A I_B + I_A I_C + I_B I_C)]^{1/2} \tag{1}$$

where I_P is the degree of polarization of the corona in that point.

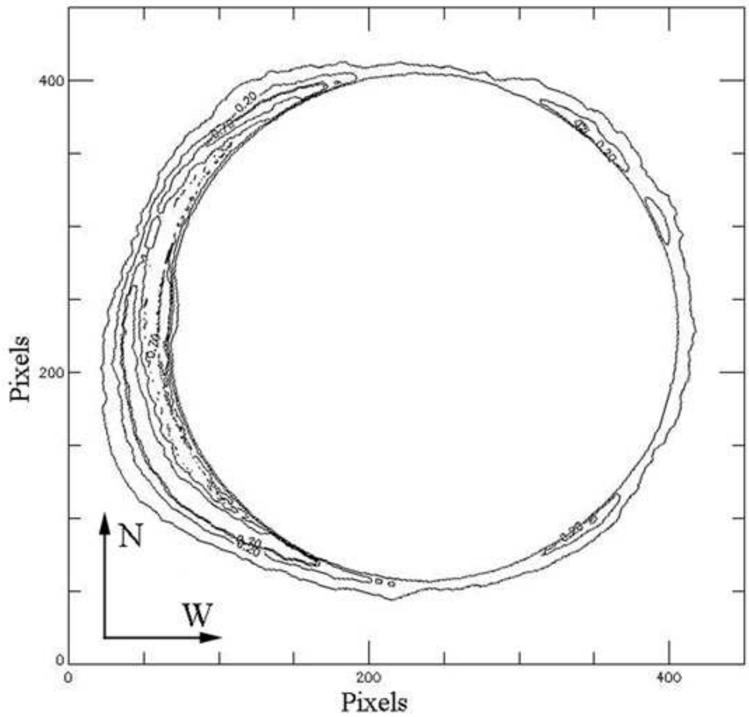

Fig. 4. Isophote map of the polarized corona with the data for the degree of polarization

The polarized corona is presented though a isophote map with the data for the degree of polarization in Fig. 4. The polarization reaches to 70 %. The values are not comparative with the results for the solar cycle minimum from other authors or results from observations during 2006 total solar eclipse (Kokotanekova et al. [2008]). The isophotes do not have a circular shape, typical for the period of minimum of the solar cycle. The variety of structural features are not distinctly seen in the distribution of the polarization. The high degree of of the polarization is connected with low and fast moving clouds during the observations.

Interferometric observations of the eclipsed sky around the Sun are very suitable for such a study. The first successful observations have been carried out during the eclipse on February 26, 1998 in Guadeloupe (Gulyaev and Shcheglov [1999]). Fine emission features present on the obtained image that is consistent with the K-line, shifted by Doppler effect. Resulting line-of-sight velocities vary from 200 to 300 $\mathrm{km\,s^{-1}}$in the heliocentric distance range of 5 to 20 solar radii. The presence of large Doppler shifts is a strong argument for belonging of the above spectral features just to emission associated with the sublimating dust. Further, it will be mentioned about discovery of a new component of the solar corona radiation in addition to well-known components such as K-, E-, F-, and T-coronas.

3 Interferometric observations of the solar corona

During the expedition in China 2009 the sodium D-line was selected for observations with a Fabry-Perot interferometric camera. The equipment for this experiment included a CCD SBIG STL-11000M, objective 50 mm f 1/2.0, D Na filter with passband FWHM = 20 Å.

Figure 5 (right) presents the interferogram of the sky around the Sun made during the eclipse on 22 July 2009. The exposure time was 120 seconds. Strongly overexposed image of the solar corona is seen not far from the center of the frame. It is seen that the emission of D Na is presented at the full area of the field of view. Fig. 5 (left) presents an image, obtained during twilight at the National astronomical observatory Rozhen, Bulgaria on 16 July 2009, taken with the same equipment.

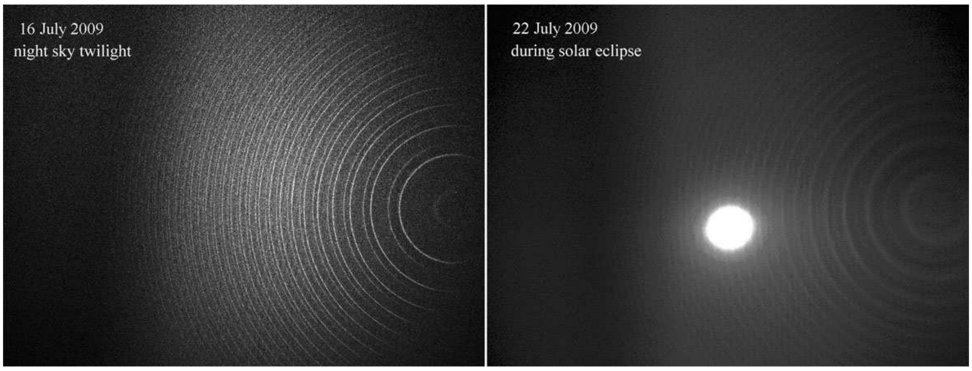

Fig. 5. Interferograms in the region of the sodium D Na of the twilight sky (left) and the sky around the Sun during the 2009 eclipse (right)

We made the photometric analysis of the above interferogram. We were not intended to get a rough estimate (say, to within the order of magnitude) of the surface brightness of sodium emission regions. For the first time, we used a CCD detector that is enough sensitive but the sky obscured by clouds did not allow obtaining of better quality images.

4 Conclusion

Unfortunately, the absolute photometric standards were absent on the images of 22 July 2009. In fact, it was impossible to see the planet Mercury, one of expect sky objects (Fig. 6), on the sky during the totality.

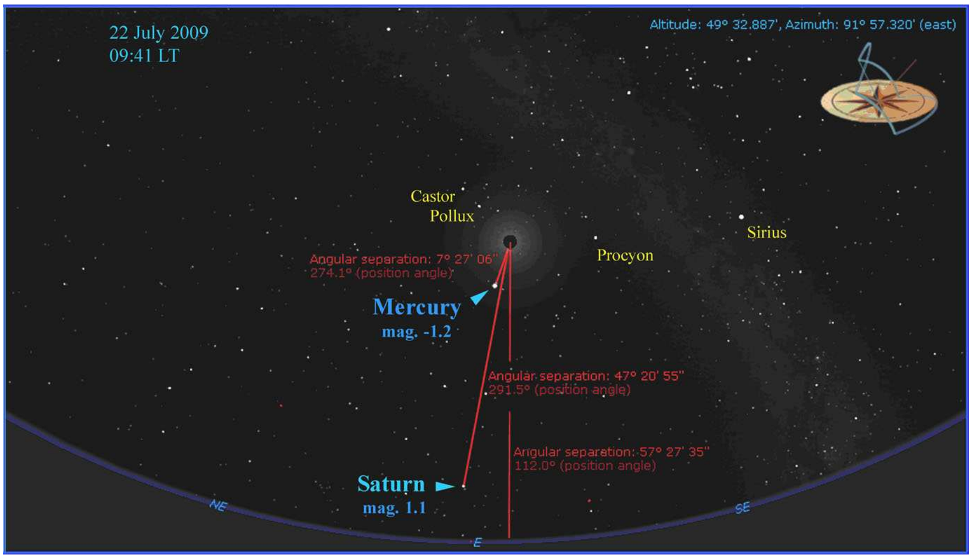

Fig. 6. Night sky objects position during totality on 22 July 2009 for Tianghuangping, China

We have investigated the behavior of the polarization in dependence on the heliocentric distance. The radial distribution of the polarization degree in different directions and coronal structures (Fig. 4) is not consistent with the results of previous our observations (Kokotanekova et al. [2008]). Hence, we can conclude that the polarization is different both as a degree and as a radial distribution. In the polar areas, the degree of the polarization reaches just about 20 % on distance around 1.1 - 1.4 $R_\odot$. In the equatorial plane, the maximum polarization is 70 % at 1.1 $R_\odot$. Maximal value of the degree of polarization reaches in the equatorial place of the corona just on the solar limb. We ascribe these results to the fast moving clouds and the results are not in good agreement with the data, obtained during other eclipses (Badalyan et al. [1993], [1997]).

It is known that the strongest emissions of the twilight belong to molecular ions N_2^+, to oxygen atoms, and particularly, to the sodium atoms (e.g., Chamberlain [1961]). The Na I resonance lines D_1 and D_2 are of specific interest to us in view of their similarity to the H and K lines of Ca II. D-lines of sodium exist permanently in the twilight spectrum though their brightness is subject to latitudinal and seasonal variations. Chamberlain [1961] gives the following values of the summary brightness of those lines: 1 kR in summer and 5 kR in winter.

The study of dynamic and evolution of the solid material penetrating into the near circumsolar space is significant in terms of cosmogony. This is essential, in particular, for understanding processes occurring in young protoplanetary systems, discovered around some stars, e.g., β Pictoris (Gulyaev et al. [2000]). Our technique for investigation of evolution of the sublimation products by resonance emissions of atoms and low-charged ions appears to be very promising. Extension of observations to resonance lines of other elements along with sodium and calcium is extremely important.

These observations were a big challenge for the members of the expedition. In spite of the data quality, limited by weather conditions during the totality, the observations were very useful and instructive for the effectiveness of the observational experiments in future expeditions. This practical effort is the base for more effective methodological and technical preparation of the future observational tasks.

Acknowledgments

The scientific expedition was financially supported by CNSys Computers & Networking, Sofia, and particularly supported by National Scientific Foundation under Grants F1510 and NIK-05.

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