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WIDE-FIELD MEASUREMENTS OF THE VELOCITY FIELD OF THE CIRCUMSOLAR DUSTY PLASMA DURING THE TOTAL SOLAR ECLIPSE ON JULY 22, 2009

L. I. SHESTAKOVA[1], F. K. RSPAEV[1], A. CHALABAEV[2], D. BRAM[3],
A. I. DUBOVITSKIJ[1], T. BONEV[4], V. GOLEV[5], and E. LE COARER[2]

[1]*Fesenkov Astrophysical Institute, Kamenskoe Plato, Almaty, 480068, Kazakhstan*

[2]*LAOG, CNRS and Université Joseph Fourier, BP 53X, F-38041, Grenoble, CEDEX 9, France*

[3]*1000 Route de Corps F-38410 Saint-Martin d'Uriage, France*

[4]*Institute of Astronomy, Bulgarian Academy of Sciences, BG-1784 Sofia, Bulgaria*

[5]*Department of Astronomy, Faculty of Physics, University of Sofia, 5 James Bourchier Str., BG-1164 Sofia, Bulgaria*

E–mail: valgol@phys.uni-sofia.bg

Abstract. We describe preliminary results of the wide-field (up to $20 \div 30\ R_\odot$ heliocentric distance) spectro-imaging of the dusty plasma grains in the solar F-corona carried out during the total solar eclipse (TSE2009) of July 22, 2009 at Yuexi, China. The aim of the measurements was to measure the radial velocity field of the circumsolar dusty plasma using the Ca II K line $\lambda\, 383.4$ nm in absorption. The instrument used was a spectro-imaging camera with a Fabry-Perot etalon. The resulting radial velocity in the selected strips is ≈ -100 km s^{-1}. The definite conclusions on the velocity field will be drawn when the final analysis of the data will be completed.

1. INTRODUCTION

Our understanding of the dusty plasma properties in the solar vicinity, its spatial distribution, and its origin was considerably evolving during last 25 years. The initially simple picture of the zodiacal light dust grains of asterodial origin falling onto the Sun due to the Poynting-Robertson effect had to be changed to take into account other phenomena, in particular the dust contribution from comets. The measurements of the radial velocities of the dust grains in the F-corona, thought to be impossible, played a decisive role in this new insight in the circumsolar dust nature (Shcheglov et al., 1987). It was shown that the dust exists well above the ecliptical disk and that there is a population of the dust grains with sizes of about 0.5 mcm, the half of that of the zodiacal light grains (Shestakova 1987). The data indicated also a dust free zone at heliocentric distances $r < 4\ R_\odot$. The intensive studies of the comet P/Halley confirmed these conclusions (see Mann 2000 and Shestakova 2003 for reviews). For TSE2009 our collaboration prepared a spectro-imaging instrument with

Fabry-Perot (FP) etalon to measure the radial velocity field of the circumsolar dusty plasma grains. The outstanding duration of the eclipse gave the possibility to carry out observations of exceptional accuracy. The spectral range of the instrument was selected to be around Ca II K line at λ 383.4 nm because the absorption due to the evaporated dust was expected to have a strong contrast.

2. OBSERVATIONS AND INSTRUMENTATION

We observed at the city of Yuexi in Anhui state of the China (30°51.0′ N, 116°22.0′ E, 1000 m above the sea level) in the middle of the TSE band. The duration of the totality was 5 min 37 s. The weather was partly cloudy but the clouds were thin enough, so the radial velocity measurements which are sensitive to the position (not to the intensity) of the interference rings were successful. We used a set-up with the FP and a narrow-band filter immediately before the objective and a camera. To obtain a better spatial sampling of the circumsolar region up to 30 $R_\odot$, the FP and the filter were inclined with the respect to the optical axis by $\approx 10°$. The filter used has a FWHM of 3 nm and was centered at λ = 395.0 nm. We used an objective Angenieux with f = 50 mm opened at $f/0.95$, and a SBIG CCD detector ST-3200 ME (1092 × 736 px 2 × 2 binned). Three frames of different exposures were secured during the eclipse. A number of calibration frames (spectral Hg I lamp, tungsten lamp, daylight sky) were exposed immediately before and after the totality at the same position of the instrument.

3. PRELIMINARY DATA REDUCTION

The frames were corrected for the hot, cold, and dead pixels and 2 × 2 binned. The determination of wavelengths from FP interferograms is based on the equation

$$m\lambda = 2d\cos\theta + \varepsilon \qquad (1)$$

where m is the order of interference, λ is the wavelength, d is the thickness of the FP etalon (the air gap between the reflecting plates), θ is the angle of incidence, and ε is the phase change at reflection. A priori only the wavelength λ = 393.366 nm is known, and we need to extract θ and d. Because the FP etalon was inclined against the optical axis, the centre of the fringe system lies outside of the CCD frame and to obtain it we fitted five of the absorption fringes in the sky interferogram with circles.

Table 1: Parameters of the FP fringe system.

Fringe number	Radius, px, px	θ, degrees	Order
1	498.467	7.72125	327.534
2	580.253	8.96894	326.489
3	651.003	10.0414	325.467
4	710.453	10.9372	324.527
5	770.639	11.8386	323.500

In Table 1 the radii of the 5 fitted circles are given, together with their angles of incidence θ, which have been used to derive the thickness of the etalon. For this purpose we used all possible pairs of fringes with orders (m, n). The actual values of orders are not known at this stage, but this does not matter, as we are interested only on the differences between all possible pairs of orders (10 different pairs are possible in the case of 5 fringes). This is immediately seen from the following relation for the thickness of the FP, which was obtained from the pairwise (for orders m and n) application (subtraction) of Eq. 1 as $d = 0.5\lambda(m - n)/(\cos\theta_m - \cos\theta_n)$

The mean thickness of the FP etalon is found to be $d = 65.010 \pm 0.005$ mcm. Having d, the measured angles and known wavelength of rest, we calculated the actual orders of interference, listed in the last column of Table 1 (the orders are half of integers because we are using absorptions in this analysis, i.e. we consider a destructive interference). These orders were used to create the λ-scale around each particular absorption minimum.

4. RESULTS AND CONCLUSIONS

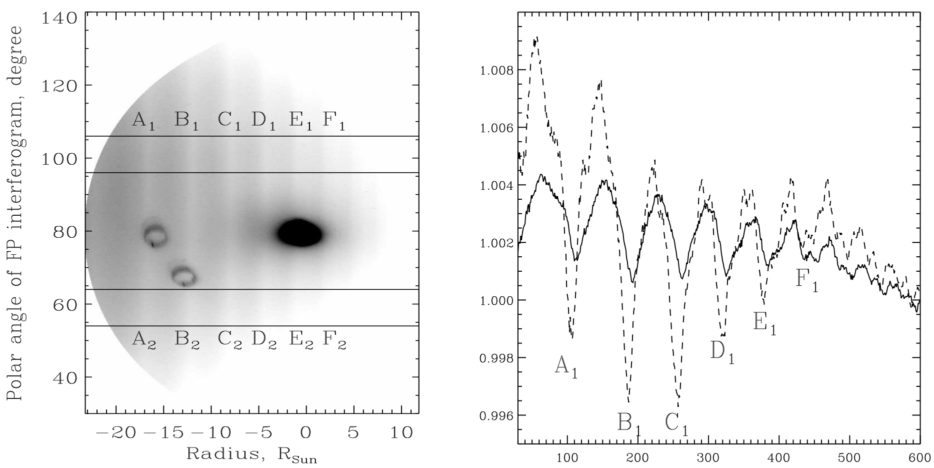

Figure 1: The eclipse interferogram transformed to polar coordinates centered at the FP fringe system (*left*). The intensity profiles (normalized) along the upper strip, averaged along the polar angle (pixels) (*right*). The eclipse profile (solid line) and the daylight sky profile (dashed line) are shown. The minima correspond to the Ca II K line absorption at different heliocentric distances.

In Fig. 1 (to the left) the eclipse interferogram transformed to polar coordinates and centered at the fringe system of the FP is shown. The polar angle is counted counterclockwise from the positive part of the X axis. The latter is renormalized to give heliocentric distances. The strips indicate the regions used for the wavelength and radial velocity estimates. The letters A, B,C, D and F indicate different FP orders. To the right in Fig. 1 the intensity profiles along the upper strip averaged along the polar angle are shown. The solid line represents the eclipse profile, dashed line the daylight sky. The minima correspond to the Ca II K line absorption at different heliocentric distances. In Fig. 2 a comparison of the F-corona (solid line) and skylight (dashed line) Ca II K line absorption profiles is shown. The wavelength shift between the profile of the F-corona and that of the skylight is clearly seen and corresponds to the line-of-sight velocity of about -100 km s^{-1}. The preliminary reduction of the FP data reported here shows that the radial velocity field of the dusty plasma grains in the solar vicinity up to $20 \div 30$ $R_\odot$ can be extracted.

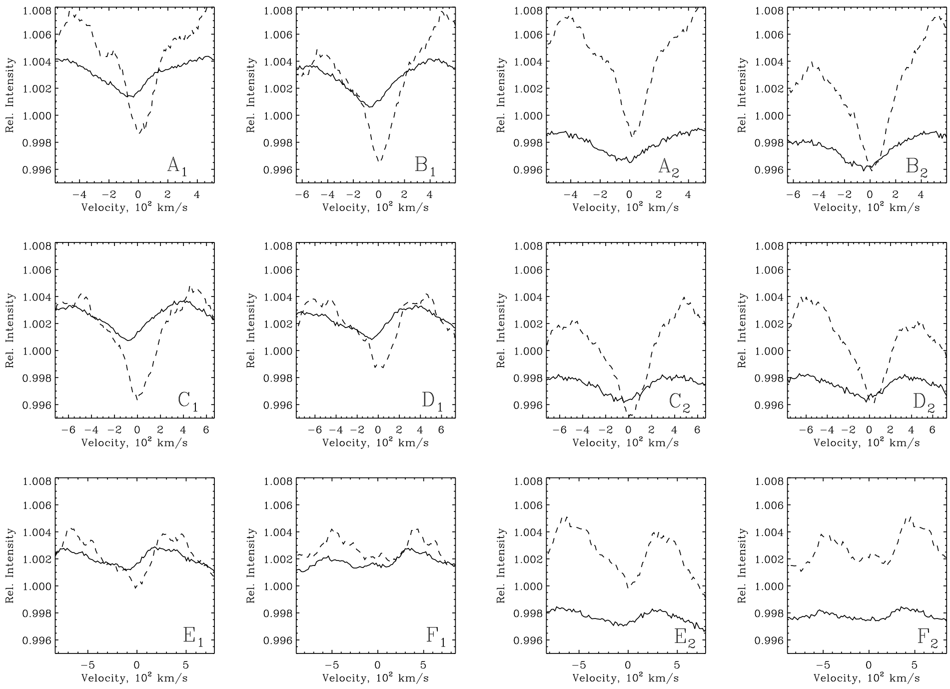

Figure 2: The velocity profiles along the upper (*left*) and lower (*right*) strips.

Acknowledgments

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