VERY HIGH RESOLUTION ANALYSIS OF THE DYNAMICS OF A CORONAL PLASMOID

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Abstract. We present the results of the analysis of a movie taken over a small field of
view in the intermediate corona at a spatial resolution of 0.5", a temporal resolution
of 1 s and a spectral passband of 7 nm. These CCD observations were made at the
prime focus of the 3.6 m aperture CFHT telescope during the 1991 total solar eclipse.

Key words: Dynamics of the Corona – Plasmoid – Coronal Heating

1. Introduction

In 1991, the combination of a solar eclipse and of the availability of a big telescope was
used by the CFHT Team, (Koutchmy et al., 1993b) in order to study the dynamics of
the corona and to analyse small scale coronal phenomena. During 4 minutes the 3.6 m
aperture Canada-France-Hawai telescope has permitted to record 3 movies with both
high speed photographic and video-CCD cameras. Here we present the first results of
the smallest one which has revealed the dynamics of a small scale coronal event. The
detector is a 756×581 px² CCD-chip used with a red interference filter centered at
637 nm (with 7 nm of FWHM, it only accepts white light and FeX line emission) put
at the prime focus of the telescope, we limit ourselves to a field of view of 135×105
arcsec². The video rate of 30 frames/s has permitted to record a sequence of 6,000
frames which gives us the best time resolution and spatial resolution never reached
on the corona during an eclipse, see Koutchmy et al. (1993a).

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Figure 1. Mosaic of frames taken every 10 s from the processed movie. The coordinates of each frame correspond to a Lagrangian system of coordinates assuming a constant velocity for the main plasmon. Axes are graduated in arcsec and count of seconds of time started at the beginning of the analyzed sequence (typically 30 s after the second contact of the eclipse).
2. Method of Analysis

First of all we would like to note an important point about the study of the plasmoid: it is neither the result of the atmosphere distortion nor of the instrument; the FWHM of the smearing function of the instrument was often smaller than 0.6 arcsec (result provided by the analysis of small sectors of the limb of the Moon) whereas the plasmoid had a cross-section of about 2 arcsec (see Vial et al., 1992). The complete sequence, recorded on VCR, has been digitized on the NSO/SPO's video and computers facilities and we have used the soft library of L. J. November (FITS-LIB) to process and analyze the data. The first process applied put the signal of the plasmoid well above the noise thanks to the use of a temporal average of the frames. On raw data, the ratio signal over background for such an event was typically 3%. Several other processes were needed to emphasis the signal of the plasmoid: i- the substraction of the background intensity gradient of the corona using a stationnary model deduced from the best polynomial fitting of the data; ii- the damping of periodic interference effects running across the frame due to reflections along the cables and the video recorder which was put at a distance of more than 100 meters during the observation. Last but not least stage of this processing has been the use of the so-called "Mad Max" operator (Koutchmy et al., 1988) which permits to enhance the boundaries of small structures in a picture and to avoid overlapping.

3. Description of the Dynamical Behavior of the Plasmoid

The "Plasmoid" revealed during this eclipse is a high density bubble located at 1.2 \( R_\odot \) showing a large proper motion. It was mentioned that his size is typically 2 arcsec (approx. 1,400 km) but it is an averaged size, because along the sequence there are deep modifications of its shape and of its dimensions (Fig. 1, see Plate II); from the beginning to approximately the middle of the sequence it has a compact structure of 2-3 arcsec. From the middle to the end of the sequence, we note the most important features: the breaking of the plasmoid in several parts with the apparition of links between them like "arms". Although they are not obvious on the mosaic, these separations appear when the main bubble is crossing the structures of the background corona; this becomes obvious when one watches the movie. This event brings two comments: first, it is impossible to determine if the plasmoid is really going through the structures (which are seen in the coronal background preferentially in a radial direction) or if they are just passing each other. The second comment concerns the reciprocity of the interactions: it is evident that a transfert of matter (increase of their intensity) is taking place between the plasmoid and the background structures.

The motion of the plasmoid is approximately monotonous at the beginning, before the previously mentioned interactions. Its speed is very constant with a modulus of 100 km/s; the direction is not the radial one but it is the direction of the highest
intensity gradient in the background corona. During the second part of the sequence, the direction of motion is almost the same for the main bubble (the central one) but its modulus has falled down to 50 km/s. The motion of created smaller plasmoids is quite the same (very low relative speed between them) except for the first one created at the very beginning of the sequence (see arrow on Fig. 1), whose motion has the same characteristics than those of the main bubble for the whole movie.

Regarding the lifetime of the plasmoid, it is significantly greater than 250 seconds (which correspond to the period of the visibility of the plasmoid in our data) but it is clear that the lifetime of this event is not much longer, because the continuous interactions with the coronal background features imply a rather fast “dislocation”. The origin of the plasmoid is unknown but if we follow back the direction given by the trajectory to the Sun, we find coronal interacting loops which could have ejected our bubble. With a velocity of 100 km/s it only needs a few hundred seconds to come in our field of view.

The density of the bubble has been deduced from the comparison of both the intensities of the plasmoid and the one of the background corona. Assuming that the average density of the corona at a distance of 1.2 R⊙ is $2.1 \times 10^8$ cm$^{-3}$ (see Koutchmy, 1992), then, we obtain a density for the plasmoid of $2.5 \times 10^9$ cm$^{-3}$ which is surprisingly close to the result found by Stellmacher et al. (1986) during the eclipse of 1981: $2 \times 10^9$ cm$^{-3}$ for very small weak almost fully ionized pieces of prominences.

4. Conclusion

The observation of a plasmoid is not the first reported one during an eclipse but it is certainly the best one for both spatial and temporal resolution. In addition, it is the first time that such observations are made with a narrow “coronal” filter; it is also the first time that we can point out the details of the dynamics of such a little event in the corona; it is impossible to say if this plasmoid is a particular event or a more general phenomenon; but, other eclipse observations show that parameters like the density and the location are identical. Unfortunately, we will have to wait for a long time before having the possibility of repeating this observation, nevertheless the potential of this sequence is most significant and more analysis is needed (temporal Fourier analysis, study of possible proper oscillation modes, local velocity map...), to better evaluate the plasmoid activity in the corona.

References


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