

MICA OBSERVATIONS OF CORONAL TRANSIENTS

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ABSTRACT

Dynamical processes are well known to occur in the inner solar atmosphere, many of them giving origin to spectacular eruptions known as coronal mass ejections (CMEs). The projected speed of propagation of these events ranges from less than 100 km/sec to greater than 1200 km/sec. In order to study the initial evolution of the faster processes it is necessary to image the inner corona at a very high cadence. Although ground-based observations of the solar corona are strongly affected by sky conditions they allow imaging at a high temporal resolution as compared to coronagraphic observations from space.

In the recently inaugurated German-Argentinean Solar-Observatory at El Leoncito, San Juan, Argentina, a mirror coronagraph (MICA) daily images the inner solar corona with high temporal and spatial resolution in two spectral ranges: the well known green (1.8×10^6 K) and red (1.0×10^6 K) coronal lines at 5303 Å and 6374 Å respectively. It is essentially similar in design to LASCO-C1 on board SOHO, its field-of-view ranging from 1.05 to 2.0 solar radii. Thus it is ideally suited to observe the hot material and reveal the fast processes that occur in the coronal plasma. In this work we will present observations of a few such events. This study would allow us to have a better understanding of the conditions that trigger the coronal mass ejections and their propagation in the inner solar corona.

Key words: green line; coronagraph.

1. INTRODUCTION

Dynamical features in the green line corona have been recorded with unprecedented sensitivity by the internally occulted C1 instrument of the Large-Angle Spectroscopic Coronagraph (LASCO) onboard the Solar and Heliospheric Observatory (SOHO) (Brueckner et al. 1995). Some structural changes

in the green line corona were seen to be fairly gradual leading to very different large-scale patterns (Schwenn et al. 1997). However in the short-scale, the underlying active regions were observed to produce sudden changes resulting in a complete rearrangement of the magnetic field pattern, many times giving origin to spectacular eruptions of matter from the Sun. Sometimes these changes could be well recorded with the available time resolution of the instrument. But other times, these changes were (are) so fast that escape the field of view during the observation time gaps. It is then of crucial importance that observation of such events at higher cadence be recorded in order to reveal more precisely the onset and time evolution of such transients.

An advantage of the ground-based telescopes over the space-based ones is that they can achieve a higher time resolution because they are not constrained by telemetry. In view of this fact, the MICA instrument daily records the inner corona in the emission of the Fe XIV green line at a relative high cadence as compared to LASCO-C1 onboard SOHO. This paper reports the morphology and evolution of two coronal transients as observed by MICA in the green line.

2. OBSERVATIONS

The Mirror Coronagraph for Argentina (MICA) (Stenborg et al. 1999) is daily observing the lower solar corona since its installation in the recently inaugurated German-Argentinean Solar-Observatory at El Leoncito (31.8 S, 69.3 W), San Juan, Argentina in August 1997. MICA is essentially similar in design to the LASCO-C1 instrument on board SOHO. Its field-of-view ranges from 1.05 to 2.0 solar radii covered by a 1280×1024 pixels Peltier-cooled CCD camera. The pixel width is equivalent to 3.7 arc sec, resulting in a spatial resolution of about 8 arc sec. A set of narrow-band interference filters is used to select the spectral range corresponding to the well known green (1.8×10^6 K) and red (1.0×10^6 K) emission-line corona at 5303 Å and 6374 Å respectively.

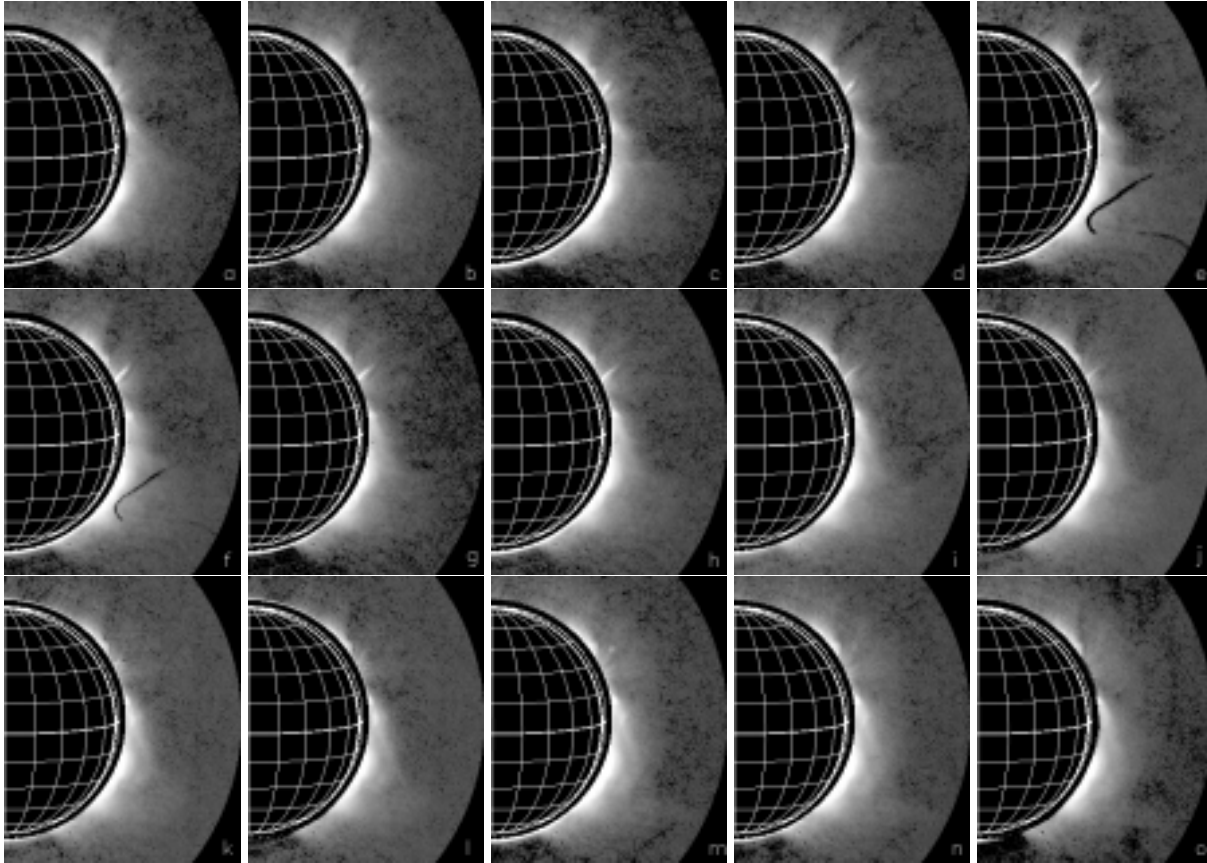


Figure 1. Time-lapse sequence of the event on September 30, 1998 as observed by MICA in green line at \sim : a) 13:16 UT, b) 13:17 UT, c) 13:20, d) 13:22 UT, e) 13:23 UT, f) 13:25 UT, g) 13:28 UT, h) 13:29 UT, i) 13:31 UT, j) 13:32 UT, k) 13:33 UT, l) 13:37 UT, m) 13:40 UT, n) 13:41 UT, o) 13:44 UT, each frame corresponding to the average of two green line processed images in order to improve the signal to noise ratio. All images used are bias-, flat- and continuum-corrected. The nearby continua used, were taken no more than 3 minutes apart from the corresponding on-line images in order to mainly reduce the sky variability (see text).

The unprocessed direct images from MICA show practically no coronal signal. They are affected by the strong radial gradient of the instrumental stray-light and the scattered light in the terrestrial atmosphere. Furthermore, the images taken at line center (on-line images) have also an additional contribution from the continuum (or 'white') corona which is due to Thomson scattering of the photospheric light by electrons in the corona. In order to remove the aforementioned contributions from the on-line images and reveal the coronal structures it is then necessary to subtract a nearby continuum image (off-line images) from the on-line ones, taken at a wavelength sufficiently far from line center, i.e., at 5260 \AA for the green line, to avoid contamination by emission in the line itself. Both on- and off-line images are bias-corrected and flat-fielded before subtraction. Since the flat-fields are also used for calibration purposes, after 14 images flat-fields for both images are taken. In order to reduce the effects of the sky variability (and also the effects of solar rotation on the structures along the line of sight) is necessary to obtain the reference continuum images very close in time to the respective on-line images. For the observations

presented here, the time difference between the on- and off-line images used is not longer than 3 minutes. A detailed description of the calibration procedure will be presented in a dedicated paper.

Time-lapse movies of the treated images are regularly examined to search for transient activity in the green line. We present here observations of two coronal transients in detail recorded by MICA. They occurred on September 30, 1998, and April 20, 1999. Unfortunately no LASCO images were taken during the occurrence of the first event due to loss of contact with SOHO spacecraft at that time.

2.1. September 30, 1998, Event

MICA observations on September 30, 1998, started at 11:53 UT. The initiation of the event was recorded at 13:15 UT (as observed by MICA). The main phases of the event are shown in Figure 1. Inspection of the frames b to h in Figure 1 reveals collimated material moving almost radially outwards in a trajectory having little or no curvature. Its duration

was about 11 minutes until the maximum elongation was reached as seen in Fe XIV emission. The outermost part reached a projected heliocentric distance of ~ 1.24 solar radii. By analogy to the findings made by Shibata et al. 1992 and Strong et al. 1992 based on YOHKOH observations, we define this transient as a green line jet, since it is observed as a transitory green line emission enhancement with an apparent collimated motion. At 13:15 UT, just before the emergence of the jet (13:17 UT), a small dark dot was also observed to appear, just at the border of the inner edge of the field-of-view at around 20°N apparent latitude (Figure 2).

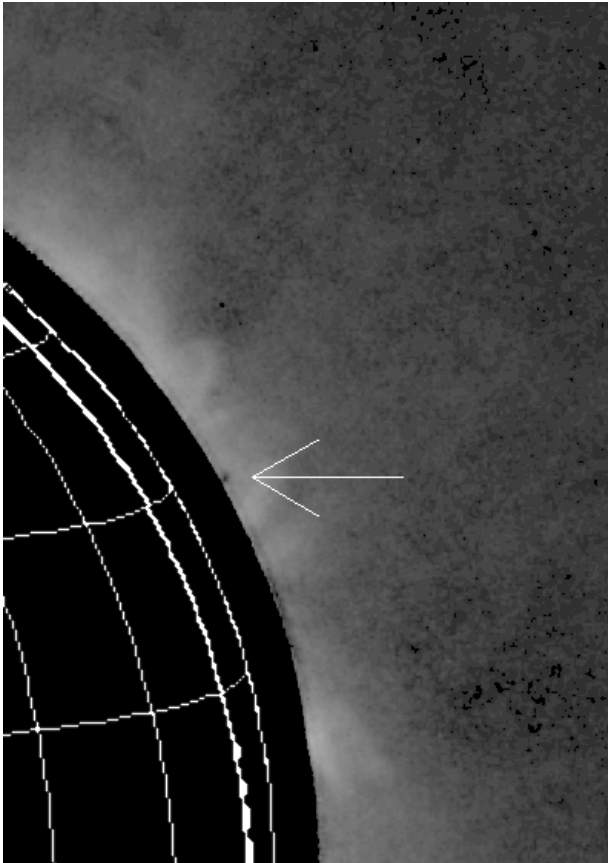


Figure 2. Processed green line image on September 30, 1998 at 13:15:45 UT. The arrow shows the position of the dark dot (see text).

The dark dot appears approximately at the same starting time and apparent position of the $\text{H}\alpha$ subflare that occurred above the NOAA AR 8340 as reported in the Solar- Geophysical Data (Number 650, Part I, 1998). After the disappearance of the jet at around 13:36 UT, a blob (bright enhancement as seen in the coronagraph field-of-view) is released somewhat displaced from the jet. The blob traces a curved path towards North of the jet (frames m to o in Figure 1). This structure rapidly fades as it moves outwards. Before the ejection of this plasmoid, another dark dot was observed at 13:27 UT slightly southwards from the first one, reappearing at 13:30

UT. In this case, this feature appears at nearly the same time as another weak subflare, this time above the NOAA AR 8345. In Figure 3 the height-time diagram of both the jet and the blob is shown.

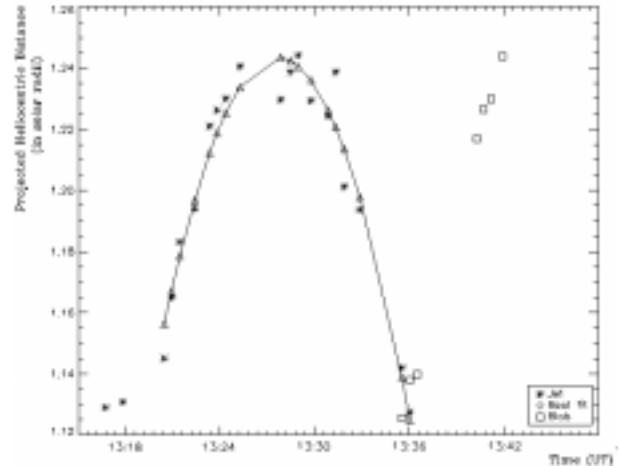


Figure 3. Height-time diagram for the observed jet and blob on September 30, 1998. The average projected speed for the rising phase of the jet is ~ 250 km/sec as estimated from the best fit, while for the blob is ~ 220 km/sec.

Since the beginning of the event as observed by MICA, a gradual change in the global structure of the green line emission at large scale is also seen. At the time of the occurrence of the first dark dot this change no longer remains gradual but becomes more abrupt. The removal of hot material can be appreciated when viewing the images as a movie. This global change can be observed in MICA images until around 14:30 UT on September 30, 1998.

2.2. April 20, 1999, Event

The dynamical event that took place on April 20, 1999 reveals another clear example of a relative fast green line transient. Figure 5 shows the green coronal pattern in the south-western limb as recorded at $\sim 12:30$ UT prior to the initiation of the event. Many coronal loops associated with one or more active regions close to the limb are visible. Figure 6 shows a ~ 90 minutes time-lapse sequence of green line processed images of the event, each frame corresponding to the average of the images taken in a time-lapse of 3 minutes. In addition, a reference treated image has been subtracted from each average image in order to enhance the visibility of the features. A sudden dimming in intensity can be observed to begin between 12:52 UT and 12:56 UT. In subsequent images the development of a cusp-like region darker than the surroundings can be observed. Unfortunately after 14:30 UT there was a data gap, allowing imaging not before 17:30 UT.

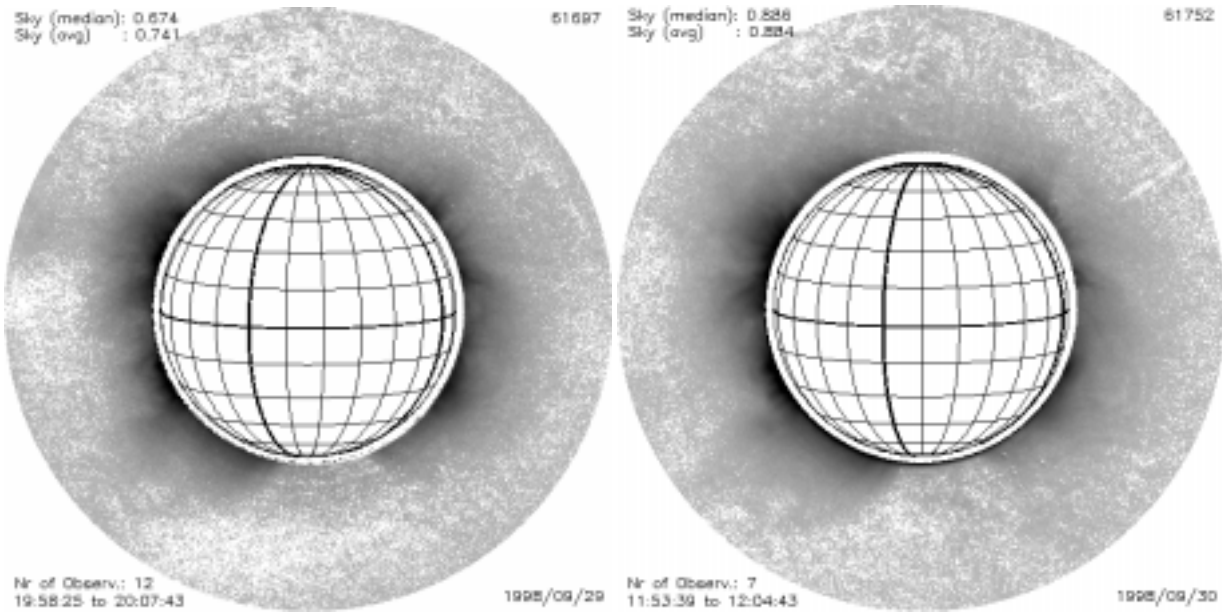


Figure 4. Last and first 10 minutes median treated image on September 20 (left) and September 30, 1998 (right) respectively. Both images are obtained as the median of the images recorded in a time-lapse of ~ 10 minutes during the time as indicated in the figure. The color table has also been inverted, to enhance the visibility of faint features. A different green line coronal pattern can be observed in the north-western limb.

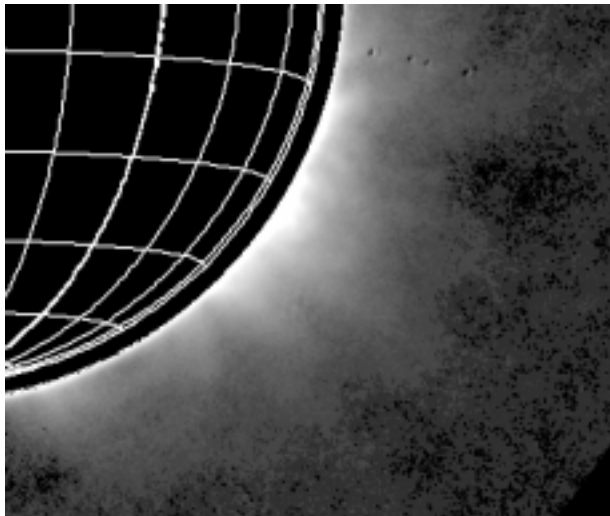


Figure 5. Pre-event green line coronal pattern at $\sim 12:30$ UT on September 30, 1998.

3. DISCUSSION

The September 30, 1998, north-western limb event was rather complex, involving a 2N flare, an $H\alpha$ surge with its counterpart in the coronal green line, the release of a blob, and an eruptive prominence, among other things. A sudden increase in energetic particles (i.e., protons with energies above 5 MeV) arriving at Earth was also detected. A detailed mul-

tiwavelength analysis of such event will be published in a dedicated paper. However it is worth to mention some interesting details as observed by MICA. The appearance of the dark dots (at $\sim 13:15$ UT and $\sim 13:27$ UT) is due in both cases to a temporary enhancement in the continuum emission. Since the continuum emission is sensitive to the Thomson scattering of the photospheric light by free electrons in the corona, the intensity change only reflects excess mass. This electron density increase is observed at around the same starting time (and apparent position) of the two $H\alpha$ subflares and seems to mark the onset of both the jet and blob release. Thus, this brightening in the continuum images could be interpreted as evidence of magnetic reconnection at the point where the dark dot appears. If this is the case, the reconnection could be the mechanism which heats the chromospheric material to temperatures approaching 1.8×10^6 K (since only at these temperatures the structures become visible in the green line) and triggers the jet and the blob. Besides, the morphology of this event shows also a gradual change at large-scale unfortunately not detected by MICA from the very beginning. Inspection of Figure 4 shows the green line emission pattern as recorded on September 29, 1998 at 20:08 UT and September 30, 1998 at 11:53 UT. If the green line emission is a good tracer of the magnetic field topology (Schwenn et al. 1997), it seems likely that a big disruption of the magnetic field had taken place during this time, possibly giving rise to a CME. Thus, the gradual change we observed at large scale is but a signature of the evolution of a gradual CME as it travels outwards.

The pre-event loops we observed for the event on April, 20 (Figure 5) are very difficult to isolate due

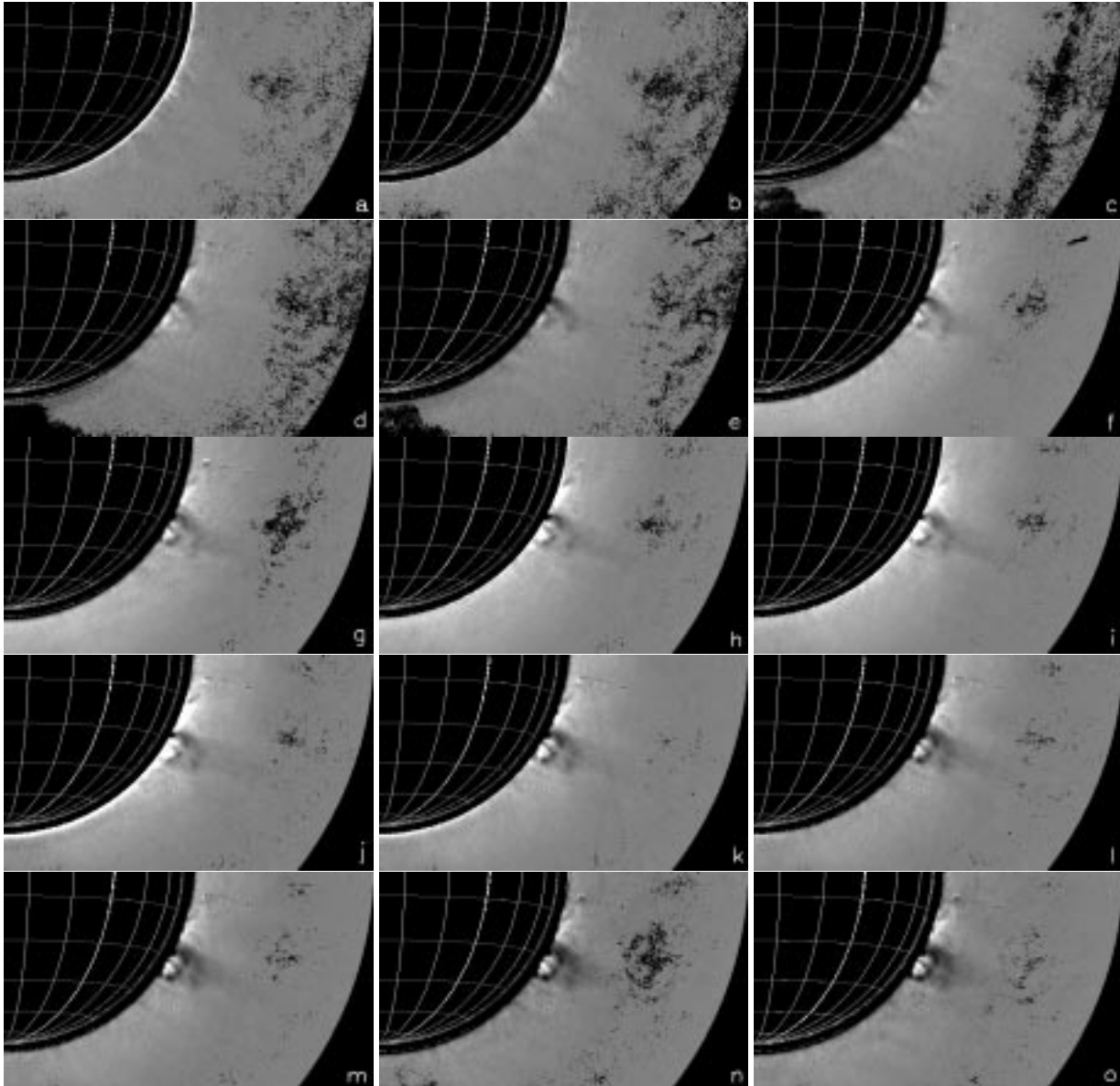


Figure 6. Development of the event on April 20, 1999: a) 12:34, b) 12:52 UT, c) 12:56 UT, d) 13:01 UT, e) 13:04 UT, f) 13:10 UT, g) 13:13 UT, h) 13:19 UT, i) 13:22 UT, j) 13:28 UT, k) 13:31 UT, l) 13:36 UT, m) 13:40 UT, n) 13:46 UT, o) 14:07 UT. Each frame results from the average of the images taken in a time-lapse of 3 minutes. In addition a reference treated image has been subtracted from each average image in order to enhance the visibility of the features. The base image was made up of the average of 12 treated images, which were obtained during the ~ 10 minutes prior to the time of the first frame. The exposure time of the corresponding on-line images were 15 or 30 seconds, depending on the brightness of the sky. For the off-line images 4 seconds was used.

to projection effects. The observed dimming (Figure 6) can be attributed either to the expansion of a loop which is at a very different temperature to that corresponding to the emission of Fe XIV ions or to increasing electron density whose signature would be an enhancement of the continuum intensity. The former seems to be more likely since inspection of time-lapse sequences of difference continuum images reveals no appreciable changes. An extensive study of this event combined with LASCO data is under way.

4. CONCLUSION

Many factors affect the ground-based observations of the faint solar corona such as variability of sky conditions, atmospheric straylight, turbulence of the air, etc. Nevertheless, the present study of dynamical events demonstrates the instrument's capability and uniqueness in particular with respect to the time resolution which is crucial to understand the trigger or the initiation of coronal transients.

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