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 (31°48^{m} S, 69°19^{m} W), San Juan, Argentina, a mirror coronagraph daily images the inner solar corona with high temporal and spatial resolution in two spectral ranges: the well known green (~ 1.8 MK) and red (~ 1.0 MK) coronal lines at 5303 Å and 6374 Å respectively (Figure 1). 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.

This paper reports the morphology and evolution of two coronal transients as observed by MICA in the green line. These events 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.

MICA Optical Layout

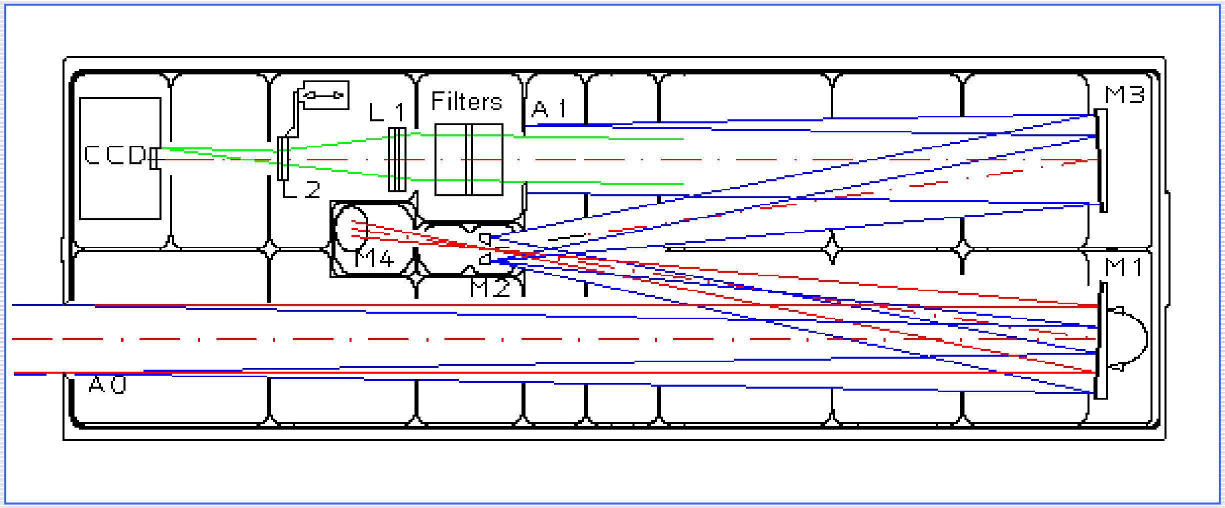


Figure 1

Elem.	Type	Aperture (in mm)	Curvature (in mm)	Remarks
A0	Circ. Aperture	59	-	Entrance
M1	Off-axis Parabola	90	FL = 750	Primary Mirror
M2	Convex Sphere	ID=7 OD=20	R = 2422	Occultor
M3	Off-axis Parabola	90	FL=750	
S	Shutter	40	-	Mechanical
A1	Annular Aperture	ID=38.4	-	Lyot Stop
TL	Telelens		-	
CCD	Camera	16 μ/pxl	-	1280x1024 pxl (~3.8 arcsec/pxl)

Filter	Aperture (in mm)	Wavelength	FWHM
Fe XIV (On line)	40 [(1)]	λ5303 Å	Δλ= 0.9 Å
FeXIV (Off line)	40 [(1)]	λ5260 Å	Δλ= 9.0 Å
Fe X (On line)	40 [(1)]	λ6374 Å	Δλ= 0.9 Å
Fe X (Off line)	40 [(1)]	λ6340 Å	Δλ= 9.0 Å
H alpha	40 [(1)]	λ6563 Å	Δλ= 3.0 Å

Some Comments on Image Processing

The unprocessed direct images from MICA show practically no coronal signal. They are affected by the strong radial gradient of the instrumental straylight 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 Å 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) it 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.

Event #1: September 30, 1998

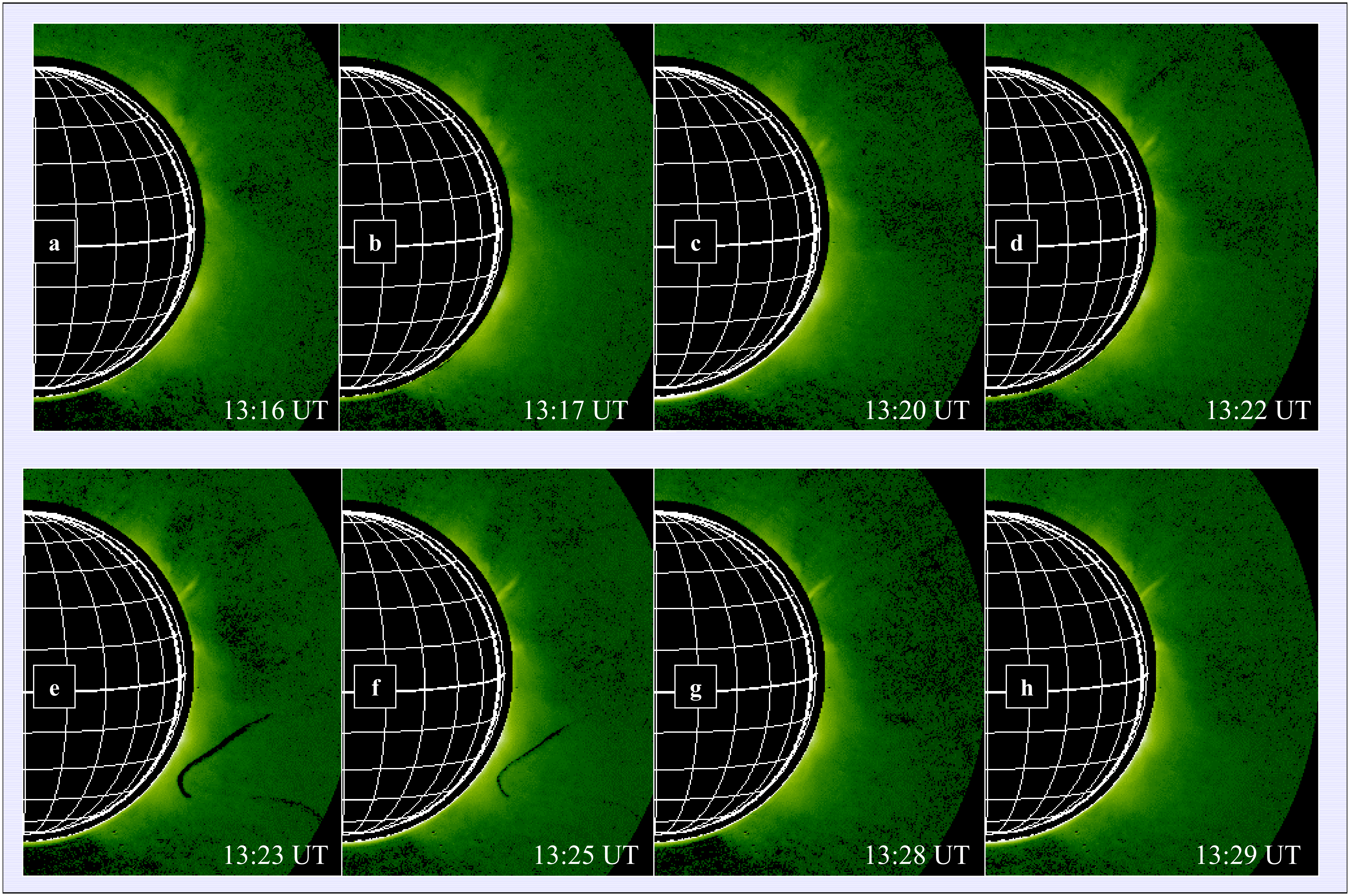
MICA observations on September 30, 1998, started at 11:53 UT. The initiation of the event was recorded at 13:15 UT (as observed by MICA). The main phases of the event are shown in Figure 2. Inspection of the frames *b* to *h* reveals collimated material moving almost radially outwards in a trajectory 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 ~1.24 solar radii. The height-time diagram of both the jet and the blob is shown in Figure 3. 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 ~20°N apparent latitude (Figure 4).

The dark dot appears approximately at the same starting time and apparent position of the Hα subflare that occurred above the NOAA AR 8340 as reported in Solar-Geophysical Data, Number 650, Part I, 1998. After the disappearance of the jet at about 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 2). 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.

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.

Event #2: April 20, 1999

The event that took place on April 20, 1999 reveals another clear example of a relative fast green line transient. In Figure 6 we can observe the green coronal pattern in the south-western limb prior to the initiation of the event. Figure 7 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.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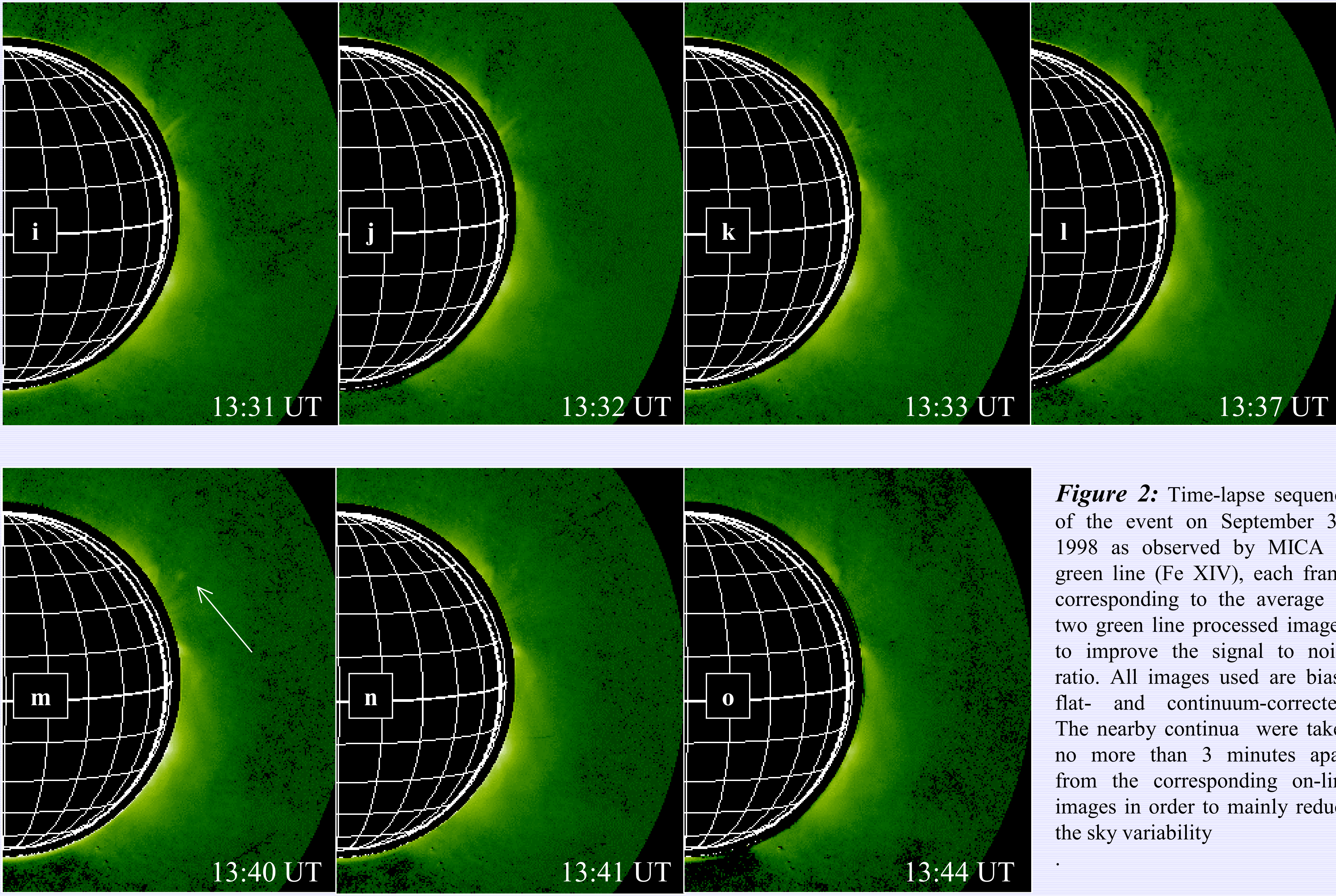

Figure 2: Time-lapse sequence of the event on September 30, 1998 as observed by MICA in green line (Fe XIV), each frame corresponding to the average of two green line processed images, to improve the signal to noise ratio. All images used are bias-, flat- and continuum-corrected. The nearby continua were taken no more than 3 minutes apart from the corresponding on-line images in order to mainly reduce the sky variability
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Height-Time Diagram
September 30, 1998 Event

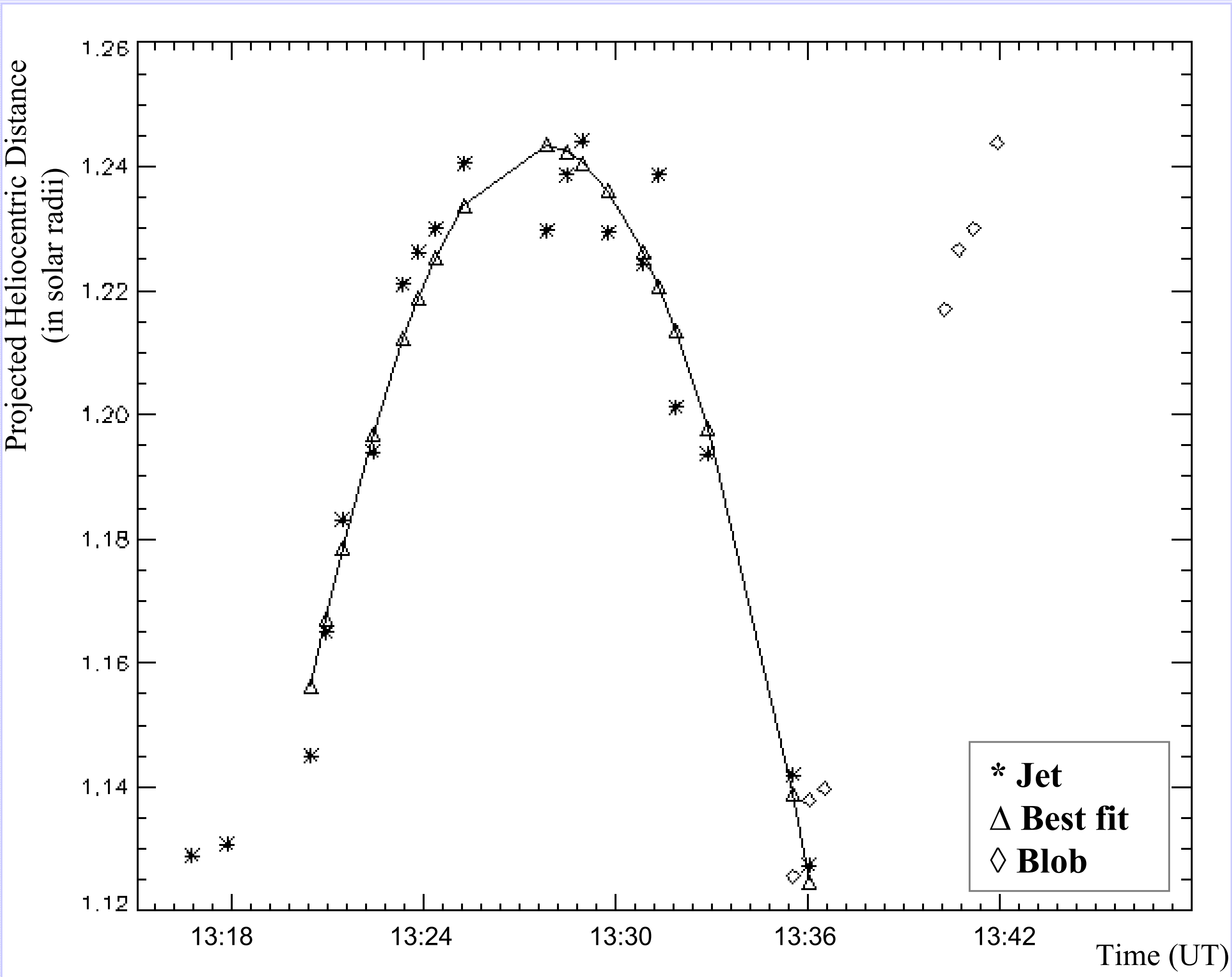


Figure 3: Height-time diagram for the observed jet and blob on September 30, 1998. The average projected speed for the rising phase of the jet is ~250 km/sec as estimated from the best fit, while for the blob is ~220 km/sec.

Height-Time Diagram
September 30, 1998 Event

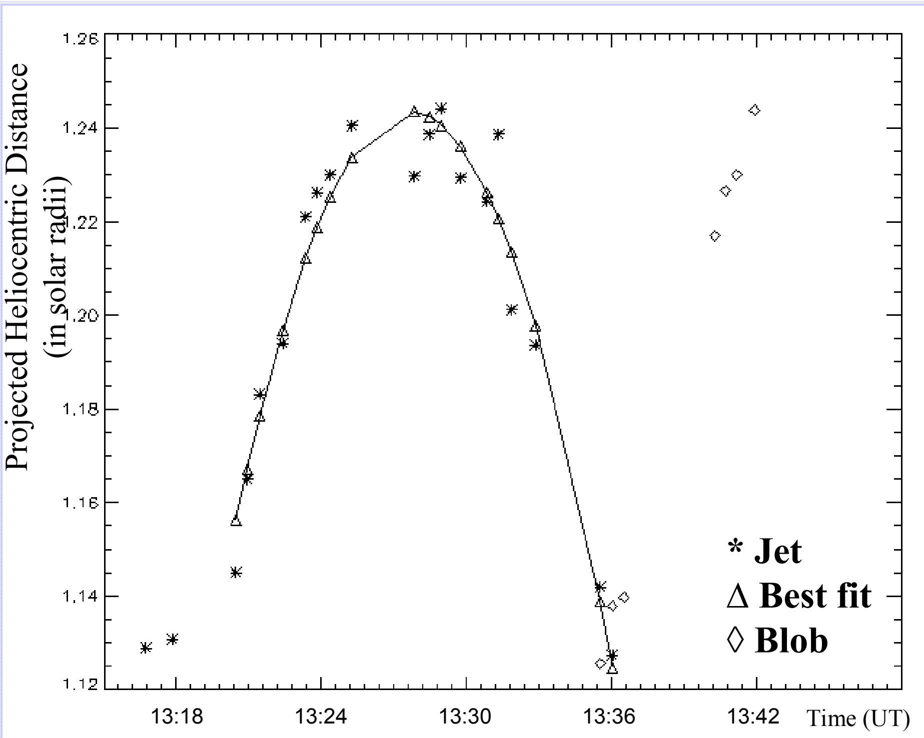


Figure 3: Height-time diagram for the observed jet and blob on September 30, 1998. The average projected speed for the rising phase of the jet is ~250 km/sec, while for the blob is ~220 km/sec.

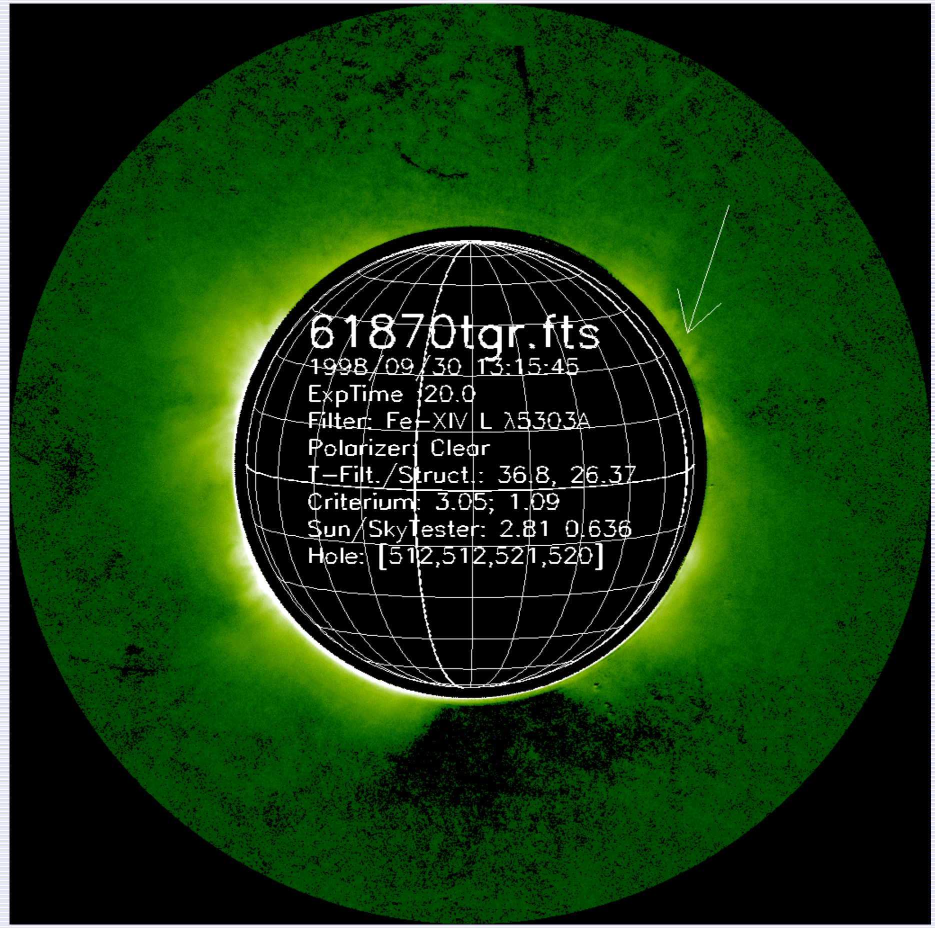


Figure 4: Processed green line image on September 30, 1998 at 13:15:45 UT. The arrow shows the position of the dark dot (see text).

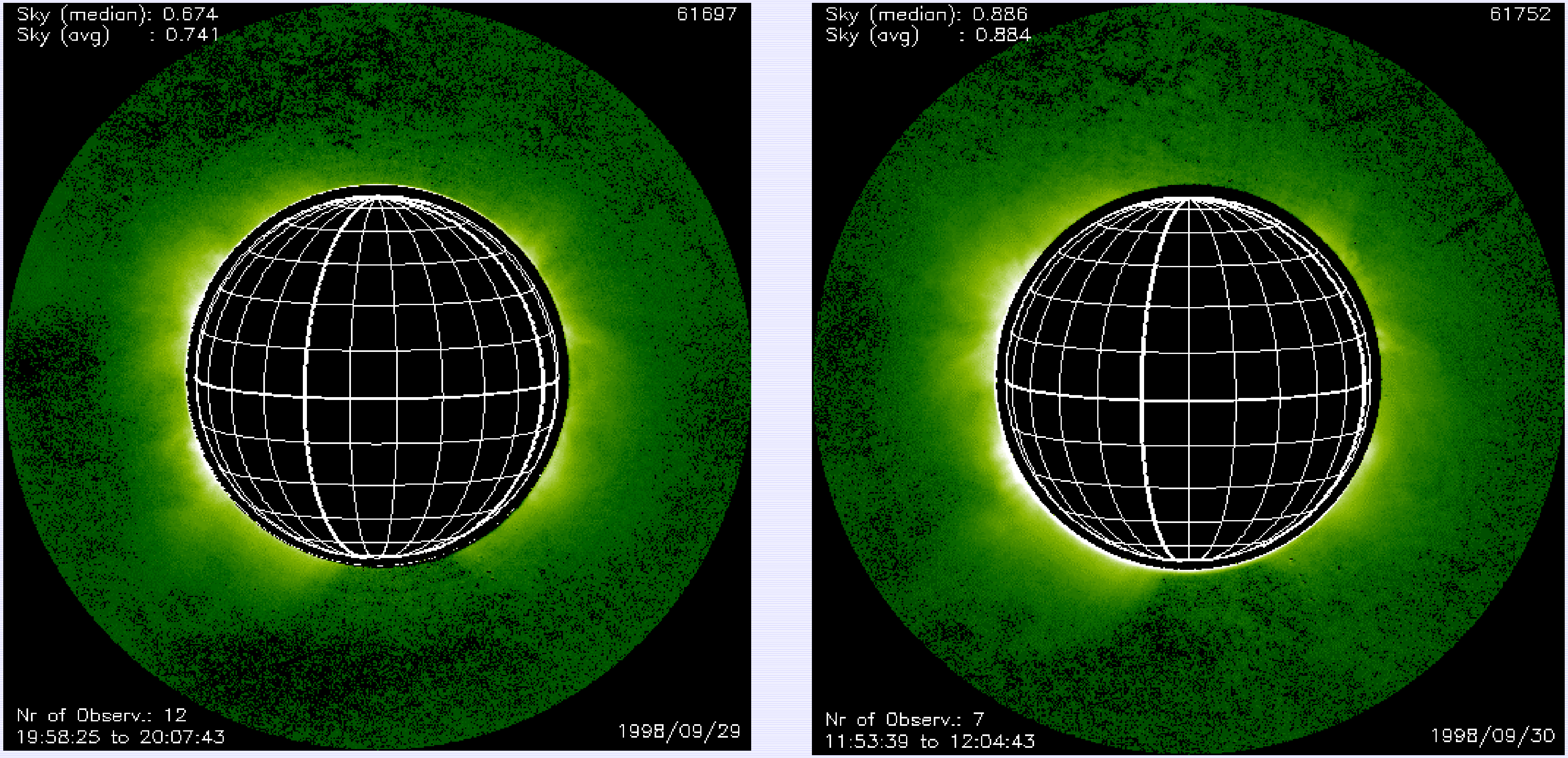


Figure 5: Last and first 10 minutes median treated image on September 29 (left) and September 30 (right), 1998 respectively. Both images are obtained as the median of the images recorded in a time-lapse of ~10 minutes during the time as indicated in the figure. A different green line coronal pattern can be observed in the north-western limb.

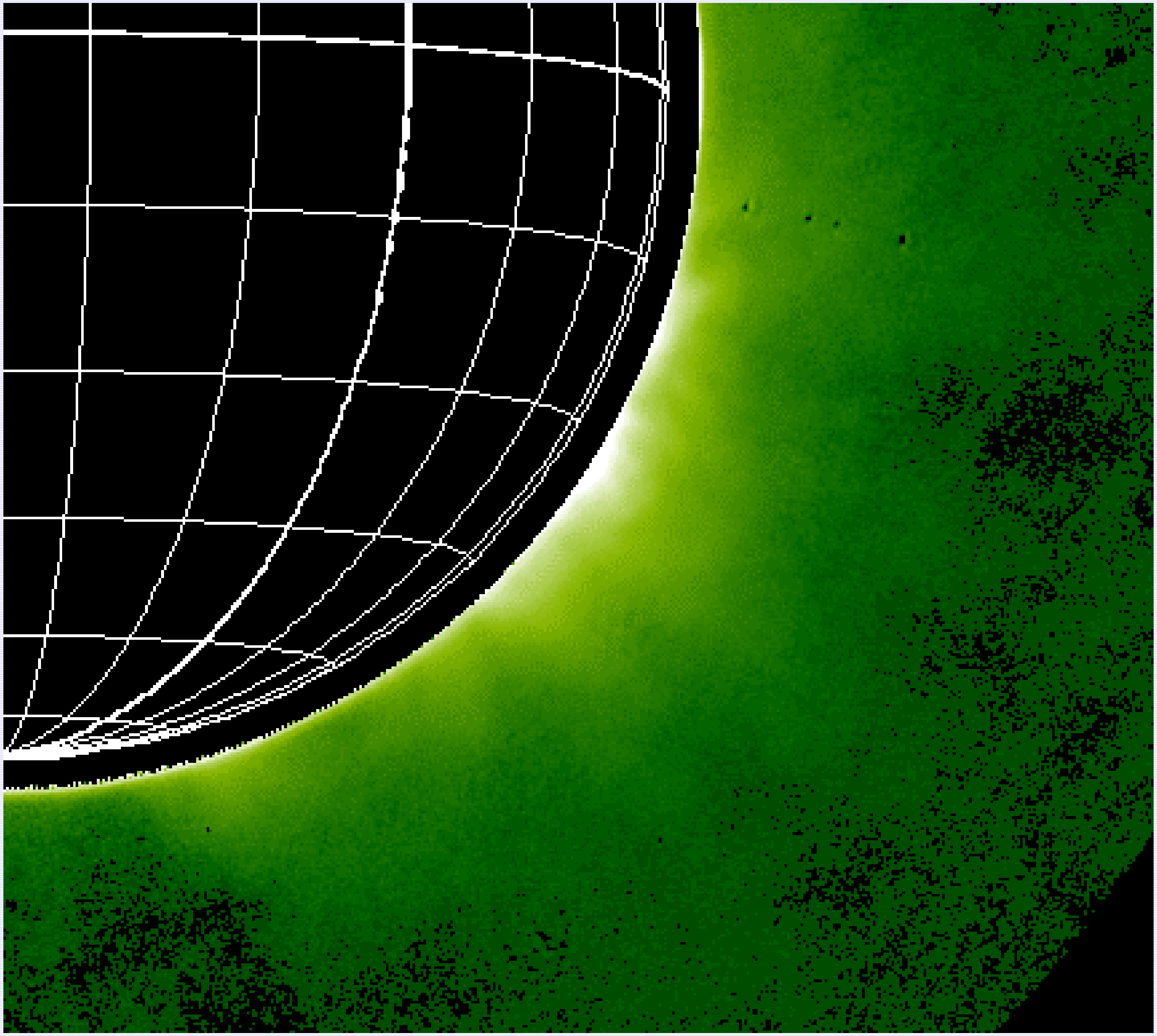
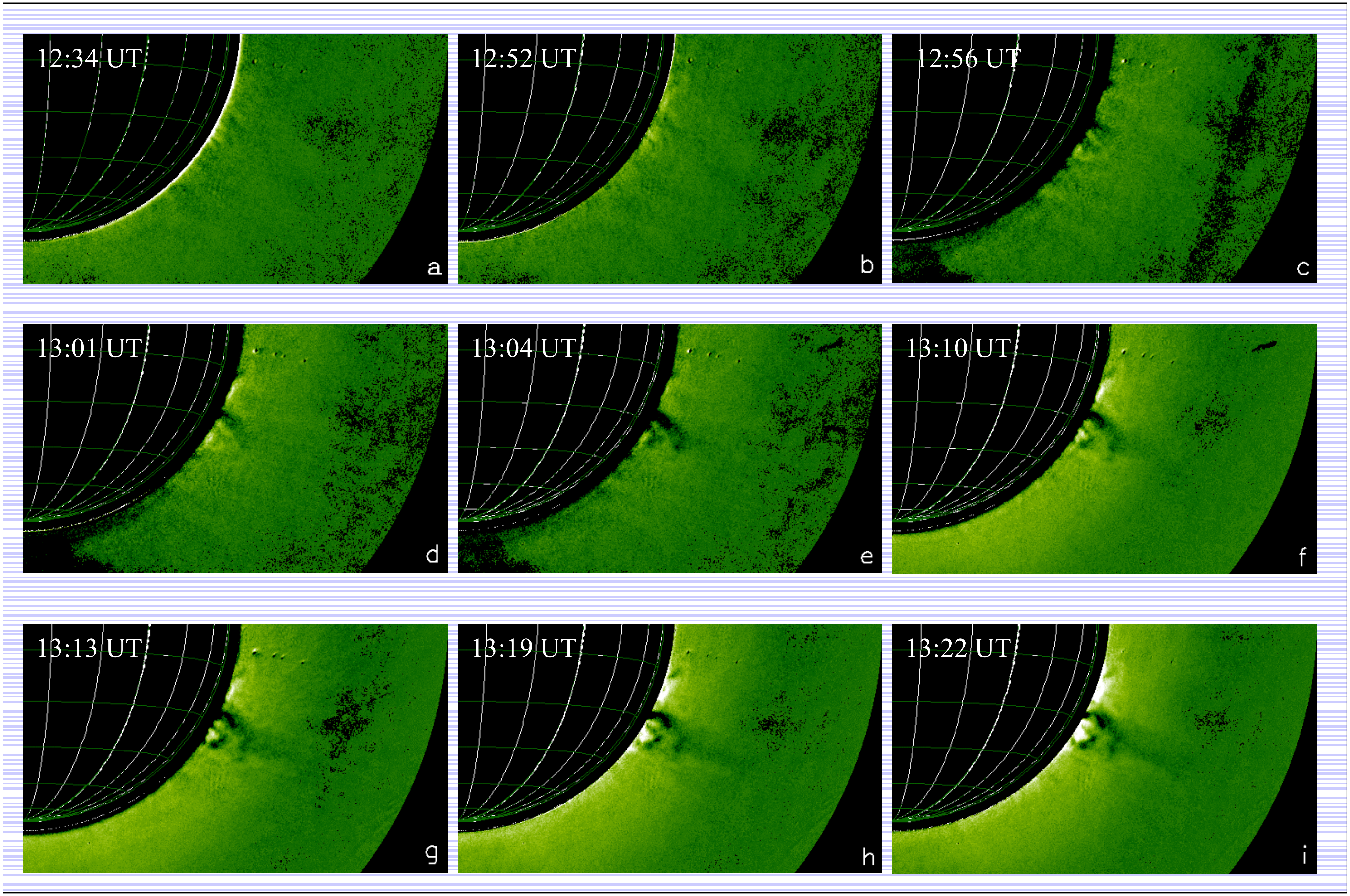


Figure 6: Green coronal pattern at ~12:55 UT on April 20, 1998, prior to the initiation of the event as observed by MICA.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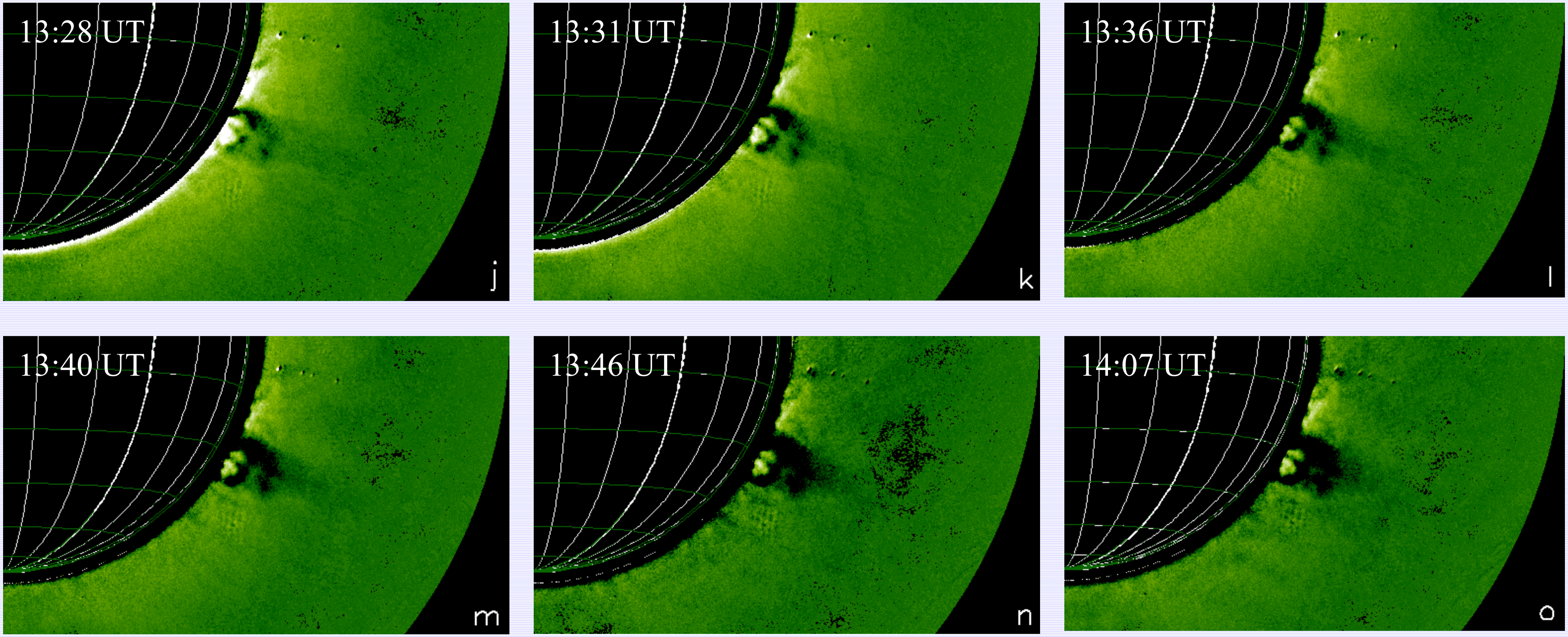

Figure 7: Development of the event on April 20, 1999, each frame corresponding to the average of the treated images as taken in a time-lapse of 3 minutes. In addition to the standard processing procedure, a reference treated image has been subtracted in all frames, to enhance the visibility of the features. The reference image was made up of the average of the treated images in a time lapse of ~10 minutes prior to the initiation of the event.

Discussion

The September 30, 1998, north west limb event was a rather complex one 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 multiwavelength analysis of the 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 ~13:15 UT and ~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 Hα 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 5 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, 1999), 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 can observe in Figure 6 for the event on April, 20 are very difficult to isolate due to projection effects. The observed dimming (Figure 7) 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.

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 as well as its evolution.

References:

Brueckner, G.E. et al 1995, Solar Phys., **162**, 357

Schwenn, R. et al. 1997, Solar Phys., **175**, 667

Shibata, K. et al. 1992, PASJ, **44**, L173

Stenborg, G., et al. 1999, Solar Wind 9, S. Habbal (eds), Conf. Proc. Vol. **471** AIP, in press.

Strong, K.T., et al. 1992, PASJ, **44**, L161

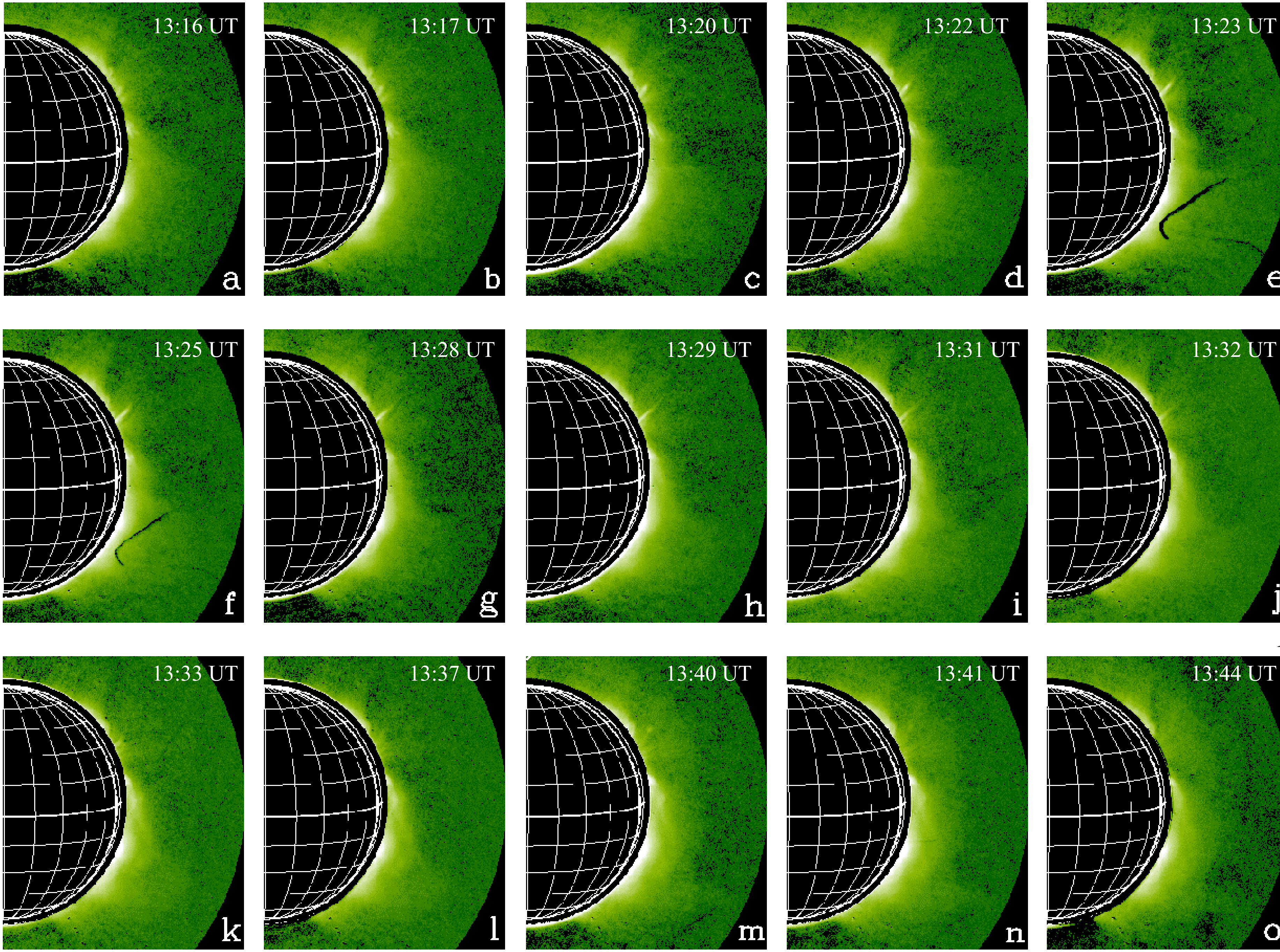
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Fig.2