Study of Filament Eruption During 2015 March 14 —15

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Outline

- Introduction
- Observations
- First Step and Second Step
- Decay Index Calculations
- Summary

Introduction

- **It is believed that the filament and CMEs are related to twisted magnetic field, called a flux rope. This flux rope can be present before the eruption or can be formed beginning the eruption by reconnection process.**

- **Different eruptions are proposed, which includes: new flux emergence, shear motions, and dispersion of the external magnetic field, and/or reconnection of field lines below or above the flux rope.**

- **Their impacts is mainly to break the overlying magnetic tension and/or to favor the rise of the flux rope until the torus instability reached (Forbes and Isenberg, 1991; Kliem and Török, 2006; Démoulin and Aulanier, 2010, Aulanier, 2014; Filippov *et al.*, 2015; Schmieder, Aulanier, and Vršnak, 2015).**

- **In Torus instability model, it is assumed that the overlying magnetic field ($B_{external}$) decreases with the increase of the height (h) from the photosphere i.e. $B_{external} \propto h^{-n}$. The flux rope becomes unstable when the decay index n at its location becomes greater than a critical value.**

- **According to observations it was found that this value lies between 1 and 1.5 (Filippov and Den, 2001; Filippov, 2013; Zuccarello *et al.*, 2014; McCauley *et al.*, 2015).**

- **In most of the cases, We find that before the eruption the filament starts to rise slowly for several hours. Afterwards it accelerate rapidly upwards and leads to a CME and flare (Schrijver et al. 2008).**

- **The eruption can be full, partial and failed.**

- **In addition to above, there two cases, when the filament is erupted in two step part (Byrne *et al.*, 2014; Gosain *et al.*, 2016).**

- **Here, We present an interesting two-step filament eruption during 14 – 15 March 2015. The filament was located in NOAA AR 12297 and associated with a halo Coronal Mass Ejection (CME). We also find jet activity in the active region during both days, which could help the filament destabilization and eruption. The different aspect of the eruption on 15 March, 2015 was studied by *Cho et al. (2017), Wang et al. (2016) and Liu et al. (2015).***

- **The decay index is calculated to understand this two-step eruption. The eruption could be due to the presence of successive instability–stability–instability zones as the filament is rising.**

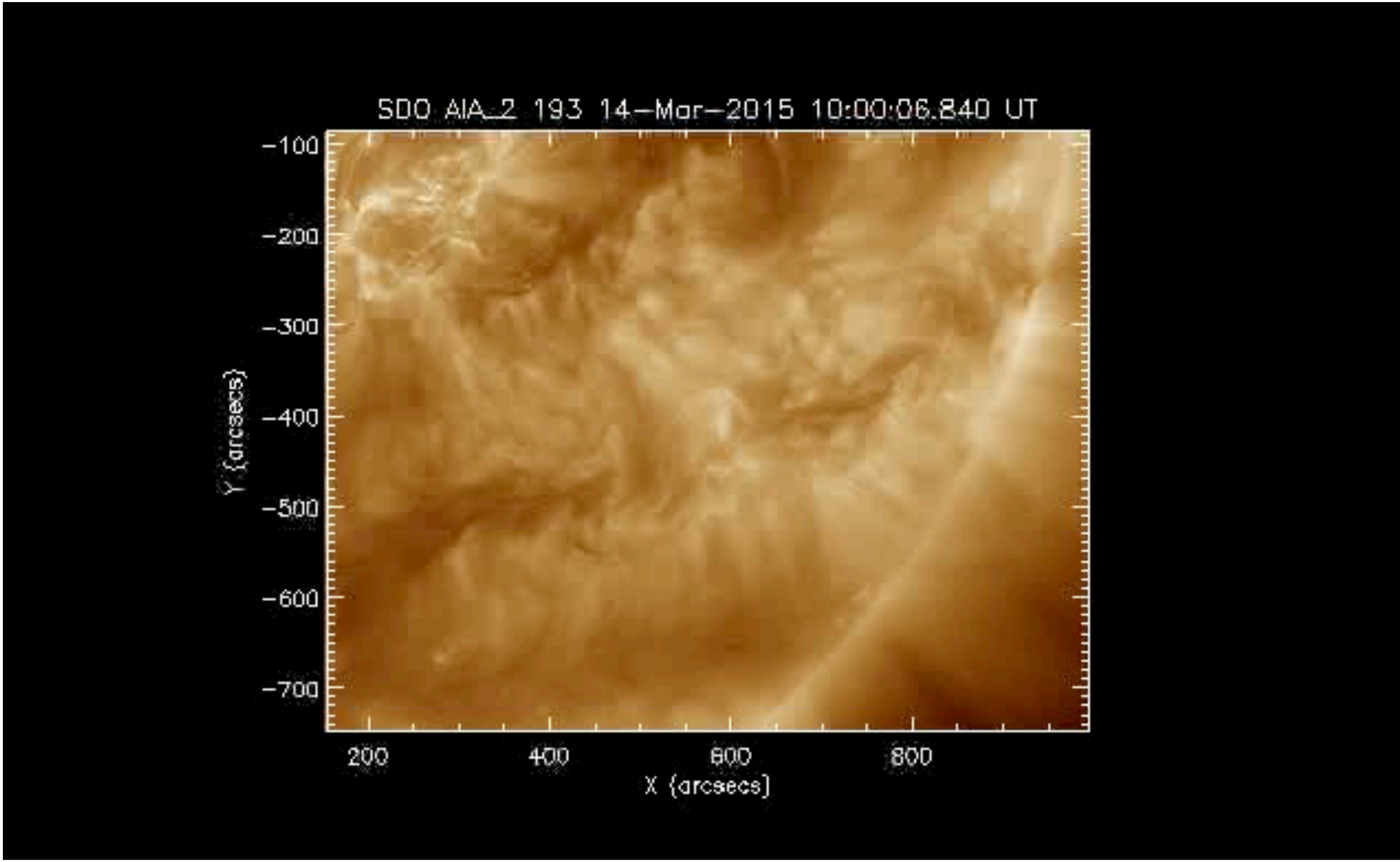
Observations

For this study, we have used the data from following sources :

- **GONG H-alpha data : GONG collected Hα images at seven sites over the globe in the 6563 Å wavelength with a spatial resolution of 1$''$ and a cadence of around 1 minute (Harvey et al. 2011). We used here the GONG Kanzelhoehe Solar Observatory data.**

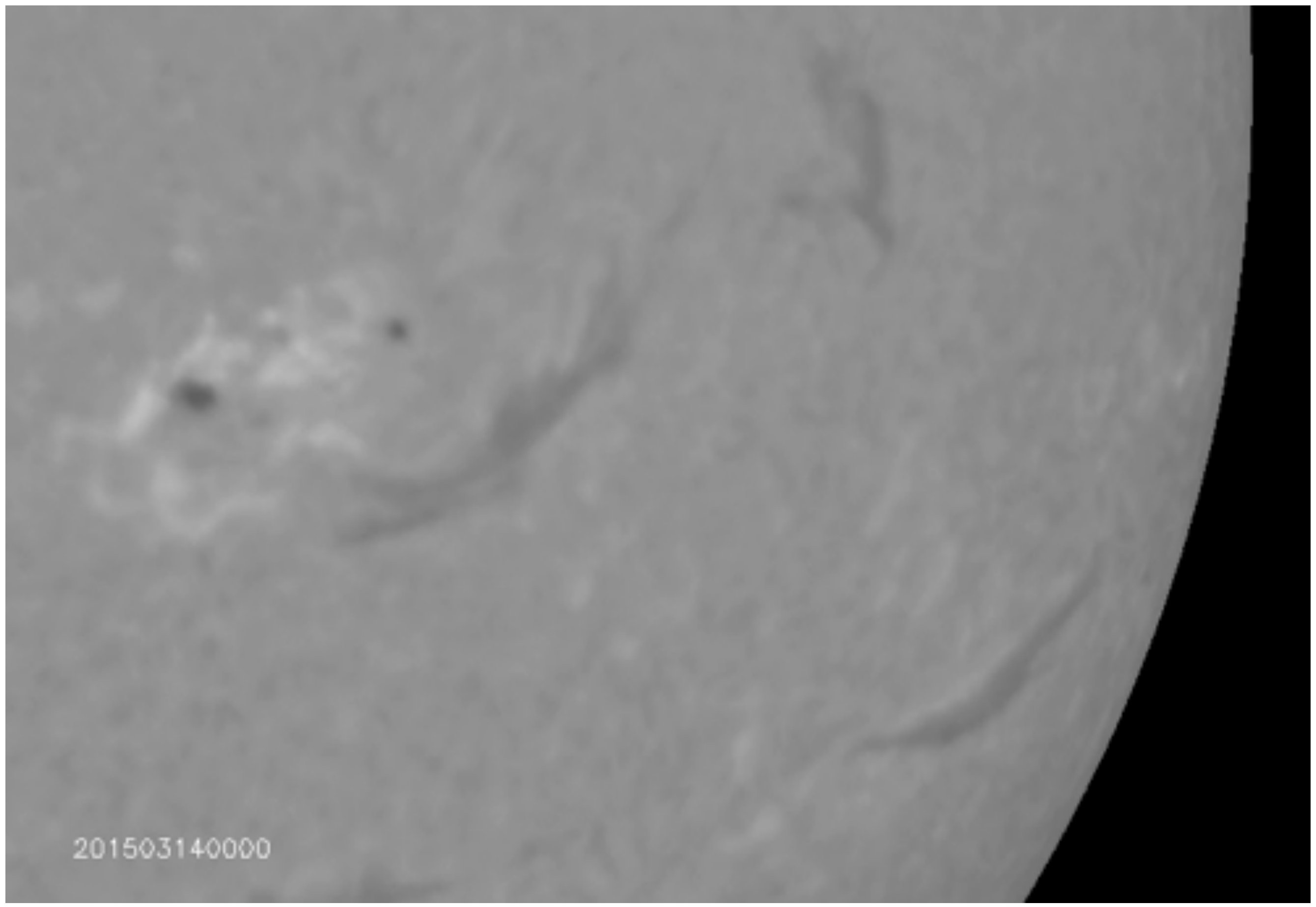
- **SDO/AIA data : AIA observes the full solar disk in three ultraviolet (UV) and extreme ultraviolet (EUV) narrowband wavelengths (Lemen et al. 2012). It has a pixel size of 0.6$''$ and cadence of 12 s. For the magnetic field, we have used the HMI (Schou et al. 2012) LOS data. We used SDO/HMI magnetogram data to find the magnetic polarity distribution near the filament channel as well as to calculate the decay index at various heights in the corona.**

- **SOHO/LASCO data : The eruption was associated with the CME observed by LASCO in C2 and C3.**

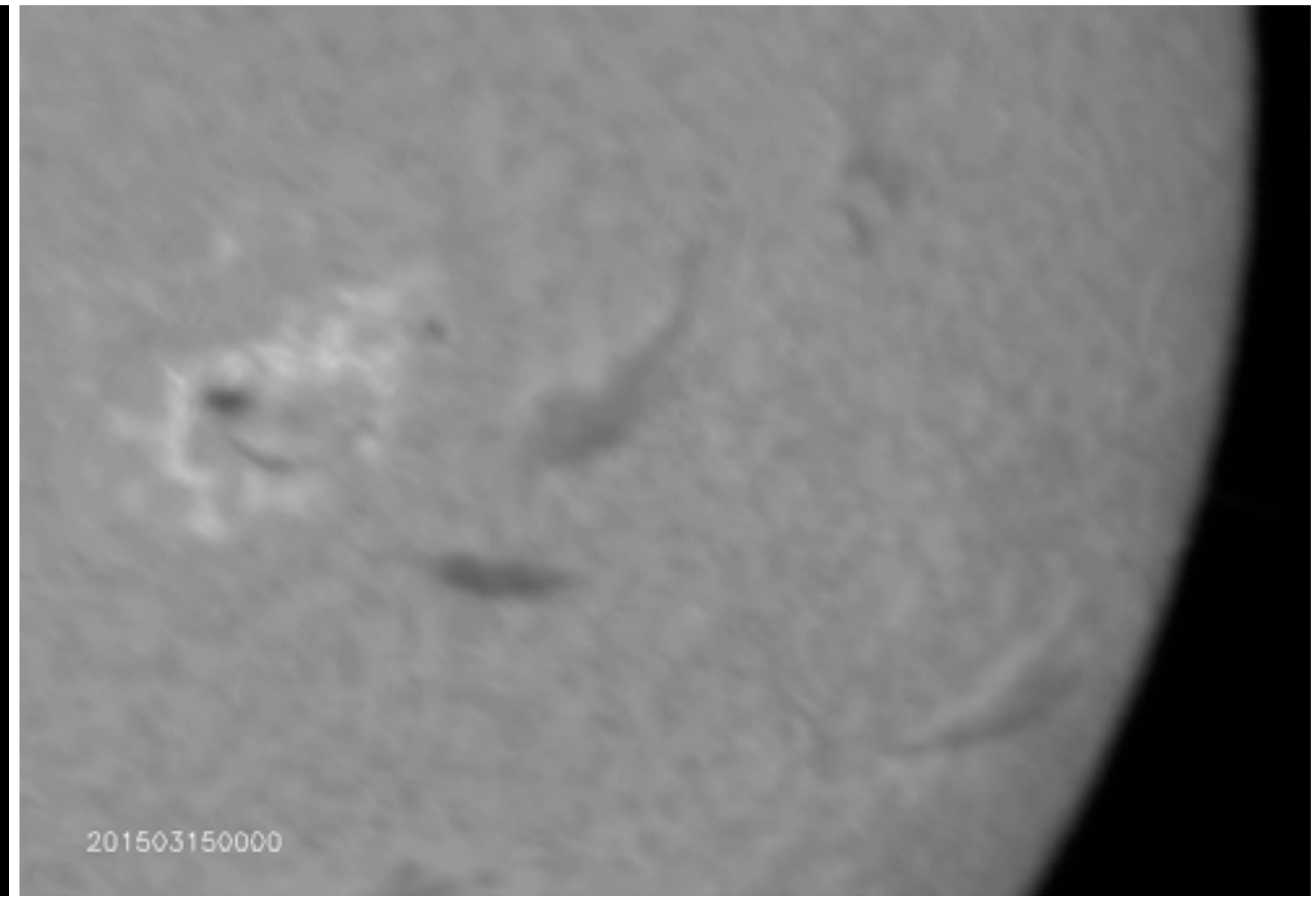


Evolution of filament eruption and jets during March 14-15, 2015 (AIA 193 A)

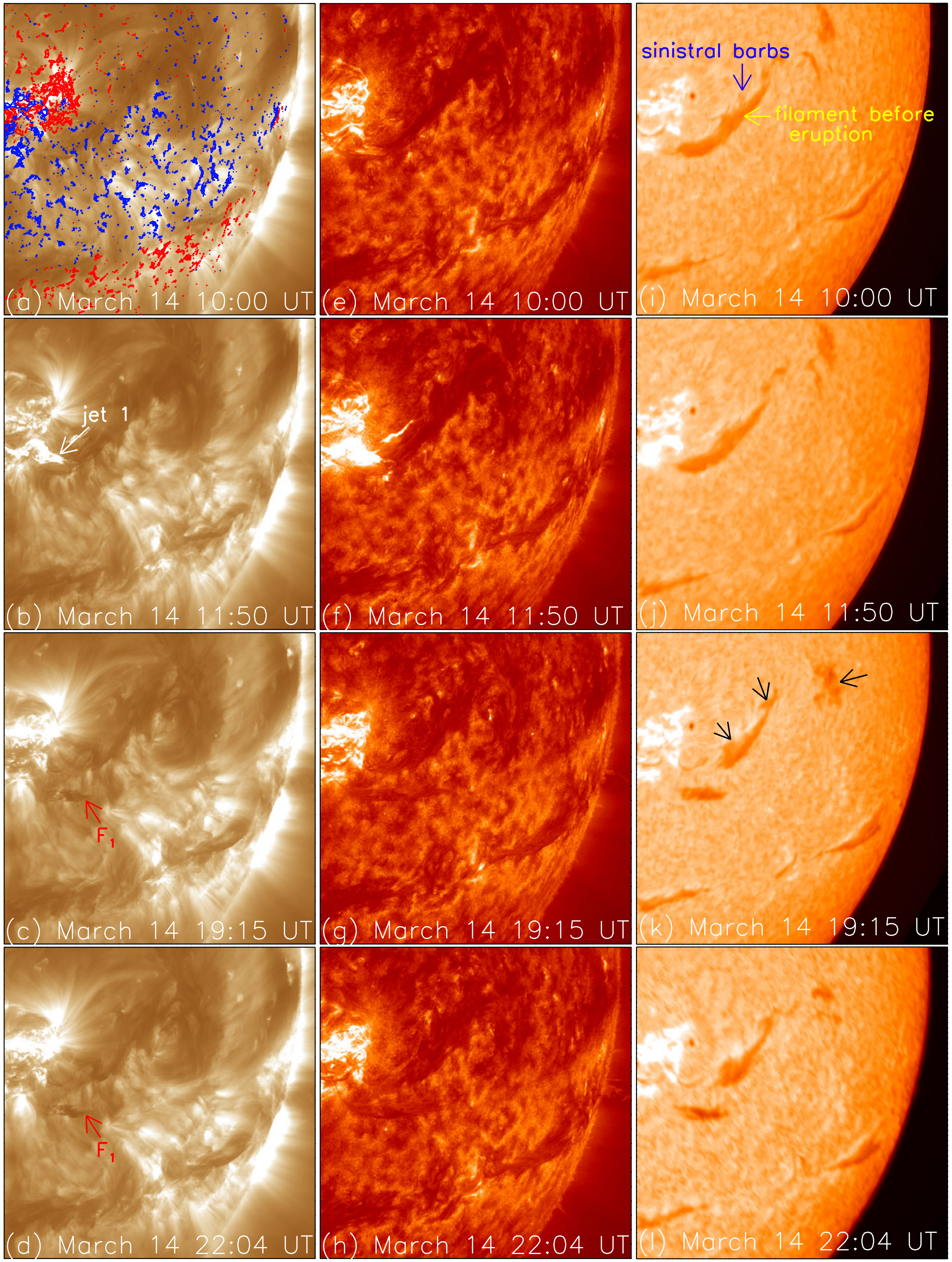
GONG H - alpha : 14/03/15



GONG H - alpha : 15/03/15



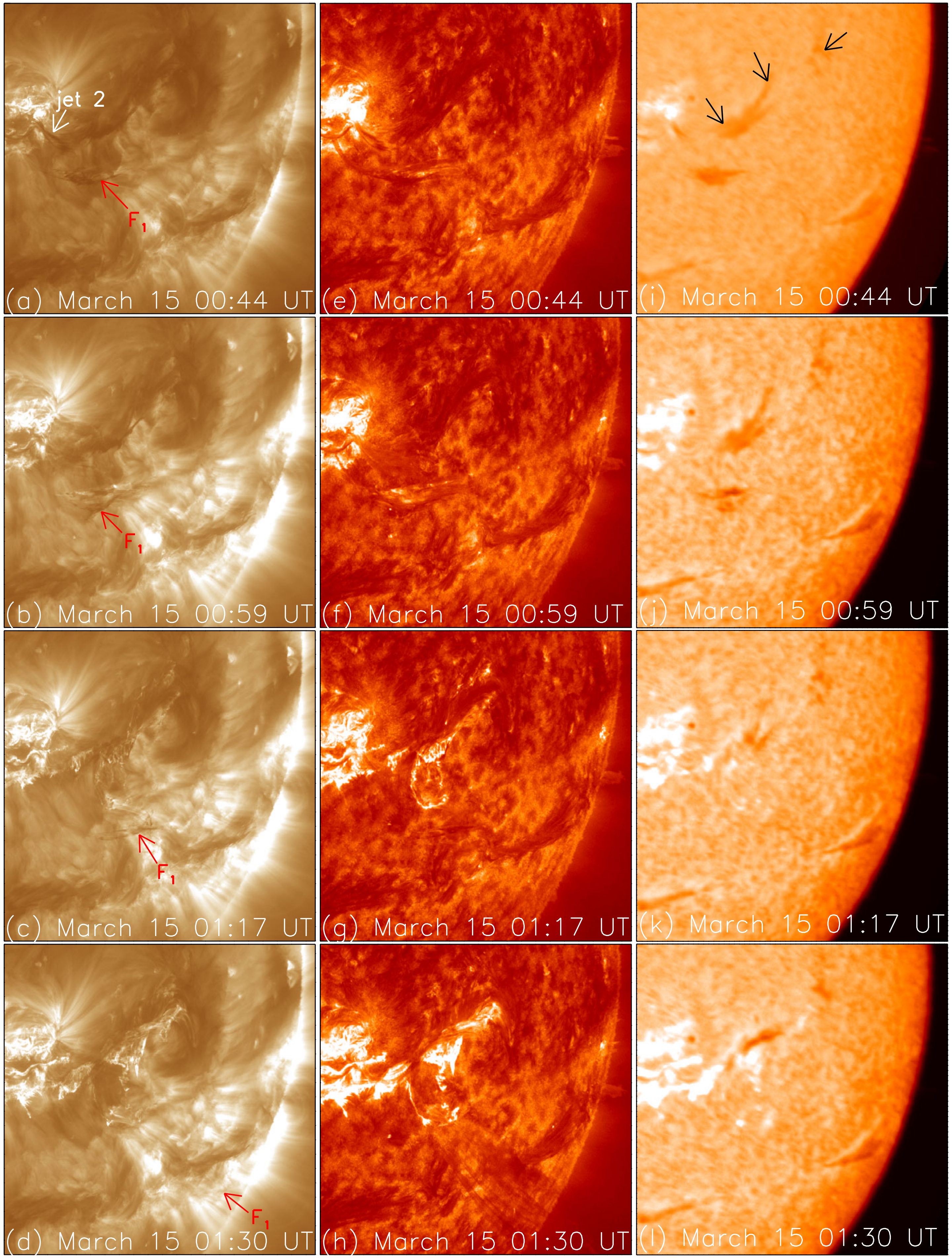
H-alpha Evolution of filament eruption and jets during March 14 and 15, 2015.



First Step

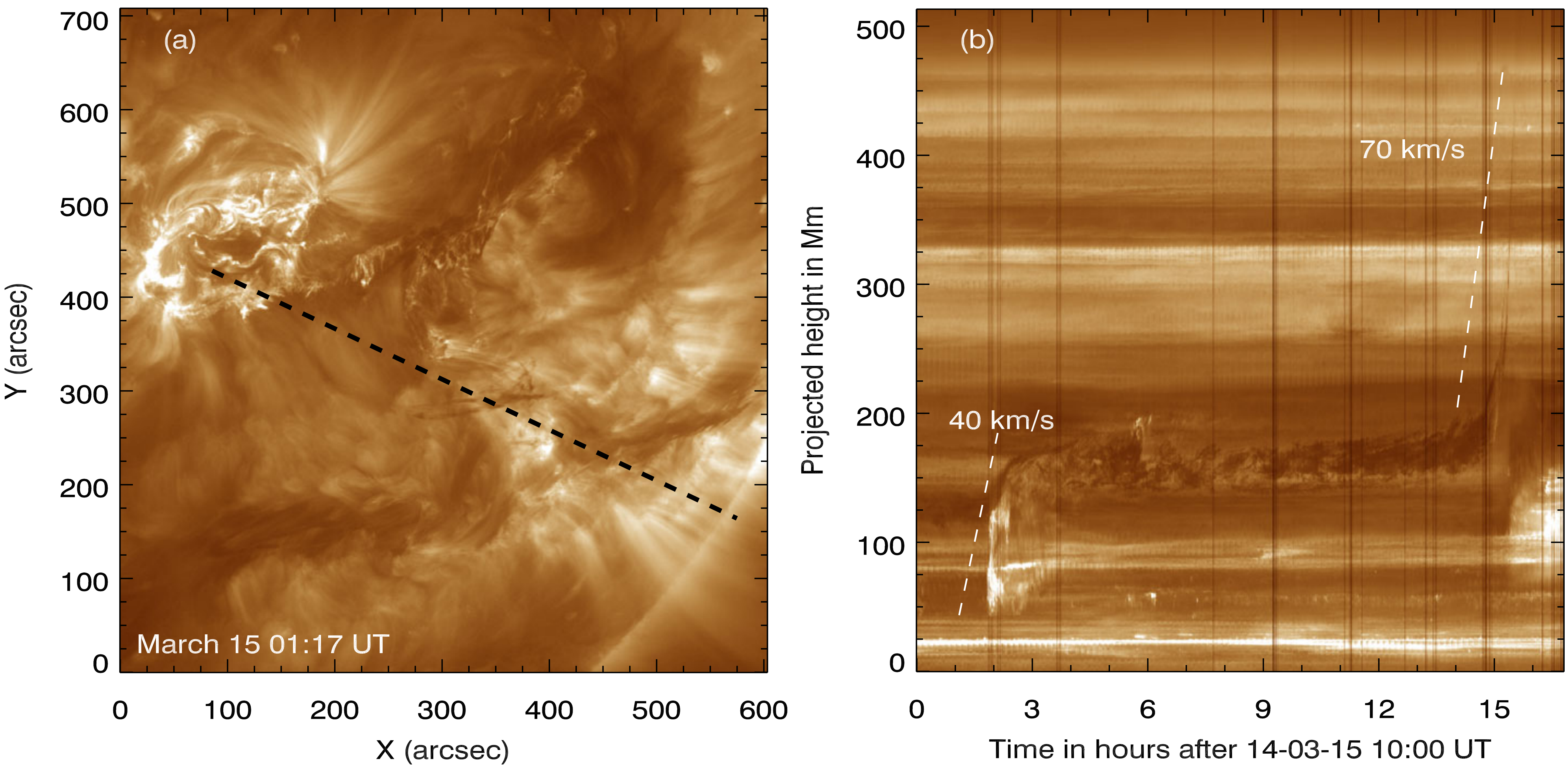
- **Jet J1 Activity started (All EUV, UV and H-alpha) ~ 11:50 UT.**
- **Due to this jet activity the left lower part of the sigmoidal filament was disturbed and separated from main body parts, rose upwards and became stable at the projected altitude ≈125 Mm.**
- **Partial Halo CME ~ 13:20 UT.**

Second Step



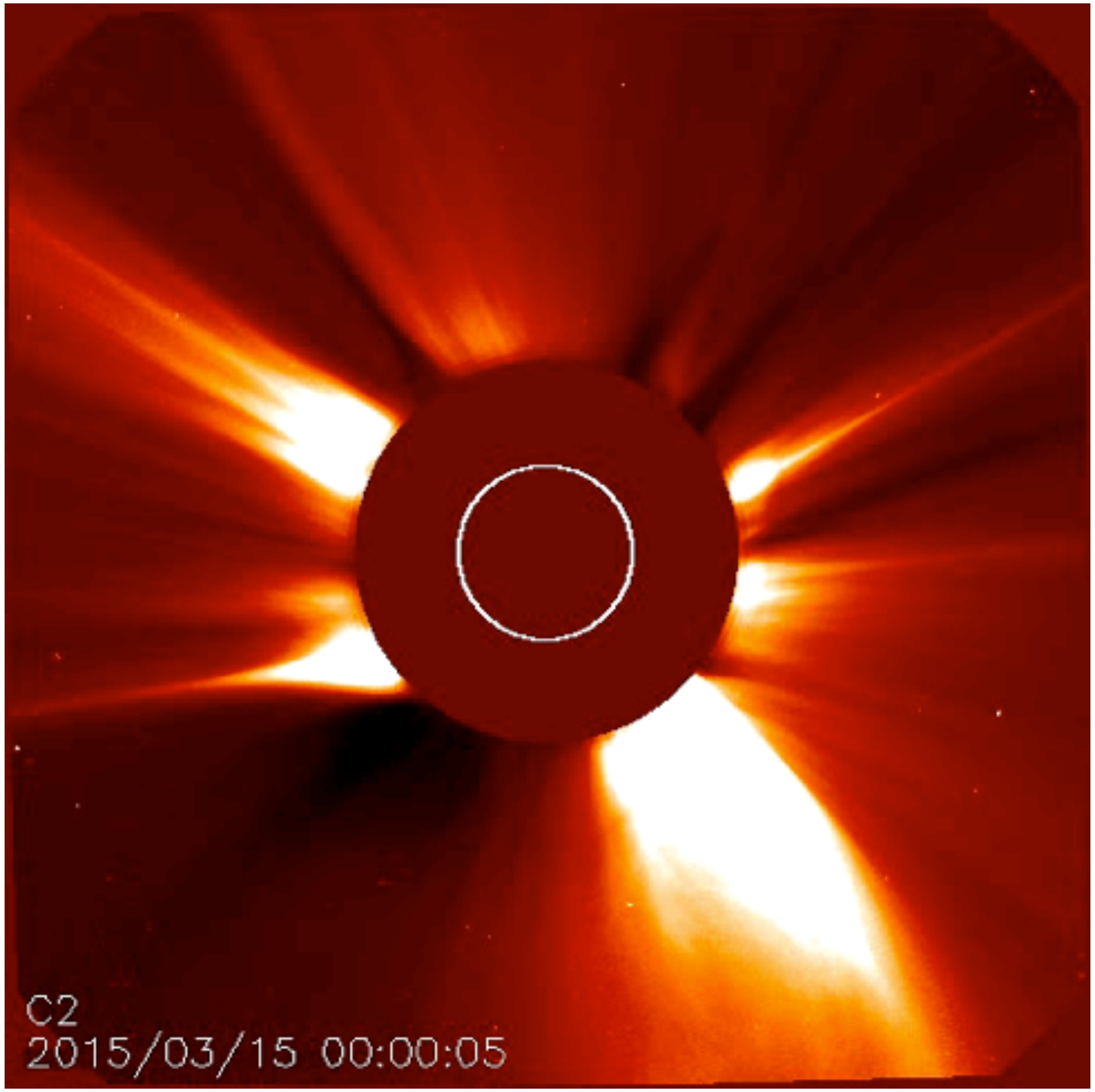
- **After 12 hrs of the jet J1, jet J2 activity started ~ 00:44 UT on 15 March, 2015.**
- **This J2 interact with filament F1 and the other part of filament.**
- **As a result of this, F1 was erupted and the other part of the filament was also disturbed, but failed to erupt.**
- **Halo CME ~ 01:48 UT (speed ~ 719 km/s)**

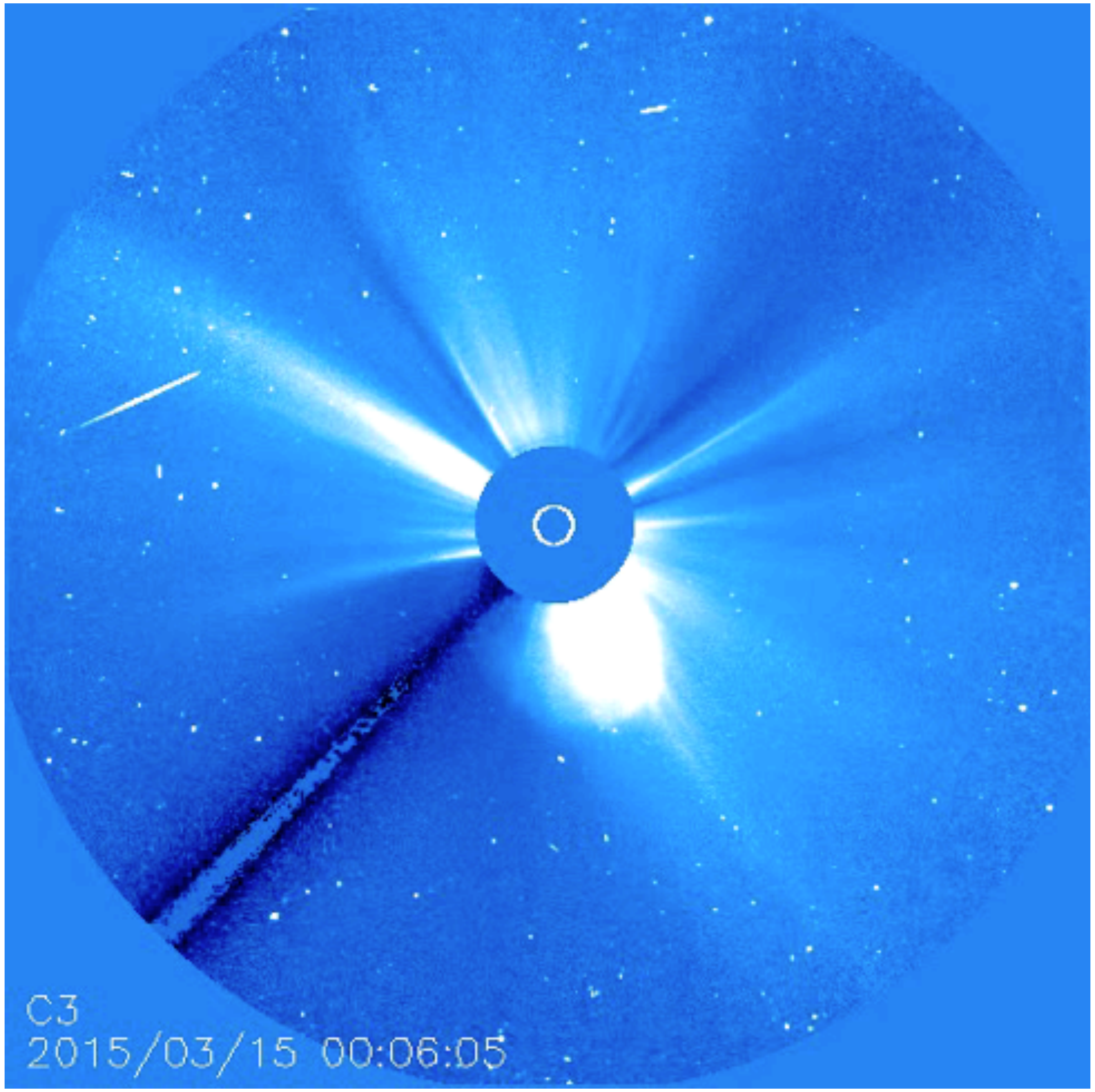
Time-Slice Analysis



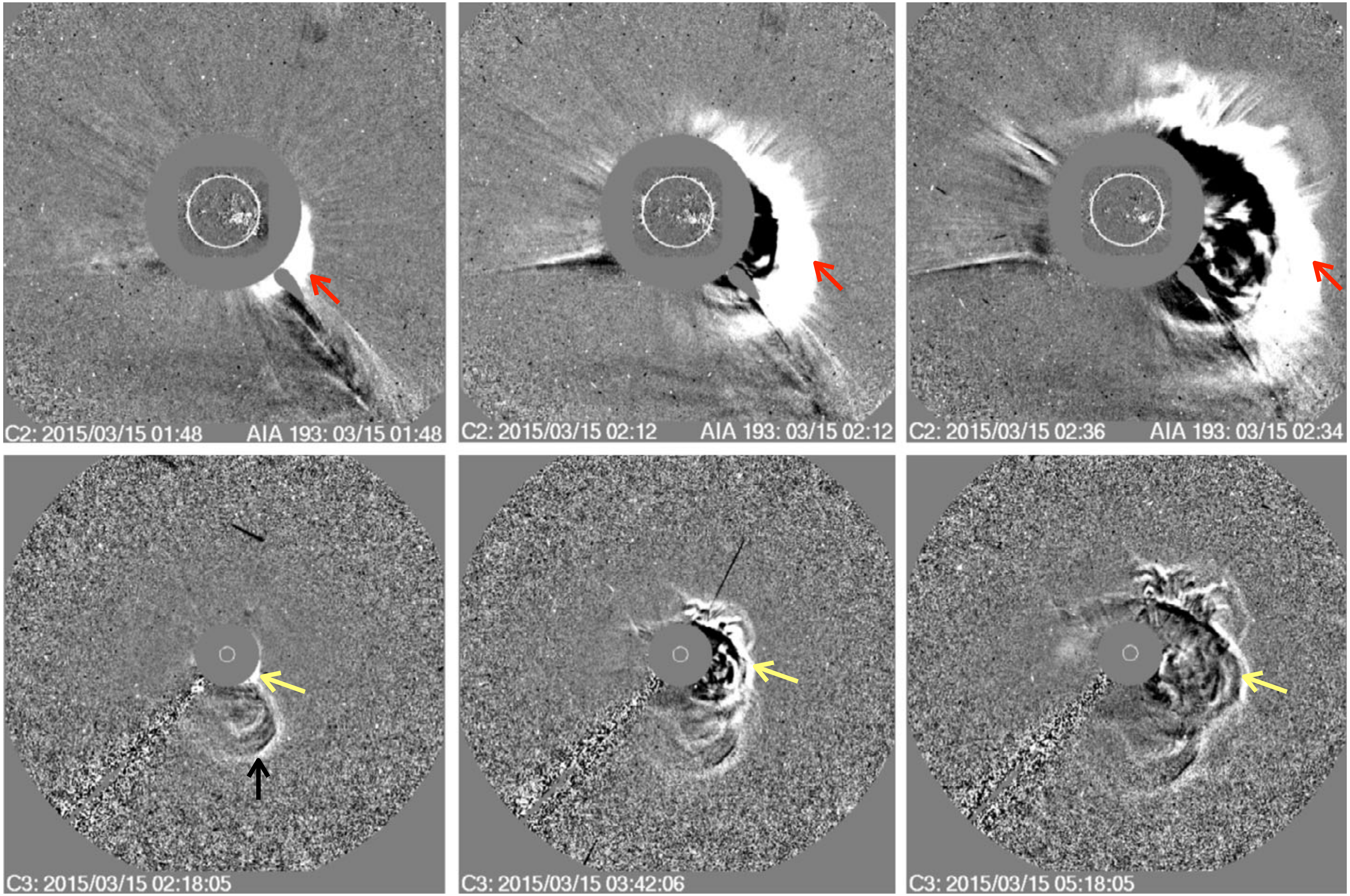
The two—step eruption is clearly visible in height-time plot

Associated CME





- **CME speed ~ 208 km/s for 14 March, 2015)**
- **CME speed ~ 719 km/s for 15 March, 2015)**

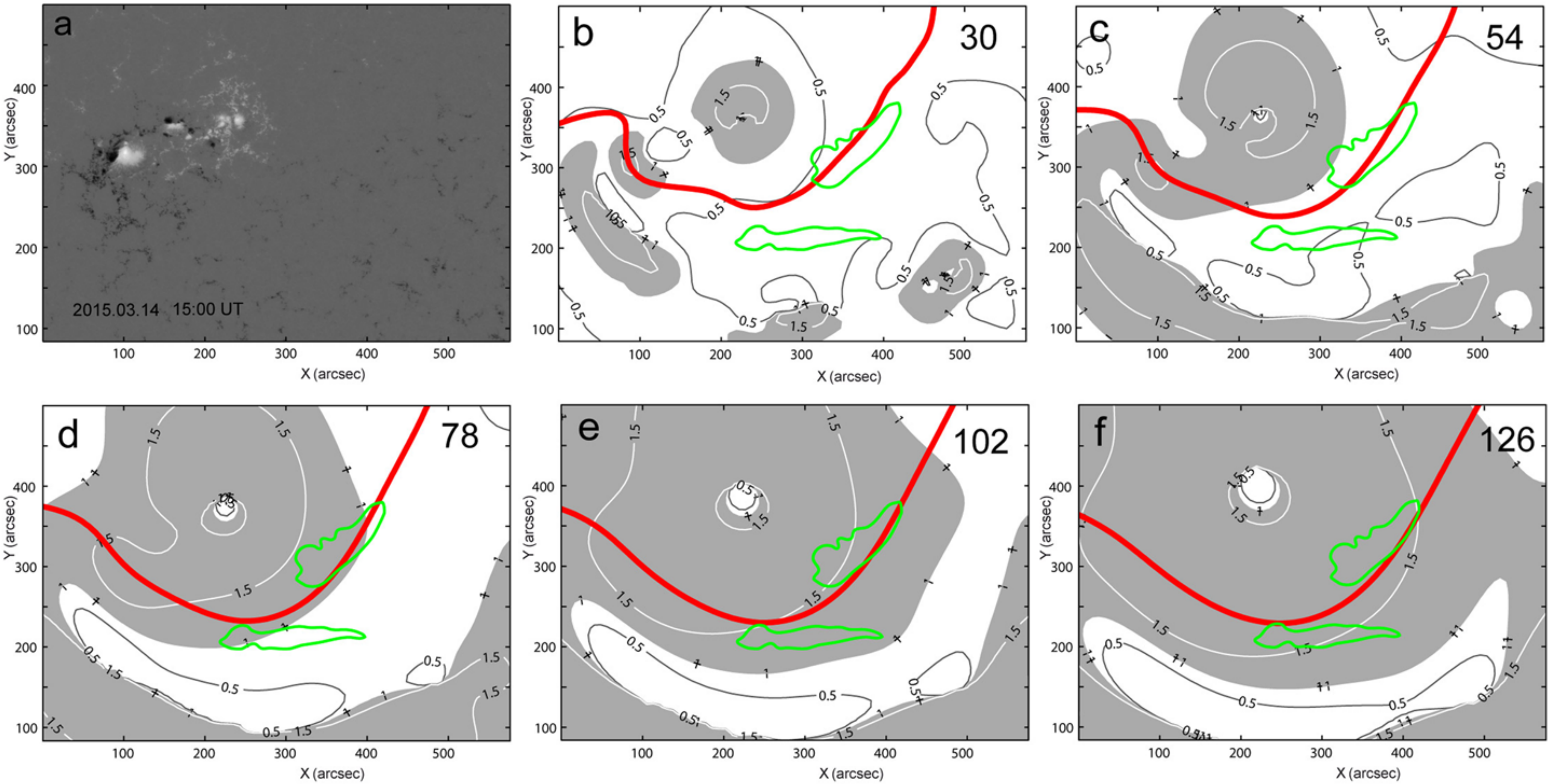


Due to the interaction of these two CMEs, on 17 March 2015 a largest geomagnetic storm (D_{st} index ≈–223 nT) of Solar Cycle 24 was observed. ***(Cho et al. (2017), Wang et al. (2016)) .***

Since the stability of the flux-rope equilibrium depends on the value of the decay index

$$n = -\frac{\partial \ln B_t}{\partial \ln h},$$

A red line indicates the position of the PILs. Areas where n > 1 are tinted with grey, while regions with n < 1 are white.



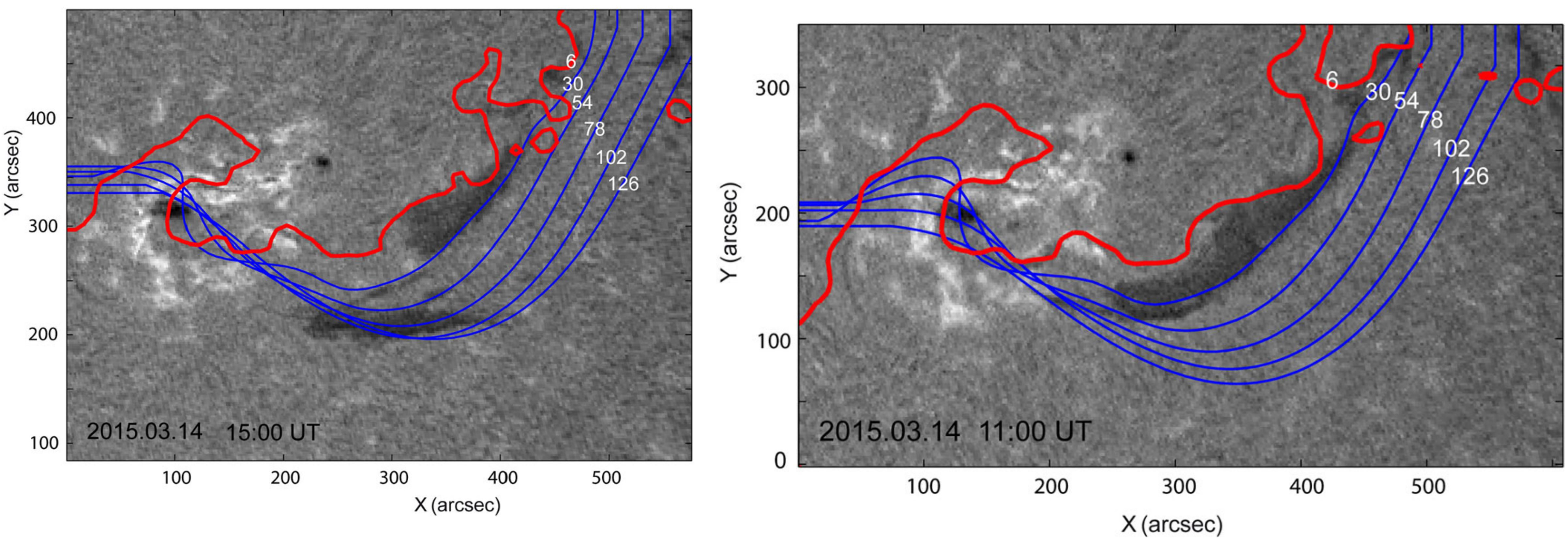
Distribution of the decay index n at different heights in Mm above the area shown in panel (a).

< 60 Mm : Condition for stable flux rope

~ 100 Mm : Condition for instability

We have estimated the heights using the method proposed by Filippov (2016b)

It is based on the assumption that the material of filaments is accumulated near coronal magnetic neutral surfaces Br = 0 (Filippov, 2016a). Comparison of the 3D shape of the neutral surface, represented in the projection on the plane of the sky as a set of PILs, with the filament shape and position allows us to obtain information about the heights of different parts of the filament including its top, or spine, which is the most reliable indicator of the flux-rope axis.



Distribution of PILs at different height (Mm) above the solar surface

Conclusions

- **The initiation of the filament eruption on 14 March 2015 and its full eruption on 15 March 2015 are associated with the jets in the active region.**

- **The decay index calculation suggests that on 14 March 2015 the filament first enters into the instability zone and after reaching some height it finds itself in the stability zone. Again on 15 March 2015 the filament enters into the instability zone and finally it erupts.**

- **The major part of filament which had not been destroyed on 14 March 2015 was activated on March 15 but could not erupt. Therefore it was a failed eruption. The coronal magnetic field calculation shows evidence that the decay index at the filament location is below the threshold of the torus instability and hence the filament fails to erupt.**

- **The observation of the same sign of the twist/helicity in the chromosphere (filaments barbs), higher solar atmosphere (sigmoid) and in the magnetic cloud evidence the conservation property of the helicity.**

- **The part of filament erupted on 14 March produced a slow partial halo CME.**

- **The destabilized part of filament on 15 March produced a medium size Halo CME. Lateron both these CMEs interact to each other and results as a largest geomagnetic storm of 17 March, 2015.**

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Thank You