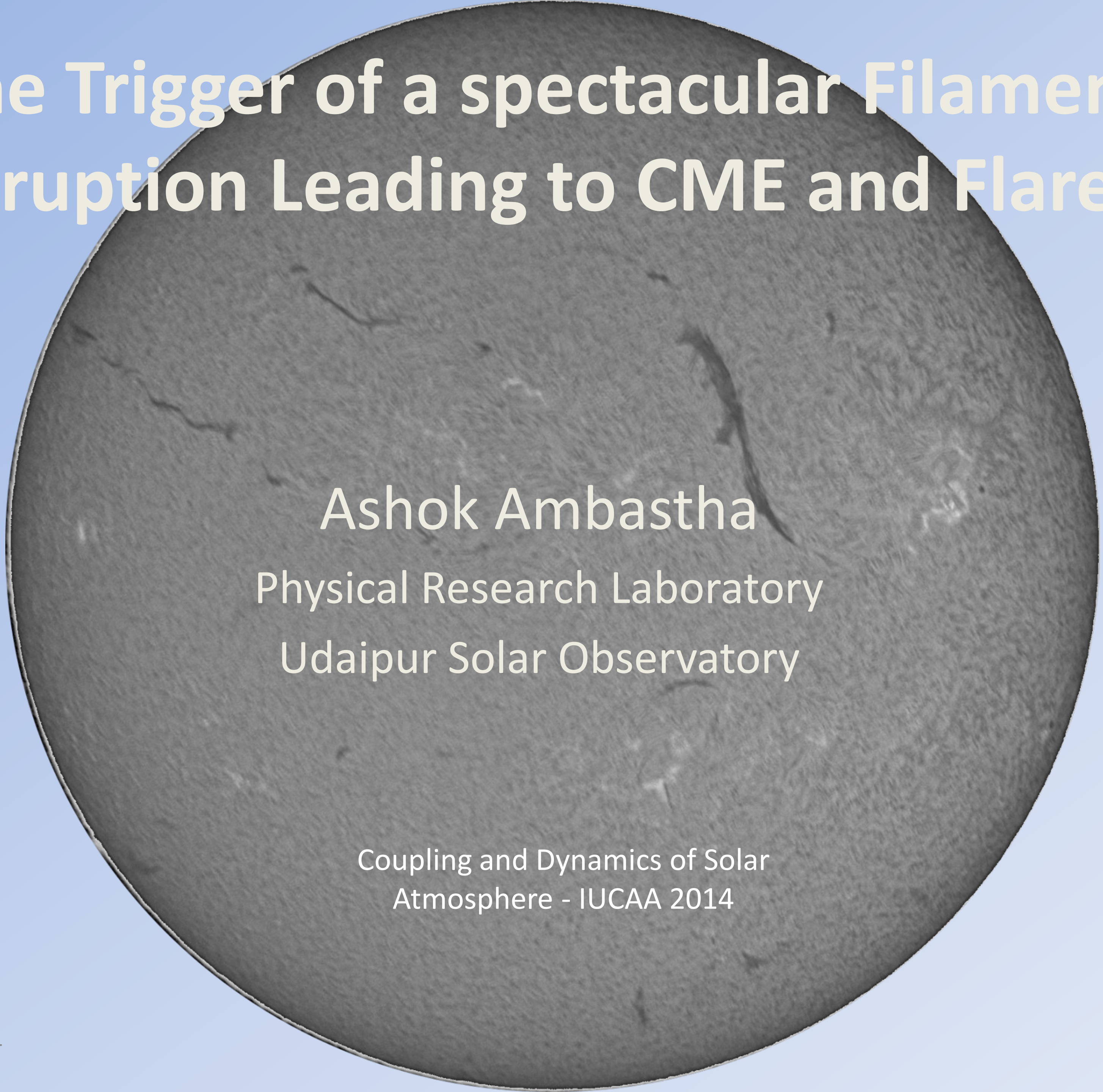

The Trigger of a spectacular Filament Eruption Leading to CME and Flare

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Coupling and Dynamics of Solar
Atmosphere - IUCAA 2014

Introduction

- Coronal mass ejections (CMEs), prominence/filament eruptions, and flares are three types of large-scale eruptive phenomena that occur in the solar atmosphere.
- It is believed that these are closely related, different manifestations of a single physical process.
- Association of CMEs and flares is not one to one. Also flares may precede or follow CMEs if they are associated. A large flare is invariably associated with a CME. (Recent large flares in super AR 2192 perhaps exceptions!)
- CMEs represent ejection of mass and magnetic flux from lower corona into the interplanetary space, and play important role in governing space weather.

Where and How do CMEs originate?

- CMEs originate from closed field regions
  Active Regions
  Filament regions
  Combination of AR and Filament regions
  Trans-equatorial interconnecting regions.

- Several CME models have been developed to describe their pre-eruption structures (or progenitors), initiations or trigger, and eruptions based on the available observations.

- Some fundamental questions - What causes a CME to erupt in the first place? The situation is similarly embarrassing as for flares.

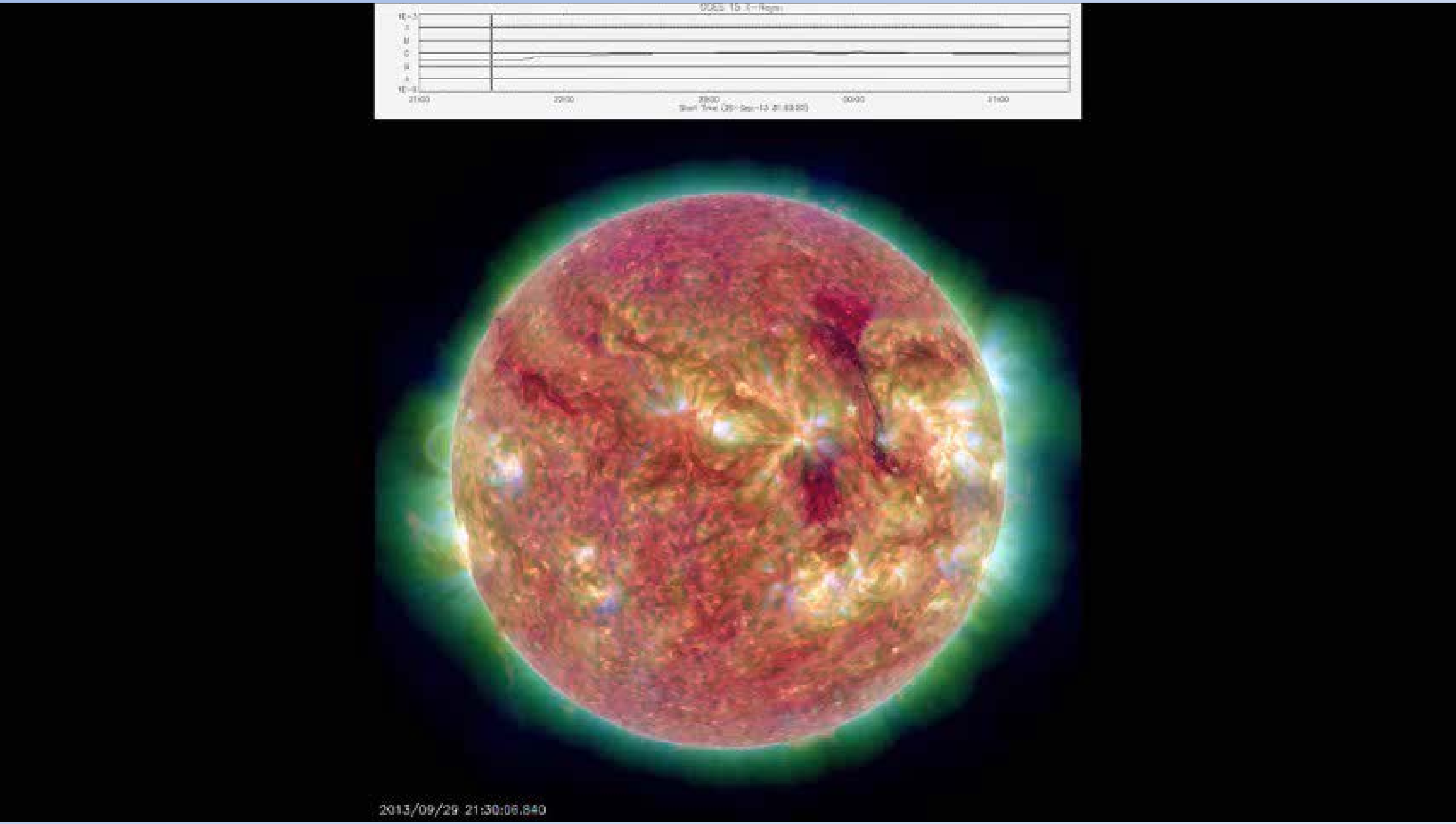
  Some candidates: the proximity of a CME site to coronal holes (Bravo et al., 1999), magnetic shear (Miki´c and Linker, 1997), filament helicity (Martin, 2003; Rust, 2003), sigmoids (Rust and Kumar, 1996; Moore et al., 2001).

- In order to disentangle the various processes around CME initiation new observations with significantly better resolution are required.

- We present some results on a long, dark quiescent filament, located in a spot-less, weak magnetic field region in the solar NW-quadrant that transited the solar disk during 20-29 September 2013.

The Event: SDO AIA 171-304

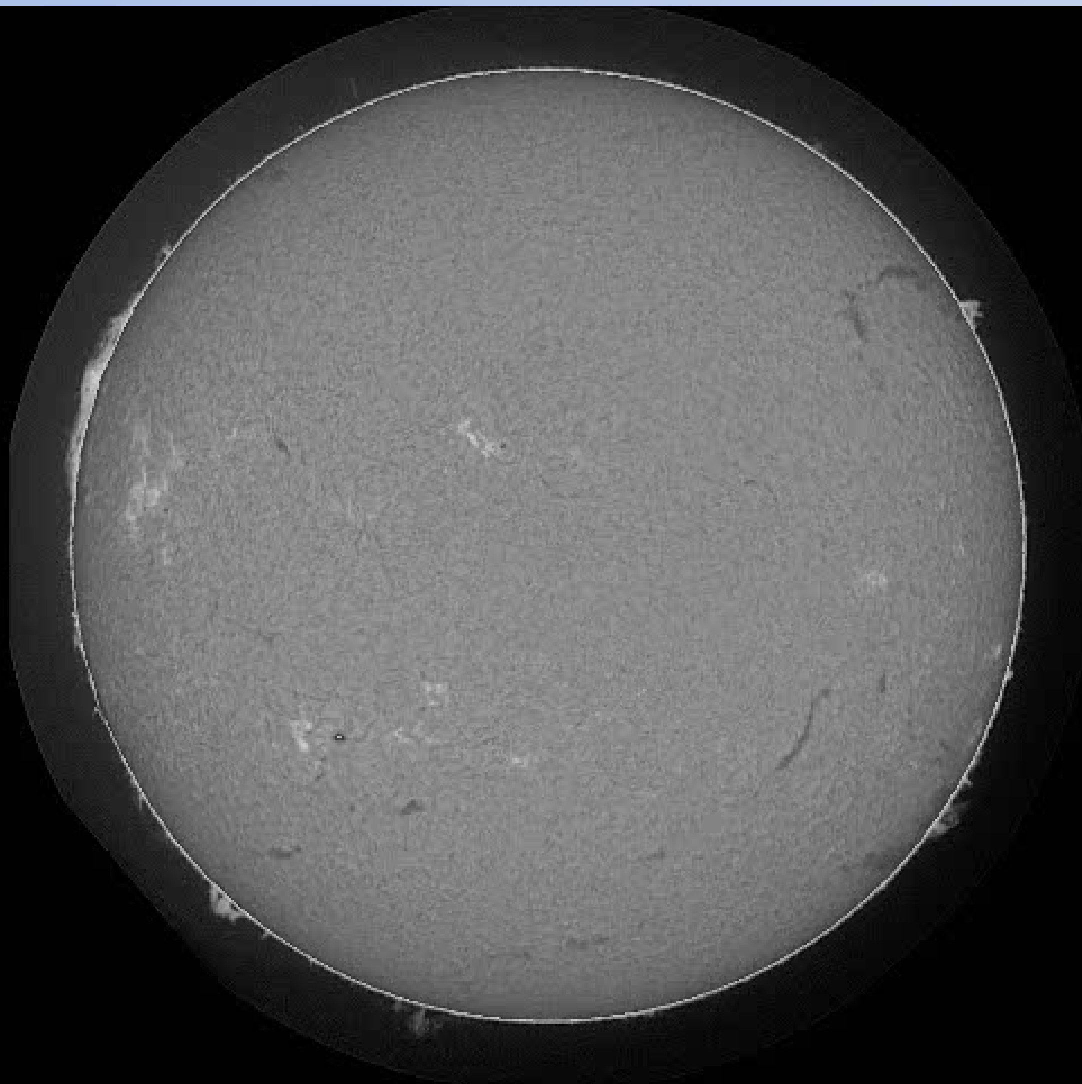
2013-09-29/16:00 - 2013-09-30/03:55 UT



The Evolution of Filament and Eruption

After several days of inactive phase, the filament began restructuring and activation and eventually erupted on 29 September 2013/21:22 UT. This eruption was seen in Hα images as sudden disappearance of the filament, historically known as a `disparition brusque' event.

2013-09-21/29 Daily | 2013-09-29/01:00-19:00 Hourly | 2013-09-29/19:00-24:00 10-min

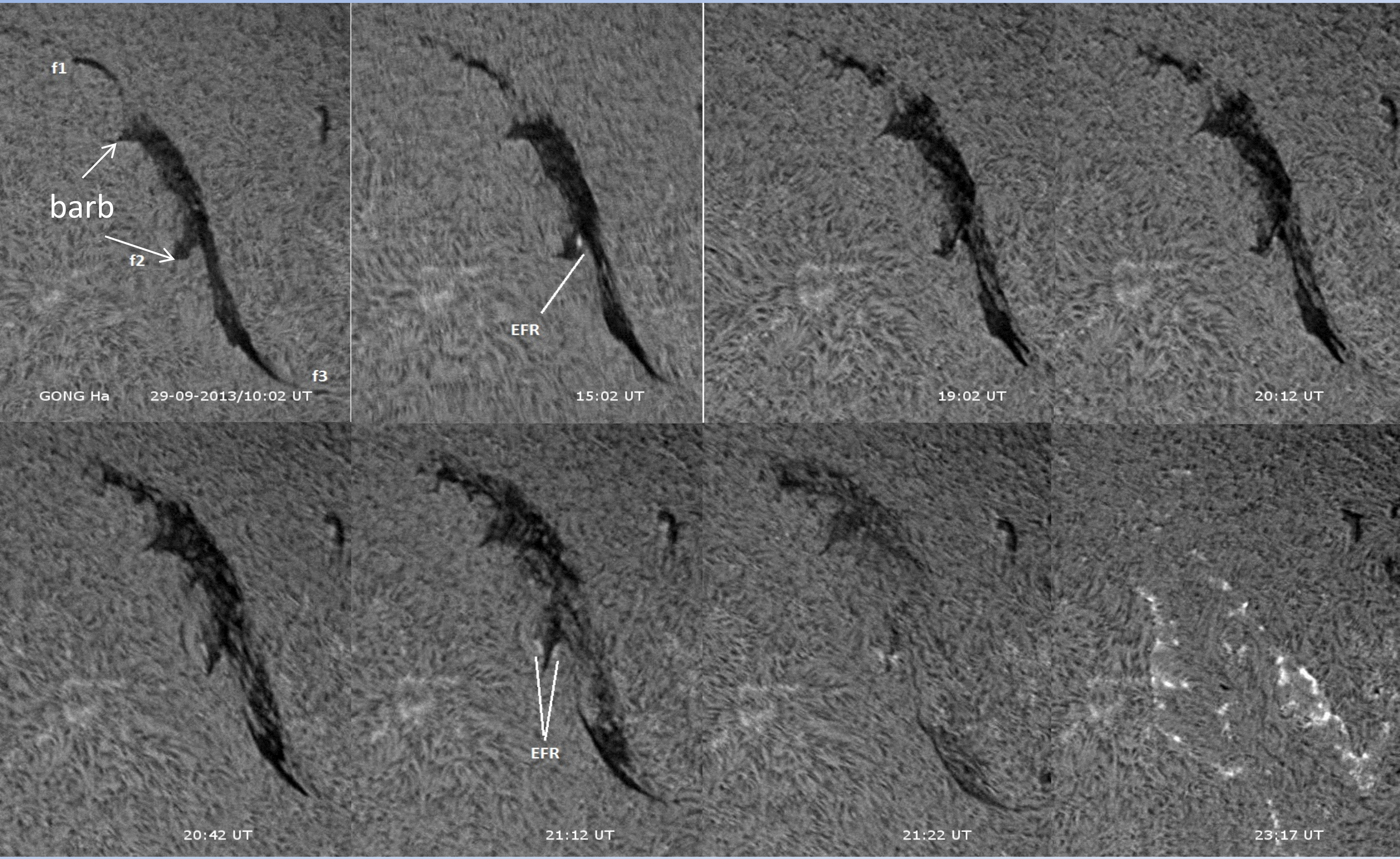


Pre-eruption Evolution

- Substantial Flux emergence near filament before eruption;
  - polarity of new flux favorable for reconnection (Feynman & Martin, 1995)
  - Confirmed by numerical simulation studies (Chen & Shibata, 2000)
- Significant changes in photospheric flux in small areas in the eruption region (Lara et al., 2000)
- However, CMEs without flux emergence are also observed (Subramanian & Dere, 2001; Wang & Sheeley, 1999)
- Reconnection - favoring flux emergence

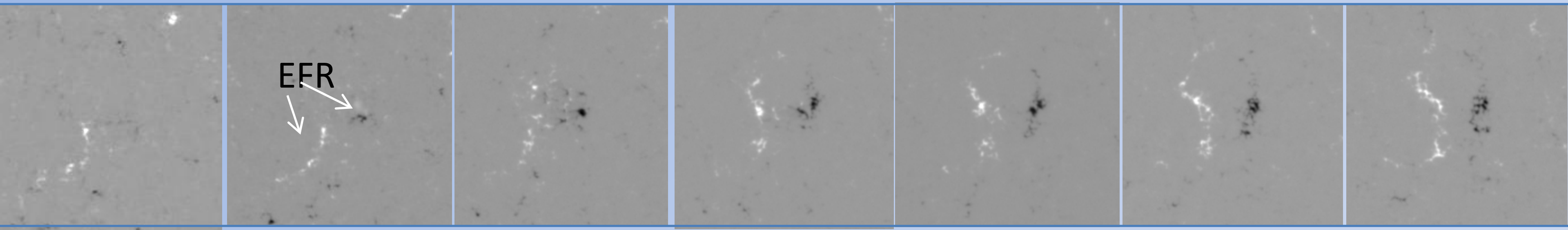
GONG H-alpha

Disparition Brusque



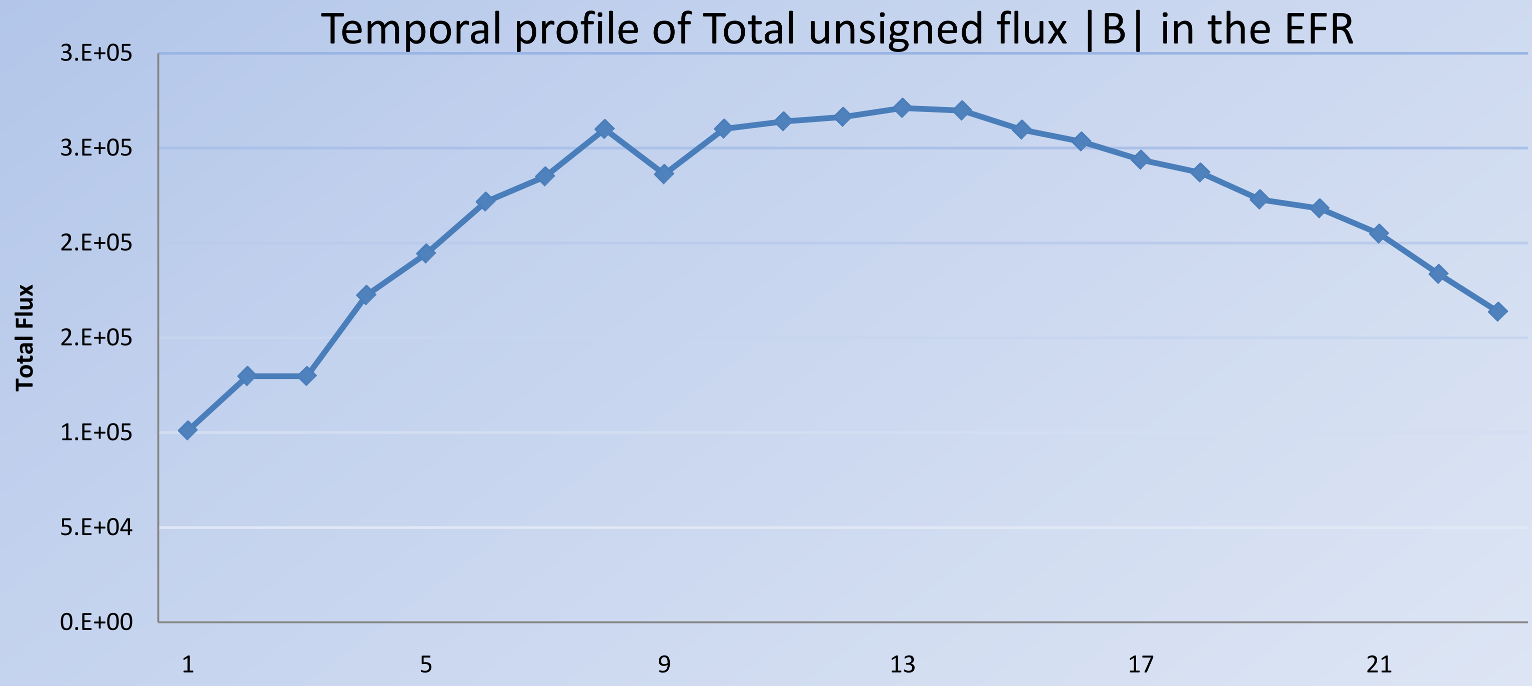
GONG Hα images clearly show a brightening adjacent to the filament's central barb, f2. This is the signature of a new emerging magnetic flux region (EFR), a small bipole.

Growth and Decay of the Emerging Bipolar Flux



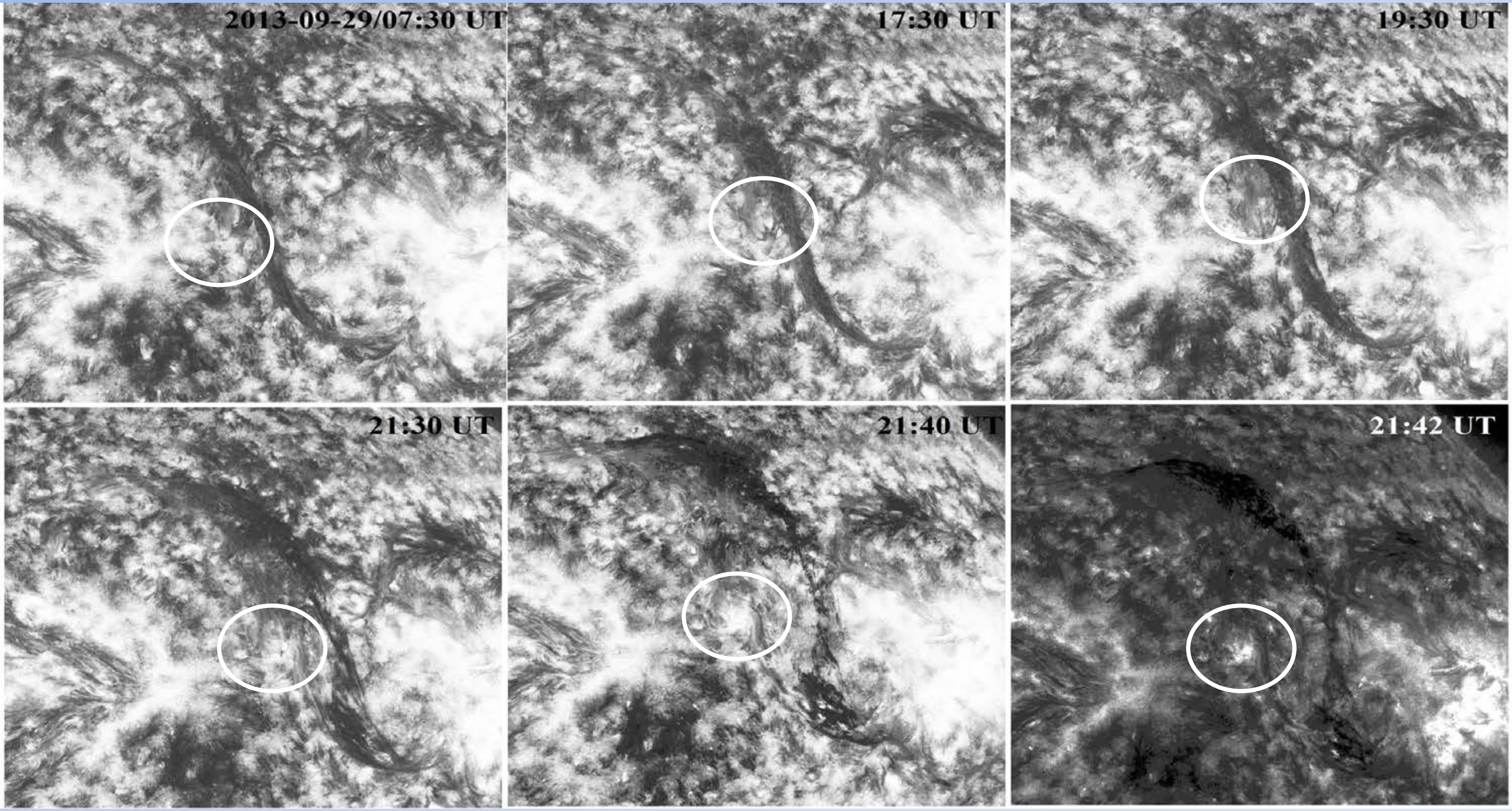
28/21:00 29/00:00 04:00 08:00 12:00 16:00 20:00 UT

SDO-HMI magnetogram movie indicated the first sign of emerging flux region (EFR) of both signs at the rate of 13.3 (-74.1) Mx/hr on 29 September 2014/02:34 UT over an area of ~1.9 x 10^8 km^2. This process increased both in rate and area with time, reached a peak ~13-15 UT and began decreasing.



The Filament Eruption and CME

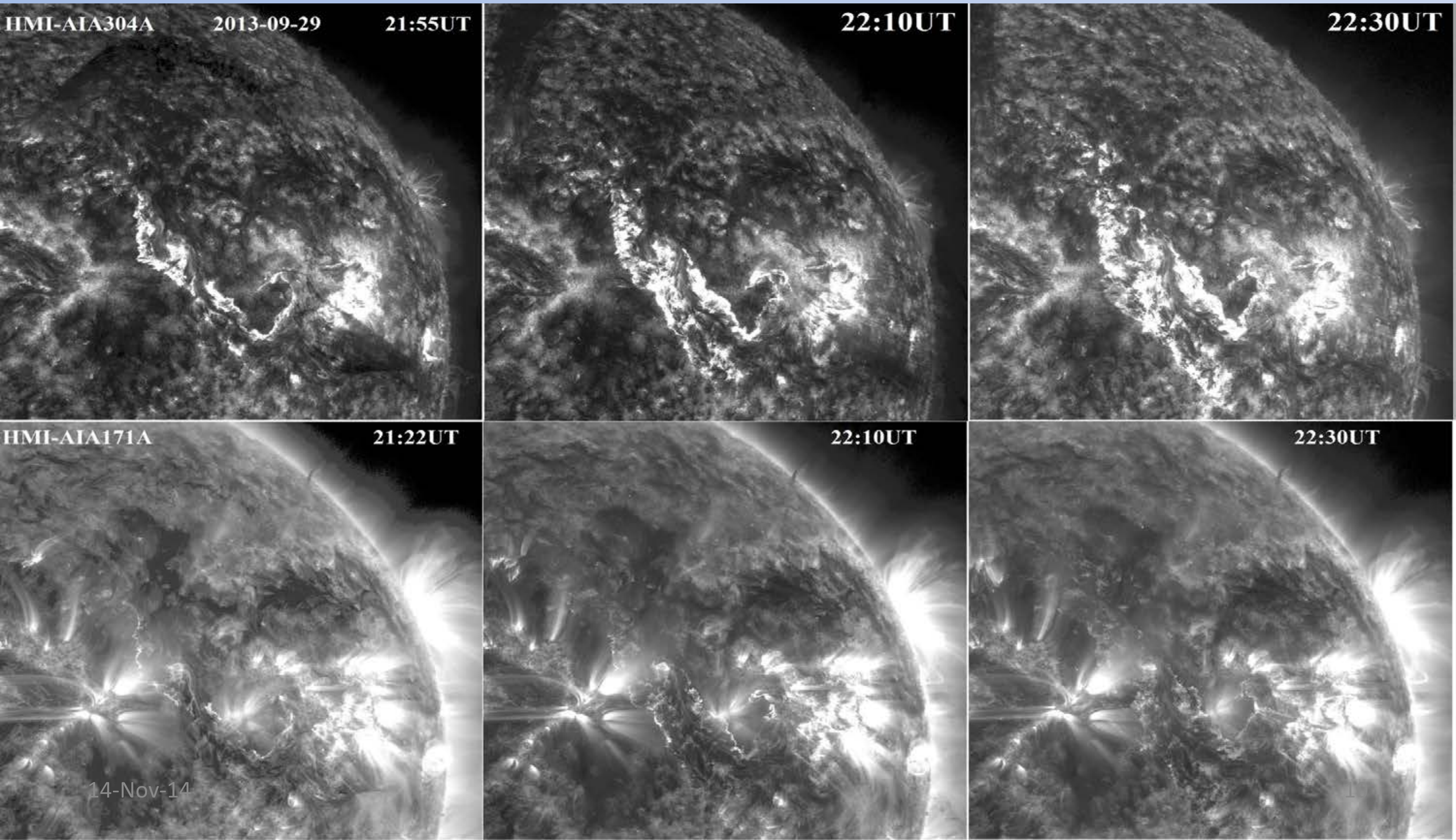
On the other hand, SDO-AIA UV and EUV images showed upward lifting of filament from the site of EFR but fixed at legs f1/f3 which gave rise to a CME travelling at a speed of approximately 900 km/s.

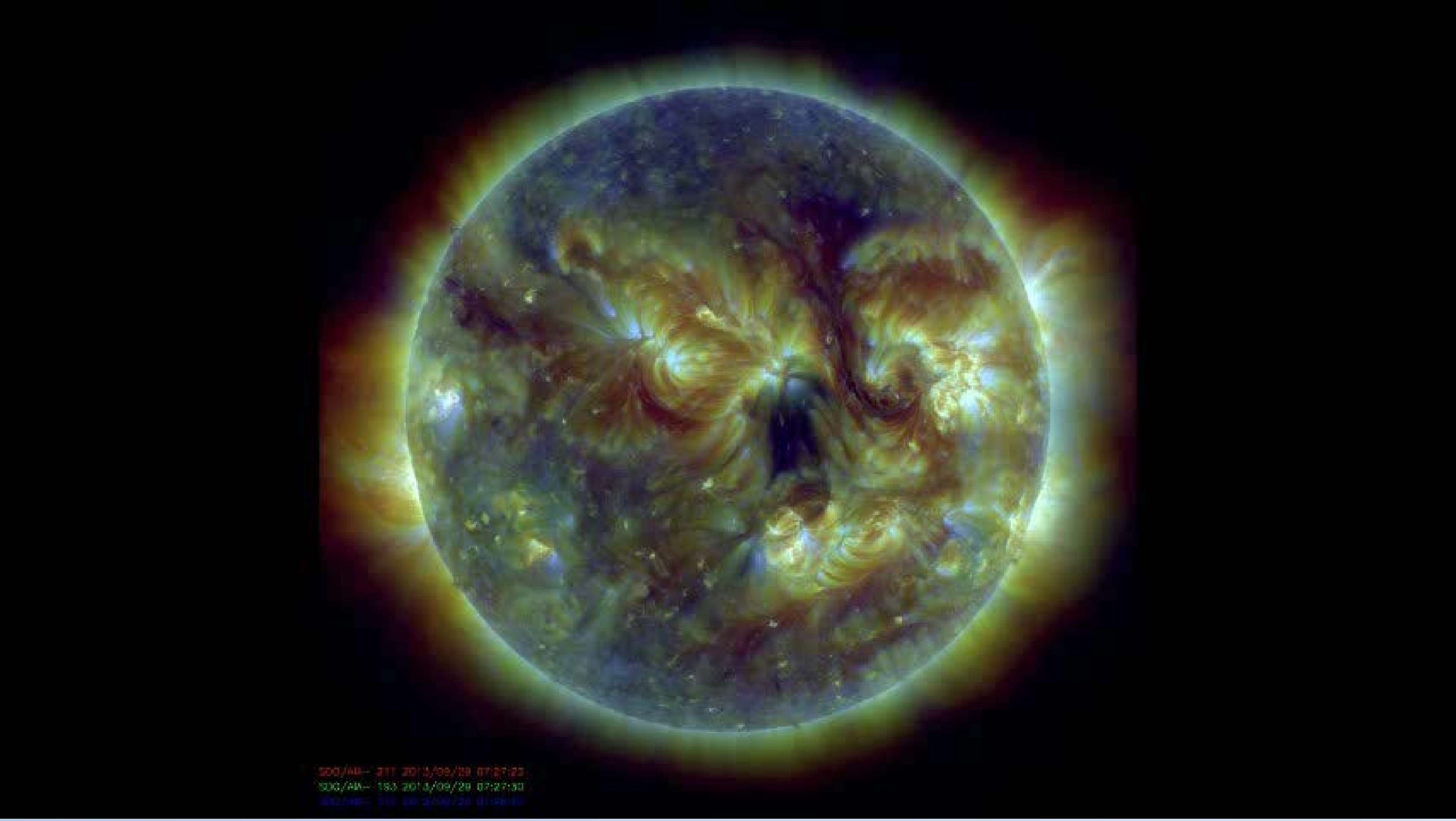


The SDO AIA 304A (50,000 K- upper Chromosphere/Transition region) images further confirm the EFR, which destabilized the filament barb, flux rope and caused its eventual eruption.

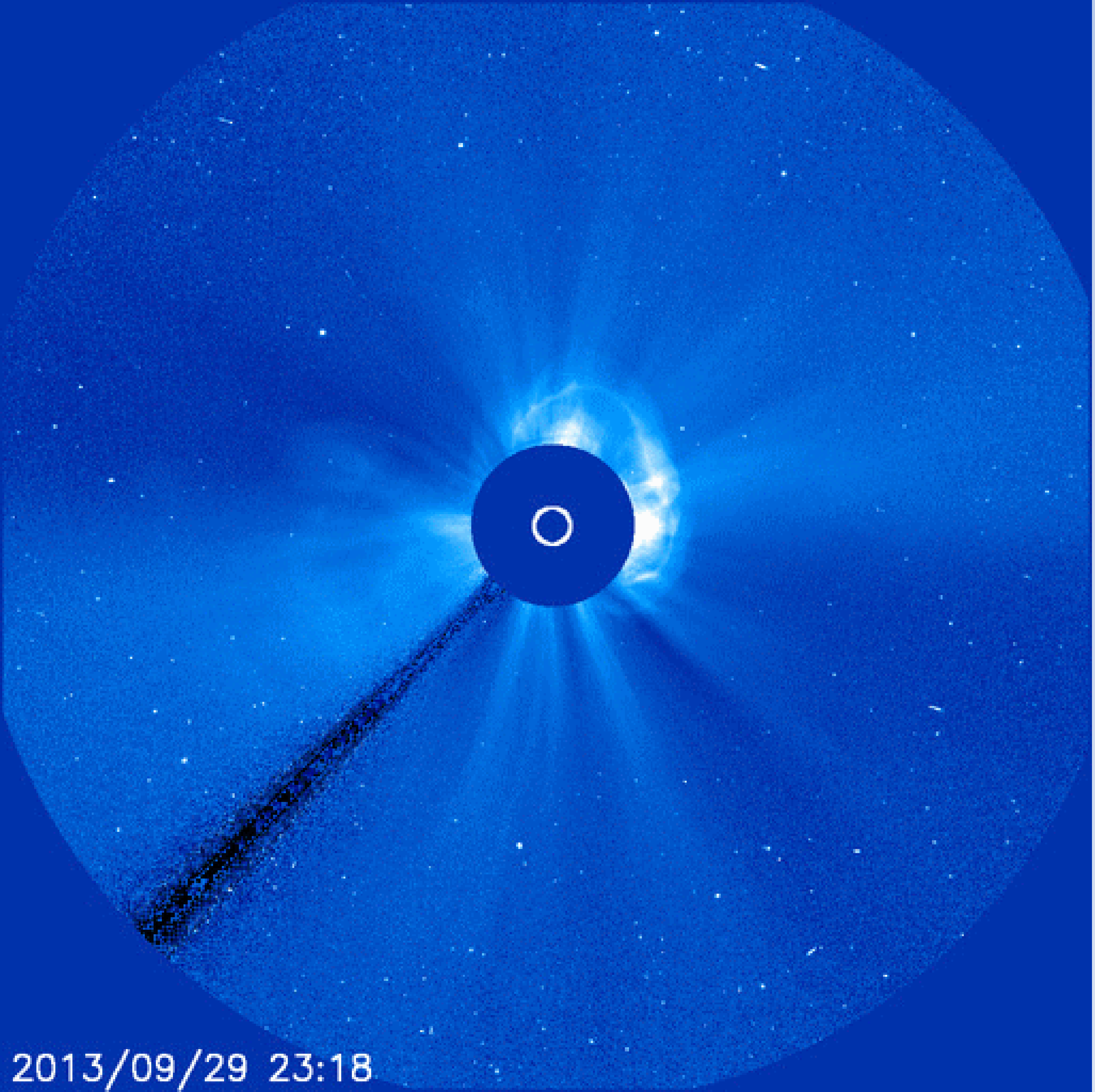
The CME and subsequent Flare

After a lapse of over 20 minutes of the filament's eruption and CME's launch, a classic long-duration, moderate C-class two-ribbon flare started developing at 21:43UT along the magnetic neutral line delineated by the filament. The flare lasted over 3 hours.



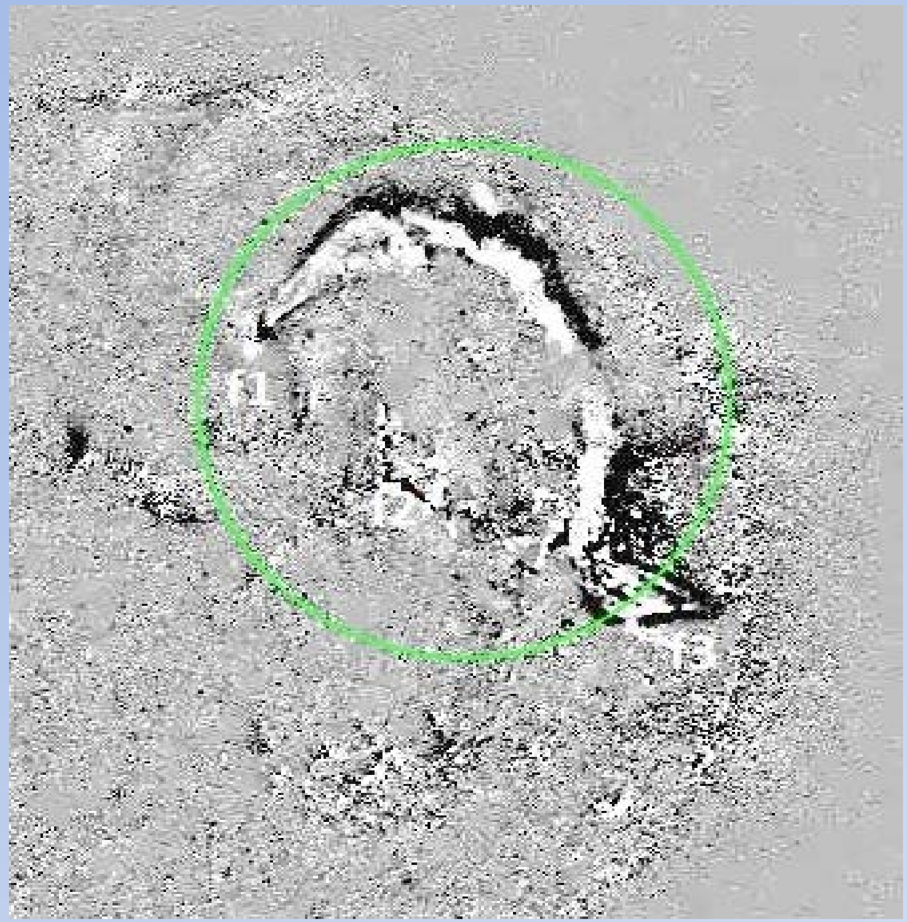


- As the flare progressed, host of post-flare loops formed during the decay phase linking the two-ribbons of the flare separating out with time.
- This indicated a reconnection process taking place below the erupting filament/CME much after the filament eruption occurred.



It was associated with a moderate proton event that continued over next several days severely affecting the space weather.

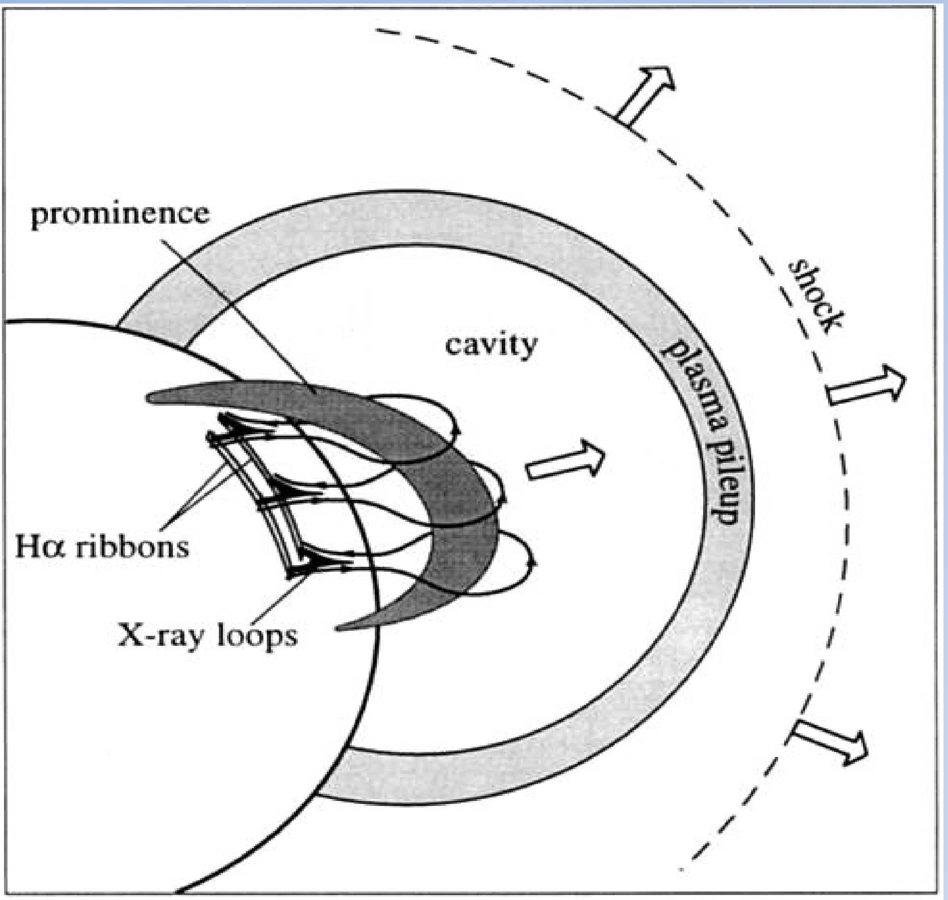
Proba2/SWAP 174A difference image of the filament eruption at 21:57 UT.



The difference images clearly show detachment of the filament and its rise at `f2', i.e., the site of EFR, while it remained connected at its two extreme legs `f1' and `f3'.

It is thus evident that the EFR destabilized the pre-existing magnetic structure at the barb site and triggered eruption of the twisted flux rope structure of the filament, leading to a bodily transport of its flux system into the corona and onwards into the interplanetary space as a CME.

Conclusions



Relationship between the filament eruption, H-alpha flare ribbons, and the CME (adopted from Forbes 2000)

- The filament was clearly the progenitor of the ensuing CME. It represented a twisted flux rope structure holding the filament in equilibrium by overlying field lines-tied to the solar surface.
- The emerging flux region near the filament channel destabilized this flux rope by the ensuing rearrangement of magnetic field structures and loss of equilibrium.
- The magnetic field lines spanning over the flux rope stretched up as the flux rope rose upwards, leading to the formation of anti-parallel field lines of opposite sign below the flux rope approaching each other.

•A current sheet formed between the approaching upwards-downward field lines, known to be susceptible to microscopic instabilities which enable resistive or collisionless fast magnetic reconnection. *The observed two-ribbon flare in the region below is indicative of this reconnection process.*

•The magnetic reconnection resulted in cutting the line-tied magnetic field lines that removed the restraint for the flux rope, and facilitated rapid eruption and upward acceleration of the flux rope.

•As a portion of the overlying magnetic loops stretched up extending to the inter-planetary space along with the flux rope, the magnetic structures near the two extreme legs `f1' and `f2' of the flux rope slipped onto the solar surface, clearly demonstrated by the SDO-AIA and Proba2 images.

•This eruption is consistent with the standard CME model.

Thank you