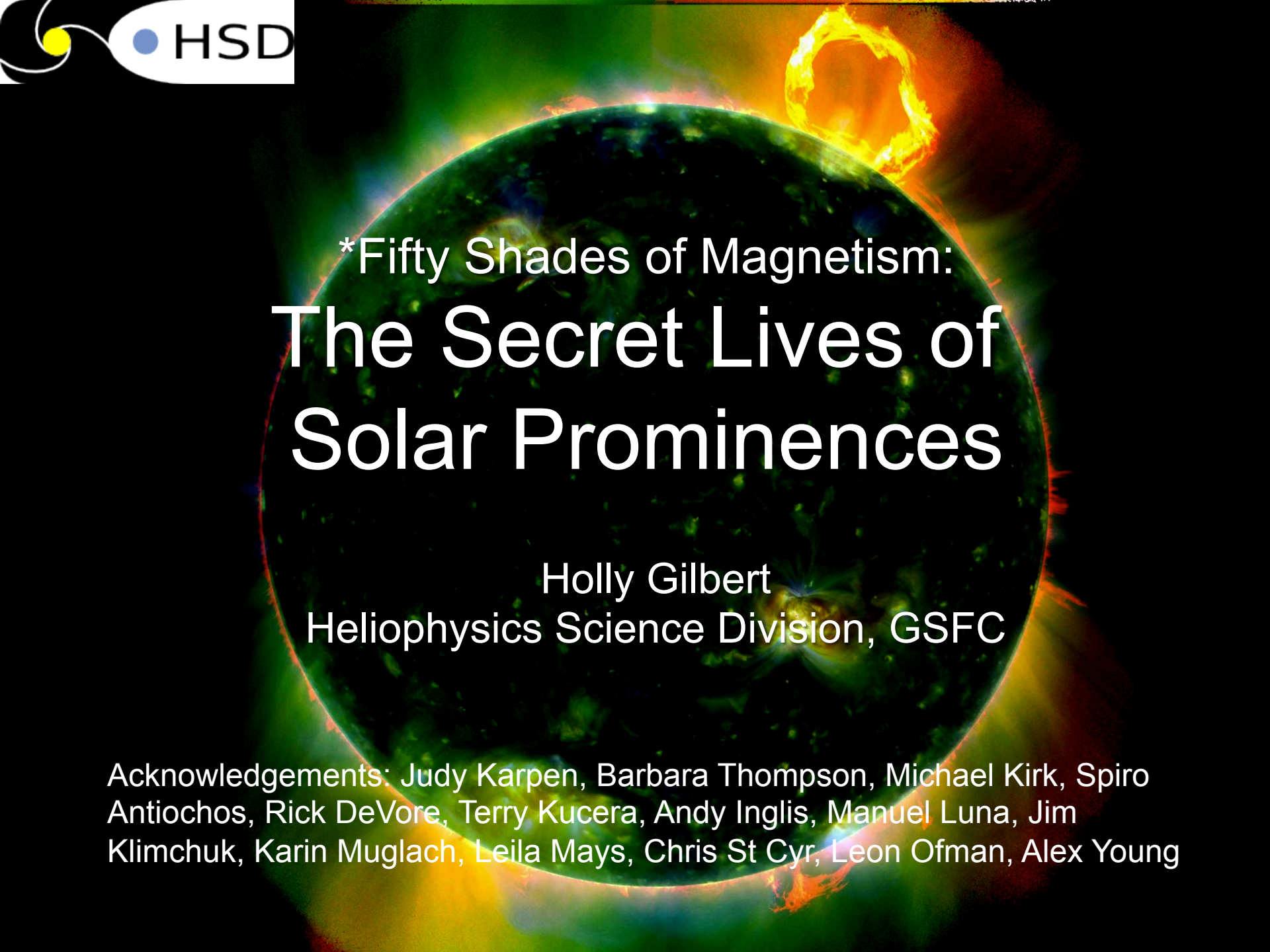


*Fifty Shades of Magnetism:

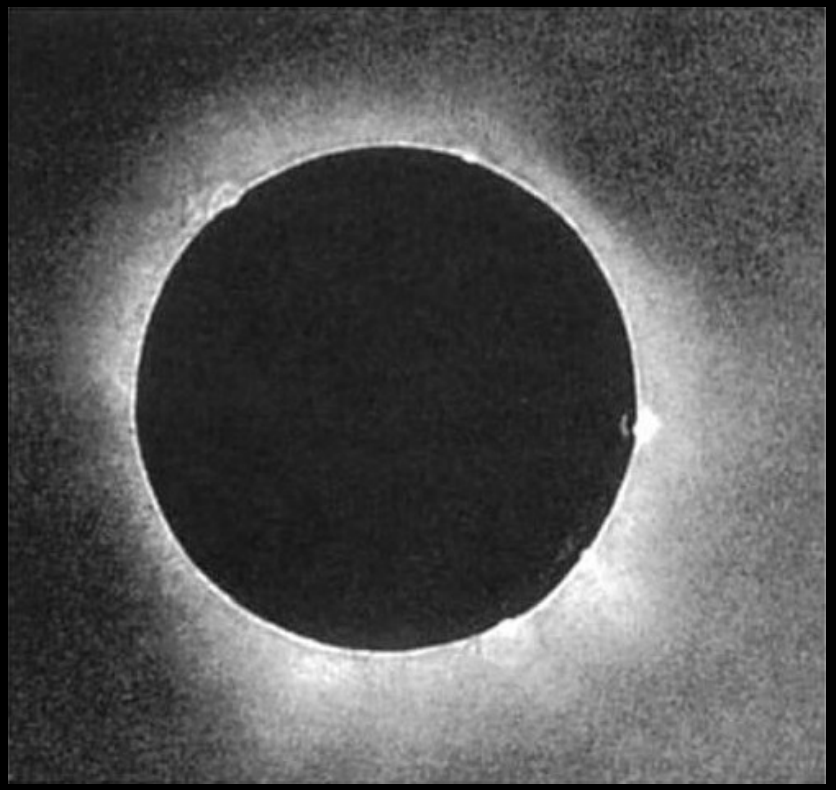
The Secret Lives of Solar Prominences

Holly Gilbert
Heliophysics Science Division, GSFC

Acknowledgements: Judy Karpen, Barbara Thompson, Michael Kirk, Spiro Antiochos, Rick DeVore, Terry Kucera, Andy Inglis, Manuel Luna, Jim Klimchuk, Karin Muglach, Leila Mays, Chris St Cyr, Leon Ofman, Alex Young

Historical perspective

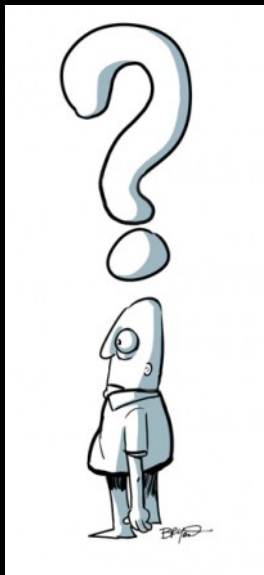
"Burning holes"
"Red flames"

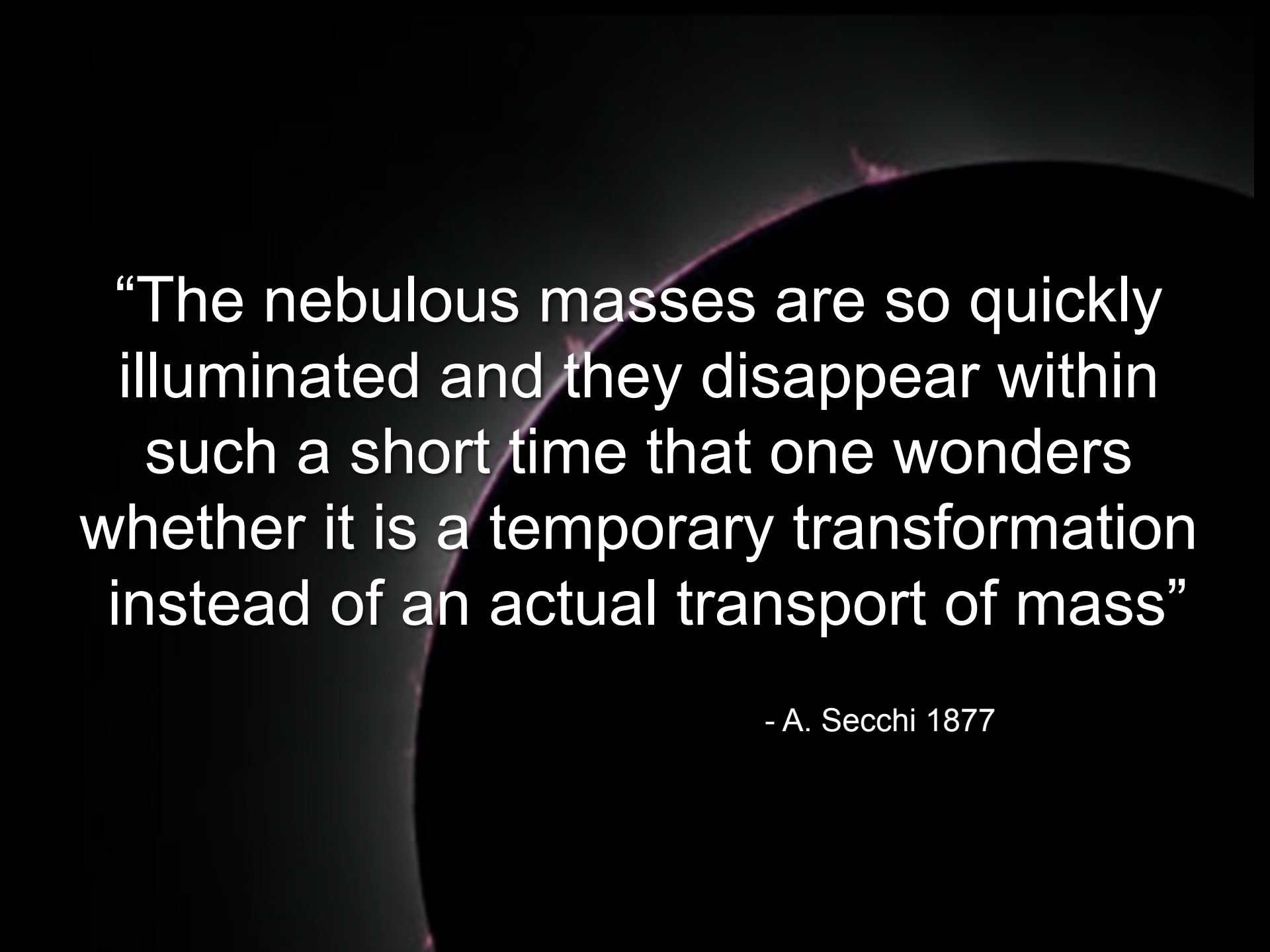


First photograph of solar eclipse 1851
(Berkowski)

Historical perspective: questions of the day

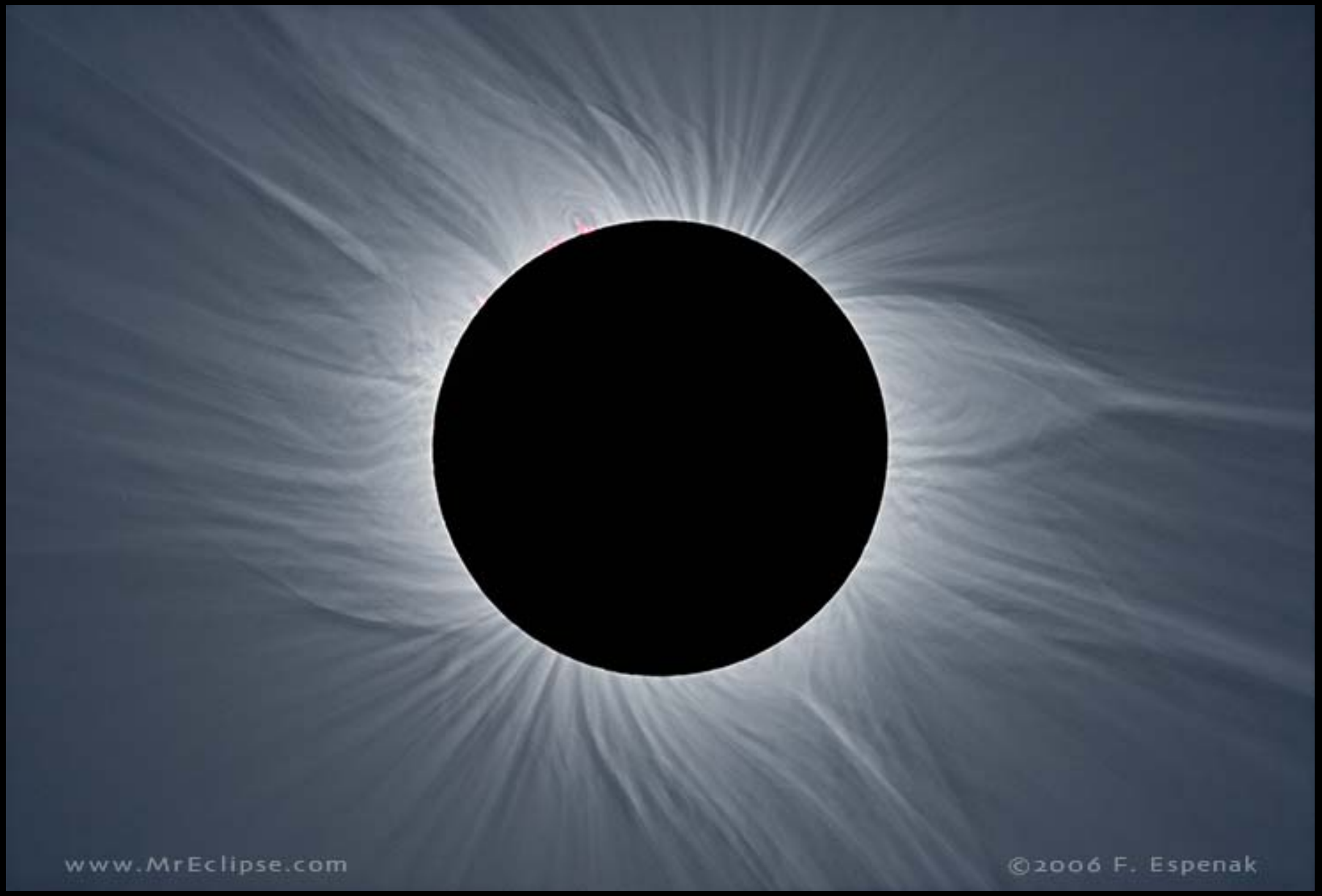
- Are these structures clouds on the Sun? On the moon?
- How are they connected to the Sun?
- Why do they appear red or pink?

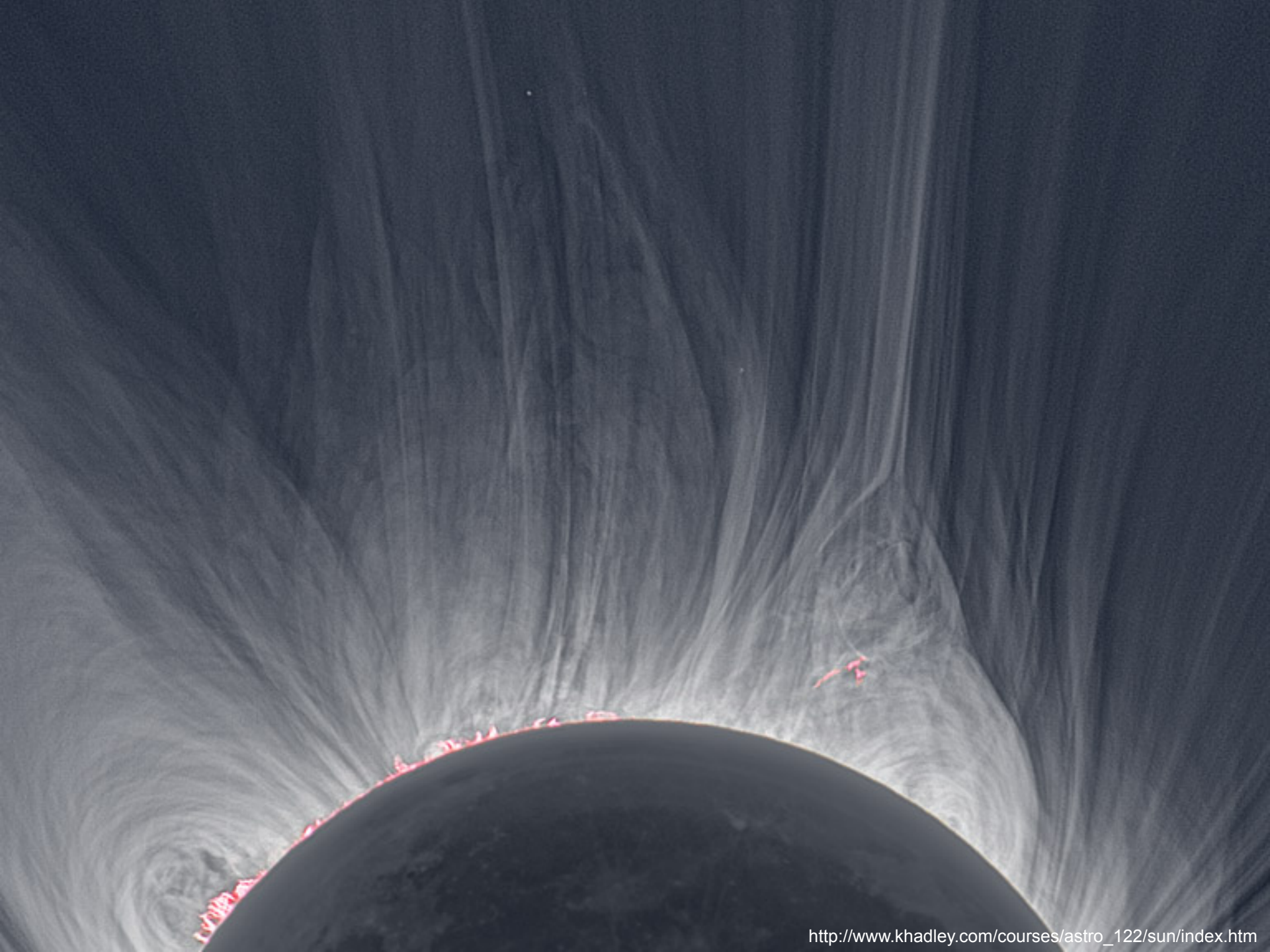



“The nebulous masses are so quickly illuminated and they disappear within such a short time that one wonders whether it is a temporary transformation instead of an actual transport of mass”
- A. Secchi 1877

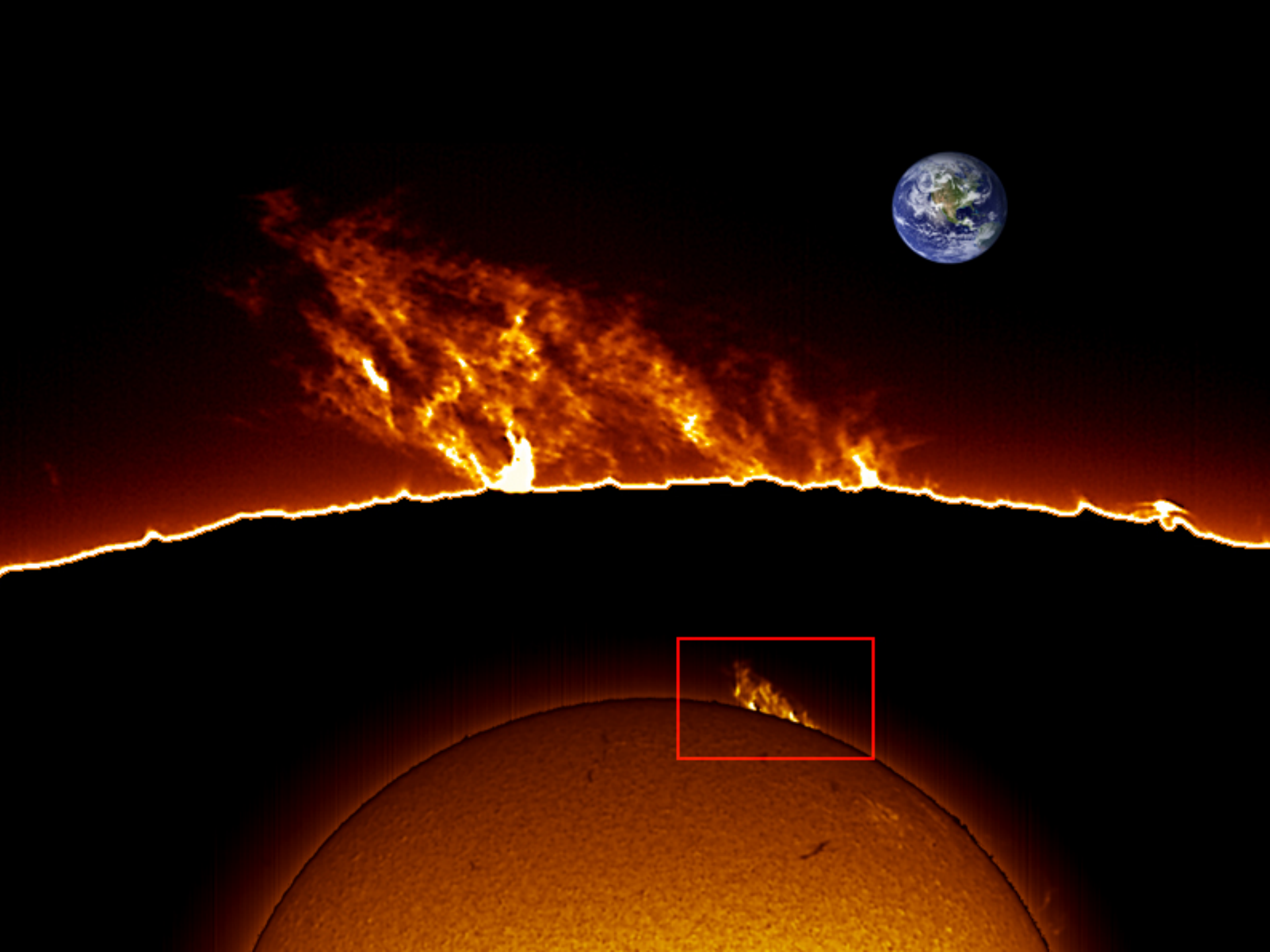
1999, France- image by Luc Viatour.

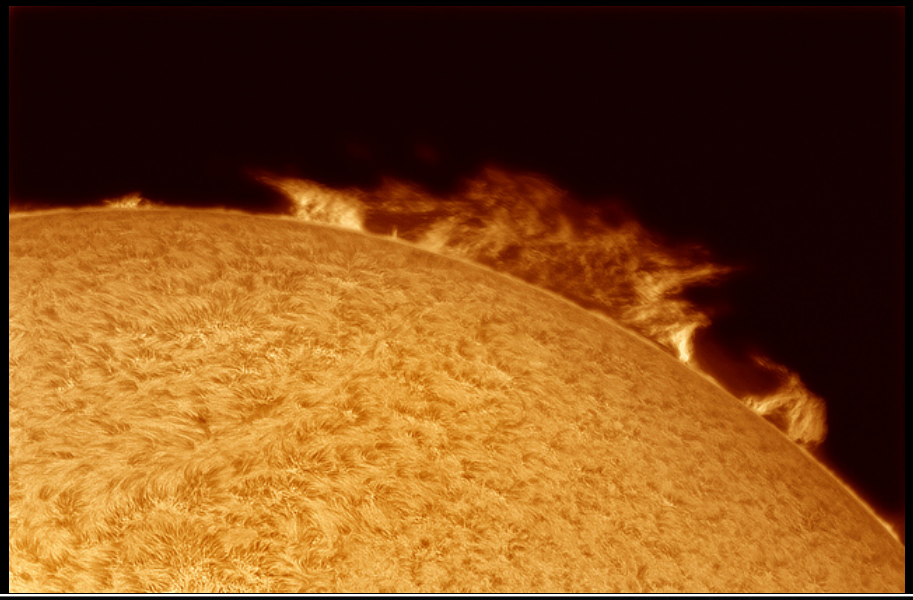
Composite - 22 images

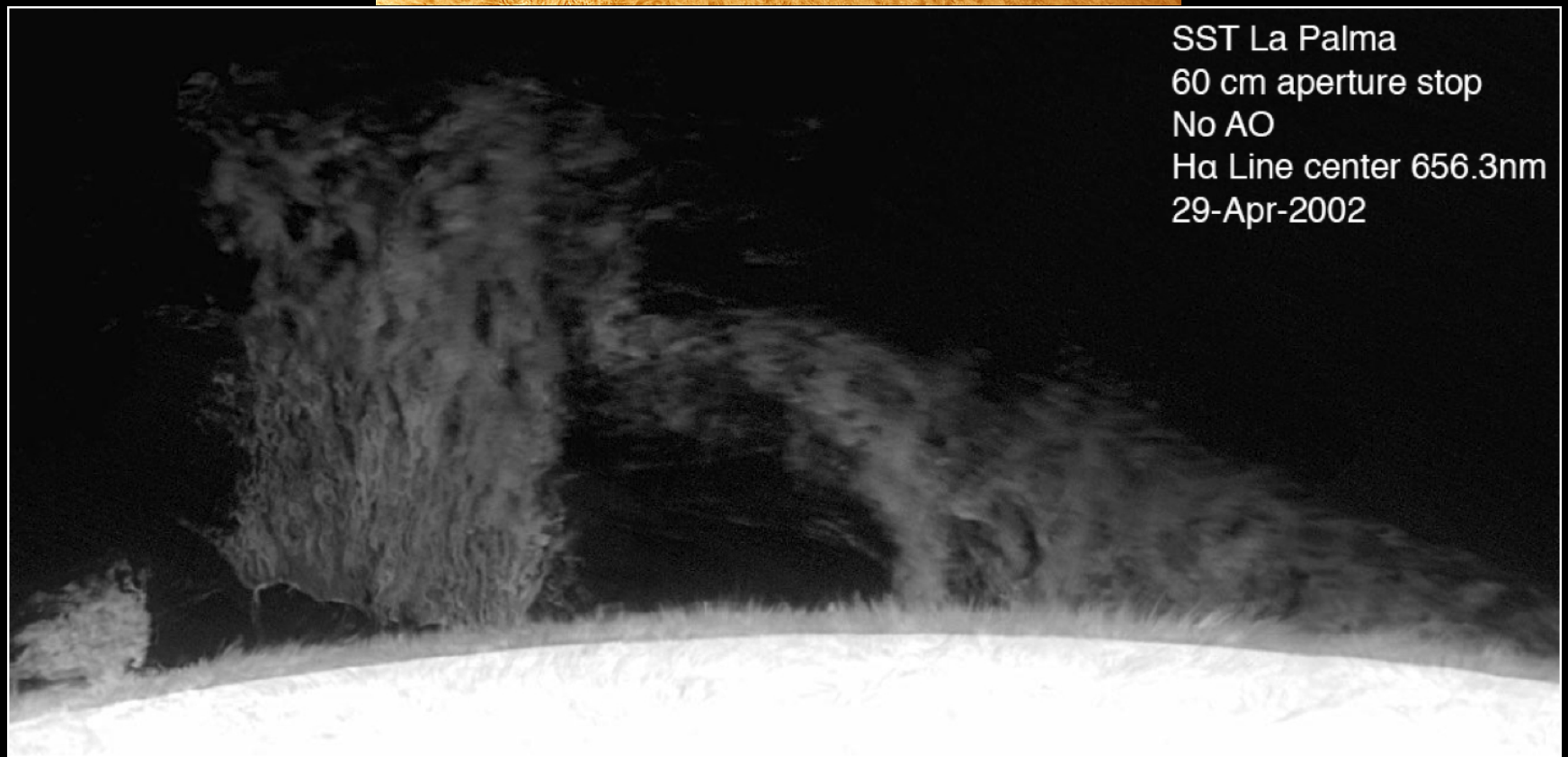




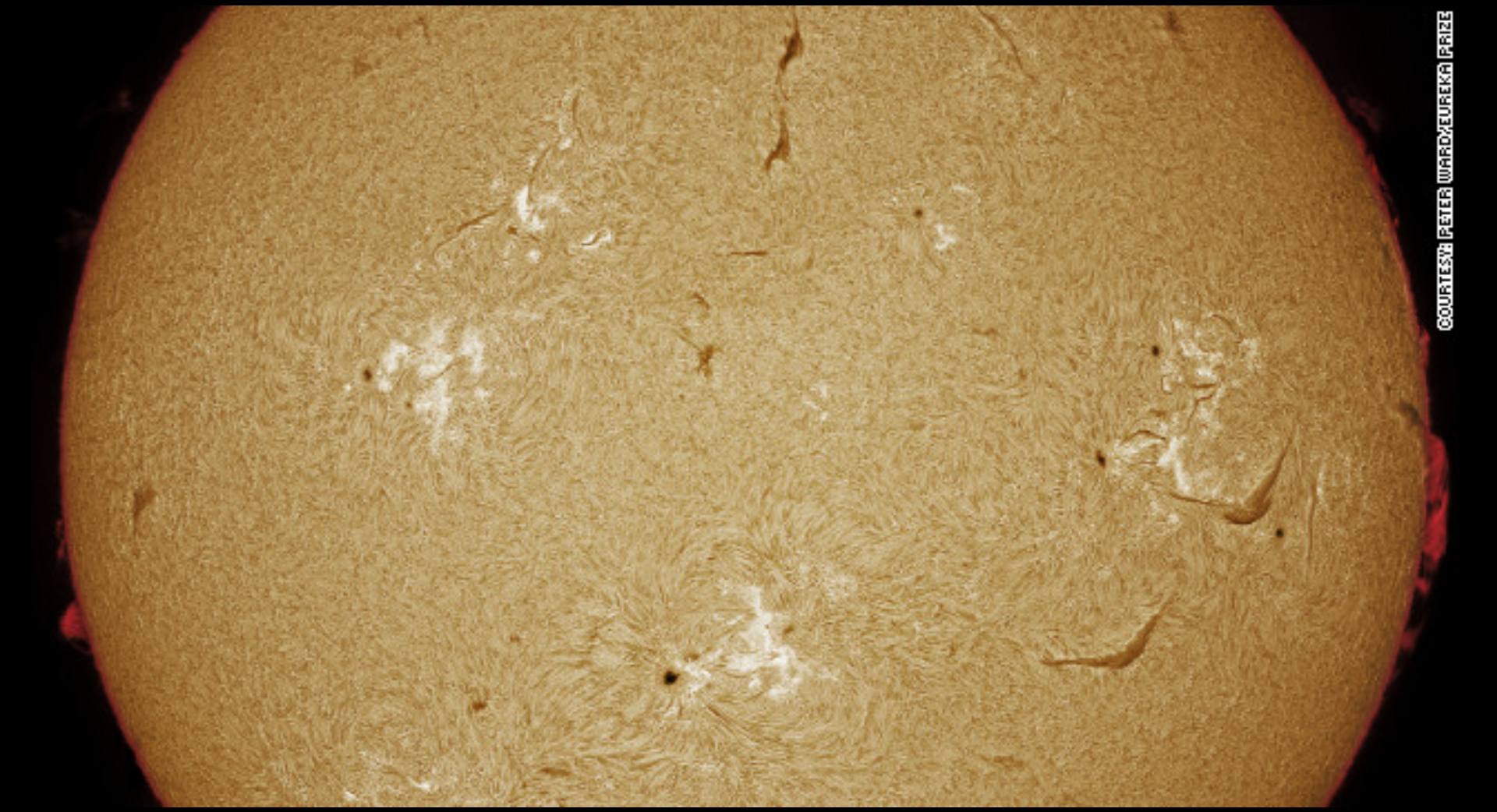
http://www.khadley.com/courses/astro_122/sun/index.htm

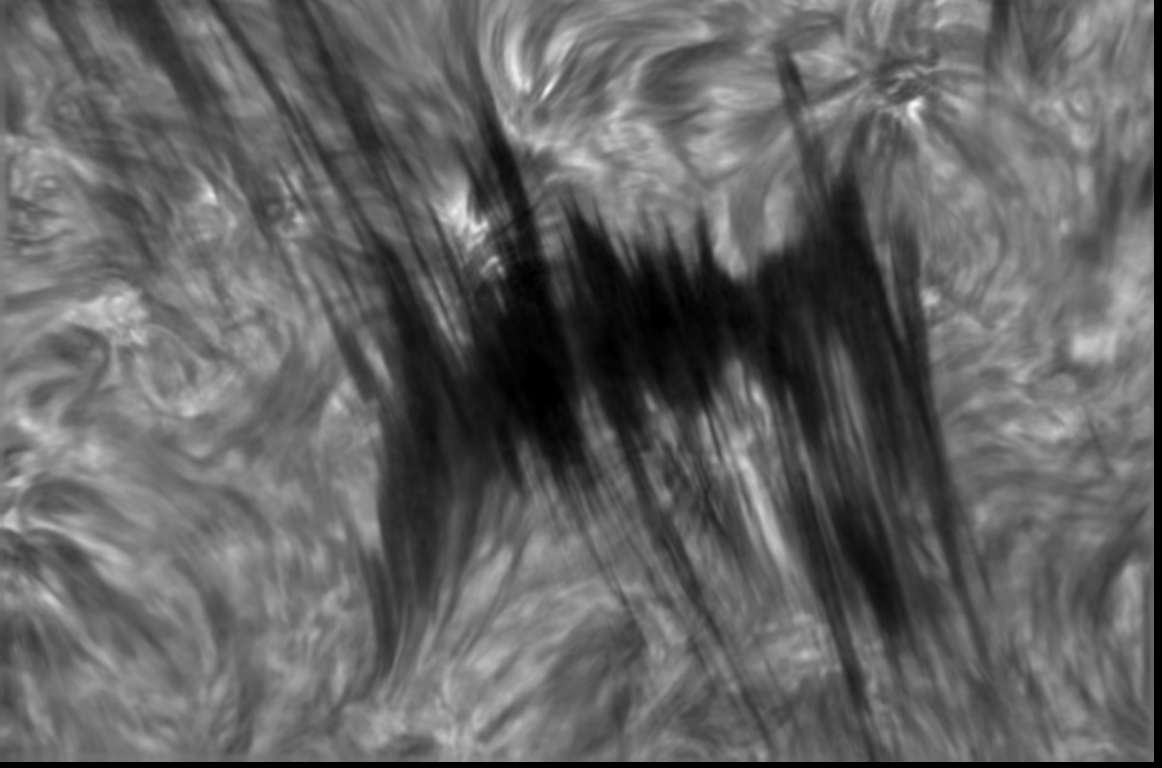


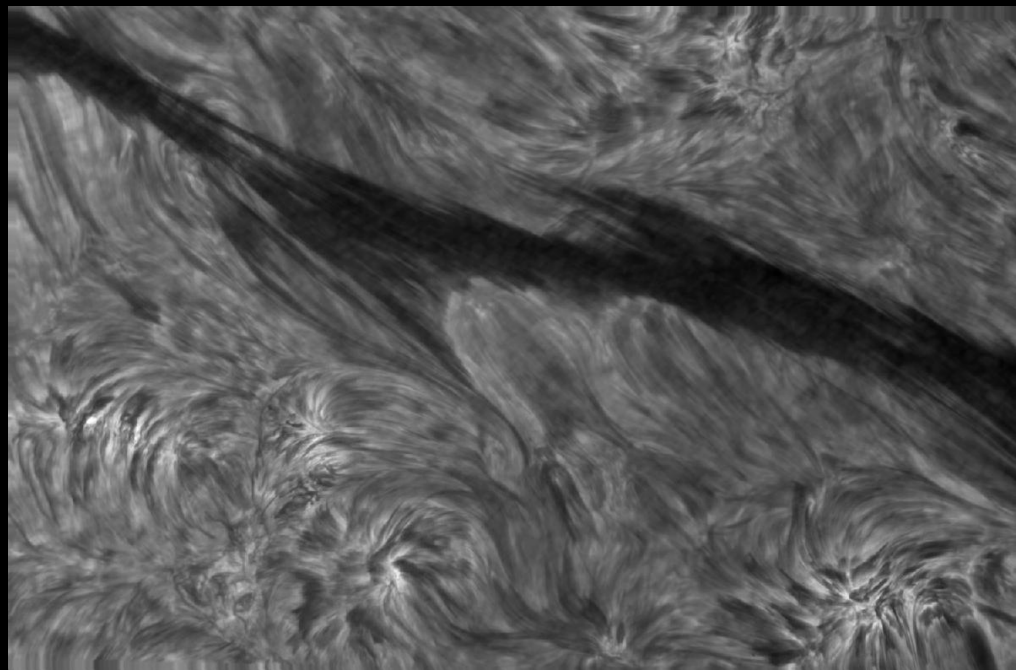



SST La Palma
60 cm aperture stop
No AO
Hα Line center 656.3nm
29-Apr-2002

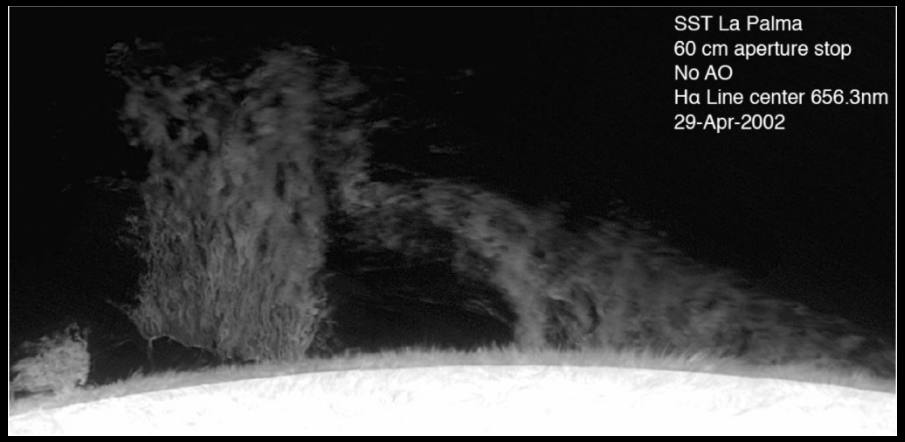
Filaments = prominences

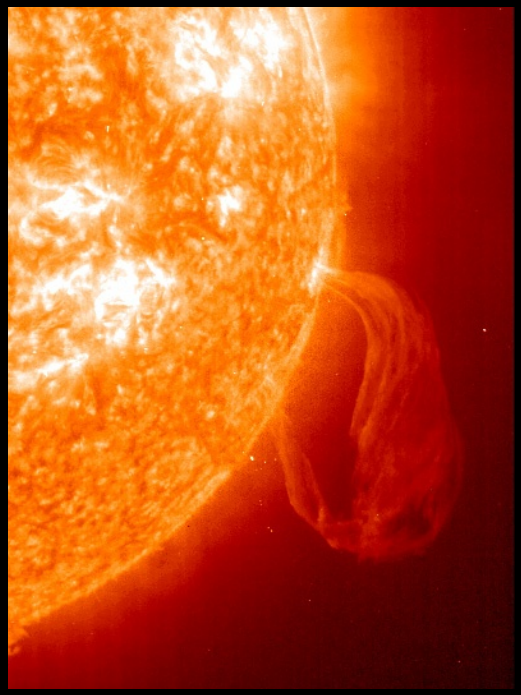




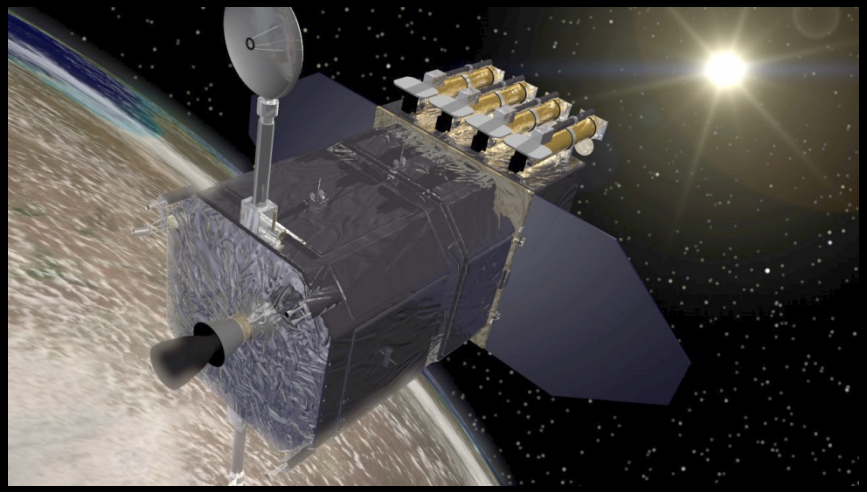


Moving upward

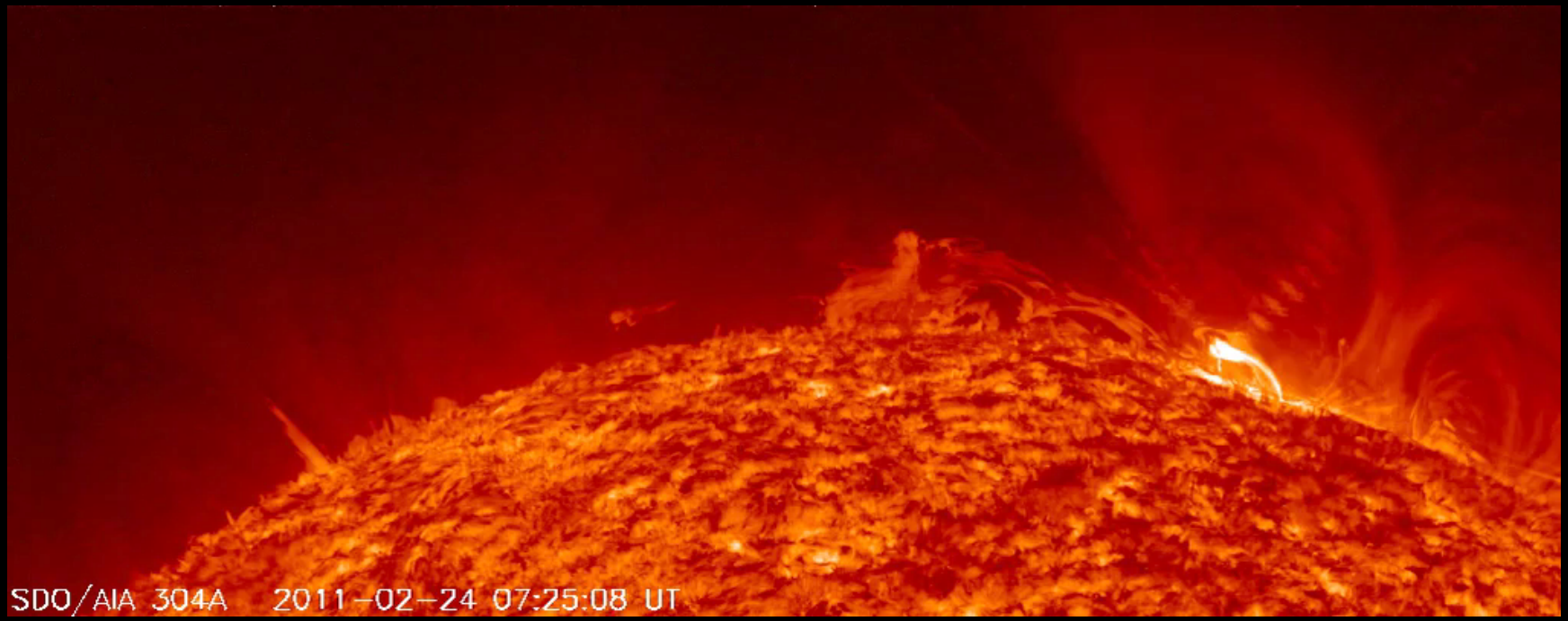




Ground-based

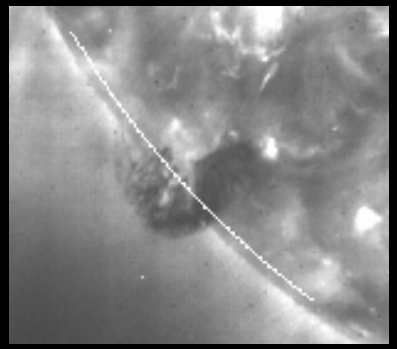


Space-based

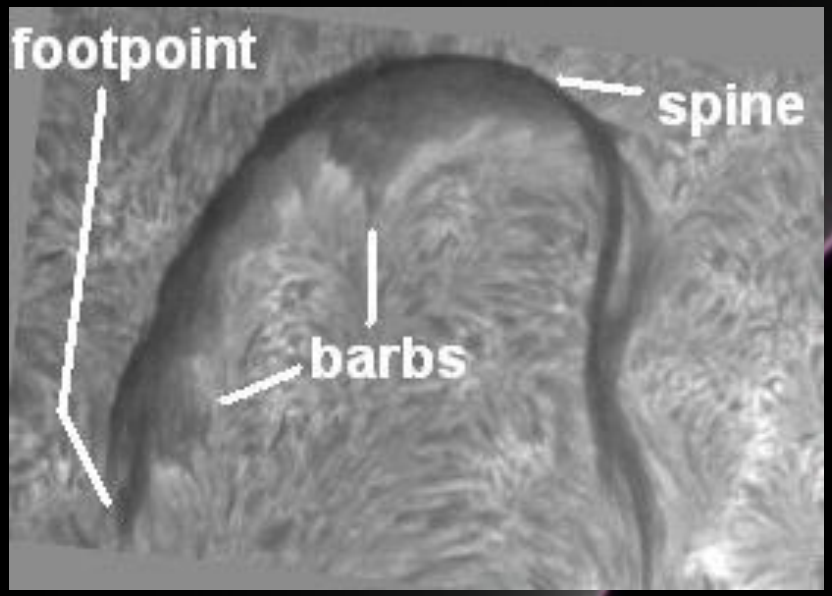

SDO/AIA 304A 2011-02-24 07:25:08 UT

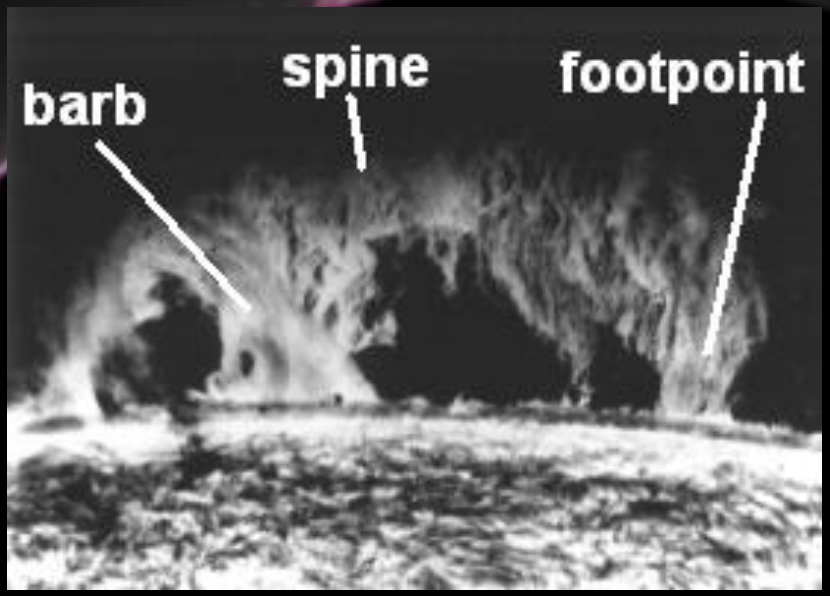
Properties

- Dynamic (knots and threads, vel ~ 5 - 100 km s^{-1})
- Spine, barbs, and footpoints (next slide)
- Length ~ 10^4 - 10^7 km, Height ~ 10^3 – 10^5 km,
  Width ~ 100 – 10,000 km
- Lifetime ~ hours – months
- T < 10^4 K, N > 10^{10} cm^{-3}, M ~ 10^{15} gm



Structure





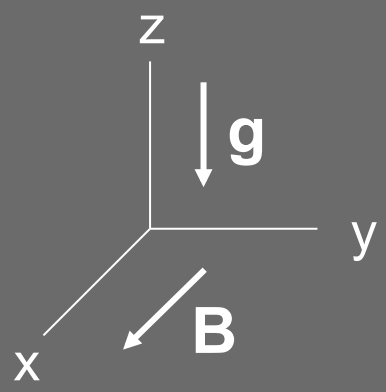
- Partially ionized plasma
- Filament channels

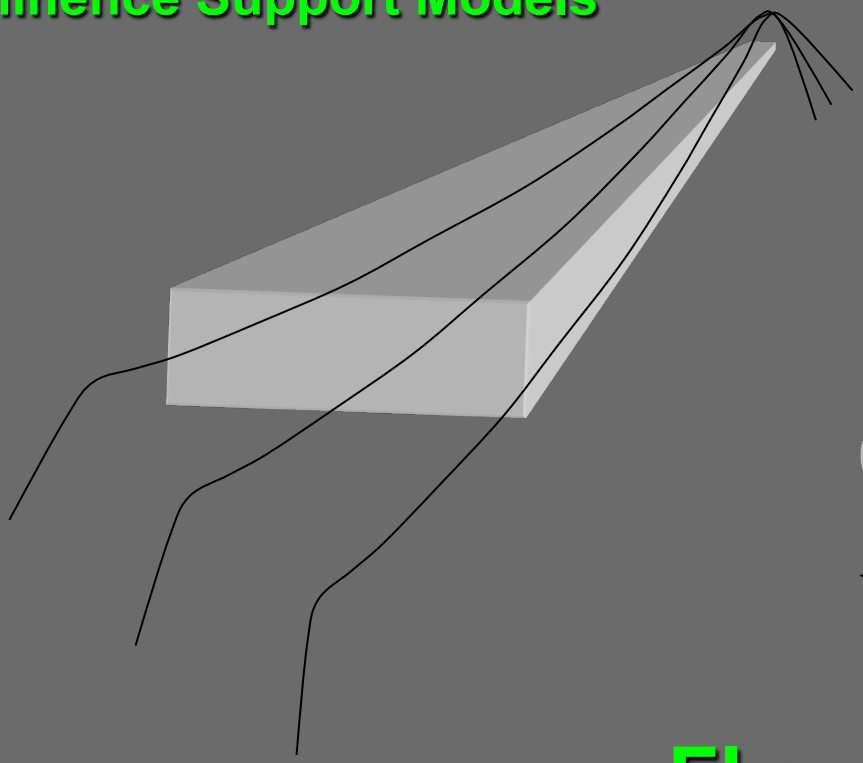
Questions (more current)

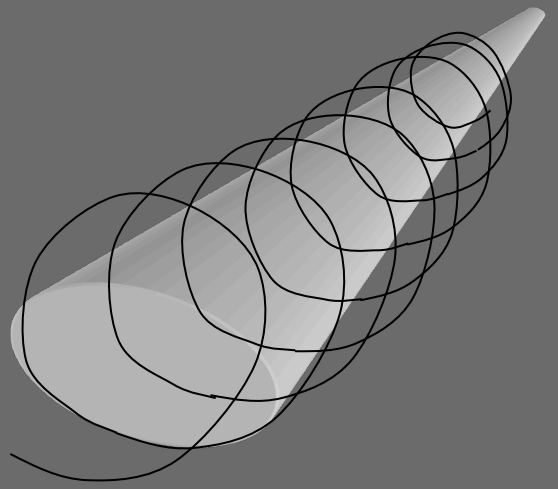
- How do these structures form?
- How is the dense mass supported?
- How is the mass coupled to the magnetic structure?

Mass support

Simple Prominence Support Models





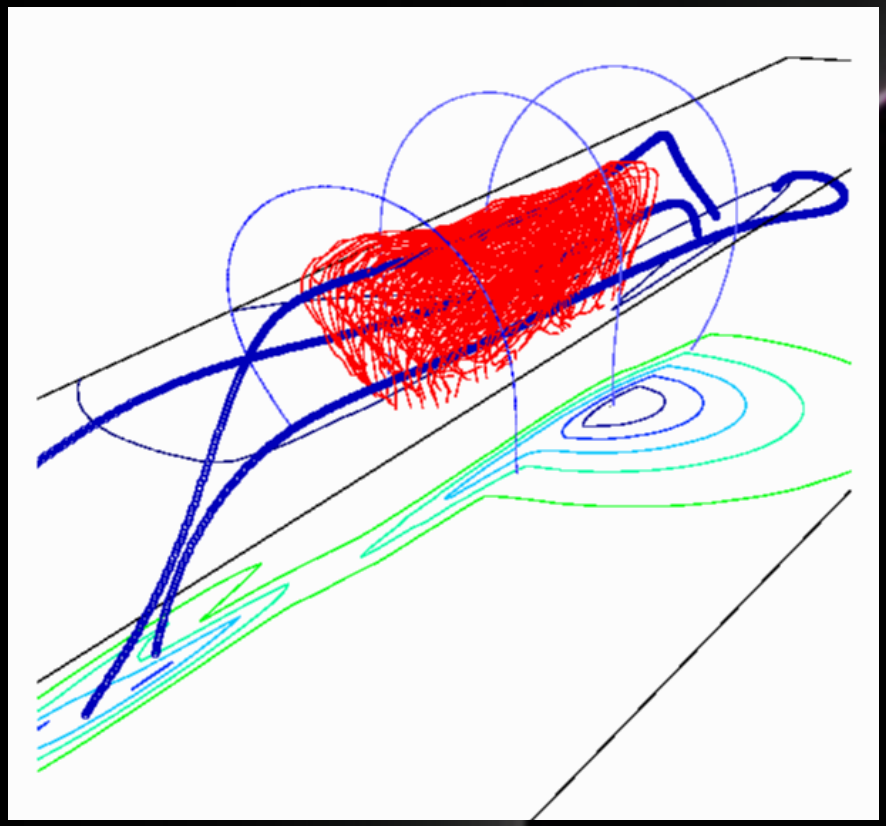


Dip Model

Flux-rope model

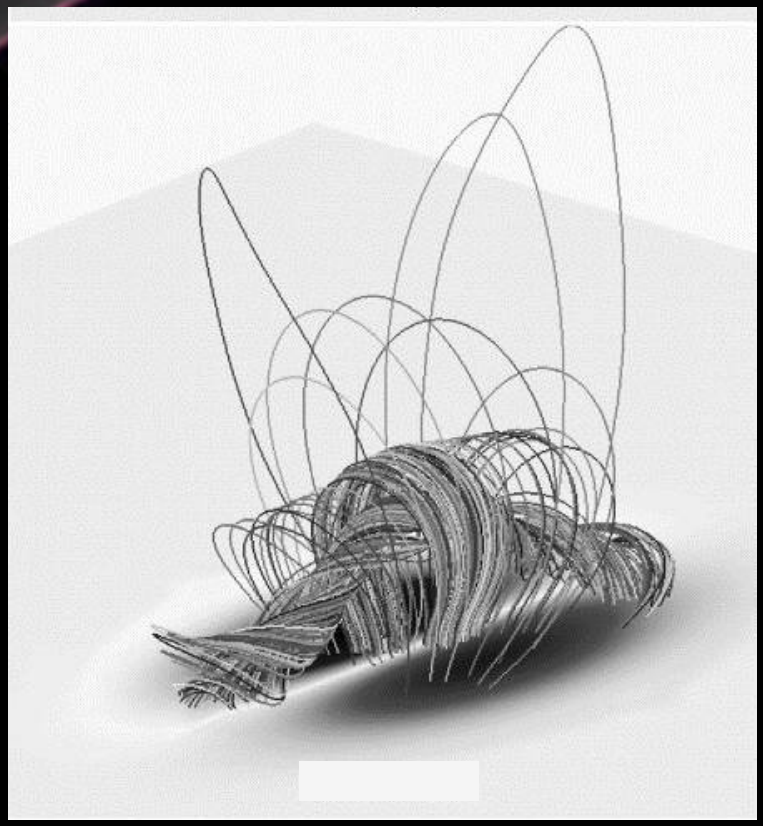
(Gilbert et al. 2002; 2007)

Filament channel structure



Sheared Arcade

Antiochos, S & C. R. DeVore, 1999



Flux Rope

Amari et al. 2000

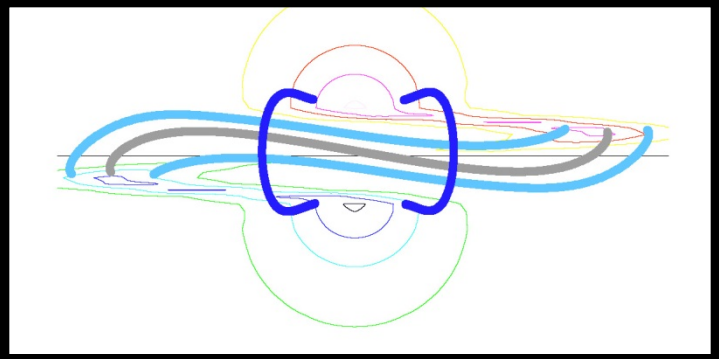
Prominence Lifecycle

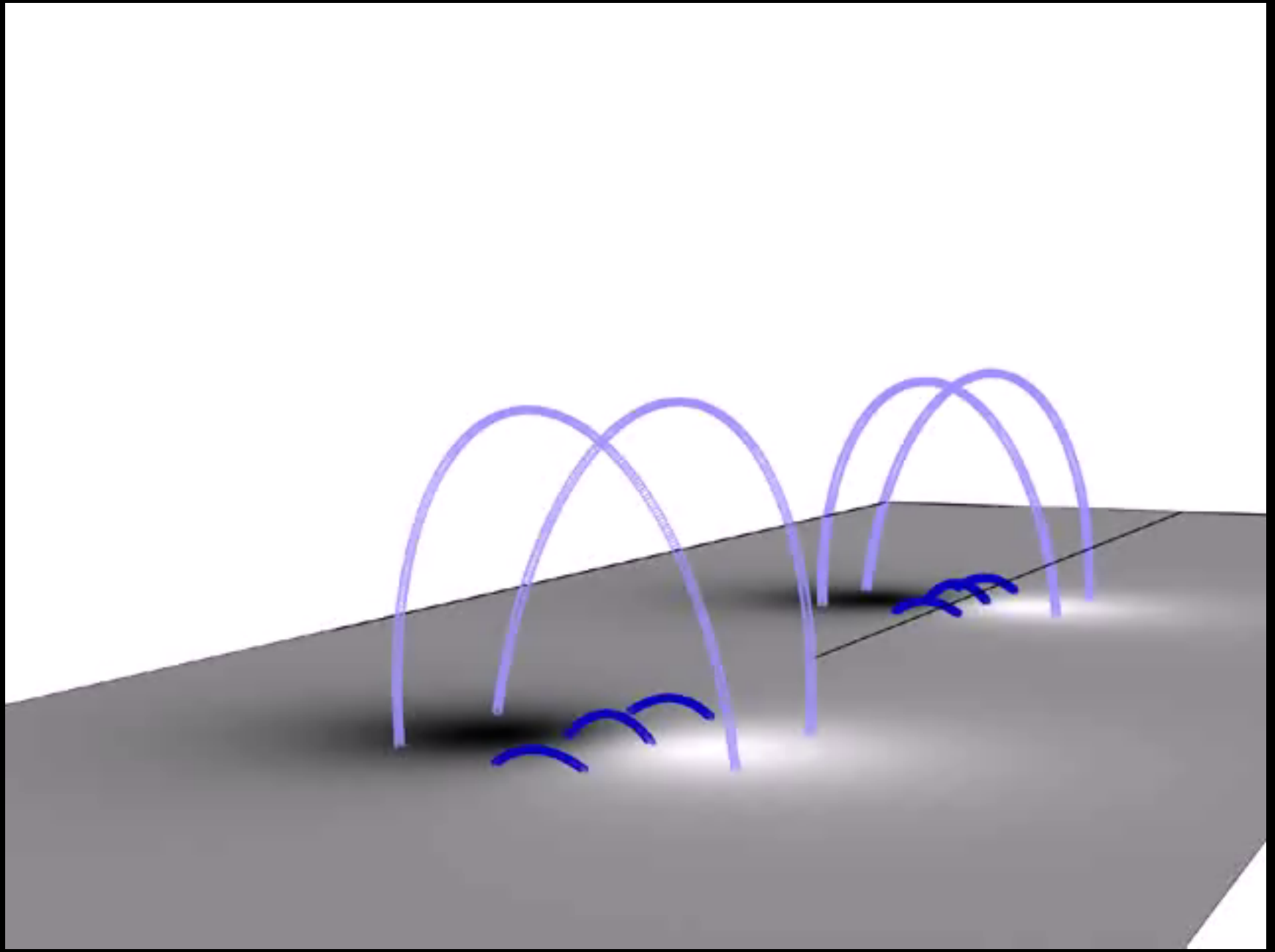
- Formation
  - Channels
  - Mass
- Dynamics
- Eruption

Formation and Dynamics

- Observations
  - Provide constraints for models
    - Location of formation (polarity inversion lines)
    - Fine structure
    - Motion of threads/knots
    - Existence of barbs
- Models
  - Magnetic forces
  - Thermal forces

C. R. DeVore & S. Antiochos, 2000





C. R. DeVore , S. Antiochos, & G. Aulanier 2005

Fundamental importance of filament channels

- Driver of eruptions and space weather
- Energy source
- Helps us understand the Sun’s magnetic-field evolution
- Provide insight into physics of magnetic stability in plasmas

Cool plasma formation

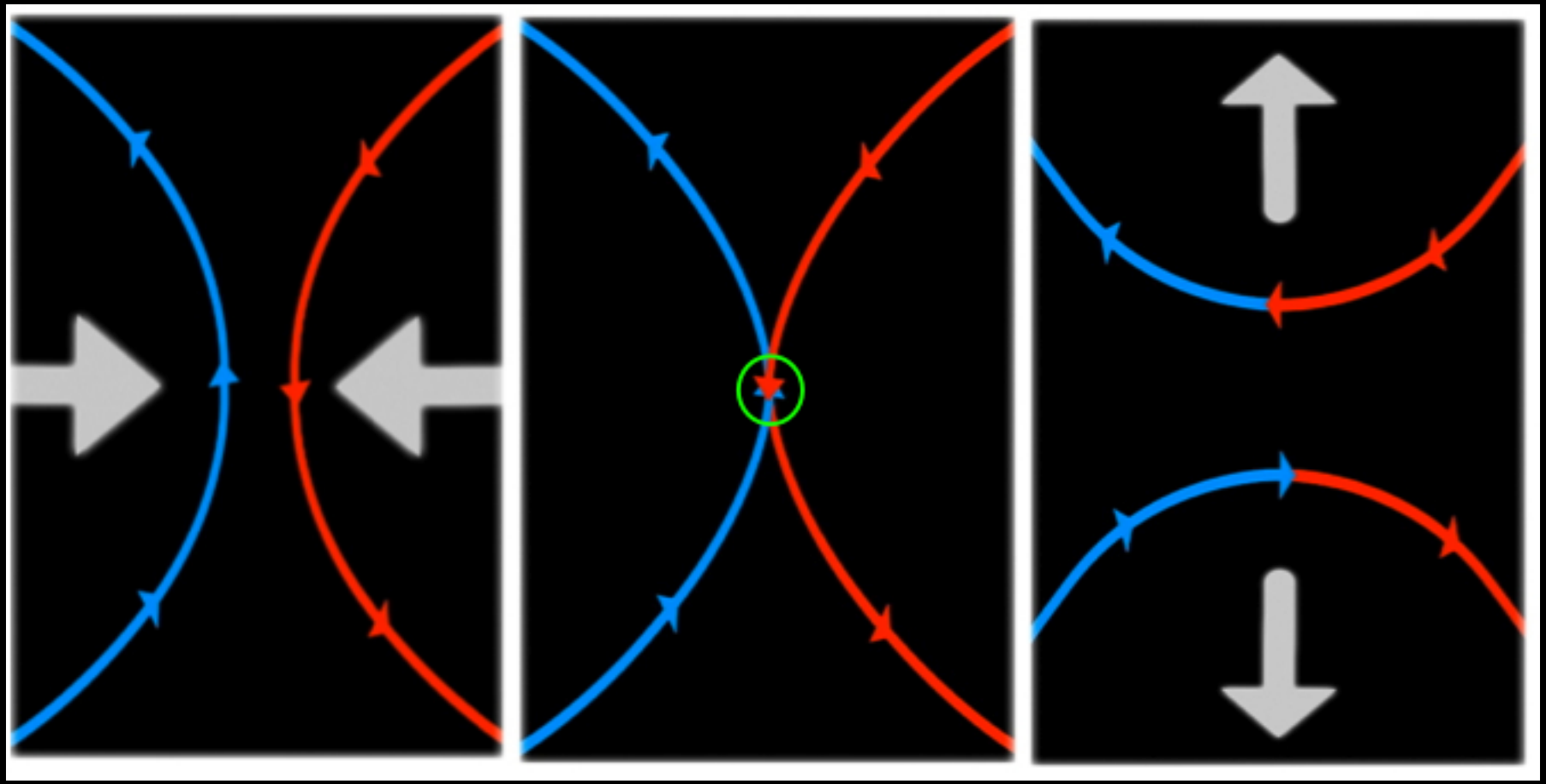
Origin of Cool Plasma

- **Levitation**

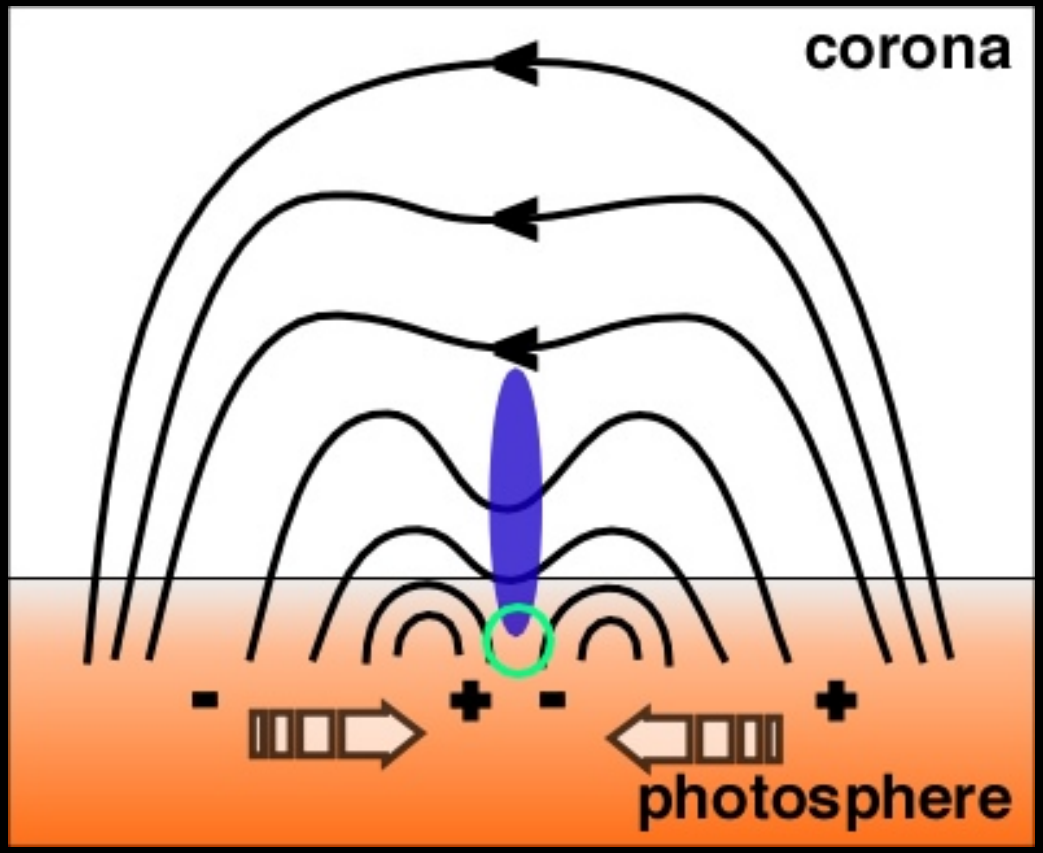
- **Injection**

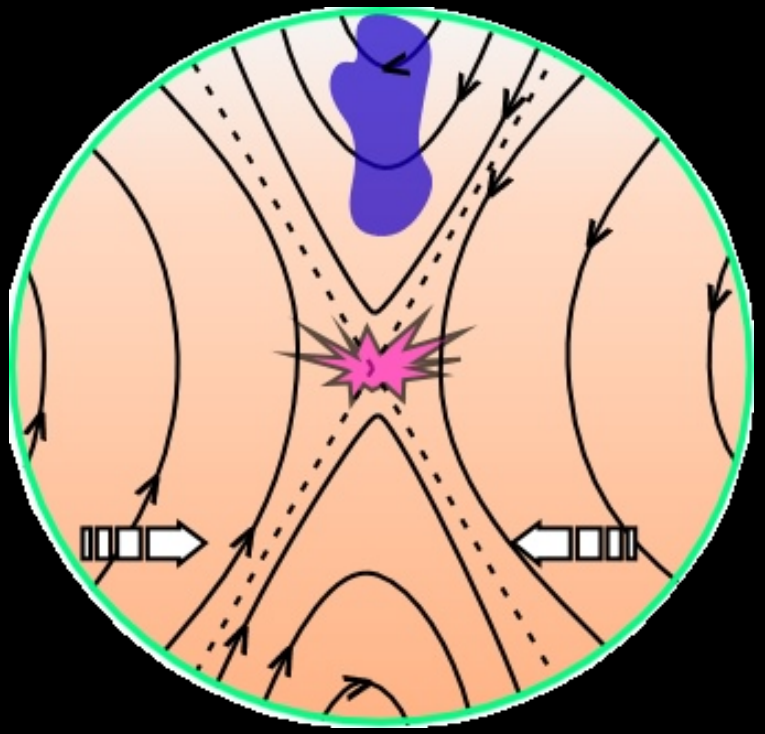
- **Evaporation-condensation**

Magnetic reconnection



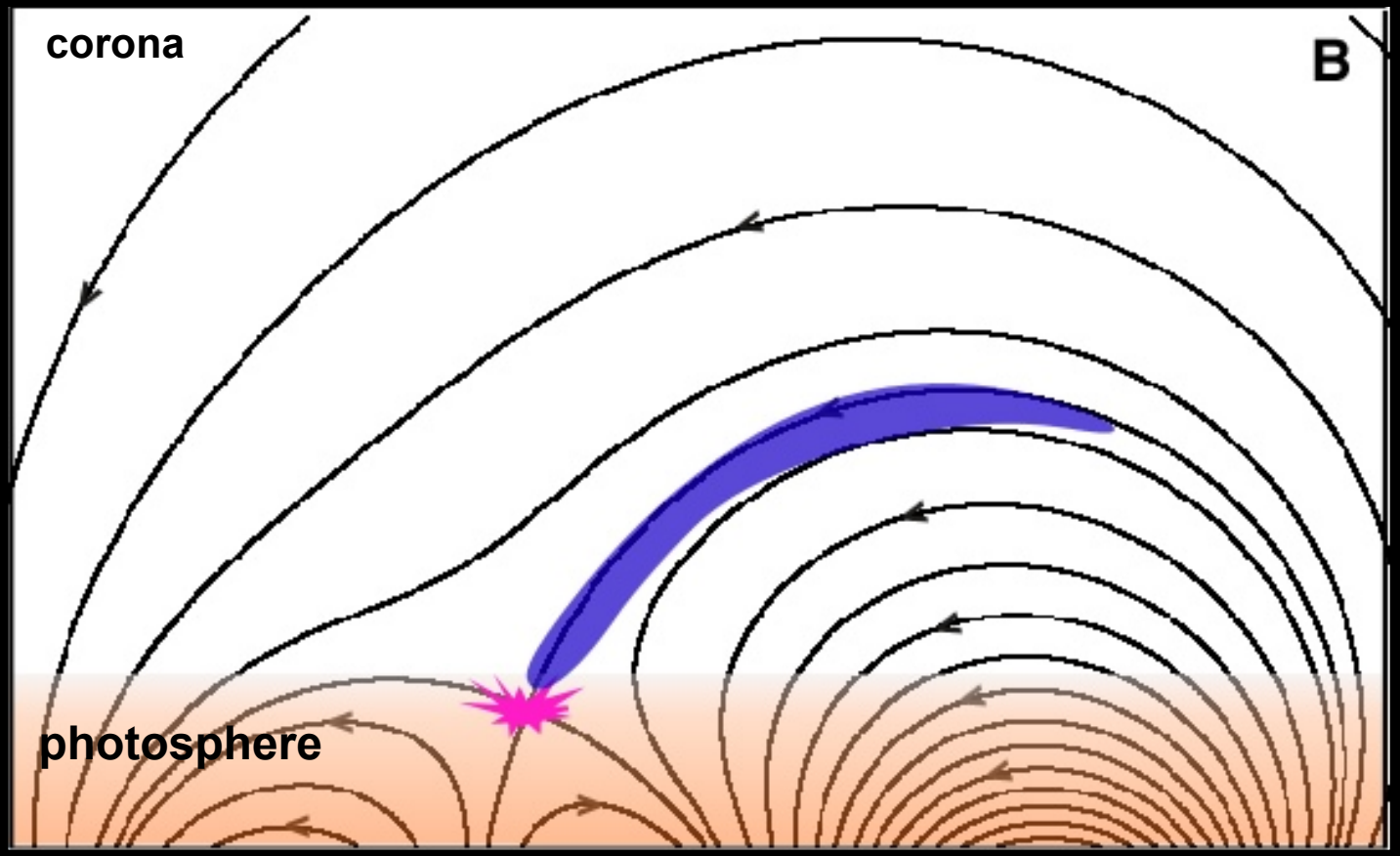
Levitation





Courtesy of Judy Karpen
(Galsgaard & Longbottom 1999, Litvinenko & Wheatland 2005)

Injection

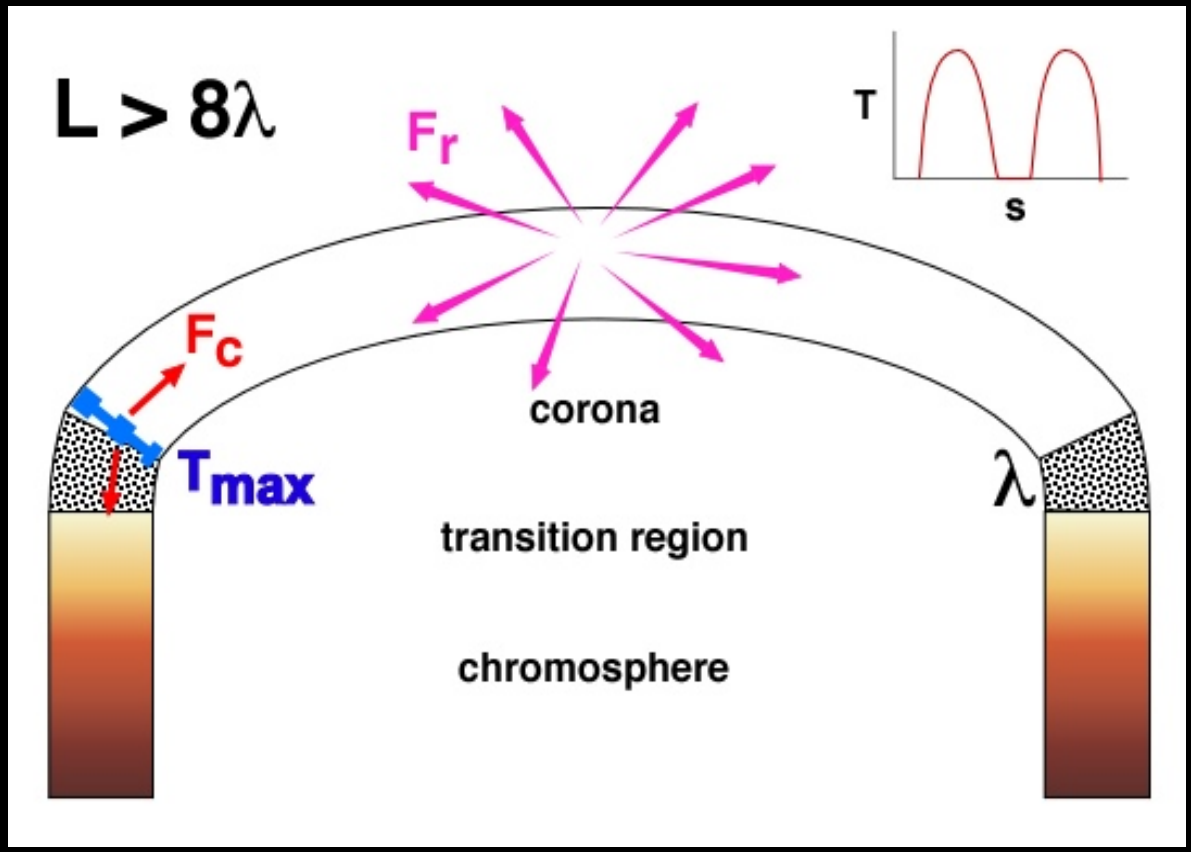


Field-aligned jets generated by reconnection (Liu et al. 2005)

Courtesy of Judy Karpen

Evaporation-Condensation

The Thermal Nonequilibrium Model: condensations are caused by heating localized above footpoints of long, low-lying loops



Courtesy of Judy Karpen

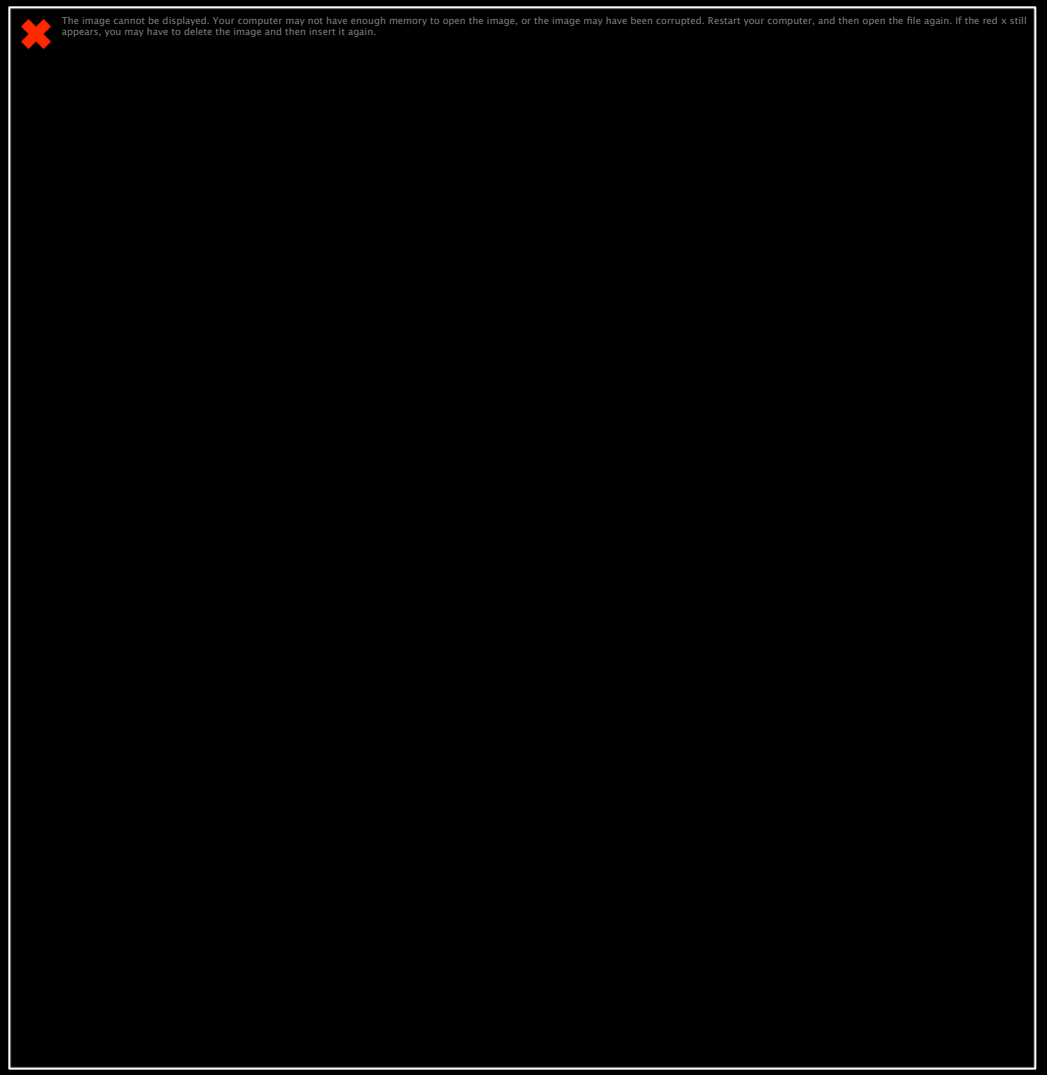
References: Antiochos & Klimchuk 1991; Dahlburg et al. 1998; Antiochos et al. 1999, 2000; Karpen et al. 2001, 2003, 2005, 2006; Karpen & Antiochos 2008

Multi-threaded model (3D sheared structure + thermal nonequilibrium process)

(Luna, Karpen, DeVore, 2012)

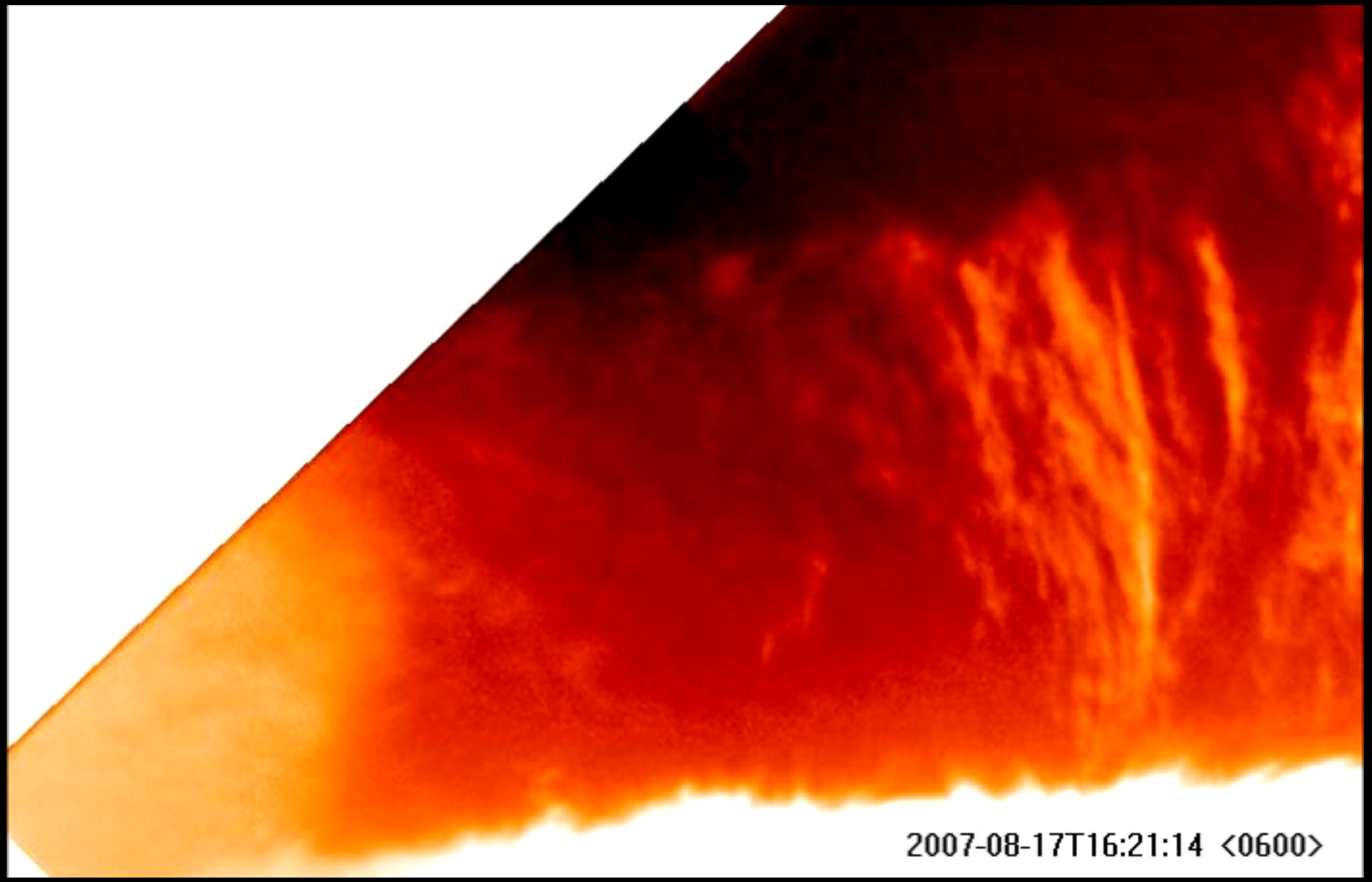
Dynamics

- Draining
- Vertical motion
- Oscillating
- Swirling
  - Tornadoes
- Kinking



Vertical motion

Kinking: failed eruption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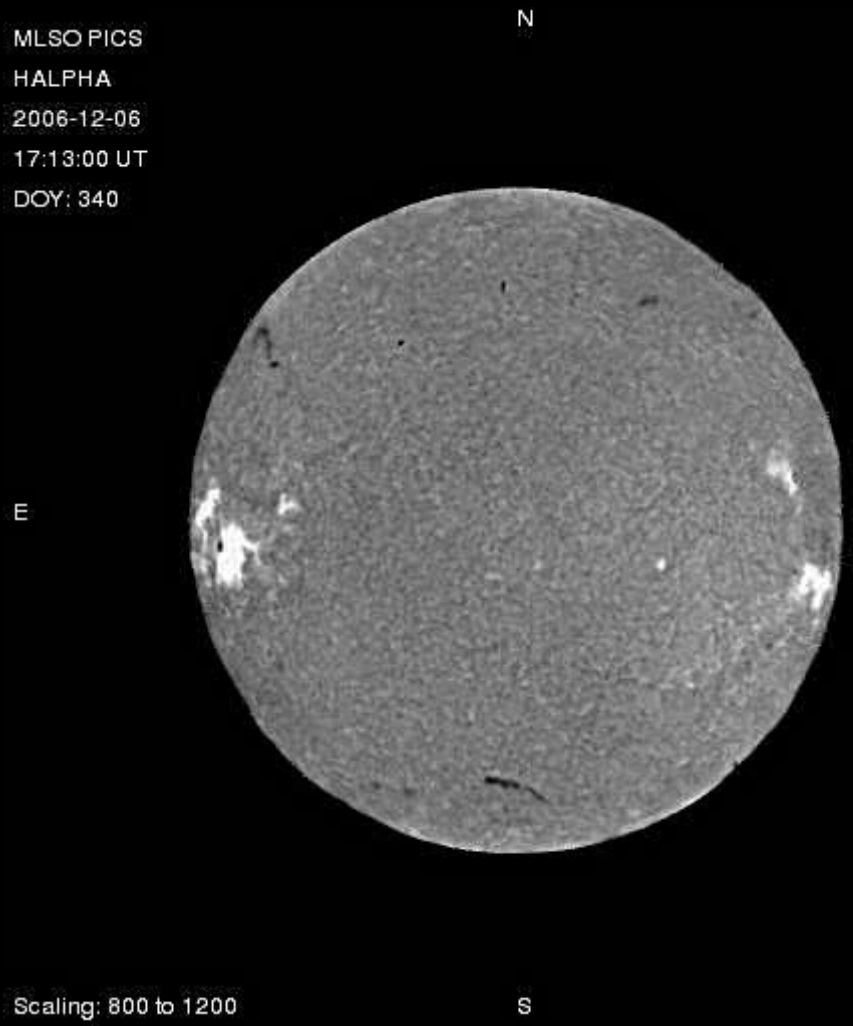
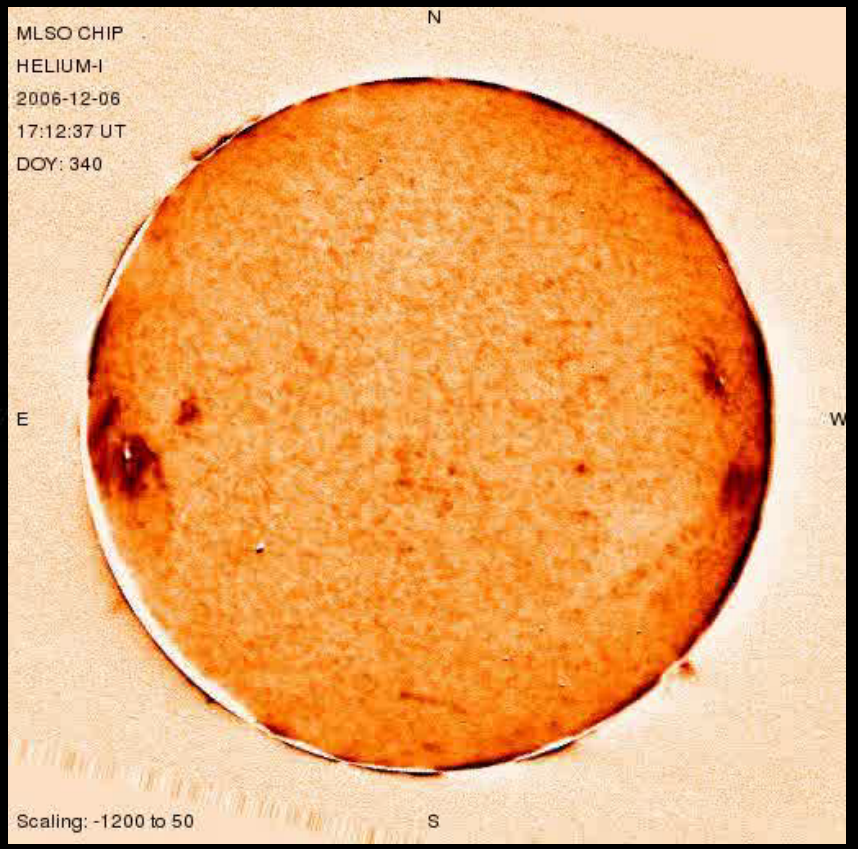
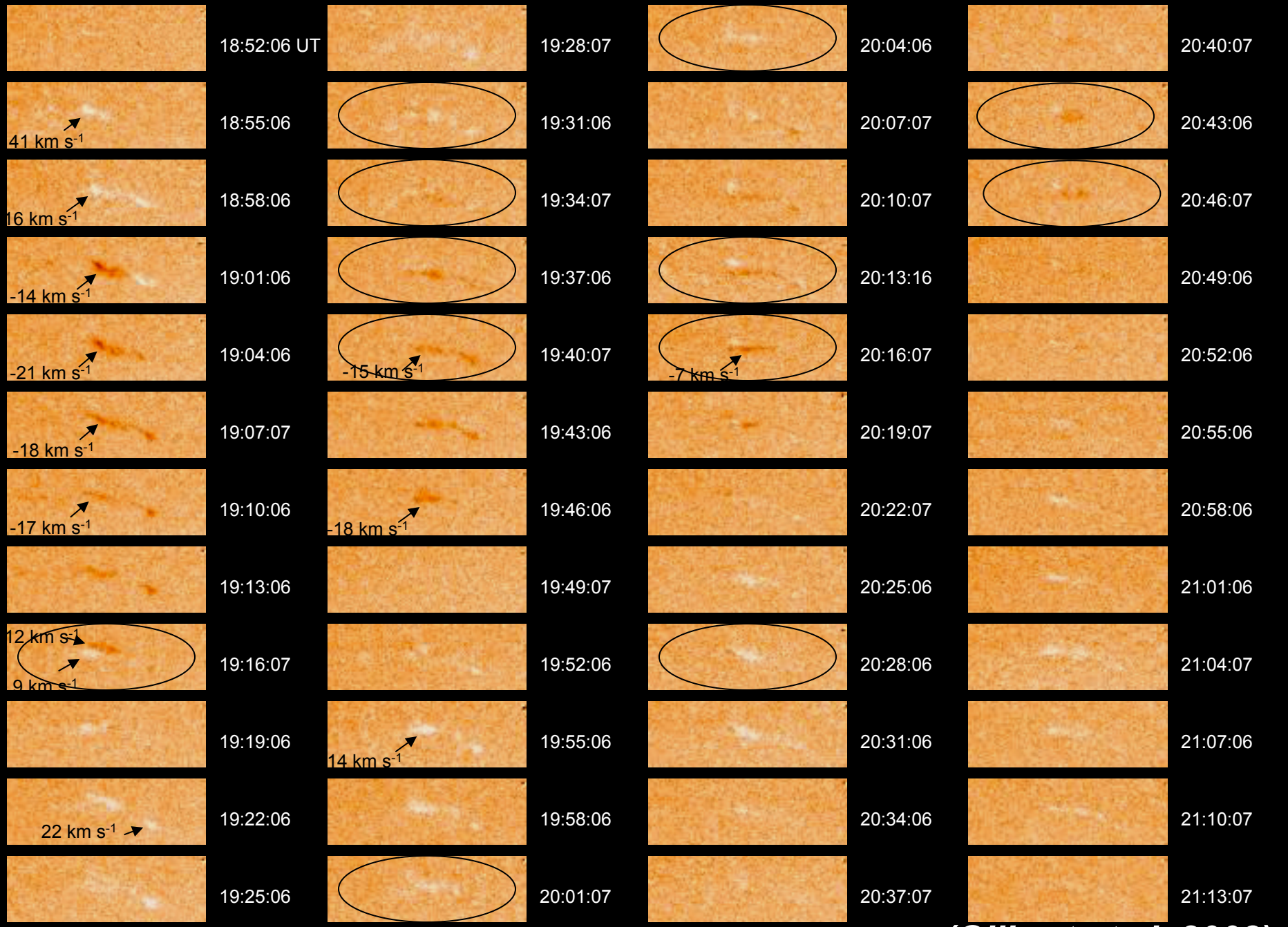
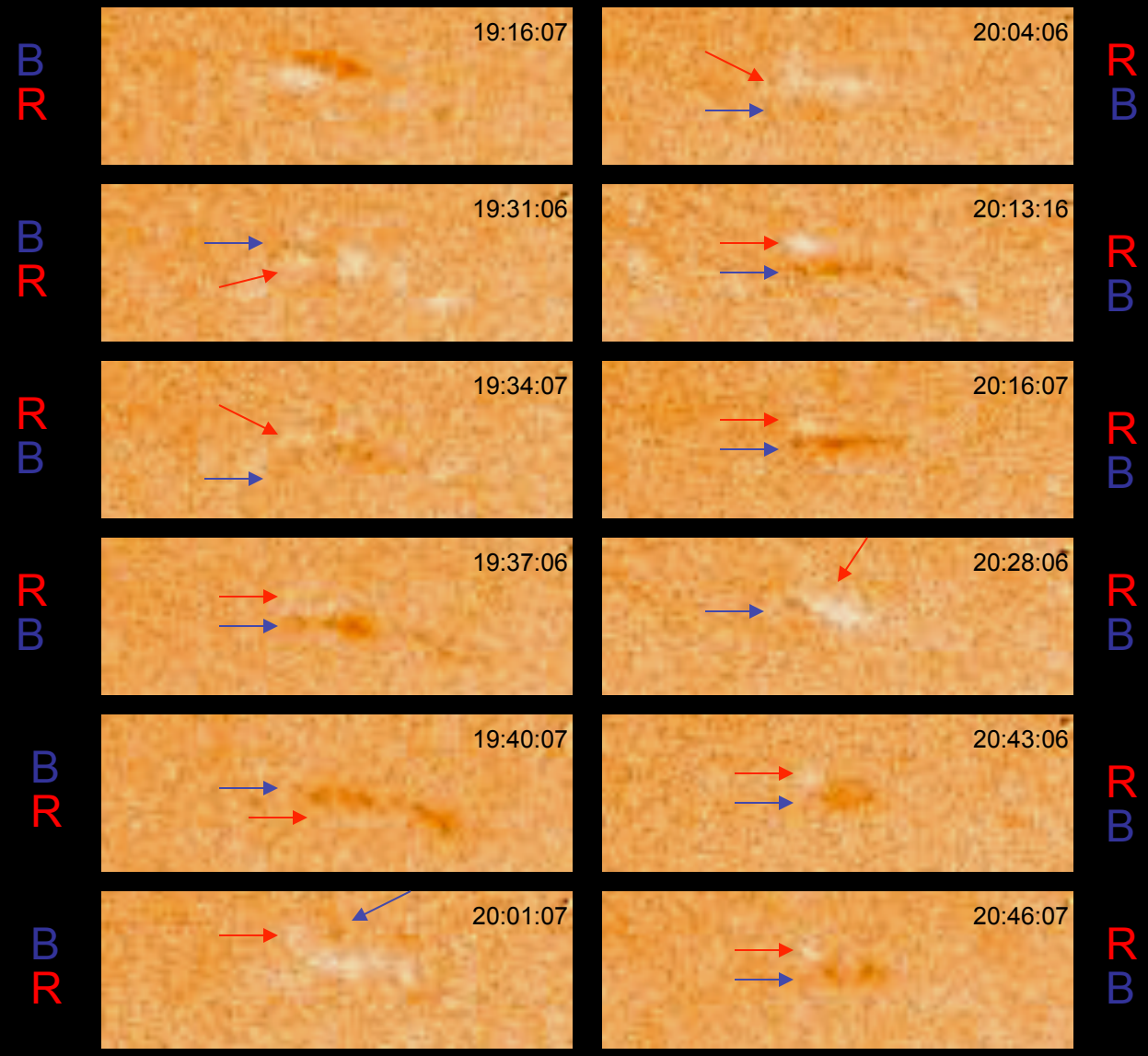
Oscillations



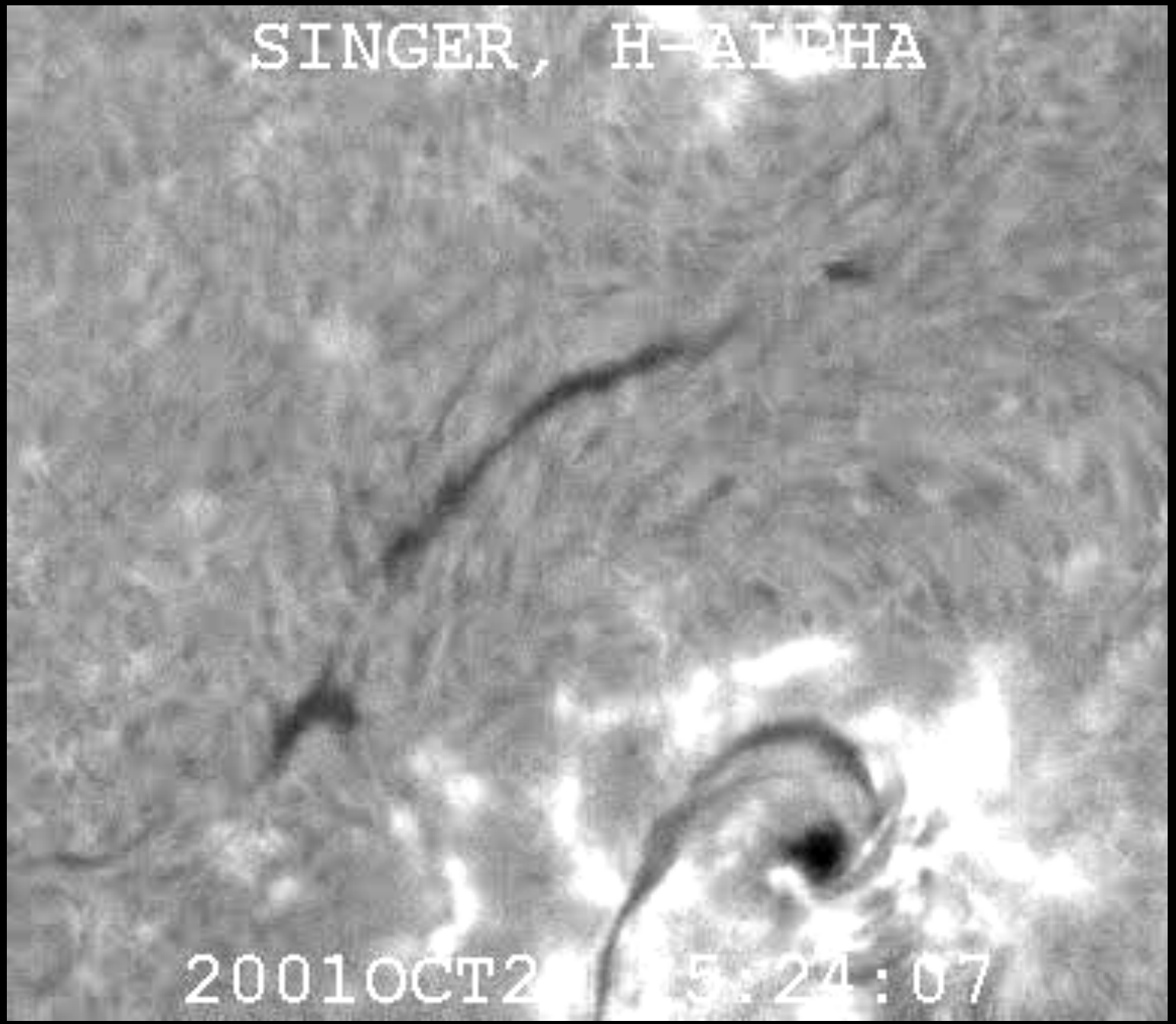




(Gilbert et al. 2008)

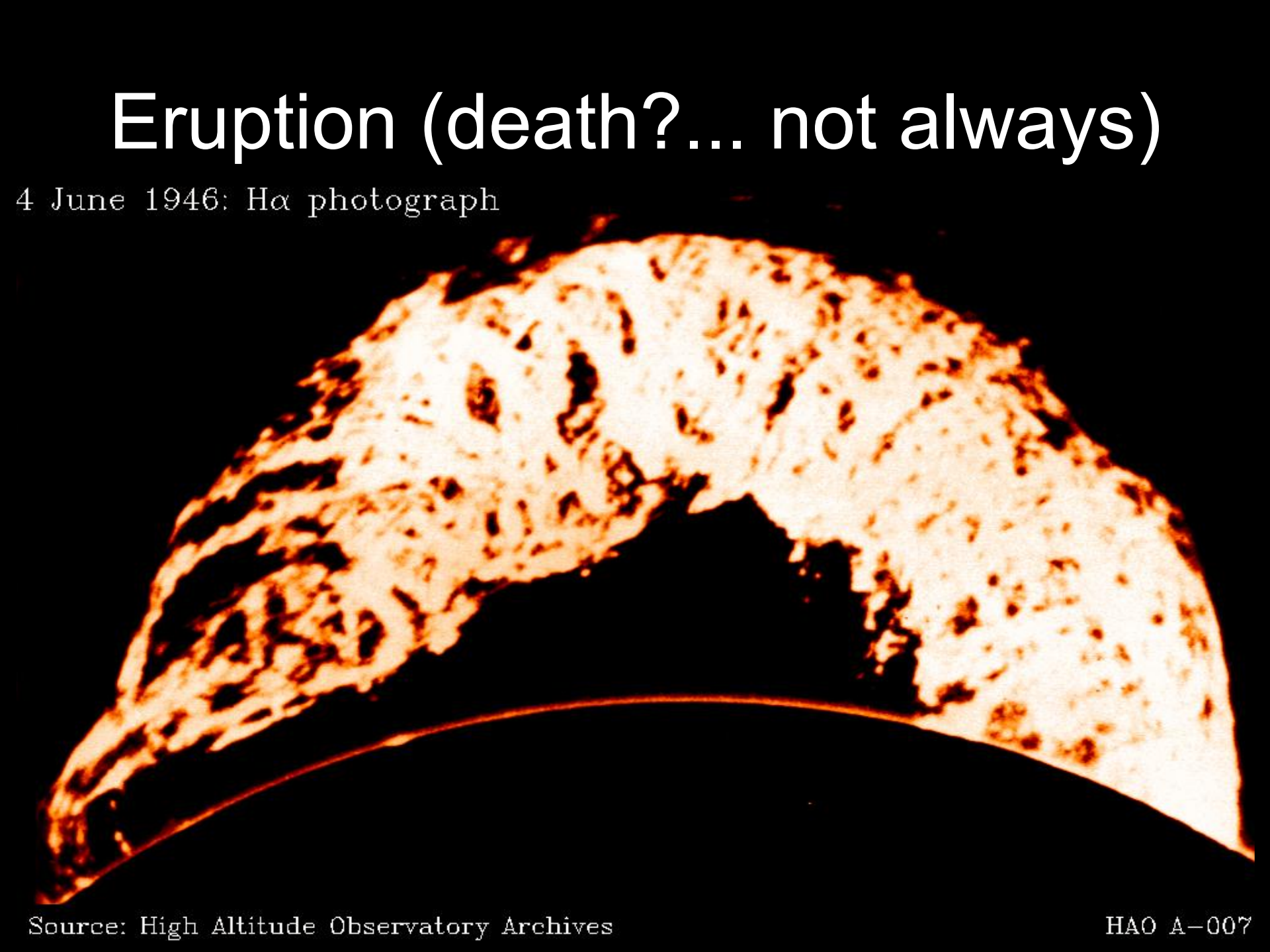


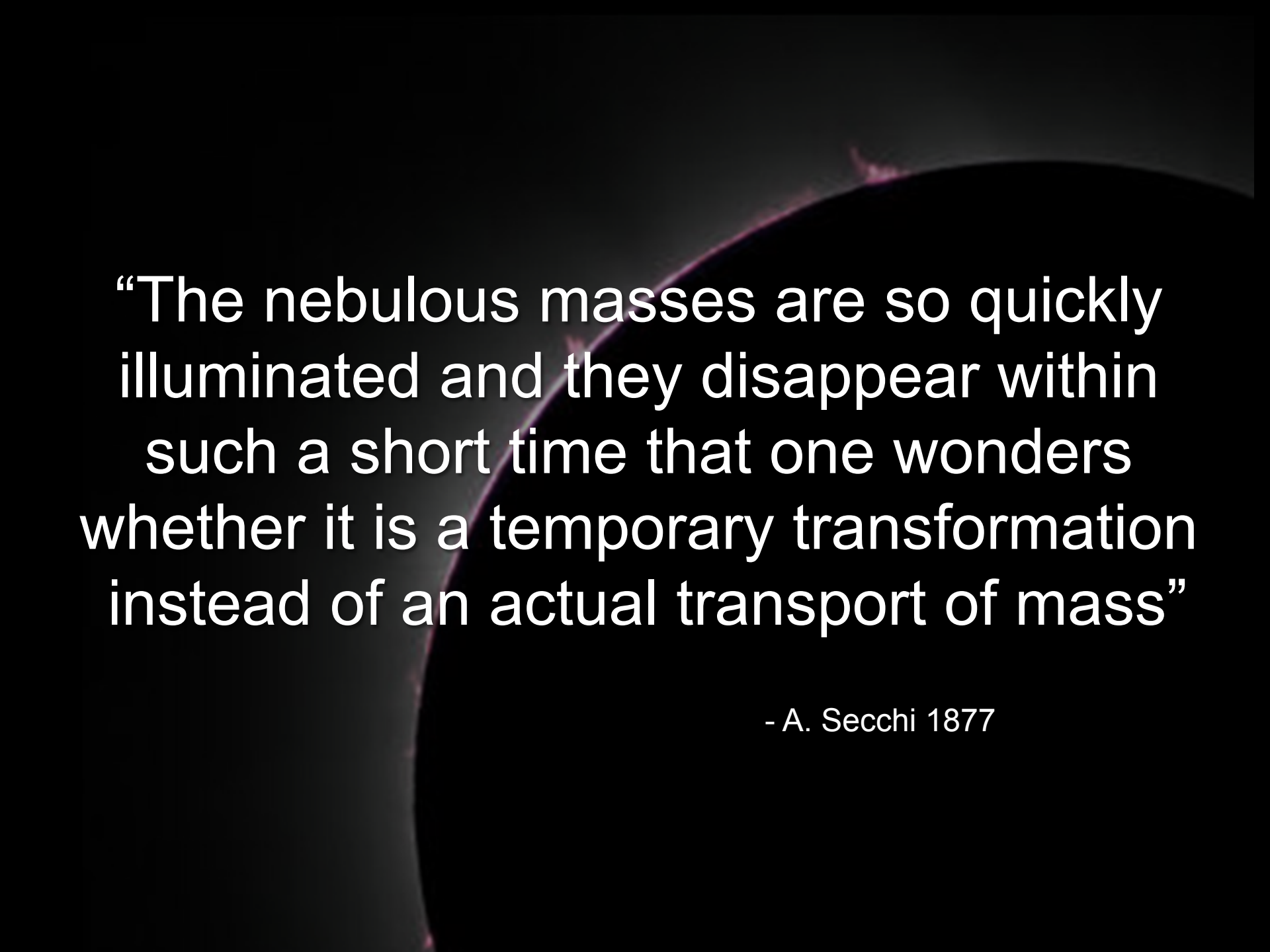
(Gilbert et al. 2008)



Jing et al., 2003

Eruption (death?... not always)



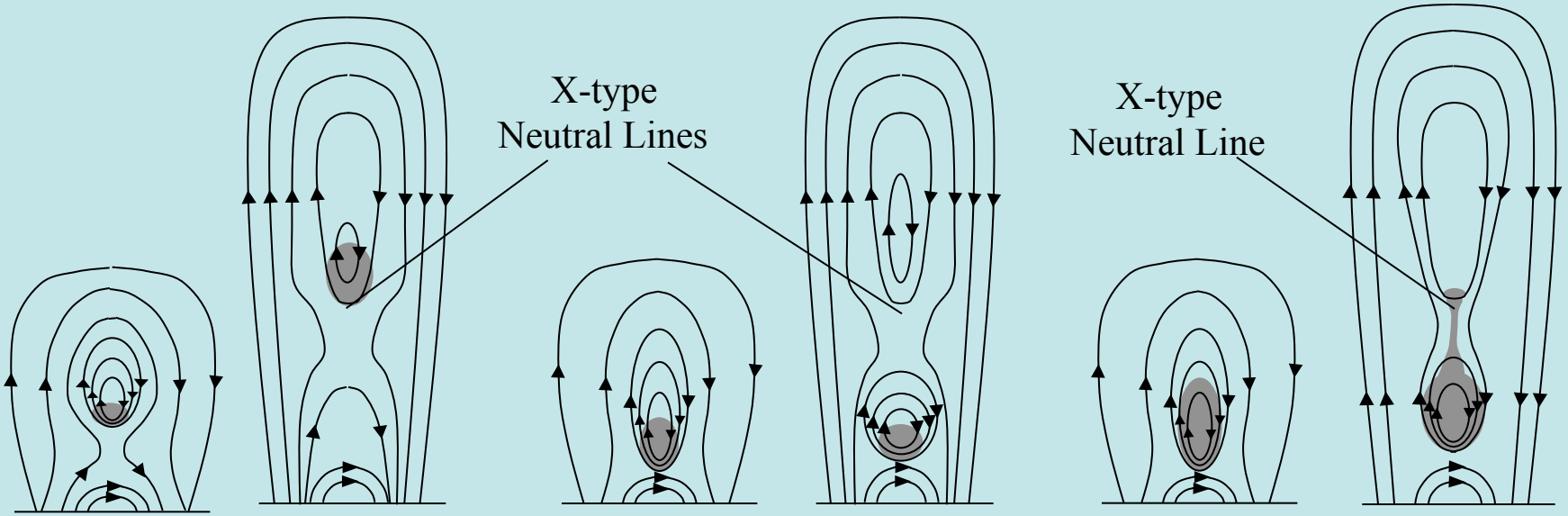

“The nebulous masses are so quickly illuminated and they disappear within such a short time that one wonders whether it is a temporary transformation instead of an actual transport of mass”
- A. Secchi 1877

June 7, 2011

Reconnection below flux rope

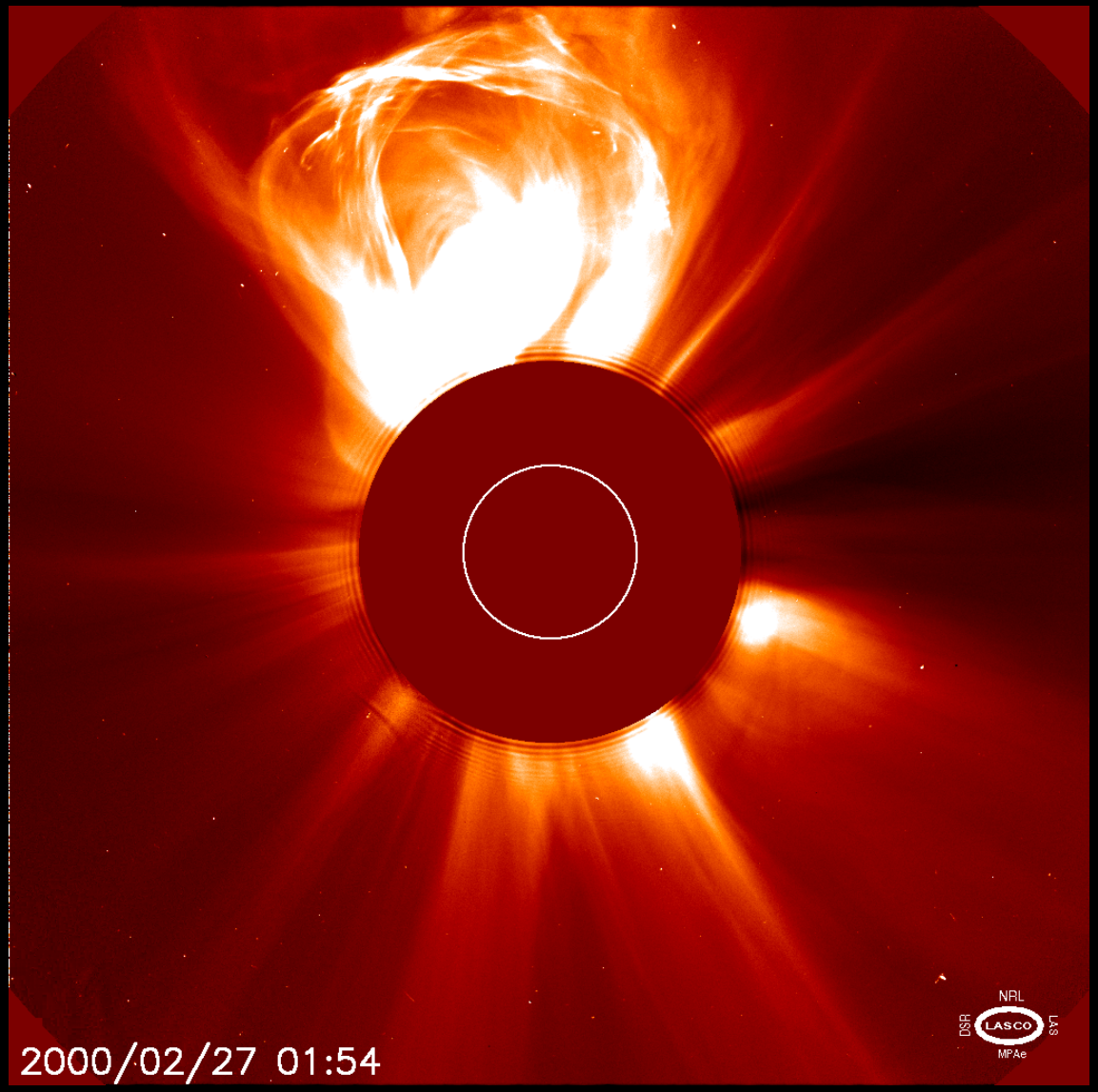
Reconnection above the prominence (within flux rope)

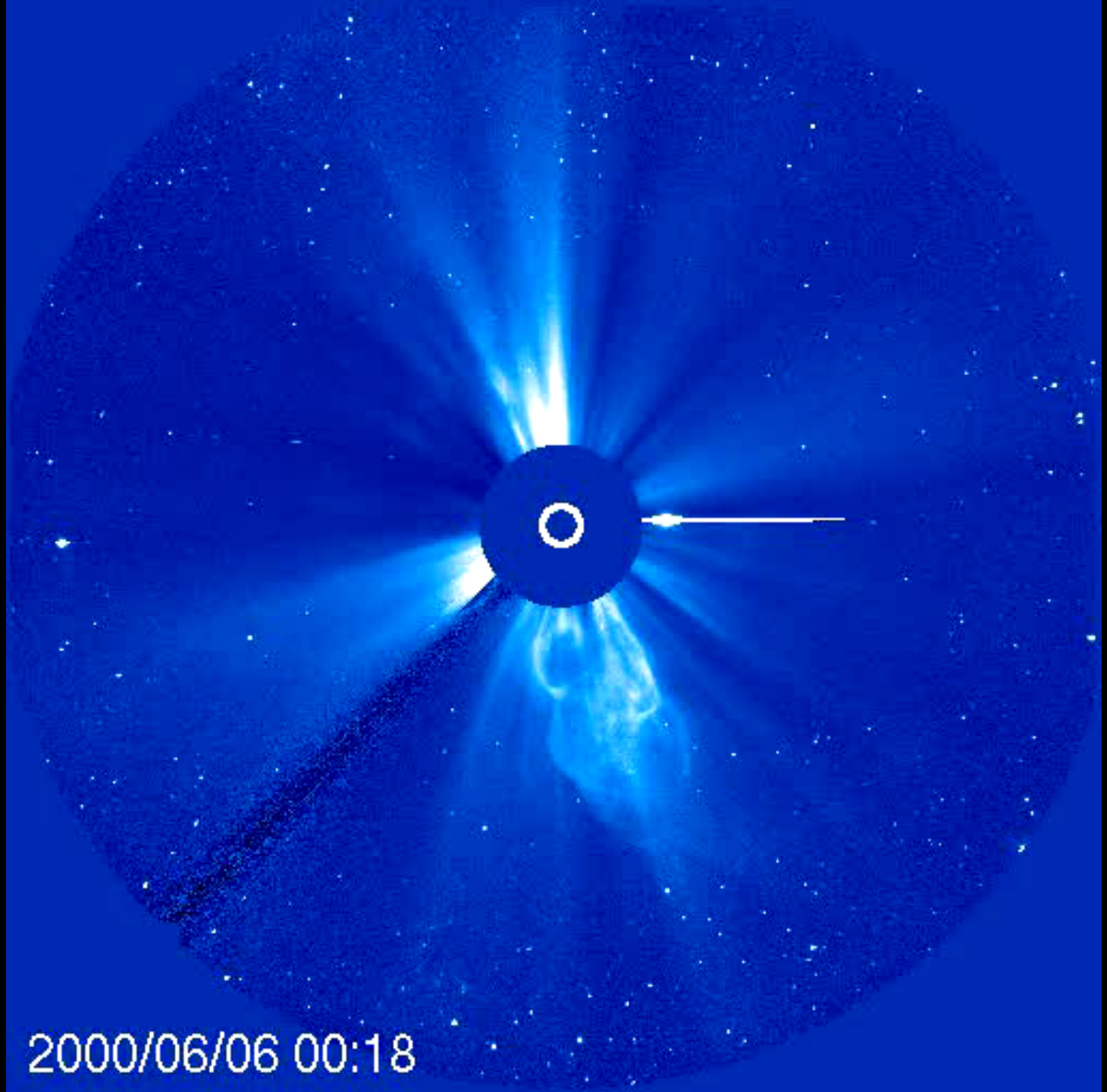
Reconnection within the prominence



Why should you care?

Coronal Mass Ejections

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Outstanding Questions

- What are the favorable conditions for prominence mass to form?
- How do condensation and drainage control the mass budget of a prominence?
- What causes vertical and vortical motions in prominences?
- What is the magnetic structure of barbs?
- Why are filaments filamentary?
- What determines the size and structure of the flows?
- Why the large range of lifetimes?

Thank you!