

Filament leg-leg reconnection as a source of prominent SADs

Jaroslav Dudík

G. Aulanier, M. Karlický, J. Kašparová,
A. Zemanová, J. Lörinčík, M. Druckmüller

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Astronomical
Institute
of the Czech Academy
of Sciences

Supra-arcade downflows (SADs)

16-Mar-11 20:05:45



09-May-11 21:38:33



16-Mar-11 20:08:09



09-May-11 21:39:45



16-Mar-11 20:10:33



09-May-11 21:40:45



16-Mar-11 20:13:33



09-May-11 21:42:33



Supra-arcade downflows:

- Dark structures moving through the hot flare emission
- Occur during peak and late phases
- Density voids trailing thin shrinking loops

Extensive literature; e.g.:

Warren et al. (2011), ApJ, 742, 92

Savage & McKenzie (2011), ApJ, 730, 98

Savage et al. (2012), ApJL, 747, L40

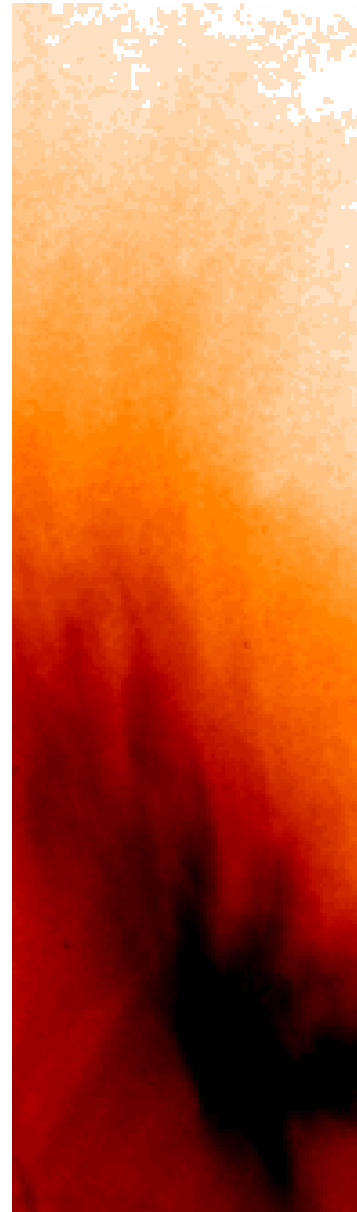
Hanneman & Reeves (2014), ApJ, 786, 95

Reeves et al. (2017), ApJ, 836, 55

Chen et al. (2017), A&A, 606, A84

Li et al. (2021), ApJ, 915, 124

Shen et al. (2022), Nat. As. Lett., 6, 317

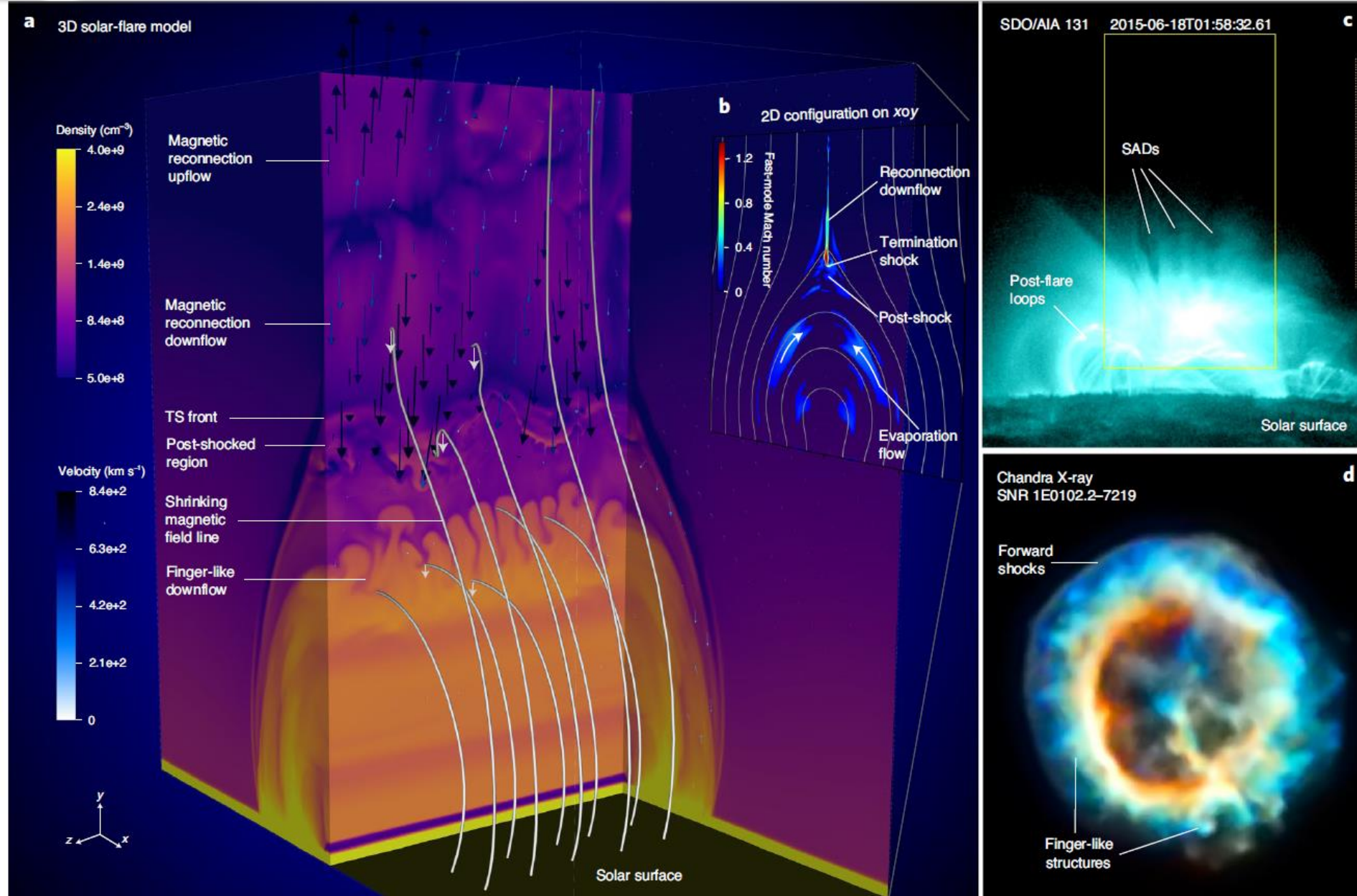


Do we understand SADs?

Shen et al. (2022)
Nat. As. Lett., 6, 317

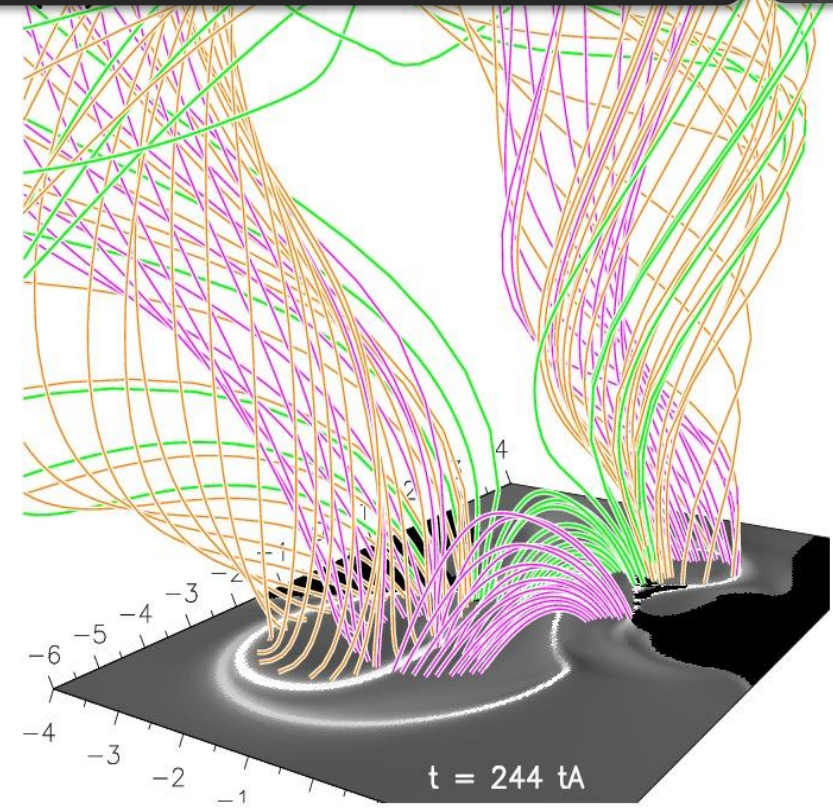
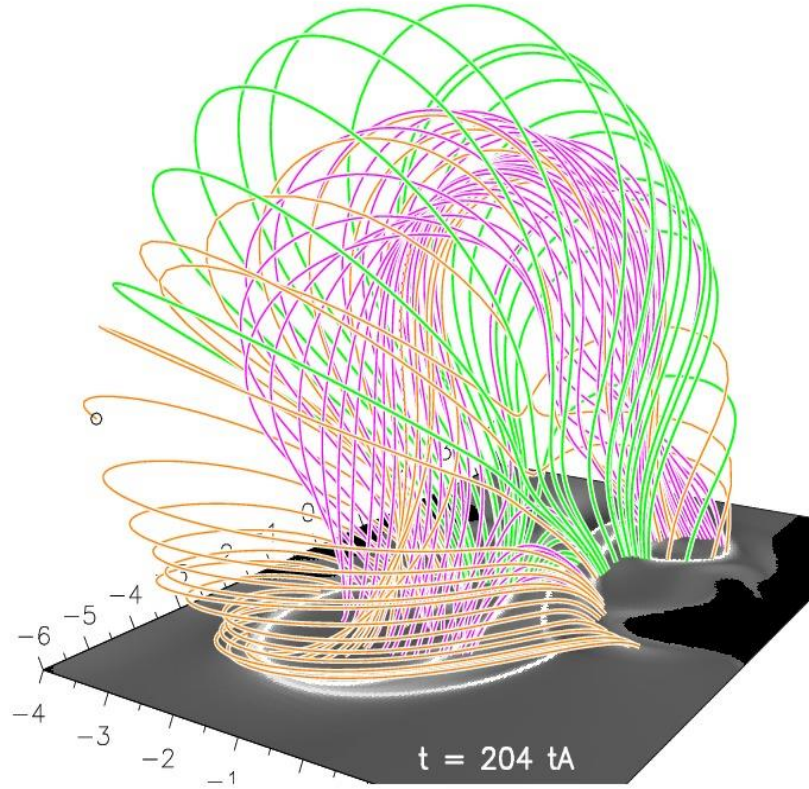
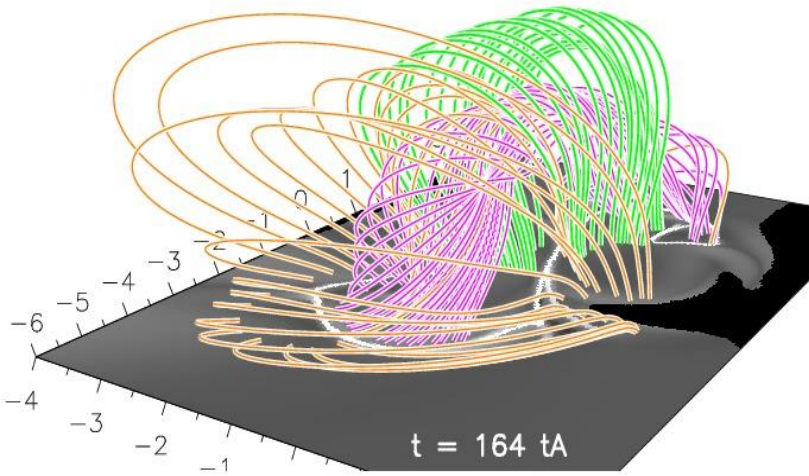
Supra-arcade downflows:

- Long interpreted as reconnection outflows
- But they **occur** in turbulent interface region **below the current sheet**
- Indirect results of reconnection outflows
- Self-organized structures formed due to R-T and Richtmyer-Meshkov instabilities

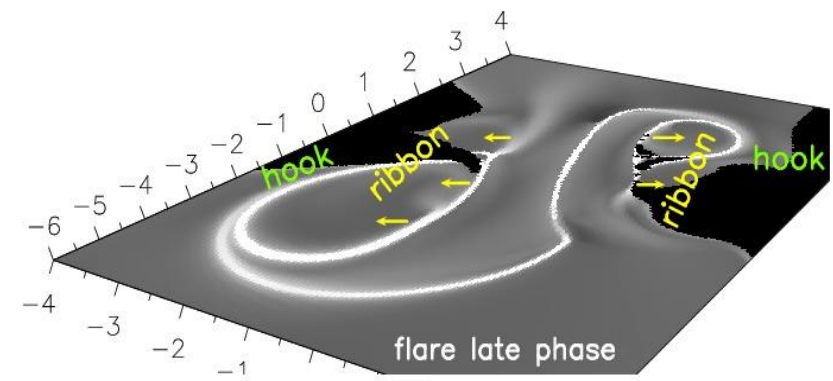
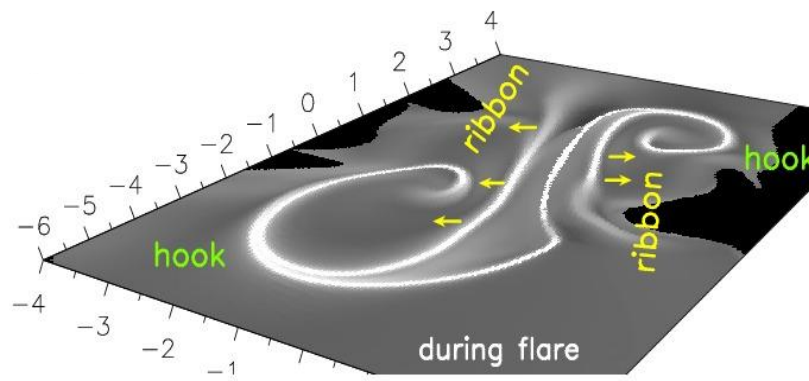
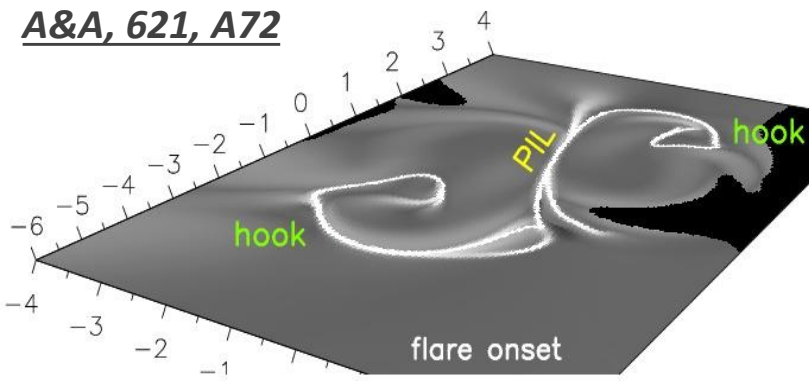


How to reconnect in an eruptive flare

- aa-rf* **Arcade + Arcade** (as in 2D)
- ar-rf* **Arcade + Rope** (3D only)
- rr-rf* **Rope + Rope** (3D only)

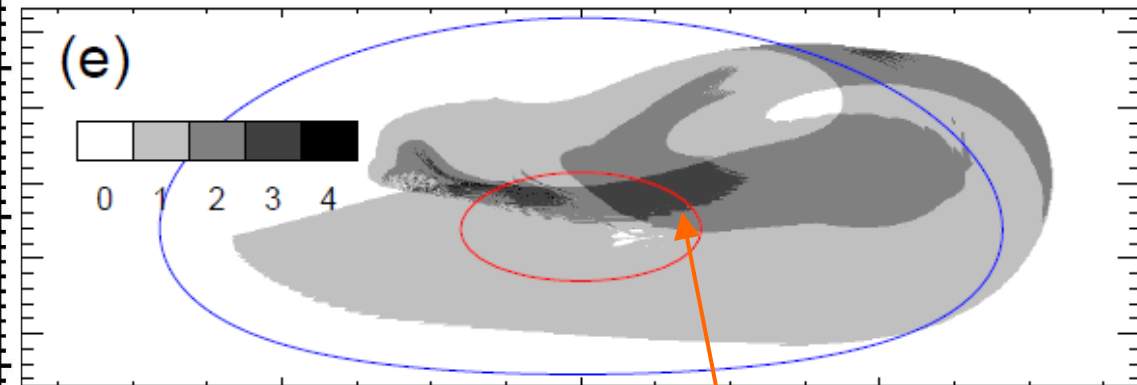
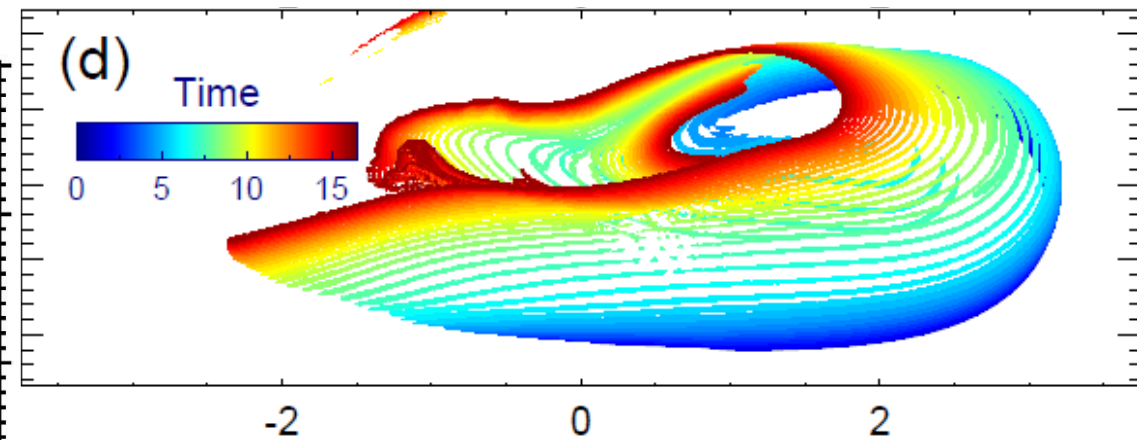
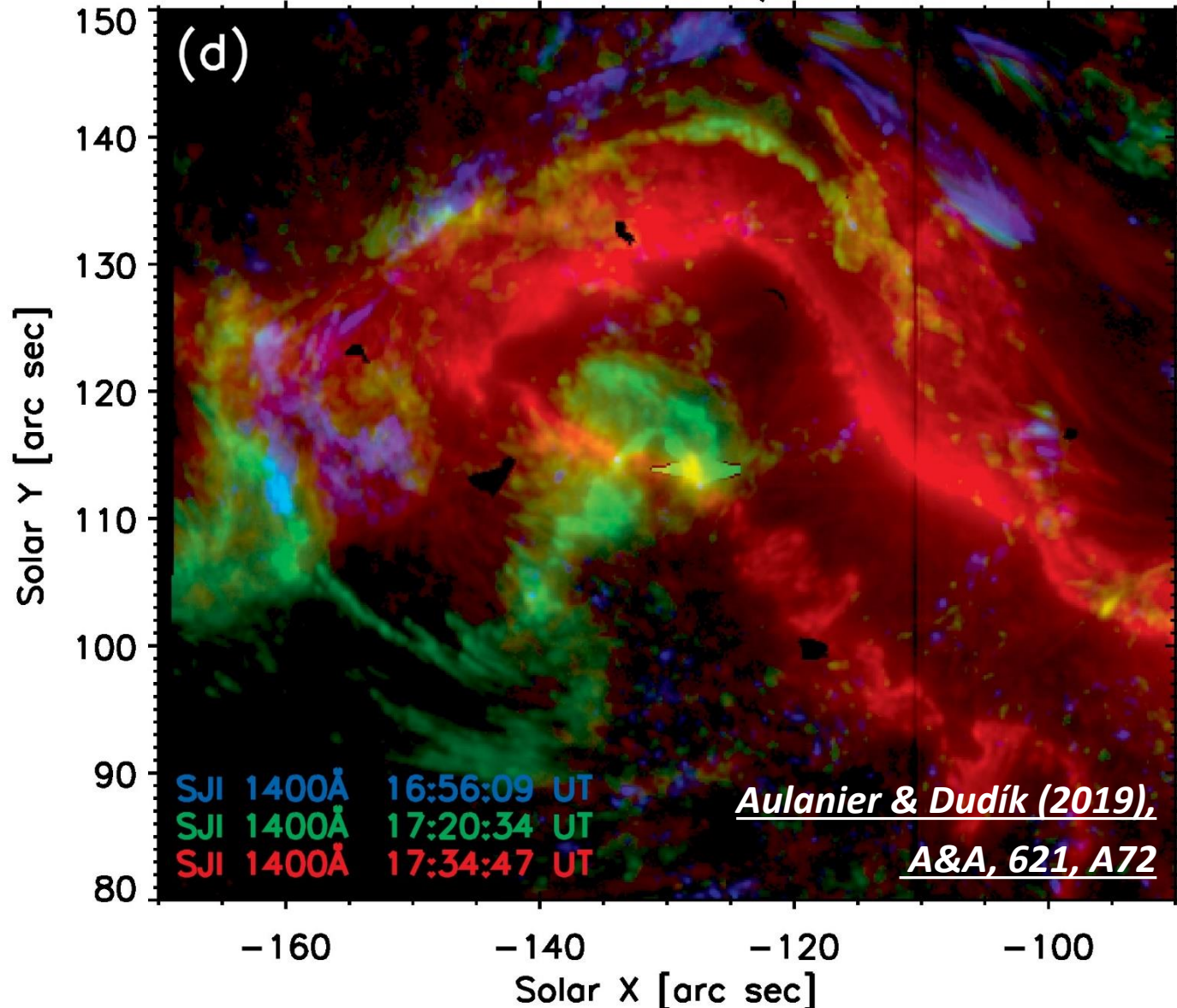


*Aulanier & Dudik (2019),
A&A, 621, A72*



3D reconnection: It works!

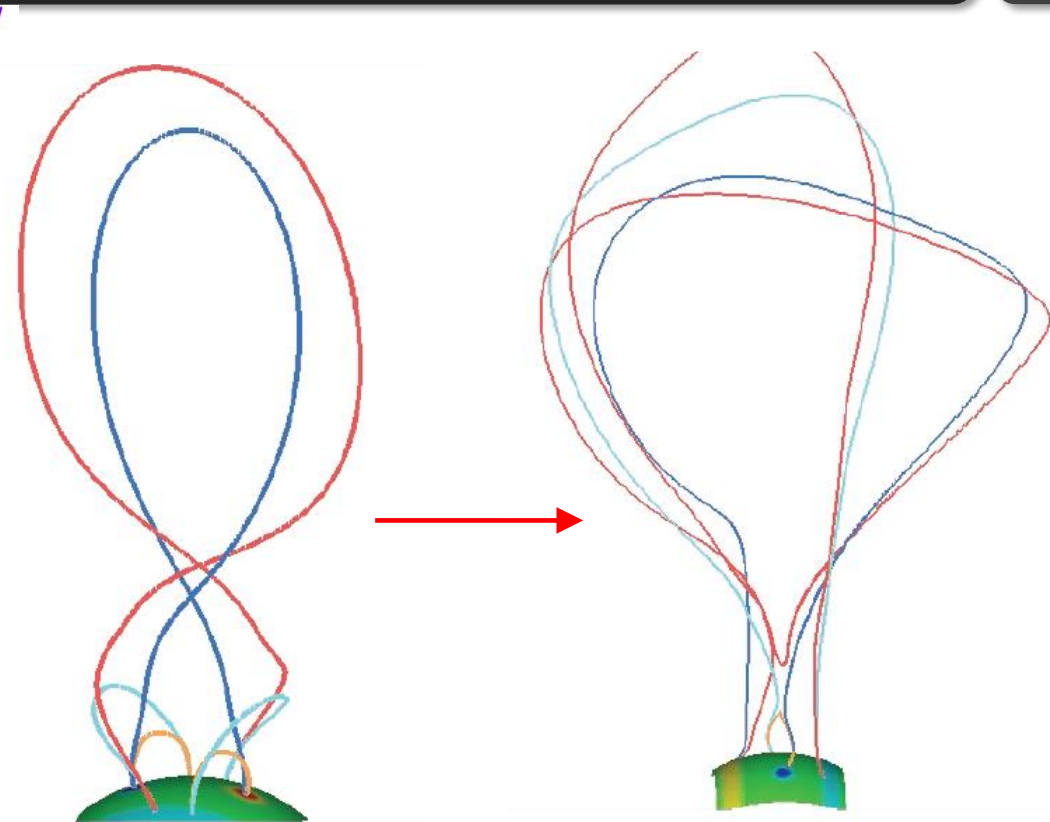
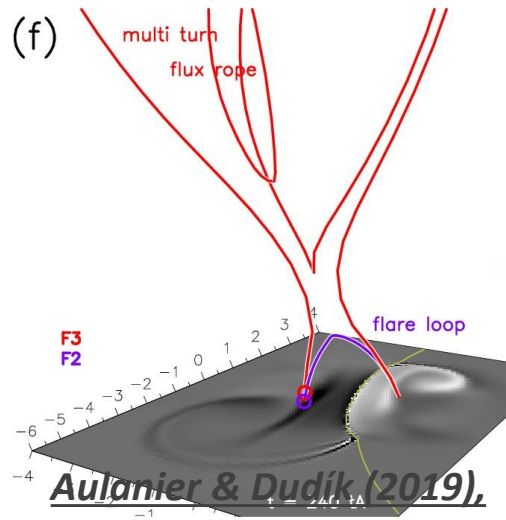
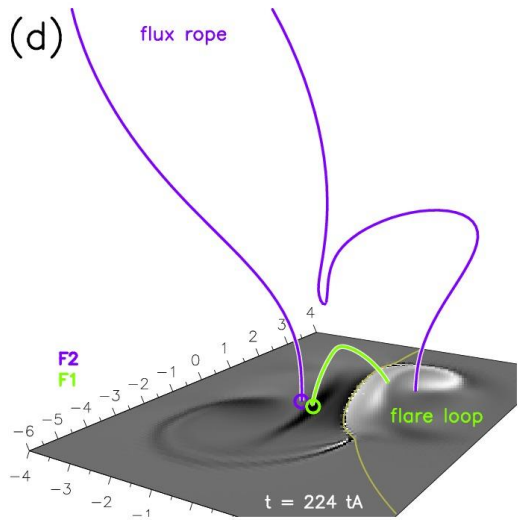
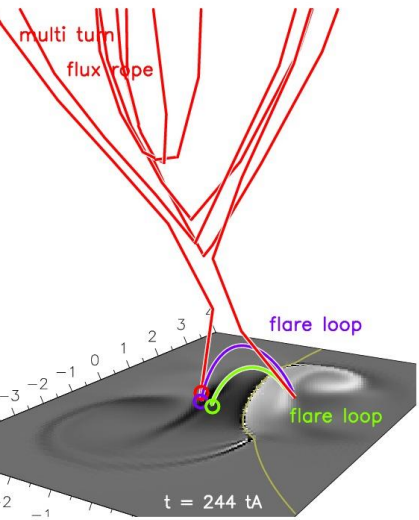
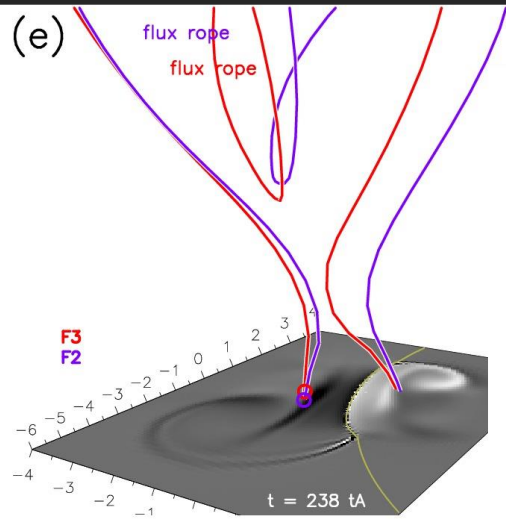
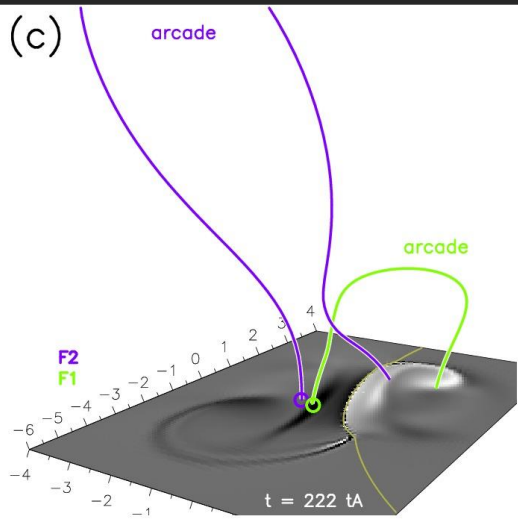
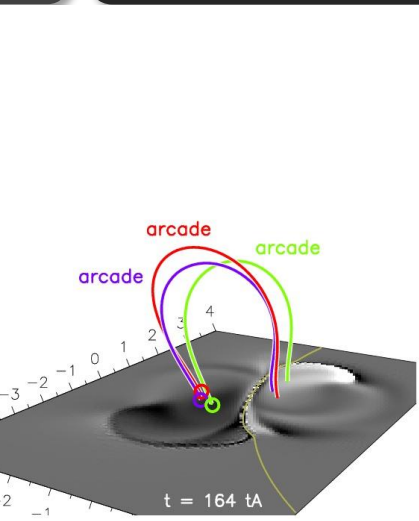
2014-09-10 IRIS/SJI 1400Å



- J-shaped ribbons evolving
- Some locations reconnect up to 4 times

*Jiang et al. (2021),
Front. Phys. 9, 575*

Leg – leg (rr–rf) reconnection



Gibson & Fan (2006), ApJ 637, L65

Ribbons spread out

$$a_{\text{arcade}} + a_{\text{arcade}} - \text{flux-}r_{\text{ope}} + f_{\text{flare-loop}}$$

“aa-rf reconnection”

$$\text{flux-}r_{\text{ope}} + \text{flux-}r_{\text{ope}} - \text{flux-}r_{\text{ope}} + f_{\text{flare-loop}}$$

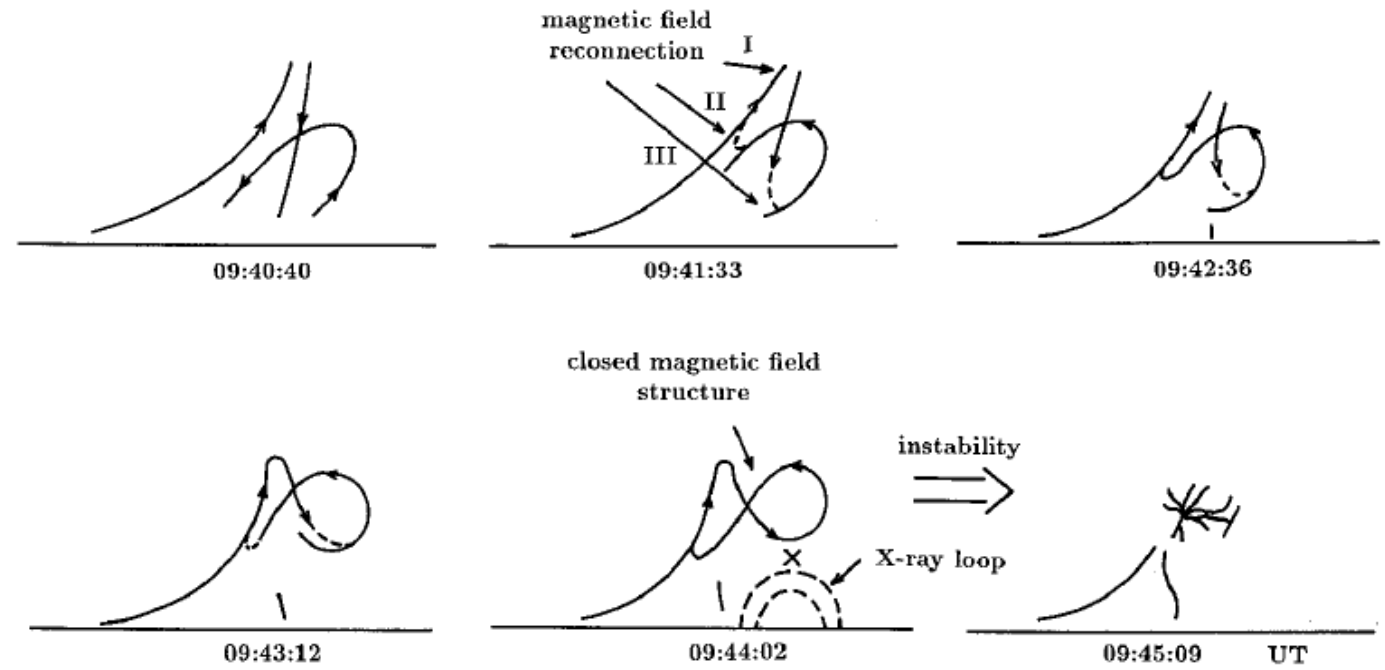
“rr-rf reconnection”

Theory:

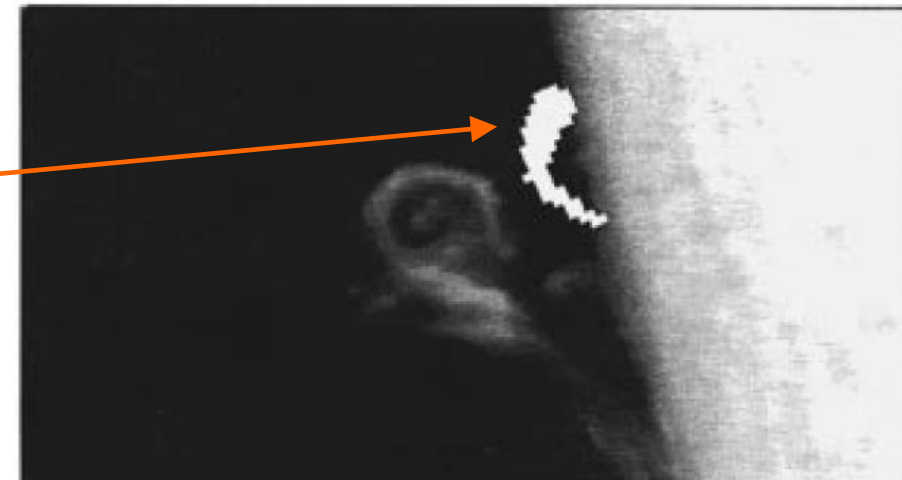
- Leg-leg reconnection is present in many MHD eruption models
- Generic process

Aulanier & Dudík (2019), A&A, 621, A72

Rope + Rope (Leg-Leg) Reconnection



- Eruptive H α prominence
- X-ray loop underneath



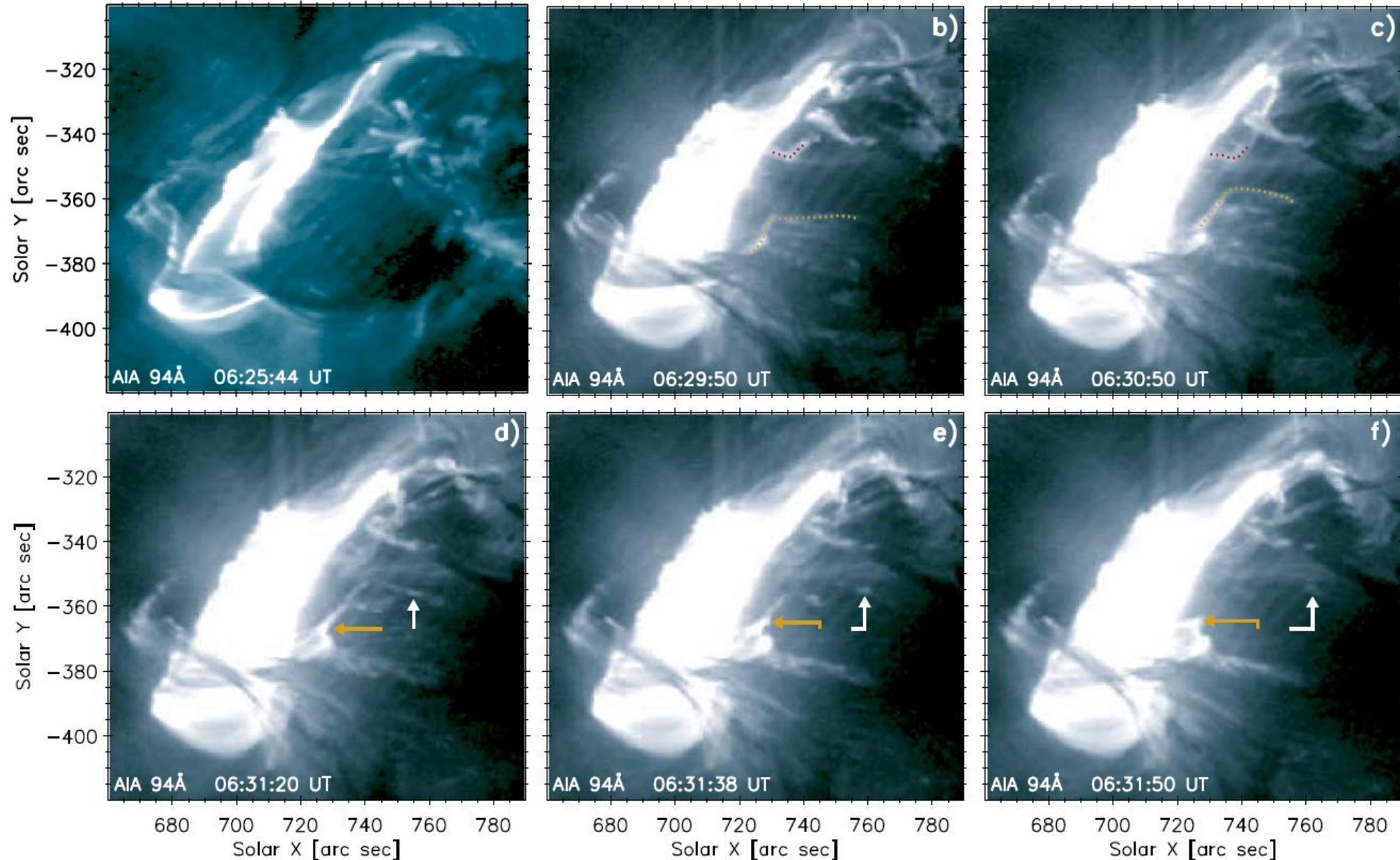
*Kotrč et al. (1998),
SoPh, 182, 393*

Rope + Rope (Leg–Leg) Reconnection

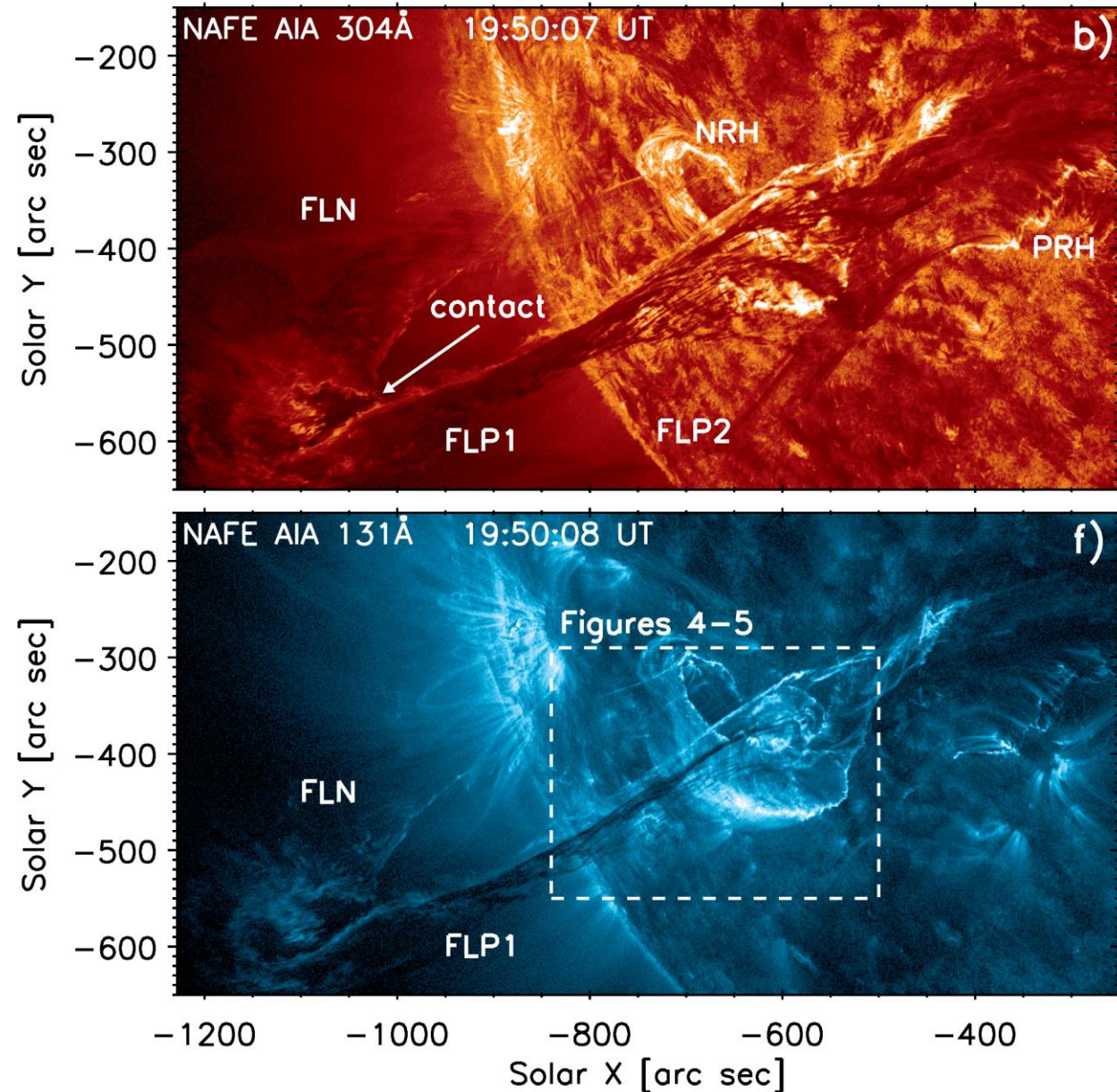
*Dudík et al. (2019),
ApJ, 887, 71*

2011 June 7 event

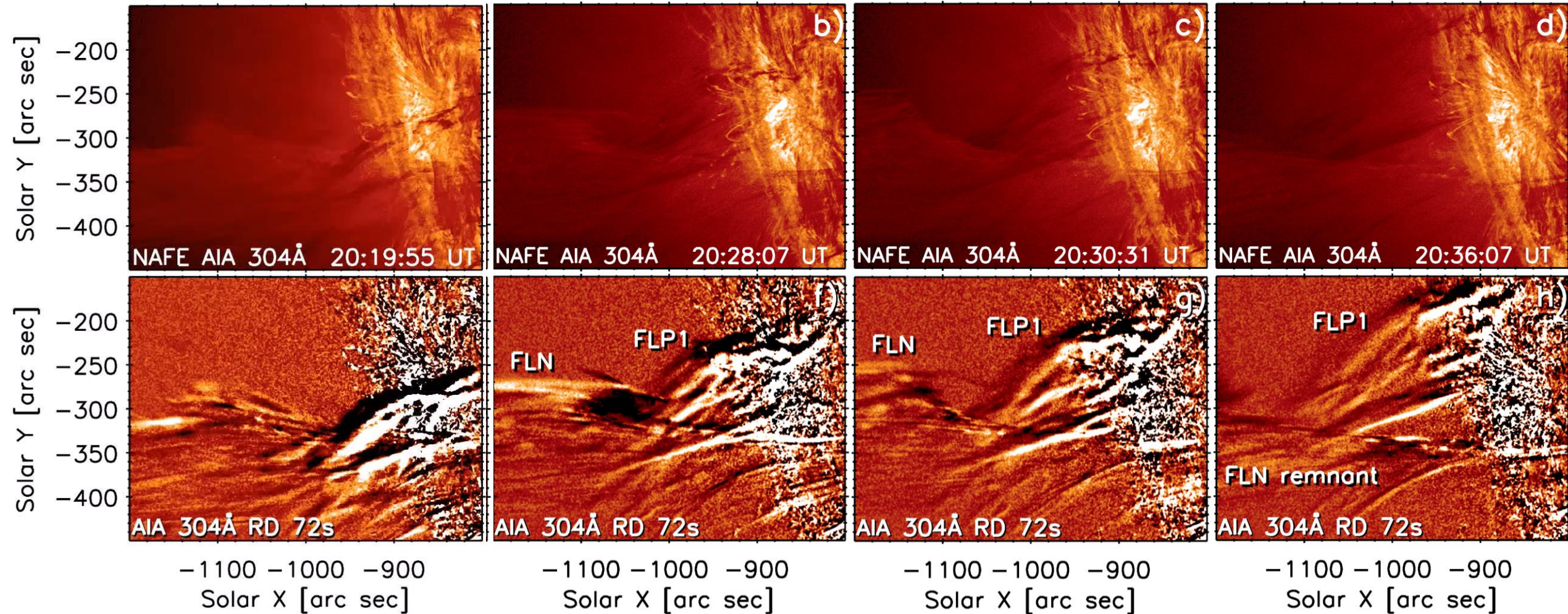
- Two filament threads approach and reconnect in an X-type geometry
- New **flare loop** is formed as a result
- A blob ascends with the filament
- rr–rf reconnection** (leg–leg)
- Also:
Filament legs drift (ar–rf reconnection)



Filament eruption of 2012 Aug 31

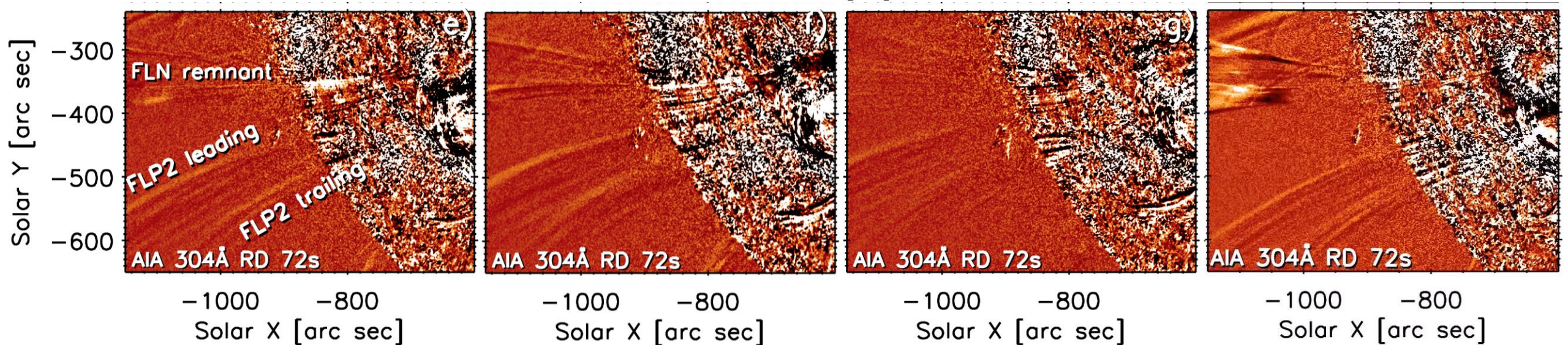
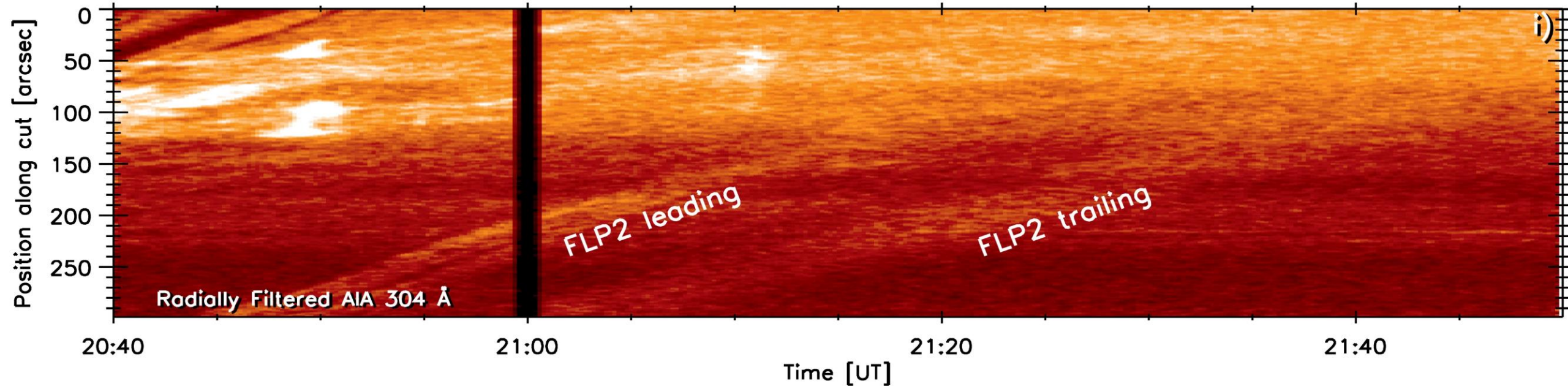


Leg – leg reconnection: Episode 1



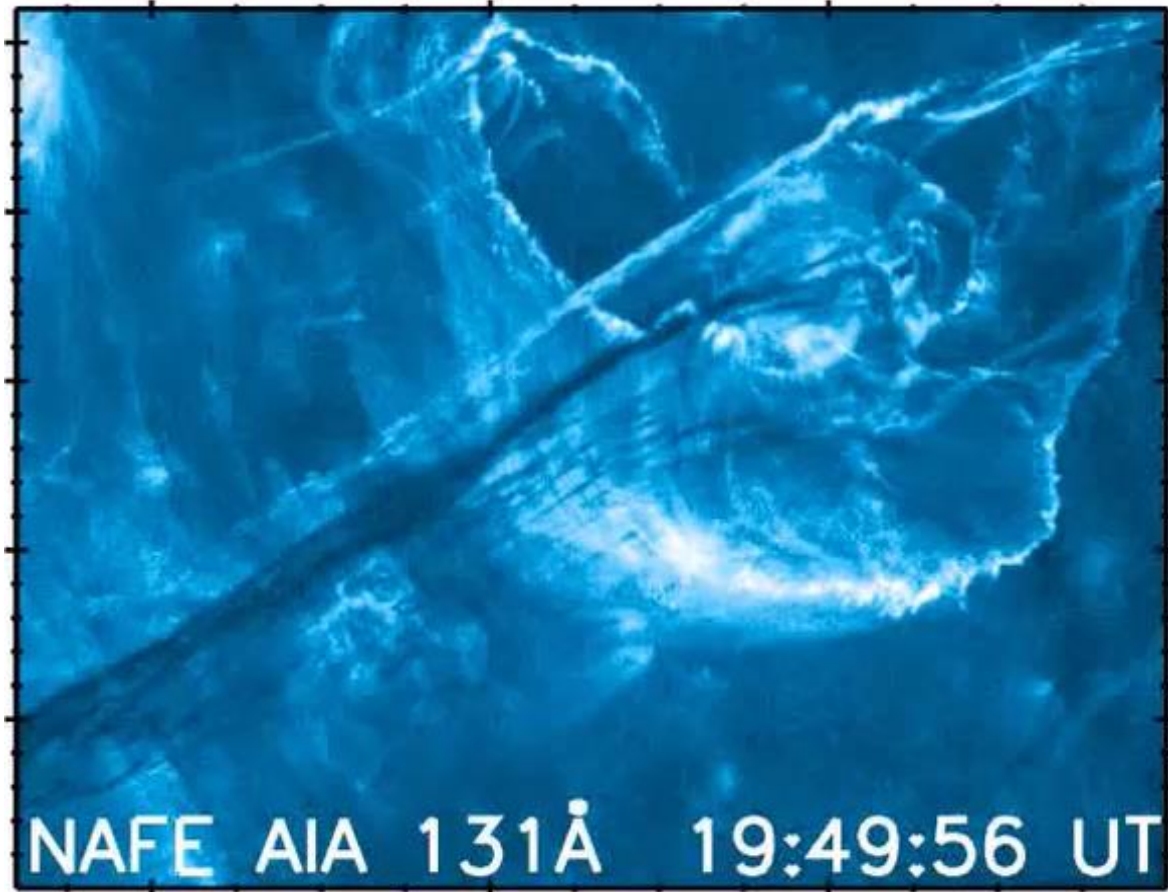
- FLP1 (leg rooted in positive polarity) runs into FLN
- Tears an opening into it
- Both weaken subsequently

- Time when this happens: $\approx 20:28$ UT
- To suppress noise, 3 running-difference (RD) images averaged in time and then by a 3x3 boxcar



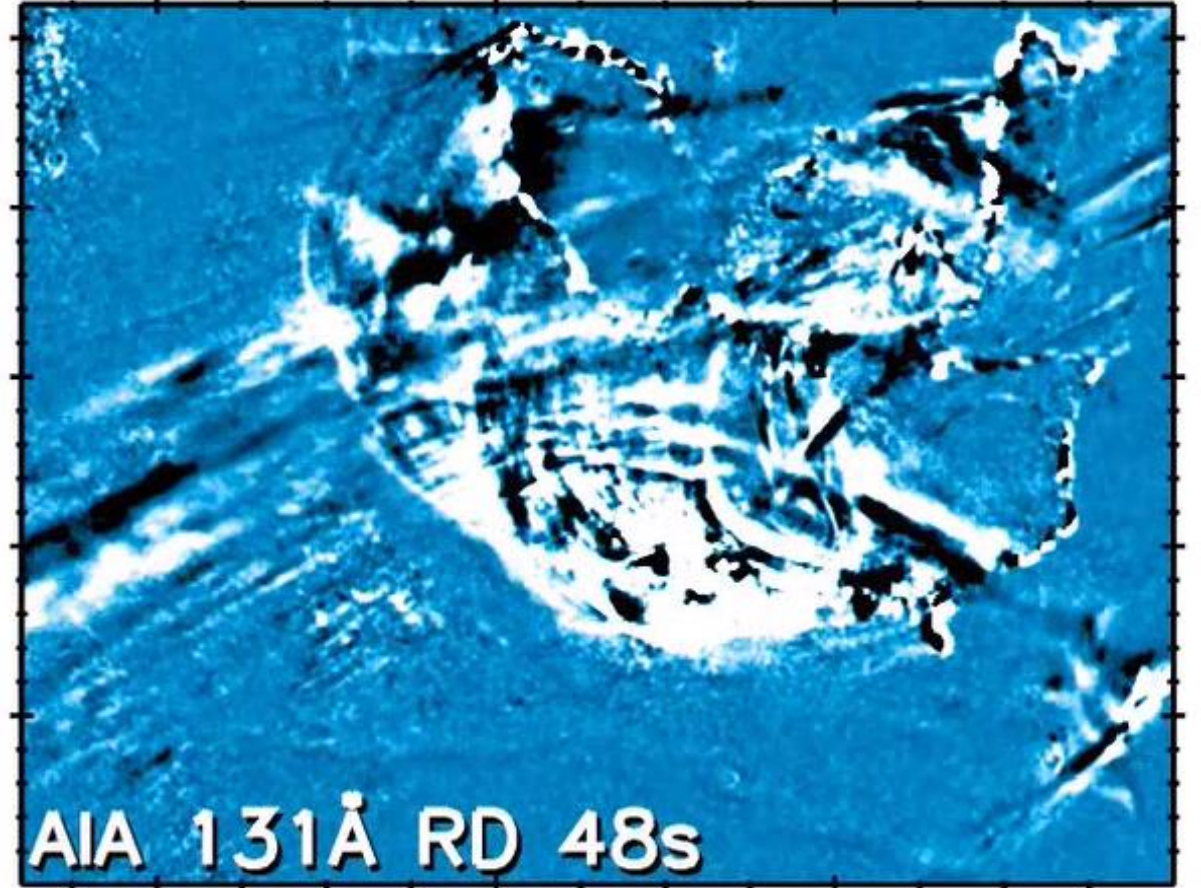
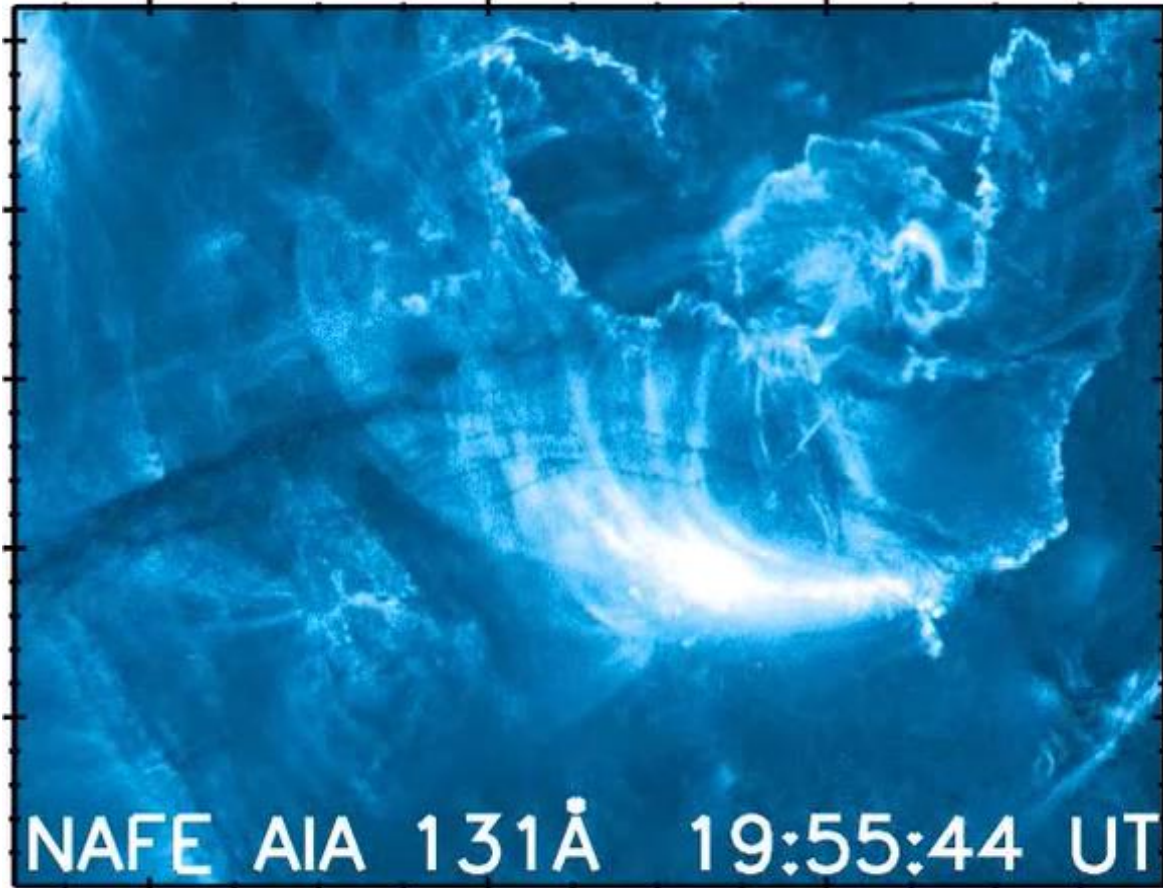
- FLP2 (splitted from FLP) converges into FLN remnant
- Almost 2D-ish „inflow“ geometry
- **Both filament legs then weaken & disappear**
- **Leading edge convergence ≈21:00 UT**
- **Trailing edge convergence ≈21:35 UT**

Supra-arcade region ...



- Hot 131 Å loops shrinking
- Flare arcade: Hot loops (Fe XXI) + cooling loops (Fe VIII)
- Supra-arcade region extends after 20:00 UT,
- Maximum brightness around 20:40 UT

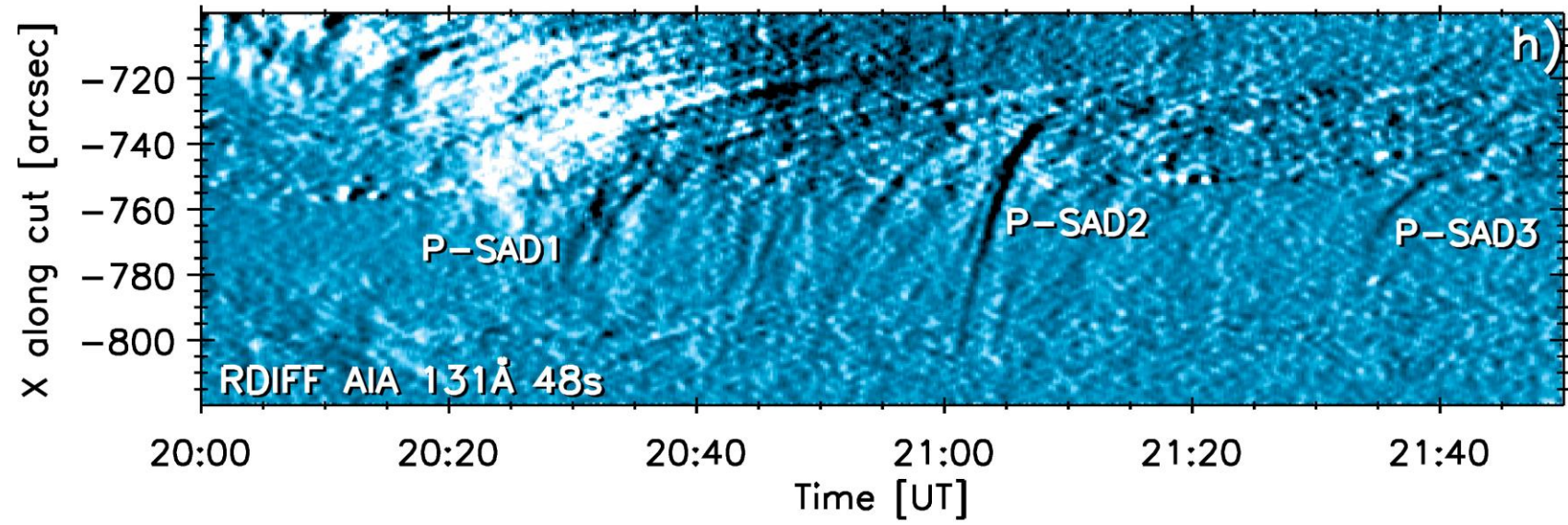
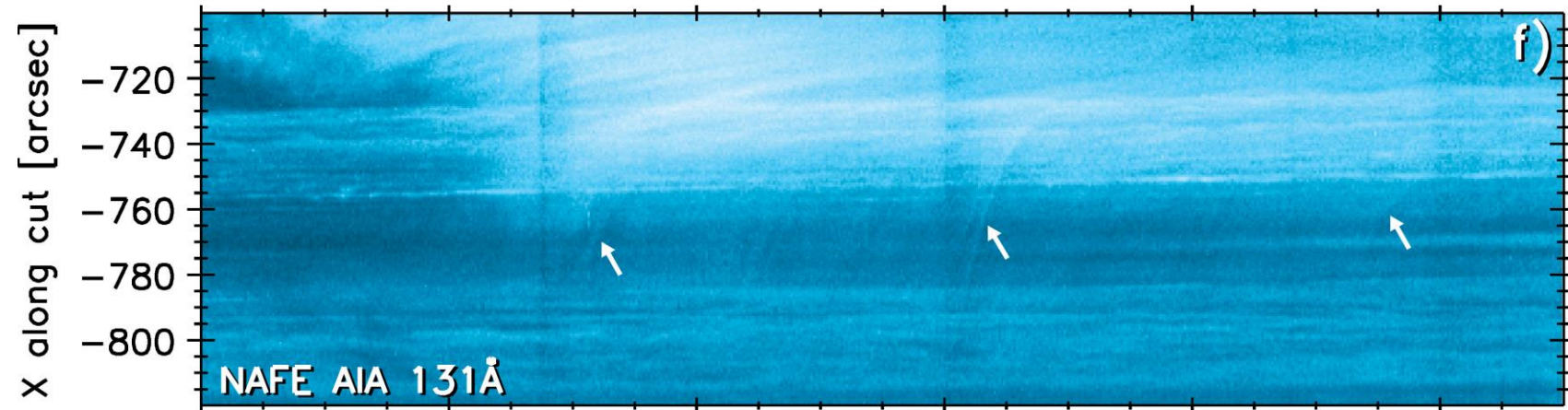
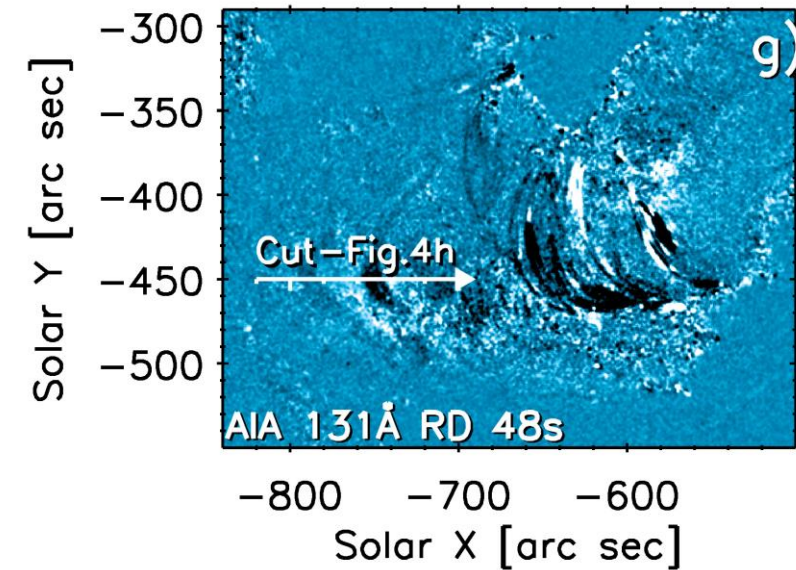
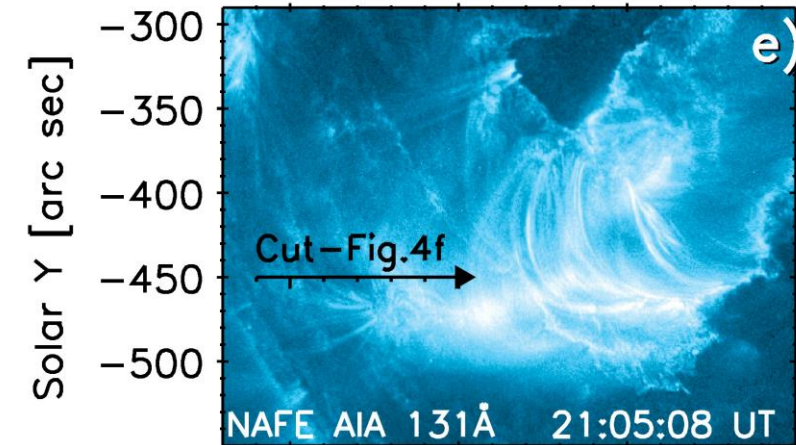
Supra-arcade region and SADs



- Hot 131 Å loops shrinking
- Flare arcade: Hot loops (Fe XXI) + cooling loops (Fe VIII)
- Supra-arcade region extends after 20:00 UT
- Maximum brightness around 20:40 UT

- Many SADs starting after 20:25 UT
- SADs occur all over
- **Some are more prominent than others**

Supra-arcade region and SADs



- Many SADs occur all the time
- Shaped as loop-tops (or even portions of loops)
- Always preceded by a bright 131 Å loop
- **Prominent ones at 20:28 UT, 21:00 UT, and 21:35 UT**

Summary

[Dudík et al. \(2022\), ApJL, 937, L10](#)

2012 August 31 event

- Famous filament eruption
- Two well-observed legs in 304 Å (underscores importance of this channel for filament eruptions)
- The legs reconnect during the eruption in multiple observed events
- 20:28 UT, 21:00 UT, 21:35 UT
- Possibly earlier episodes
- **RR-RF (leg-leg) reconnection is both significant and long-lasting**
- **All prominent episodes of leg-leg reconnection lead to prominent SADs**
- Why – unknown
Possibly related to the larger magnetic field strength in the erupting filament

