

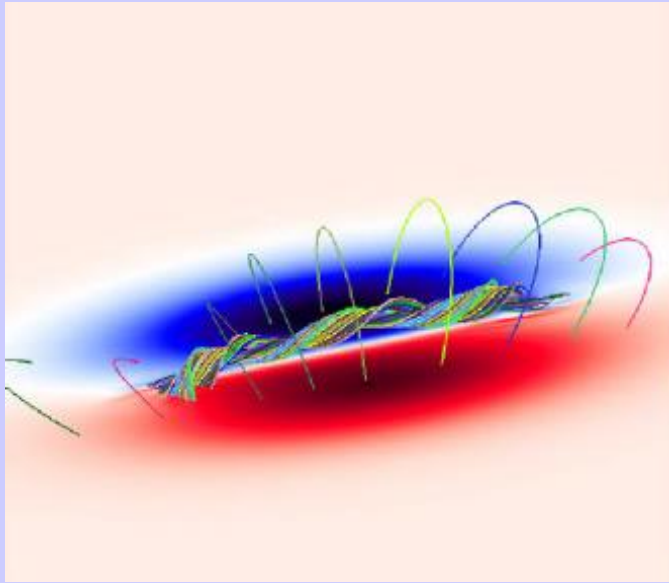
How Common are Hot Magnetic Flux Ropes in the Low Corona? A Statistical Study of EUV Observations

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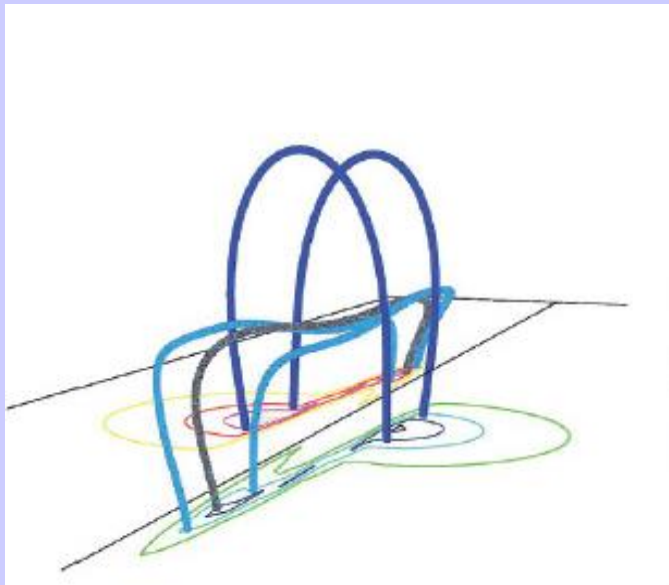
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Pre-eruptive Magnetic Configurations



Magnetic Flux Rope



Sheared Arcade

Purpose of the study

- A few previous case studies of HFRs associated with CMEs. Their main focus: whether the FR forms before or during the eruption
- These works were single-event studies leaving unclear the importance of HFRs in CMEs
- We search for HFRs using an extensive dataset of large flares
- We don't address the question on whether the FRs formed before or during eruptions
- Instead we address the more fundamental question of how common HFRs are in the low corona (irrespective of their formation time relative to the onset of eruptions)

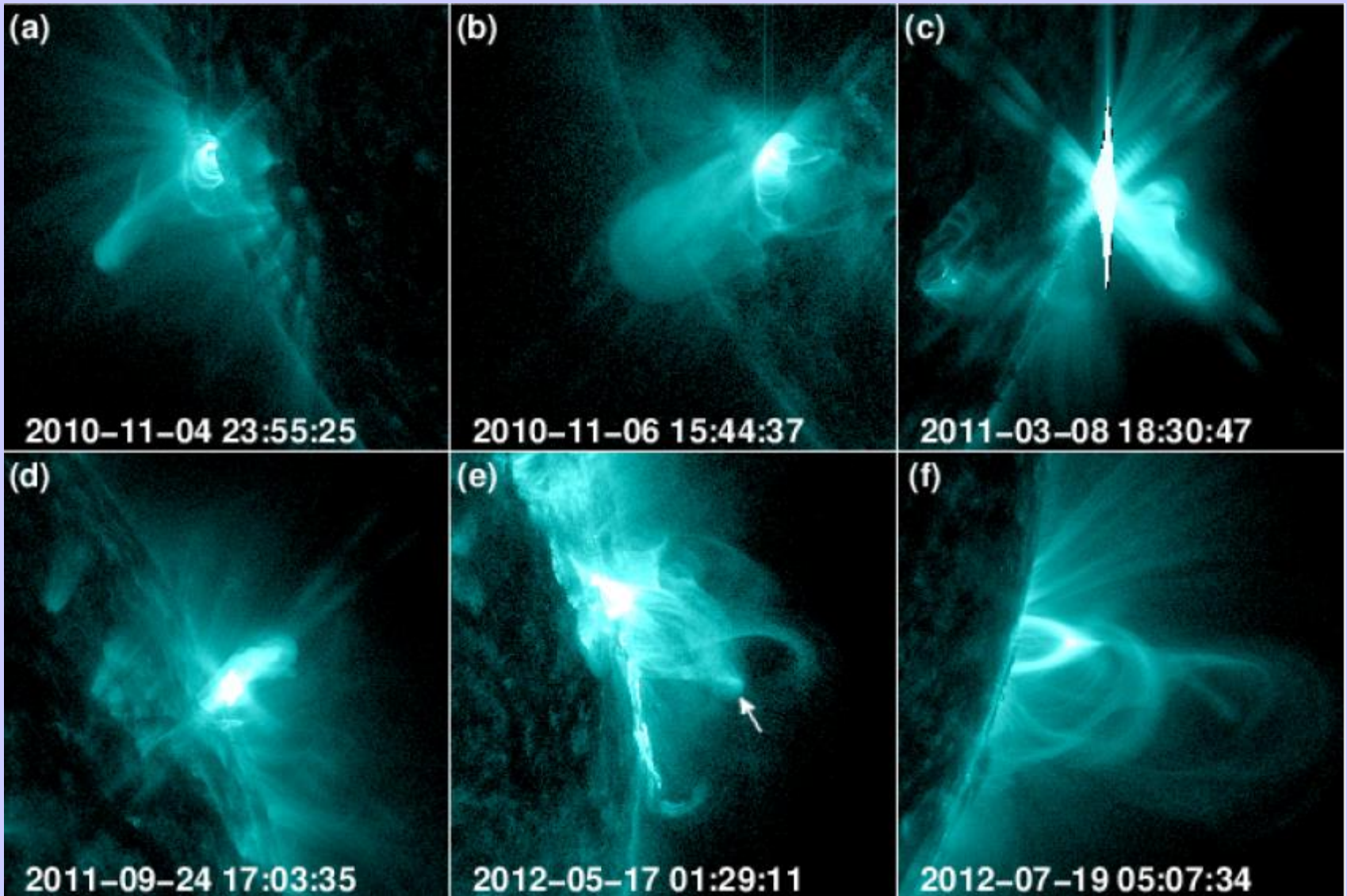
Data

- 141 M- and X-class flares occurred at longitudes $> 50^\circ$
- SDO/AIA images at 131 Å (\rightarrow 0.4 MK, 10 MK), 171 Å (\rightarrow 0.6 MK), 304 Å (\rightarrow 0.05 MK)
- LASCO C2 coronagraph images
- Supplementary Hinode/XRT data (for 40 events)

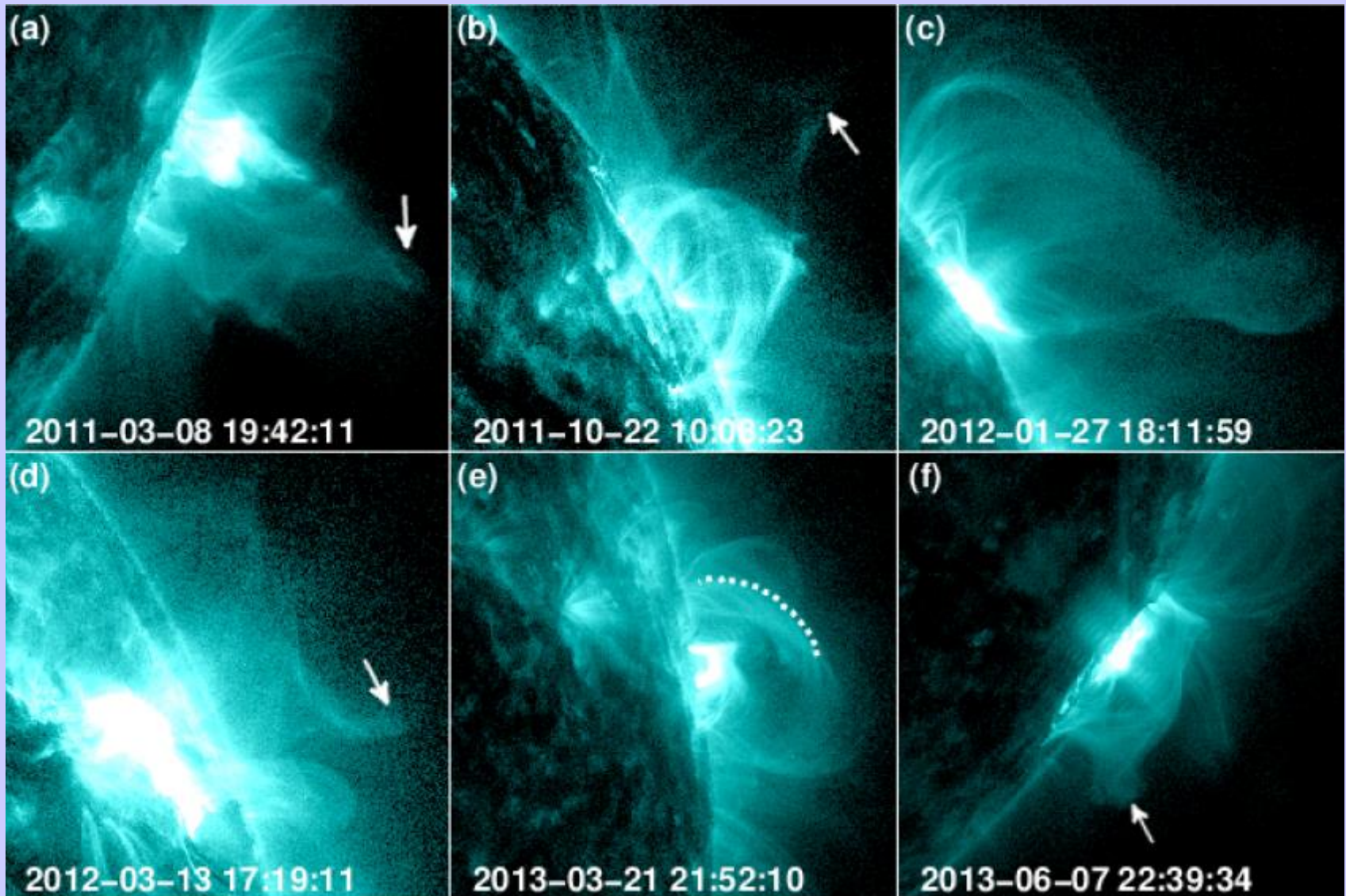
Analysis

- The observed morphology of FRs depends on its inherent twist and viewing angle
- Search for FRs in 131 A movies using morphological criteria for FRS seen:
 - edge-on
 - face-on
 - viewed from intermediate angles
- The FRS are hot if they appear in 131 A but not in 171 A and 304 A

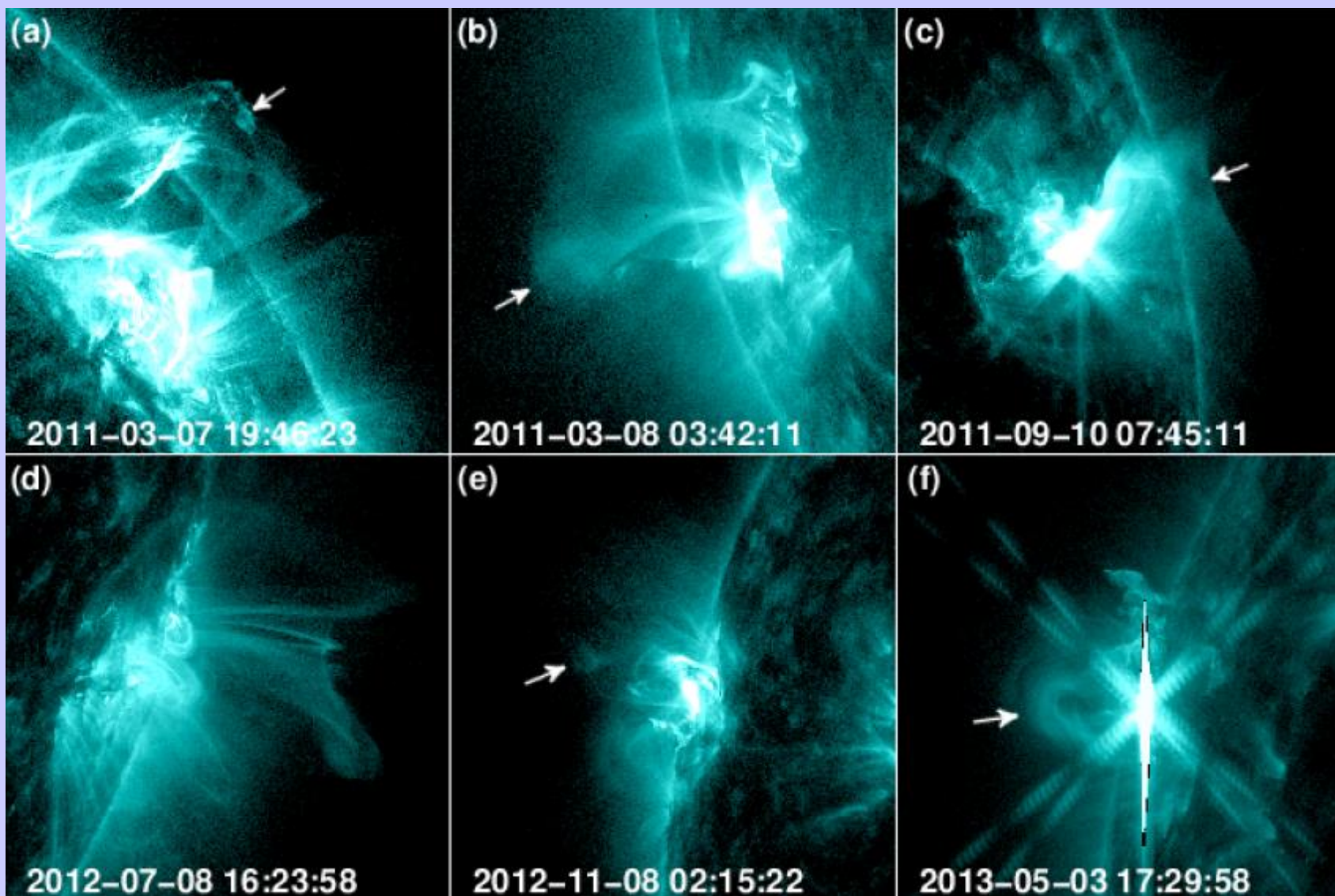
FRs seen edge-on



FRs seen face-on



FRs viewed from intermediate angles

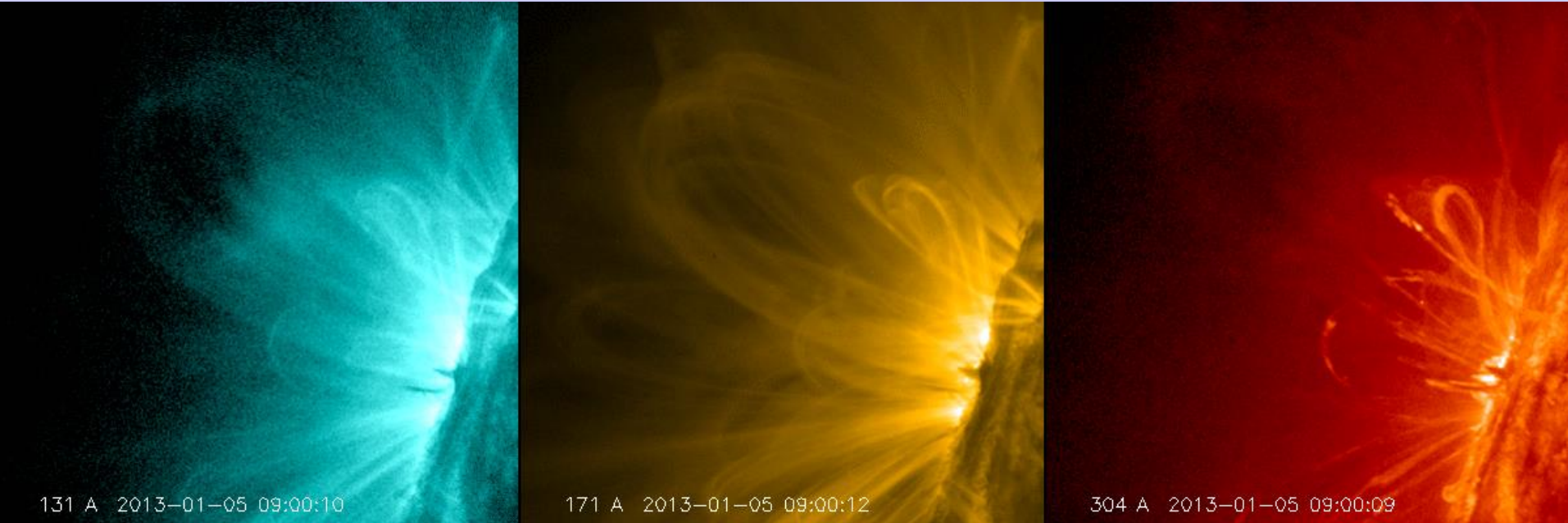


Classification of events

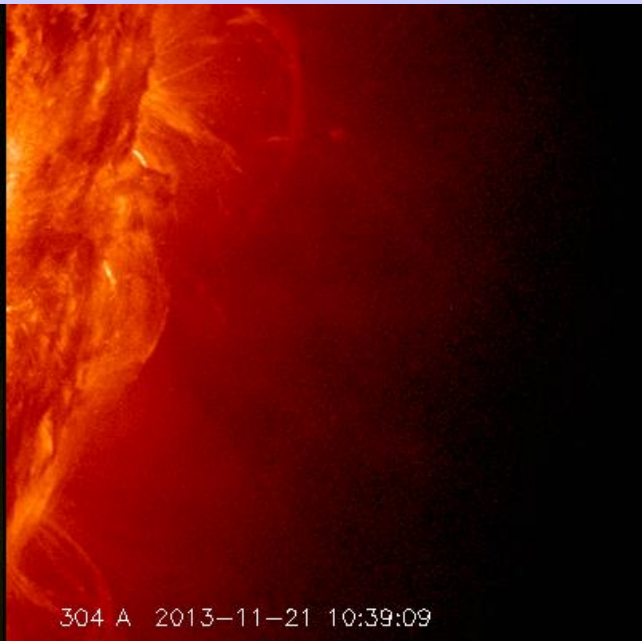
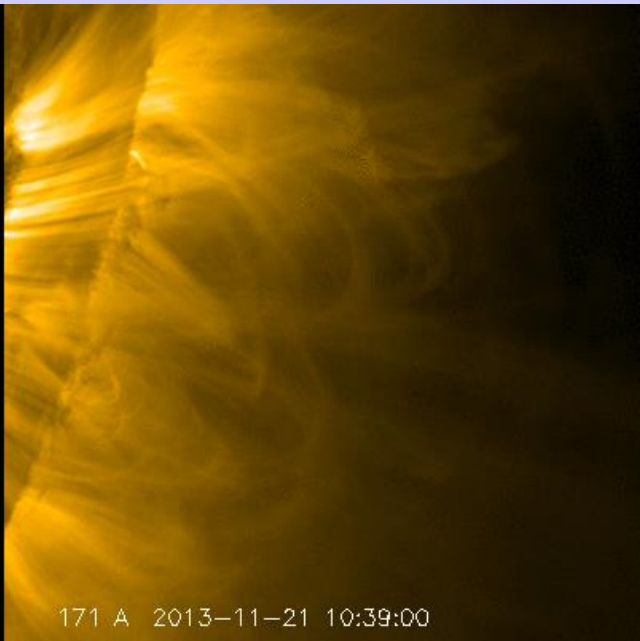
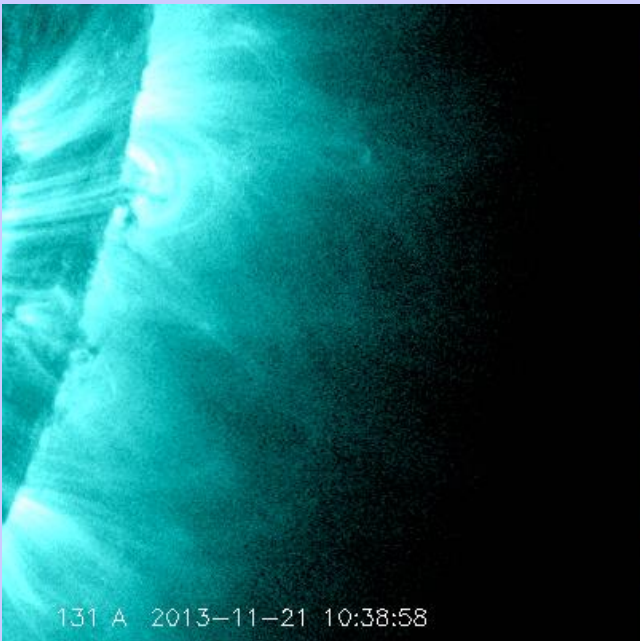
45 events (32%) were associated with HFRs and 96 (68%) were not. In more details:

- Confined flare events with hot flux ropes (CFR) -11 events
- Eruptions with hot flux ropes (EFR) -34 events
- Prominence eruption events without hot flux ropes (PE) -19 events
- Eruptions without hot flux ropes or prominences (PFL) -24 events
- Confined flare events without hot flux ropes (CFL) -53 events

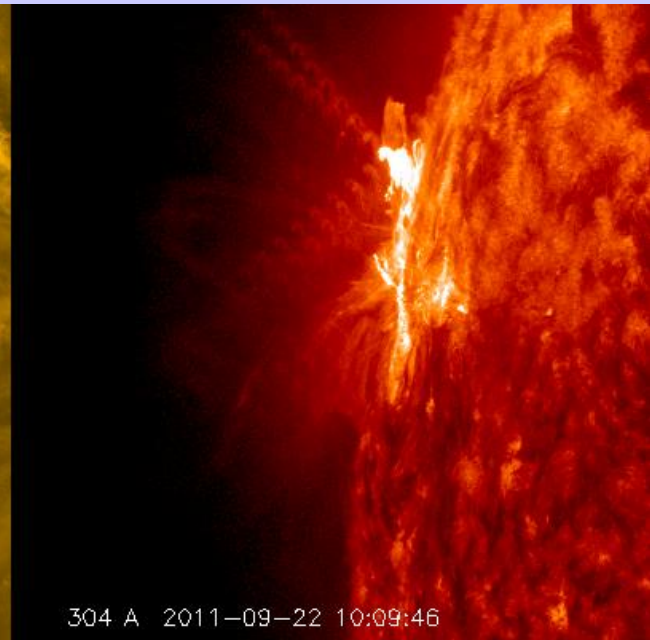
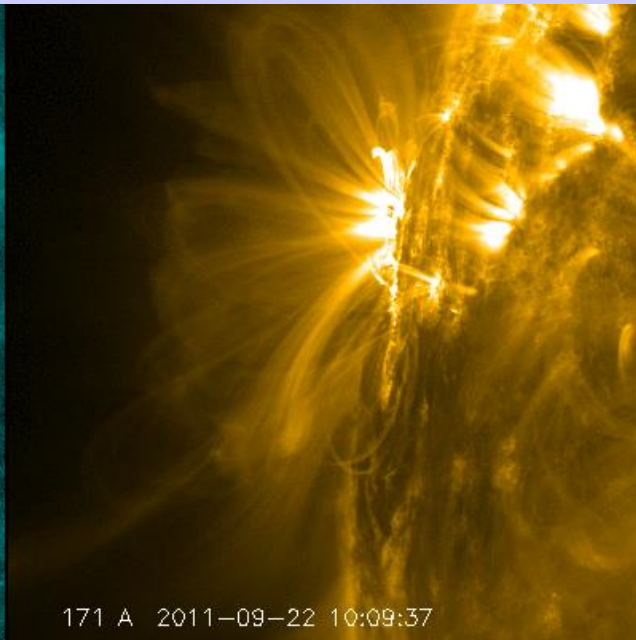
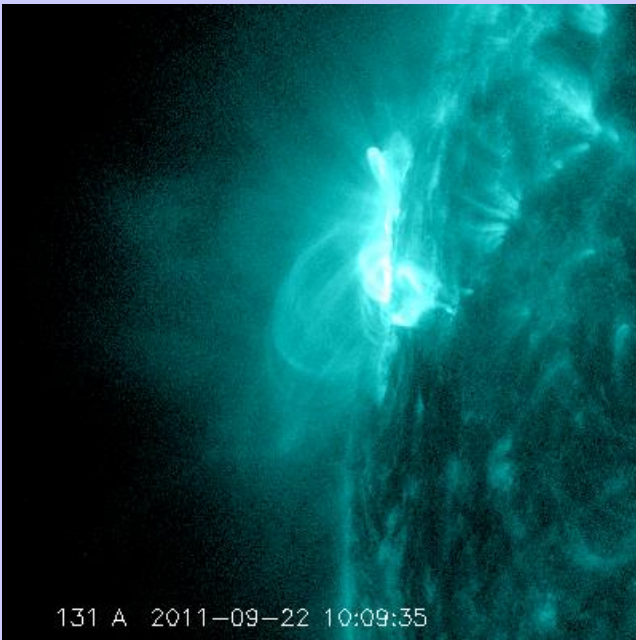
Confined event with hot flux rope (CFR)



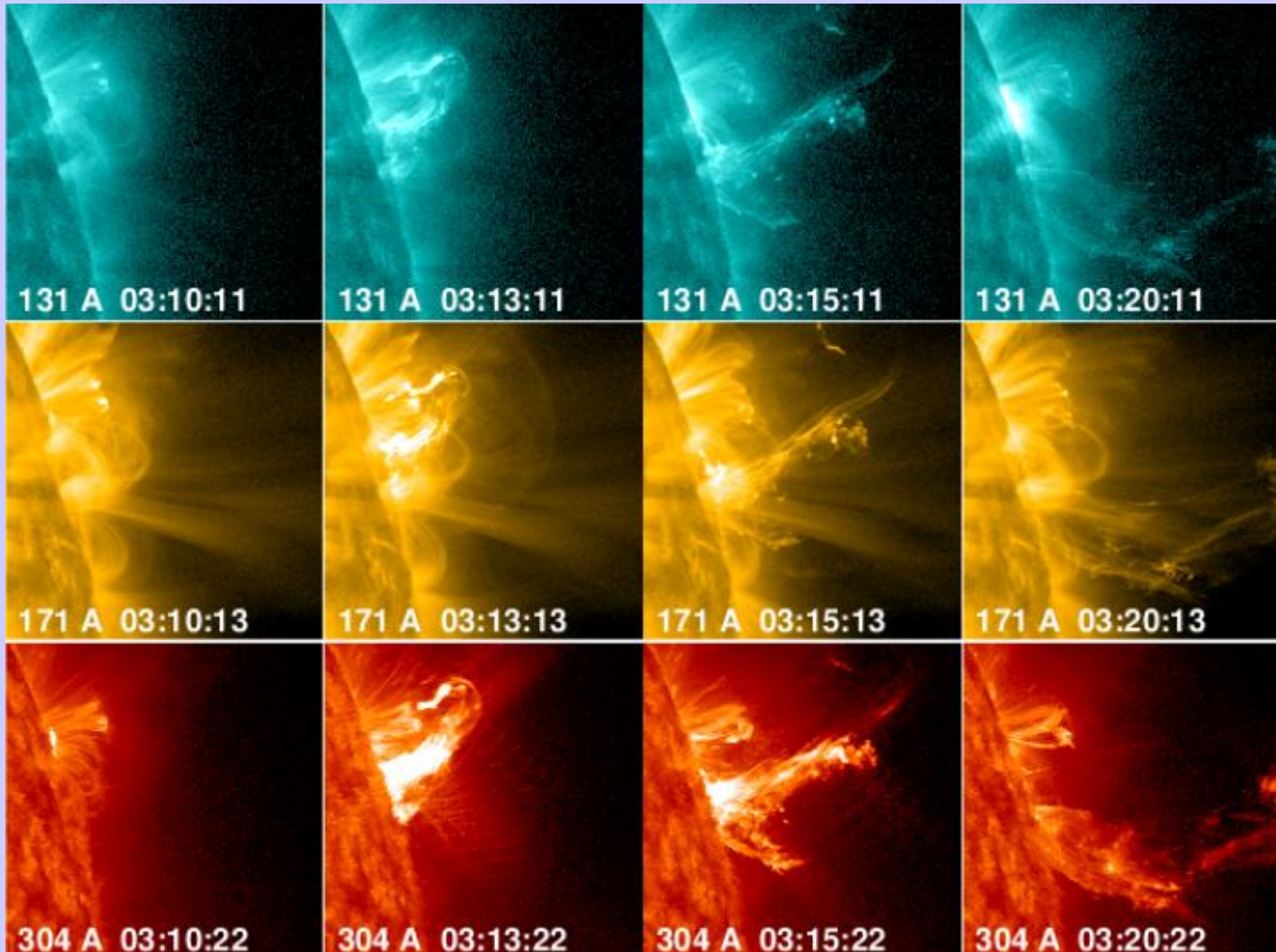
Eruptive event with hot flux rope (EFR)



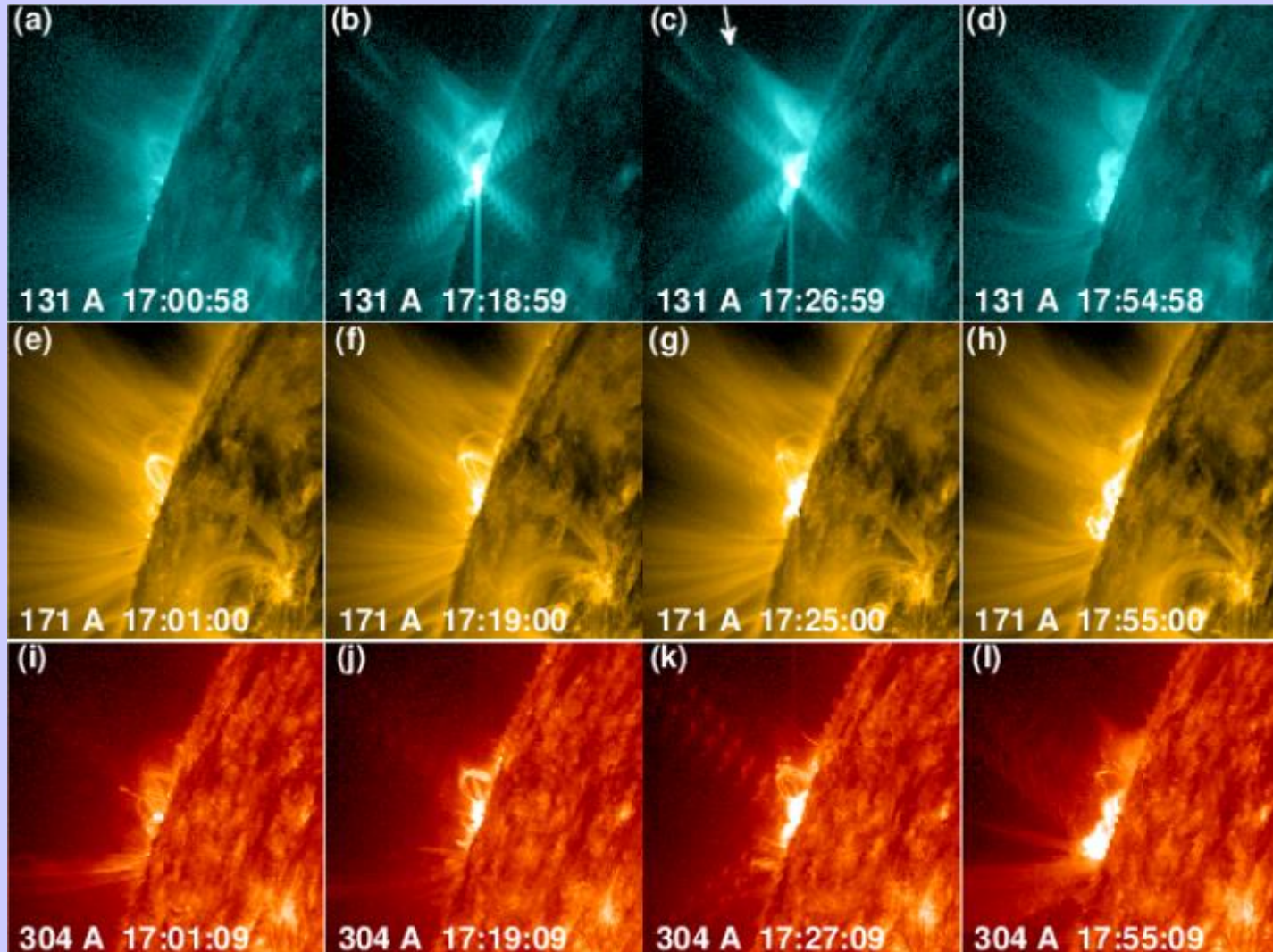
Eruptive event with hot flux rope (EFR)



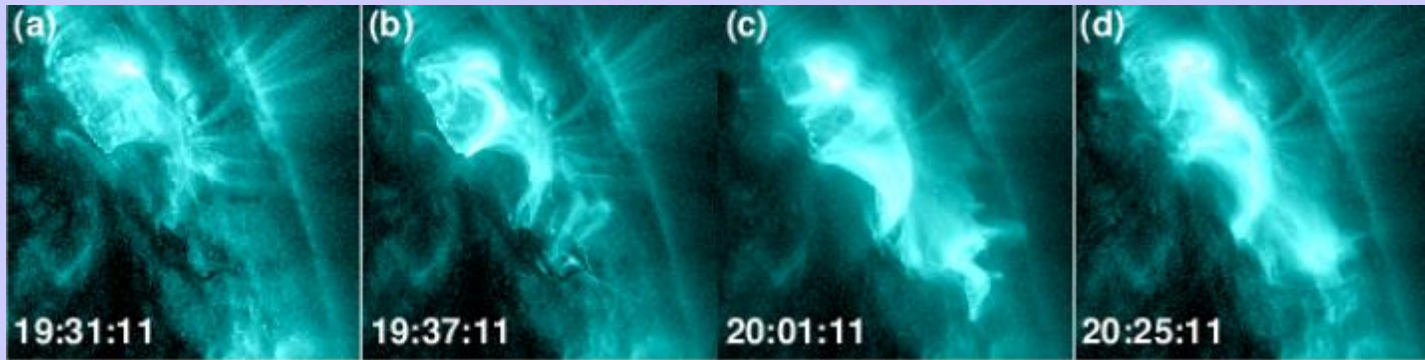
Prominence eruption without hot flux rope (PE)



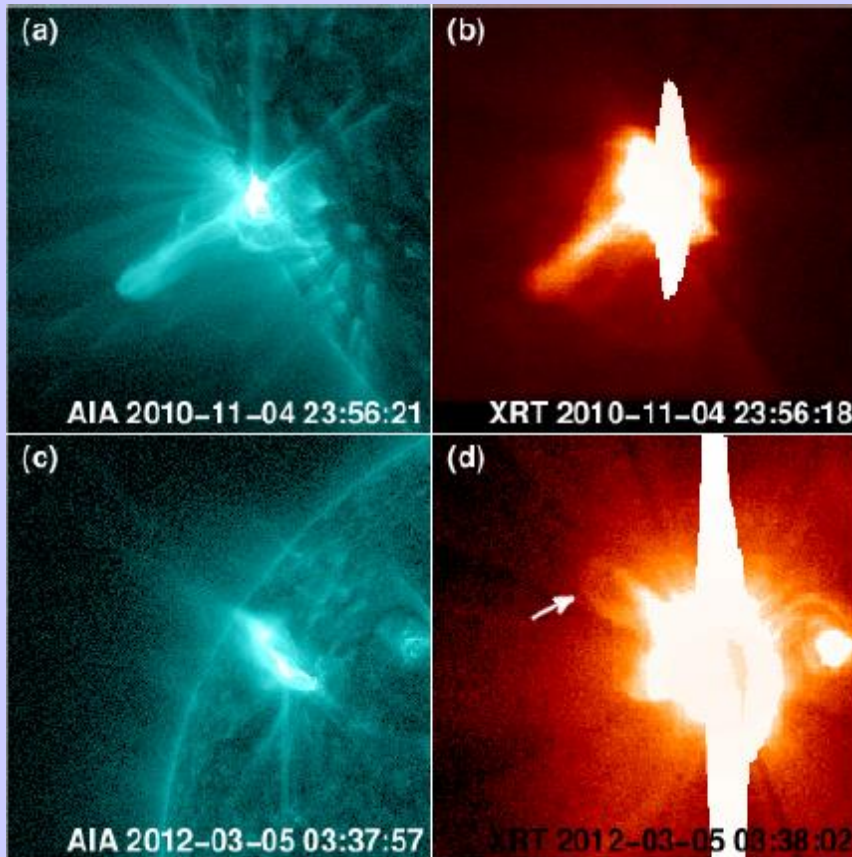
Eruptive event without hot flux rope or prominence (PFL)



Confined flare without hot flux rope (CFL)



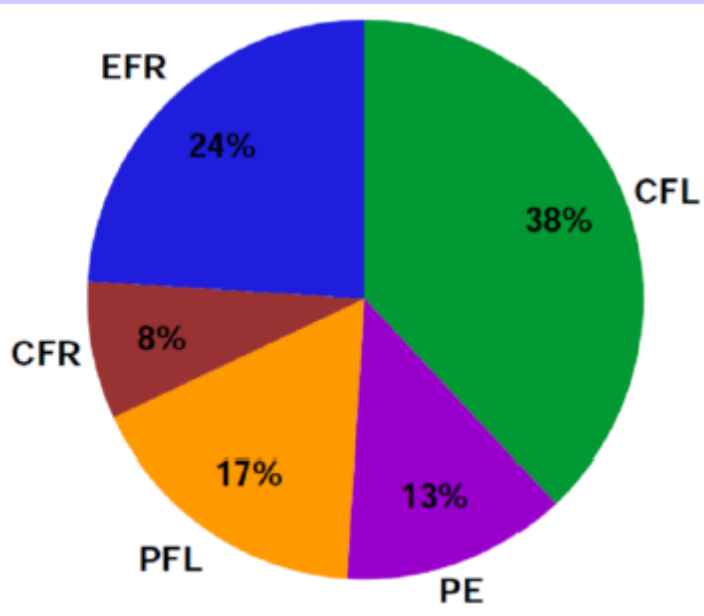
Comparison with *Hinode* XRT



- 40 events with simultaneous AIA and XRT observations
- 11 out of the 14 events with AIA HFRs showed FRs in XRT (~79%)
- XRT detected FRs in 6 events with no HFRs in AIA

Conclusions

- 32% of the flares contain HFRs
(34 EFR + 11 CFR)/141]



- 70 flares associated with CMEs → a HFR configuration was involved in 49% of the eruptive events
- What about the remaining 51%? FR exists but it is too cool to be detected in 131 A and too hot to show in 171 A and 304 A (see the detection of FRS with the XRT in 6 events with no such signatures in 131 A AIA data)

→ The above percentages are lower limits for the rate of occurrence of HFRs