Observations of thermal non-equilibrium cycles in a solar pseudo-streamer

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CROSSWIND

Thermal non-equilibrium (TNE)

Key process for the mass and energy transport in the solar corona

- ★ Set by a stratified and quasi-steady heating that will induce evaporation and condensation cycles e.g. Antiochos and Klimchuk, 1991
- ★ Global behaviour that connect many different scales (temporal, spatial, temperature and density conditions) and all the solar atmospheric layers

Widespread in the solar corona, manifestations includes:

➡ **Long-period EUV intensity pulsations** (periods of a few hours): reflecting the temperature and density evolution in the corona
Auchère et al, 2014; Froment et al. 2015, 2017, 2020; Auchère et al. 2018; Pelouze et al. 2020; Sahin et al. 2023

➡ **Coronal rain**: cool and dense material, observed in chromospheric and ransition-region lines, produced by a thermal instability
e.g. Kawaguchi 1970, Leroy 1972, De Groof et al. 2004, Antolin & Rouppe van der Voort 2012

Is TNE restricted to closed fields?

Implications relatively well-known for closed-field structures, what about TNE at open-closed boundaries and in open structures?

Recent numerical works in open field structures
- transient coronal rain formed in open field Kohutova et al. 2020
- TNE cycles in open field Scott et al. 2024, Le Nestour et al. in prep

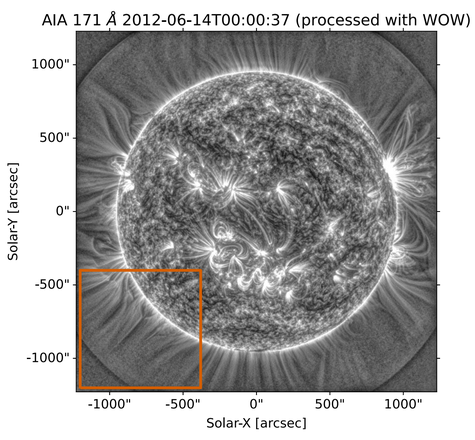
Relationship of these events with TNE to be investigated

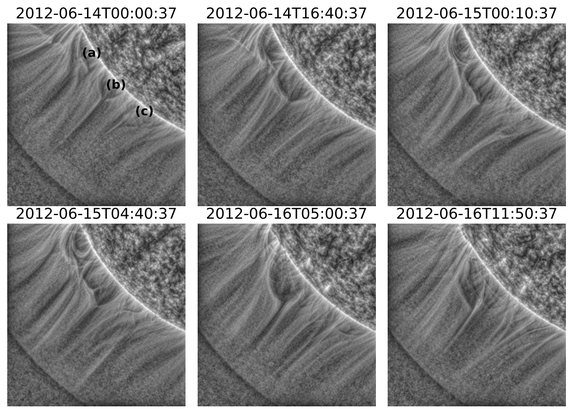
Hybrid prominence-coronal-rain events
(Liu et al. 2014, Antolin & Froment 2022)
➡ Common, recurrent phenomenon in the quiet Sun
Li et al. 2018, 2019, 2020, Mason et al. 2019
➡ Topological structures: Fan-spine topologies and pseudo-streamers

Mason et al. 2019 proposed interchange reconnection and TNE for the formation mechanism of these events

Case study in a pseudo-streamer (PS)

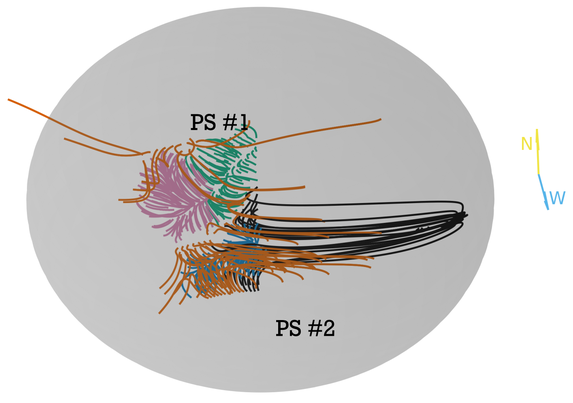
Global evolution in EUV (SDO/AIA)

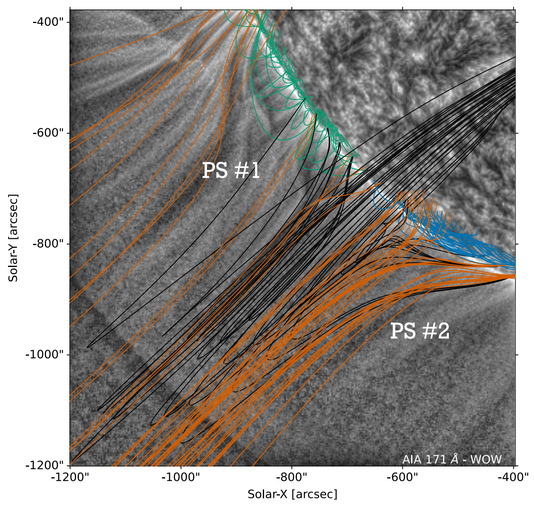




3 EUV lobes (?) => the northern and the middle lobes are in reality from the same PS-dome but with a change in its orientation.

Magnetic topology (PFSS extrapolations)



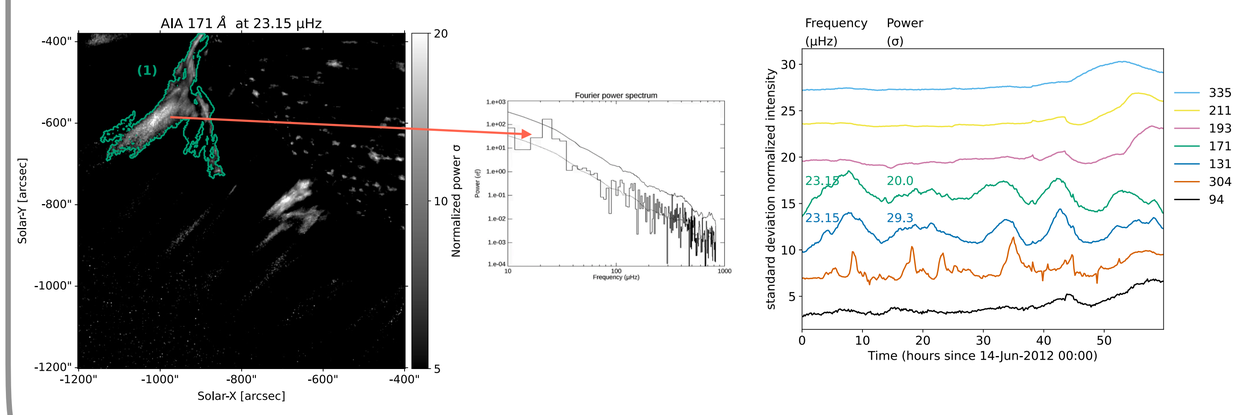


Pseudo-streamer:
➡ closed fields lines confined by a dome separatrix surface
➡ an open vertical fan or separatrix curtain, located at the interface between two open-field regions of the same polarity. Wang et al. 2007; Titov et al. 2011, 2012; Scott et al. 2021

➡ PS #1 is the focus of our study: non-eruptive pseudo-streamers

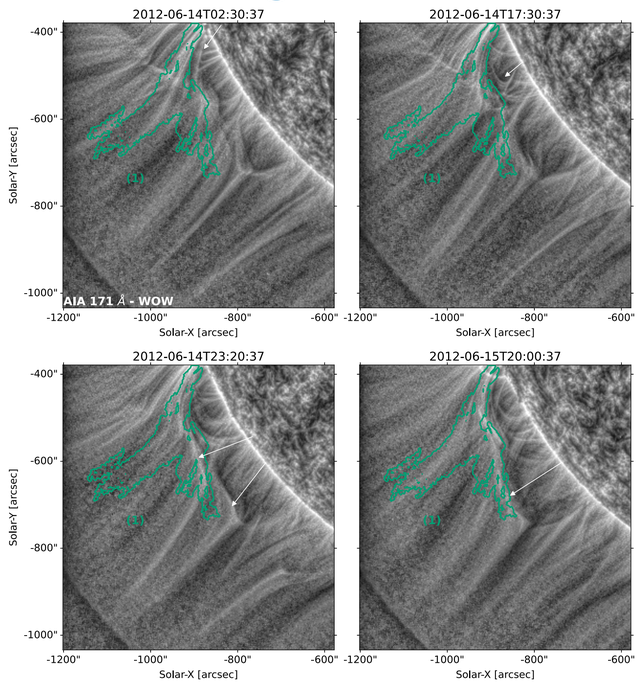
Long-period EUV pulsations detections

The detection is done in the Fourier space for every pixel of the field-of-view Auchère et al. 2014
➢ We **do not** look for pulsations in a particular structure



➡ **Detections in two channels (period of 12 hours) + quasi-synchronous recurring behaviour in 304**

Pseudo-streamer dynamics: evidence for interchange reconnection



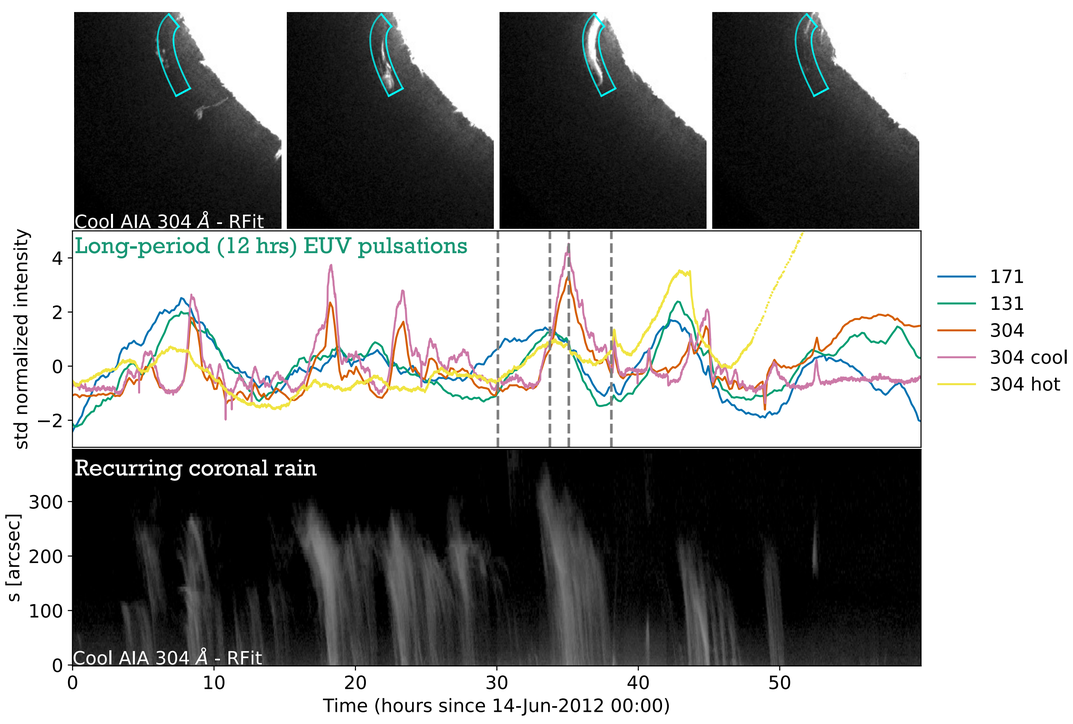
➡ Dynamical opening and closing of the closed and open field respectively

➡ Interchange reconnection occurs continuously during the entire observation and a**ll along the open-closed boundary**

➡ Consistent with the observations of Masson et al. 2014 and MHD modeling of Pellegrin-Frachon et al. 2023

EUV pulsation contour includes both closed and open fields
➡ its eastern section follows almost perfectly the EUV open-closed boundary

Evidence for thermal non-equilibrium (evaporation & condensation) cycles, first detection in open field!



304 Å components extracted with the RFit method of Antolin et al. 2024

➡ Coronal rain showers happen in both the open and closed field

Takeaways and perspectives

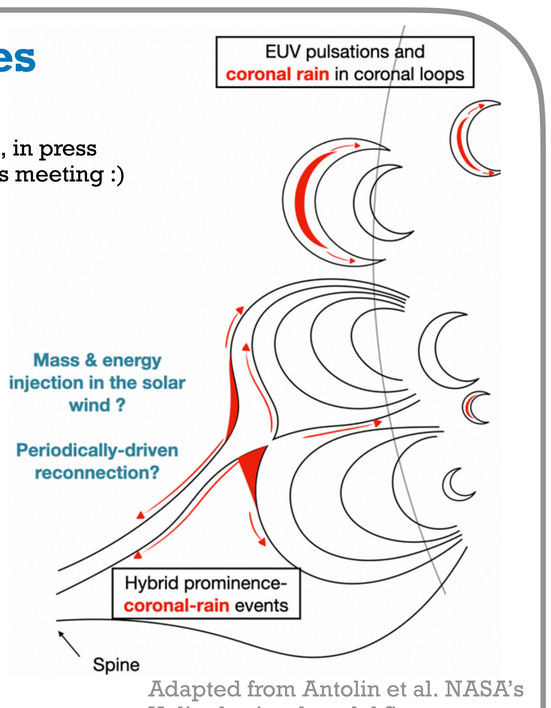
Check the paper!
Froment & Masson 2026, Solar Physics, in press
Hopefully published by the time of this meeting :)

✳ Interplay between thermal non-equilibrium and interchange reconnection?

TNE periodically forcing the reconnection?

- formation of a filament above an X-point structure followed by coronal rain draining from the magnetic dip Johnston et al. 2025
- TNE cycles driving periodic reconnection in helmet streamers Schlenker et al. 2021

and/or
Reconnection events could destabilise structures that are marginally thermally unstable (close to TNE-prone conditions)



Adapted from Antolin et al. NASA's Heliophysics decadal Survey

✳ Injection of mass and energy outward?
✳ Any solar wind variability driven by this kind of events?

e.g. quasi-periodic density structures injected on a timescale up to a few hours Viall et al. 2010, Viall & Vourlidas 2015