Modeling Coronal Bright Points:

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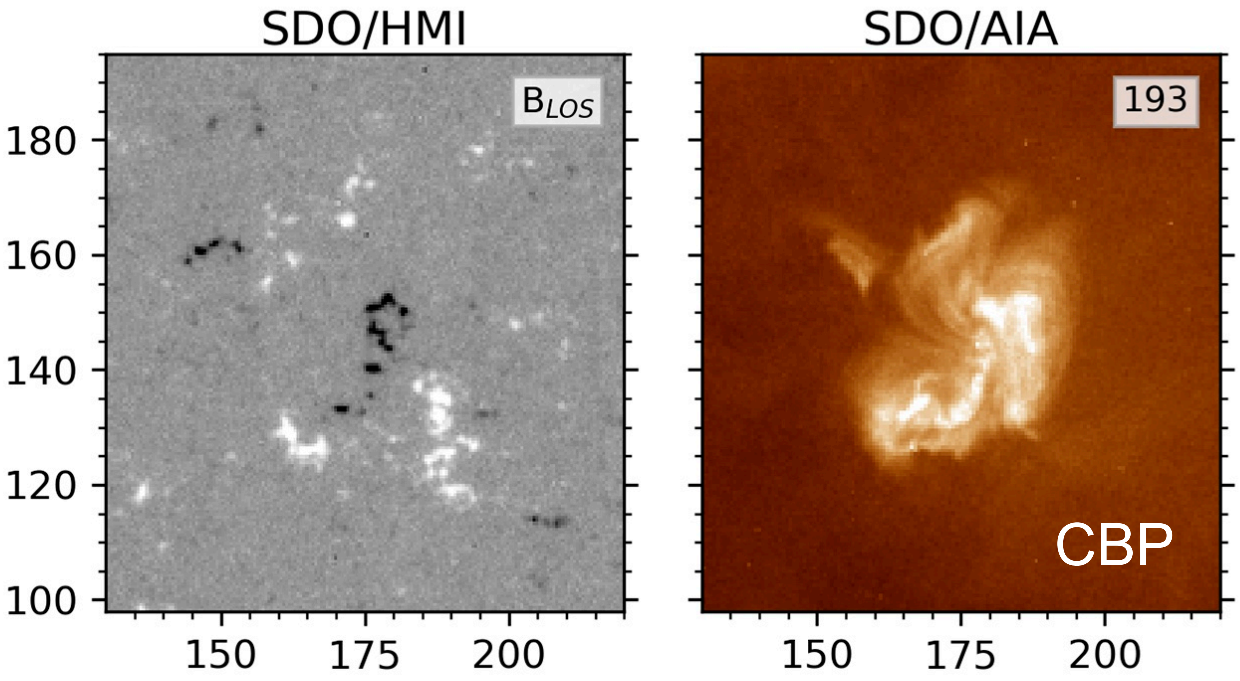
Introduction.

- **What are Coronal Bright Points (CBPs)?**

  - Bright structures in EUV and X-rays consisting of hot coronal loops.
  - Diameters of 4 to 43 Mm.
  - Related to opposite-polarity magnetic patches.
  - Duration from hours up to a few days.
  - They are abundant and ubiquitous.

(e.g., Golub et al. 1974, 1977, Nolte et al. 1979, Habbal and Withbroe 1981, Harvey 1985, Priest et al. 1994, Parnell et al. 1995, Longcope 1998, Ugarte-Urra et al. 2004, von Rekowski et al. 2006, Santos and Büchner 2007, Javadi et al. 2011, Kumar et al. 2011, Hong et al. 2014, Ning and Guo 2014, Alipur and Safari 2015, Chandrashekhar and Sarkar 2015, Li et al. 2016, Mou et al. 2016, Galsgaard et al. 2017, Kayshap and Dwivedi 2017, Mou et al. 2018, Priest et al. 2018, Wyper et al. 2018, Kumar et al. 2019, Madjarska 2019, Madjarska et al. 2021, 2022, Gao et al. 2022, among many others)

Check the recent review by
Madjarska et al. (2019) for further details.



Introduction.

CBP formation.

CBPs are observationally found to be formed by

- *Magnetic flux emergence.*

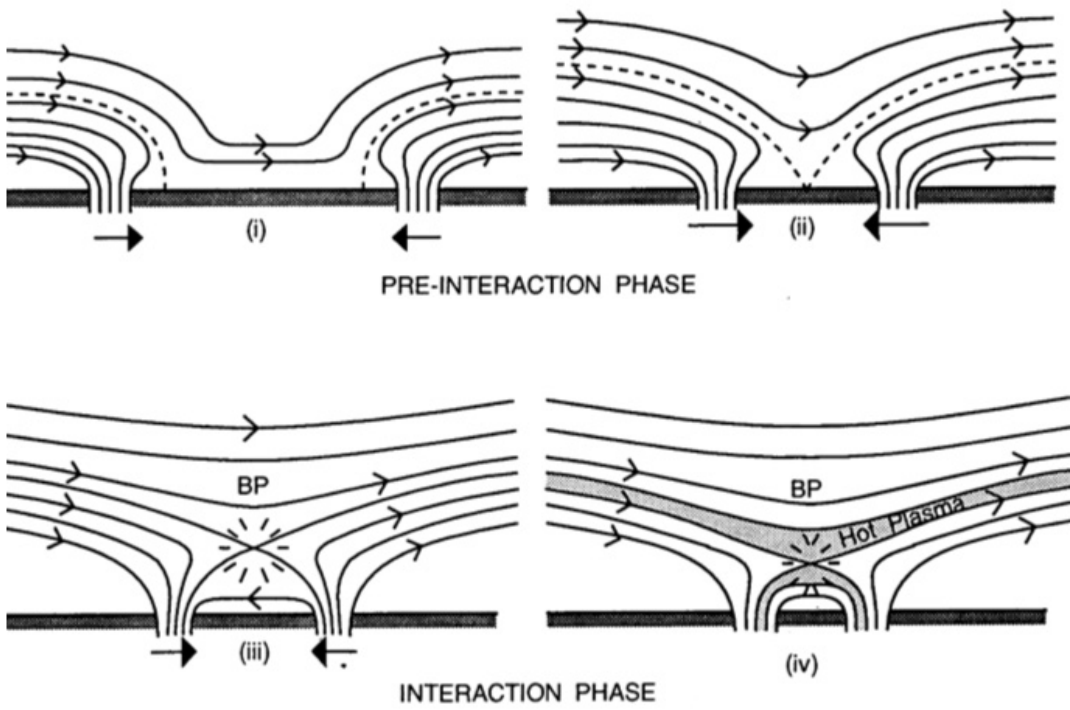
- *Convergence of opposite magnetic polarities.*

(e.g., Harvey 1985, Webb et al. 1993, Mou et al. 2016, Mou et al. 2018)

First explanations about the 2nd mechanism came in the 1990's through models called *Converging Flux Models.*

(e.g., Priest et al. 1994, Parnell and Priest 1995, Priest and Titov 1996)

Priest et al. (1994)



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Wyper et al. (2018)

- ## CBP numerical modeling.

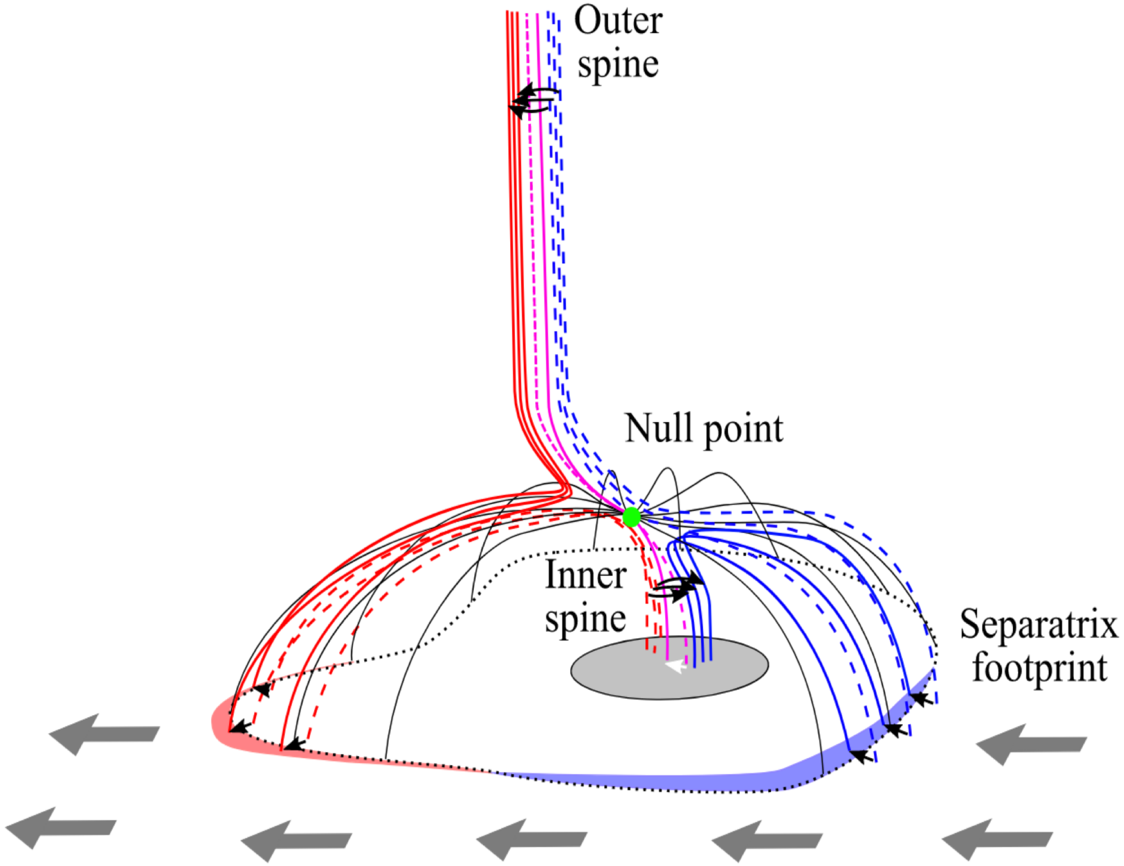
Available CBP models are idealized:

- They rely on ad-hoc driving mechanisms.

- They lack radiation transfer to model the lower layers of the atmosphere.

- They miss optically thin losses and/or thermal conduction to properly capture the CBP thermodynamics

(e.g., Dreher et al. 1996, Neukirch et al.1997, Longcope 1998, Galsgaard et al. 2000, von Rekowski et al. 2006, Santos and Büchner 2007, Javadi et al. 2011, Wyper et al. 2018, Priest et al. 2018, Syntelis et al. 2019)

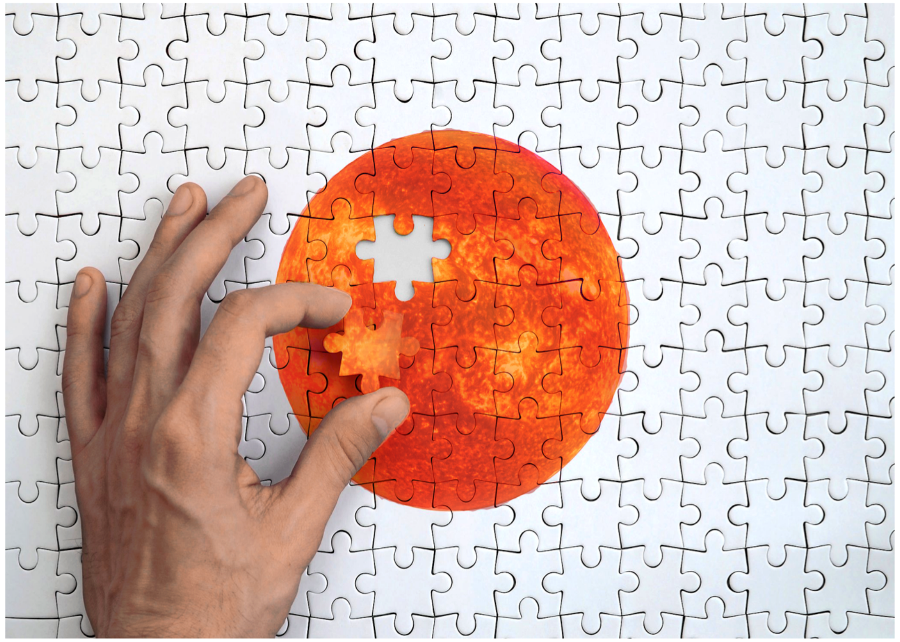


Introduction.

- **Big open questions.**

  - *The CBP energization:*
    Is the granulation enough to drive reconnection at coronal heights to explain the CBP lifetimes?

  - *The chromosphere underneath:*
    What is the impact of specular activity on CBPs and vice versa?



Methods.

- ## Numerical setup:

- *Code:*

2D experiment performed with **Bifrost** (Gudiksen et al. 2011).

- *Background stratification:*

From previous relaxed snapshot with developed convection.

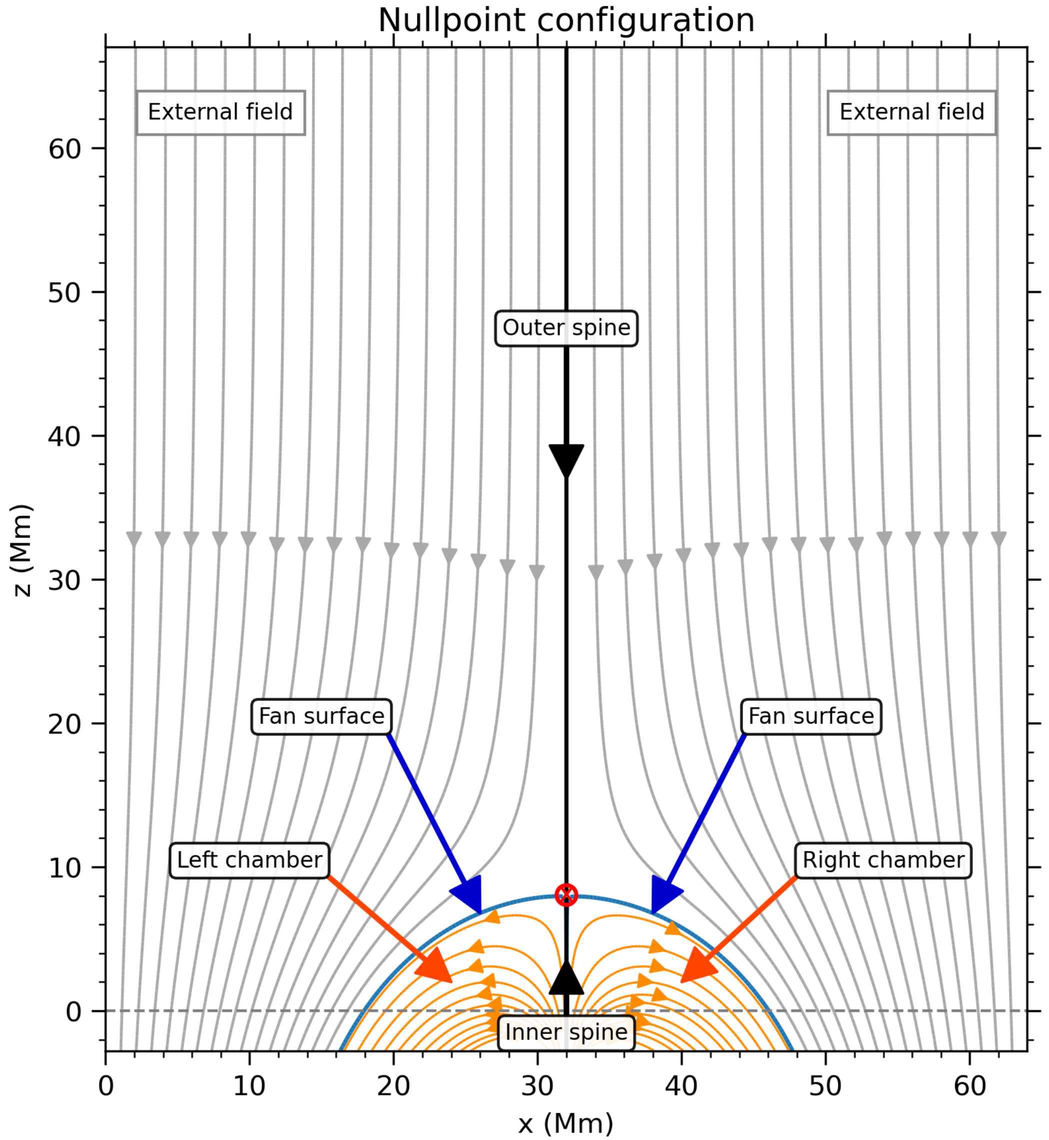
Domain: $-2.8 \leq z \leq 67$ Mm and $0.0 \leq x \leq 64.0$ Mm.

Uniform resolution: $\Delta z = 17.0$ km and $\Delta x = 15.6$ km.

- *Potential null-point configuration:*

The null point is located at $(x, z) = (32{,}8)$ Mm.

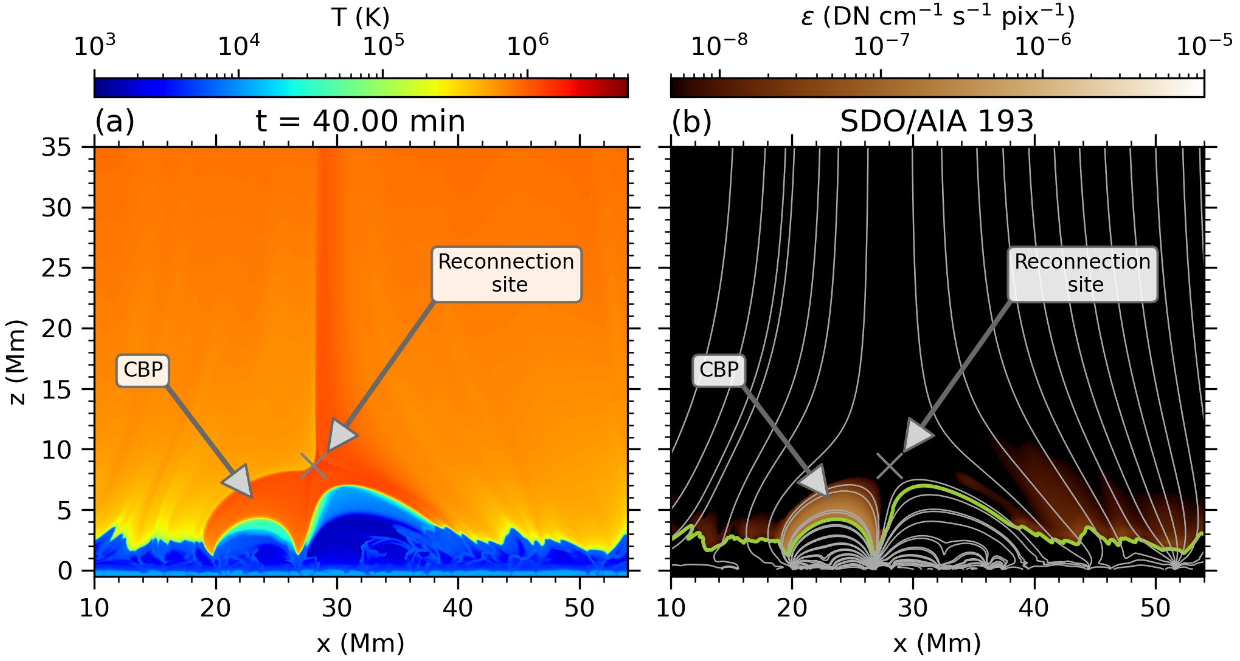
The field tends to a coronal hole structure with $B_z = -10$ G.



Results: Overview.

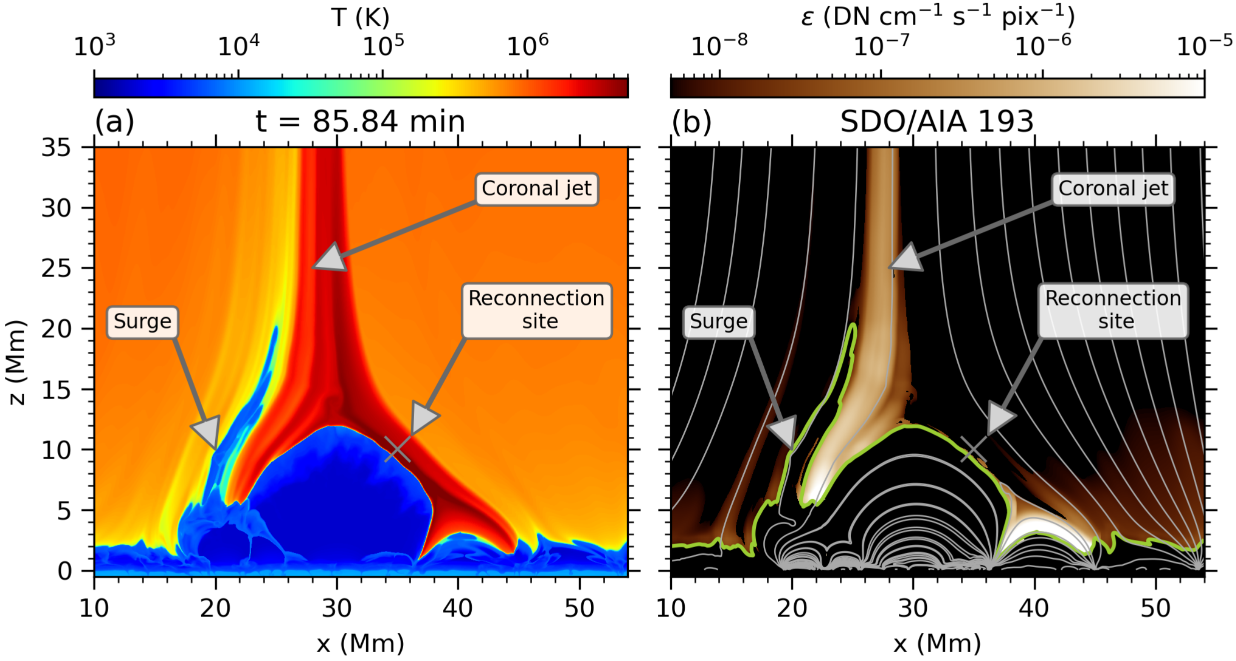
- **Main stage** (from $t = 0$ to $t \approx 65$ min).

  It covers the appearance of post-reconnection hot loops that lead to a CBP.



- **Eruptive stage** (from $t \approx 65$ min onwards).

  It covers the end of our CBP due to multiple ejections related to magnetic flux emergence.



Results: Main Stage.

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- **Magnetic reconnection at the corona**

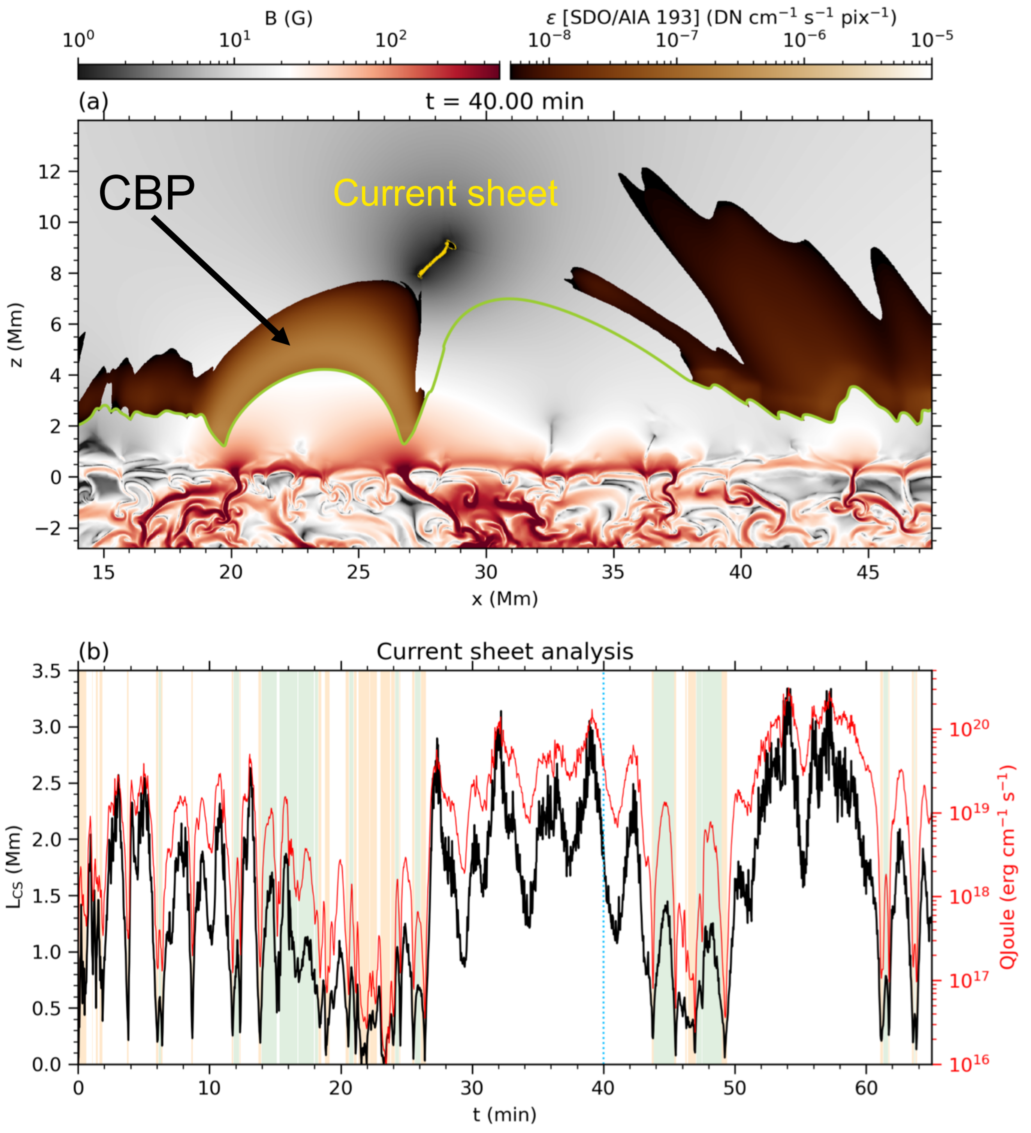
  - The reconnection (and associated heating) behaves in a intermittent bursty way.

    Consistent with observed CBP variations

    (Habbal & Withbroe 1981, Ugarte-Urra et al. 2004, Kumar et al. 2011, Ning & Guo 2014, Chandrashekhar & Sarkar 2015, Gao et al. 2022).

  - The reconnection is oscillatory:

    Similar to observations (Zhang et al. 2014).



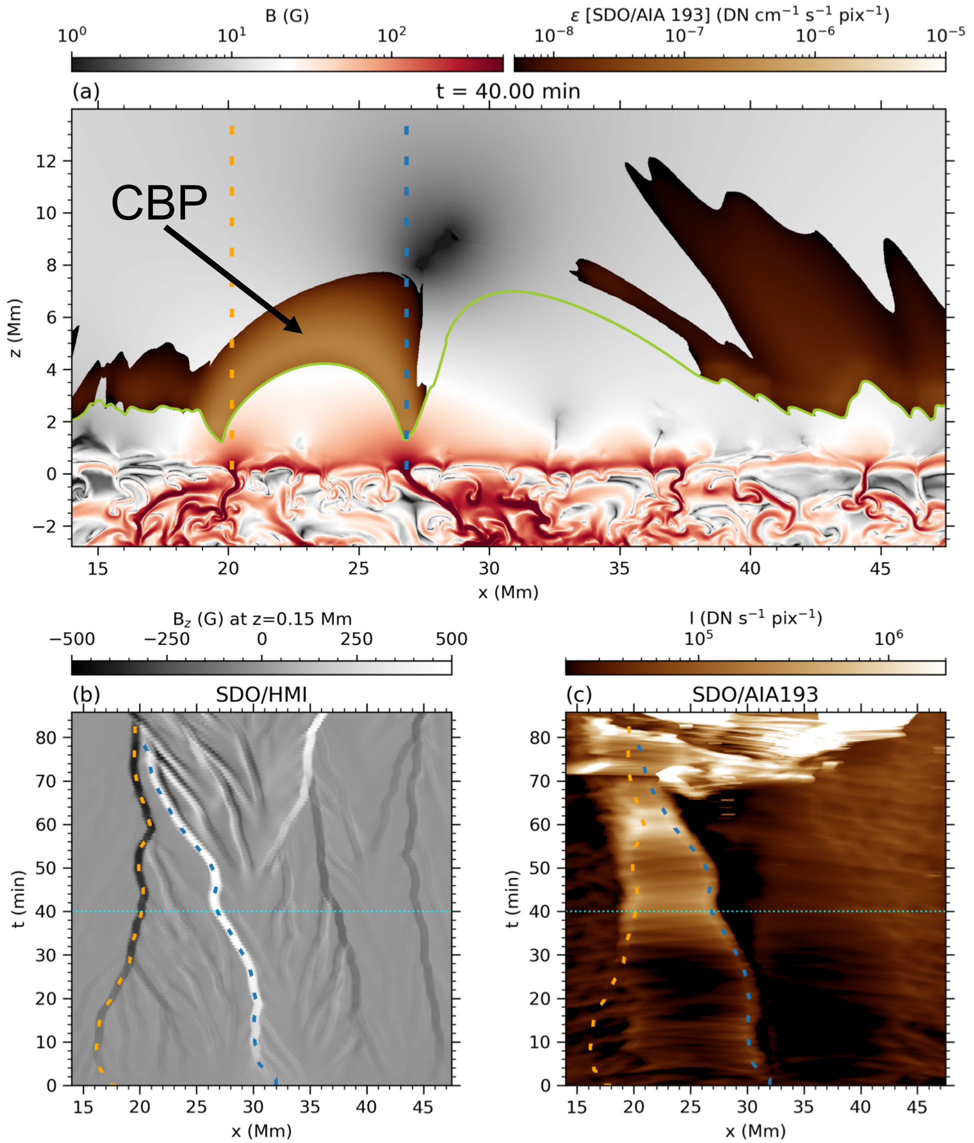
Results: Main Stage.

- **The photospheric magnetic field**

  - The magnetic field is dragged by the granular motions, leading to strong magnetic patches at the solar surface.

  - There is convergence of two strong opposite polarities.

    Convergence is frequently observed in CBP formation (Mou et al. 2016, 2018).

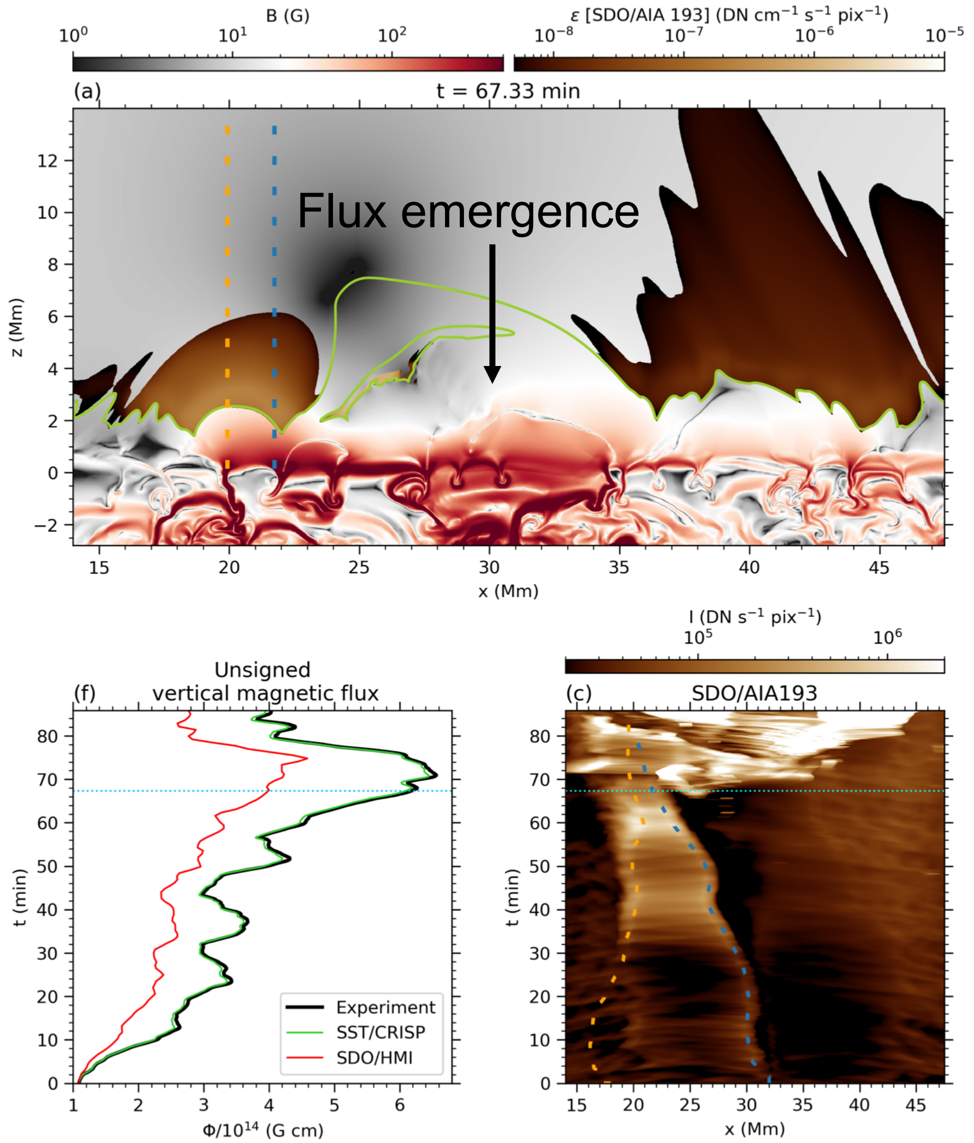


Results: Eruptive Stage.

- **Magnetic flux emergence**

  - The magnetic structures developing around the inner spine become buoyant and rise.

  - The emergence episode destabilizes the CBP structure, leading to UV bursts, EUV jets and surges.



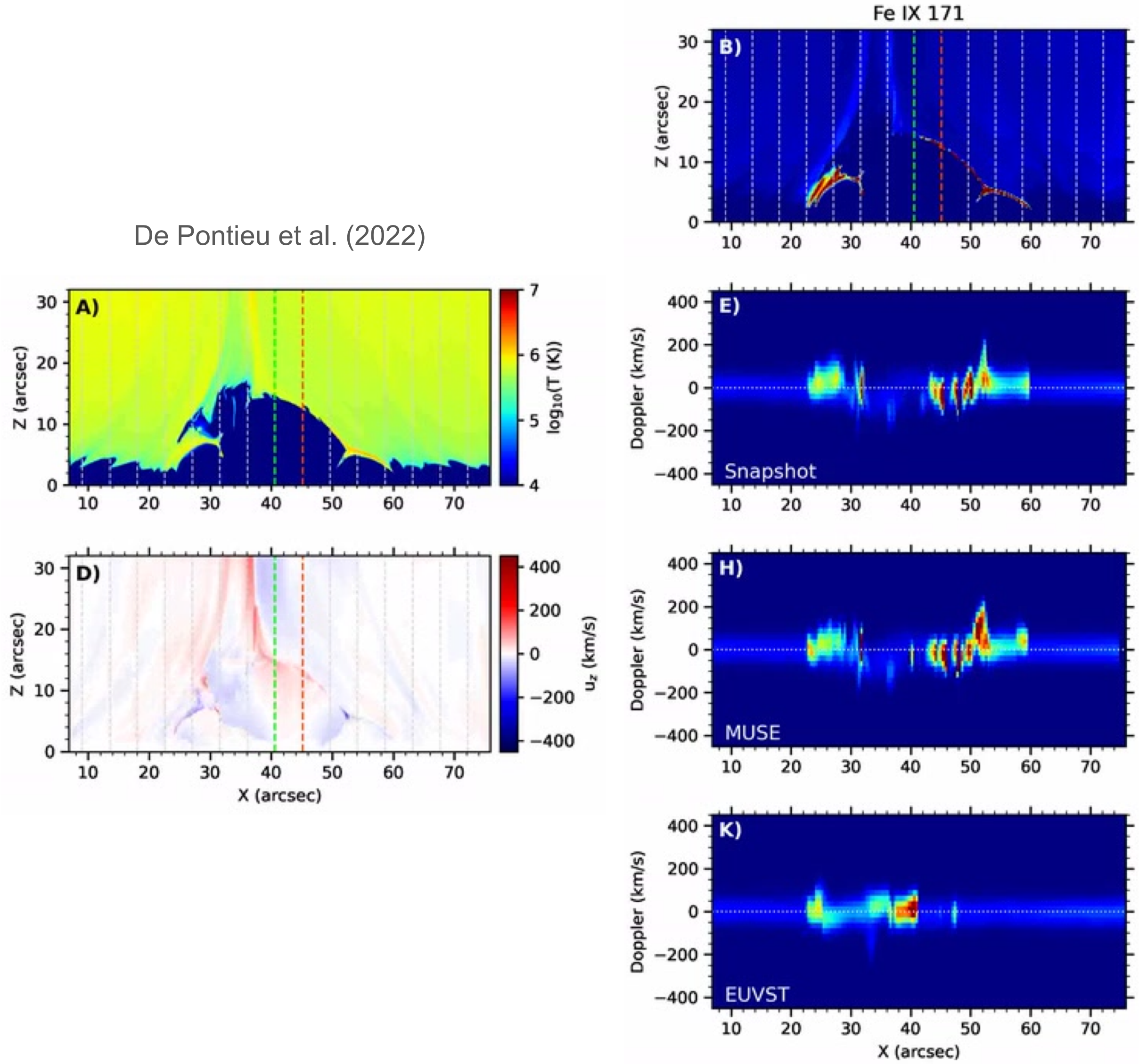
Results: Eruptive Stage.

- **MUSE capabilities**

  - MUSE will test, e.g., whether plasmoids at subarcsec scales exist and track their dynamical evolution.

  De Pontieu et al. (2022), Cheung et al. (2022)

De Pontieu et al. (2022)



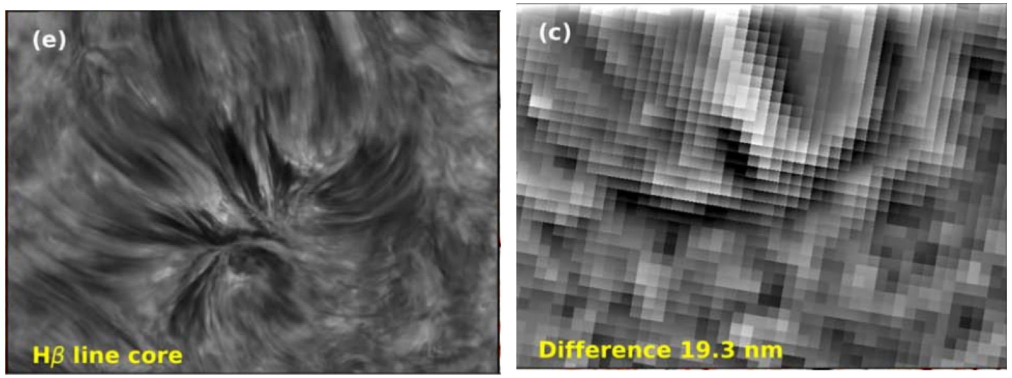
Results: The chromosphere.

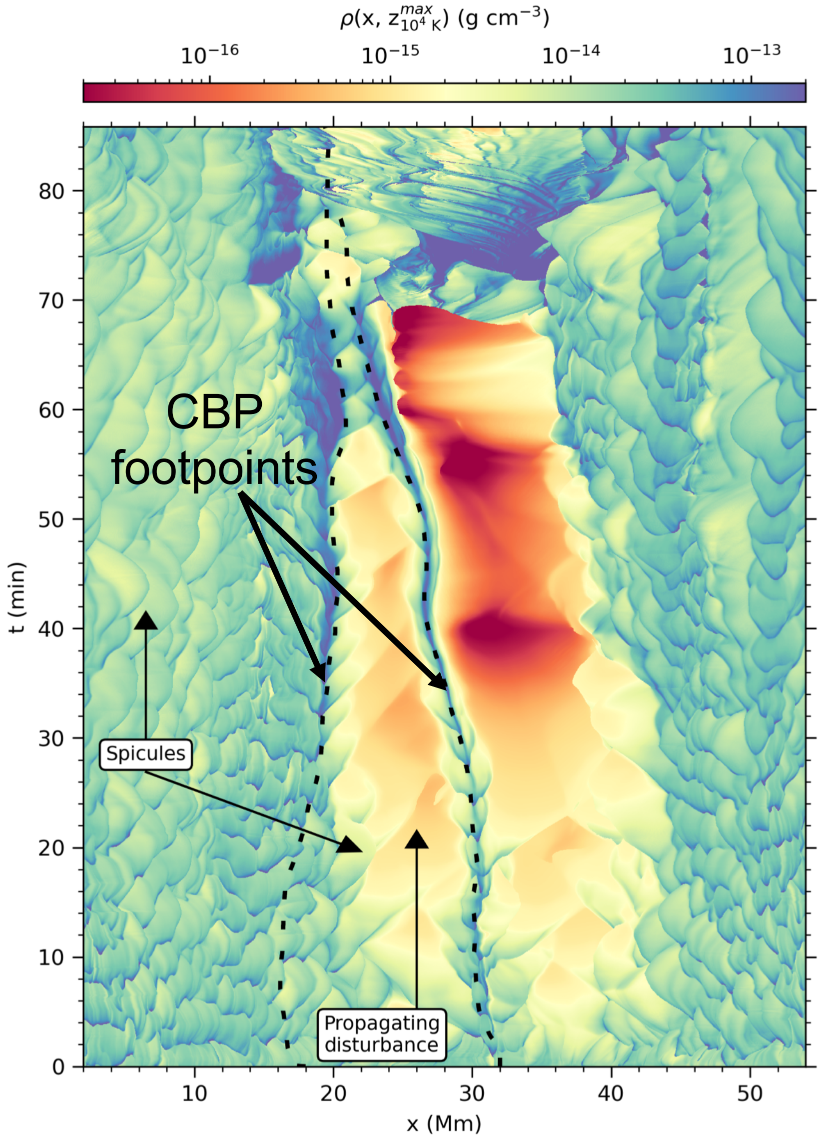
Chromospheric counterpart

- CBP spicules originate around its footpoints.

- CBP related spicules have propagating coronal disturbances, which could perturb the CBP brightness.

Recently confirmed from observations by Bose et al. (2023)





Conclusions.

- **Take away messages from this model:**

  - CBP can be formed through stochastic granular motions, mediated by magnetic reconnection in the corona.

  - Our experiment shows striking similarities to observed CBP features.

  - Emergence within a few granules can disrupt CBPs and lead to eruptive phenomena.

  - CBP related spicules mainly originate around its foopoints (accompanied by PCD),
    which could perturb the CBP brightness.