Heating, magnetism and geometry of hot coronal loops from CBPs

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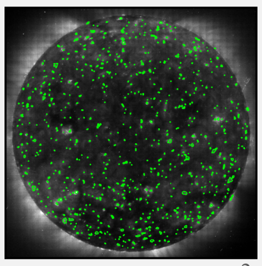
What is a CBP?

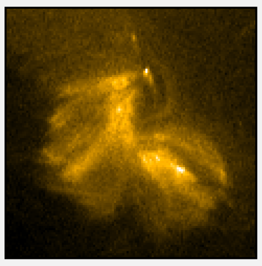
Coronal bright points (CBPs) are **key pieces of the corona** composed of **small-scale loops**. CBPs are relevant to understand the coronal heating due to their **ubiquitous presence and large energy output**[1].

We aim to study the **properties of CBP hot loops** and **their heating mechanisms**.



670 CBPs in one day![2]

Solar Orbiter video of CBP



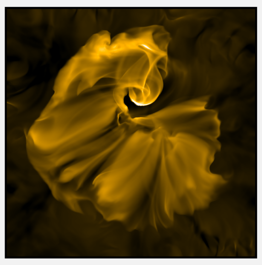
CBP from Solar Orbiter

How do we study CBP hot loops?

We use 3 **radiative-MHD Bifrost**[3] CBP simulations.

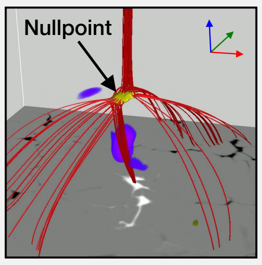
- A **3D** simulation[4] with a nullpoint at z = 8 Mm **("8 Mm")**.
- A **3D** simulation[5] with a nullpoint at z = 6 Mm **("6 Mm")**.
- A **2D** simulation[6] with a nullpoint at z = 8 Mm **("2D")**.

We **trace** the **magnetic field lines** for several hundreds of snapshots and select loops with $T_{\max} > 2$ MK (hot loops).



Synthetic from CBP model[4]

Example of hot loops



Fan-spine topology

Are the CBP hot loops semi-circular?

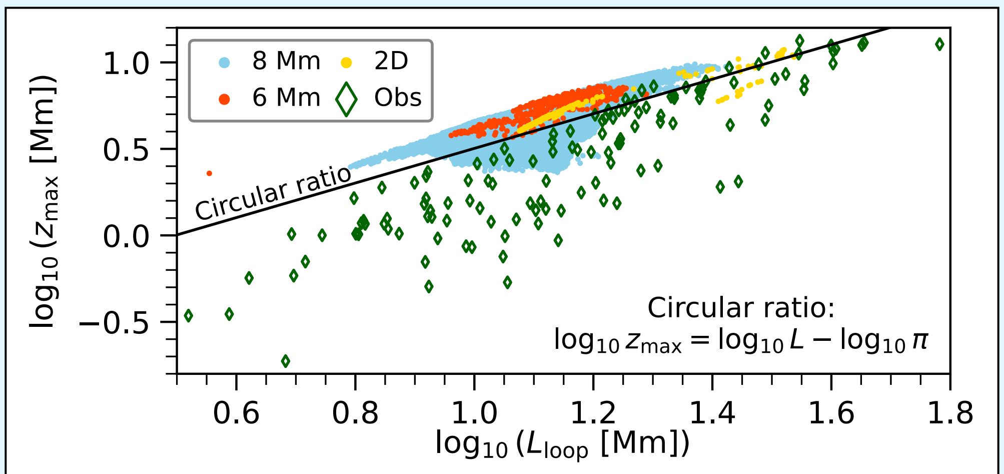


Fig. 1: Correlation between maximum height $z_{\max}$ and length L of all the loops for the simulations[4,5,6] and published observational data[7].

Both simulations and observations are well correlated and present **deviations from circularity**. The presence of very short hot loops suggests a source of **heating in the low atmosphere**, far away from the nullpoint in the corona.

What is the EUV intensity like?

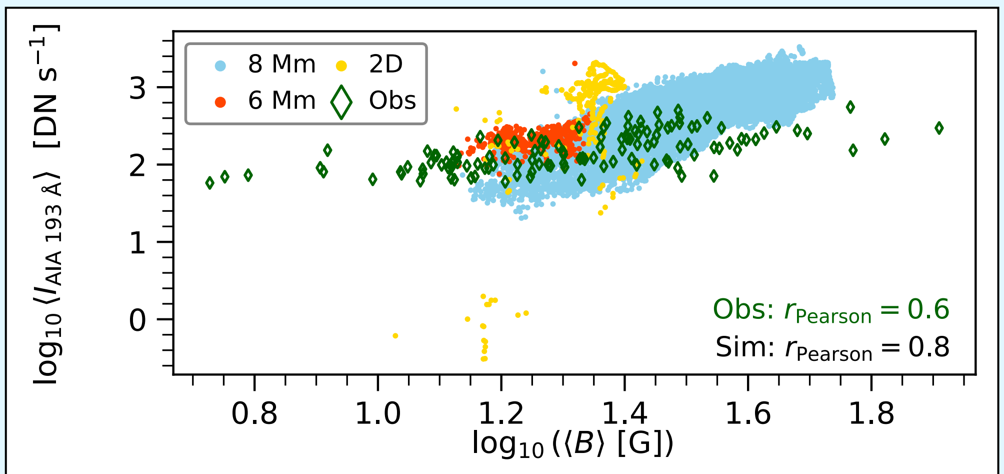


Fig. 2: Correlation between average EUV intensity $I_{\rm AIA\ 193\ Å}$ and average magnetic field B along the loop for simulations[4,5,6] and observations[7].

The **positive correlation** may imply **heating dependent on** B. This correlation was found to be stronger for $\langle B \rangle$ than for B at the loop top, reinforcing that **relevant heating is likely happening in the low atmosphere.**

and more importantly... ...how and where are these CBP loops heated?

Both **3D** simulations **show differentiated loop footpoints in terms of the Joule heating.** The loop footpoint with stronger B has **very efficient heating in the low atmosphere,** with **timescales below 100 s.** We believe this is a **direct consequence of magnetic field line braiding,** which cannot be reproduced in two dimensions.

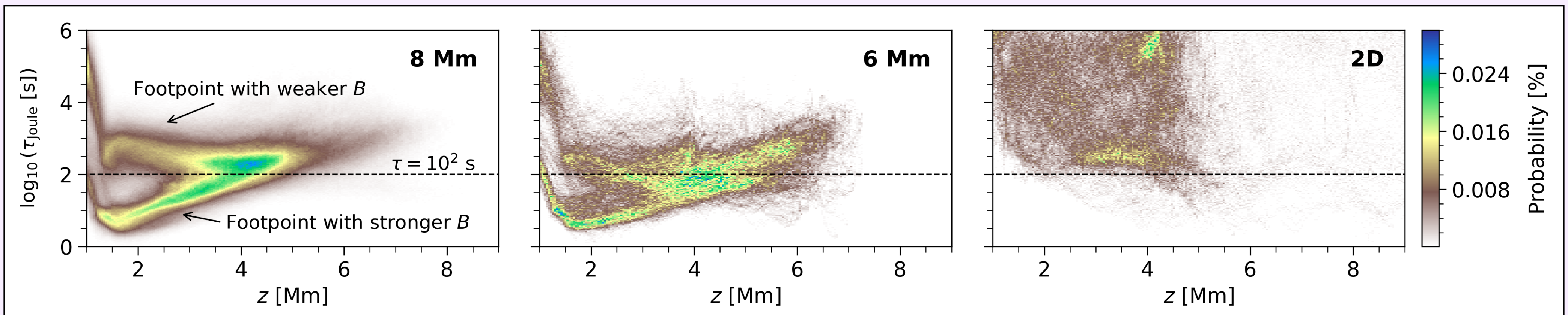


Fig. 3: JPDFs of the Joule heating timescale $\tau_{\rm Joule}$ vs. height z for each simulation. The heating timescale is defined as: $\tau = eQ^{-1}$, where e is the internal energy per unit volume and Q is the corresponding heating term.

Take-away message FOR FREE!

The hot loops from CBP models **reproduce the geometry and EUV intensity** of the observations. We find evidence of **heating in the low atmosphere** related to the **magnetic field**. In 3D models, the **Joule heating** is remarkably efficient at **low heights, especially** in the **footpoint with stronger magnetic field**, likely due to **line braiding**.

References: [1]Madjarska 2019, [2]Alipour & Safari 2015, [3]Gudiksen et al. 2011, [4]Nóbrega-Siverio et al. 2023, [5]Nóbrega-Siverio et al. in prep, [6]Nóbrega-Siverio et al. 2022, [7]Madjarska et al. 2024

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