Polarity relevance in flux-rope deflections triggered by coronal holes

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Introduction

Coronal mass ejections (CMEs) are eruptive events in which large amounts of solar mass are released, usually with an associated magnetic flux rope (FR) structure. It is well known that **not all CMEs evolve radially** and the deflections are mainly attributed to the magnetic structures surrounding the CME source region. To study the cases in which a deflection occurs, it is necessary to **characterise the coronal environment** during the early evolutionary stages of the ejection.

In the present work we study the evolution of FRs interacting with coronal holes (CHs) [1]. Numerical simulations and an observational analysis is presented.

Modelling

Our simulation consists in a 2.5D FR and a CH. We evolved the initial configuration solving the ideal MHD equations .

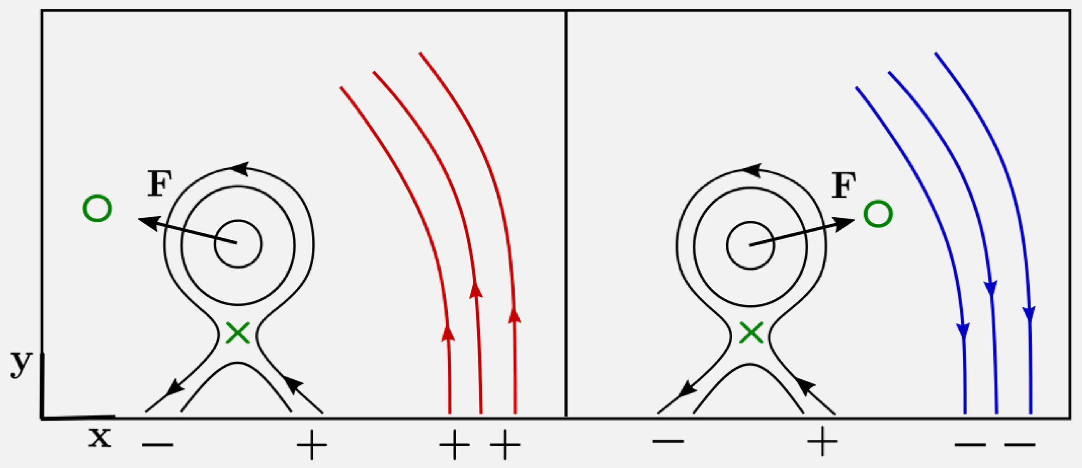

Figure 1: The initial configuration of the simulations produces a magnetic null point (green circle) where the FR and CH magnetic fields counteract.

Figure 1 shows how the local magnetic energy distribution depends on the relative polarity alignment. If the FR footpoint closest to the CH has the same polarity as the CH, we say they are **aligned** (left panel), if this footpoint has different polarity then we say they are **anti-aligned** (right panel).

The alignment changes the relative position of the magnetic null point, which is determinant in the early evolution of the FR. We performed several simulations changing the CH parameters (magnetic strength, size, and distance) and we conclude that **the dynamical behaviour of FRs depends on the polarity alignment**.

Simulation results

Figure 2 shows an aligned and an anti-aligned case, which are representative of all our simulations. When the FRs are aligned with the CH they deflect once, away from the CH location. In contrast, when the FRs are anti-aligned with the CH they are deflected twice, first towards the CH and then away from it. It occurs because the null point attracts the FR at first, and then the CH field lines guide the FR towards the least resistance path.

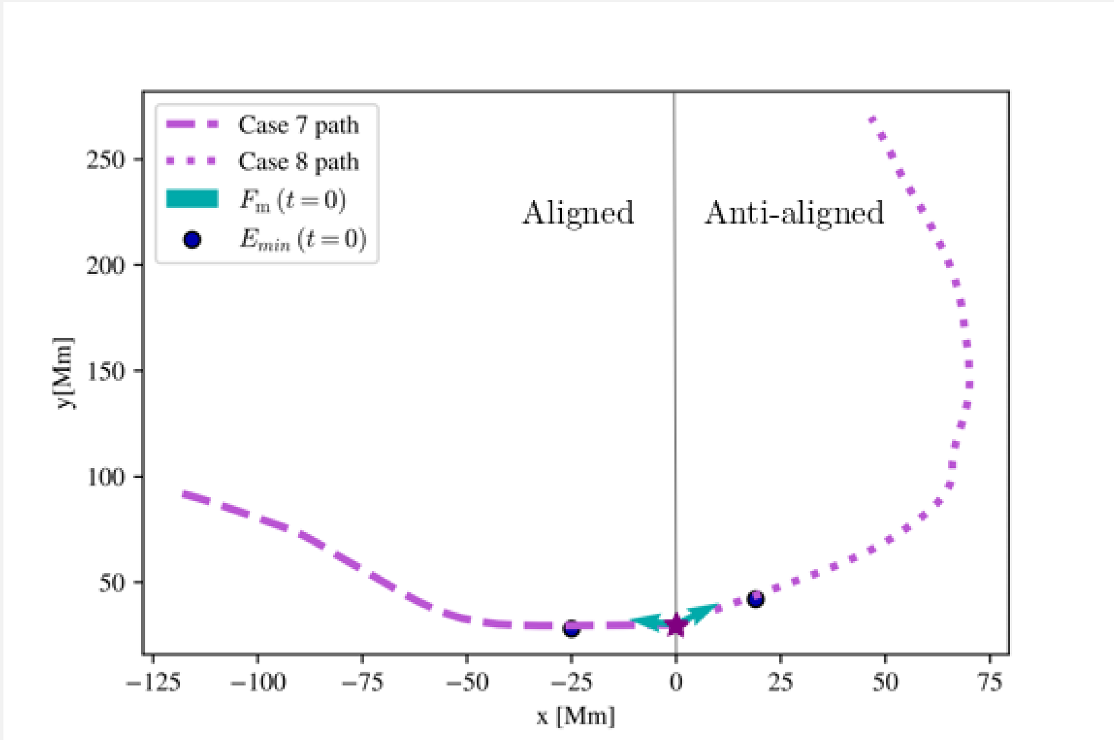

Figure 2:

Observational case

A prominence erupted on 30 April 2012. It deflected twice, apparently due to the interaction with a CH. Figure 3 shows positions of the prominence (initial 0, closest to the CH *cl* and final *f*), it also shows the magnetic structures and magnetic distribution. The darker region between the initial and the closest position may indicate a null point, the prominence ended near the heliospheric current sheet (dashed line) which is the least resistant path.

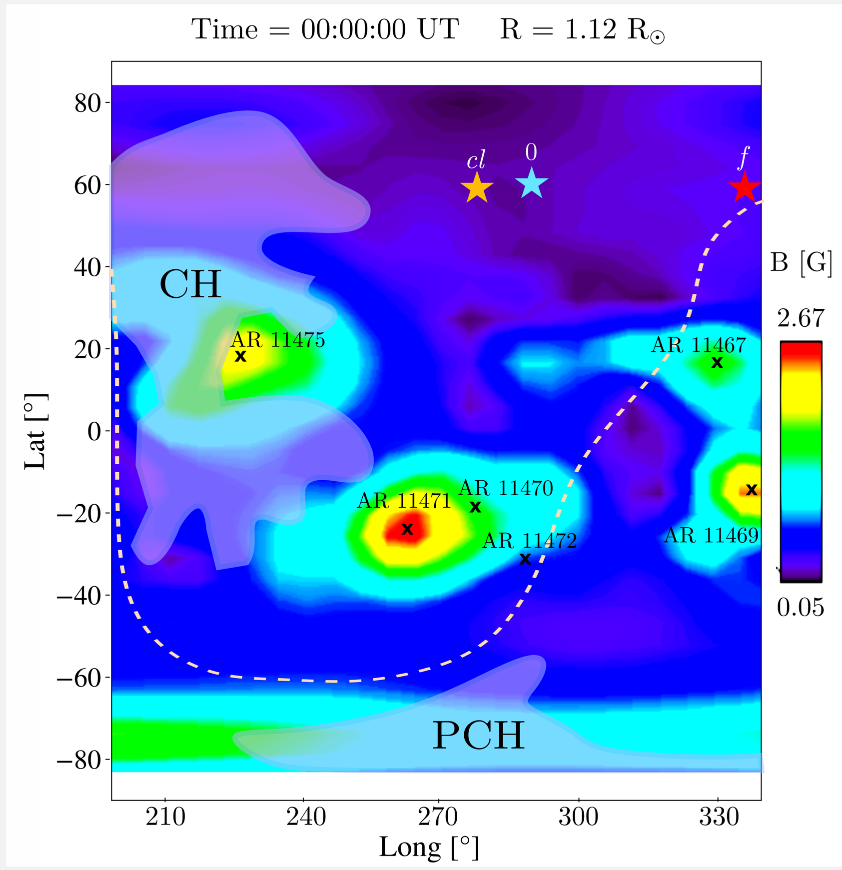

Figure 3:

Important Results

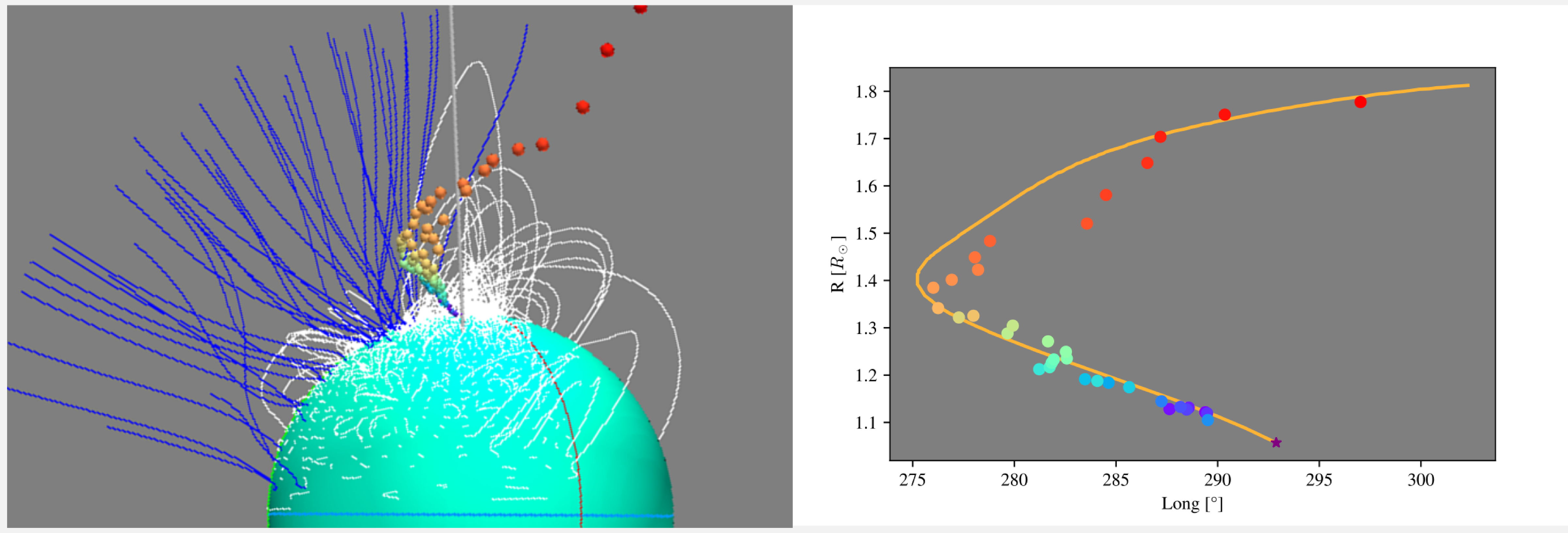

Figure 4: *Left:* Reconstruction of the magnetic field lines and the 3D trajectory of the prominence. *Right:* Longitudinal deflection vs. height of the prominence (dots) and our simulation (solid line)

Observations show that CHs act as "magnetic walls", deflecting CMEs away from them [2,3]. However, there are events where the CME source approaches the CH because other magnetic structures push the FR in this direction [4]. Here we present a simulated scenario in which a CH and a FR interact, we conclude that the first deflection direction depends on the polarity alignment. This means that CHs do not always act as "magnetic walls".

We found an event that approached a CH, had the anti-aligned configuration and had no other magnetic structure around it. We performed a simulation with the anti-aligned configuration whose trajectory satisfactorily matches the observed trajectory. So, the interaction between the filament (and its FR) with the CH seems to be the reason for the double-deflection.

References

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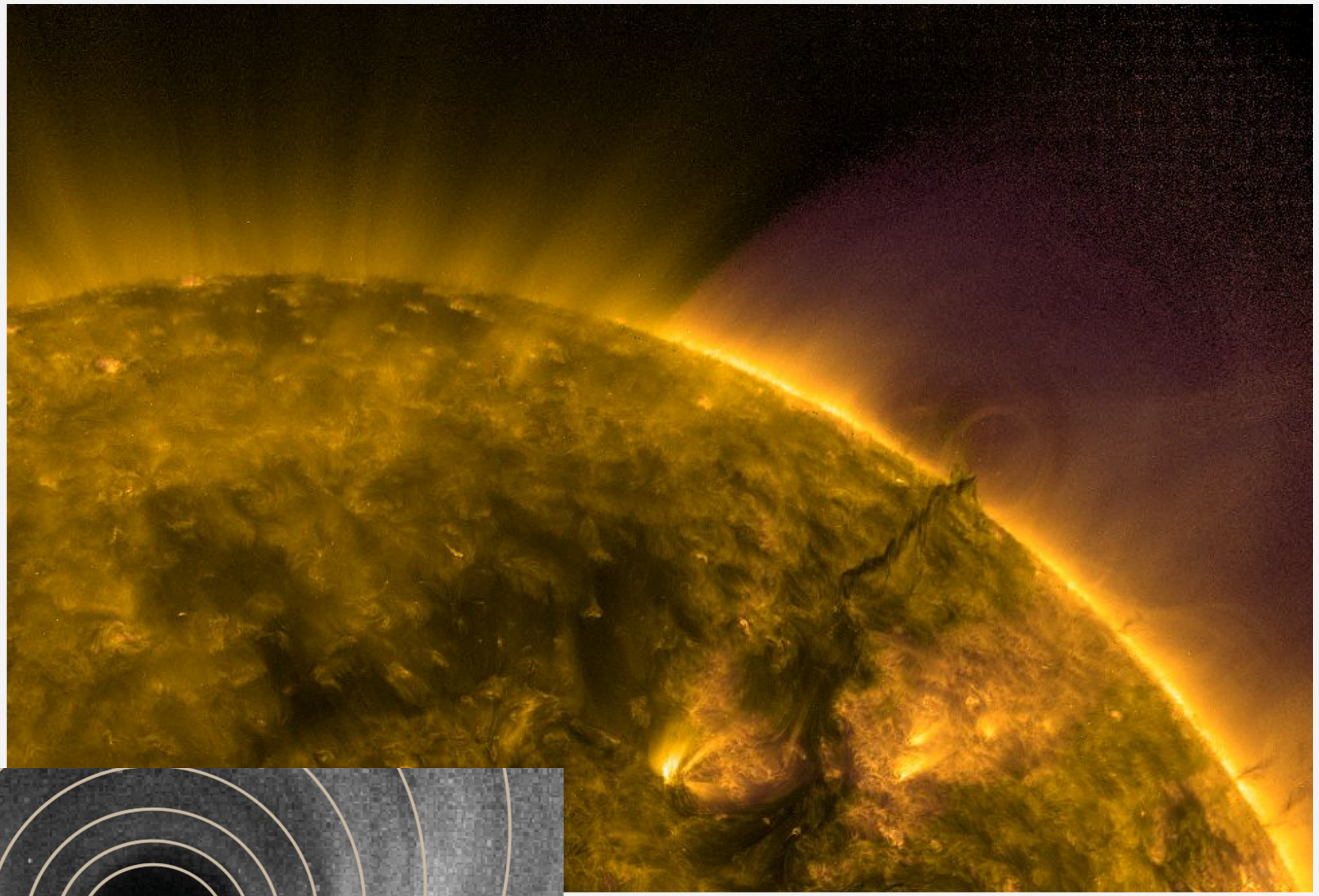
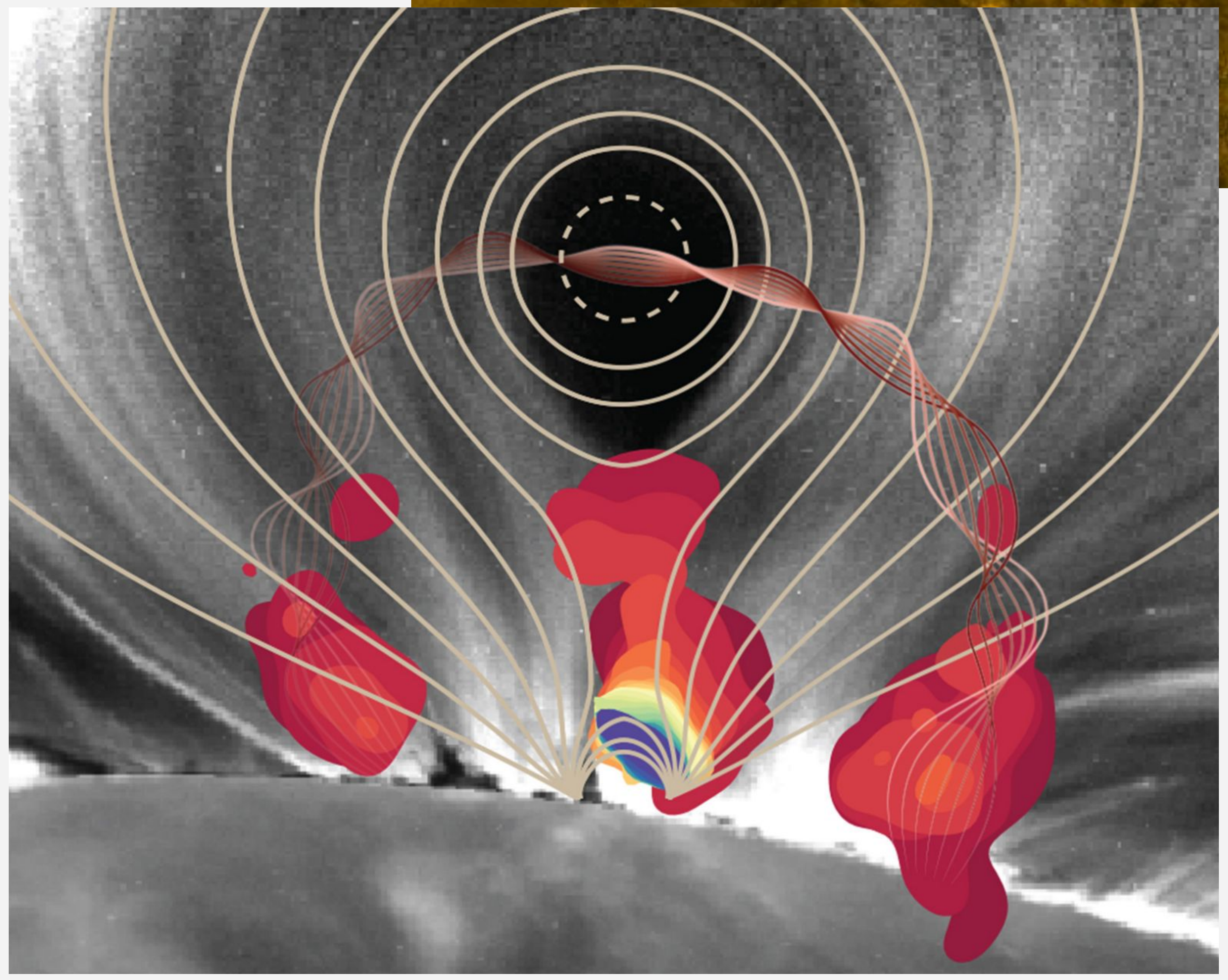
Introduction

Many CMEs show signs of having a magnetic flux-rope structure. These eruptive events can be deflected by magnetic structures close to the source region.

We studied the interaction between flux ropes (FR) and coronal holes (CH).

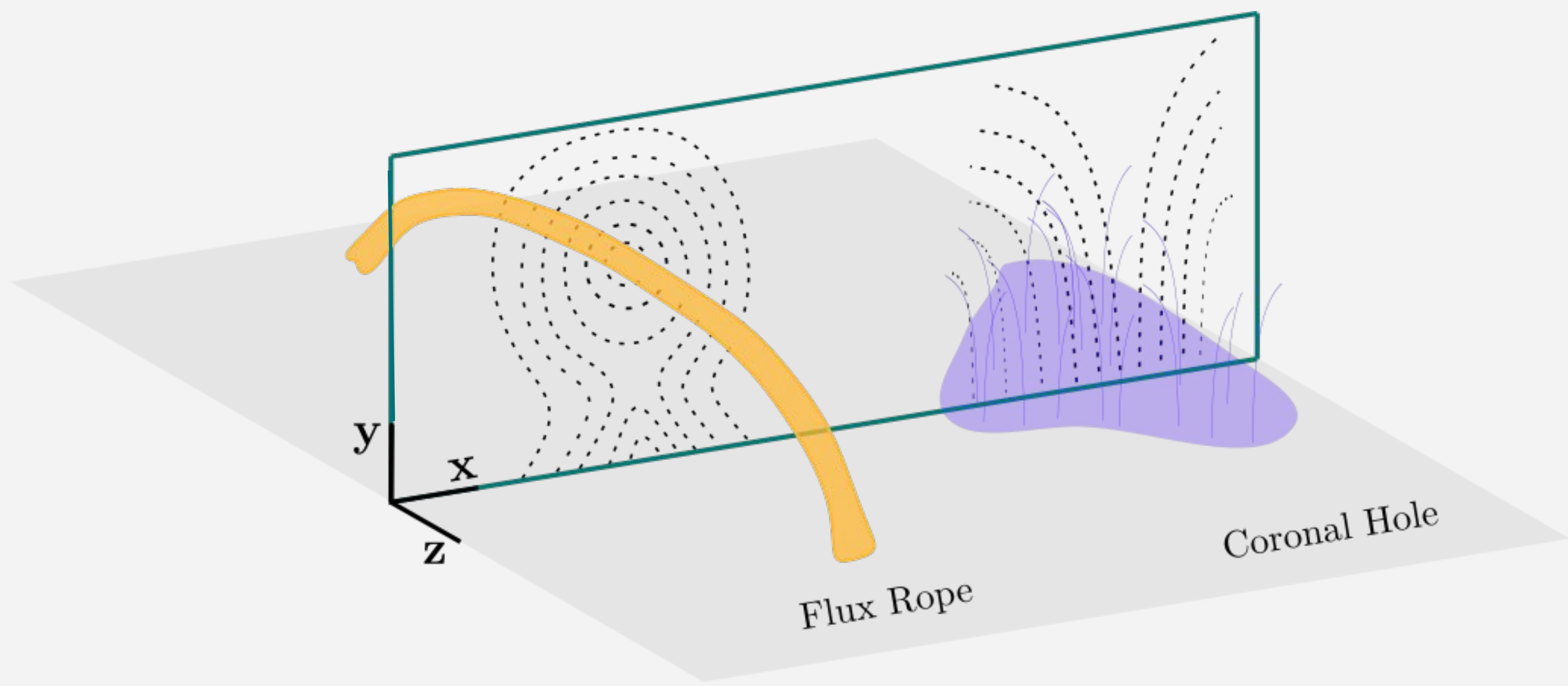




🠕 SDO/AIA
🠔 Adapt. Chen et al. (2020)

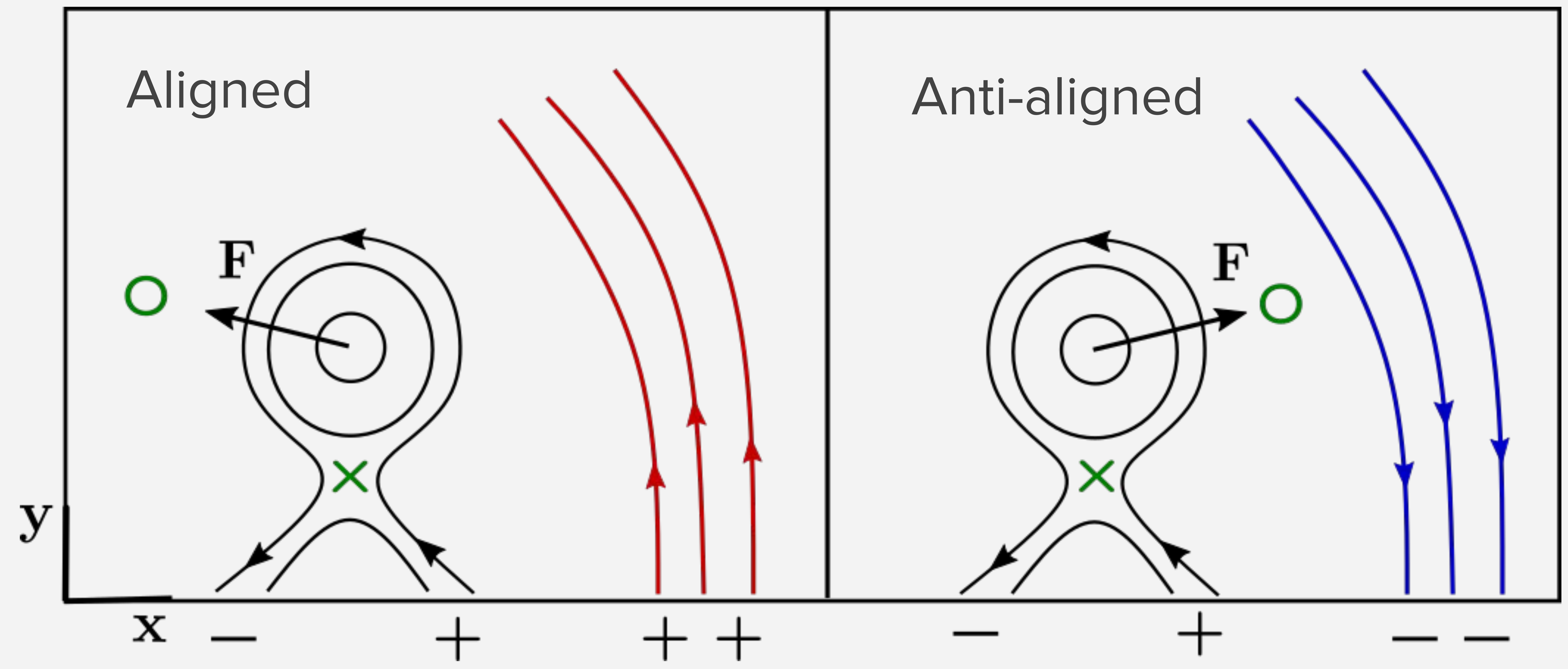
Modelling

2.5D MHD numerical simulations were used to evolve a FR and a CH.



The local magnetic energy distribution depends on the relative polarity alignment.

The alignment changes the relative position of the magnetic null point and the initial direction of the magnetic force.



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Simulation results

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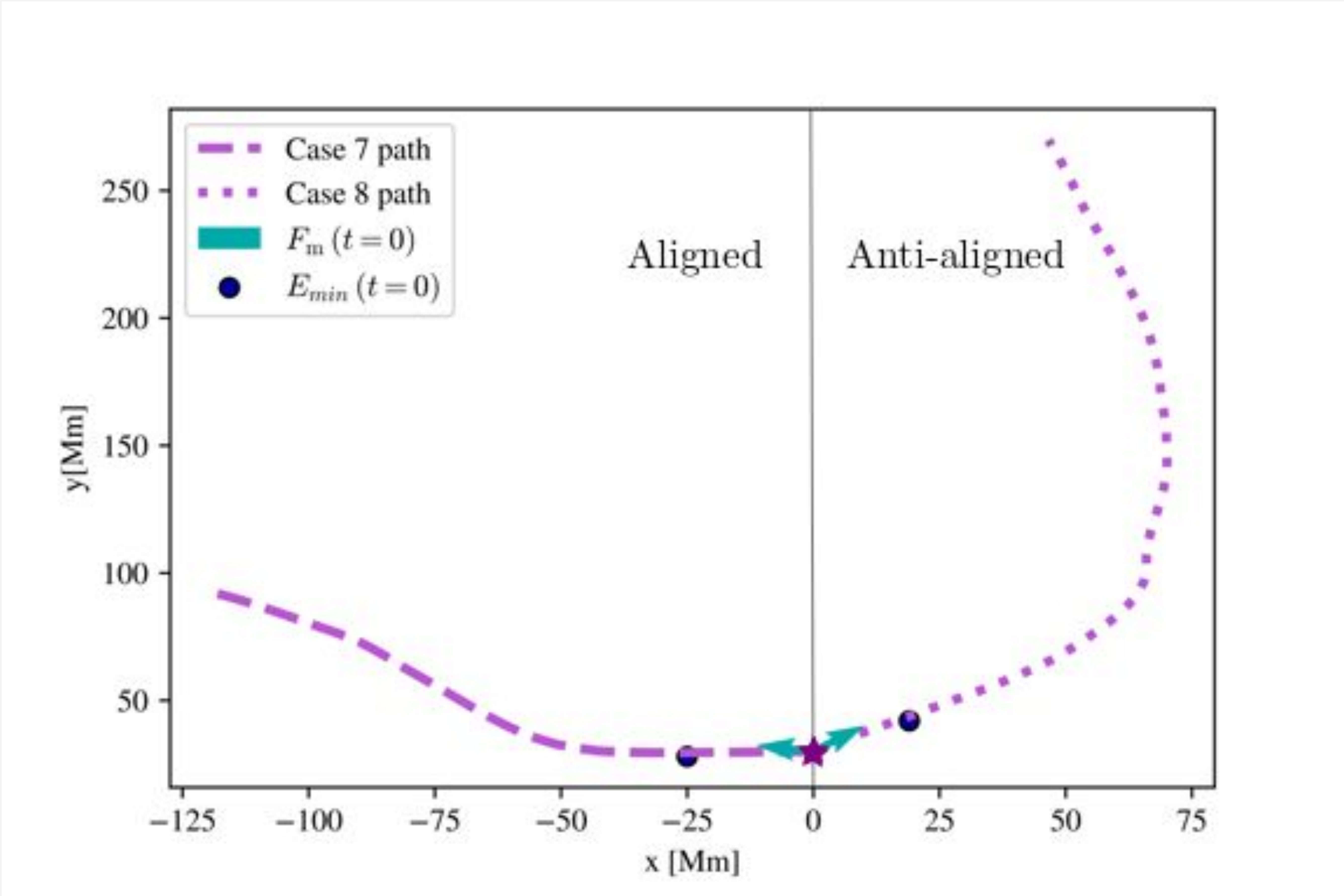

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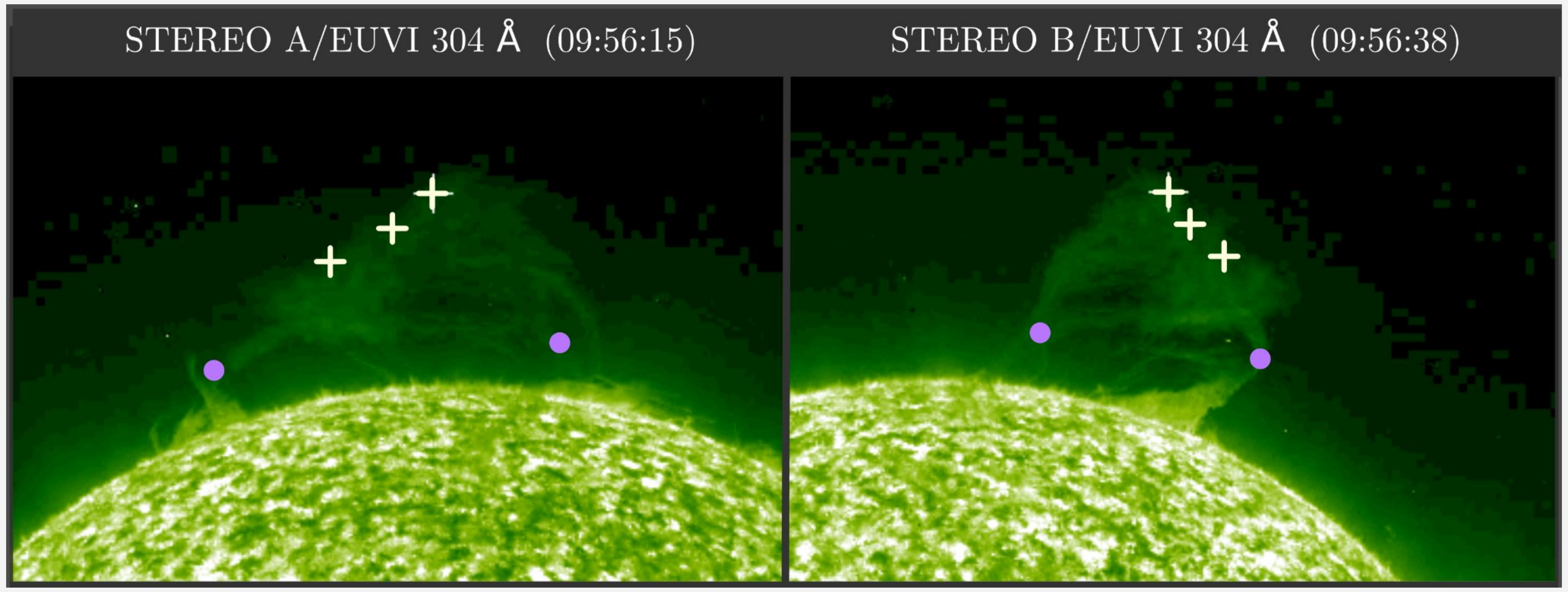
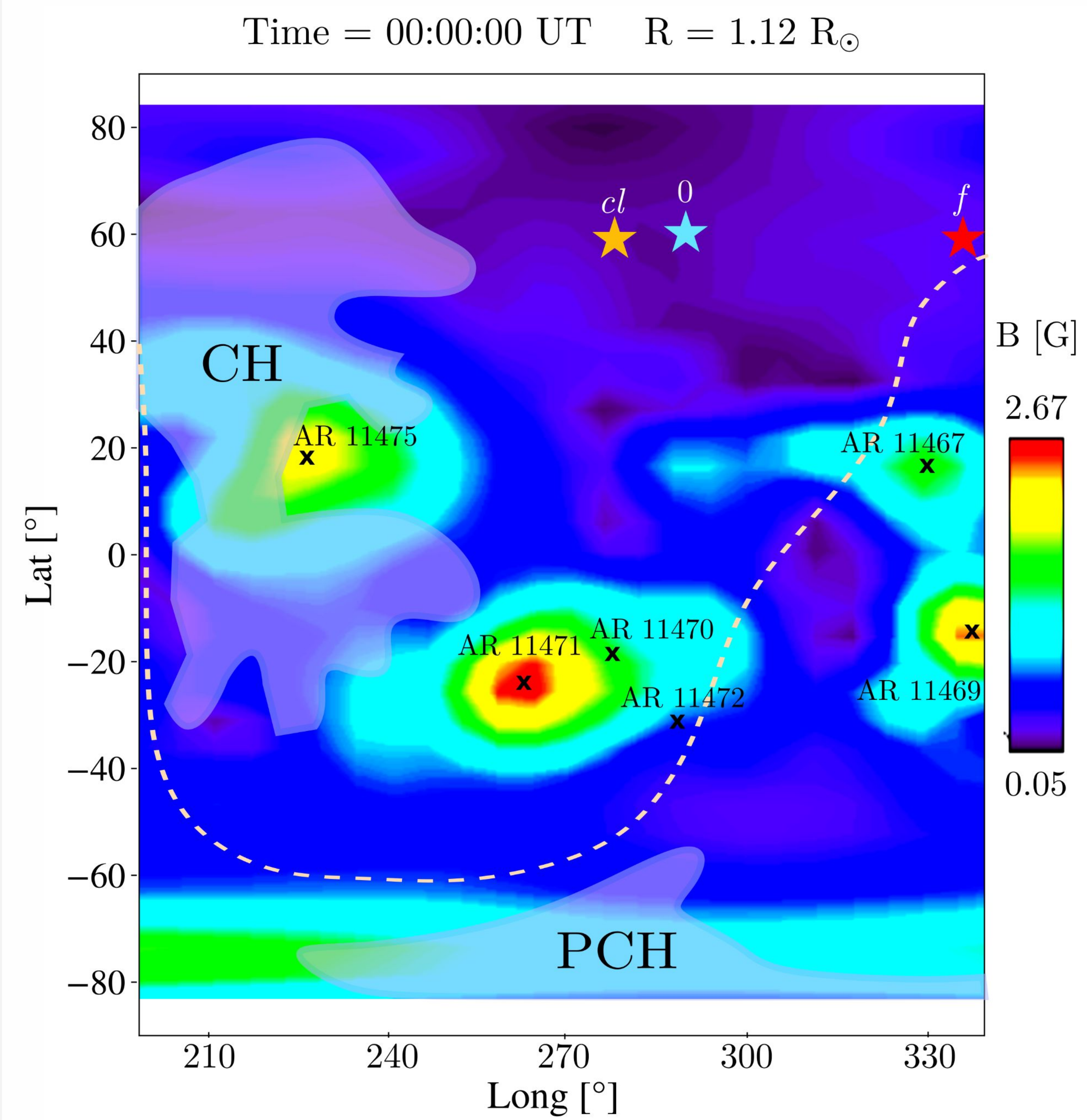
Observational case

A prominence erupted on 30 April 2012. It deflected twice, apparently due to the interaction with a CH.



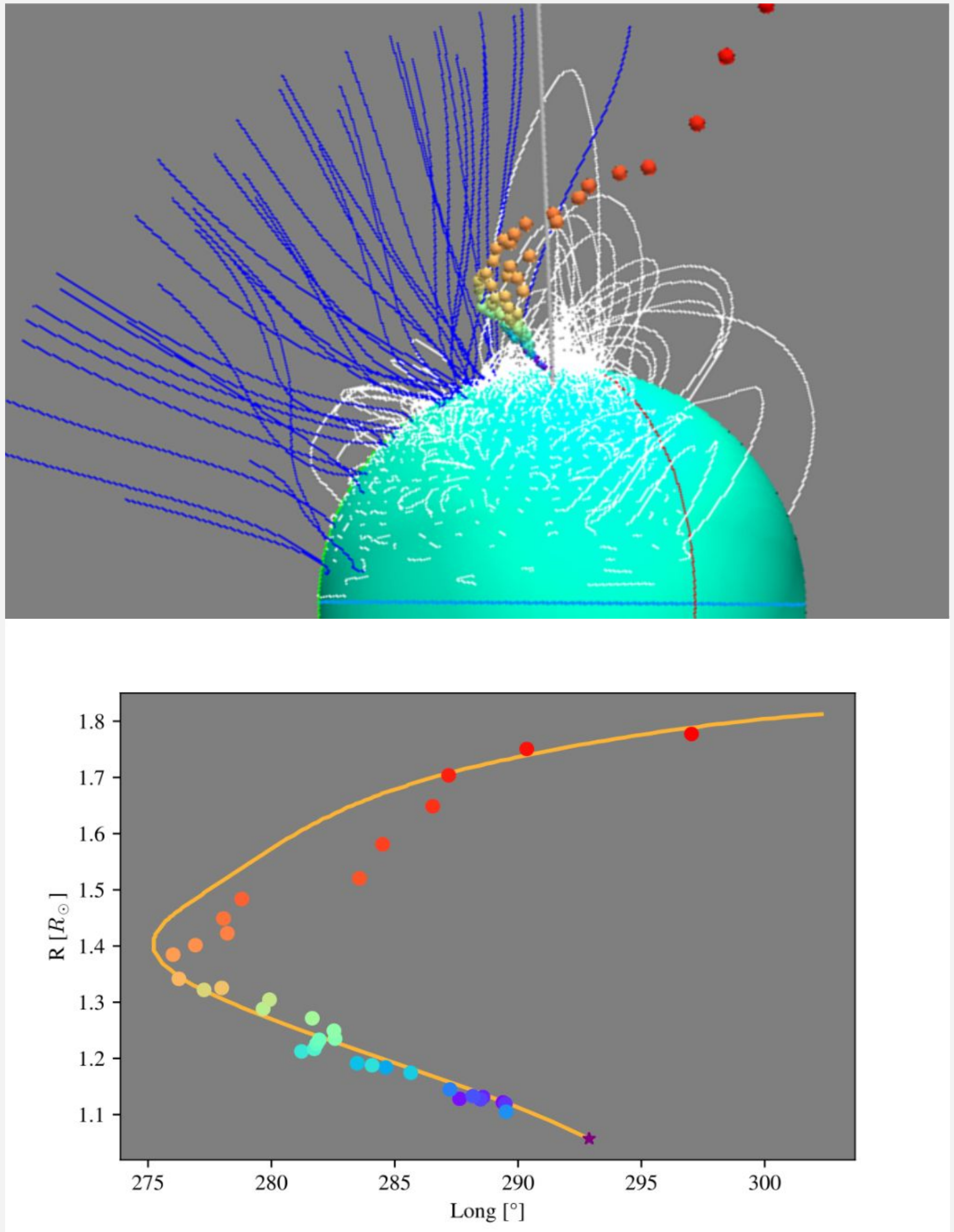


Sahade et al. (2021)

Important Results

From the simulations, we conclude that the first deflection direction depends on the polarity alignment.

Furthermore, we performed a simulation whose trajectory successfully matches the trajectory of the 30 April 2012 event. Therefore, it is possible that this eruption had a double deflection due to the interaction with the CH.



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Thank you for your attention

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