European Solar Physics Meeting 2024, 9-13 September, Turin, Italy

MAX PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH

Funded by the European Union

European Research Council

(ERC, ORIGIN, 101039844)

Deciphering Magnetic Reconnection Dynamics in the Large and Small-Scale Explosions on the Sun

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1. Introduction

* Solar flares and jets are explosive events driven by magnetic reconnection.

* Complex 3D structures—magnetic flux rope, 3D null, separatrices, and quasi-separatrix-layers (QSLs) are the underlying topologies contributing to the reconnection during flaring and jet activities on the Sun.

2. Objectives

* Investigation of 3D magnetic reconnection dynamics during an eruptive flare and explore the Hall effect for the solar flaring region as a testbed.

* To understand the magnetic origin of the jetlets and flows in the coronal hole plume.

3. Methods and Data

* **Part I: 3D magnetic reconnection and Hall effect in a flaring solar active region (AR)**

- The flare is selected using the GOES soft x-ray and SDO/AIA multi wavelength observations.

- The magnetic field in the corona is constructed by extrapolating the SDO/HMI vector magnetic field data using the non force-free model. To obtain the dynamical evolution, the extrapolated data is simulated using the EULAG MHD code.

- 3D magnetic structures: magnetic flux rope and QSLs have been found using the quantitative measure of the field-aligned twist parameter and squashing factor.

* **Part II: Magnetic origin of the jetlets and flows in the coronal hole plume**

- A fully radiative MHD code, MURaM, has been used to simulate the coronal hole plume from convection zone to corona.

- The squashing factor Q has been calculated to locate QSLs.

4. Results Part I - 3D Magnetic Reconnection and Hall Effect in a Flaring Solar AR in EULAG Simulation

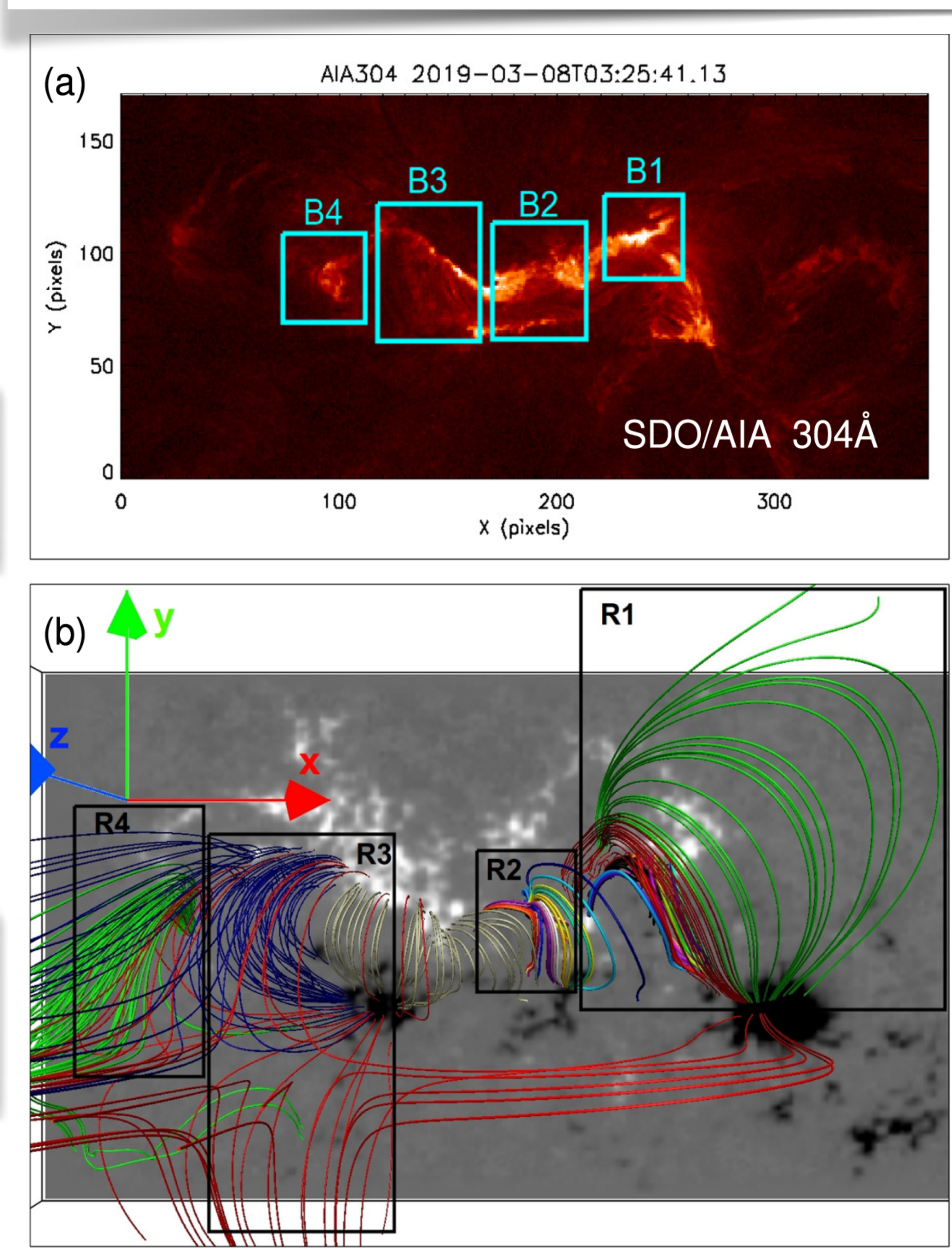

Figure 1. (a) The SDO/AIA map in 304 Å filter gram, where the flare ribbon brightening has been divided into four parts B1, B2, B3, and B4 based on their spatiotemporal development. (b) An overall magnetic topology of NOAA AR 12734 with the B_z-component of the magnetogram at the bottom boundary.

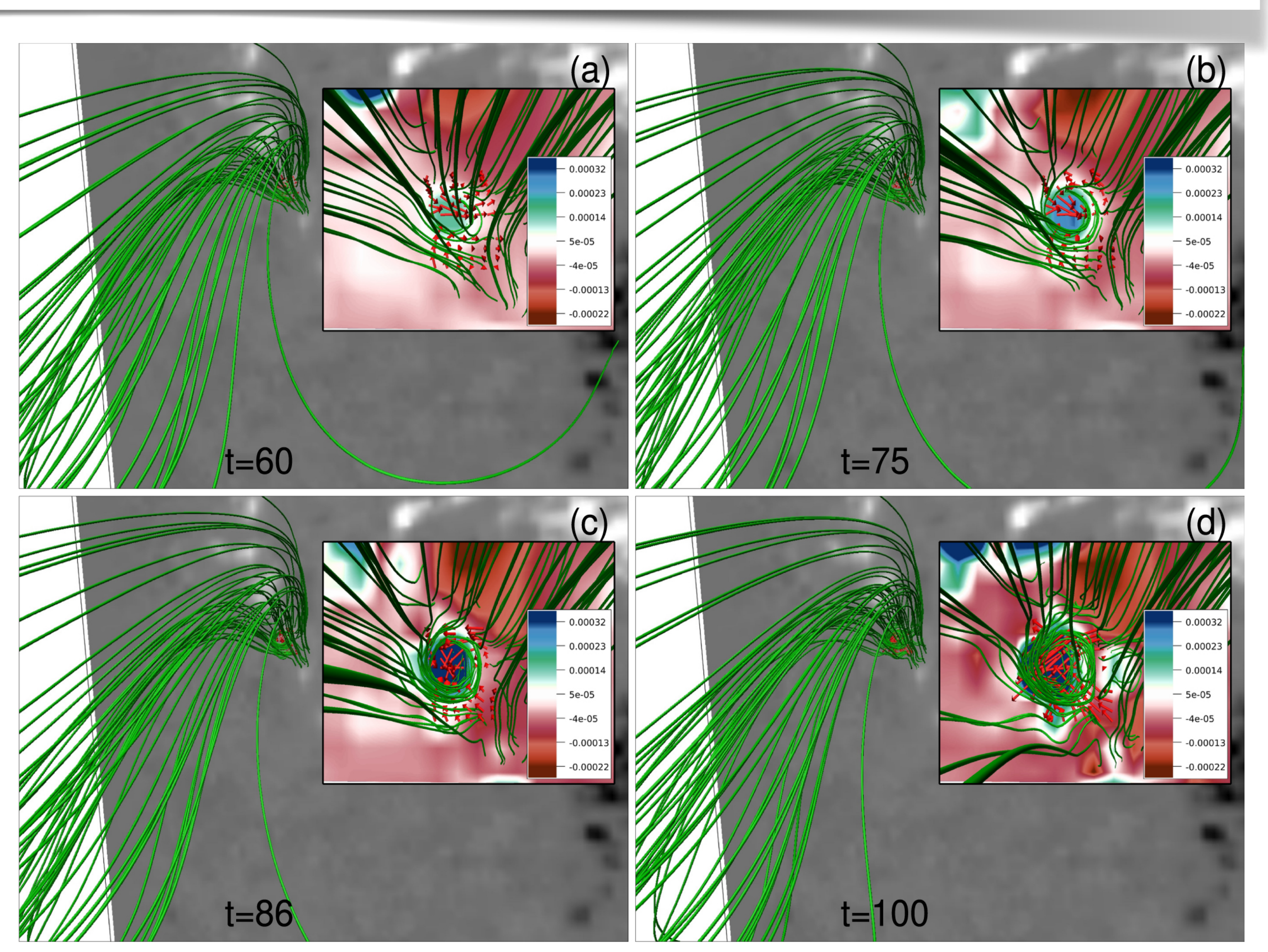

Figure 3. The snapshots from the Hall MHD evolution of region R4. Inset images in each panel depict the temporal development of the rotational motion of magnetic field lines due to Hall effect. The background (in all insets) shows the variation of the z-component of flow within [−0.00022, 0.00032] range. The red vectors represent the plasma flow.

For the comparison of full dynamical evolution of AR with and without Hall effect see the paper.

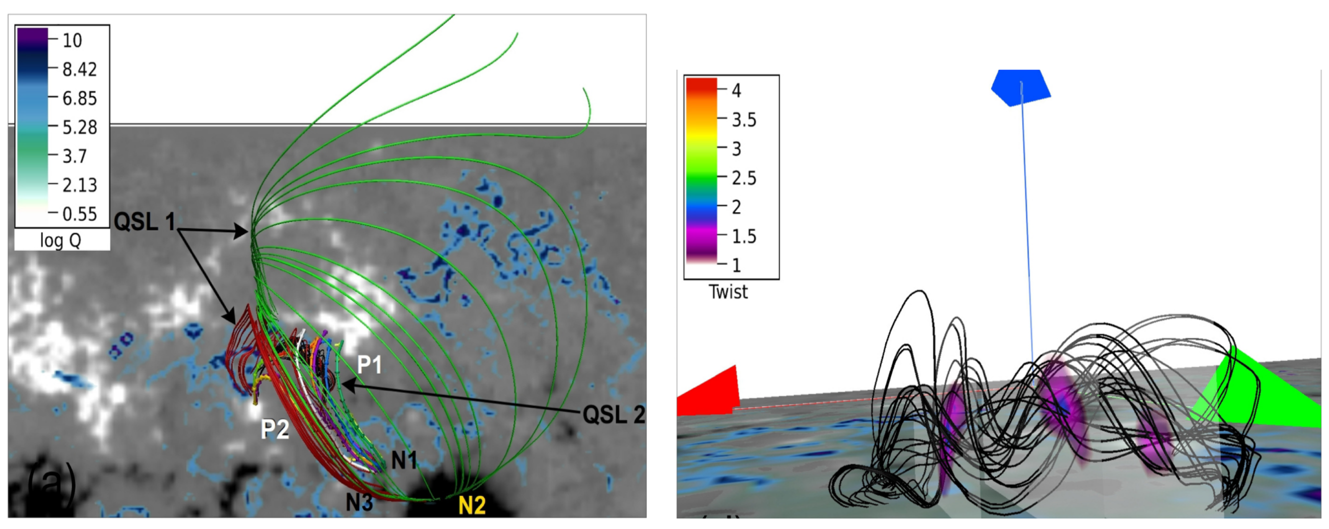

Figure 2. (a) Magnetic topology of region R1 between positive and negative polarities P1, P2, N1, N2, and N3, respectively. (d) Flux rope (below the QSLs) along with the twist values T_w.

Conclusions: Part I

➢ Combined dynamics of the flux rope and overlying QSLs are found to be the underlying cause behind the start of the flare *(K. Bora et al 2022 ApJ 925 197).*

➢ Inclusion of Hall effect reproduces the observed plasma rotation in the simulation *(K. Bora et al 2022 ApJ 925 197).*

5. Results Part II - The Flows Structured along the QSLs in the Coronal Hole Plume : MURaM Simulation

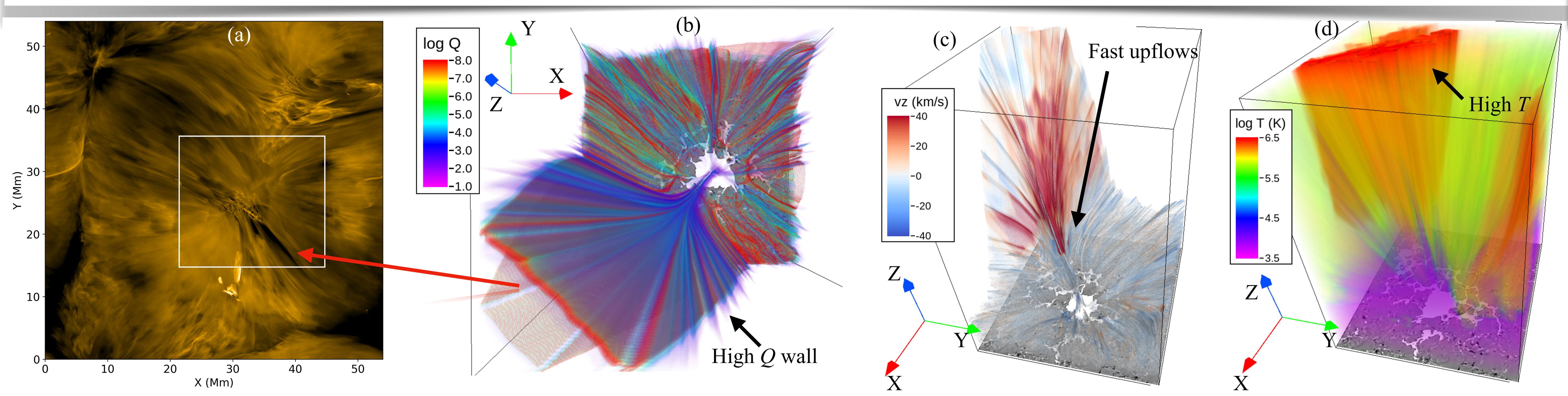

Figure 4. (a) Synthesized intensity map in EUI 174 Å passband. (b) Direct volume rendering (DVR) of log Q for the field of view marked by a white rectangle in (a) with the B_z map as bottom boundary (top-down view). (c) DVR of $2.5 \leq \log Q \leq 5$ colour coded with the vertical component of velocity v_z (side-view) and (d) DVR of temperature for the same field of view. The red, green, and blue arrows in panels (b)-(d) are indicating the $x, y,$ and z-axes of Cartesian coordinate system. The bottom boundary B_z is saturated with ±300 G in panels (b)-(d).

Conclusions: Part II

➢ Uplows $v_z \geq 40$ km/s follow the fine-structures of high-Q values ($\log Q \geq 2$) at the boundary of plume.

➢ High temperature ($\log T \geq 6.0$) is also co-located along the high-Q wall.

➢ Existence of QSLs and the heated plasma flowing with a high speed along them indicates the magnetic reconnection.

Acknowledgement: We acknowledge the use of *VAPOR* (www.vapor.ucar.edu) to visualise the DVR and magnetic field lines.