High-resolution observations of small-scale activity in coronal hole plumes

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0. OVERVIEW

- Plumes, largely radial ray-like structures often observed in coronal holes, might channel MHD waves and the solar wind into the heliosphere.
- Though high-speed propagating disturbances (PDs) are well detected in plumes, their nature cannot yet be clearly understood (MHD waves or mass flows).
- Small-scale transients riddle the plume bases (observed in EUV). Their role in plume formation and evolution, and their relation to PDs, remain unclear.

In this work
- We use observations from the High Resolution Imager EUV (HRI_{EUV}), part of the Extreme Ultraviolet Imager (EUI) on board Solar Orbiter.
- The properties of the small-scale brightenings at the plume bases are investigated to interpret their nature and relation with PDs.

1. OBSERVATION

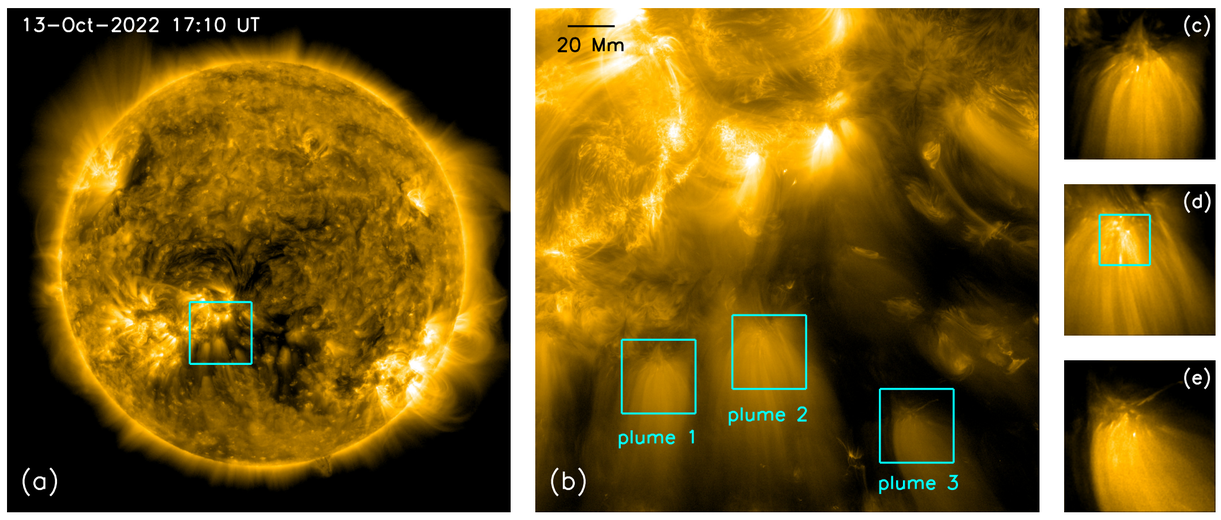


Figure 1:
(a) Full-disk image of the Sun provided by FSI/EUI (Full Sun Imager). The box indicates the region covered by HRI_{EUV}. (b) Image of HRI_{EUV} field of view, featuring boxes that highlight the base regions of the three plumes depicted in panels (c) to (e).

- Oct 13, 2022 (17:00 UT-17:30 UT), HRI_{EUV} captured an observation of three plumes (spatial resolution: ~ 200 km; time cadence: 5 s).
- These plumes were located in an equatorial coronal hole, adjacent to active regions.
- They have highly-dynamic base regions with brightenings appearing near their footpoints and showing apparent outward motions.

CONCLUSION

The PDs are more likely high speed mass flows than slow-mode magnetoacoustic waves.

Base brightenings and PDs are likely unrelated. We hypothesize that they might instead correspond (or be related) to Type I and Type II spicules, respectively.

2. METHODS

Visual identification detection:

Contours representing the brightenings at different times are overplotted in the same images to show the movement of the brightenings.

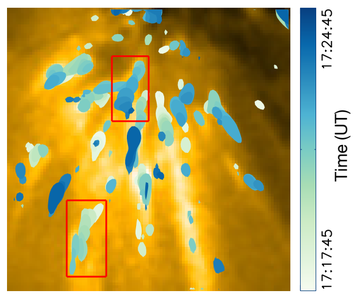
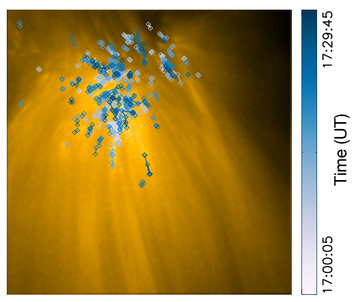


Figure 2:
Image of the footpoint region of plume 2. Red boxes show examples of the color gradient patterns illustrating the trajectory of the brightenings (colors indicate time progression) .

Automatic detection:



We track the temporal evolution and motion of brightenings by searching for their presence in successive frames within a 6-pixels radius until they become indistinguishable.

Figure 3:
Image of plume 2 base with the overplotted position of the intensity-weighted center of each brightening over its temporal evolution (colors indicate the time of the first appearance of each brightening).

- **50 brightenings** are visually selected.
- Automatic detection identifies **451 brightenings**.

3. RESULTS

Statistical distributions of base brightenings' properties: intensity, lifetime, area, length/width ratio and PoS velocity.

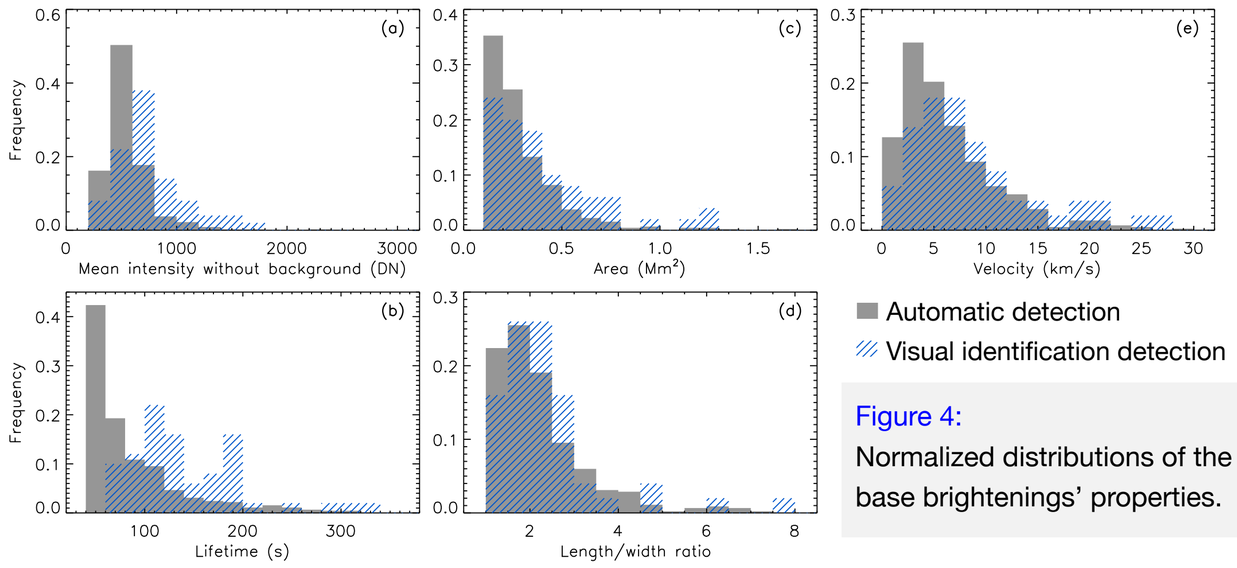
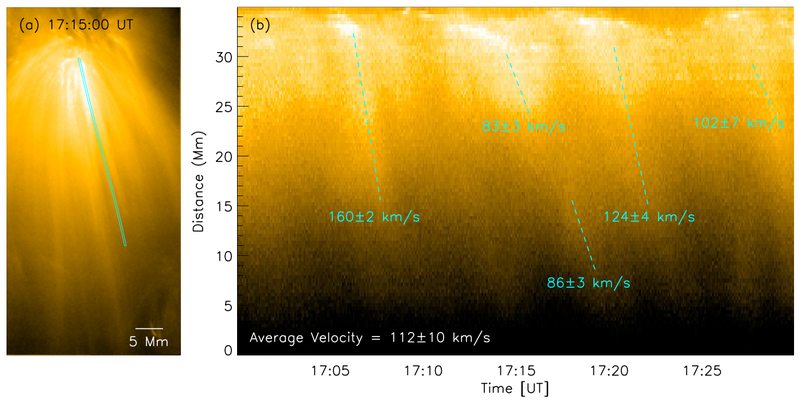


Figure 4:
Normalized distributions of the base brightenings' properties.

- The majority of the observed brightenings can be characterized by small-scale, transient behavior, and slightly elongated morphologies.
- The intensities of brightenings from different plumes are identical once the plume background is subtracted.
- Brightenings show complex movements. Most of the brightenings appear to move with a velocity component in the PoS of less than 10 km s^{-1}.

On the other hand, the PoS velocities of PDs are distributed over a wide range, from 80 to 160 km s^{-1}.

Figure 5:
(a) Image of plume 2. The cyan box shows the position of the slice that is taken to create the timeslice plot shown in panel (b). (b) PDs are marked with cyan dashed lines.



- The extrapolation of magnetic field (data provided by SO/PHI) shows the 3D morphology of the magnetic field and helps to de-project the PoS velocity to the real velocity.
- After de-projection, the velocity of brightenings are still much smaller than that of the PDs.

4. DISCUSSION

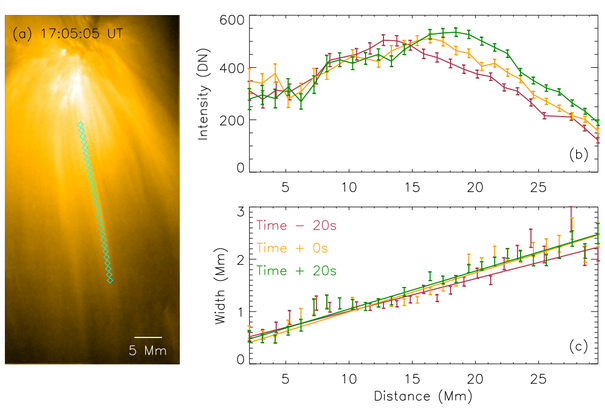


Figure 6:
(a) Positions at different distances are marked with diamonds. (b) and (c) show the peak intensity and FWHM of the fitted Gaussian functions.

- The intensities profiles along cuts perpendicular to the stream direction at different positions (see Figure 6 (a)) are fitted by a Gaussian function. We find that:

  EUV emission doesn't decay along with height like in hydrostatic equilibrium. Thus, PDs are more likely to be mass flows.

  Mass conservation considerations suggest that base brightenings are likely not related to PDs.
- Observational similarities can be found between: base brightenings and type I spicules & PDs and type II spicules.

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