PUNCHing Through the Alfvén Surface

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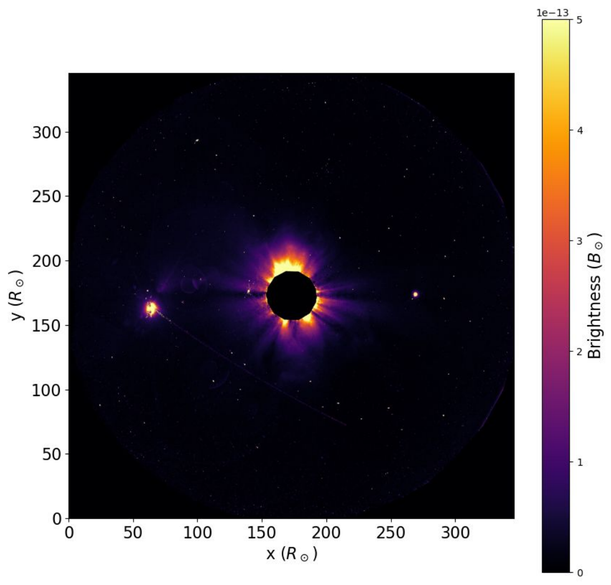
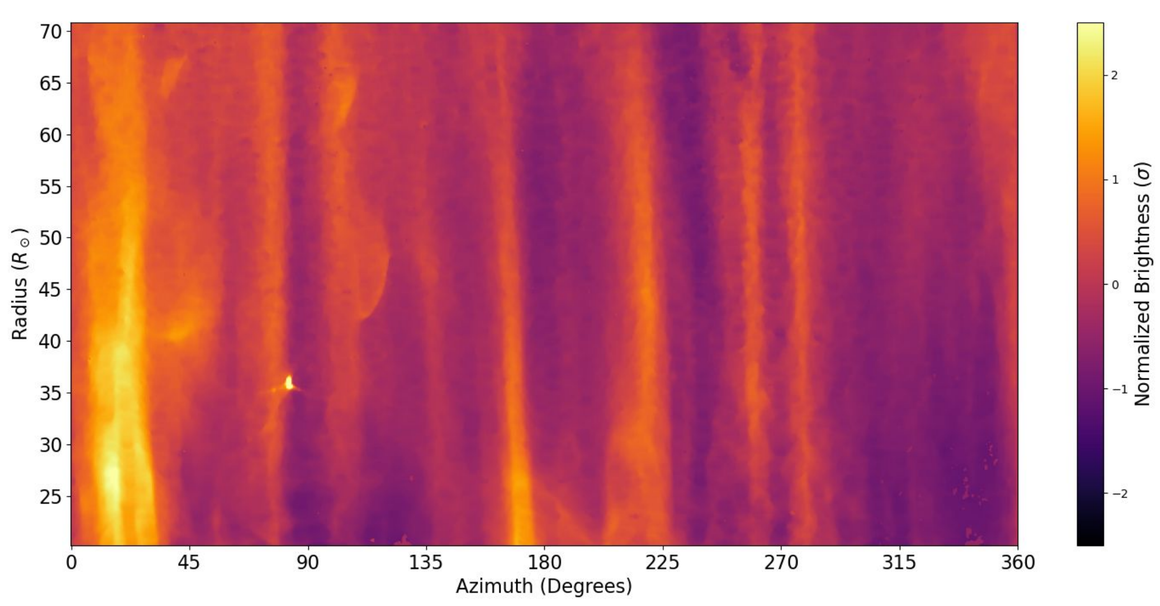
Background

The Alfvén surface is a boundary that separates the corona from the solar wind. It is defined as the region in which the outward plasma flow exceeds the Alfvén speed, and no inward motion is possible. Precisely locating the Alfvén surface is a key element to better modeling coronal turbulence, solar spin down, magnetohydrodynamic waves, and more. Previous work Fourier transformed images (from radius over time to wavenumber over frequency) to separate the data into inbound and outbound moving features[1]. Now, with the launch of PUNCH, these methods should also apply and could map inbound features across larger regions of the corona.

Image Preparation

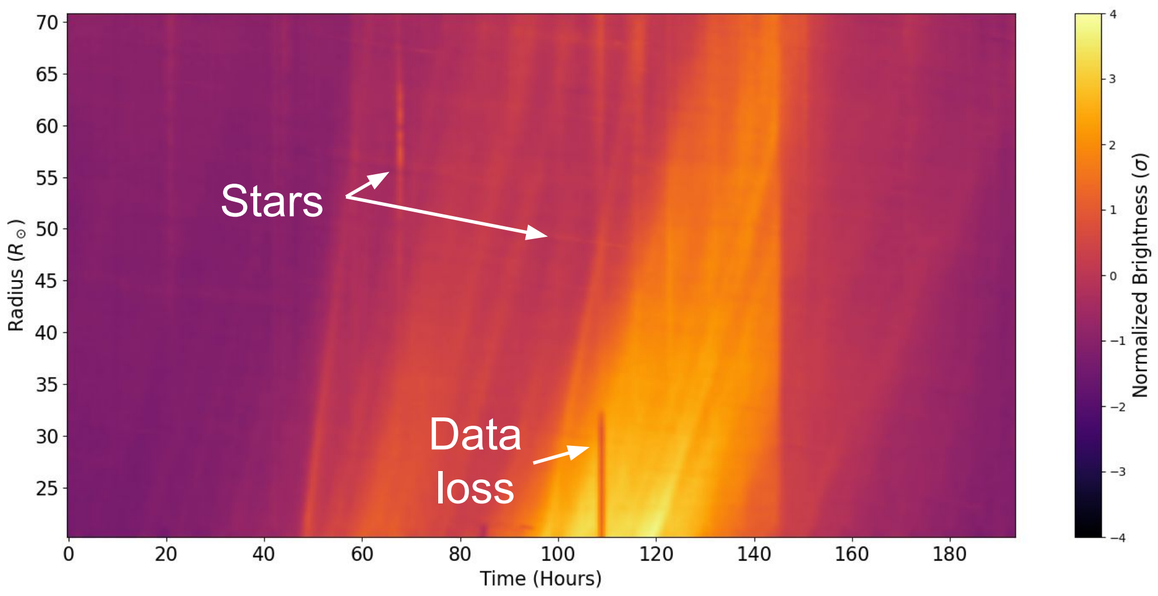


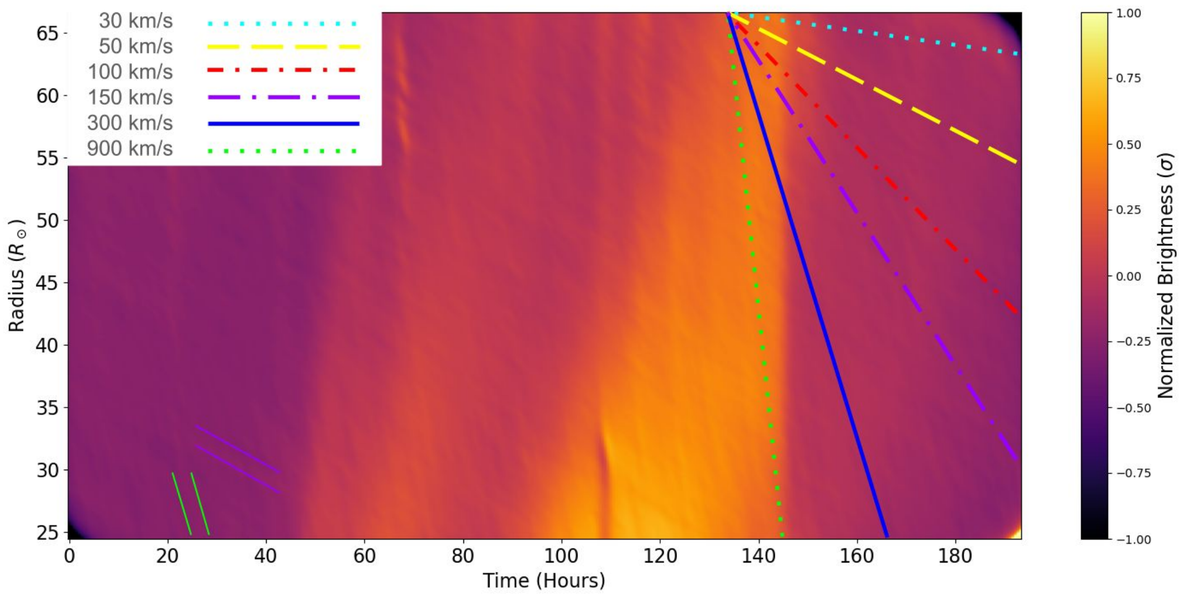


- Level 3 CAM data (v0k) between Sept. 20th, 2025 and Sept. 29th 29th, 2025 used.
- Each image was reprojected into radial coordinates using SunPy's HelioprojectiveRadial and Astropy's reproject_adaptive.
- At each pixel location, the 10th percentile value was computed in a neighborhood of 5 pixels and subtracted.
- This result was then subtracted from the original images.
- Each row was normalized by multiplying by its radius to the third, and then dividing by the average brightness across azimuth and time.

Left: Untouched L3 CAM (v0k) data taken on September 24th at 12:00 pm UTC.
Right: Reprojected and normalized data at the same time as on the right.

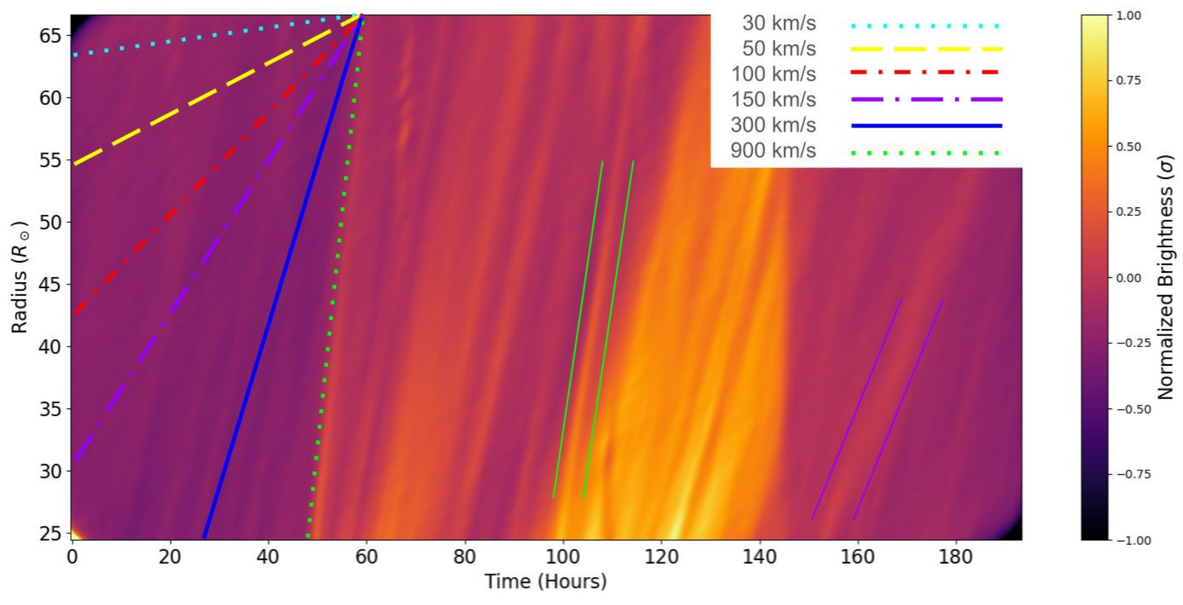
Fourier Filtering





- Averaged across +/- 1 degree azimuth and smoothed with a Gaussian blur with sigma = 1 pixel.
- Along constant azimuth, the images were Fourier transformed, and a speed mask was applied.
- Mask was created by creating an array of 1s and setting relevant regions equal to 0, then blurring with a Gaussian blur with sigma = 3 pixels.
- Minimum speed = 30 km/s, Maximum speed = 900 km/s.
- Inverse Fourier transformed masked data.

Top Left: Unfiltered radius over time data along 25 degrees azimuth.
Top Right: Inbound filtered data. Solid purple line = stars moving at ~35 km/s. Solid green line = Typical inbound feature with speed ~200-300 km/s
Bottom Right: Outbound filtered data. Solid green line = Fast CME moving around 500 km/s, solid purple line = Slow CME moving ~200 km/s



Conclusions

- Possible inbound features exist between 0-100 hours in the inbound filtered images.
- These features are long-lived, quasiperiodic, and differ from the filter slopes.
- The features also exist below ~30 R⊙, whereas the Alfvén surface is expected to be between 10-20 R⊙.
- A speed-spectrum plot would be useful in distinguishing these features from noise.
- Fourier filtering effectively separates out inbound and outbound motion, and with speed masks can eliminate some noise.
- PUNCH data looks great!

References

[1]C. E. DeForest, T. A. Howard, and D. J. McComas. Inbound waves in the solar corona: a direct indicator of Alfvén Surface location. The Astrophysical Journal, 787(2):124, May 2014.

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Any questions or feedback? Please reach out to mateokadmire@gmail.com