A STATISTICAL STUDY OF PLASMOIDS ASSOCIATED WITH A POST-CME CURRENT SHEET

RITESH PATEL[1,2], VAIBHAV PANT[2], KALUGODU CHANDRASHEKHAR[3], DIPANKAR BANERJEE[1,2,4]

[1] INDIAN INSTITUTE OF ASTROPHYSICS, BENGALURU, INDIA
[2] ARYABHATTA RESEARCH INSTITUTE OF OBSERVATIONAL SCIENCES, NAINITAL, INDIA
[3] INSTITUTE OF THEORETICAL ASTROPHYSICS, UNIVERSITY OF OSLO, PO BOX 1029, BLINDERN 0315, OSLO, NORWAY
[4] CENTER OF EXCELLENCE IN SPACE SCIENCE, IISER KOLKATA, INDIA

Abstract

We investigate the properties of plasmoids observed in the current sheet formed after an X-8.3 flare followed by a fast CME on September 10, 2017 using Extreme Ultraviolet (EUV) and white-light coronagraph images. The main aim is to understand the evolution of plasmoids at different spatio-temporal scales using existing ground- and space-based instruments. We identified the plasmoids in current sheet observed in the successive images of Atmospheric Imaging Assembly (AIA) and white-light coronagraphs, K-Cor and LASCO/C2. We found that the current sheet is accompanied by several plasmoids moving upwards and downwards. Our analysis show that the downward and upward moving plasmoids have average width of 5.92 Mm and 5.65 Mm, respectively in the AIA field of view (FOV). However, upward moving plasmoids have average width of 64 Mm in the K-Cor which evolves to a mean width of 510 Mm in the LASCO/C2 FOV. Upon tracking the plasmoids in successive images, we observe that downward and upward moving plasmoids have average speeds of ~272 km s^{-1} and ~191 km s^{-1} respectively in the EUV passbands. We note that the plasmoids become super-Alfvénic when they reach at LASCO FOV. Furthermore, we estimate that the null-point of the current sheet at ≈ 1.15 $R_\odot$ where bidirectional plasmoid motion is observed. The width distribution of plasmoids formed is governed by a power law with a power index of -1.12. Unlike previous studies there is no difference in trend for small and large scale plasmoids. The presence of accelerating plasmoids near the neutral point indicates a longer diffusion region as predicted by MHD models.

Introduction

- Magnetic reconnection, the driver of solar flares are accompanied by formation of bidirectional plasmoids in the current sheet due to tearing mode instability.
- Guo et al. (2013) found the width distribution of plasmoids are different for sizes less than and greater than 50 Mm using LASCO/C2 data.
- Based on 2D resistive MHD simulation for magnetic reconnection, it was reported that upward and downward moving plasmoids attain speeds of the order of ambient Alfvén speed and fraction of this speed respectively (Bárta et al. 2008; Forbes et al. 2018).
- Due to limited observations, upward moving plasmoids speed do not vary within current sheet, while the downward moving ones show deceleration (Forbes et al. 2018).
- In spite of several observational and modelling studies, we do not have a clear understanding of the plasmoids evolution and their role in fast magnetic reconnection.

Analysis

- Active Region 12673 led to a X8.3 flare on September 10, 2017 near the west solar limb and is also associated with a fast CME of speed ~3200 km s^{-1}.
- A current sheet was observed in extreme-ultraviolet (EUV) and white light images starting from 16:10 UT.
- We used EUV images of AIA 131 Å and white-light coronagraph images from K-Cor and LASCO.

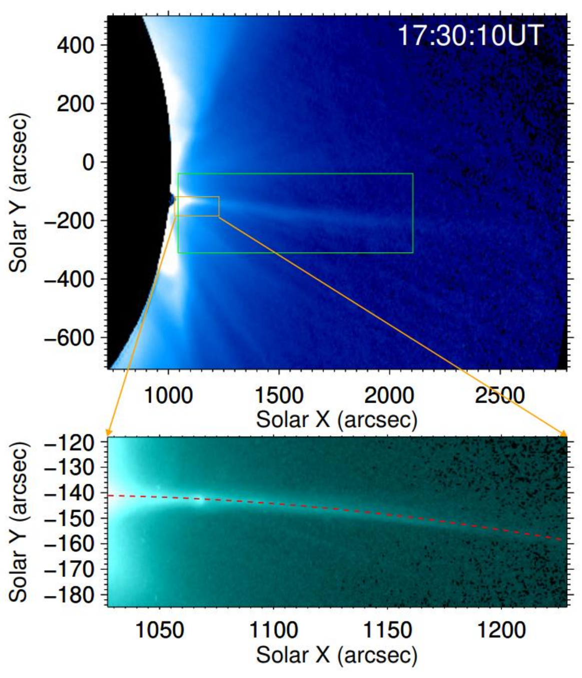

Fig 1. Context image for the current sheet in the K-Cor data. Green and red rectangular boxes in the *Top* panel corresponds to ROI chosen for the analysis in the K-Cor and AIA 131 Å data *(Bottom)* respectively.

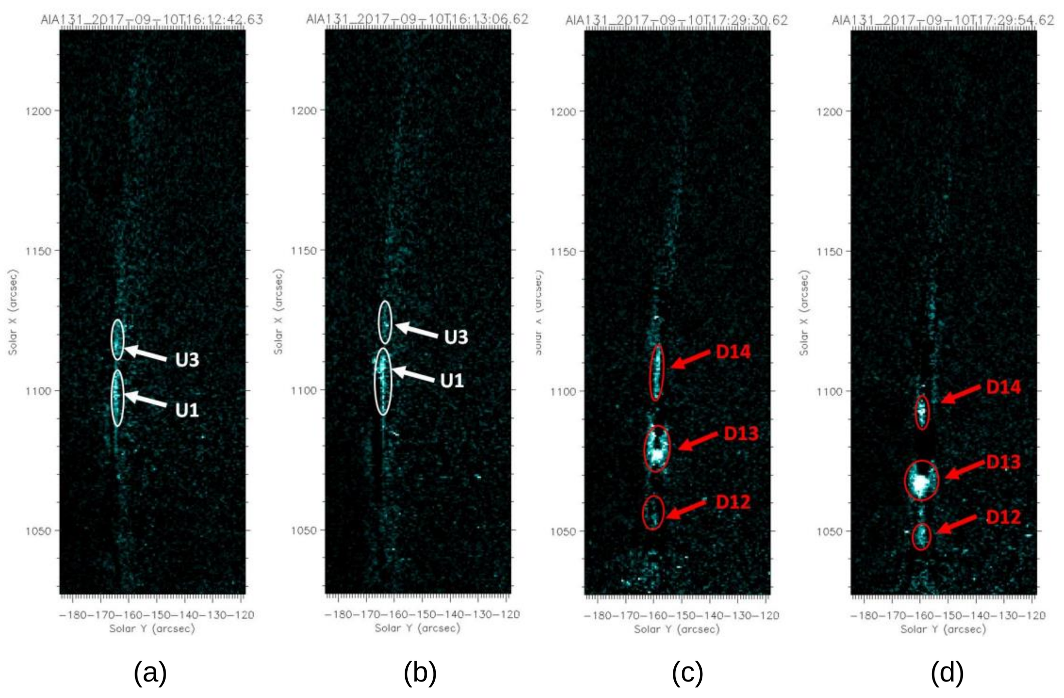

Fig 2. Plasmoids identified in radial filtered difference images of AIA 131 Å along the current sheet. The outward and downward moving plasmoids are shown from (a, b) and (c, d) panels encircled in white and red colors respectively.

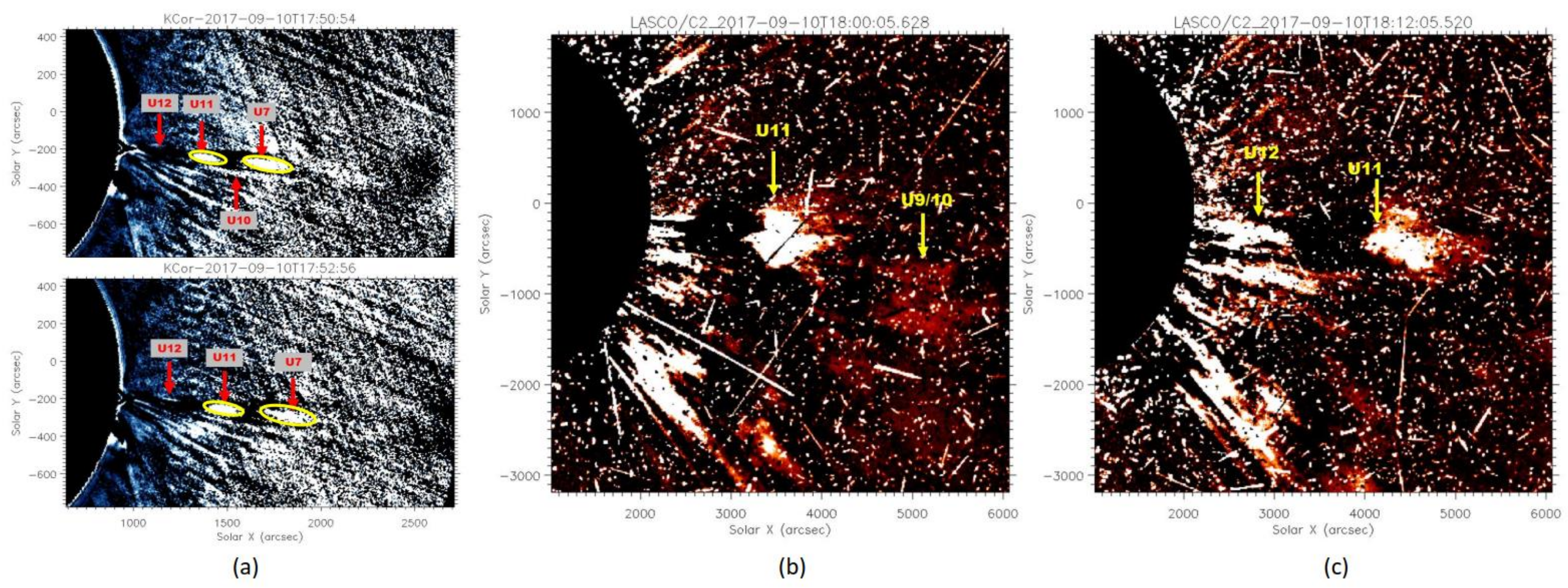

Fig 3. Identification of plasmoids in successive frames of white-light coronagraph images, (a) In K-Cor difference image plasmoids are marked with yellow contours, (b) and (c) In LASCO/C2 difference image the location of identified blobs are pointed with yellow arrows.

Results

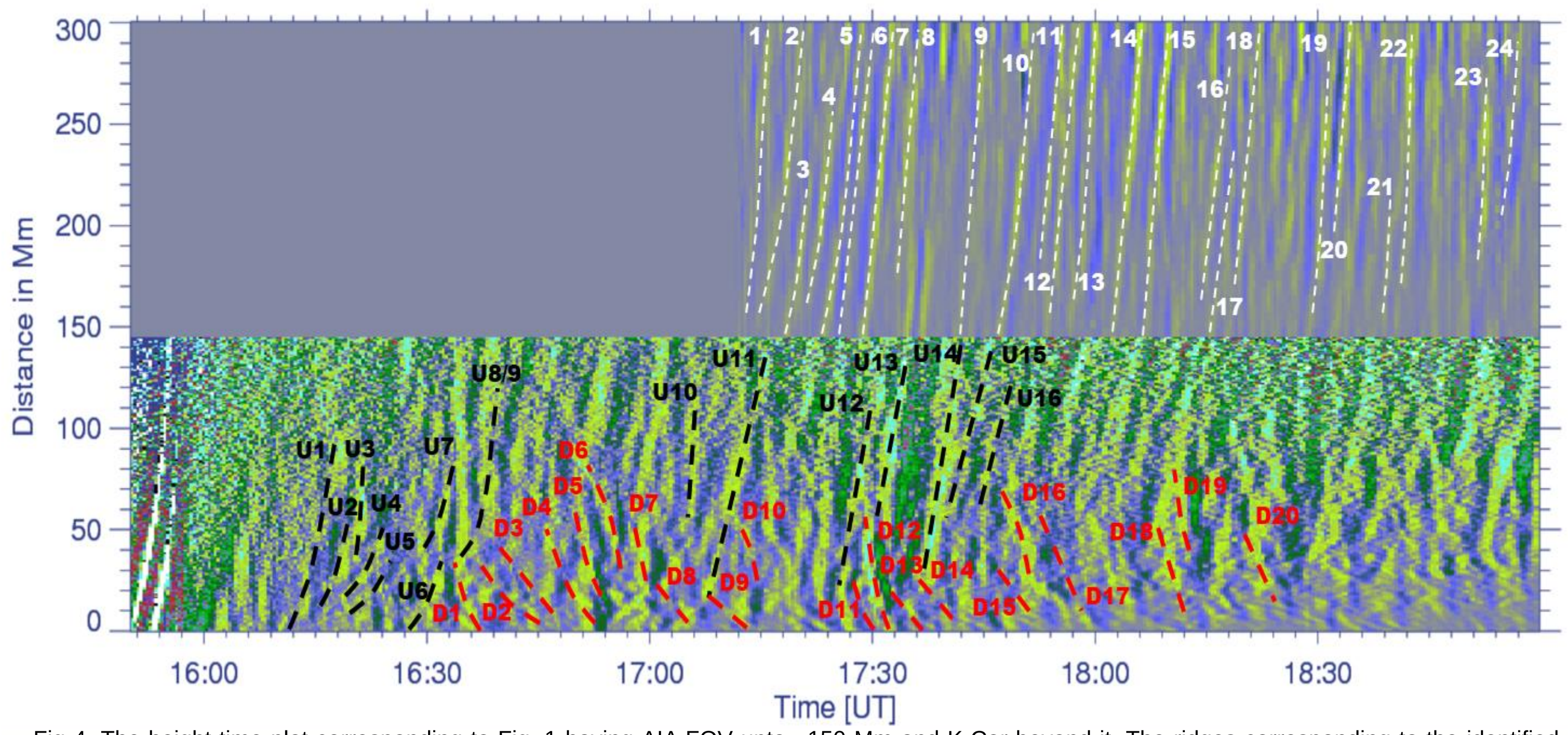

Fig 4. The height-time plot corresponding to Fig. 1 having AIA FOV upto ~150 Mm and K-Cor beyond it. The ridges corresponding to the identified blobs are marked by dashed lines in black and red colors respectively in AIA FOV and in white within K-Cor FOV. The serial number of the plasmoid in the top panel have their corresponding ridges in the bottom height-time plot.

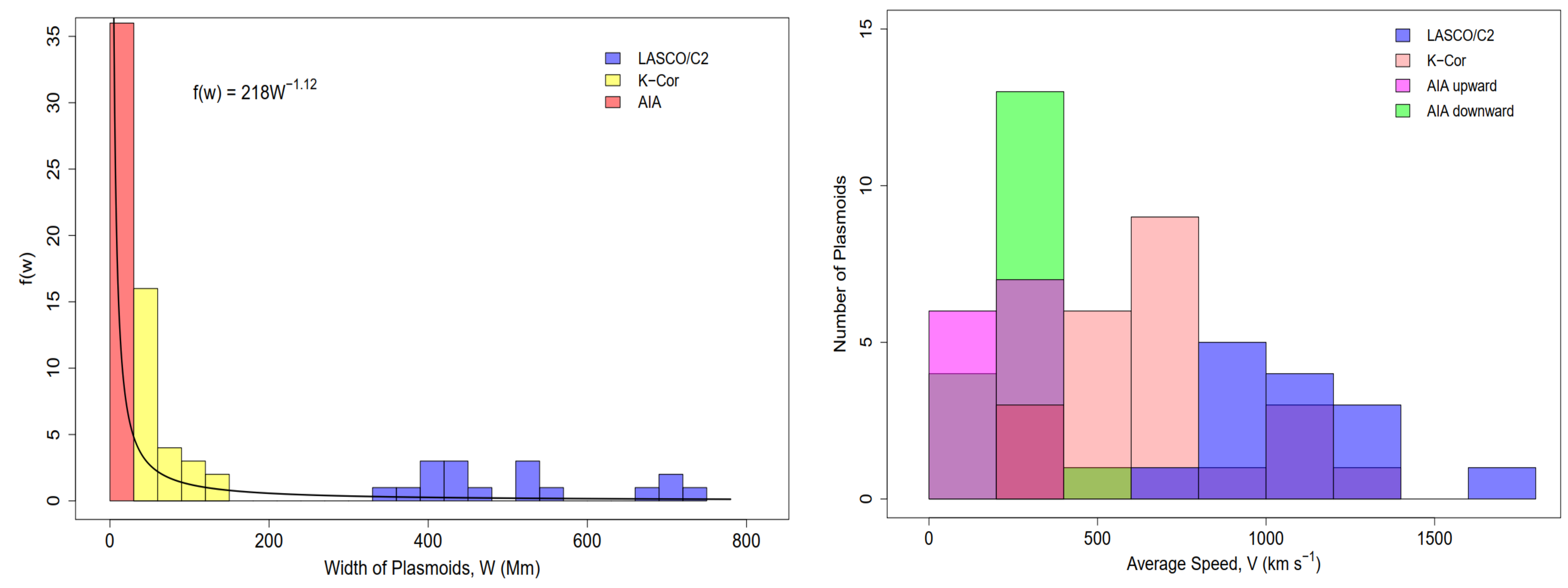

Fig 5. *Left:* Width distribution of plasmoids identified in AIA, K-Cor and LASCO C2 images, *Right:* Speed distribution of all plasmoids observed from inner to outer corona.

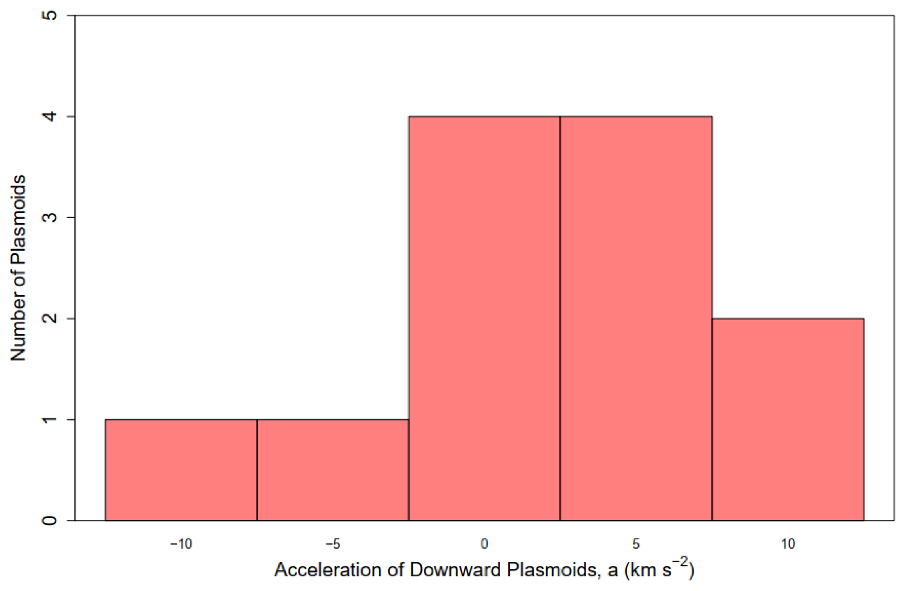

Fig .6 Distribution of the acceleration of the downward moving plasmoids observed in AIA 131 Å images.

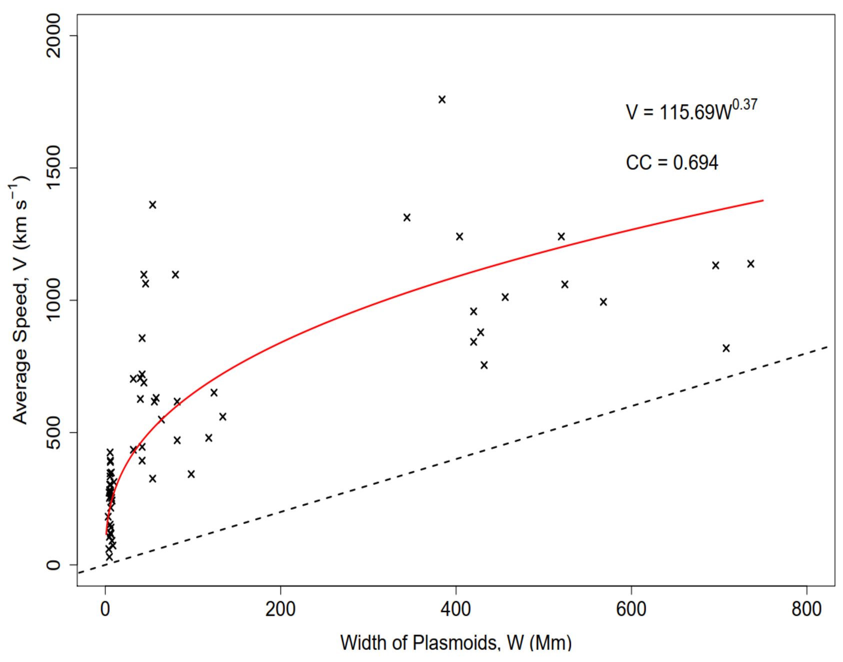

Fig 7. Relation between width and average speed of plasmoids. The red line represents the power law associated with the plasmoid width and average speed.

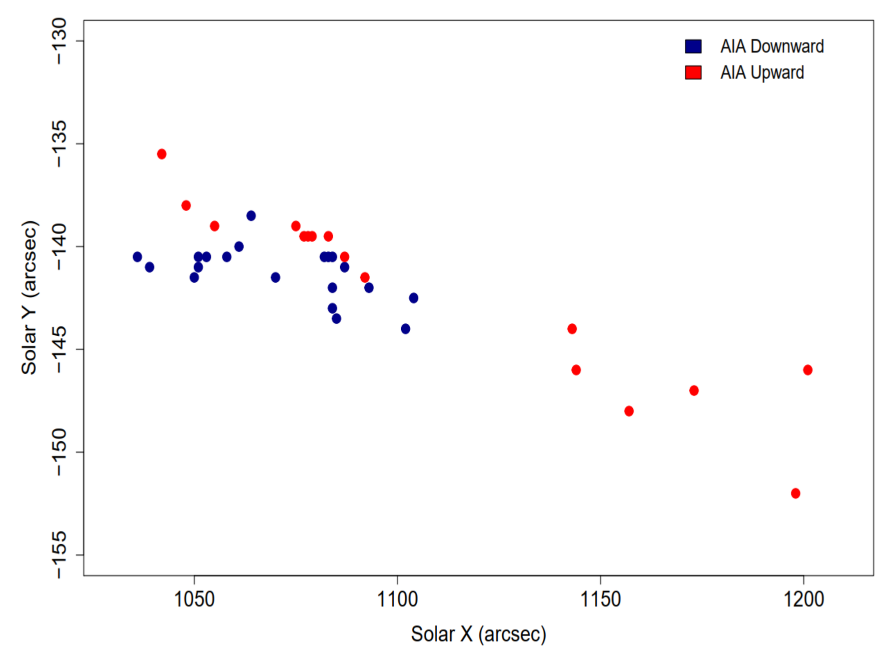

Fig 8. Location of the blobs identified manually from AIA 131 Å passband images.

- No downward moving plasmoids appear higher than ~1110 arcsec (1.1 $R_\odot$).
- This is speculated to be the X-point.

Summary

- We visually identified and tracked the plasmoids in EUV and white-light images. We found 20 downward and 16 upward moving plasmoids in AIA 131 Å images while in Kcor and LASCO/C2 images 24 and 17 upwards moving plasmoids were identified respectively.
- The size distribution of plasmoids reveals that it follows a power-law with index of -1.12. This is the first observational study to support power-law size distribution as predicted by MHD simulations.
- We found that the upward moving plasmoids have super-Alfvénic speeds while the downward moving ones are sub-Alfvénic in nature as predicted by the MHD simulations.
- The downward moving plasmoids show an acceleration ranging from -11 m s^{-2} to 8 m s^{-2}. Such accelerating plasmoids moving downwards were not reported earlier due to limitations in observations.
- We found an empirical relation explaining the evolution of the plasmoids as V = 115.69W$^{0.37}$ where V and W are the speed and widths of the plasmoids respectively. These relations will be helpful to constrain the numerical simulations to understand the formation and evolution of plasmoids and their role in reconnection.

References

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ritesh.patel@iiap.res.in