White-Light Blobs: Tracers of the Solar Wind, Deprojected Aspect-Ratio Evolution, and Their 3D-Shape

Cynthia López-Portela[1,2] and Nicholeen Viall[2]

1 University of Maryland, Baltimore County, MD, USA
2 NASA-Goddard Space Flight Center, Greenbelt, MD, USA

Abstract

Blobs detected in white-light data, are a subset of density mesoscale structures and are excellent tracers of the solar wind. The application of deprojected-reconstruction-techniques instead of projective geometries, permits to determine the position of blobs in the 3D-space with high accuracy. In this work we use the pair combinations of coronagraphs C2 & C3 and Cor2 A/B on board LASCO/*SOHO* and SECCHI/*STEREO*, respectively. One of the most interesting applications of the 'real' position of blobs is, for example, to study the dynamics of the 'blob-solar wind' system. Also, the deprojected information of blobs enables to study their radial elongation and transverse size, and in conjunction, their deprojected aspect-ratio evolution. Finally, in this work we determine the 3D-shape of blobs based on the multi-spacecraft of white-light observations. The reduction of projective effects is of major importance to determine the locations of tracers of the solar wind, which is one of the PUNCH mission goals.

Methodology

Projected white-light images | **Synchronized evolution-time maps**

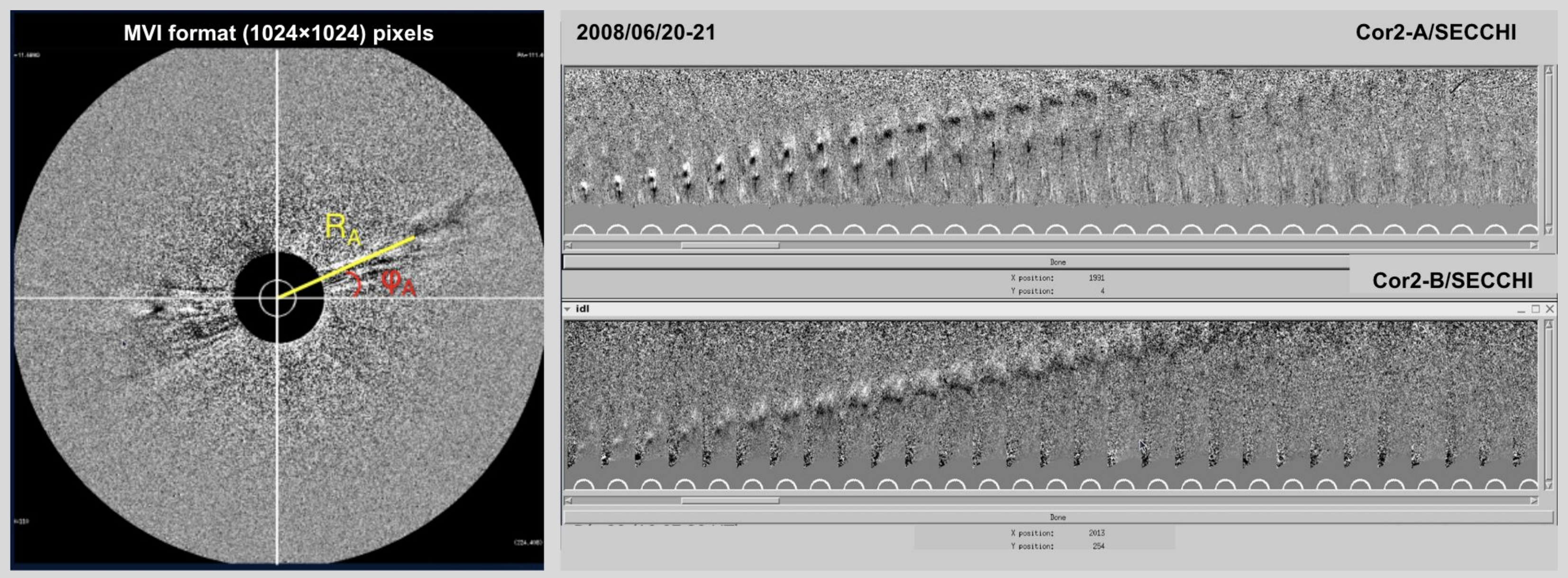
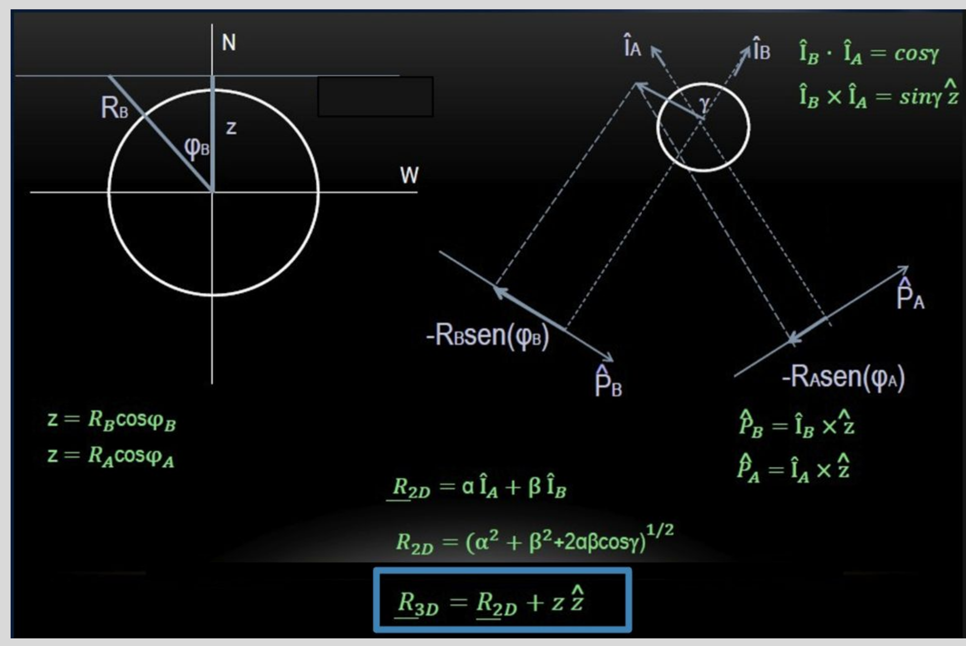


Figure 1. Height-time analysis technique applied to coronagraphs. (**Left**) Blob selection event on the protected image (Cor2-A). (**Right**) Two synchronized evolution-time maps (López-Portela *et al.*, 2018) to obtained the parameters required for the HT-technique (Mierla *et al.*, 2008).

Height-Time Technique: Deprojected Radial Size with Position in Time



The triangulation is based on a coordinate system build by an epipolar geometry (Inhester 2006), assuming that:

1) S/C are in the same ecliptic plane,
2) the geometrical vector analysis is appropriate for the reconstruction instead of using projective geometry, and
3) epipolar lines (EP) can be treated in each coronagraph image parallel to the ecliptic plane.

Crucial parameters:
* Position angle (PA: φ_A and φ_B)
* Radial distance (R_A and R_B)
* Spacecraft separation angle (γ)

Figure 2. Vectorial geometry implemented by the HT-technique. The epipolar geometry to generate the coordinate system (Inhester 2006; Mierla *et al.*, 2008).

2D Analysis

Aspect Ratio Size Distribution

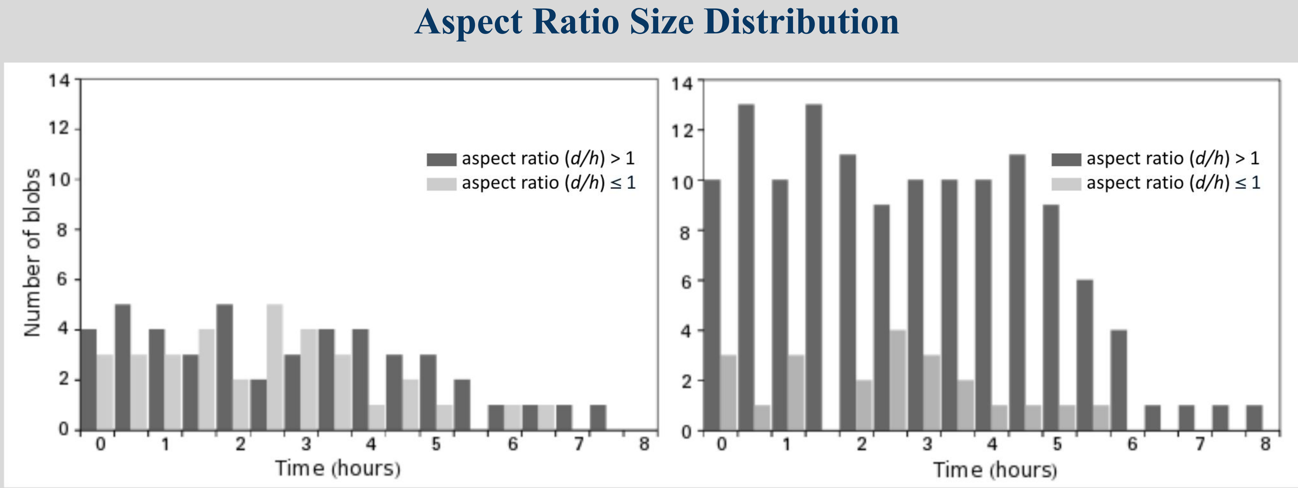


Figure 3. Projected blobs' aspect-ratio related to their acceleration. The less accelerated blobs (**Left**) and more accelerated (**Right**) blobs of the sample. The graphs suggest that the more accelerated blobs tend to present larger elongation lengths along their radial component (*d*) than in their transverse component (*h*). Indicating that the radial component of the ambient solar wind, is a significant component for blobs' shape evolution.

2D Analysis

Projected Radial and Transverse Length Evolution

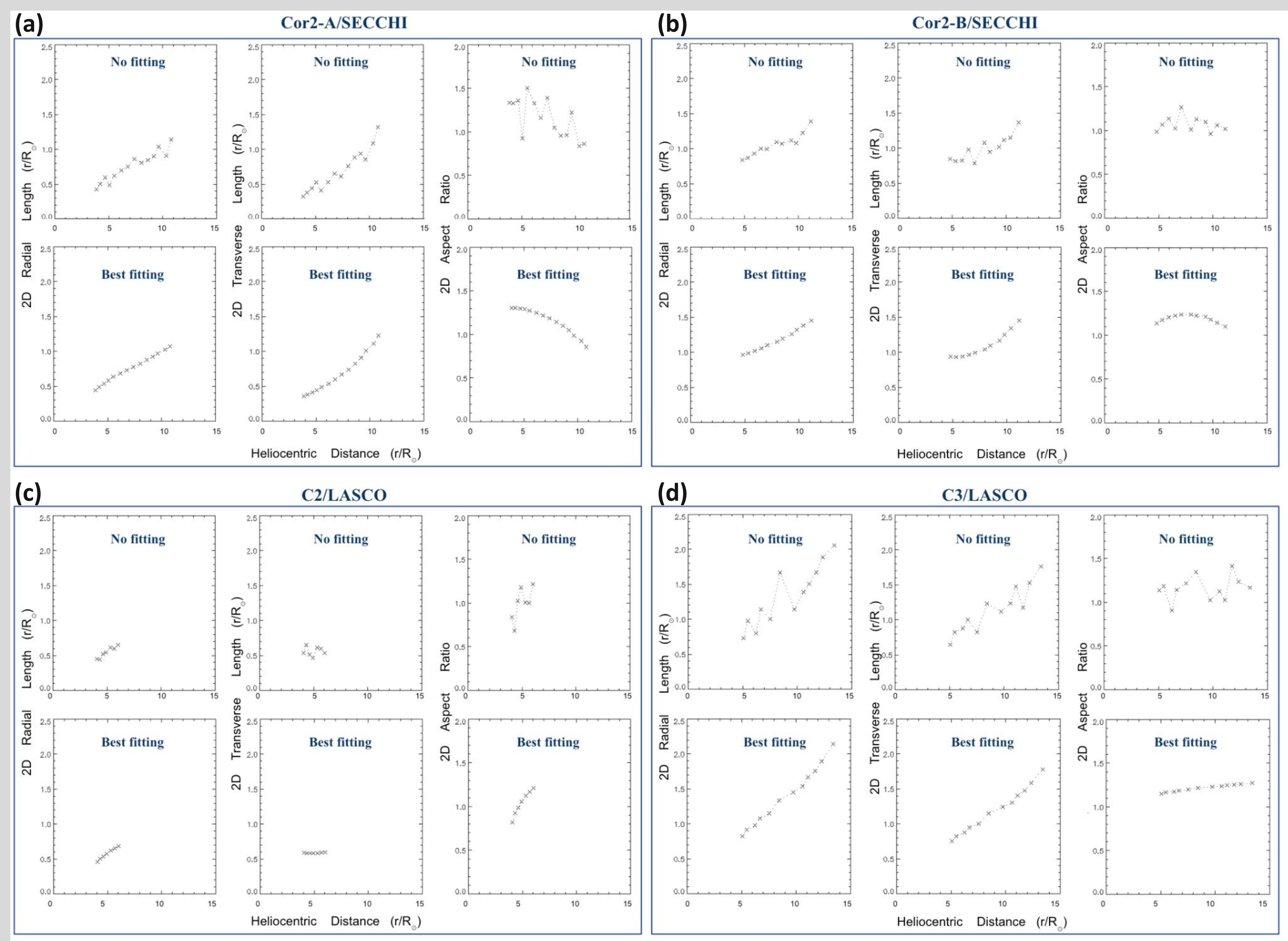


Figure 4. Projected blobs' radial and transverse length, and aspect ratio. **(a)** Cor2-A, **(b)** Cor2-B, **(c)** C2, and **(d)** C3. Panels without fitting (**Top**) and their corresponding best fitting (**Bottom**). The data sample corresponds to event 10 published in López-Portela *et al.*, 2008 and López-Portela *et al.*, (submitted).

3D Analysis

Deprojected Radial and Transverse Length Evolution

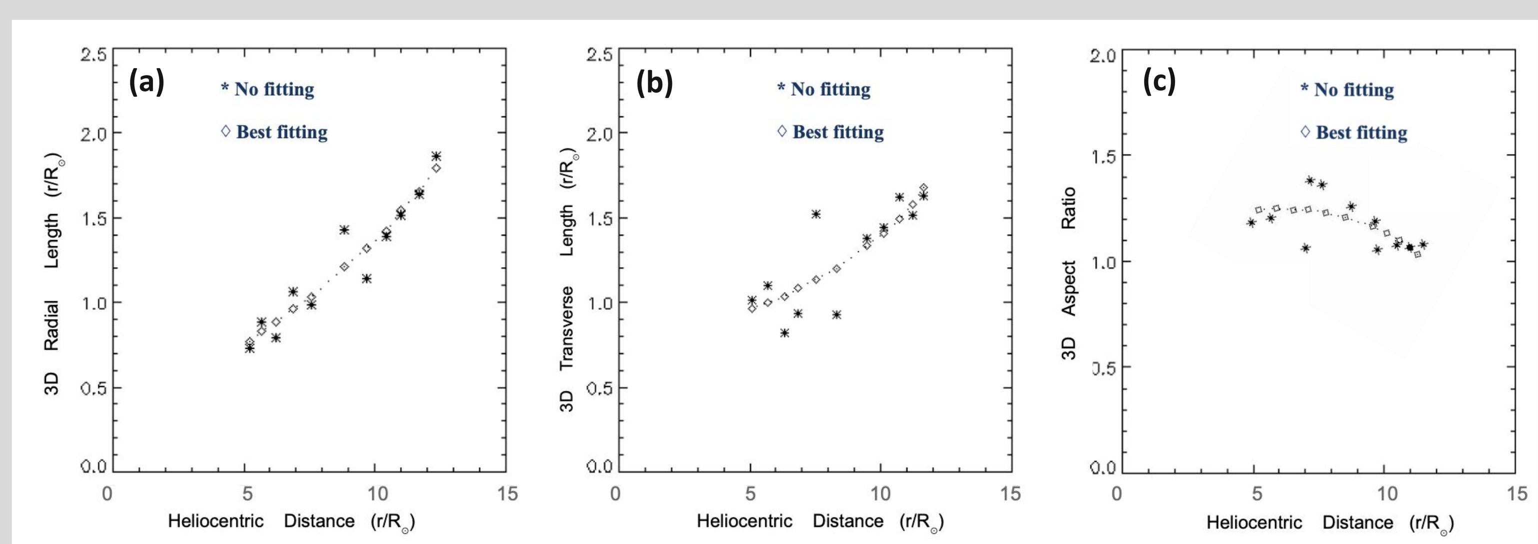


Figure 5. Deprojected blobs' radial and transverse length, and aspect ratio. **(a)** The 3D radial length shows the kinematic behavior of the blob, **(b)** the 3D transverse length suggest the profile of the blob's material filling the space, and **(c)** the aspect ratio indicates that the most dominant component is the radial length in comparison with the transverse length (aspect ratios > 1). The pair of spacecraft used in the HT-analysis technique are Cor2-A and C3 for the same event in Figure 4.

Acknowledgements

CLP and NV are supported by NASA-Goddard Space Flight Center Heliophysics Internal Scientist Funding Model (HISFM)

3D Analysis

A Blob 3D-Shape

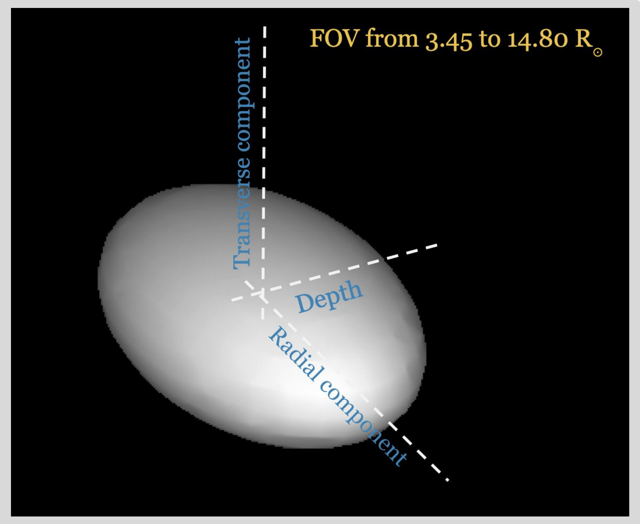


Figure 6. An option to approximate the 3D-shape of blobs based on the deprojected radial and transverse length. The image sketches the estimation of the tridimensional shape of blobs base on the results of the deprojected lengths using the five combinations of spacecraft in the HT-technique (not shown here).

Exploration

Dynamics of the blob-solar wind system

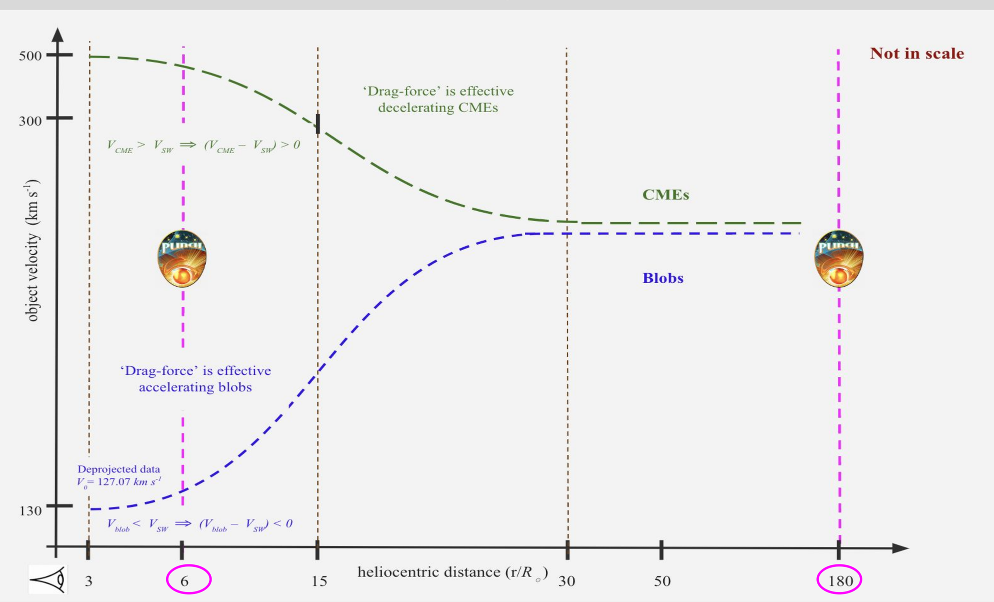


Figure 7. 'Drag-force' acting on CMEs and blobs. The graph depicts the behavior of a 'drag-force' model acting on CMEs (green) and blobs (blue), based on the detection of events in white-light data by different instruments using (de)projected data). **PUNCH** mission will give crucial observational evidence to verify this type of analysis, due to its broad field-of-view (pink).

Takeaways

- The 3D-reconstruction-techniques (e.g., Mierla *et al.*, 2008) are appropriate for coronagraph data permitting to produce deprojected positions in a 3D-coordinate-system, taking advantage of **multi-spacecraft analysis**. This enables to performed the 'flow-tracking' of density mesoscale structures (Viall *et al.*, 2010) to characterize the different types of solar wind through the exploration of kinematic/dynamic models (e.g., Borgazzi *et al.*, 2009, Cranmer *et al.*, 2007 and 2021).
- The measurement of the 3D radial and transverse length and the exploration of the blob 3D-shape density distribution, will give a crucial information to understand the interaction of the 'blob-solar wind' system described by more complete dynamic models (e.g., López-Portela *et al.*, [in preparation]).
- Expanding the detection of density mesoscale structures with other white-light experiments (e.g., Solar Orbiter Heliospheric Imager [SoloHi]) will enriched our knowledge of the solar wind behavior at longer distances (overlap FOV [6-50] R☉).
- The future white-light instruments (e.g., *PUNCH* mission) will enhance the detection of density mesoscale structures, extending our exploration of the solar wind behavior taking advantage of **multi-spacecraft analysis** (overlap FOV [3-90] R☉).
- One of the most interesting applications of producing deprojected data is that it can be used to "test" models in space-weather forecasting, opening an opportunity to perform 'data assimilation' to constraint the simulations in the Sun-Earth context.

References

[1] López-Portela *et al.*, 2018, *Deprojected Trajectory of Blobs in the Inner Corona*. Solar Physics.
[2] Mierla *et al.*, 2008, *A Quick Method for Estimating the Propagation Direction of Coronal Mass Ejections Using STEREO-COR1 Images*. Solar Physics.
[3] López-Portela *et al.*, [submitted], *A Drag-Force Analysis of Solar Wind White-Light Tracers in the Inner Heliosphere*. The Astrophysical Journal.
[4] Viall N. & Vourlidas A., 2015, *Periodic Density Structures and the Origin of the Slow Solar Wind*. The Astrophysical Journal.
[5] Borgazzi *et al.*, 2009, *Dynamics of Coronal Mass Ejections in the Interplanetary Medium*. Astronomy & Astrophysics.
[6] Cranmer *et al.*, 2007, *Self-Consistent Coronal Heating and Solar Wind Acceleration from Anisotropic Magnetohydrodynamic Turbulence*. Astrophysical Journal Supplement.
[7] Cranmer *et al.*, 2021, *Inward-propagating Plasma Parcels in the Solar Corona: Models with Aerodynamic Drag, Ablation, and Snowplow Accretion. The Astrophysical Journal.*
[8] López-Portela *et al.*, [in preparation], *Dynamics of Blobs Mass Accretion and the Snowplow-Effect in the FoV from 3 to 15 R☉*, The Astrophysical Journal.