Deprojected White-Light Tracers of the Slow Solar Wind

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Section 5 - Tomography and 3D tracking: Part One

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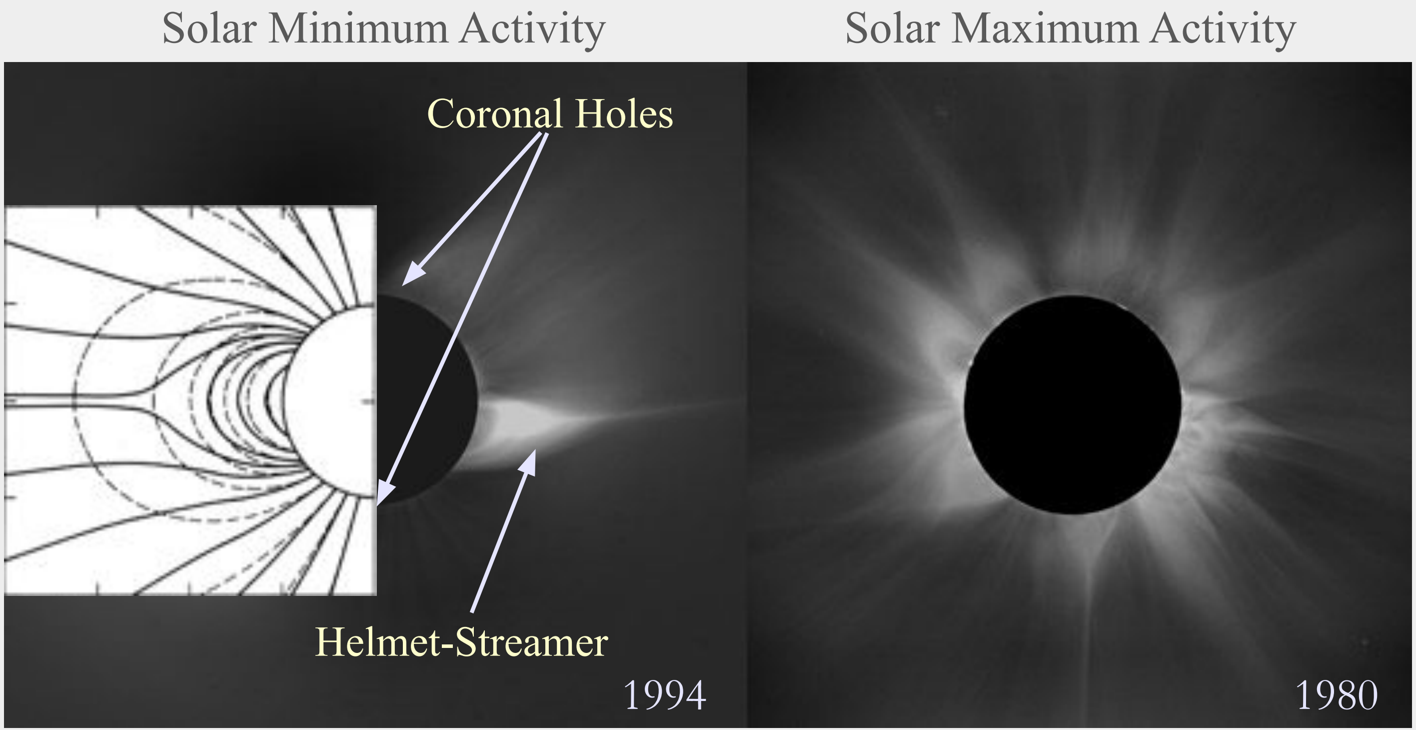
Quasi-static solar coronal structures and the slow solar wind



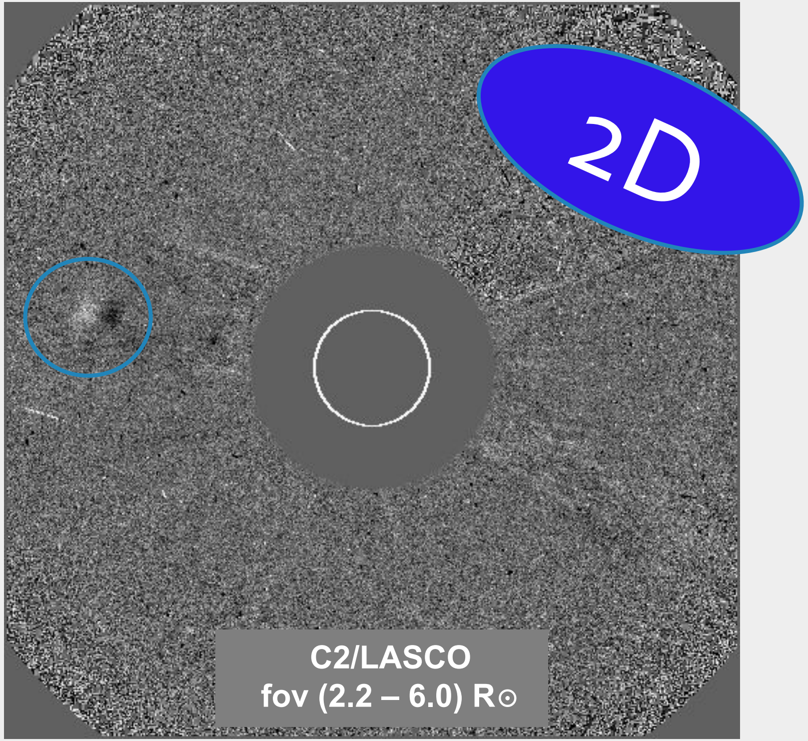
High Altitude Observatory, NCAR,Boulder, Colorado, USA

Mesoscale structures: tracers of the solar wind

Characteristics of blobs in white-light data
(e.g., Sheeley et al. 1997 and Song et al. 2009):

- **Compact structures detectable in brightness intensity**
- ***Running-difference*** **technique is applied**
- **Radial size from 0.1 to 3.0 R⊙**
- **Constant angular extension of 3° (~ 1 R⊙)**
- **Detected from ~ 3 to 30 R⊙**

2008/06/20
16:06:04 UT



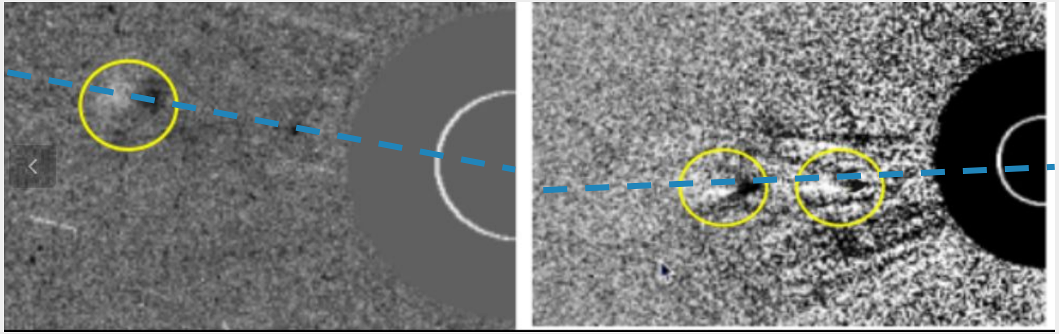
Motivation:

"The exploration of appropriate techniques to reduce projective effects in white-light trajectories allows us to take advantage of different spacecraft locations to perform accurate 'flow-tracking' the solar wind to analyze its kinematic behavior. Which is one of the goals of PUNCH mission."

Height-time analysis technique: deprojected data from coronagraphs

Data selection:

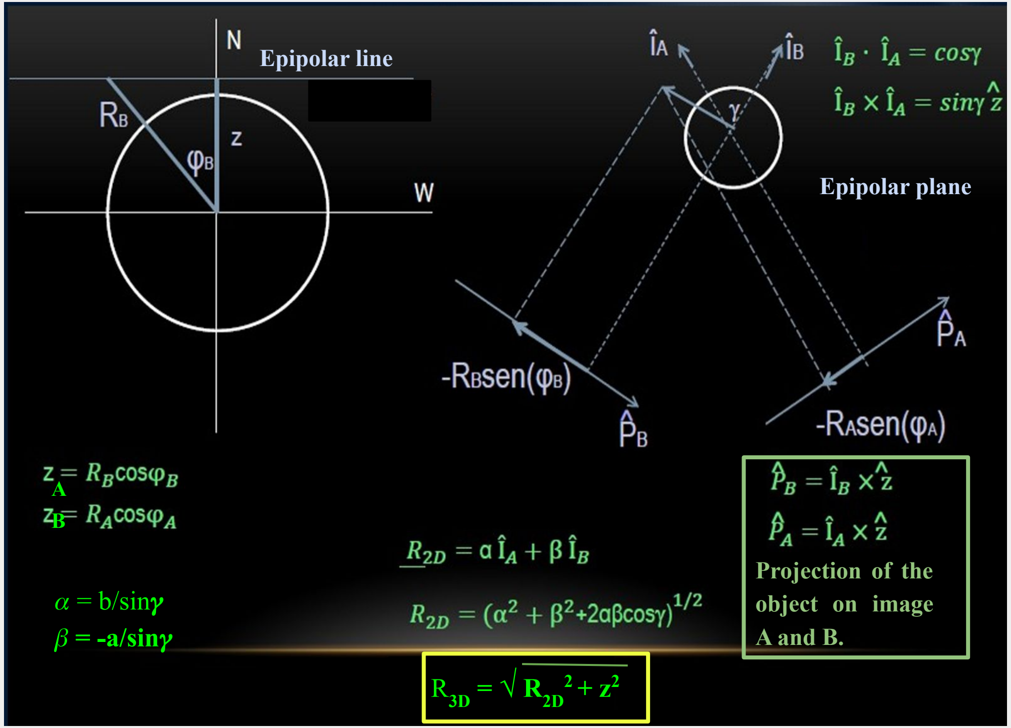
- **Mesoscale structures that propagate in quasi-radial trajectories are excellent candidates for the HT-technique (not appropriate for large structures like CMEs, *Mierla et al 2008*).**
- **The structure has to be detected at least by two coronagraphs (C2/C3 LASCO-SoHO and Cor2-A/B SECCHI-STEREO).**
- **Detections should be performed at equatorial latitudes (in my case ± 35°).**



López-Portela et al (2018)

Height-time analysis technique: deprojected data from coronagraphs

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



Mierla et al (2008)

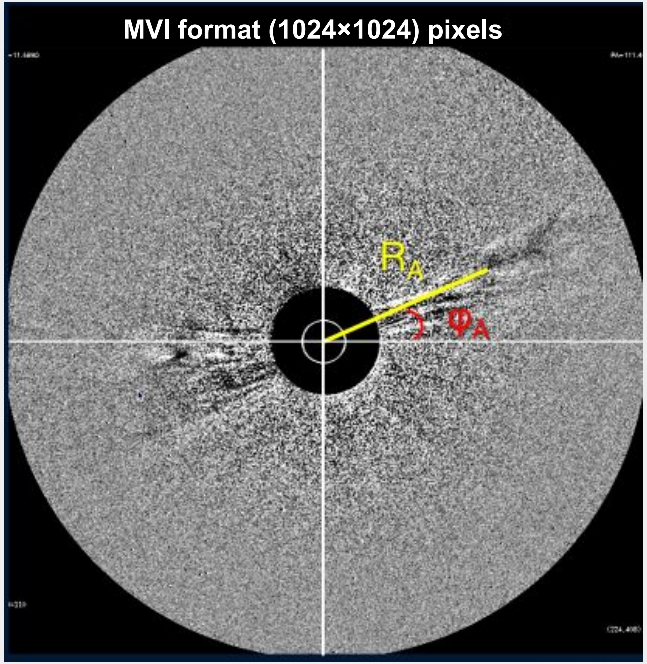
1) **S/C are in the same ecliptic plane,**
2) **the geometrical vector analysis is appropriate for the reconstruction instead of using projective geometry, and**
3) **epipolar lines (EP) can be treated in each coronagraph image parallel to the ecliptic plane.**

z_A and z_B: distance off the ecliptic
$\boldsymbol{\gamma}$: S/C separation angle
φ_A and φ_B: position angle (PA), anticlockwise from North (0°)
R_A and R_B: radial distance on the coronagraph image

The real space position in spherical coordinates:
R_{3D}: magnitude of the position
Θ: ecliptic latitude
λ: ecliptic longitude

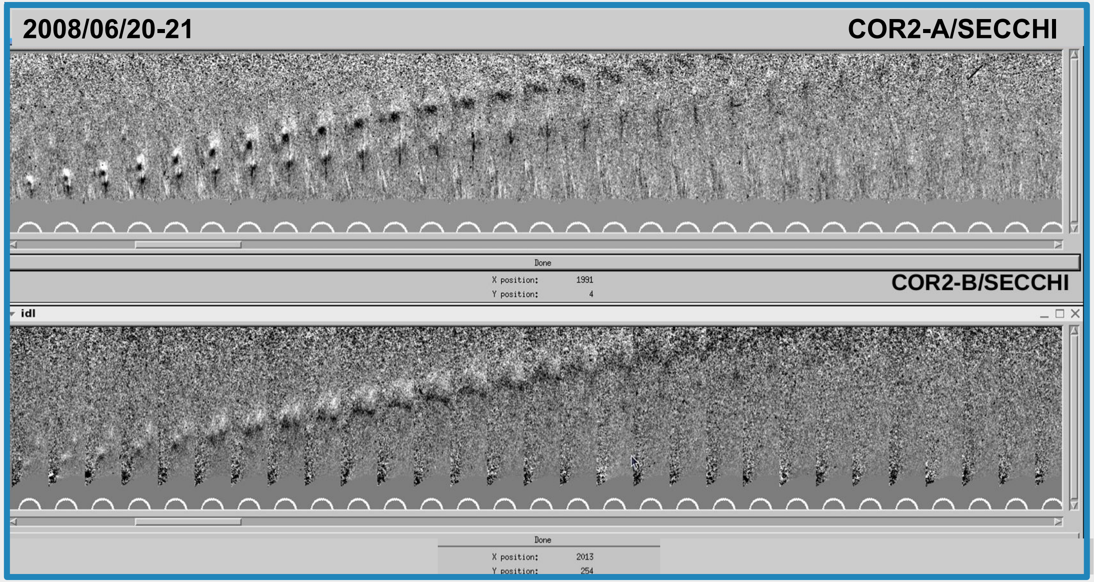
Height-time analysis technique: deprojected data from coronagraphs

3D-reconstruction Technique



HT-technique
Mierla et al. (2008)

Synchronized evolution-time maps



From a pair of coronagraph images:
* PA (φ_A and φ_B)
* Radial distance (R_A and R_B)
* Spacecraft separation angle (ɣ)

López-Portela et al (2018)

Height-time analysis technique: deprojected data from coronagraphs

Coordinate system, S/C separation angle, HT-analysis technique uncertainty

The real space-position in spherical coordinates is given by:

R_{3D}: magnitude of the position
Θ: ecliptic latitude [-π/2 : π/2]
λ: ecliptic longitude

➔ R_{3D} position uncertainty calculation ranges from *6.7 to 14.6%* when applied for 13 mesoscale structures (equivalent to 44 single coronagraph detections from 3 to 15 solar radii analyzed in 2007 and 2008).

➔ *Supposition: LAT of the object is the same as the S/C LAT*

➔ *Fact: the smaller |LONG S/C- LONG object|, the brighter and more visible the object is on the plane of the sky of the coronagraph. This happens when the S/C separation angle of ~ 30° (2007 and 2008).*

Applications of deprojected trajectories from coronagraphs

- Calculate 3D-parameters (position, radial velocity profile, and acceleration) through the application of **kinematic** models based on "real" trajectories to characterize the solar wind flows.

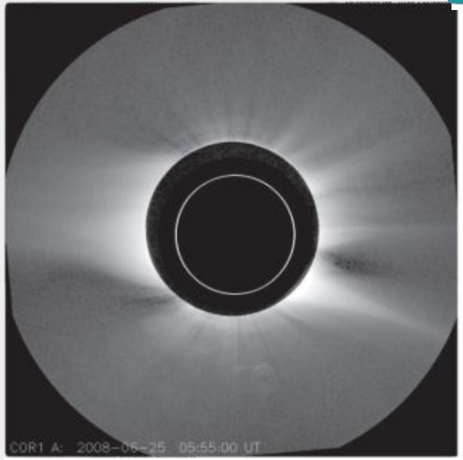
- 3D-parameters (physical and morphological) can be applied to explore the motion of mesoscale structures testing different **dynamic** models.

- **Testing models** that use observations, like magnetograms with coronagraphs images (e.g., Müller et al 2013, Wang-Sheeley-Arge [WSA] model) for inferred and calculated radial velocities of the solar wind.

- **Compare** with solar wind 'flow-tracking' techniques and observations in the 3D space like PUNCH mission will produce.

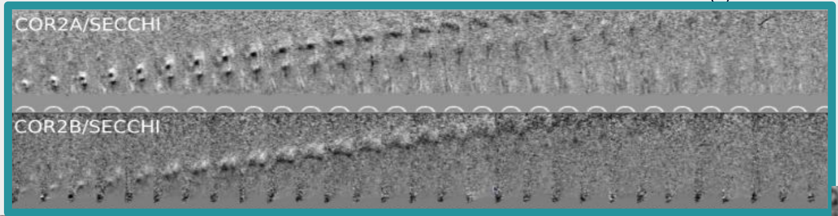
Explore the HT-technique in other White-Light Experiments

COR1 fov [1.65: 3.0]$R_\odot$



Koi et al (2022)
Alzate et al (2021)

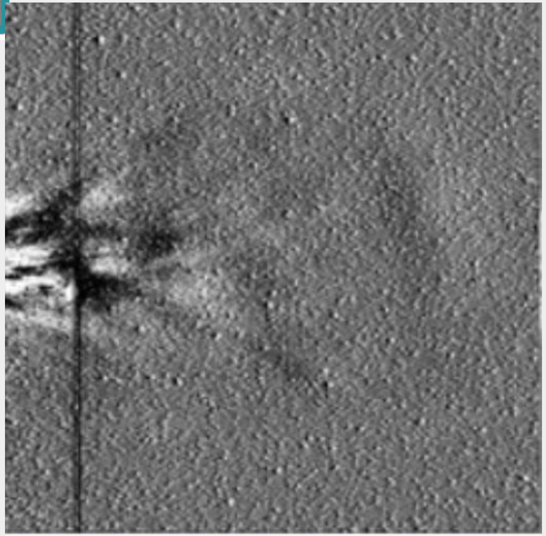
Deprojected trajectory fov [4 : 15] $R_\odot$



López-Portela et al (2018)

With this extrapolation we would be able to have more information about the origin location and evolution as they propagate in heliosphere by the wide-field-images of 3D polarized VL images from [6 :180]$R_\odot$.

HI-1 fov [15:90]$R_\odot$



DeForest et al (2018)

Future Work:

HT-technique Exploration with other White-Light Data

Conclusions:

- HT-analysis technique is appropriate for *coronagraph data* (LASCO and SECCHI) permitting to produce *deprojected positions* in a 3D-coordinate-system along the *fov* [3:15]$R_\odot$, with high accuracy. Hence HT-analysis technique enables to performed the ‘flow-tracking’ of mesoscale structures in the solar wind at solar equatorial latitudes. The good news is that…

PUNCH’s white-light instruments will enhance the detection of mesoscale structures, *fov* [6:30]$R_\odot$, extending our knowledge and exploration of the solar wind behavior.

- One of the most interesting applications of producing *deprojected data* is that it can be used to “test” models in space weather forecasting. What is even more…

PUNCH mission will open the opportunity to perform ´data assimilation´ to constraint the simulations in space weather.

Thanks for listening!

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