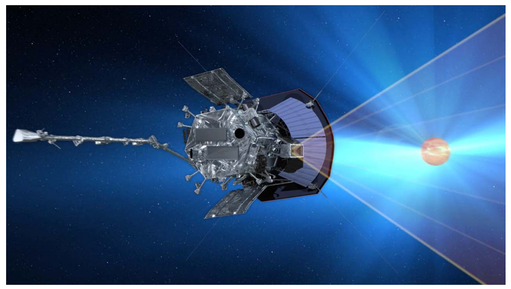
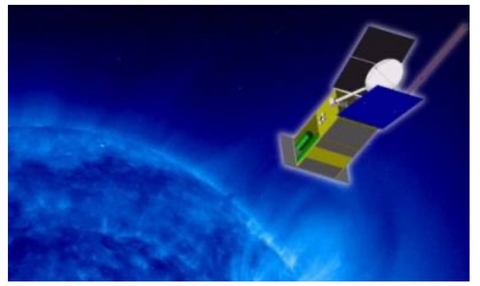


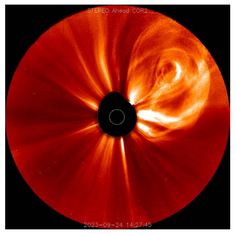
Multi-Viewpoint Analysis with Existing White-light Telescopes and PUNCH: A Quick Look at Possibilities & Tools

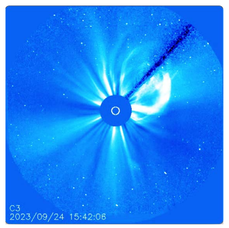
Paulett C. Liewer, JPL; Robin Colaninno, NRL; Angelos Vourlidas, APL; Phil Hess, NRL
Alessandro Liberatore, JPL & INAF



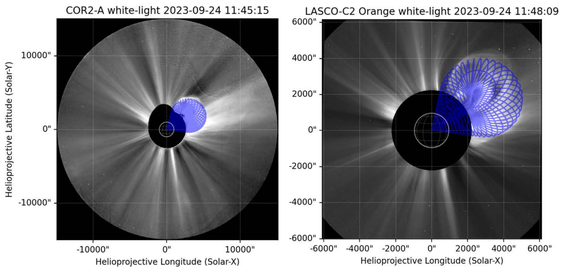
Extend GCS CME Model deep into Heliosphere by including images from SoloHI and/or WISPR & soon also PUNCH images

- On 2023/9/24 LASCO, STEREO-A, SoloHI & WISPR observed 4 CMEs
- Enabled use of **Graduated Cylindrical Shell (GCS)** Solution from the Sun to 40 $R_\odot$



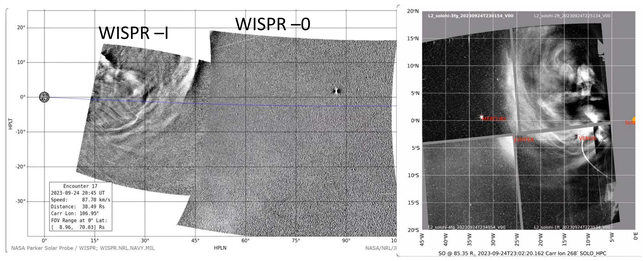


CME2 on 9/24 as viewed by COR2A at 14 UT (left) and LASCO/C3 at 16 UT (right)



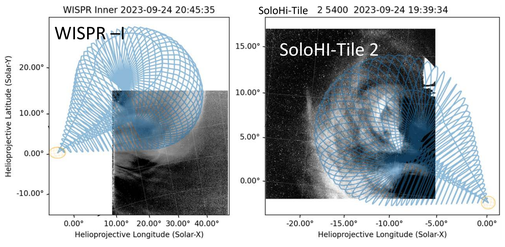
Here, COR2A & C2 with GCS fit at 11 UT

GCS solution has 6 parameters defining location, height, tilt, width (leg & overall)



CME2 as viewed by WISPR (left) & SoloHI(right) at 22 UT

4 Tiles of SoloHI image mapped into HPC coordinates

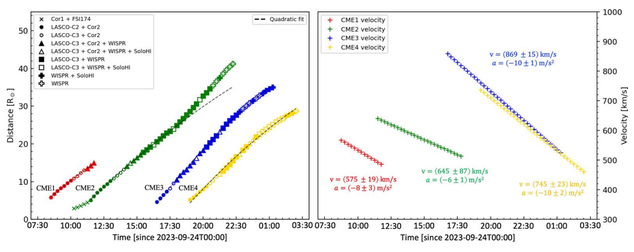


Same GCS model as above extended self-similarly (all parameters except height are fixed) to fit to WISPR-I (left) and SoloHI Tile-2 (right) at 20 UT. CME now at about 40 $R_\odot$

GCS CME velocity & acceleration determined from height of GCS vs. time

Height & velocity versus time for 4 CMEs on 9/24

Plot legend gives telescopes used to get each point



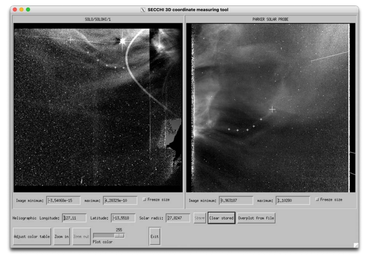
- All 4 CMEs show deceleration ..and CME2 seems to shows acceleration (*Liberatore et al, 2025 – in review)*

The PUNCH instruments will be a major addition to the current suite of operating space-based white-light telescopes: STEREO-A/SECCHI (COR1&2,HI-1&2), SOHO LASCO(C2,C3) , PSP/WISPR and Solar Orbiter/SoloHI

- **PUNCH** will enable many more opportunities for observations of CMEs (and other solar wind features) from two or more viewpoints allowing determination of structure and trajectories in 3D.
- More multiple viewpoints at larger distances from the Sun enables more complete analyses of their evolution in space and time.
- **PUNCH** and **SOHO/LASCO** both view from near Earth.
- The increasing separation of **STEREO-A** from Earth, now 30°, will provide an important second viewpoint from the Sun to 15 $R_\odot$ to help interpret PUNCH data.
- **SoloHI** and **WISPR**, in elliptical heliocentric orbits, can provide crucial viewpoints off the Sun-Earth line at a wide range of distances from the Sun when taking data.
- **Parker Solar Probe**, now in orbit with perihelion of 9.9 $R_\odot$, is expected that will remain in this 3-month orbit, continuing operations for as long as NASA supports the mission. **WISPR** will provide high resolution images of the internal structure of CMEs and the corona during encounter periods (inside of 0.25 AU).
- **SolO**'s orbit will gradually be raised further out of the ecliptic plane, reaching a heliographic latitude of 24° by the end of 2026. Thus, **SoloHI** will provide not only high-resolution images of the internal structure of CMEs, but also unique images from locations out of the ecliptic.
- **Techniques for Analysis of Multi-Spacecraft** white-light observations have been developed and are in use:
- The **Graduated-Cylindrical-Shell** (GCS; Thernisien, 2006ApJ) used widely and successfully to determine CME trajectories near the Sun from two viewpoints (Thernisien et al, 2009) using white-light telescopes at 1 AU. Now, images from WISPR and/or SoloHI have added to extend GCS solutions further out into the heliosphere, where the effects of solar wind on the velocity can be studied (Braga et al., 2024ApJ; Liberatore et al., 2025; Romeo et al., 2023ApJ). See results from Liberatore et al (2025, submitted) to the left.
- Use of **Triangulation** developed using STEREO A&B. Now using SSWIDL software scc_measure.pro to triangulate between any pair from the above list of white-light telescopes. See column to the right.

Use scc_measure.pro for triangulating to determine CME location, velocity & study internal structure

- Triangulate using SoloHI and WISPR simultaneous views of CME2 on 2023/09/24 23 UT

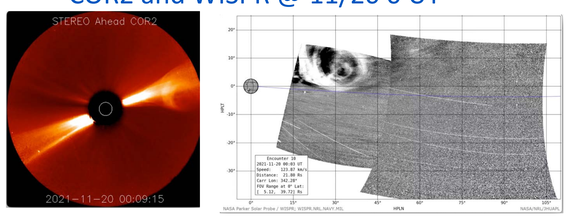


SoloHI Tile 1 and WISPR–I in **scc_measure** tiepointing window

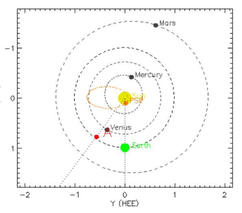
Results of tiepoints in window:
24-28 $R_\odot$ at 23 UT
Consistent with GCS leading edge at 40 $R_\odot$ at 23 UT

- Multiple View of a CME2 on 2021/11/20 STERE0-A and WISPR viewing West Limb

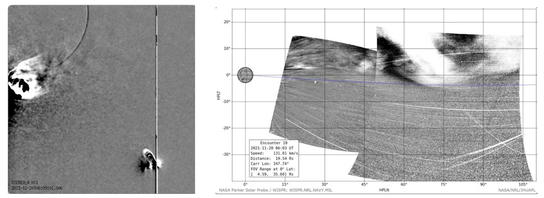
COR2 and WISPR @ 11/20 0 UT



SC Locations

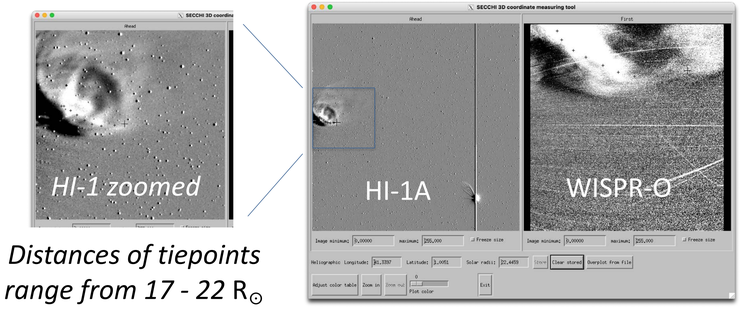


HI-1 & WISPR @ 11/20 6 UT



Triangulated at both times:
0 UT – COR2A & WISPR-I
6 UT – Hi-1A & WISPR-O

- **scc_measure** window for tiepointing features in simultaneous images from STEREO-A/HI-1 and WISPR-O 11/20 @ 6 UT



Distances of tiepoints range from 17 - 22 $R_\odot$

Using results of triangulation at both times on 9/20 (0 and 6 UT):

Velocity of CME trailing edge approximately = 166 km/s

Velocity of CME center approximately = 366 km/s

Conclusion

Multi-Spacecraft White-light Triangulation is a valuable tool for studying evolution of CMEs