CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

Upcoming orbital alignments of inner heliospheric spacecraft with the PUNCH Field of View

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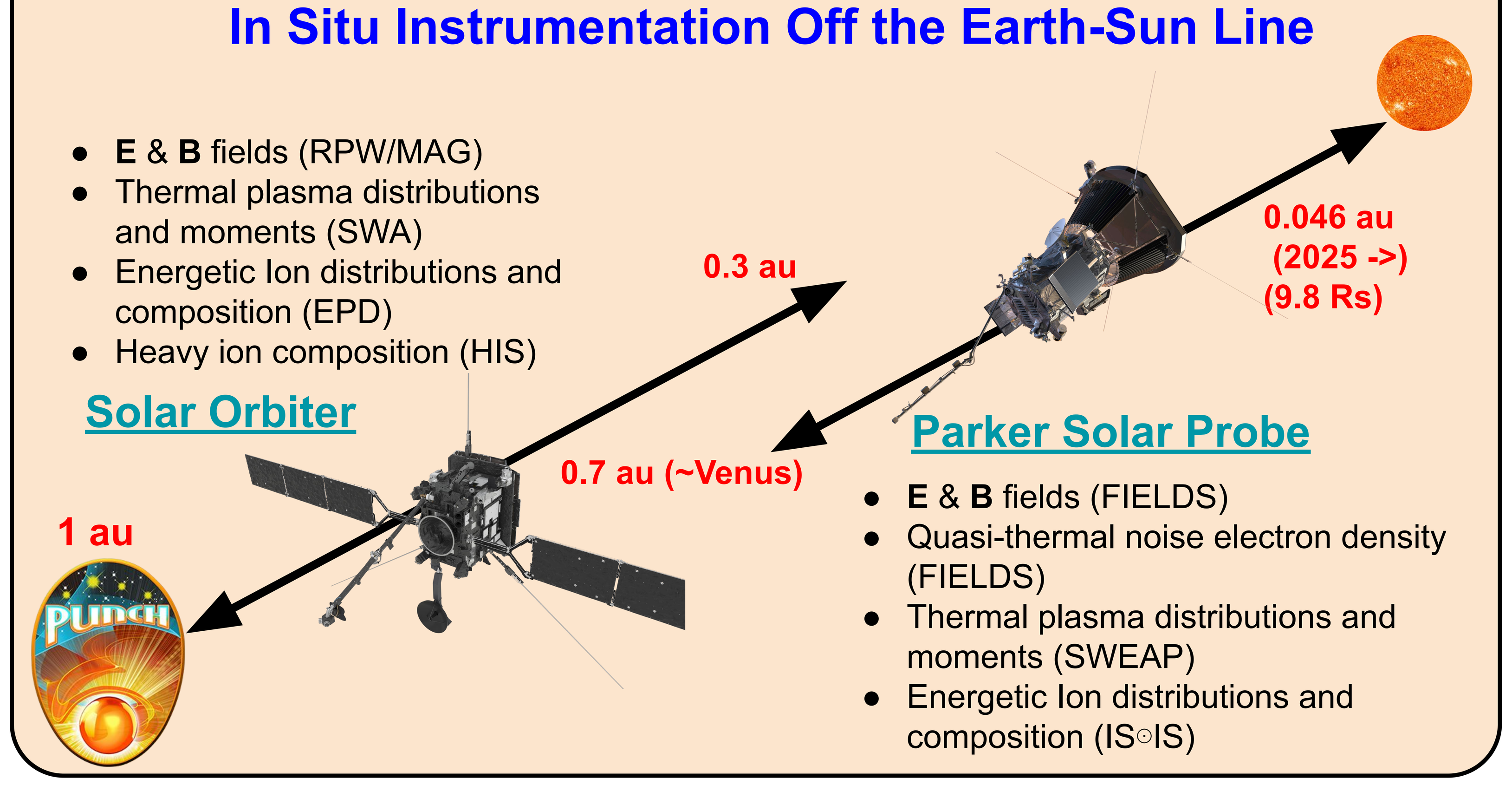
Abstract

Parker Solar Probe completed its last planned Venus Gravity Assist (VGA) on November 6th 2024, and Solar Orbiter will complete a VGA in February 2025 and won't modify its orbit again until late 2026. Both missions, therefore, now have paths through space off the Earth-Sun line which are predictable throughout much of the PUNCH nominal mission. In this poster, we illustrate the relationship between the PUNCH field of view and these upcoming trajectories. We highlight the evolving coverage and key times in the coming years when in situ data will be most directly relevant to testing and contextualizing structure observed by PUNCH.

Parker Solar Probe and Solar Orbiter : In Situ Instrumentation Off the Earth-Sun Line



Solar Orbiter

- **E & B** fields (RPW/MAG)
- Thermal plasma distributions and moments (SWA)
- Energetic Ion distributions and composition (EPD)
- Heavy ion composition (HIS)

Parker Solar Probe

- **E & B** fields (FIELDS)
- Quasi-thermal noise electron density (FIELDS)
- Thermal plasma distributions and moments (SWEAP)
- Energetic Ion distributions and composition (IS☉IS)

Alignment Highlights and Takeaways

Every 1-2 months there are likely to be direct connections between in situ data close to the Sun and PUNCH synoptic information density structure and velocity structure.

Parker Solar Probe

- Will be inside the PUNCH FOV continuously,even at aphelion
- Will cross the PUNCH plane of sky 1-2x per orbit (88 days) and the PUNCH thomson sphere 1-3x per orbit. There is always at least one crossing close to perihelion
- For orbits with fewer crossings, the inbound and/or outbound legs of the orbit run close to tangential to the PUNCH Thomson sphere.

Solar Orbiter

- Will interact with the PUNCH FOV/Thomson sphere every other Parker encounter (perihelia rather than aphelia).
- At aphelia, the complementary remote sensing observations may be more useful, Solar Orbiter is almost stationary on the sky wrt to the motion of Parker. (See Rivera et al. poster at this conference)
- Provides extremely complementary latitude sampling. Some Thomson sphere crossings will be at latitude extremes.

Cautions

- Keeping a 3D picture in mind is essential to relate in situ data to PUNCH observations, just projecting the trajectories on PUNCH images can give a false sense of relevance.
- Sampling time varies drastically, particularly at Parker perihelia.

References and Acknowledgements

Parker Solar Probe
- Mission : Fox et al. (2016)
- In Situ Instruments
  - FIELDS : Bale et al. (2016)
  - SWEAP : Kasper et al. (2016)
  - ISOIS : McComas et al. (2016)

Solar Orbiter
- Mission : Muller et al. (2020)
- In Situ Instruments
  - MAG : Horbury et al. (2020)
  - SWA : Owen et al. (2020)
  - EPD : Rodrigues-Pachecho et al. (2020)

Parker Predicted Spice Kernels are available at : https://psp-gateway.jhuapl.edu/website/Ancillary/LongTermEphemerisPredict

Solar Orbiter SPICE kernels are available at : https://www.cosmos.esa.int/web/spice/solar_orbiter

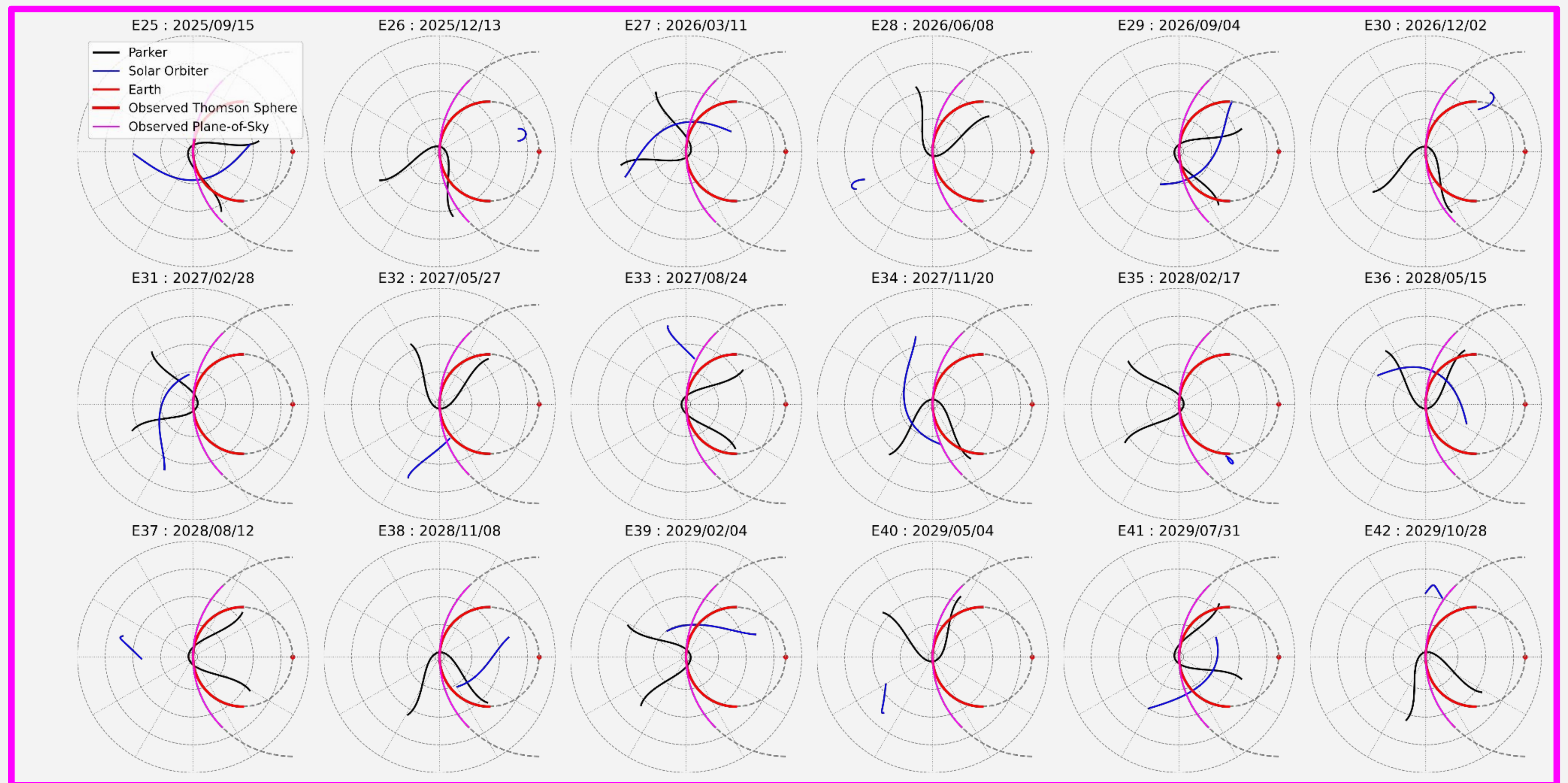
Synthetic PUNCH data courtesy of Chris Lowder, Matt West, Elena Provornikova and the PUNCH SOC

Parker Solar Probe was designed, built, and is now operated by the Johns Hopkins Applied Physics Laboratory as part of NASA's Living with a Star (LWS) program (contract NNN06AA01C). Support from the LWS management and technical team has played a critical role in the success of the PSP mission. The FIELDS and SWEAP experiments on the Parker Solar Probe spacecraft were designed and developed under NASA contract NNN06AA01C. S.T.B is supported by the SWEAP experiment under NASA contract NNN06AA01C

Solar Orbiter is a mission of international cooperation between ESA and NASA, operated by ESA.

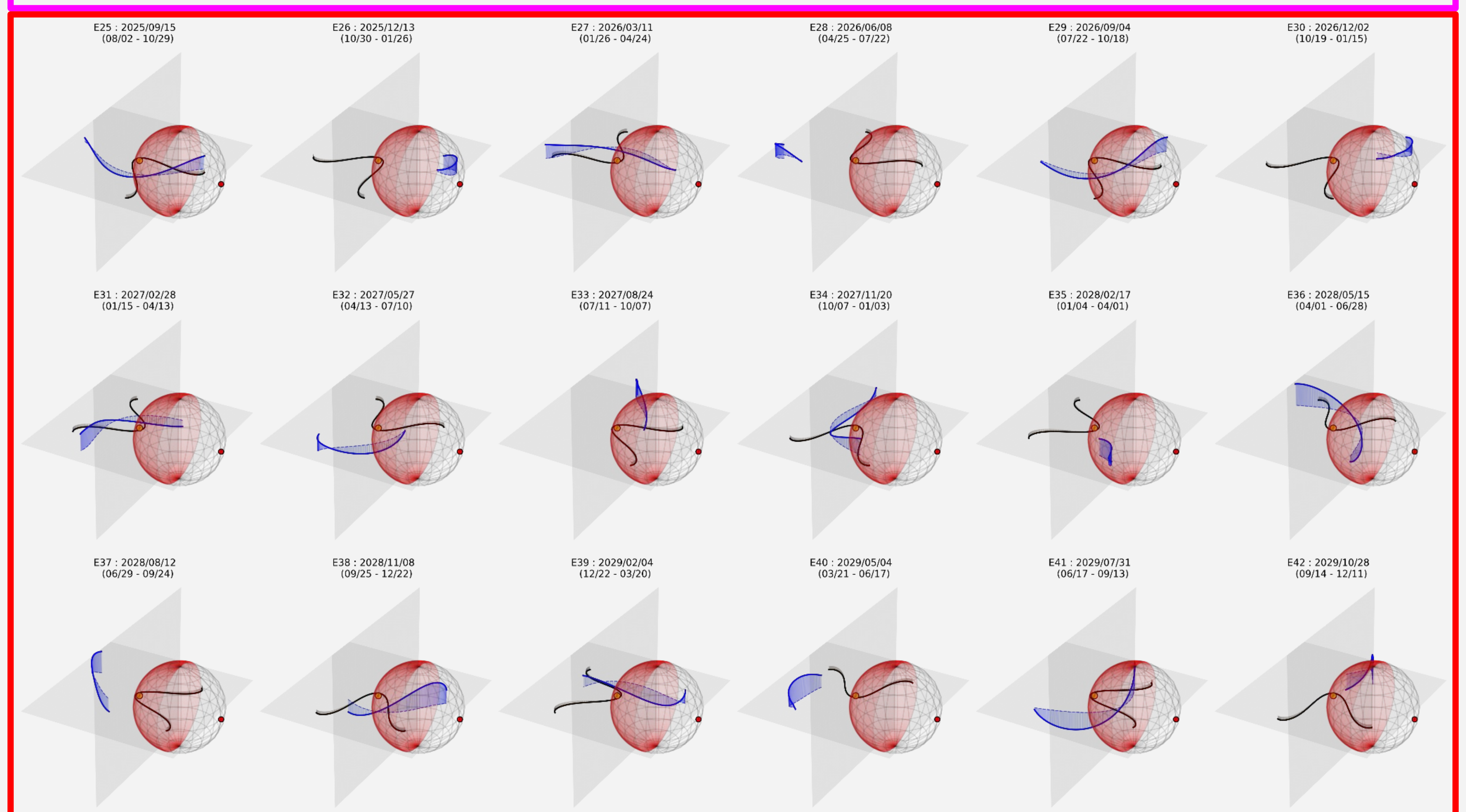
Software: SunPy, Astropy, SpiceyPy

Orbital Geometries and the PUNCH Field of View and Thomson Sphere : Parker Perihelia 25-42 (03/2025 -> 10/2029)



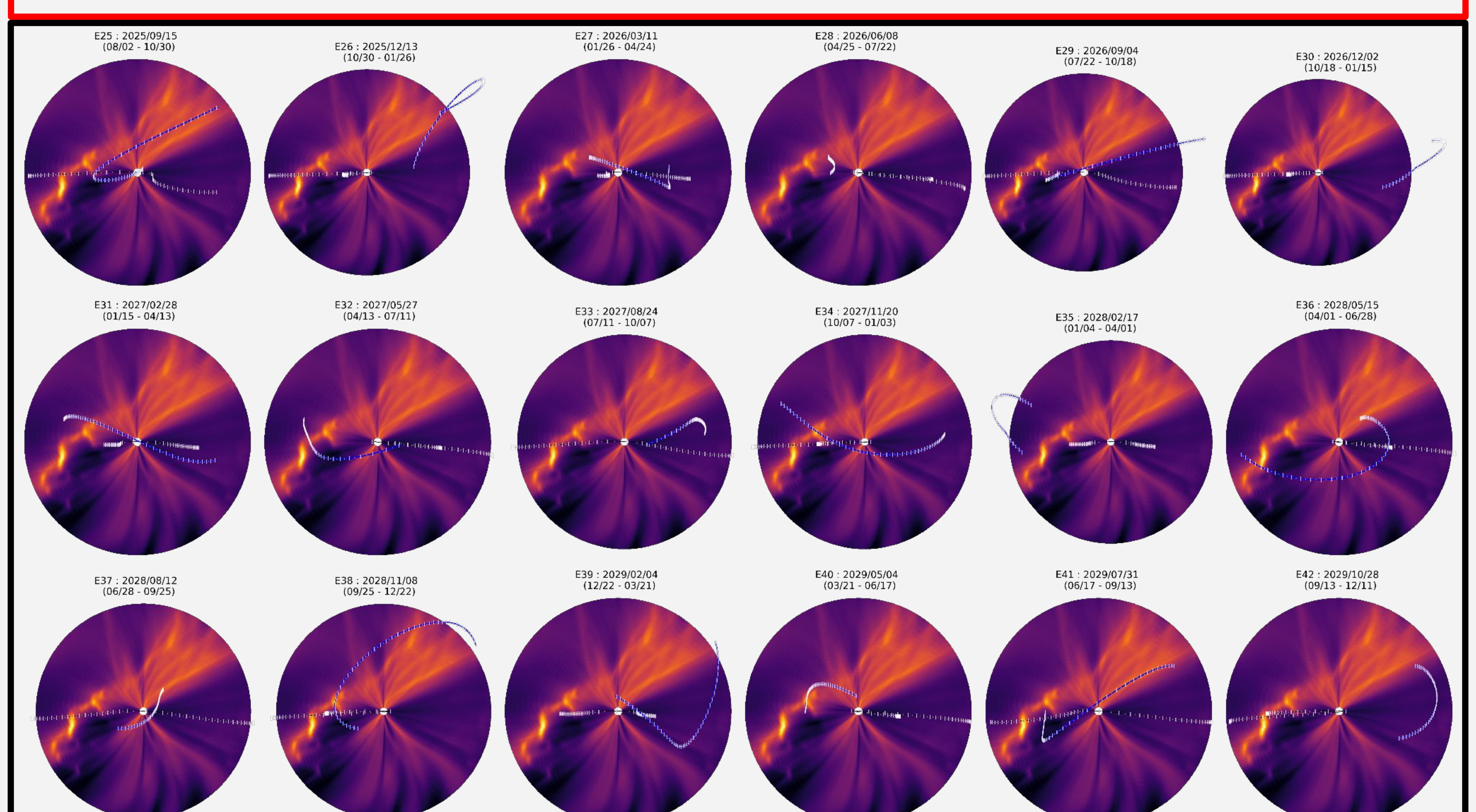
Top Down View, HEE Frame

- Parker trajectory (black), Solar Orbiter trajectory (blue) the 90 degree portion of the plane of sky seen by PUNCH (magneta) and corresponding portion of the thomson sphere (red), all seen projected onto the ecliptic plane in HEE coordinates (Earth/PUNCH fixed)
- Portions of trajectory broken up by Parker Solar Probe orbits (~88 days). Parker orbital parameters are expected to remain fixed with a 9.86 Rs perihelion distance.
- Solar Orbiter's trajectory does evolve, primarily in latitude, which is projected out in this view.
- Shows when/where the spacecraft cross the plane of sky and thomson sphere corresponding to PUNCH observations.



Isometric View, HEE Frame

- As above but shown in a 3D/isometric view point showing 3D structure.
- Vertical lines and a dashed curve show the ecliptic projection of the Solar Orbiter trajectory whose latitude and therefore z-component evolves significantly.
- Separated by Parker encounters, Solar Orbiter alternates between aphelion where it stays almost still in the HEE reference frame and perihelia where it movies more rapidly.
- Parker is very close to the ecliptic.
- Red shading indicates about half of the Earth-referenced thomson sphere is observed by PUNCH



As viewed by PUNCH

- Trajectories now overplotted in helioprojective coordinates on a synthetic PUNCH image.
- White tickmarks show 24 hour spacing along trajectories
- Demonstrates Parker's projection remains within the PUNCH FOV the for the whole orbit.
- Solar Orbiter is normally in it but can be outside for unfavorable aphelia.
- Solar Orbiter latitude is shown to vary and be projected over nearly the whole PUNCH image
- However, this projection must be considered with regard to the above 3D information: Many time intervals appear like the in situ data is directly related to the PUNCH images, but in many cases can be far away from the dominant contribution to brightness.