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Observing the corona and inner heliosphere with Parker Solar Probe

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Summary. — The recently launched Parker Solar Probe (PSP) mission is expected to provide unprecedented views of the solar corona and inner heliosphere. In addition to instruments devoted to taking measurements of the local solar wind, the spacecraft carries a visible imager: the Wide-field Imager for Solar PRobe (WISPR). WISPR will take advantage of the proximity of the spacecraft to the Sun to perform local imaging of the near-Sun environment. WISPR will observe coronal structures at high spatial and time resolutions, although the observed plane-of-sky will rapidly change because of the fast transit at the perihelia. We present a concise description of the PSP mission, with particular regard to the WISPR instrument, discussing its main scientific goals, targets of observations, and outlining the possible synergies with current and upcoming space missions.

1. – The Parker Solar Probe mission

Parker Solar Probe (PSP) is a historic NASA mission aiming to explore for the first time the near-Sun environment [1] (1). PSP was launched on 12 August 2018 on a Delta IV Heavy rocket from Cape Canaveral Air Force Station for a seven-year-long mission. PSP will use seven gravity assists with Venus, the first one occurring on 3 October 2018, to progressively reduce its orbit closer to the Sun (Fig. 1). The first perihelion at a distance of about 35 solar radii occurred on 5 November 2018. By this time, PSP had already broken two records: it achieved the closest perihelion (formerly held by the German-American Helios 2 spacecraft) and became the fastest man-made object at a

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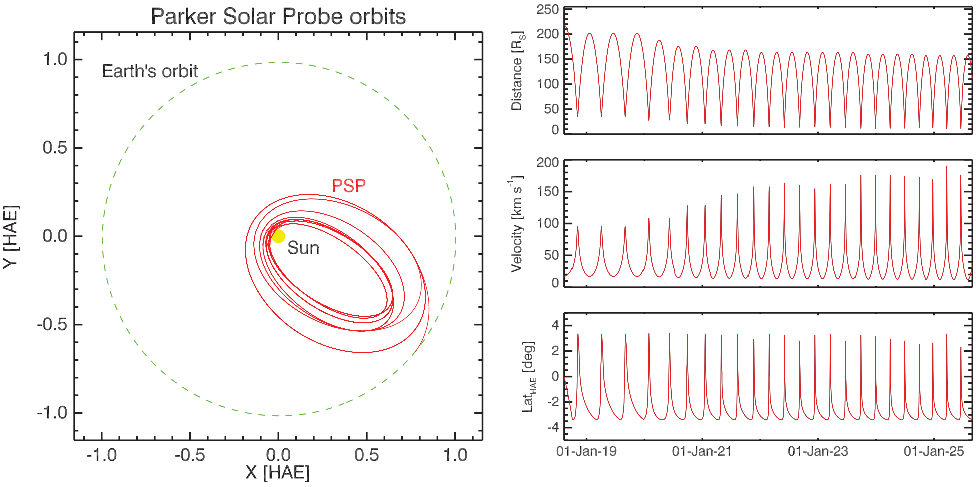

Fig. 1. – PSP's trajectory projected onto the ecliptic plane in the Heliocentric-Aries-Ecliptic (HAE) coordinate system (left). Temporal variation of the distance from the Sun, orbital speed, and heliocentric latitude during the entire mission (right).

speed of 95 km s^{-1}. Nevertheless, both records are expected to be surpassed by 2024 when PSP will reach a perihelion distance below ten solar radii and an orbital speed of about 200 km s^{-1}. The integrity of the spacecraft and its instruments against the intense solar radiation is guaranteed by the Thermal Protection System, a heat shield made of special composite carbon material.

The spacecraft is equipped with three experiments with instruments to acquire in-situ measurements of the local plasma and one white-light imager. Namely:

- the FIELDS experiment provides measurements of the electric and magnetic fields, plasma density and temperature, and radio emissions [2];
- the Integrated Science Investigation of the Sun (IS⊙IS) is a suite of two instruments aiming to measure energetic particle in different energy bands [3];
- the Solar Wind Electrons Alphas and Protons (SWEAP) Investigation measures the electrons, protons and alpha particles in the solar wind [4];
- the Wide-field Imager for Solar PRobe is the only optical instrument aboard PSP which allows white-light observations of the corona and inner heliosphere [5].

In the next sections, we provide some details on the WISPR instrument, presenting its capabilities, objectives, and discuss the goals of PSP and the synergies with current and upcoming space missions.

2. – The Wide-field Imager for Solar PRobe

The WISPR instrument is similar to the heliospheric imagers of the Solar TErrestrial RElations Observatory (STEREO). It consists of two white-light imagers with their optical axes off-pointed from the Sun's centre, recording the Thomson scattered emission

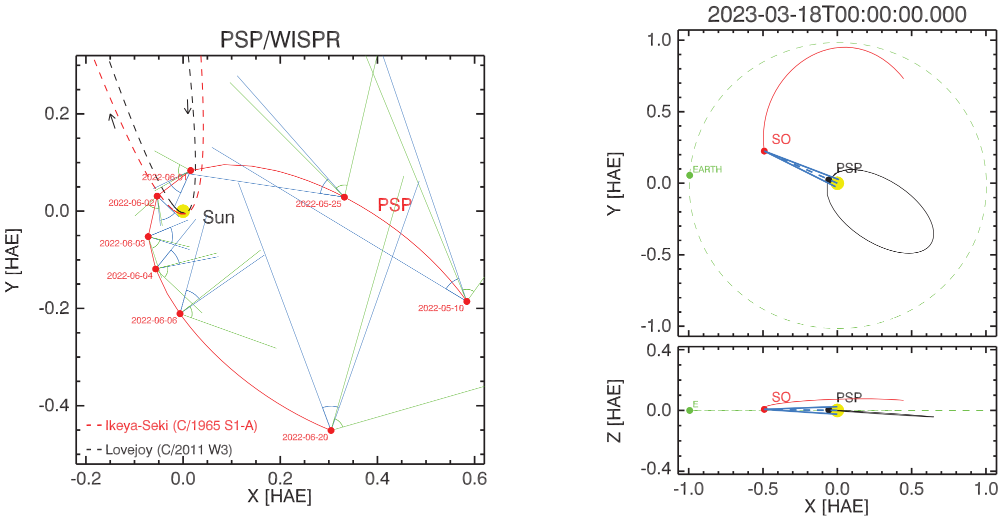

Fig. 2. – Left panel: PSP's orbit between May and June 2022 with the FoVs of WISPR-IT (blue) and WISPR-OT (green). The red and black dashed lines are the orbits of Comet Ikeya-Seki and Comet Lovejoy as an example of sun-grazing comets belonging to the Kreutz group. Right panel: positions of SO and PSP in March 2023 with PSP crossing the FoV of the coronagraph METIS.

of coronal/heliospheric structures. Direct solar imaging with PSP was not considered, since this option would have required holes in the shield for the optics, threatening the thermal protection of the instrument itself and the entire spacecraft.

The Inner Telescope (IT) has a field-of-view (FOV) of 40 deg, ranging between 13.5 and 53.5 deg in elongation, with a plate scale of 1.2 arcmin per pixel, while the Outer Telescope (OT) has a 58 deg FoV, partially overlapping with IT, with an extension between 50 and 108 deg of elongation and a pixel size of 1.7 arcmin. Both cameras use Active Pixel Sensor (APS) devices with a size of 2048x1920 pixels, which differ from standard CCD detectors for a better tolerance to radiation damage, and will record images with a cadence ranging from tens of minutes to seconds during the perihelion phase.

The WISPR instrument is mounted on the ram side of the spacecraft to provide a contextual view of large-scale structures (e.g. helmet streamers, coronal mass ejections, solar wind flows) that will be eventually crossed by PSP during its perihelion passages and surveyed with in-situ instruments. The first light of the two cameras was successfully obtained on the 9 September 2016 (2).

3. – PSP capabilities and objectives

By taking advantage of the rapid perihelion transits lasting about 10 days, the WISPR images allow performing tomographic reconstructions of the solar corona. Preliminary tools for geometric triangulation have been developed in order to retrieve the three-dimensional location of white-light coronal structures observed by WISPR [6, 7].

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(2) `https://svs.gsfc.nasa.gov/13072`

The continuous change of the plane-of-sky will affect the Thomson scattered emission from density structures in the instrument's FoV, because of the variation of the scattering angle. Proper analysis of the total brightness profile can be useful to constrain the kinematic status of propagating features, like solar wind condensations, CMEs, etc. (work in preparation).

Besides coronal structures and solar wind density inhomogeneities, WISPR will be ideal to study objects like comets. In fact, [8] has recently shown that oscillations of comet tails could be explained in terms of vortex shedding phenomena arising from the interaction between comets and the solar wind flow. Moreover, sun-grazing comets have caught the attention as a tool to probe the near-Sun environment [9]. Comets belonging to some groups, like the well-known Kreutz group [10], may be observed from WISPR (e.g. Fig. 2-left with the orbits of C/1965 S1-A Ikeya-Seki and C/2011 W3 Lovejoy), which will help study the interaction of comets with the solar wind and the deposition and evolution of dust particles in the near-Sun environment with a spatial and temporal resolutions better than those achieved by current white-light imagers from 1 AU.

Furthermore, current and upcoming space missions will take advantage of PSP, offering the possibilities of synergies. For example, the Solar Orbiter (SO) mission, is scheduled to be launched in 2020 and will perform observations of the solar corona with the Multi Element Telescope for Imaging and Spectroscopy (METIS) coronagraph [11]. It will offer opportunities for joint campaigns since both missions will perform observations and measurements from unusual locations in space. The middle and bottom panels of Fig. 2 show two examples of PSP's transits in the FoV of METIS, which will have a duration of about one day and allow for coupled analysis between remote observations, achieved by SO, and in-situ measurements, obtained with PSP.

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