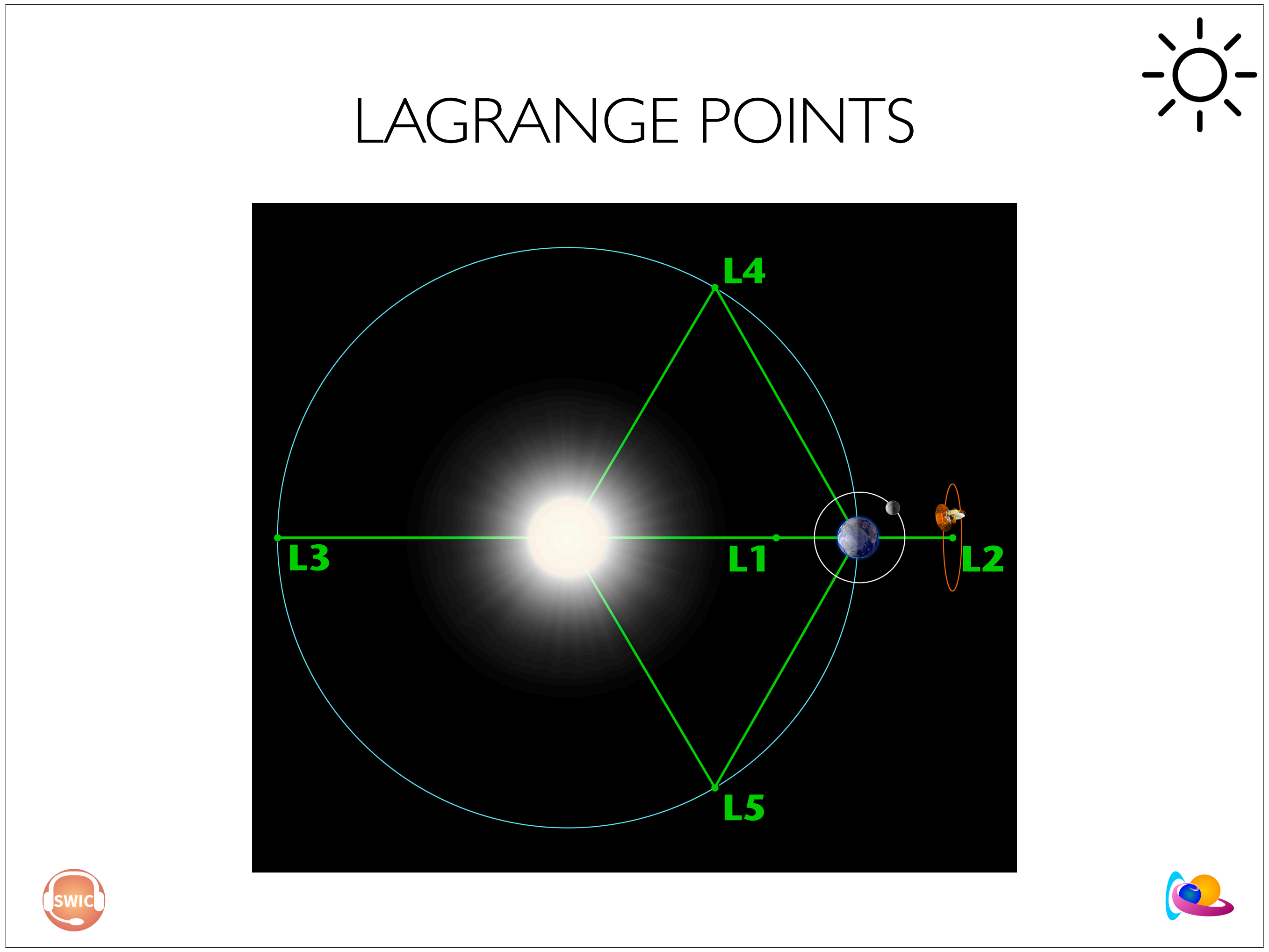


LAGRANGE POINTS

The Lagrange points are orbital points near two large co-orbiting bodies, in this case the Sun and the Earth. Normally, the two objects exert an unbalanced gravitational force at any given point, altering the orbit of whatever is at that point. At the Lagrange points, the gravitational forces of the two large bodies and the centrifugal force balance each other. This can make Lagrange points an excellent location for satellites, as few orbit corrections are needed to maintain the desired orbit.
(https://en.wikipedia.org/wiki/Lagrange_point)

(Image not to scale)

SPACECRAFT ORBITING EARTH (INSIDE MAGNETOSPHERE)

PROBA2
- ➡ SWAP - LYRA

SDO
- ➡ AIA - HMI - EVE

GOES
- ➡ SUVI - EXIS - SEISS

We list here some of the most frequently used space weather satellites that are orbiting in different locations: Earth, L1 and then the ones with more exotic orbits.

When orbiting around Earth, satellites are relatively well shielded from the adverse effects of space weather. To be able to observe the Sun in other wavelengths than the visible spectrum, they need to be orbiting above the Earth's atmosphere since that absorbs (E)UV light. However, in their low-earth orbits, they are still protected by the magnetosphere.

These satellites provide solar imaging, irradiance measurements, magnetograms, …

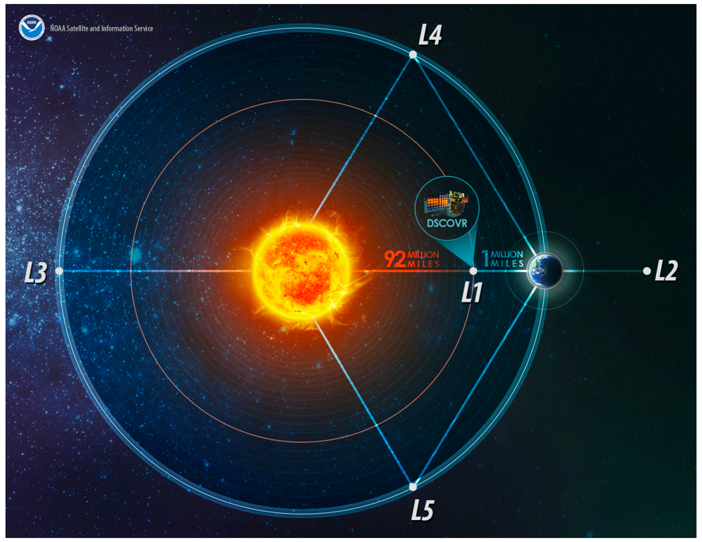
PROBA2: PRoject for Onboard Autonomy – Sun-sychronous LEO (polar) orbit
LYRA: Large Yield RAdiometer
SWAP: Sun Watcher using Active Pixel System detector and Image Processing

SDO: Solar Dynamics Observatory – Geosynchronous orbit at altitude of ~36 000 km
AIA: Atmospheric Imaging Assembly
HMI: Helioseismic and Magnetic Imager
EVE: Extreme Ultraviolet Variability Experiment

GOES: Geostationary Operational Environmental Satellite - Geosynchronous orbit at altitude of ~36 000 km
SUVI: Solar Ultraviolet Imager
EXIS: Extreme UV and X-Ray Irradiance Sensor
SEISS: Space Environmental In-Situ Suite

Image credit: https://www.nesdis.noaa.gov/content/currently-flying

SPACECRAFT ORBITING L1 (OUTSIDE MAGNETOSPHERE)



SOHO
- ➡ EIT - LASCO - MDI

DSCOVR
- ➡ PLASMAG

ACE
- ➡ SWEPAM - MAG

WIND
- ➡ MFI - SWE

L1 is especially interesting for solar observations. We place satellites there that measure the solar wind and the particles in situ. This give us a lead time of 1h approximately.

Satellites SOHO – ACE – DSCOVR – WIND are at L1.

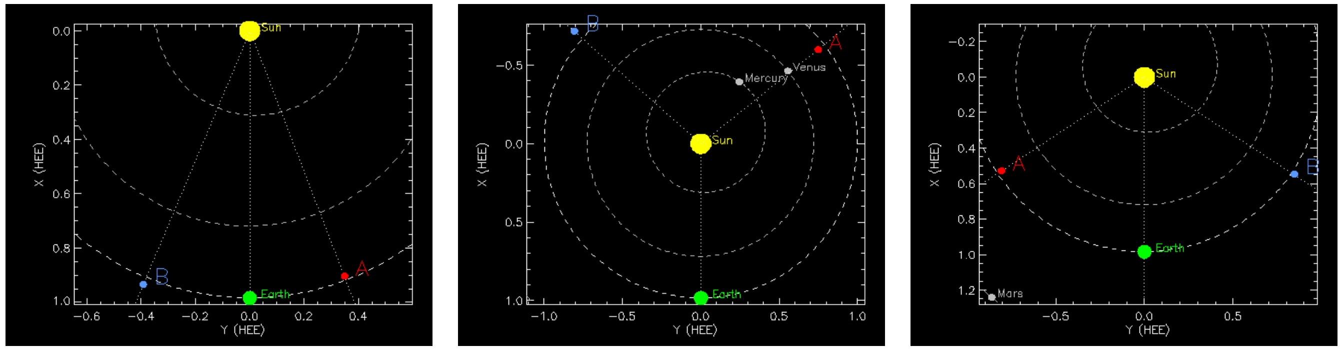
Imaging
SOHO: Solar and Heliospheric Observatory
    EIT: Extreme ultraviolet Imaging Telescope
    LASCO: Large Angle and Spectrometric Coronagraph
    MDI: Michelson Doppler Imager (magnetogram)

Solar Wind Measurements
DSCOVR: Deep Space Climate Observatory
    PLASMAG: Plasma–Magnetometer, Measures solar wind particles and magnetic field vector

ACE: Advanced Composition Explorer (Solar Wind Measurements)
    SWEPAM: Solar Wind Electron, Proton, and Alpha Monitor
    MAG: Magnetometer

WIND: Comprehensive Solar Wind Laboratory for Long–Term Solar Wind Measurements
    MFI: Magnetic Field Investigation
    SWE: Solar Wind Experiment

EXOTIC ORBITS: STEREO



January 1, 2008 January 1, 2013 January 1, 2021

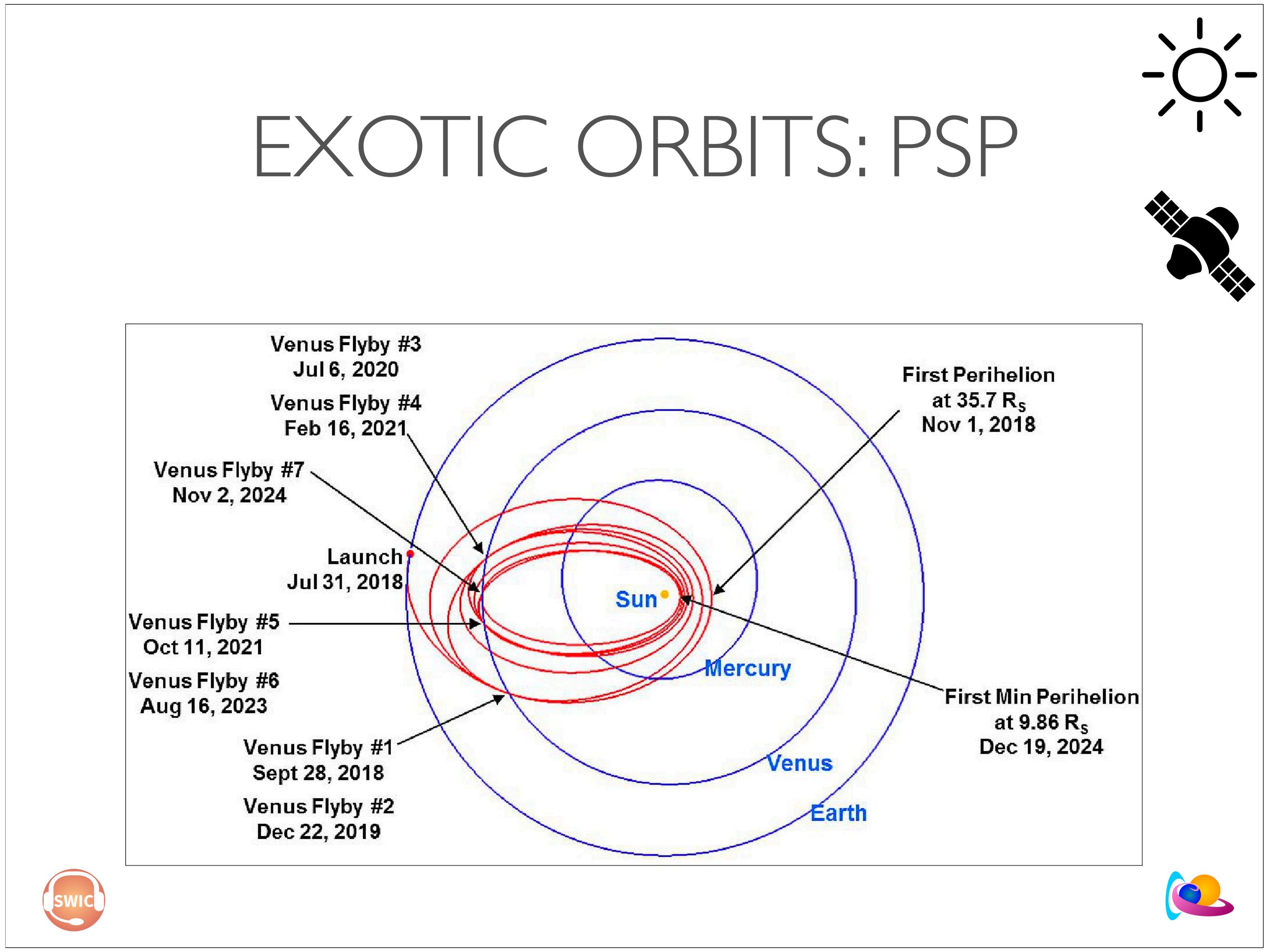
SECCHI: EUVI - COR1 - COR2 - HI
SWAVES - IMPACT PLASTIC

The STEREO (Solar TErrestrial RElations Observatory) mission consists of two nearly identical spacecraft in heliocentric elliptical orbit in the ecliptic plane at approximately 1 AU from the sun: one drifting ahead of the Earth and one behind. Simultaneous measurements are obtained by the satellites instruments at gradually increasing separations over the course of the mission, allowing for stereoscopic observations and e.g. triangulation of solar events as well as following eruptions along the Sun-Earth line.

The STEREO spacecraft were launched in 2006. For a brief period, from 2011 to 2014, scientists had the unprecedented opportunity to see the Sun's entire atmosphere at once. During that time, observations from NASA's SDO (Solar Dynamics Observatory) were supplemented by measurements from NASA's STEREO mission, which included two spacecraft orbiting the Sun. Collectively, the three observatories provided a 360° view of the Sun.

Communications with Solar Terrestrial Relations Observatory-B (STEREO-B) were lost on Oct. 1, 2014, due to multiple hardware anomalies affecting control of the spacecraft orientation. Communications with STEREO-B were re-established on Aug. 21, 2016, during a monthly attempt to reach the spacecraft using NASA's Deep Space Network. During the next weeks, the NASA and the Johns Hopkins APL STEREO teams worked tirelessly to discover the spacecraft's current conditions and to recover the spacecraft fully. The attempt to recover the spacecraft was not successful. STEREO-B has now been out of contact since Sept. 23, 2016. Four years after the initial loss of communications anomaly with the Behind observatory, NASA directed that periodic recovery operations cease with the last support on October 17, 2018.
(https://directory.eoportal.org/web/eoportal/satellite-missions/s/stereo)

Instruments
- SECCHI: Sun Earth Connection Coronal and Heliospheric Investigation
  - SECCHI EUVI: Extreme UltraViolet Imager
  - SECCHI COR1: Inner Coronagraph
  - SECCHI COR2: Outer Coronagraph
  - SECCHI HI: Heliospheric Imager
- SWAVES: STEREO/WAVES
- IMPACT: In-Situ Measurements of particles and CME transients
- PLASTIC: Plasma and Suprathermal Ion Somposition



EXOTIC ORBITS: PSP

Venus Flyby #3
Jul 6, 2020

Venus Flyby #4
Feb 16, 2021

Venus Flyby #7
Nov 2, 2024

Launch
Jul 31, 2018

Venus Flyby #5
Oct 11, 2021

Venus Flyby #6
Aug 16, 2023

Venus Flyby #1
Sept 28, 2018

Venus Flyby #2
Dec 22, 2019

First Perihelion
at 35.7 R_S
Nov 1, 2018

First Min Perihelion
at 9.86 R_S
Dec 19, 2024

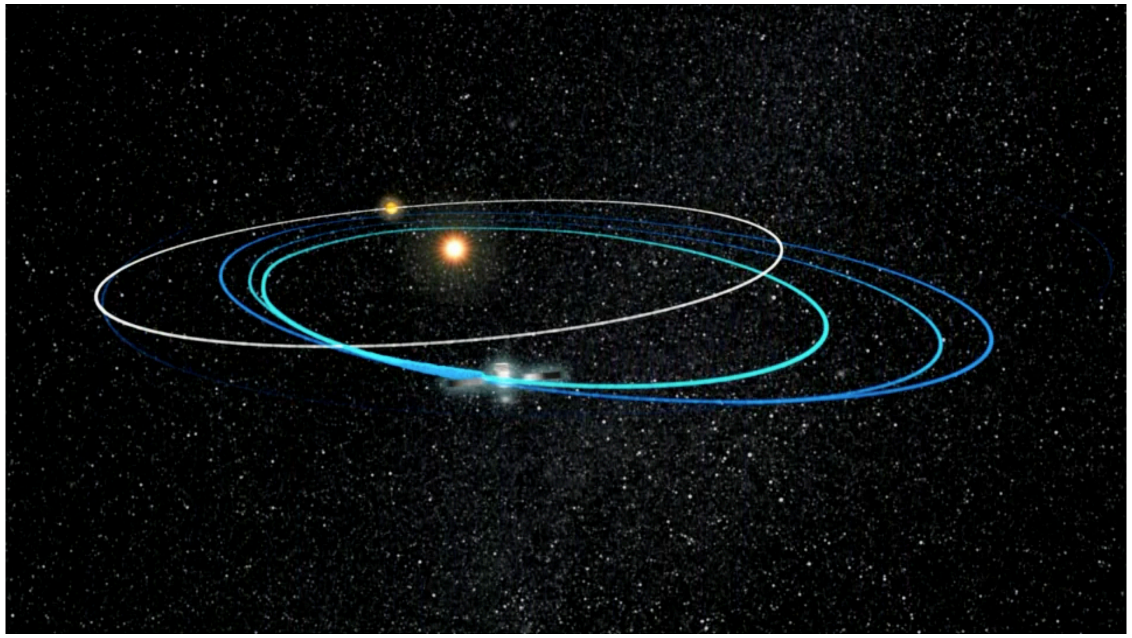
Parker Solar Probe was launched in 2018. The spacecraft will fly through the Sun’s atmosphere as close as **6 million km** to our star’s surface, well within the orbit of Mercury and more than seven times closer than any spacecraft has come before. (Earth’s average distance to the Sun is 149 million km.)

In 2017, the mission was renamed for Eugene Parker. In the 1950s, Parker proposed a number of concepts about how stars -including our Sun- give off energy. He called this cascade of energy the solar wind, and he described an entire complex system of plasmas, magnetic fields, and energetic particles that make up this phenomenon. Parker also theorized an explanation for the superheated solar atmosphere, the corona, which is - contrary to what was expected by physics laws -- hotter than the surface of the sun itself. This is the first NASA mission that has been named for a living individual.
https://www.nasa.gov/content/goddard/parker-solar-probe-humanity-s-first-visit-to-a-star

Instruments

- FIELDS measures the electric field around the spacecraft with five antennas
- WISPR: Wide-Field Imager for Parker Solar Probe
- SWEAP: Solar Wind Electrons Alphas and Protons investigation
- ISOIS: Integrated Science Investigation of the Sun

EXOTIC ORBITS: SOLAR ORBITER



Solar Orbiter was launched in 2020 and takes images of the Sun from closer than any spacecraft before and for the first time looks at its uncharted **polar regions**. By combining observations from Solar Orbiter's six remote-sensing instruments and four sets of in situ instruments, scientists hope to find answers to some profound questions: What drives the Sun's 11-year cycle of rising and subsiding magnetic activity? What heats up the upper layer of its atmosphere, the corona, to millions of degrees Celsius? What drives the generation of the solar wind? What accelerates the solar wind to speeds of hundreds of kilometres per second? And how does it all affect our planet? (http://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter)

The movie shows several gravity assist manoeuvres (slingshot) with planets to travel to final operational orbit using much less propellant than would otherwise be needed. Each one is designed to change the trajectory of the spacecraft targeting the next planet in the sequence, while reducing the orbital energy and bringing the spacecraft closer and closer to the sun. The orbit also becomes more and more inclined, allowing (for the first time ever) to observe the solar poles directly.

Once the satellite will be in its operational mission (>November 2021), the in-situ instrumentation will be permanently active. The remote-sensing instruments will only be operational during 3 distinct science windows: at minimum and maximum latitude and during the closest approach. Of these, the closest approach is scientifically most interesting. At this point in the orbit, the angular velocity of the spacecraft approaches the angular velocity of the sun, which means we can perform co-rotating observations, allowing continuous observations of the same regions on the solar surface for extended periods.

In-situ instruments:
- EPD: Energetic Particle Detector
- MAG: Magnetometer
- RPW: Radio and Plasma Waves
- SWA: Solar Wind Plasma Analyser

Remote-sensing instruments:
- EUI: Extreme Ultraviolet Imager
- METIS: Coronagraph
- PHI: Polarimetric and Helioseismic Imager (photospheric vector magnetic field and line-of-sight (LOS) velocity)
- SoloHI: Heliospheric Imager
- SPICE: Spectral Imaging of the Coronal Environment
- STIX: X-ray Spectrometer/Telescope