



# Multi-spacecraft coordinated observations during the cruise phase of BepiColombo: scientific cases and windows of opportunities



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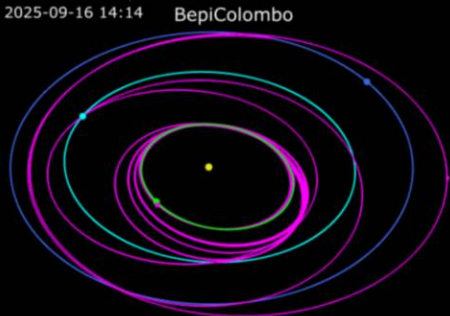
05/05/2020



# Context

## Cruise phase of BepiColombo

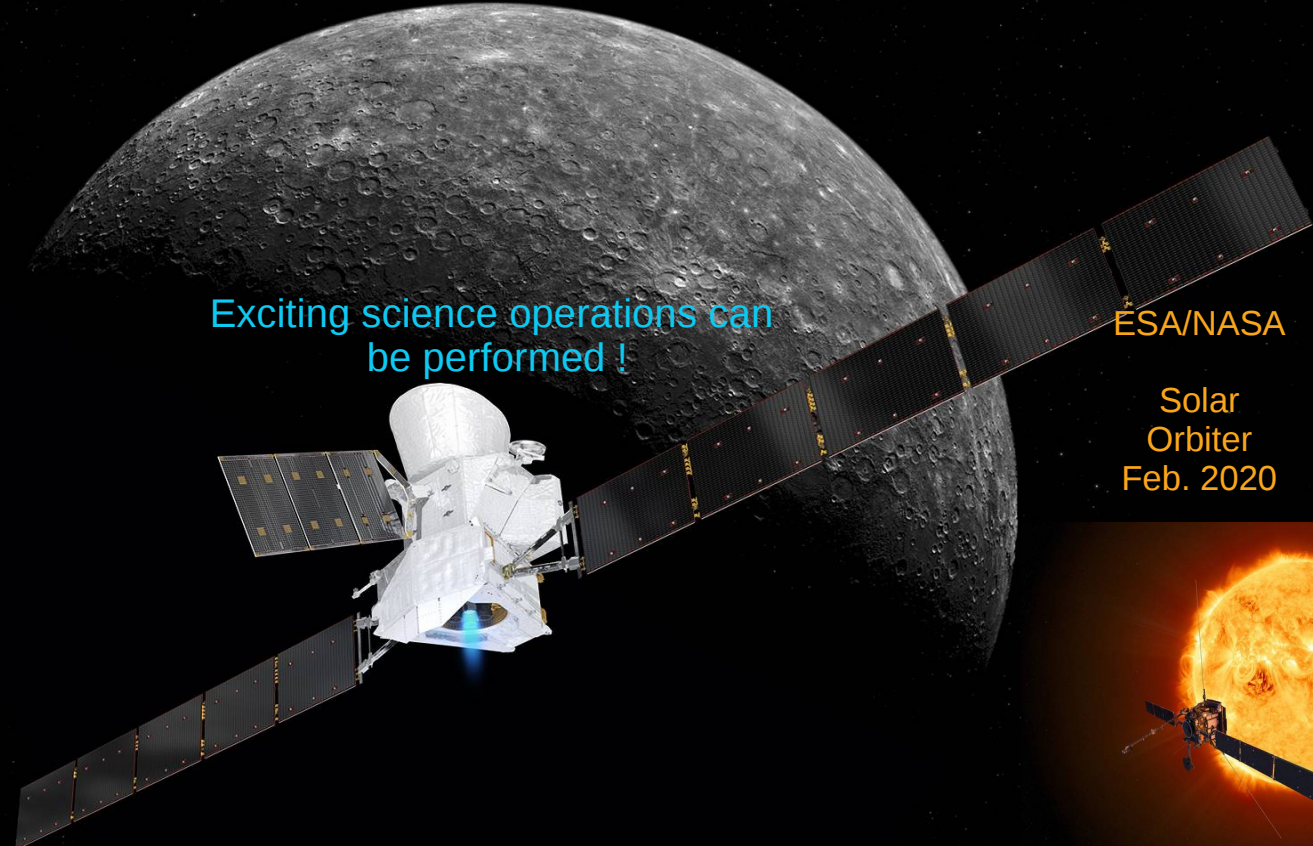
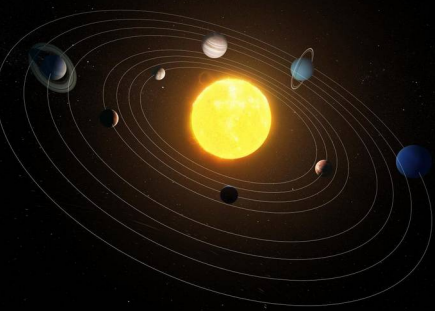
October 2018 – November 2025



45.917km/s 3,301,226km

1.2 AU to 0.3 AU

Other heliospheric  
& planetary missions



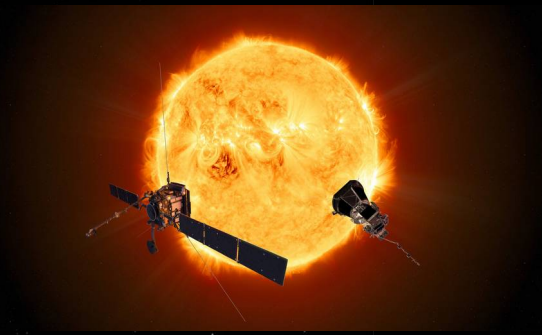
Exciting science operations can  
be performed !

ESA/NASA

NASA

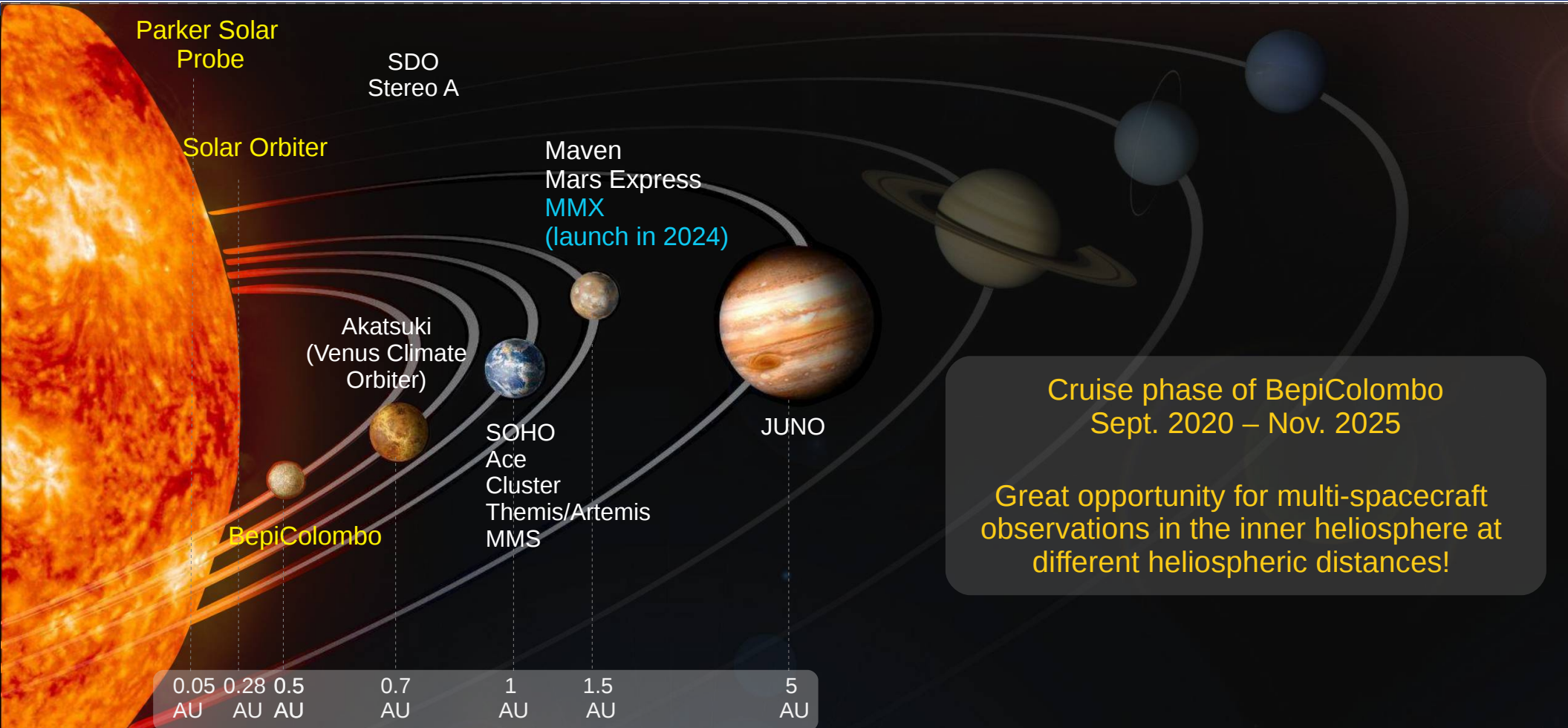
Solar  
Orbiter  
Feb. 2020

Parker  
Solar Probe  
Aug. 2018



# Context

## Cruise phase of BepiColombo: heliospheric observations



# Working Group main goal

Identification of science opportunities during the cruise phase of BepiColombo  
(September 2020 – December 2025)

September 1<sup>st</sup> 2020: report to ESA and JAXA

## 27 members:

T. Alberti, S. Aizawa, N. André, J. Benkhoff, Z. Bebesi, M. Dosa, V. Génot, L. Griton, L. Z. Hadid, G. C. Ho, T. S. Horbury, K. Iwai, M. Janvier, E. Kilpua, B. Lavraud, A. Madar, A. Milillo, Y. Miyoshi, D. Mueller, G. Murukami, R. Pinto, A. P. Rouillard, J. M. Raines, N. Raouafi, D. Shiota, A. Walsh, J. Zender, Y. Zouganelis.



JOHNS HOPKINS  
APPLIED PHYSICS LABORATORY

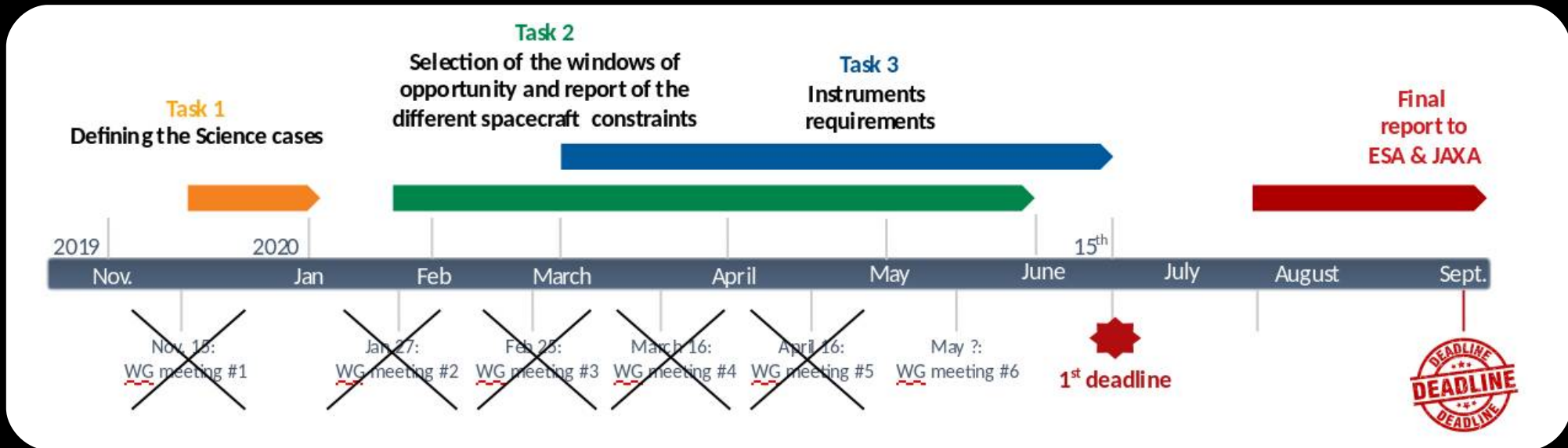
Imperial College  
London



National Institute of  
Information and  
Communications Technology

# Main tasks and timeline

- **Task 1:** Identification of the **science cases**.
- **Task 2:** Identification of the **windows of opportunities** related to BepiColombo, Solar Orbiter, Parker Solar Probe, Akatsuki (Venus Climate Orbiter), and other available spacecraft in the solar wind and other planets (Earth, Venus, Mars).
- **Task 3:** **Operational instruments** related to the different science cases and opportunities.



# Task 1

## Potential science cases

### 1) Intrinsic solar wind properties

- **Turbulence** properties:
  - *How do they evolve with the radial distance ?*
  - *How do they vary with longitude and radial distance in large-scale solar wind structures ?*

### 2) Large and small scales structures

- Small scale – **magnetic holes**
  - *what is their relation to mirror mode waves?*
- Small scale – **transients (flux ropes)**
  - *How do their occurrence and properties evolve with radial distance from the Sun?*
  - *Do they have origin at the Sun or in heliosphere?*
- Large scale – **transient CMEs, ICMEs** properties
  - *How do they evolve with the radial distance ?*
  - *Interaction of multiple CMEs, or CME + SIR.*
  - *Validation of different heliospheric models (EUHFORIA/ENLIL) at varying radial distances and longitudes from the Sun.*
- Large scale – **CIRs**
  - *Magnetic sector boundaries*
  - *3D evolution*

# Task 1

## Potential science cases

### 3) Solar Energetic Particles

- Acceleration and transport processes:
  - *Cross-field diffusion ? Interplanetary shocks ?*

### 4) Comets and dust

- Water production rates in the hydrogen coma – (target example: comet PANSTARRS)
- Particles in the cometary trails
- Interplanetary dust distribution in the inner solar system

### 5) Solar corona

- Properties: density fluctuations and bulk speed of coronal plasma

### 6) Background radiation and general relativity test

- Gamma Ray Burst detection and localization
- Galactic cosmic rays
- Gamma rays of solar flares

# Task 2

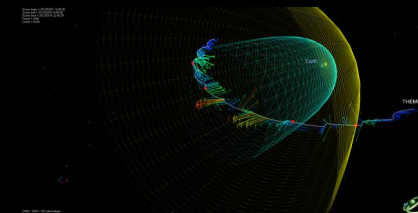
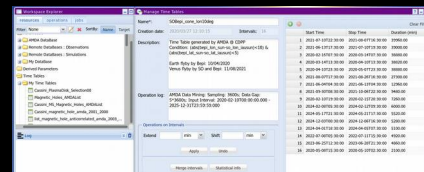
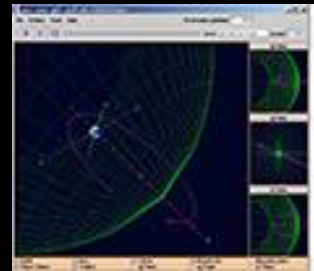
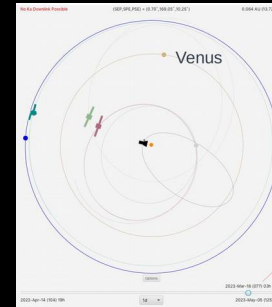
## Windows of opportunity: tools

→ Soltra 2 tool, based on the solar wind speed (Wigner Research Centre for Physics, Budapest)

→ SPADER: Inner heliospheric centric Parker Solar Probe tool (Johns Hopkins/APL)

→ [SSC 4D Orbit Viewer](#) tool (NASA)

→ [Amda](#) and [3D view](#) tools (CDPP)



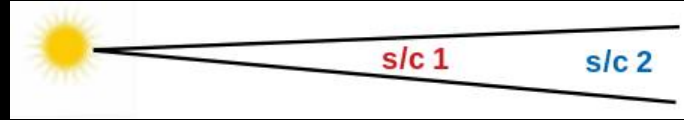


# Task 2

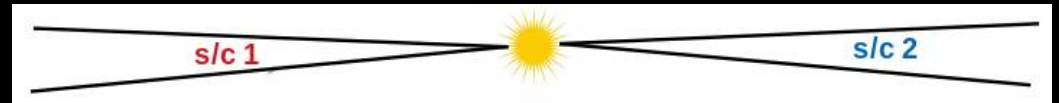
## Windows of opportunity: spacecraft geometries

### 1. Radial alignment (cone)

→ function of latitude and longitude

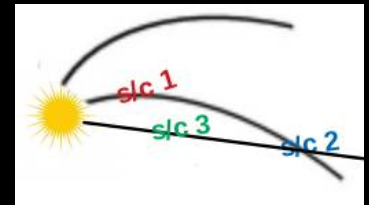
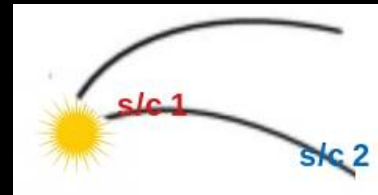


### 2. Radial alignment with opposition



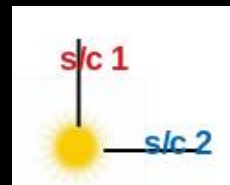
### 3. Parker field lines

→ function of the solar wind speed, source surface, latitude and the field line footprint longitude



### 4. Parker field lines + radial alignment

### 5. Quadrature geometry / 90°



### 6. Solar Orbiter out of the ecliptic plane

# Task 2

## Windows of opportunity: radial alignment

### 1) Radial alignment (cone $10^\circ \times 5^\circ$ ): 95 time intervals

#### ➤ Pair cases (including Earth, Mars and Venus)

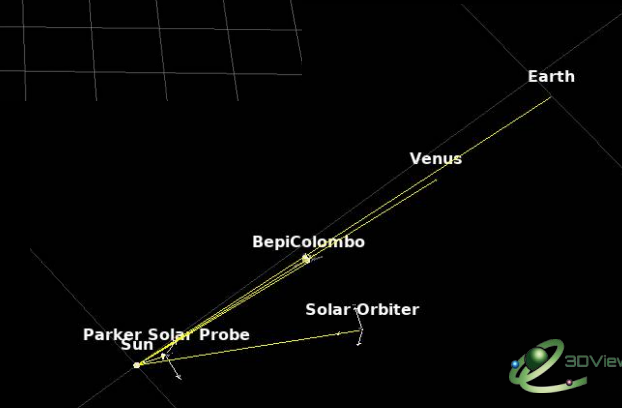
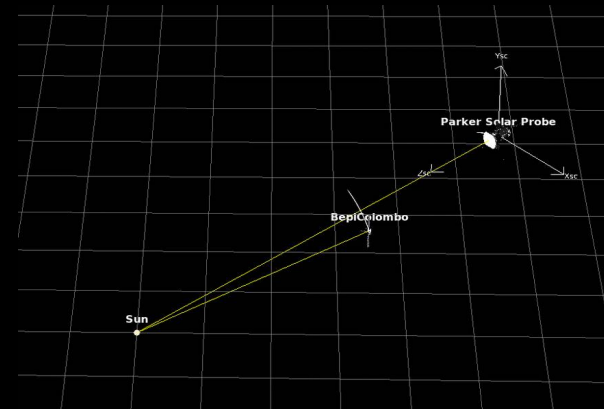
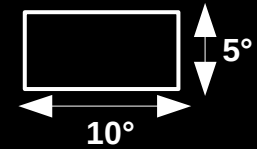
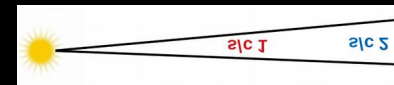
- ➔ BepiColombo – Solar Orbiter (11 cases)
- ➔ BepiColombo – Parker Solar Probe (29 cases)
- ➔ BepiColombo – Earth (9 cases)
- ➔ BepiColombo – Venus (16 cases)
- ➔ BepiColombo – Mars (15 cases)

#### ➤ Triad cases (including Earth, Mars and Venus)

- ➔ BepiColombo – Solar Orbiter – Parker Solar Probe (1 case)
- ➔ Earth – BepiColombo – Solar Orbiter (1 case)
- ➔ Earth – BepiColombo – Parker Solar Probe (1 case)
- ➔ Venus – BepiColombo – Solar Orbiter (4 cases)
- ➔ Venus – BepiColombo – Parker Solar Probe (4 cases)
- ➔ Mars – BepiColombo – Solar Orbiter (1 case)
- ➔ Mars – BepiColombo – Parker Solar Probe (2 cases)

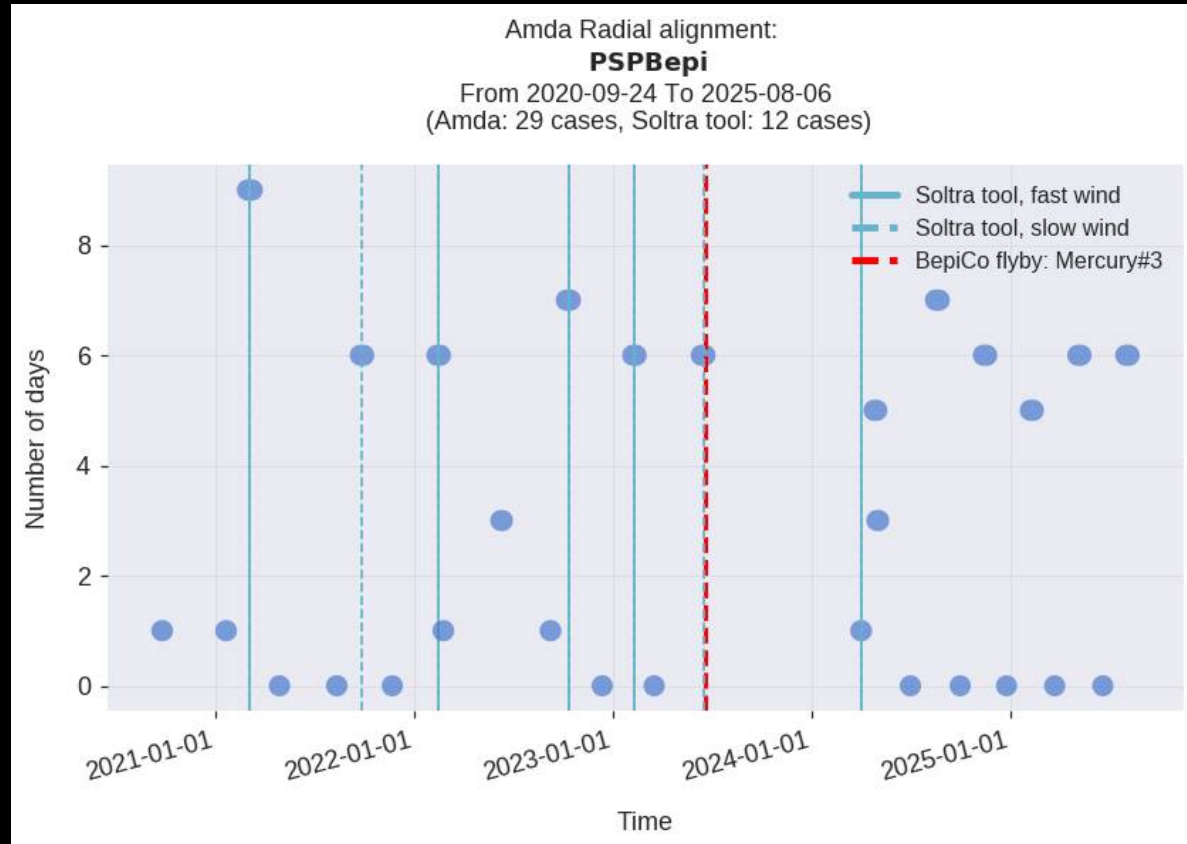
#### ➤ > triad cases

- ➔ BepiColombo – Solar Orbiter - PSP – Mars – Venus (1 case)



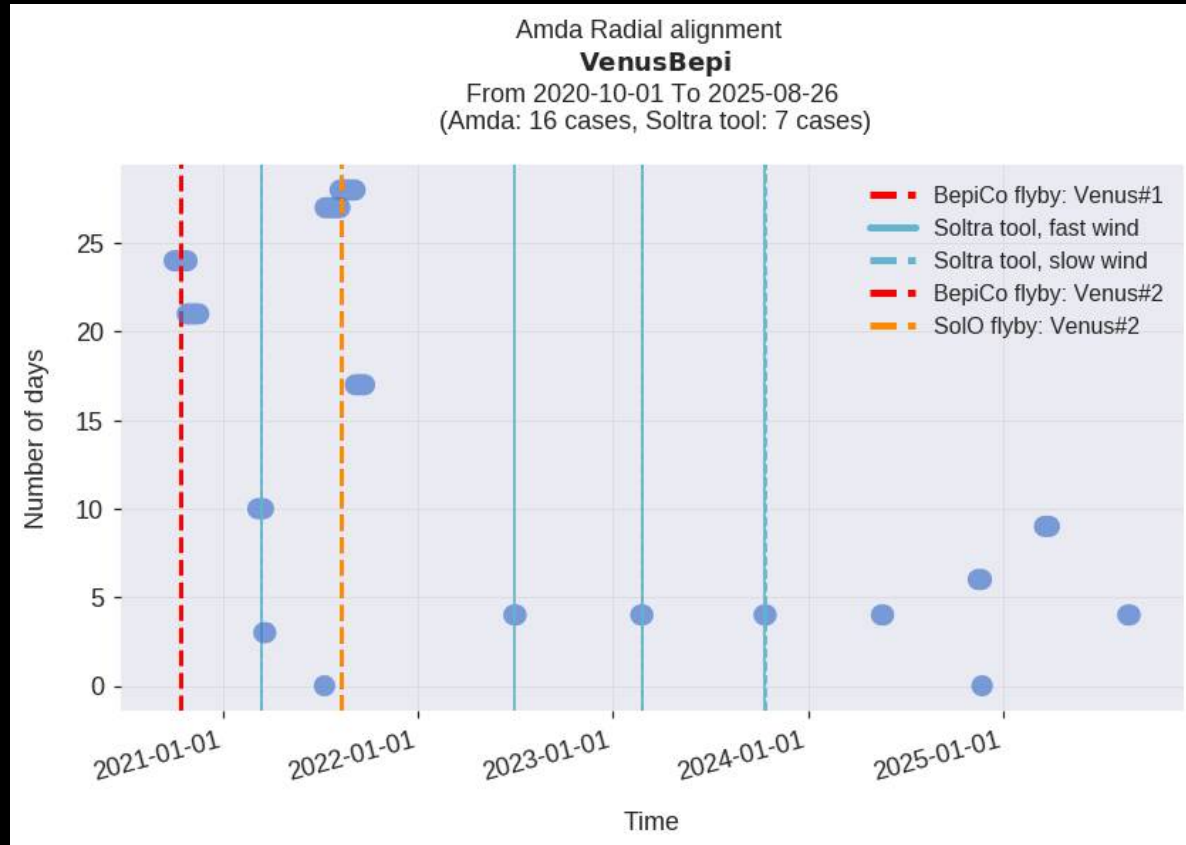
# Task 2

## Radial alignment: BepiColombo – Parker Solar Probe



# Task 2

## Radial alignment: BepiColombo – Venus



# Task 2

## Windows of opportunity: radial alignment with opposition

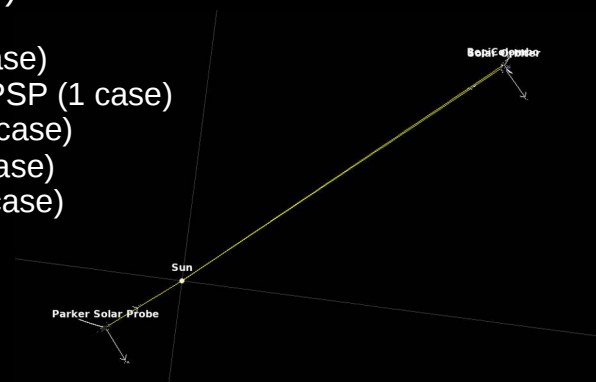
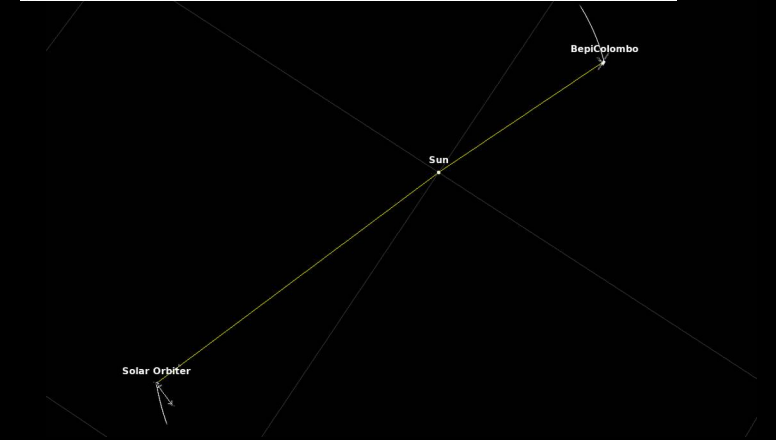
### 2) Radial alignment with opposition: 45 time intervals

#### ➤ Pair cases (including Earth, Mars and Venus)

- ➔ BepiColombo – Sun – Solar Orbiter (5 cases)
- ➔ BepiColombo – Sun – Parker Solar Probe (16 cases)
- ➔ BepiColombo – Sun – Earth (8 cases)
- ➔ BepiColombo – Sun – Venus (5 cases)
- ➔ BepiColombo – Sun – Mars (6 cases)

#### ➤ Triad cases (including Earth, Mars and Venus)

- ➔ BepiColombo – Solar Orbiter – Sun – PSP (1 case)
- ➔ BepiColombo – Venus – Solar Orbiter – Sun – PSP (1 case)
- ➔ BepiColombo – Solar Orbiter – Sun – Venus (1 case)
- ➔ BepiColombo – Solar Orbiter – Sun – Mars (1 case)
- ➔ BepiColombo – Sun – Solar Orbiter – Mars (1 case)



# Task 2

## Windows of opportunity: Parker field lines

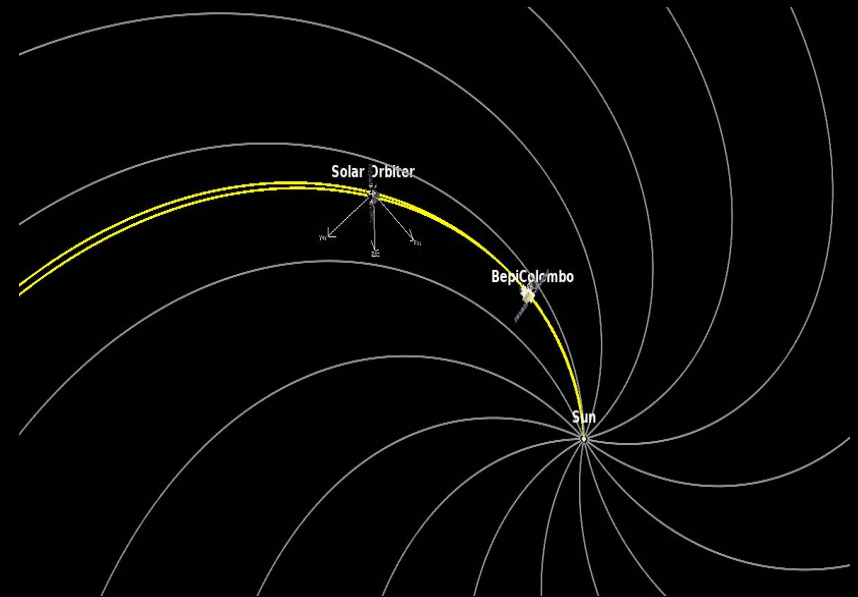
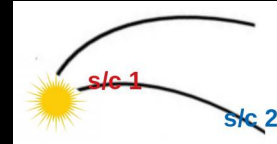
### 3) Parker field lines: 163 time intervals

#### ➤ Pair cases (including Earth, Mars and Venus)

- BepiColombo – Solar Orbiter (12 cases)
- BepiColombo – Parker Solar Probe (44 cases)
- BepiColombo – Earth (19 cases)
- BepiColombo – Venus (30 cases)
- BepiColombo – Mars (50 cases)

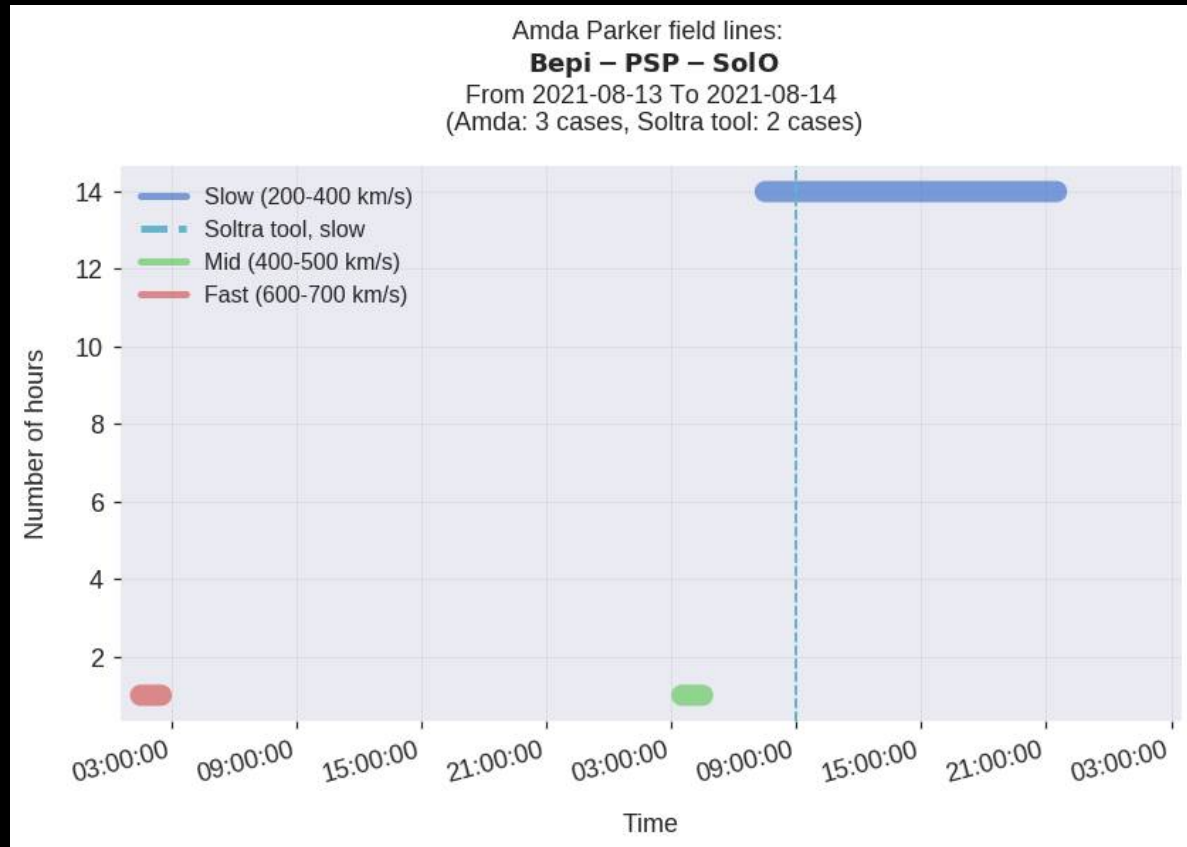
#### ➤ Triad cases (including Earth, Mars and Venus)

- BepiColombo – Parker Solar Probe – Solar Orbiter (3 cases)
- BepiColombo – Earth – Mars (1 cases)
- BepiColombo – Venus – Mars (4 cases)



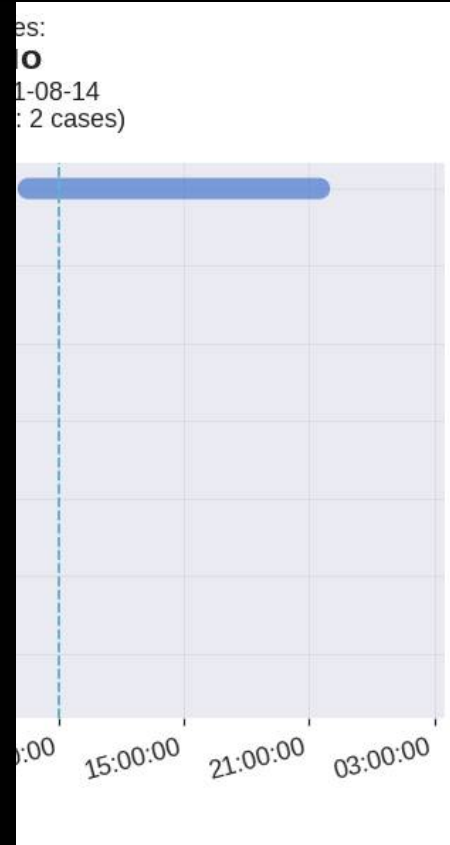
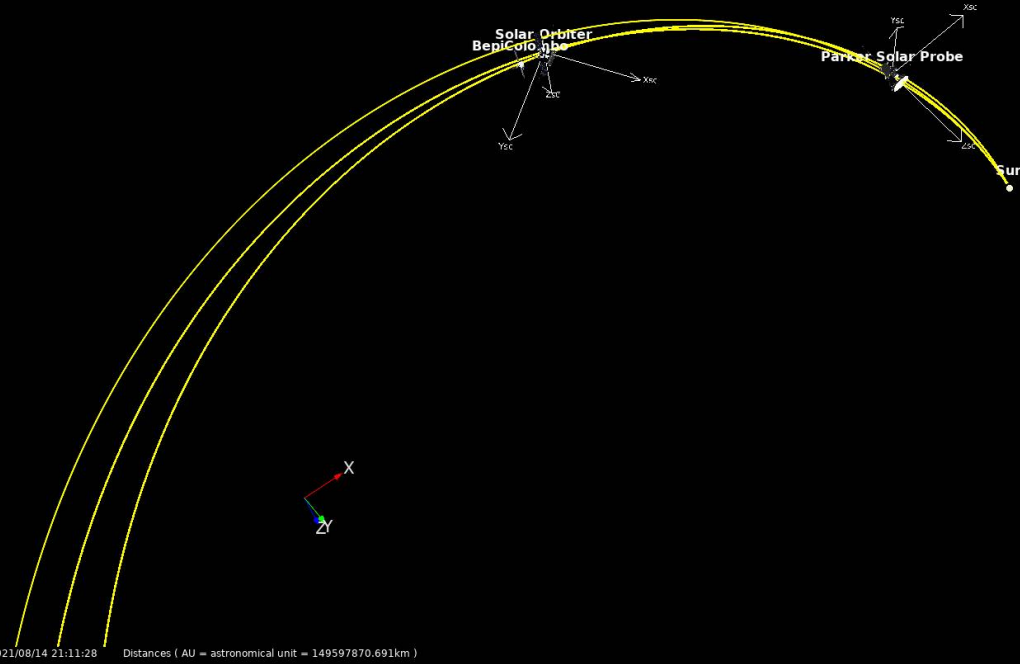
# Task 2

## Parker field lines: BepiColombo – Solar Orbiter – Parker Solar Probe



# Task 2

## Parker field lines: BepiColombo – Solar Orbiter – Parker Solar Probe



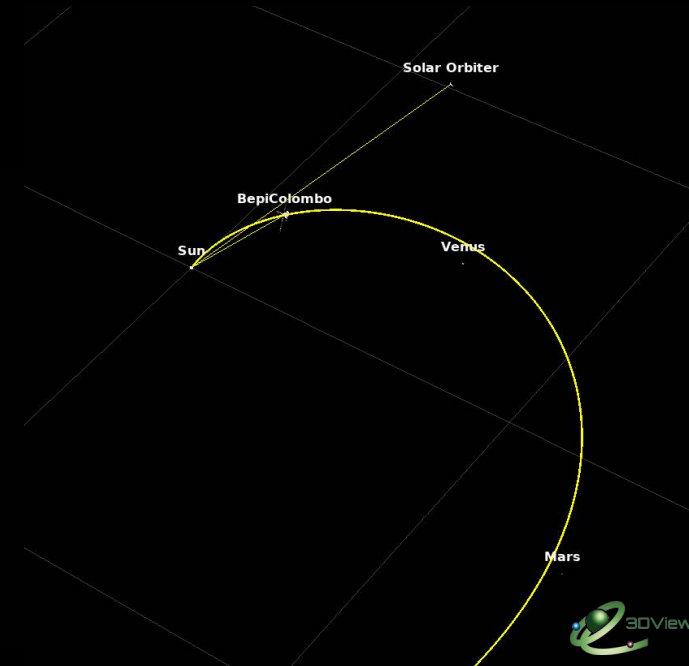
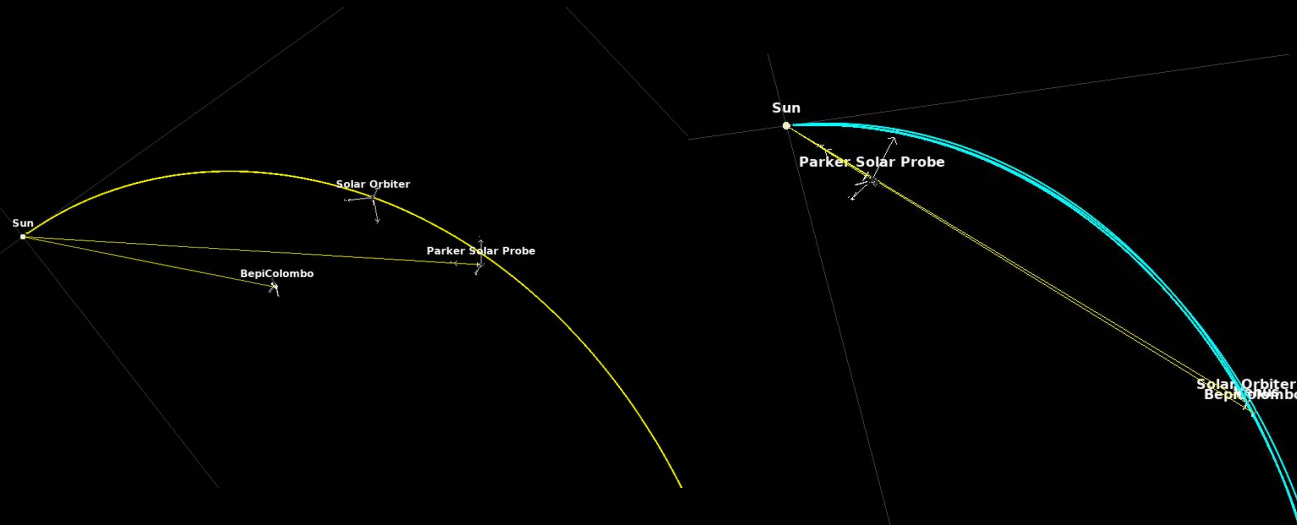
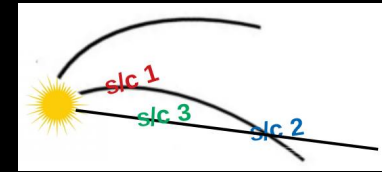


# Task 2

## Windows of opportunity: Parker field lines + radial alignment

### 4) Parker field lines + radial alignment: 64 time intervals

- Radial alignment pair – Parker pair (including Earth, Mars and Venus)
- Radial alignment triad – Parker pair (including Earth, Mars and Venus)
- Radial alignment pair – Parker triad (including Earth, Mars and Venus)



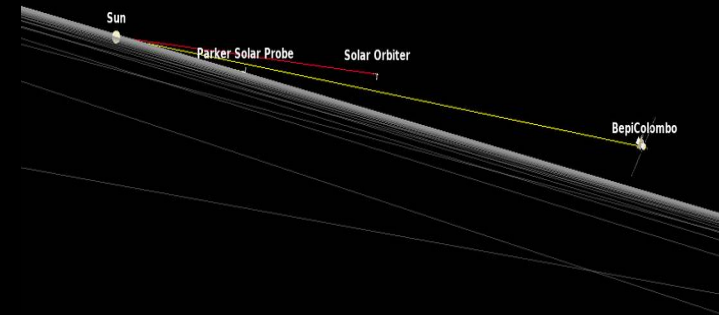
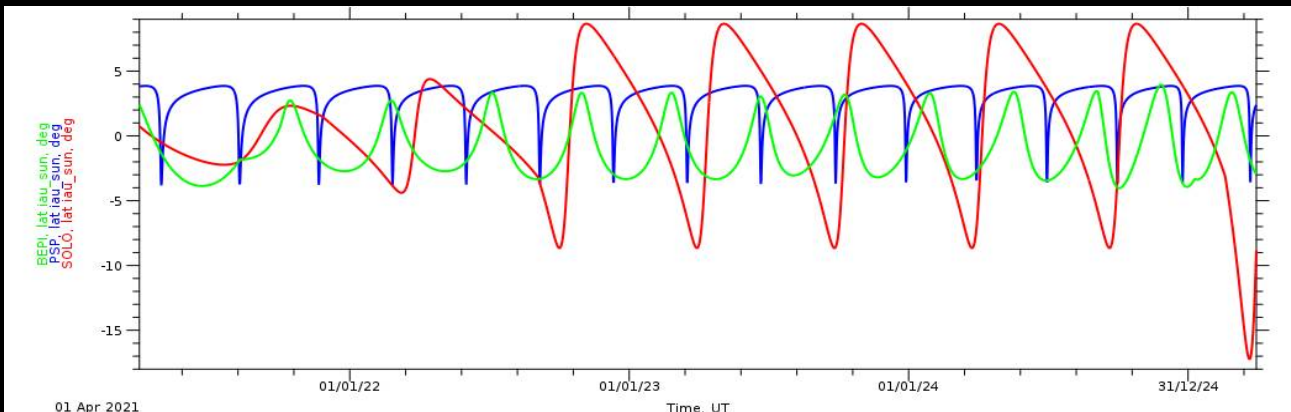
# Task 2

## Windows of opportunity: Solar Orbiter out of the ecliptic plane

### 5) Solar orbiter out of the ecliptic plane: 8 time intervals

- Radial alignment
- Radial alignment with opposition
- Parker field lines
- Parker field lines + radial alignment

Latitude variation of  
BepiColombo, PSP and Solar Orbiter



# Task 3

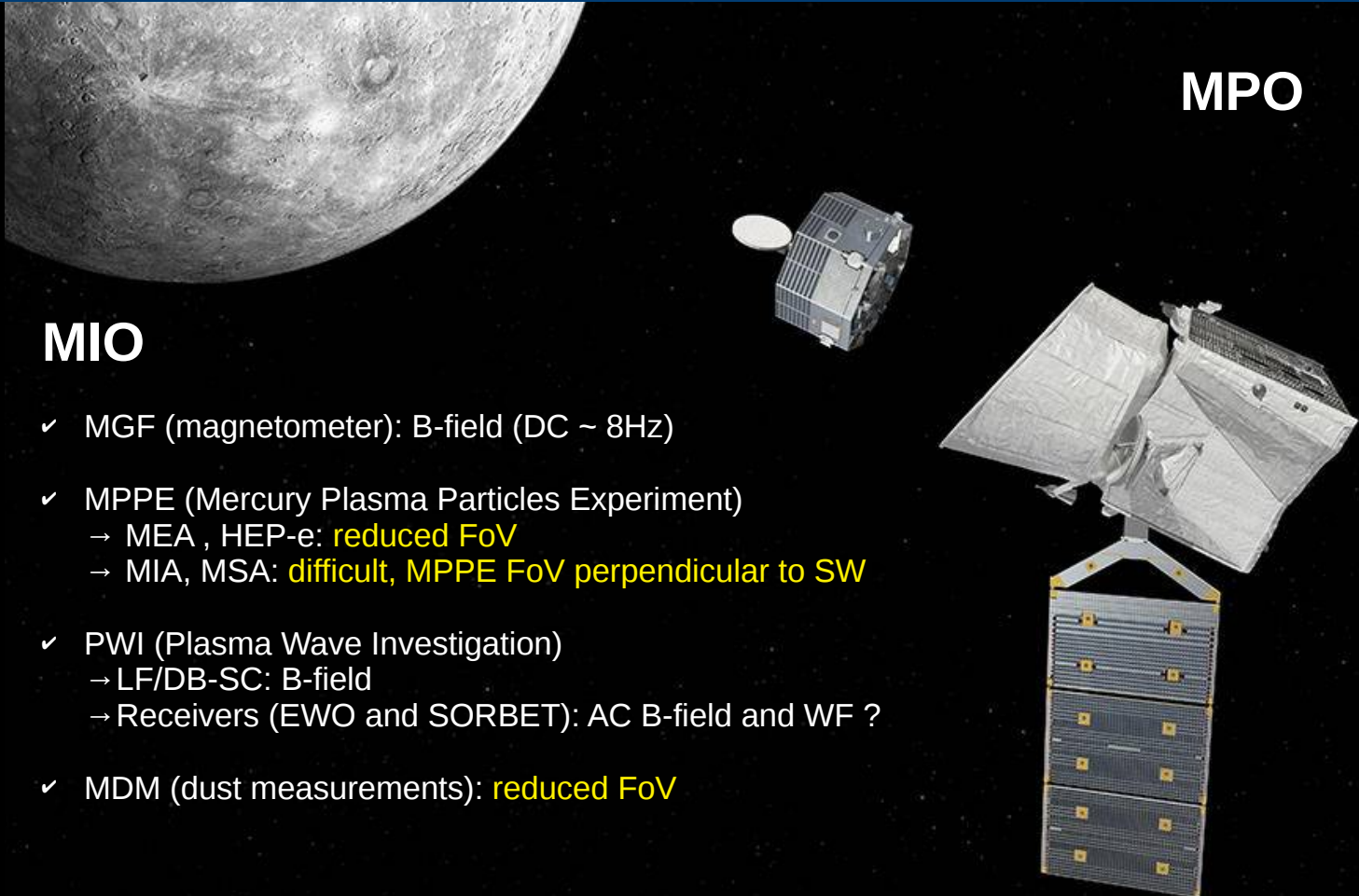
## Operational instruments of BepiColombo during the cruise phase

### MIO

- ✓ MGF (magnetometer): B-field (DC ~ 8Hz)
- ✓ MPPE (Mercury Plasma Particles Experiment)
  - MEA, HEP-e: **reduced FoV**
  - MIA, MSA: **difficult, MPPE FoV perpendicular to SW**
- ✓ PWI (Plasma Wave Investigation)
  - LF/DB-SC: B-field
  - Receivers (EWO and SORBET): AC B-field and WF ?
- ✓ MDM (dust measurements): **reduced FoV**

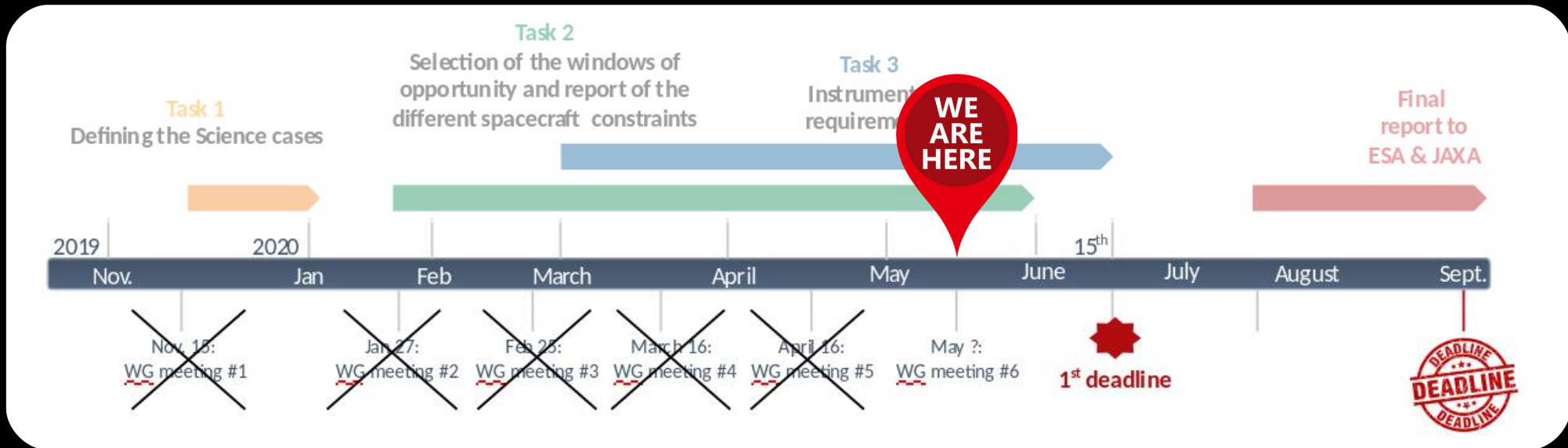
### MPO

- ✓ MPO-MAG (magnetometer)
  - 4 or 16 Hz, ~1 nT
- ✓ BERM (radiation monitor)
- ✓ SERENA: MIPA & PICAM (Ion analyser and Ion camera)
  - **FoV perpendicular to SW**
- ✓ SIX-S (Solar Intensity X-rays)
  - **Obstructed FoV**
- ✓ PHEBUS (UV spectroscopy)
  - **May be operating...**
- ✓ MORE (Gravity field), MGNS (Gamma rays and neutron), ISA (accelometer), MERTIS



# Work in progress

- ~~Task 1: Identification of the science cases.~~
- Task 2: Identification of the windows of opportunities related to BepiColombo, Solar Orbiter, Parker Solar Probe, Akatsuki (Venus Climate Orbiter), and other available spacecraft in the solar wind and other planets (Earth, Venus, Mars).
- Task 3: Operational instruments related to the different science cases and opportunities.



# Next steps and deadlines

## Task 2: Windows of opportunity

- Loosen the altitude condition in Amda tool.
- Investigate the cases for the “Quadrature” geometry (including STEREO A, and SDO).
- Cross check timetables from the different tools.
- **1<sup>st</sup> June: deliver final list of events.**

## Task 3: Operational instruments

- Complete the [Science&Instruments](#) spreadsheet:
  - Type of measurement, name of the instrument, multipoint observations (yes/no) and type of geometry.

## Spacecraft constraints

- Complete the [Spacecraft constraints](#) document.
  - Solar Orbiter, Parker Solar Probe

## Final report to ESA and JAXA

- **1<sup>st</sup> September 2020**

Thank you for your attention

Stay tuned!

