Cruise phase science opportunities with the JUICE spacecraft

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Update of the original report (from Feb 15, 2022) to reflect the actual launch date and cruise trajectory

Contents

Chapter 1

Abstract

The Jupiter Icy Moons Explorer of ESA was launched on April 14 2023. During its eight-year-long cruise phase, there will be plenty of time to perform experiments. In this report, we have identified two types of science opportunities during the cruise phase. The first one involves measuring the properties of the solar wind during conjunctions between JUICE and other spacecraft. We found several conjunctions between JUICE and the Europa Clipper, Parker Solar Probe, BepiColombo, Solar Orbiter, MAVEN, and Mars Express spacecraft. These conjunctions allow for measuring variations of the solar wind along with one of the coordinates of the heliocentric coordinate system (radius distance, latitude, and longitude). There are several periods in which variations along distance (radial alignment) or latitude (radial and longitudinal alignment) can be detected in this way. The other type of experiment that could be performed during the cruise phase is the detection of interplanetary dust in the dust clouds that are thought to envelop the orbits of Venus and Mars [1–3]. During the cruise phase, five crossings through the primary population of the Martian dust halo, and two through Venus' dust belt take place. If the instruments on JUICE can detect the dust grains, the density of the belt along the direction of motion could be mapped.

Chapter 2

Introduction

On April 14 2023, the Jupiter ICy moons Explorer (JUICE) was launched from Kourou in French Guiana. For at least three years, it will study the planet Jupiter and three of its Galilean moons: Europa, Ganymede, and Callisto. One of its objectives is to study Jupiter's magnetosphere and interactions concerning magnetic fields and plasma that occur in the Jovian system. Before it reaches Jupiter in July 2031, the spacecraft will spend more than eight years in the cruise phase while on its way to the gas giant [4]. During this period before the cruise phase, a wide variety of experiments can be performed [5]. Among these possibilities, the ones which will be discussed in this report are multiple ways of studying the solar wind, and the detection of interplanetary dust. Other science opportunities that have been put forward, but that will not be discussed in this report are the measurement of relativistic electrons that escape the Jovian system, testing general relativity during a conjunction, observing the cosmological background radiation, and a possible asteroid flyby. JUICE carries a total of 104kg payload of instruments, including the Juice-Magnetometer (J-MAG), the Particle Environment Package (PEP), and the Radio & Plasma Wave Instrument (RPWI). For a list of all the instruments on board and a more elaborate description of each of them, we refer to [4]. With some of these instruments, JUICE can perform in-situ measurements of the magnetic fields and plasma of the interplanetary medium. An especially interesting experiment would be to do simultaneous measurements involving another spacecraft that carries a similar science package at moments when they are radially, or angularly aligned. Especially the Solar Orbiter (SOLO) and the Parker Solar Probe (PSP), BepiColombo (orbiting Mercury in 2025), and Europa Clipper (arriving at Europa in April 2030) are suited for such alignments with JUICE as they all carry similar instruments that can detect electric- and magnetic fields, and plasma particle populations (see Table 2.1). A comparison between the specifications of the instruments on JUICE and Europa Clipper can be viewed in Figure 5.9 of the appendix.

JUICE	**Europa Clipper**	**Parker Solar Probe**	**Solar Orbiter**	**BepiColombo**	**MAVEN**	**Mars Express**
J-Mag	ECM	FIELDS	MAG	MERMAG	MAG	
PEP	PIMS	SWEAP, IS$\odot$IS	EPD, SWA	MPPE	SWEA, SWIA	ASPERA-3
RPWI			RPW	PWI	LPW	

Table 2.1: A table containing the comparable instruments aboard each of the spacecraft, relevant for studying the solar wind. For more information about the instruments, we refer to [4, 6–11].

2.1 The solar wind

The sun is continuously ejecting a varying stream of charged particles. This plasma which consists mainly of protons and electrons is called the solar wind. Regions near the equator emit rapidly varying slow solar wind, while zones closer to the poles eject a more stable and faster solar wind. As the magnetic fields are essentially 'frozen in' into the plasma, the solar wind takes the magnetic field of the sun out into space, explaining the origin of the interplanetary magnetic field (IMF). The solar wind is not constant, however, as the solar activity fluctuates on both long time scales, like the 11-year solar cycle, and on shorter time scales due to the unstable nature of the solar atmosphere. There is also a variation of the solar wind along the latitude of the sun. Short events like coronal mass ejections and solar flares may eject a sudden high-density burst of particles at a high velocity while corotating interaction regions that are longer lived, act as a source of a quickly moving solar wind. As we move away from the sun, the particle density drops with $\propto 1/r^2$, and while the IMF in radial direction drops with $\propto 1/r^2$, the fields in the polar and azimuthal direction drop by $\propto 1/r$ [12]. The interplanetary magnetic field and particle densities in the solar wind can be detected using magnetometers and particle detectors respectively. In this way, JUICE can study the evolution of the solar wind while it cruises through the solar system, and if one could link the information obtained by JUICE with that of another probe, even more, extensive experiments can be performed. JUICE carries a magnetometer (J-MAG) to measure the interplanetary magnetic field, a PEP that can detect negative ions, electrons, exospheric neutral gas, thermal plasma, and energetic neutral atoms. While the Radio and Plasma Wave Investigation (RPWI) can measure the electric and magnetic fields in the plasma.

v	400 km/s
B	5 nT
n_e	5 cm^{-1}
T_e	$5-10$ eV

Table 2.2: Properties of the solar wind. A table containing some typical values for the solar wind at 1 AU. Taken from: [13].

2.2 Dust halos

Recently, during its cruise phase on the way to Jupiter, the Juno spacecraft detected interplanetary dust particles (IPD) of sizes ranging from 1 to 100μm [1]. These particles collided with the 60m^2 solar panels that served as a collecting area, while the 4 on-board star cameras acted as detectors. The highest concentration of dust was found in a Keplerian orbit between the aphelion of the Earth (1.02AU) and the 4 : 1 mean resonance of Jupiter (2.065AU). This dust extended in a torus-like shape with a primary high-concentration region extending to 1.85° on both sides of the ecliptic plane, and a secondary population resulting from the Kozai-Lidov mechanism stretching to 7.4° from the ecliptic plane [1]. Because the dust cloud occupies a region bounded by the earth's aphelion and Jupiter's 4 : 1 mean resonance and appears to have a Keplerian orbit, Jorgensen et. al have proposed a possible Martian origin of the dust. On its way to Jupiter, JUICE also crosses the orbit of Venus multiple times, as part of the gravity assist manoeuvre. Like Mars, Venus' orbit also seems to be enveloped by a dust halo [2, 3], which could be studied by JUICE as well. The dust particles in the halos are much bigger than the electrons and protons usually found in the solar wind, but they could still be detected with JUICE's onboard instruments. For example, the RPWI might be able to detect the ringing of the E-field caused by dust particles, or by the detection of ions that reside in the vicinity of the dust. Another method would be to use the solar panels of JUICE as a collection area for the IPD in a similar way as in [1]. The solar panels of JUICE have a larger total area (85m^2) compared to JUNO, which increases its detection abilities. The disadvantage of this technique, however, is that it is not sensitive to smaller dust particles. Furthermore, it is not clear if the different type of solar panels used on JUICE as well as JUNO for such a detection method, or whether the cameras aboard JUICE can serve as detectors.

Chapter 3

Science opportunities

In Figure3.1 the trajectories of all the spacecraft mentioned in this report are shown. It is visible that the trajectory of JUICE lies in the ecliptic plane. JUICE will have several fly-bys which serve as a gravity assist that launches the spacecraft to Jupiter. They occur in the following order: moon-Earth-Venus-Earth-Moon-Earth. During this interplanetary phase, JUICE will cross the orbits of Venus and Mars multiple times, see Figure3.2, during these crossings dust measurements could be performed. Another notable feature is the highly eccentric orbit of the Parker Solar Probe, with a perihelion very close to the Sun. The other solar probe, SOLO, starts at a low inclination, but after a few orbits, it reaches high inclinations of about 28.7 degrees from the ecliptic plane. BepiColombo gradually moves closer to Mercury and will have multiple flybys around the planet, until it is finally inserted into Mercury's orbit at the end of 2025.

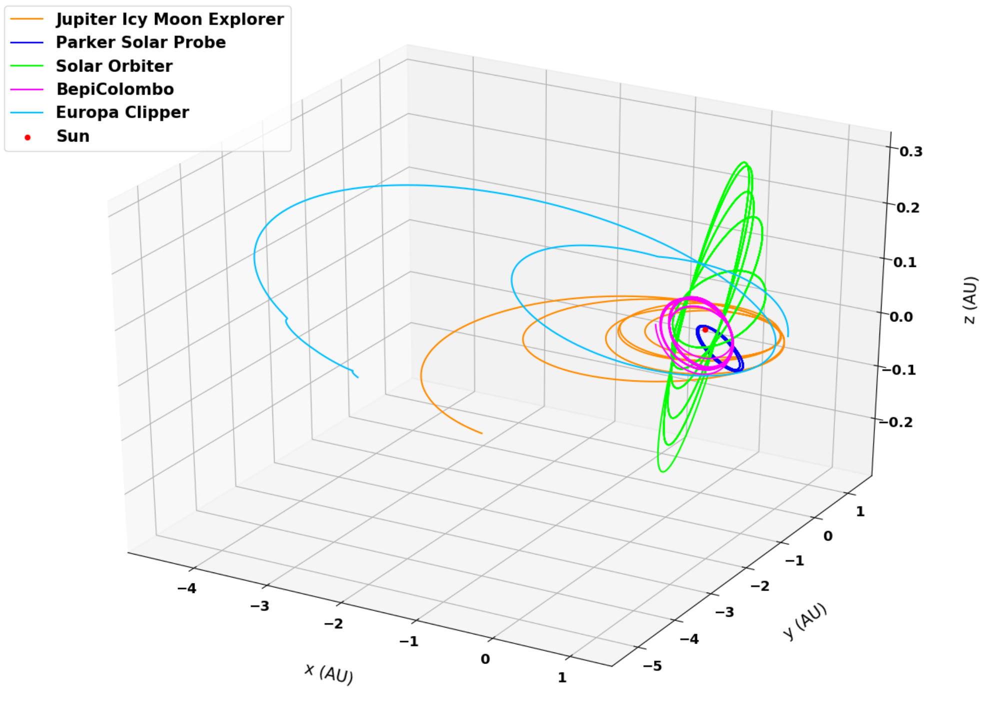

Figure 3.1: Left: The trajectories of JUICE and the other spacecraft. Right: The orbits of JUICE, Venus, and Mars.

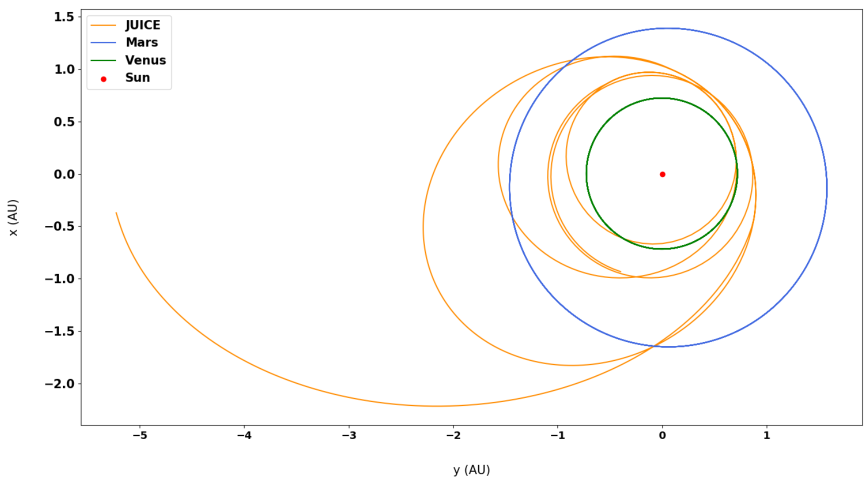

Figure 3.2: Left: The trajectories of JUICE and the other spacecraft. Right: The orbits of JUICE, Venus, and Mars.

In this report, all the coordinates are in the ecliptic coordinate system with the Sun at the origin. In this coordinate system, the longitudinal angle revolves in the ecliptic plane, while the latitude indicates the elevation above or below the ecliptic plane. The spherical coordinates of JUICE throughout its journey are plotted in Figure3.3. The absolute latitude never exceeds 1°, and its latitude changes during the first six years, but as soon as it gets its final gravitational assist from the Earth early in 2029, it will head for Jupiter with a lower angular velocity. In Figure3.4, it is visible that JUICE's aphelion increases after its first flyby with Venus in August 2025 and during the Earth flybys in September 2026 and in the beginning of 2029.

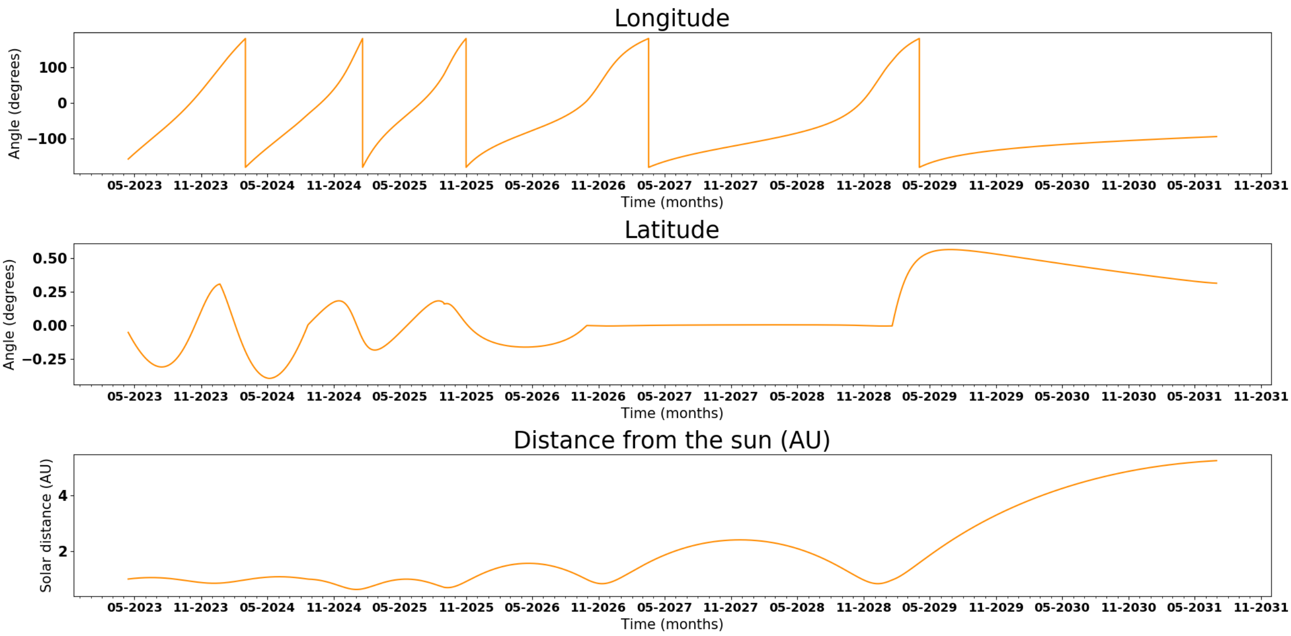

Figure 3.3: Coordinates of the Jupiter Icy Moons Explorer.

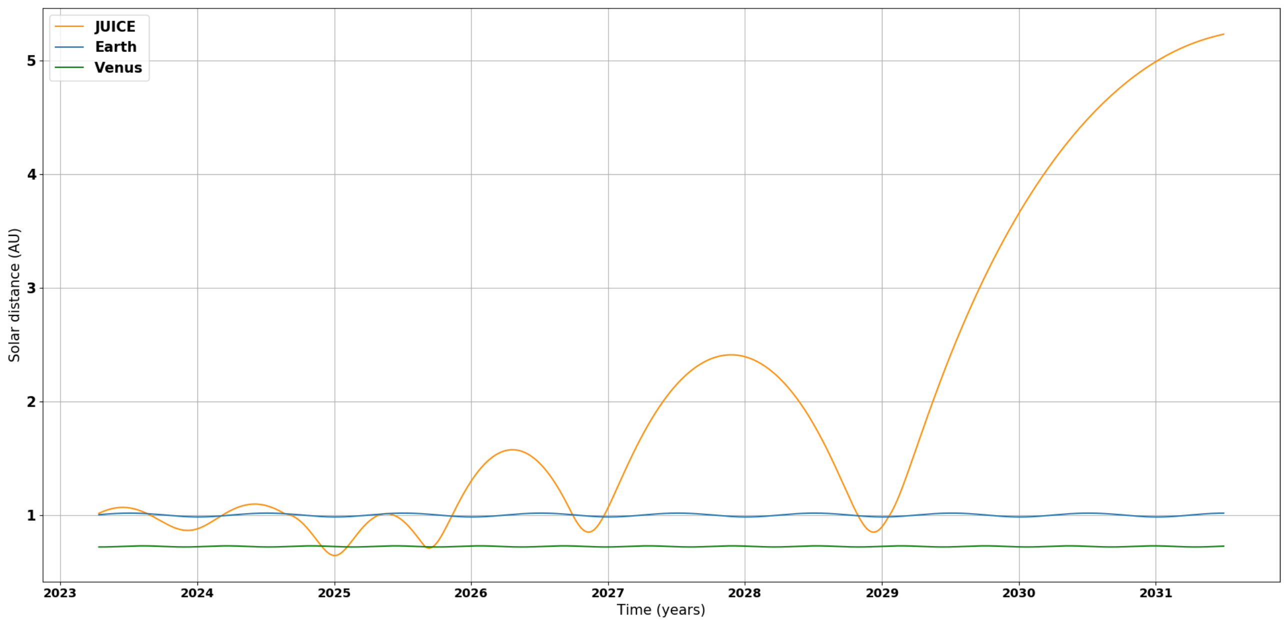

Figure 3.4: Solar distances of JUICE, Venus, and the Earth.

3.1 Alignment between spacecraft

A class of experiments that JUICE can perform during the cruise phase is to perform plasma measurements when it is aligned with other spacecraft. These conjunctions would allow us to study the solar wind, and its variation in the radial direction, away from the Sun (in case of radial alignment), or across latitude (when the probes are both radially and longitudinally aligned).

3.1.1 Radial alignment

In Figure3.5 the periods of radial alignment between JUICE and the other probes within 15 degrees can be seen. At the beginning of the cruise phase, the conjunctions with the longest periods occur between JUICE and the Parker Solar Probe and last for a month or more. But these occur when JUICE is around 1AU, so they are not very interesting from a science perspective. On the other hand, the later alignments between JUICE, BepiColombo, and Europa Clipper are more interesting. During this period, JUICE is beyond 1 AU as it has received its last gravitational assist and is then on its way to Jupiter. Since Europa Clipper is already at the orbital radius of Jupiter and BepiColombo close to the Sun during these alignments, JUICE can study the evolution of the solar wind throughout the outer solar system. These periods with a double alignment last about 10 days each and occur every 3 months since the orbital period of Mercury is 88 days, roughly the equivalent of 3 months. Other periods when JUICE is aligned with two other spacecraft at the same time are listed in Table 3.1. During the first five double alignments, JUICE is at a distance of between 0.68 AU to 1 AU away from the Sun, so these are not very useful since there are already multiple spacecraft studying the solar wind between the Sun and the Earth. The later conjunctions when JUICE has moved past the orbit of Mars (~ 1.5 AU) are the most interesting. The reason for this is that there are simply no spacecraft probing the interplanetary medium between Mars and Jupiter. Finally, another interesting science opportunity that we identified in Figure3.5 occurs at the beginning of the last period of alignment between JUICE and SOLO at the end of November 2026. This interval could be used to compare the measurements of the two spacecraft and to calibrate the instruments of JUICE because, in it, the JUICE and SOLO are not only radially aligned but also at the same distance from the Sun.

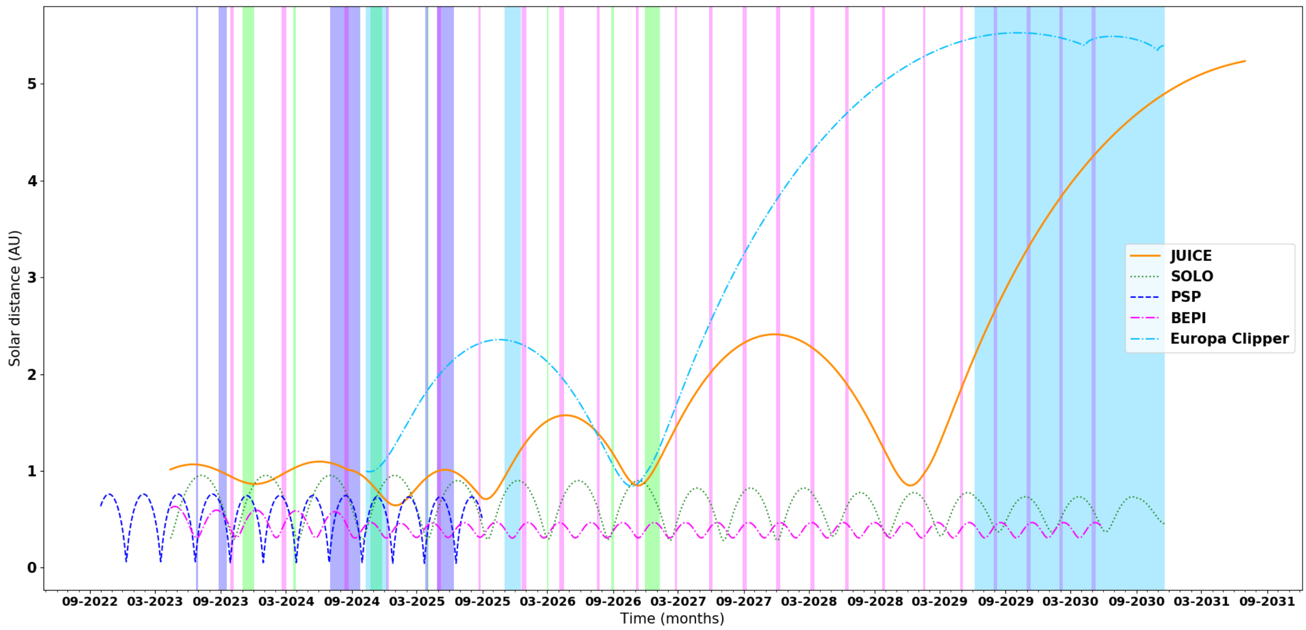

Figure 3.5: Radial alignment between JUICE and the other spacecraft within an angular separation of 15 degrees. The periods of alignment are marked in the colour of the respective spacecraft that is in conjunction with JUICE at that moment.

Period	**Spacecraft**
11/8/2024 - 23/8/2024	BEPI-PSP
23/10/2023 - 25/11/2024	EUCL-SOLO
6/12/2024 - 11/12/2024	BEPI-EUCL
31/3/2025 - 1/4/2025	PSP-SOLO
28/4/2025 - 8/5/2025	BEPI-PSP
29/7/2029 - 8/8/2029	BEPI-EUCL
29/10/2029 - 8/11/2029	BEPI-EUCL
28/1/2030 - 8/2/2030	BEPI-EUCL
28/4/2030 - 9/5/2030	BEPI-EUCL

Table 3.1: The periods of nine double conjunctions involving JUICE and two other spacecraft.

3.1.2 Radial alignment with Europa Clipper

During the cruise phase, JUICE is radially aligned with Europa Clipper on multiple occasions. The periods for which there is radial alignment within 10 degrees are shown in Figure3.6. There are four intervals during which JUICE and Europa Clipper are in conjunction. The most interesting period is the third one between 1/7/2029 and 12/2/2030, because throughout this conjunction JUICE is in the outer solar system, and the difference in distance to the Sun between the probes is large. For an alignment within 5 degrees, this interval spans the dates between 3/8/2029 and 12/11/29. For a separation of 1 degree, the period lasts from 11/9/2029 to 19/9/2029. All the dates of the periods of alignment between JUICE and Europa Clipper can be found in Table 3.2.

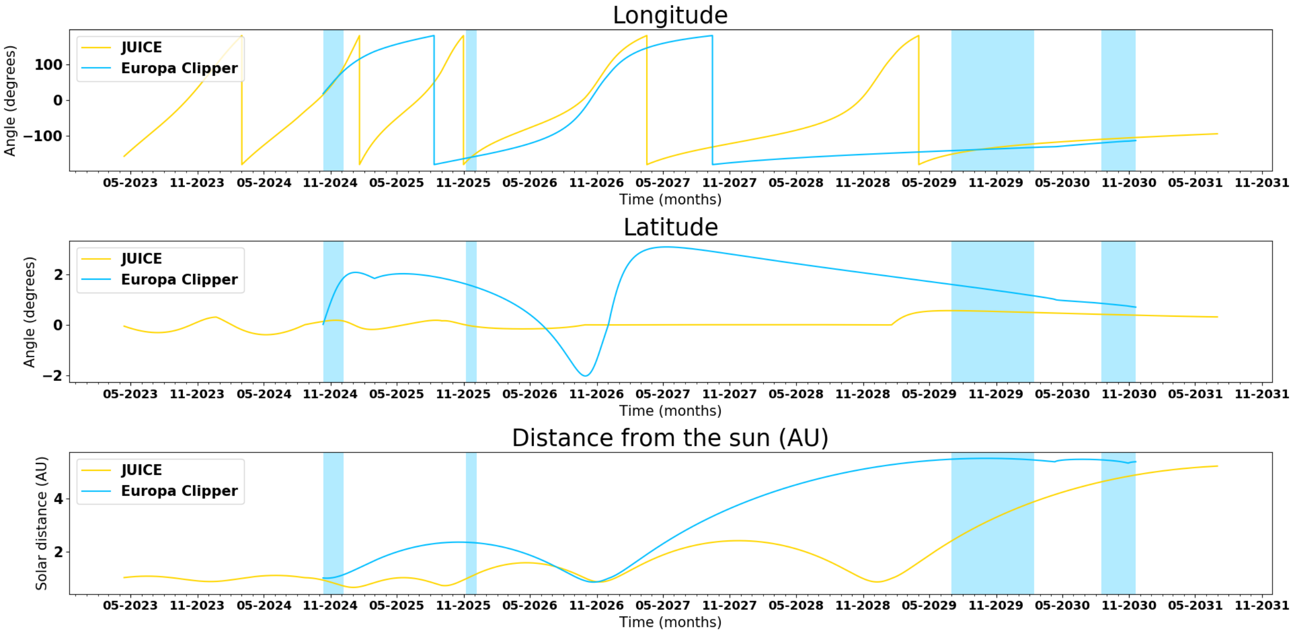

Figure 3.6: Radial alignment of JUICE with Europa Clipper. The blue strips mark periods when JUICE and Europa Clipper are radially aligned within 10 degrees.

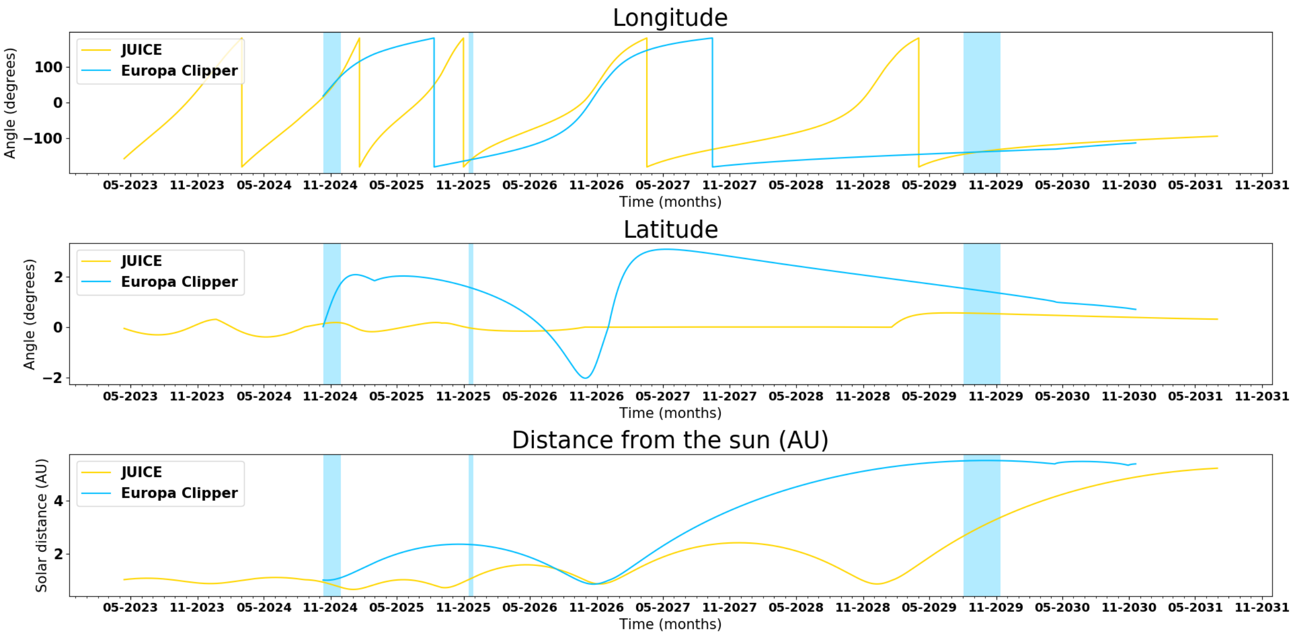

Figure 3.7: Radial alignment of JUICE with Europa Clipper. The blue strips mark periods when JUICE and Europa Clipper are radially aligned within 5 degrees.

Range (°)	From	To
1°	11-9-2029	19-09-2029
5°	11-10-2024	28-11-2024
	13-11-2025	28-11-2025
	03-08-2029	12-11-2029
10°	11-10-2024	05-12-2024
	07-11-2025	07-12-2025
	01-07-2029	12-02-2030
	17-08-2030	18-11-2030
15°	11-10-2024	10-12-2024
	01-11-2025	17-12-2025
	06-06-2029	18-11-2030

Table 3.2: A calendar of periods during which JUICE and Europa Clipper are radially aligned within 1°, 5°, 10°, and 15°.

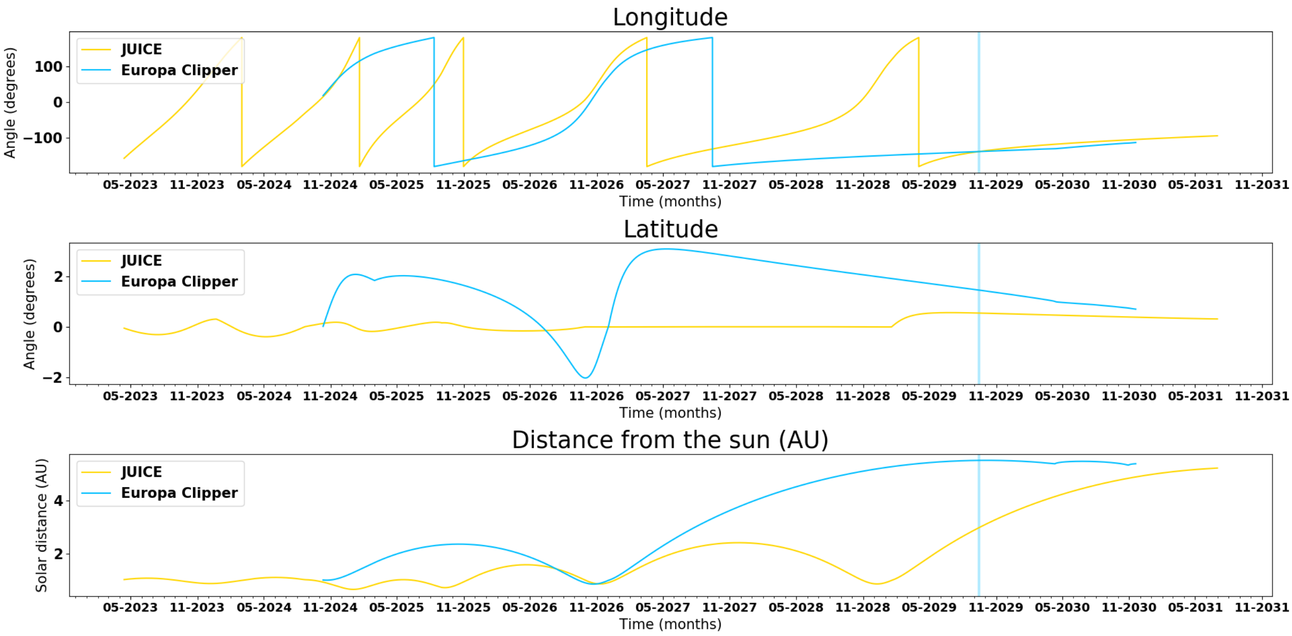

Figure 3.8: Radial alignment of JUICE with Europa Clipper. The blue strips mark periods when JUICE and Europa Clipper are radially aligned within 1 degree.

3.1.3 Latitude variation in the solar wind

Another experiment that can be performed to learn more about the solar wind is when JUICE and a solar probe are located at the same distance from the Sun, while also being aligned in longitude, but not in latitude. Then the only significant motion between the spacecraft is along the latitude. This is especially of interest when there is a prolonged period in which the latitude difference between the probes increases rapidly so that changes in the solar wind across latitude can be measured. The Solar Orbiter is especially suited for this, because it reaches high latitudes during its orbit around the Sun, as can be seen in Figure3.1.

In Figure3.9, graphs containing the spherical coordinates of both JUICE and Solar Orbiter can be seen. There are multiple periods in which JUICE and SolO are aligned. Still, the early alignments are not of very useful since the angular separation in longitude between Solar Orbiter is rather small. More interesting are the latter two periods of alignment, which are also the longest and in them Solar Orbiter reaches high latitudes. In the second-last alignment, the maximum latitude that is reached is 12.6° and during the last one, a maximum separation in latitude of more than twice as much, 25.3°, is achieved. Unfortunately, the longitude separation between the spacecraft associated with these intervals is quite wide, extending to as far as 45°. At the same time, the difference in Sun distance between the probes can be as big as 0.83 AU. At such large separations between the spacecraft, there is no good alignment and therefore the measurements may not be as useful in studying the latitudinal variations of the solar wind.

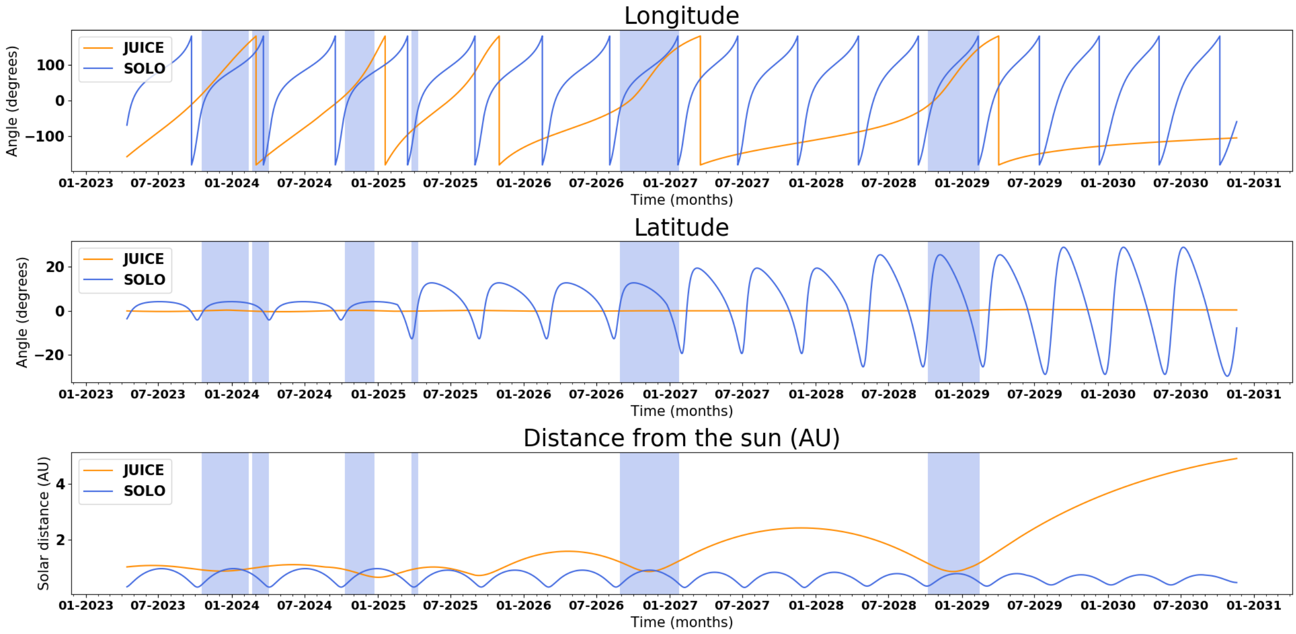

Figure 3.9: Longitudinal alignment between JUICE and Solar Orbiter within 45° and at a maximal spacecraft radial separation of 0.83 AU. Areas of overlap have been coloured light blue. Note that these marked periods offer a window of opportunity to study the solar winds' latitudinal variation.

An interval with better alignment between the two spacecraft but that still covers a large range of angles is the period in which Solar Orbiter decreases its latitude from 6/11/2028 to 22/1/2029 is shown in Figure3.10 Here the difference in distance from the Sun between the spacecraft is at most 0.35 AU, and the maximum difference in longitude is 35°. During this conjunction, the Solar Orbiter decreases its latitude from 25.4° to 3.6°.

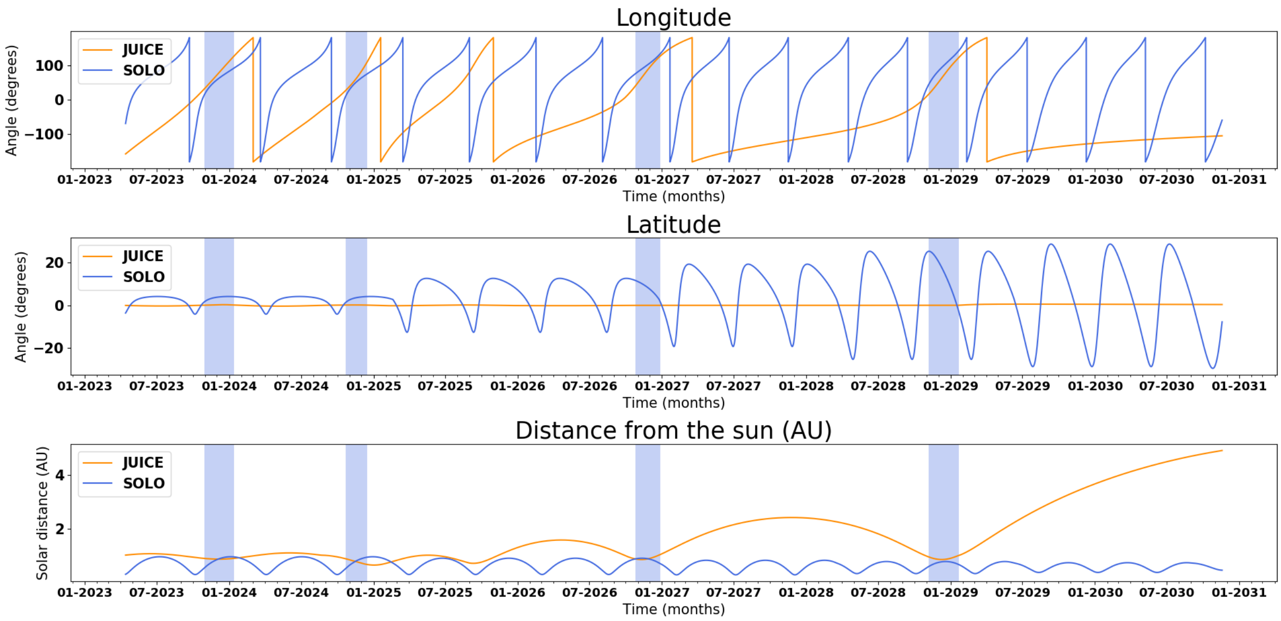

Figure 3.10: Longitudinal alignment between JUICE and Solar Orbiter within 35° and at a maximal spacecraft radial separation of 0.35 AU. Areas of overlap have been coloured light blue. Note that these marked periods offer a window of opportunity to study the solar winds' latitudinal variation.

3.1.4 Alignment with Mars orbiters

Another science opportunity is conjunctions between JUICE and the spacecraft that orbit Mars. ESA's Mars Express and NASA's MAVEN have orbited the red planet since 2003 and 2014. It is visible in Table 2.1, that MAVEN has the most instruments on board that could perform measurements in tandem with the instruments on JUICE during a conjunction. The goal of such an experiment would be to see how the solar wind evolves further away beyond the Earth's orbit. MAVEN has comparable instruments to JUICE while Mars Express carries only the ASPERA-3 (Analyzer of Space Plasmas and Energetic Atoms), see Table 2.1. The periods during which JUICE is aligned with Mars (and therefore also with the two satellites) within an angle of 10° are marked in Figure3.11. In total, there are four conjunctions of which the first two and last occur when JUICE is around or below 1 AU. The third conjunction starts on 31/5/2027 and lasts until 20/8/2027. During this period JUICE is at 2 AU from the sun, which is outside of the Martian orbit. This reason, together with the fact that the third alignment period is the longest, makes it the most suitable for an experiment involving simultaneous measurements of two spacecraft.

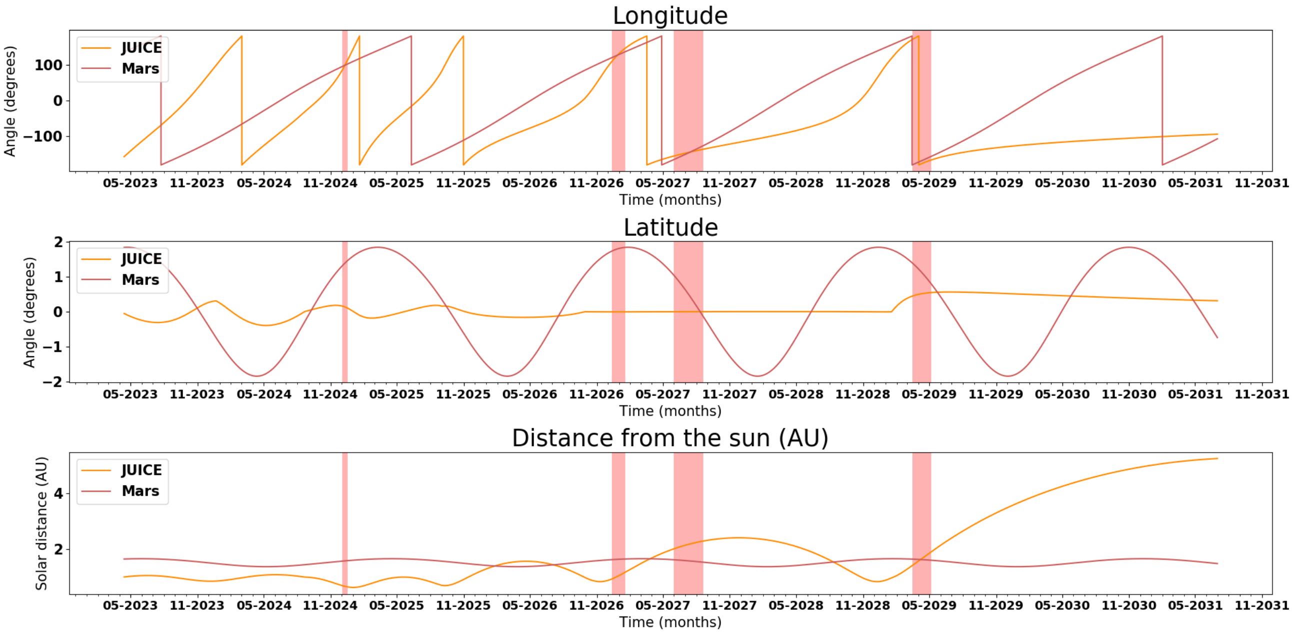

Figure 3.11: Radial alignment of JUICE with Mars. The red strips indicate periods when JUICE and Mars are radially aligned within 10 degrees.

If the conjunction is made even more strict and only intervals during which the spacecraft is aligned within 5 degrees, only three periods of alignment are found, see Figure3.12. The third one occurs between 24/6/2027 and 3/8/2027 and is the most suitable since it is the only one of the three where JUICE is beyond 1 AU.

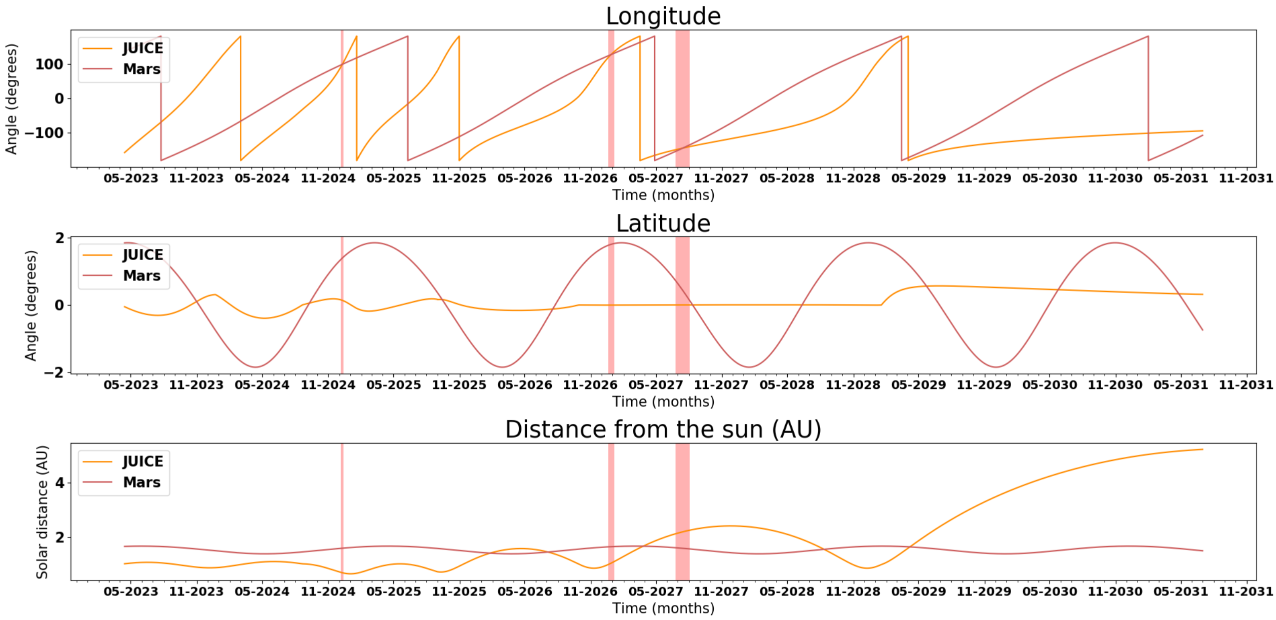

Figure 3.12: Radial alignment of JUICE with Mars. The red strips indicate periods when JUICE and Mars are radially aligned within 5 degrees.

3.2 Dust detection

As mentioned in the introduction, one of the science opportunities for JUICE during the cruise phase is to detect and map the density of interplanetary dust in the solar system. In contrast to JUICE, JUNO did not cross the orbit of Venus, as it only used the Earth for its gravitational assist. Therefore it would be interesting to utilise the opportunity that JUICE offers us to study the dust halo surrounding the orbit of Venus. In Figure3.13, a trajectory plot for each date at which JUICE crosses the orbit of Venus is shown. These crossings will occur on 29 November 2024, 4 February 2025, 31 August 2025, and 19 September 2025. The dust halo near the orbit of Venus has previously been measured to be roughly extending up to 1.7° from Venus' orbital plane [2]. Because Venus itself has an orbital inclination of about 3.394° [14], JUICE will not pass through the dust cloud each when it crosses the orbit of Venus. In Figure3.14 it can be seen that JUICE passes through the dust cloud in November 2024, and again during the Venus flyby in August 2025. During the two other crossings in February 2025 and September 2025, the latitude of JUICE will be too low to pass through the dust halo.

Similar to Venus, the region that surrounds the orbit of Mars also possesses a dust belt. The primary population of the Martian dust in the halo is thought to lie within ±1.85° from the ecliptic plane [1]. In Figure3.15 it can be seen that the five crossings will occur during the period between 19 February 2026 and 8 April 2029. A glance at Figure3.12 shows that JUICE moves through the central region of the dust cloud every time it passes the orbit of Mars since its latitude always remains within ±0.4° from the ecliptic plane.

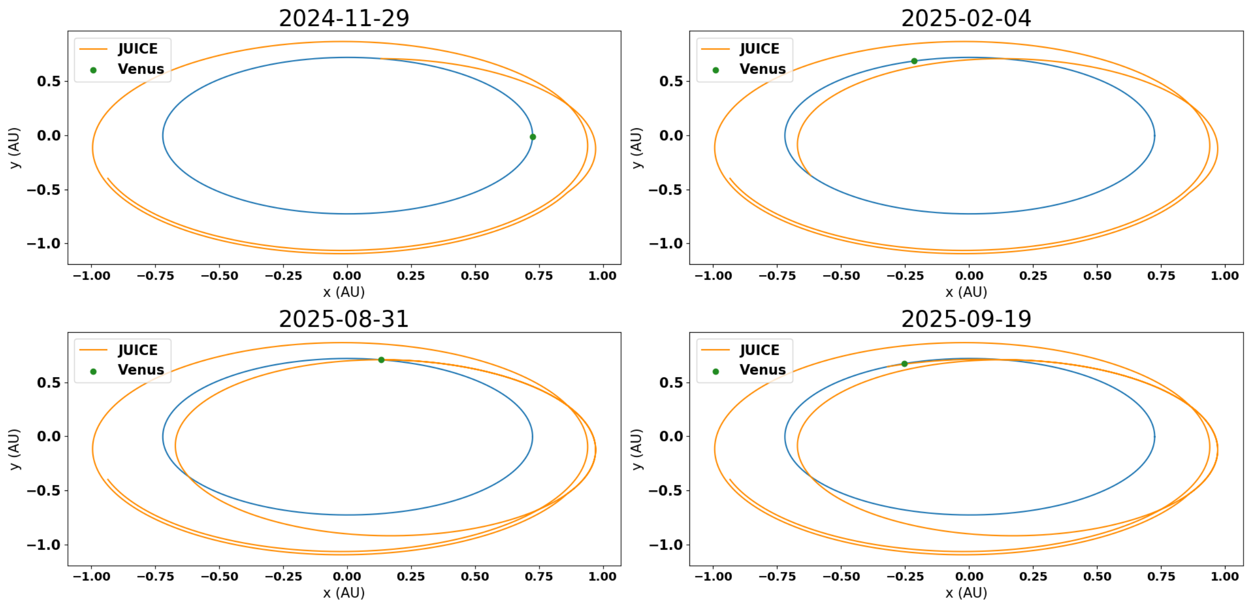

Figure 3.13: Crossing points of JUICE with the orbit of Venus and their respective dates. After launch, the spacecraft crosses through the orbit of Venus 4 times (as seen from the ecliptic plane). The Venus flyby, serving as a gravitational assist manoeuvre, can be seen in the bottom left panel.

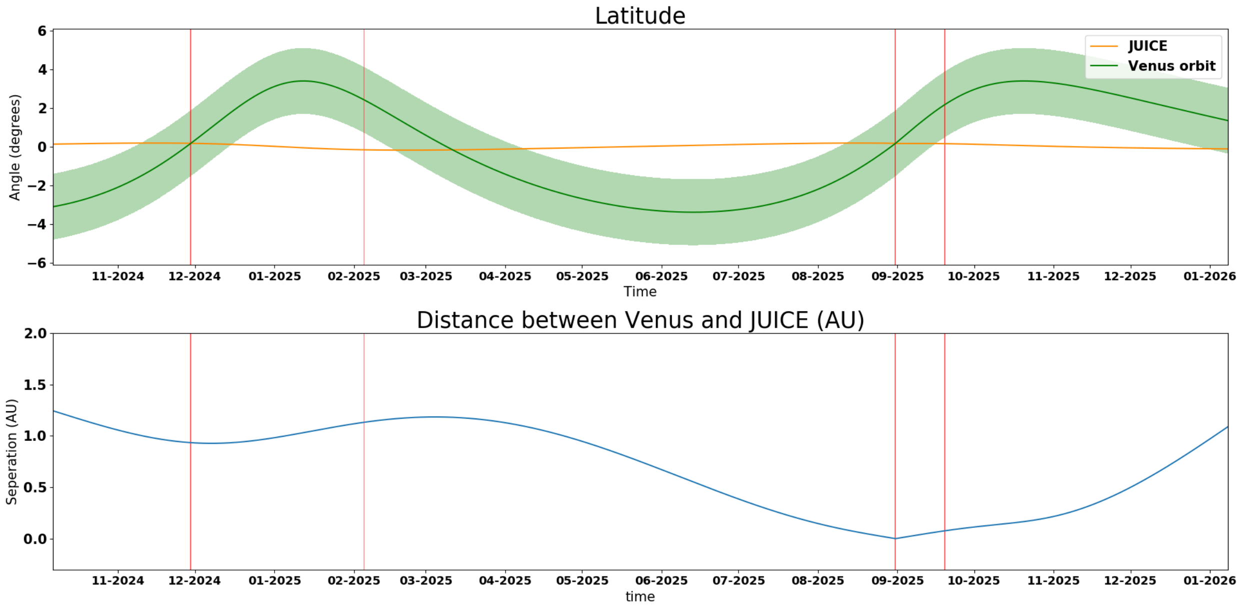

Figure 3.14: **Upper figure:** The latitude of JUICE and the Venus dust halo. The latitudes for the orbit of Venus are taken at the same longitudes as JUICE. The green region around the line of the Venus orbit indicates the extent of the dust halo. The red lines mark the moments at which JUICE crosses the orbit of Venus. **Bottom figure:** The distance between JUICE and Venus. The second-last crossing marks JUICE's Venus flyby.

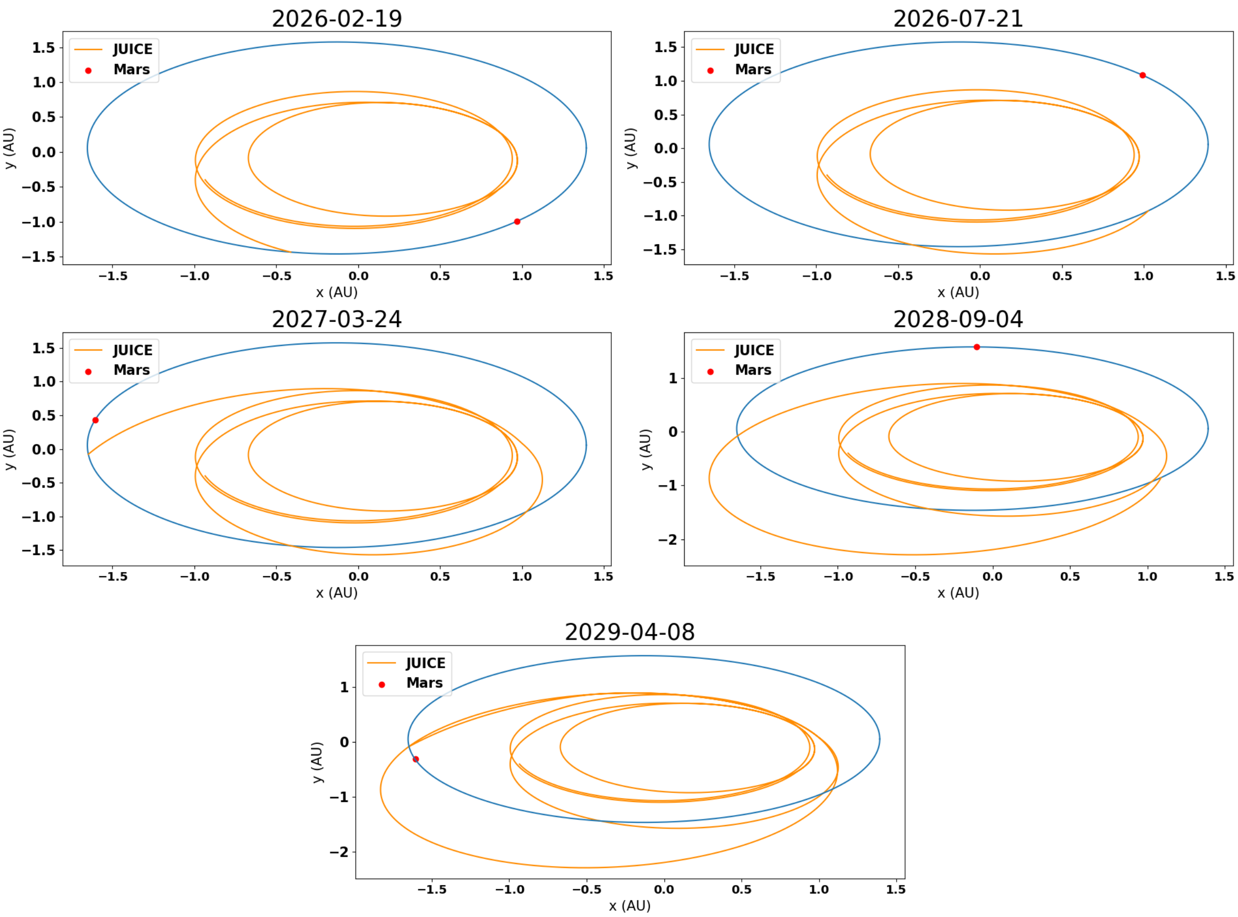

Figure 3.15: Crossing points of JUICE with the orbit of Mars at the respective dates. After launch, the spacecraft crosses through the orbit of Mars 5 times. Two times while moving inwards and three times while oriented outwards, with respect to the Martian orbit.

Chapter 4

Conclusion

In this report, 8 science opportunities during the cruise phase of ESA's JUICE spacecraft have been discussed, and their feasibility in terms of orbital alignment was assessed. An overview of all these opportunities is displayed in Figure 4.1. Alignments of JUICE with Europa Clipper, PSP, BEPI, Solar Orbiter, MAVEN and Mars Express will occur multiple times during JUICE's cruise phase. For studying the solar wind in the outer solar system, the most interesting conjunctions will occur after March 2027, when JUICE has moved past the orbit of Mars and is on its way to Jupiter. During this period, the intervals during which there is an alignment between JUICE, BepiColombo and NASA's Europa Clipper at the same time are of particular interest. These 'double alignment' intervals happen periodically every three months lasting about 10 days each. They offer a possibility to study the evolution of the solar wind from Mercury's orbit at 0.44 AU to around Jupiter's orbit between 5.35 AU and 5.53 AU. JUICE also has three conjunctions within 5° with the two Mars orbiters. Of these, the most suitable interval for simultaneous measurements is between 24/6/2027 and 3/8/2027, when JUICE is in the outer solar system at a radial distance of about 2.2 AU.

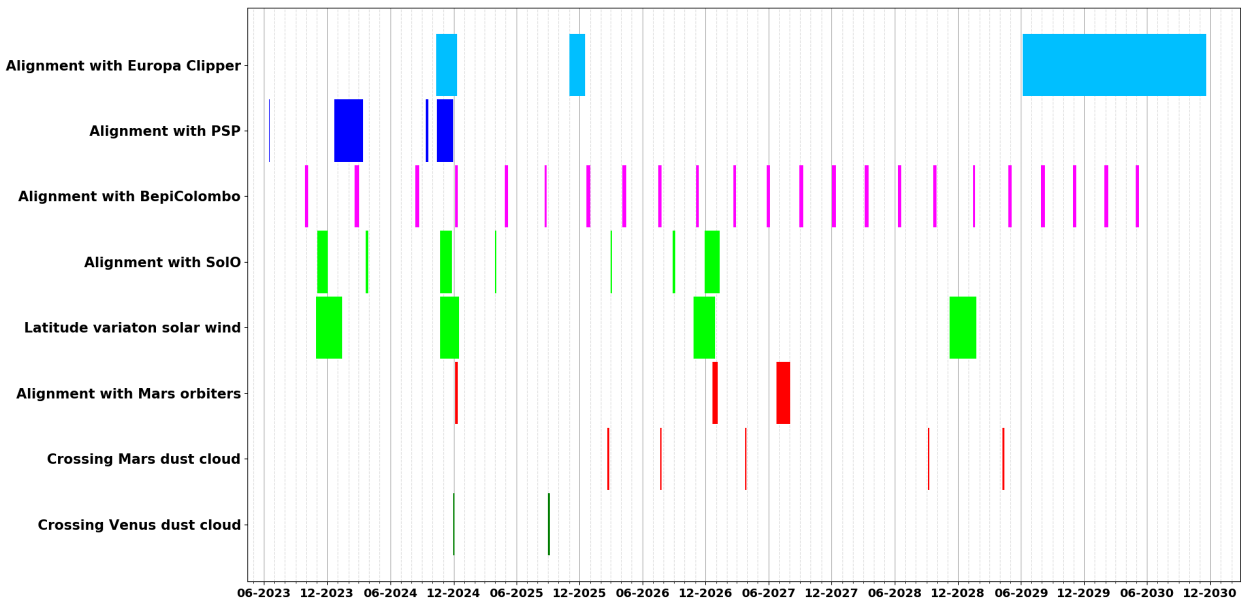

Figure 4.1: JUICE science opportunities calendar. This chart offers an overview during which periods all the science opportunities mentioned in this report occur.

Another science opportunity during JUICE's cruise phase is the start of the last period of alignment between JUICE and Solar Orbiter on 28/11/2026. Because the spacecraft will be close to each other at that time, the event could be used to calibrate the instruments of JUICE by comparing measurements performed simultaneously by the Solar Orbiter. We also found an opportunity for an experiment with both longitudinal and radial alignment between JUICE and Solar Orbiter. While Solar Orbiter changes latitude, it could measure solar wind variations while being in alignment with JUICE. Especially between 6/11/2028 and 22/1/2029, a large range of latitude angles is covered from 25.3° to 3.6°. In that period, the separation between the spacecraft in longitude of 35° and radial distance of 0.35 AU is large. Thus it is not sure if the variation in the solar wind along this direction is small enough to consider it a useful alignment.

Finally, we have also shown that JUICE crosses the dust halos of Mars five times and the one of Venus two times during the cruise phase. Therefore, one would expect JUICE to be able to detect the interplanetary dust in these regions, depending on the ability of the instruments on the spacecraft to perform such measurements.

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Chapter 5

Appendix

5.1 Other graphs

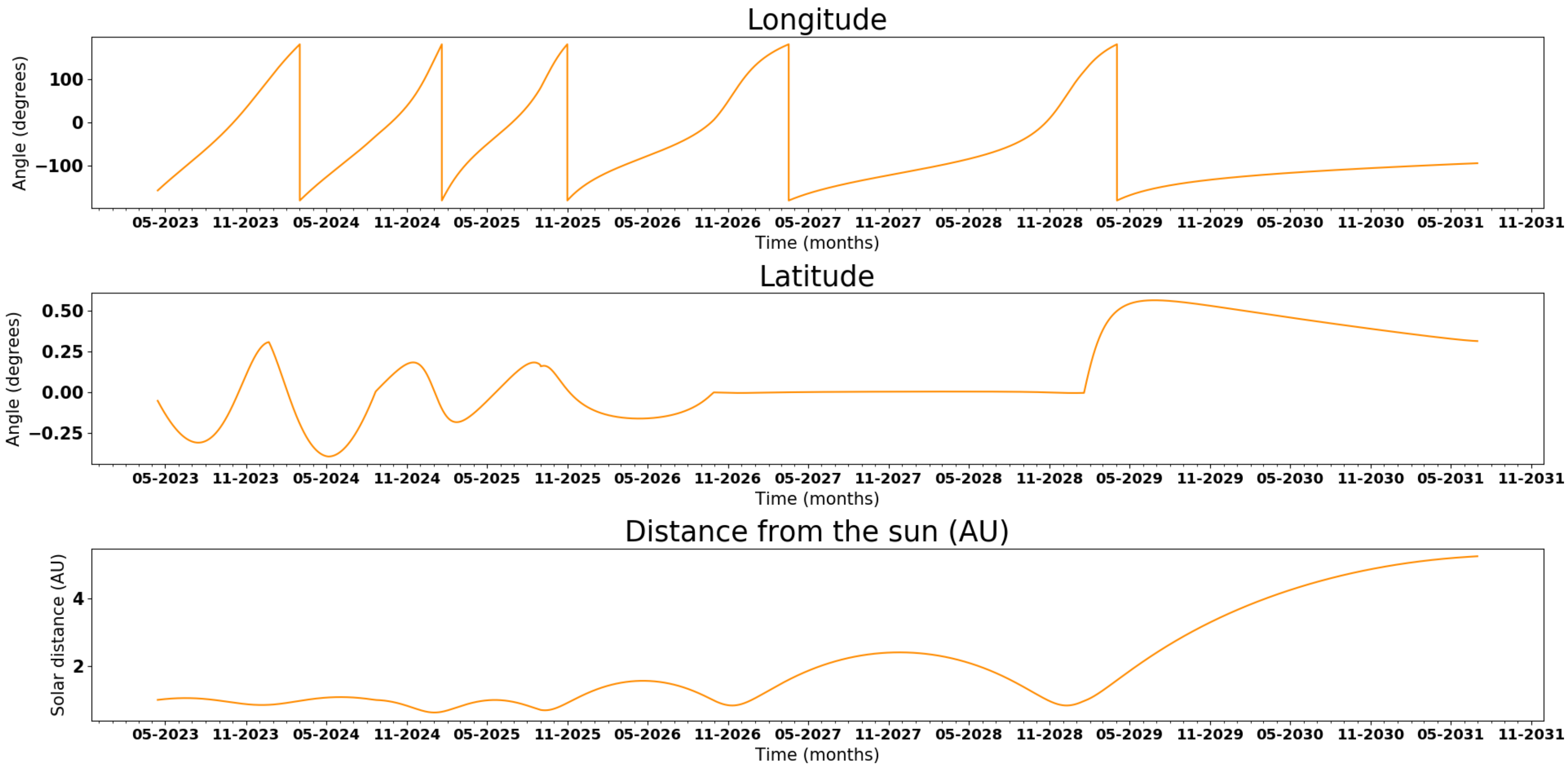

Figure 5.1: The coordinates of the Jupiter Icy Moons Explorer.

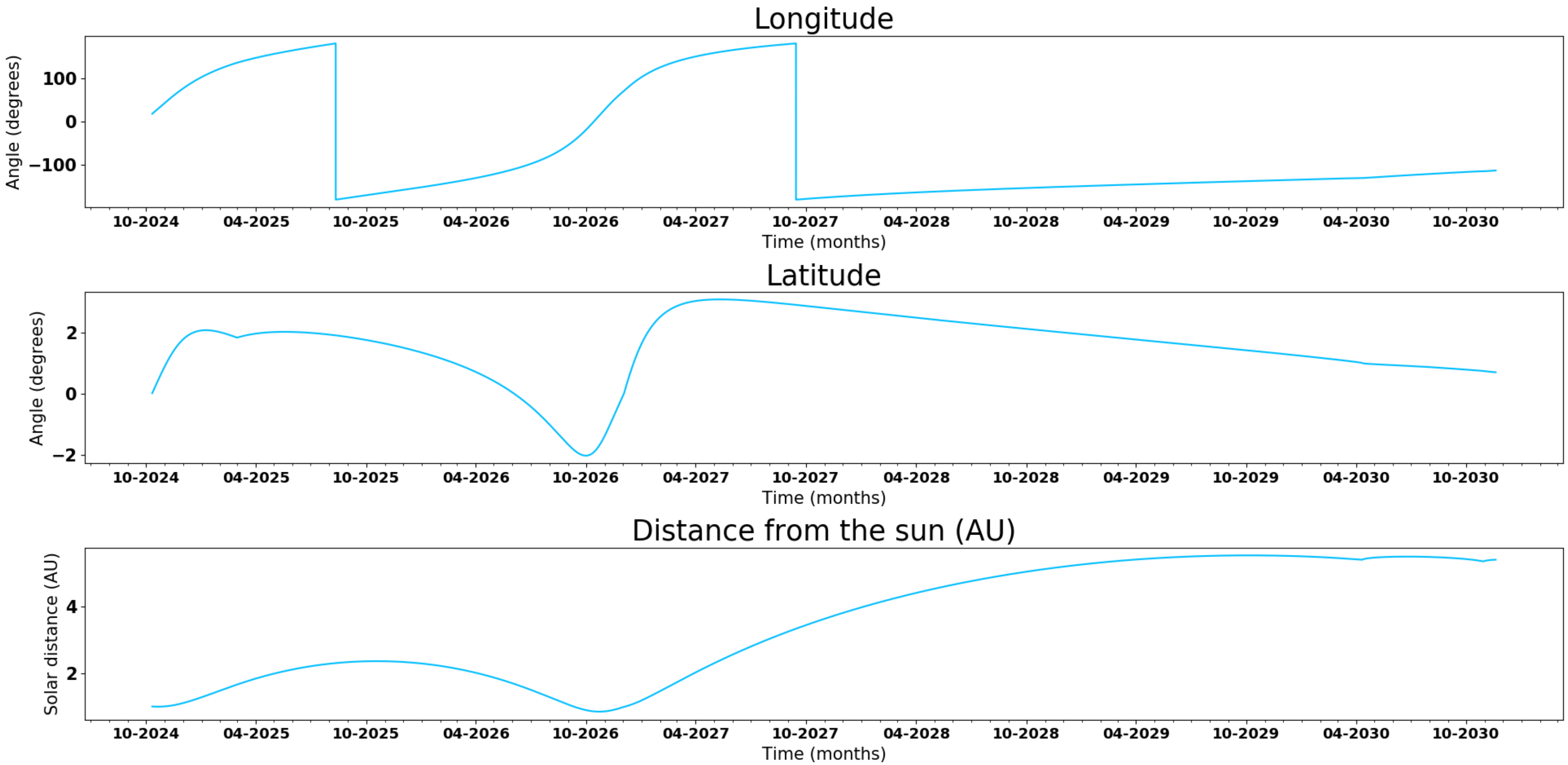

Figure 5.2: The coordinates of the Europa Clipper.

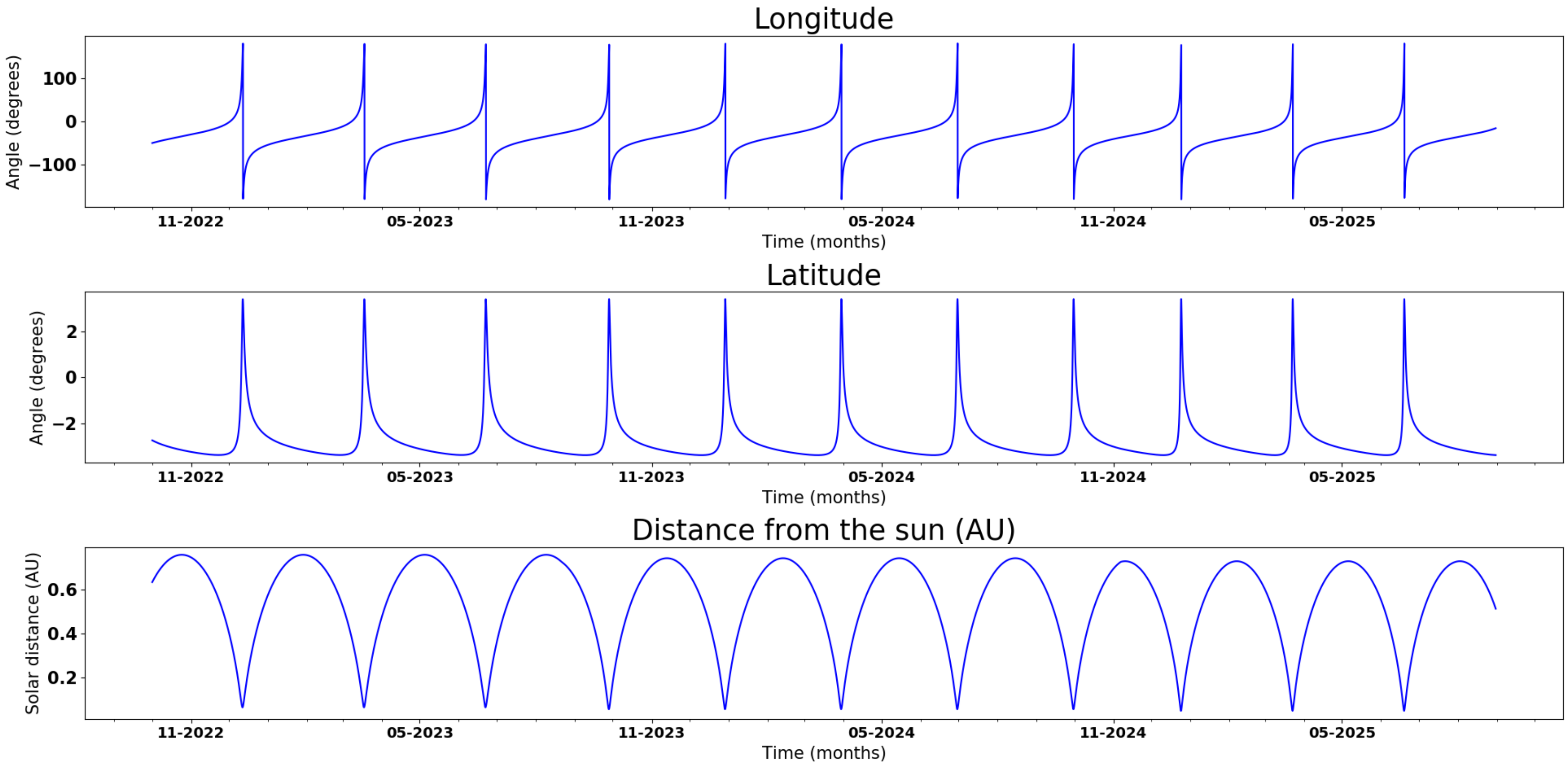

Figure 5.3: The coordinates of the Parker Solar Probe.

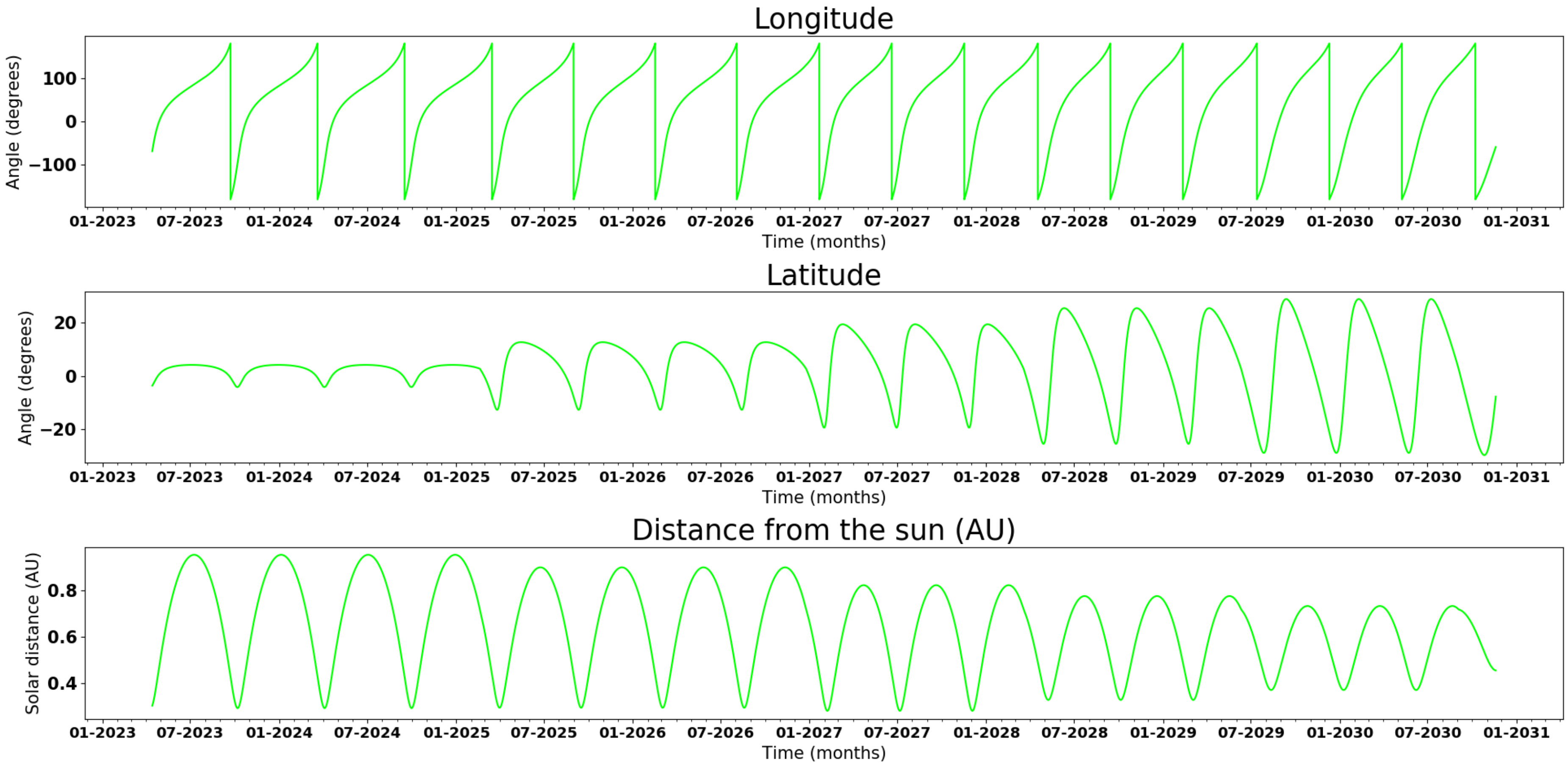

Figure 5.4: The coordinates of Solar Orbiter.

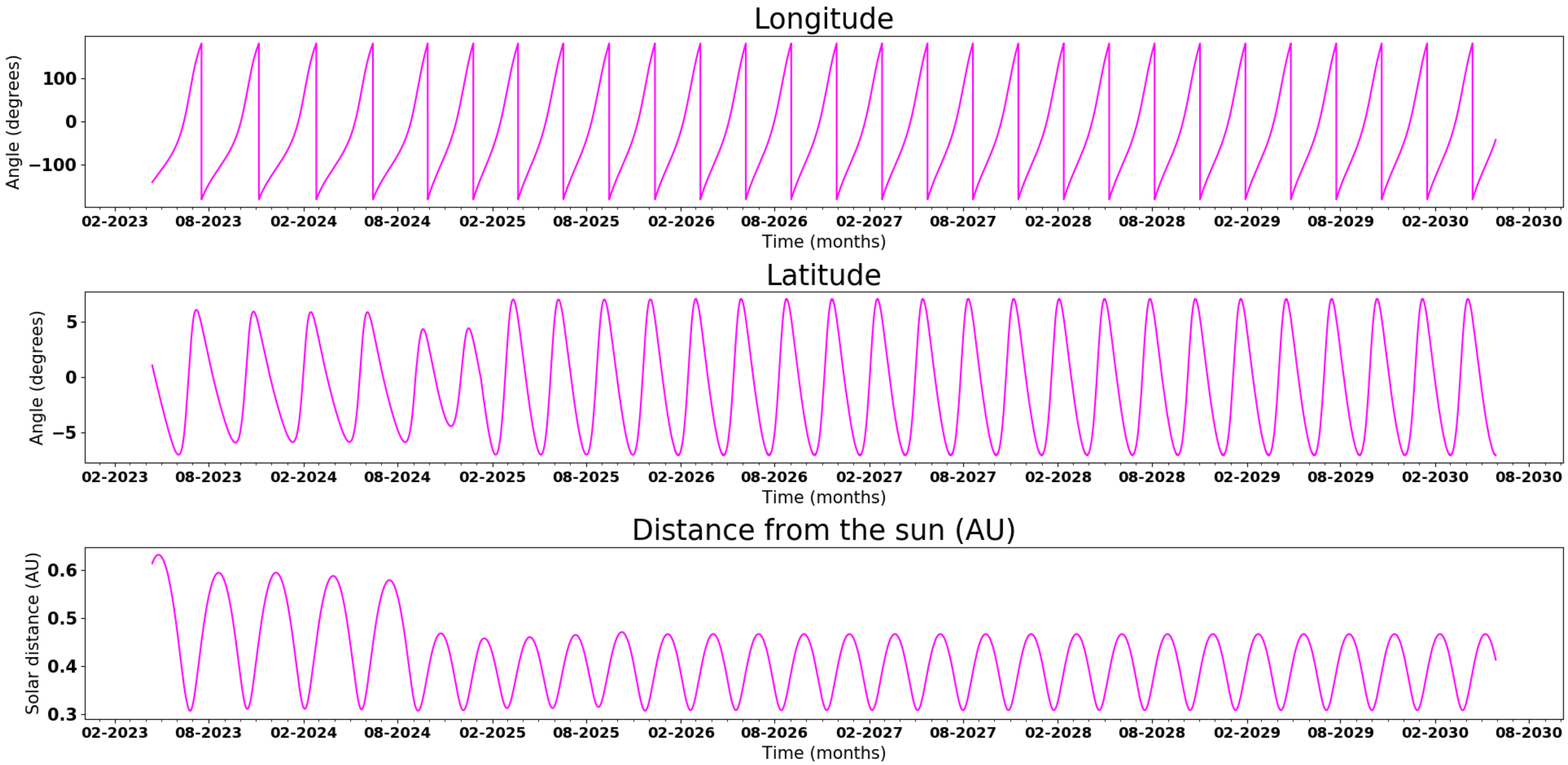

Figure 5.5: The coordinates of BepiColombo.

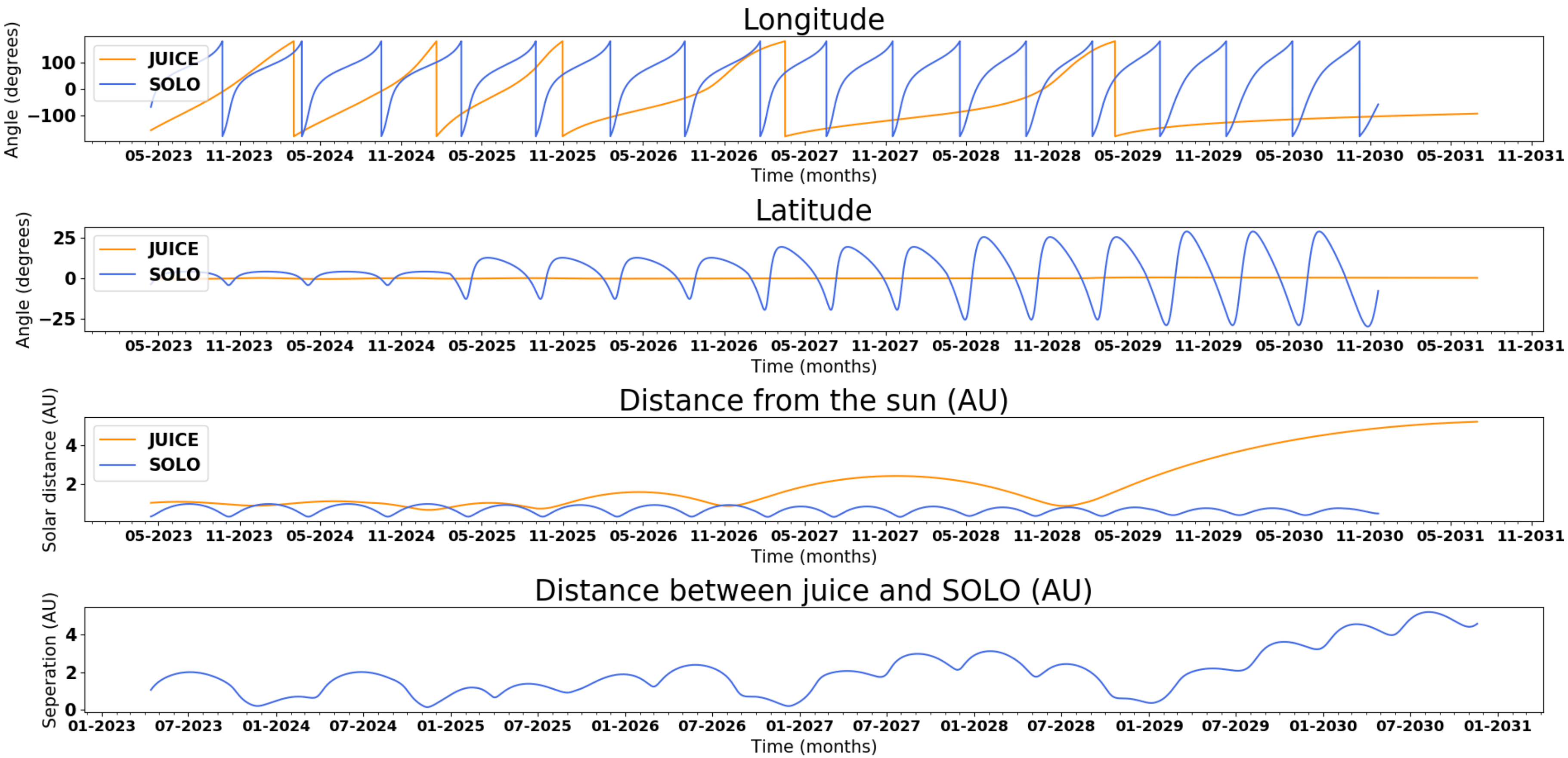

Figure 5.6: The coordinates of JUICE and SOLO.

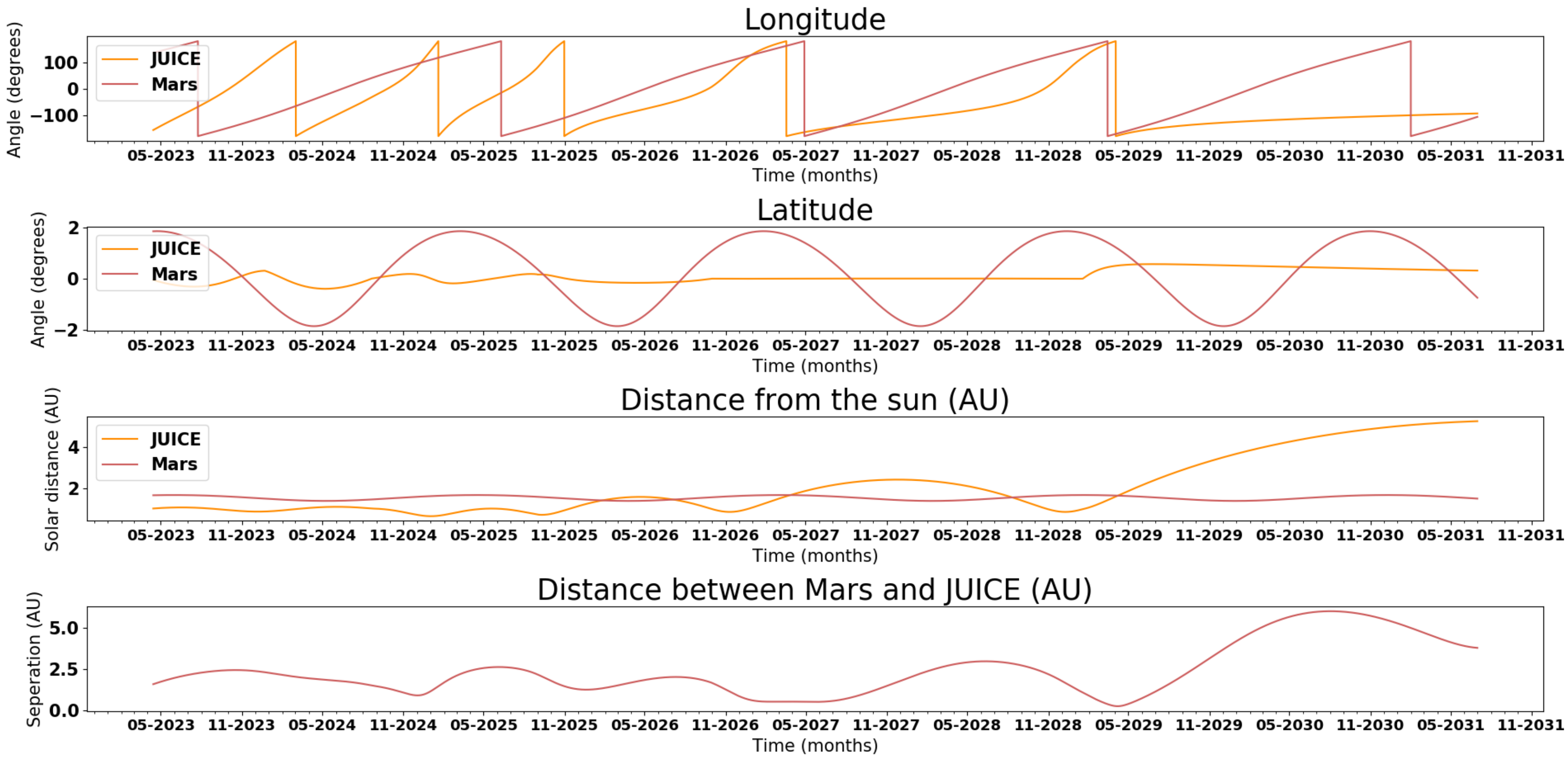

Figure 5.7: The coordinates of JUICE and Mars.

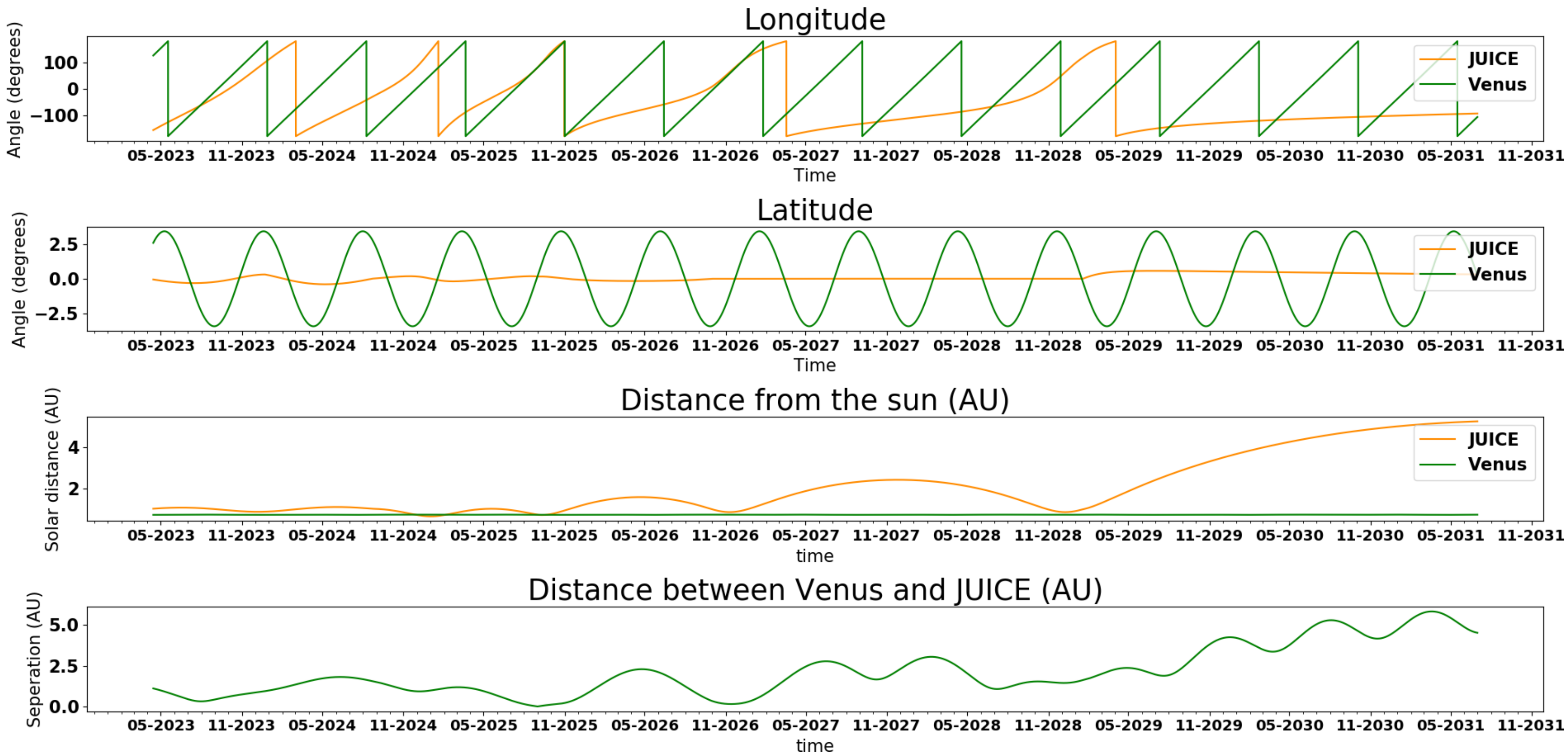

Figure 5.8: The coordinates of JUICE and Venus.

5.2 Instrument comparison

Europa Clipper — Plasma Investigation

PIMS: Key Instrument Parameters	
Ion Energy Range	0.1 – 50 eV/q, 0.02 – 7 keV/q
Electron Energy range	0.1 – 50 eV, 0.01 – 2 keV
Energy Resolution	<15%
Sensitivity	0.5 – 10^5 pA/cm^2
Time Resolution	1 – 4 s

JUICE — Key Instrument Parameters

PEP-JEI		PEP-JoEE		PEP-JDC		PEP-JENI		PEP-JNA	
Ion Energy Range		Ion Energy Range		Ion Energy Range	1 eV – 41 keV	Ion Energy Range	500 eV – 5 MeV	Ion Energy Range	
Electron Energy Range	1 eV - 55 keV	Electron Energy Range	25 keV – 1 MeV	Electron Energy Range		Electron Energy Range		Electron Energy Range	
Neutral Energy Range		Neutral Energy Range		Neutral Energy Range		Neutral Energy Range	500 eV – 300 keV (ENA)	Neutral Energy Range	10 eV – 3.3 keV (ENA)
Energy Resolution	8%	Energy Resolution	20%	Energy Resolution	12%	Energy Resolution	<14%	Energy Resolution	100%
Time resolution	2D per 512 ms / 3D per 4.1 s	Time resolution	1 s	Time resolution	2D per 250 ms / 3D per 8 s	Time resolution	≤10 s (ions) ≤5 min (ENA)	Time resolution	15 s nominal

Magnetometer

ICEMAG: Key Instrument Parameters	
Vector magnetic field accuracy	< 0.8 nT
Range	± 1500 nT
Precision	0.01 nT
Baseline stability	< 0.1 nT over > 3 yr
Spacecraft magnetic field knowledge	< 0.5 nT
Sampling rate	16 samples / sec

J-MAG: Key Instrument Parameters	
Absolute Accuracy	0.1 nT
Range	± 8000, ± 50000 (MAGOBS), ±16000(MAGIBS), 0-50000 (SCALAR)
Resolution	3 pT (scalar)/15pT(fluxgate, in ±8000nT range)
Baseline stability	0.2 nT (long term), 0.1 nT (short term)
Sampling rate	32-128 vectors/sec

Radio and Plasma Waves

RPWI: Key Instrument Parameters	
Electrons and ions	Number densities: 10-4 to 105/cm3 (with 20% accuracy) Electron temperature: 0.01 to 100 eV (with 20% accuracy) Bulk ion drift speed: 0.1 to 200 km/s (with 20% accuracy) Ion temperature: 0.02 to 20 eV
Plasma waves	Electric field variations: up to 1.6 MHz Magnetic field variations: 0.1 Hz-20 kHz. Spectral sensitivity (f>500Hz): 2 uV/m/sqrt(Hz) Angular and phase accuracy: 3 deg Amplitude accuracy: 3 dB
Radio waves	Frequencies: up to 45 MHz Accuracy of polarization: 10% Absolute flux calibration accuracy: 3dB Accuracy on direction of arrival: 1 degrees
DC electric fields	Electric field: DC <1 Hz range Amplitude accuracy: 0.1 mV/m
Spacecraft potential	±100 V (with 10% accuracy)

Jovian System Ephemeris

PRIDE: Key Instrument Parameters	
Wavelength	X-band (Ka-band optional)
Lateral position (1σ precision)	0.3 nrad (ICRF, S/C)

Overview Comparison

Type	Europa Clipper Instrument	JUICE Instrument
UV Spectrograph	Europa-UVS	UVS
Camera System	EIS	JANUS
NIR Spectrometer	MISE	MAJIS
Ice Penetrating Radar	REASON	RIME
Magnetometer	ICEMAG	J-MAG
Plasma Instrument	PIMS	PEP
Radio Emission		RPWI
Thermal Emission	E-THEMIS	
Mass Spectrometer	MASPEX	PEP-NIM
Dust Analyzer	SUDA	
Radio Science	Gravity	3GM
Very Long Baseline Interferometry		PRIDE
Sub Millimeter Wave		SWI
Laser Altimeter		GALA

Figure 5.9: A table containing the specifications of similar instruments on Europa Clipper and JUICE. For this report only the plasma investigation and the magnetometer instruments are relevant. The tables were taken from [11].