

The orbit of Solar Orbiter: characterization and  
implications for the METIS coronagraph (part I)  
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Rapporto nr.125

23/11/2009

# The orbit of Solar Orbiter: characterization and implications for the METIS coronagraph (part I)

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## ABSTRACT

In this report the main properties of the Solar Orbiter spacecraft orbit are characterized in the three different mission phases: after a general description of the total orbit, the report focuses on its characteristics around all passages at perihelia. Main implications for the METIS coronagraph field of view (which is expected to observe for about 30 days around perihelium passages) are discussed and limits on the maximum allowed off-pointing are provided.

	Nbr.	Time (years after launch)	Heliocentric distance (AU)
Cruise phase	1	0.28	0.72
	2	1.44	0.72
	3	2.08	0.41
	4	2.74	0.41
	5	3.40	0.41
	6	3.98	0.33
Nominal mission	7	4.43	0.28
	8	4.89	0.29
	9	5.35	0.28
	10	5.81	0.29
	11	6.24	0.23
	12	6.66	0.25
	13	7.05	0.23
	14	7.46	0.26
Extended mission	15	7.87	0.26
	16	8.27	0.27
	17	8.66	0.31
	18	9.08	0.30
	19	9.50	0.30
	20	9.87	0.35
	21	10.29	0.35
	22	10.69	0.35
	23	11.08	0.37
	24	11.47	0.37
	25	11.89	0.37

Table 1: heliocentric distances and latitudes at different Solar Orbiter perihelia.

## 1. SOLAR ORBITER ORBIT PROPERTIES

The Solar Orbiter mission has been divided in the following three phases:

- Cruise Phase (CP): first 3.83 years (2017-2020)
- Nominal Mission (NM): next 3.37 years (2020-2024)
- Extended Mission (EM): last 2.41 years (2024-2026)

The Solar Orbiter heliocentric distances as a function of time during these three phases are shown in Figure 1, where each star symbol represents a perihelium passage. Different colors in this Figure represent different phases during the mission: cruise phase (black), nominal mission (red) and extended mission (blue and green). In particular, there will be 8 perihelia during the nominal mission and 11 perihelia during the extended mission periods. Heliocentric distances and latitudes at each perihelium passage are shown in Figure 2: the closest approach will occur at perihelium nbr. 11, then in the following years the distance at perihelium will continuously increase, as it is also shown by values in Table 1.

In the meanwhile, latitudes at perihelia becomes larger: this is related to the progressive increase in the orbital plane inclination (with respect to the ecliptic) as a function of time. Figure 3 demonstrates this increase: in particular, plots in this Figure show the Solar Orbiter orbit as seen if projected above the planes X-Z (top) and Y-Z (bottom), where X is the nodal line and X-Y is the ecliptic plane. Again, different colors represent different mission phases (to be compared with same colors in Figure 1). As a consequence, the

Solar Orbiter spacecraft will spend different amounts of time at different latitudes during the various mission phases. This is quantitatively shown in Figures 4, 5 and 6: these bar plots show for each one of the three mission phases the number of days spent by the spacecraft over different latitude intervals. While during the nominal mission phase the spacecraft will never be located at latitudes larger than  $25^\circ$  (Figure 5), during the extended phase the spacecraft will spend 249, 225 and 48 days in the latitude intervals between  $25^\circ$ - $30^\circ$ ,  $30^\circ$ - $35^\circ$  and  $35^\circ$ - $40^\circ$ , respectively. Similar plots can also be created in order to show the time spent by the spacecraft at different heliocentric distances: Figure 7 shows the number of days spent over different heliocentric distance intervals during the nominal and extended mission periods.

## **2. METIS FOV CHARACTERISTICS related to the above orbital properties.**

Plots in Figure 7 have been created by taking into account the whole nominal and extended mission periods, while the METIS instrument will observe only over smaller time intervals of  $\sim 30$  days centered over the perihelium passage times. Hence, by taking into account only the METIS observation intervals around perihelia, it turns out that during the nominal mission period the METIS instrument will observe over a very small amount of time with the spacecraft between 0.25-0.27 AU (Figure 8) and a much larger time interval between 0.27-0.29 AU, while during the extended mission period METIS will never observe closer than 0.29 AU (Figure 9).

The FOV of the METIS instrument will change during the mission as it is shown in Figure 10, where the upper and lower FOV limits are plotted. As a consequence, the angle  $\theta_{\text{sun}}$  over which METIS see the distance of  $1 R_{\text{sun}}$  will also change with time, as it is shown by the plot in Figure 11: in particular this plot shows that the METIS inner occulter angle ( $1.3^\circ$ , upper solid straight line) is larger at any time than the angle  $\theta_{\text{sun}}$ . Nevertheless, in case of an off-pointing by  $1^\circ$ , the Sun light will hit the detector almost at any time during the orbit. This is better shown in Figure 12, where the maximum METIS off-pointing is plotted as a function of time over the whole mission period, both in degrees (upper panel) and  $R_{\text{sun}}$  (lower panel); obviously, the maximum off-pointing minimizes where the spacecraft distance also is minimum, hence at perihelia. Hence, in particular during perihelia, METIS instrument will have to be turned off at any off-pointing manoeuvre.

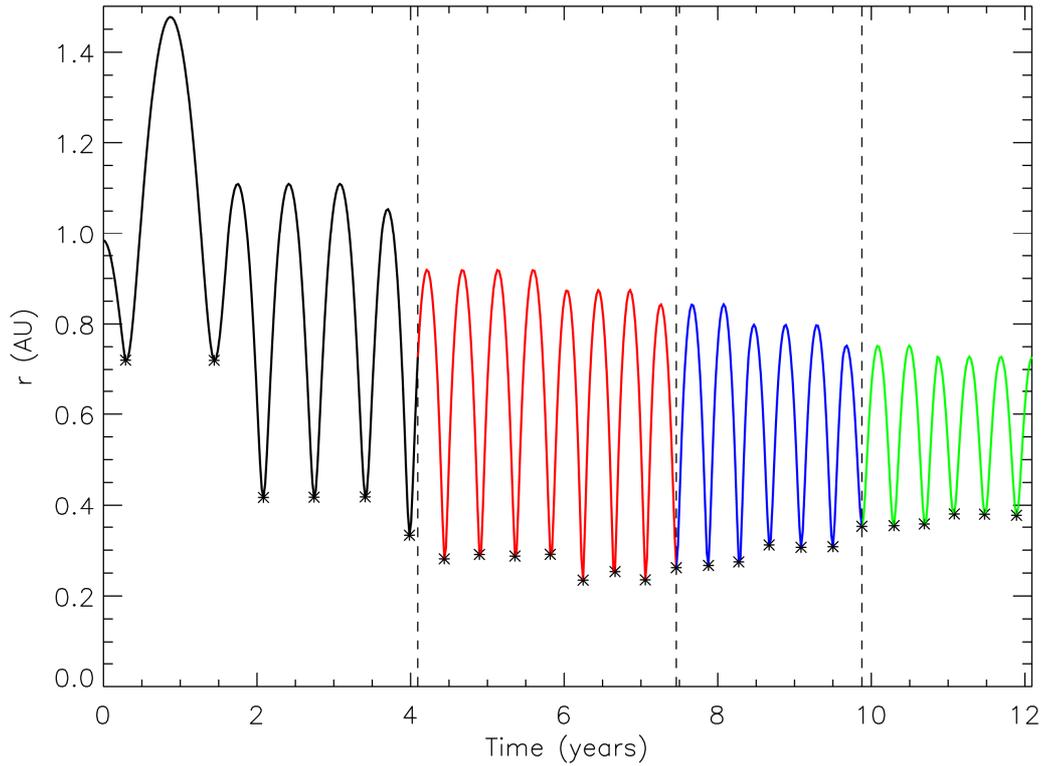


Figure 1: Solar Orbiter heliocentric distance during the whole mission period. Different colors outline different mission phases, in particular: cruise phase (black), nominal mission (red) and extended mission (blue and green).

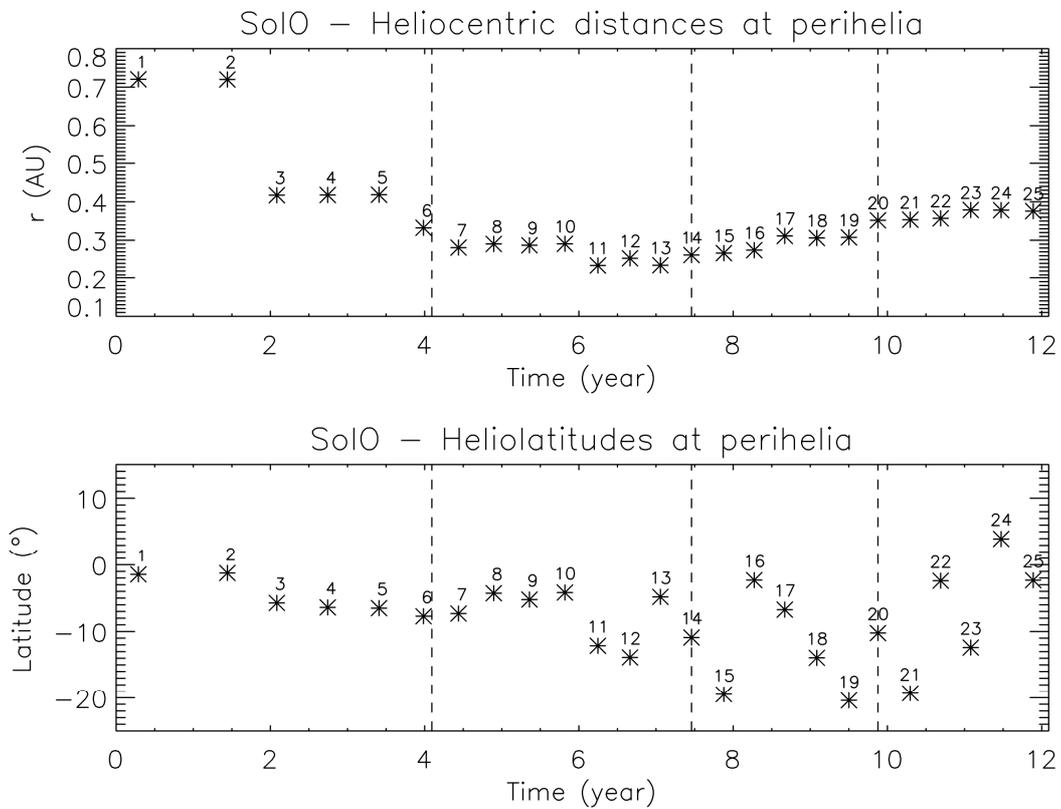


Figure 2: heliocentric distances (top) and latitudes (bottom) for each one of the spacecraft passages at perihelium.

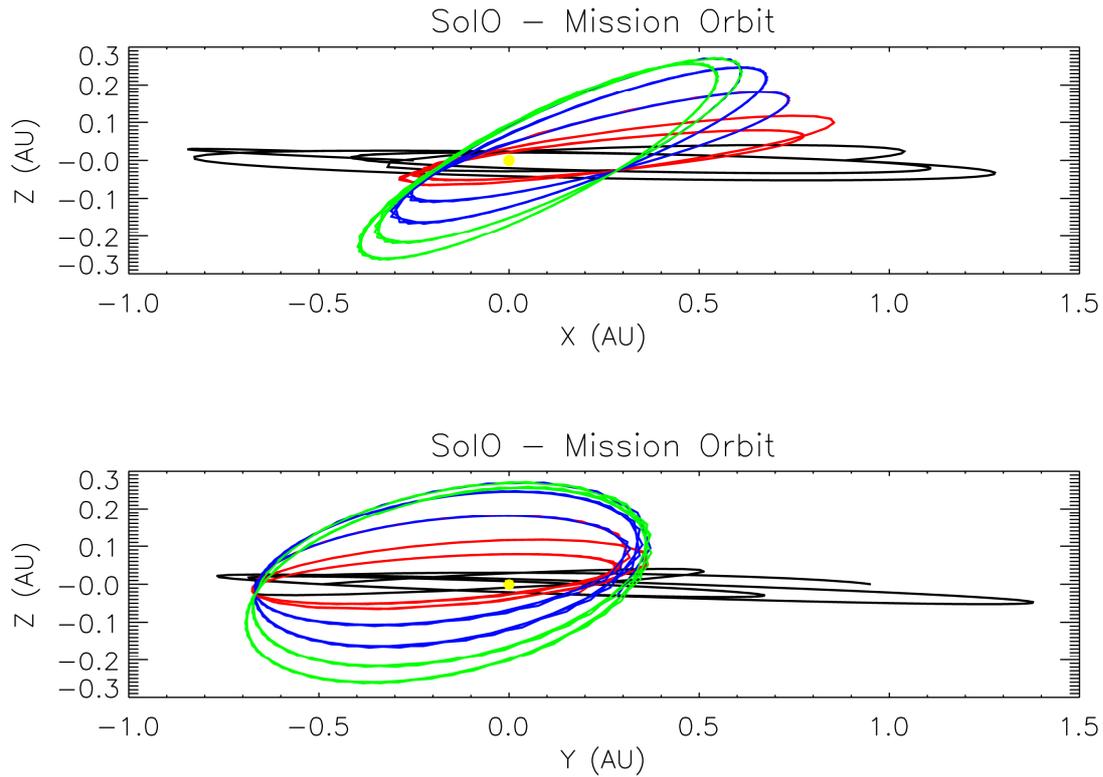


Figure 3: the Solar Orbiter orbit as seen if projected over the X-Z (top) and Y-Z (bottom) planes; different colors correspond to different mission phases (see Figure 1).

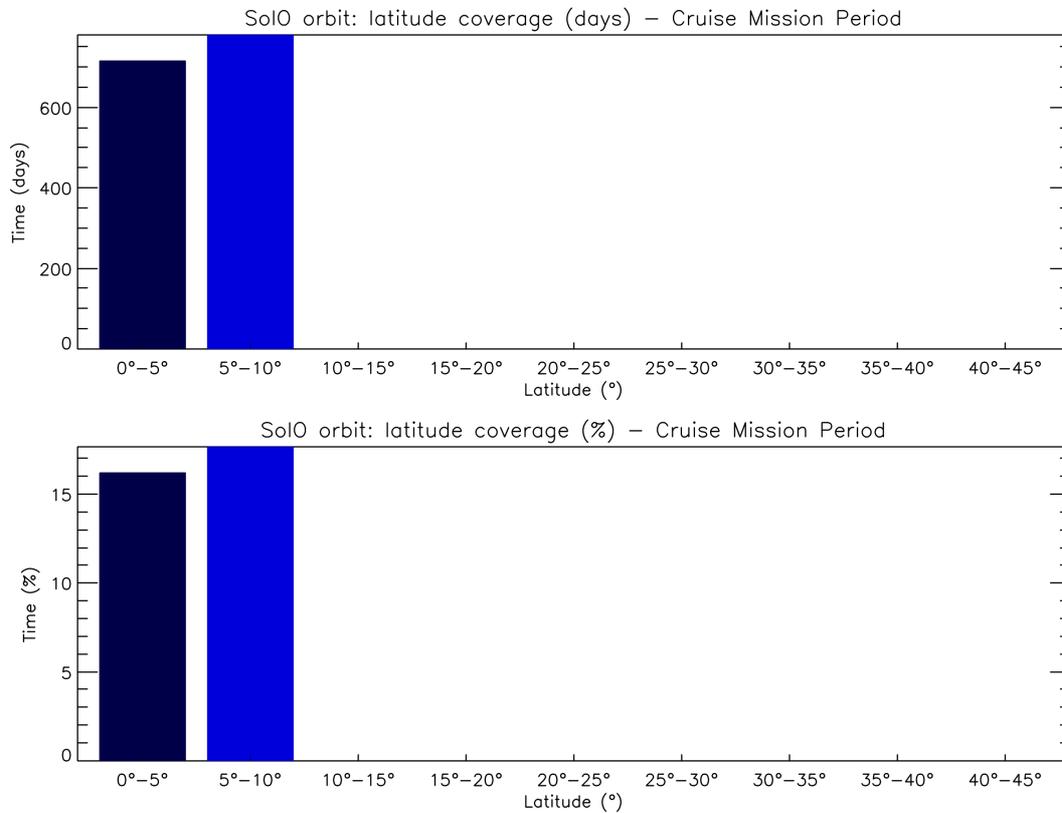


Figure 4: number of days spent by the Solar Orbiter spacecraft over different latitude intervals during the cruise phase.

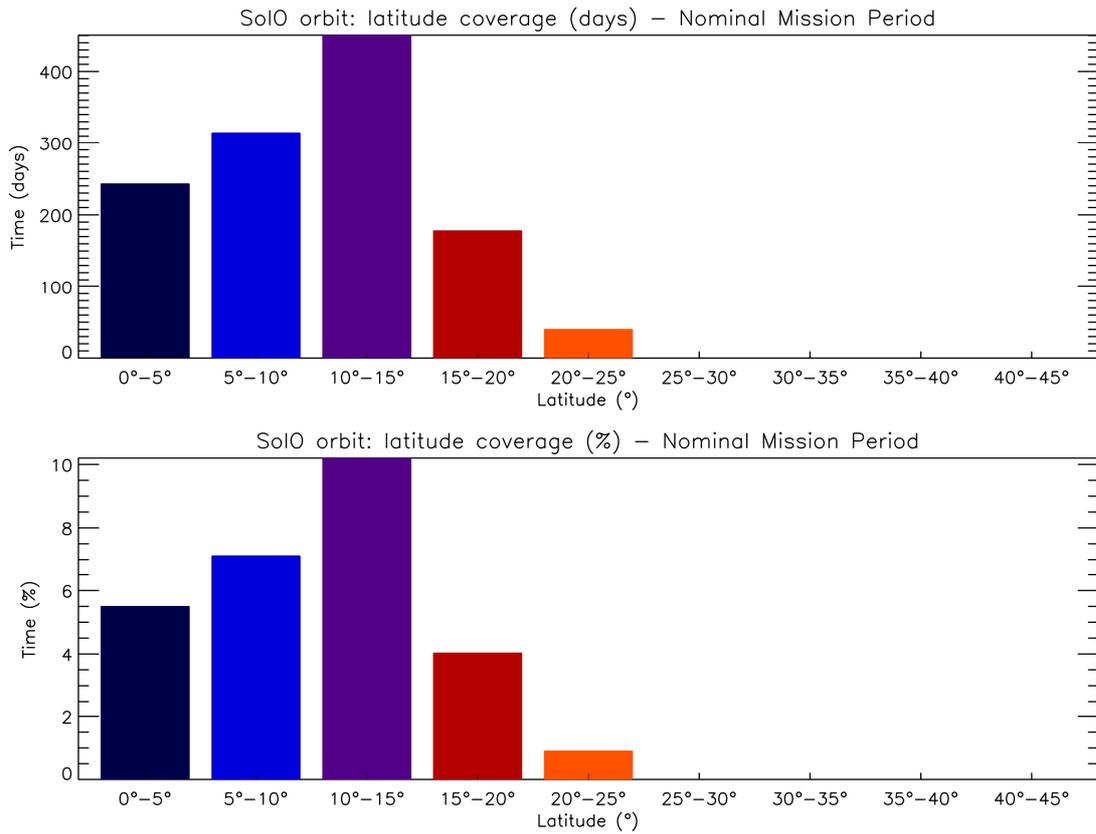


Figure 5: number of days spent by the Solar Orbiter spacecraft over different latitude intervals during the nominal mission phase.

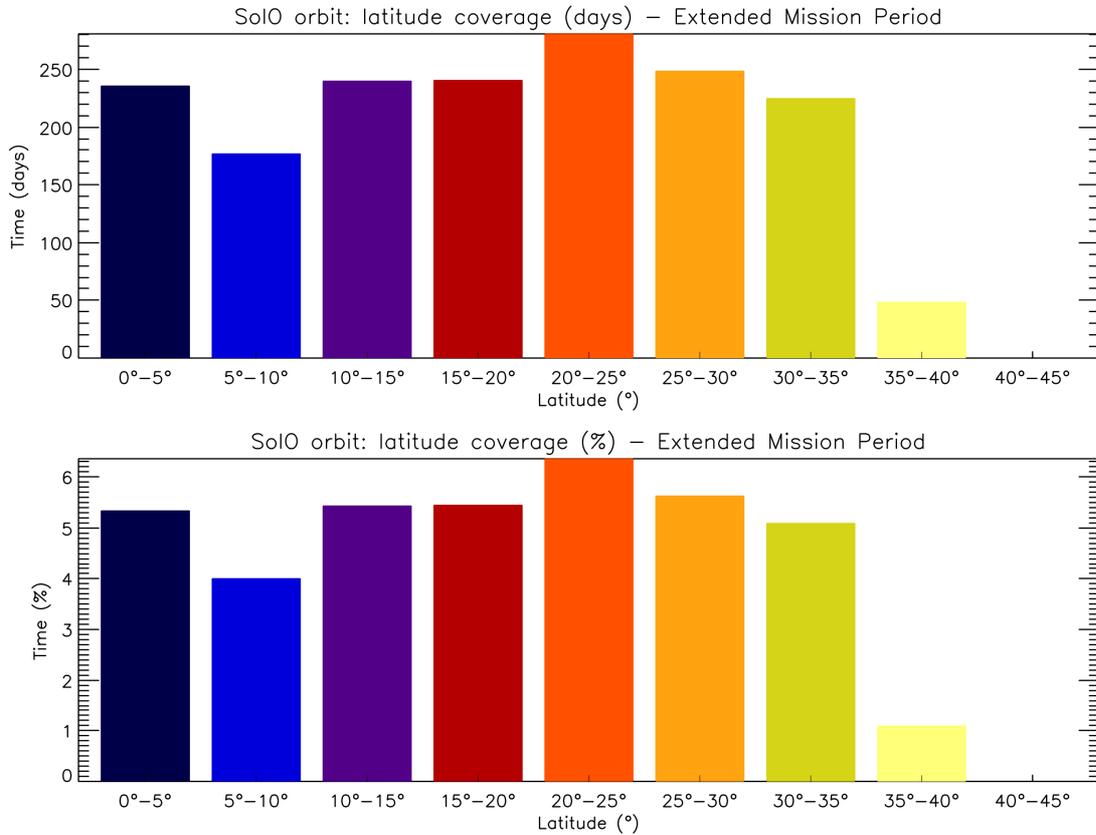


Figure 6: number of days spent by the Solar Orbiter spacecraft over different latitude intervals during the extended mission phase.

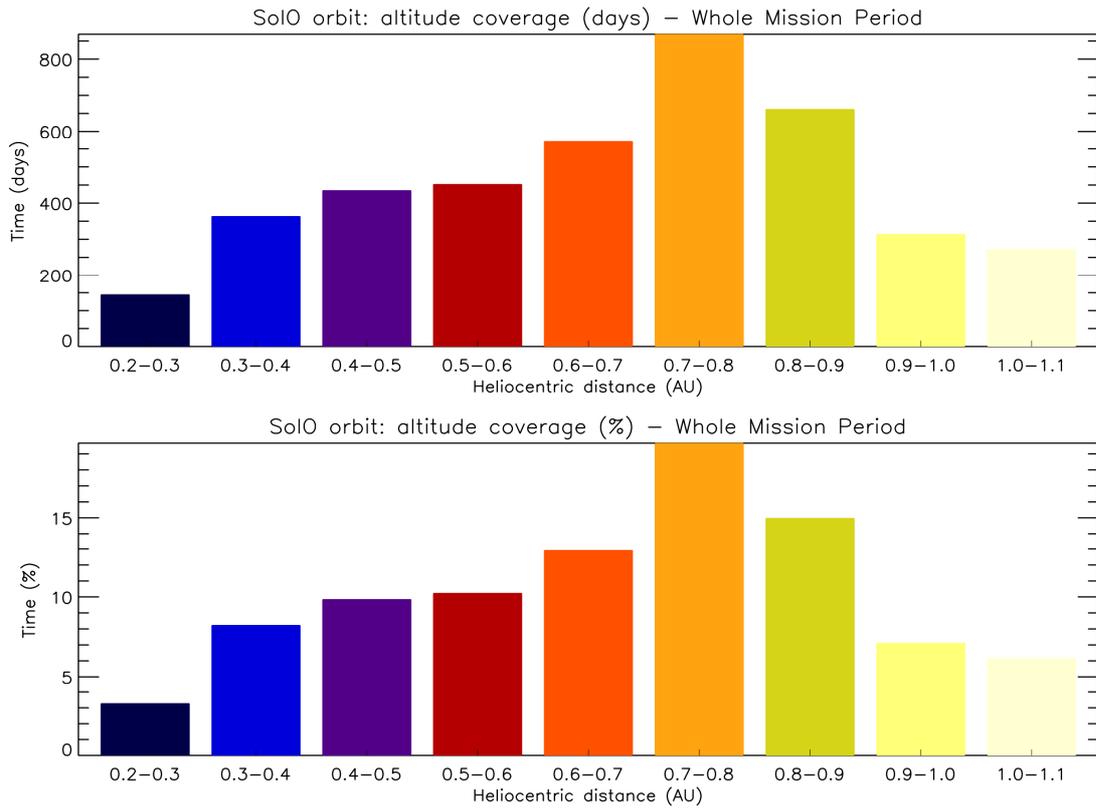


Figure 7: number of days spent by the Solar Orbiter spacecraft over different heliocentric distance intervals during the whole mission period.

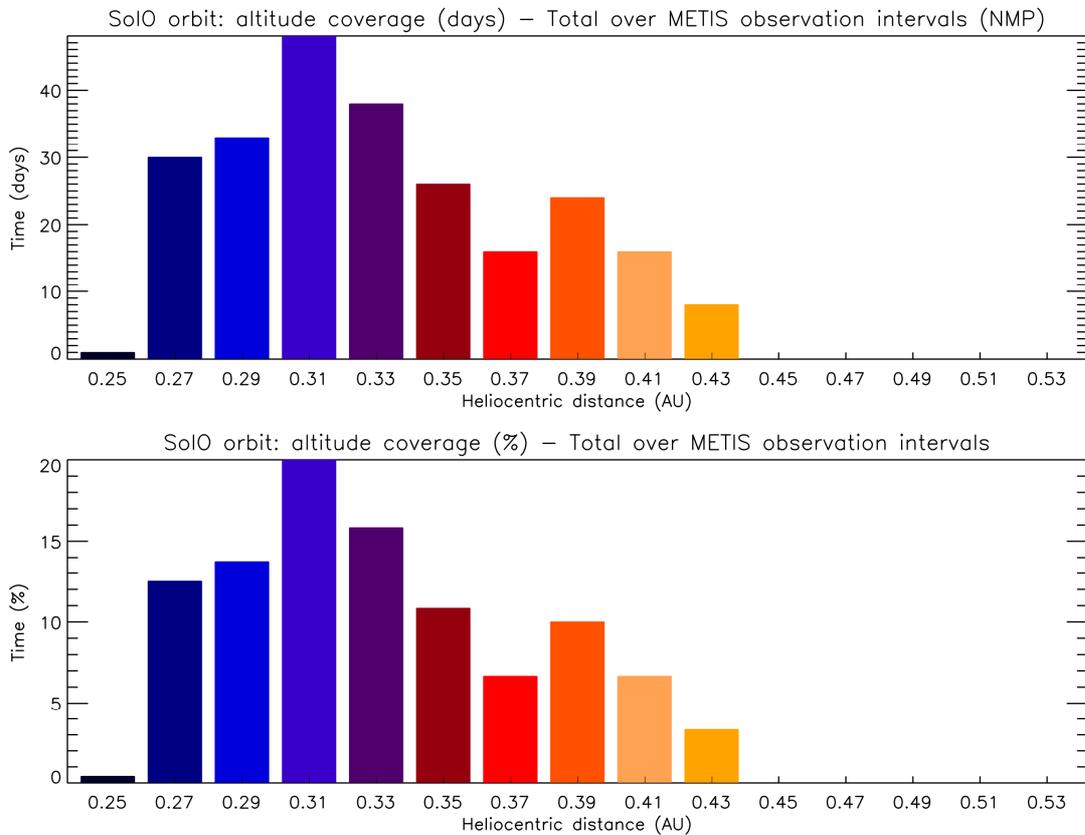


Figure 8: number of METIS observation days around perihelia over different heliocentric distance intervals during the nominal mission phase.

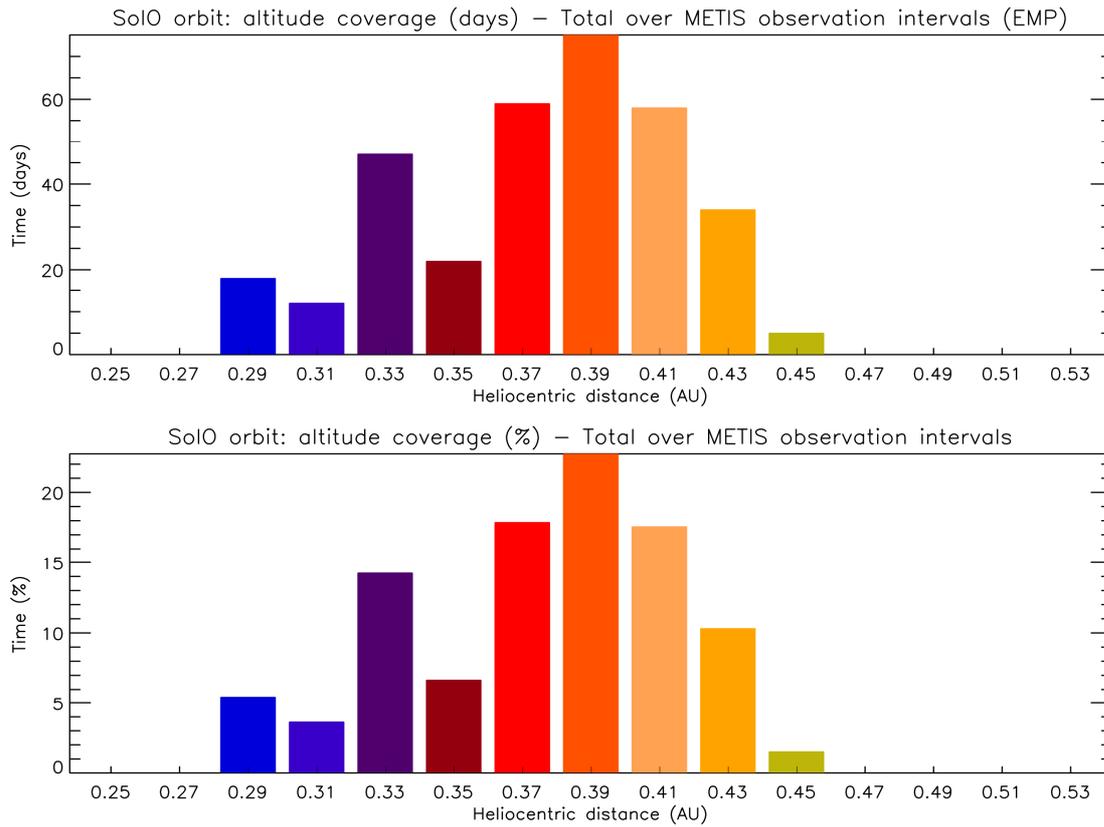


Figure 9: number of METIS observation days around perihelia over different heliocentric distance intervals during the extended mission phase.

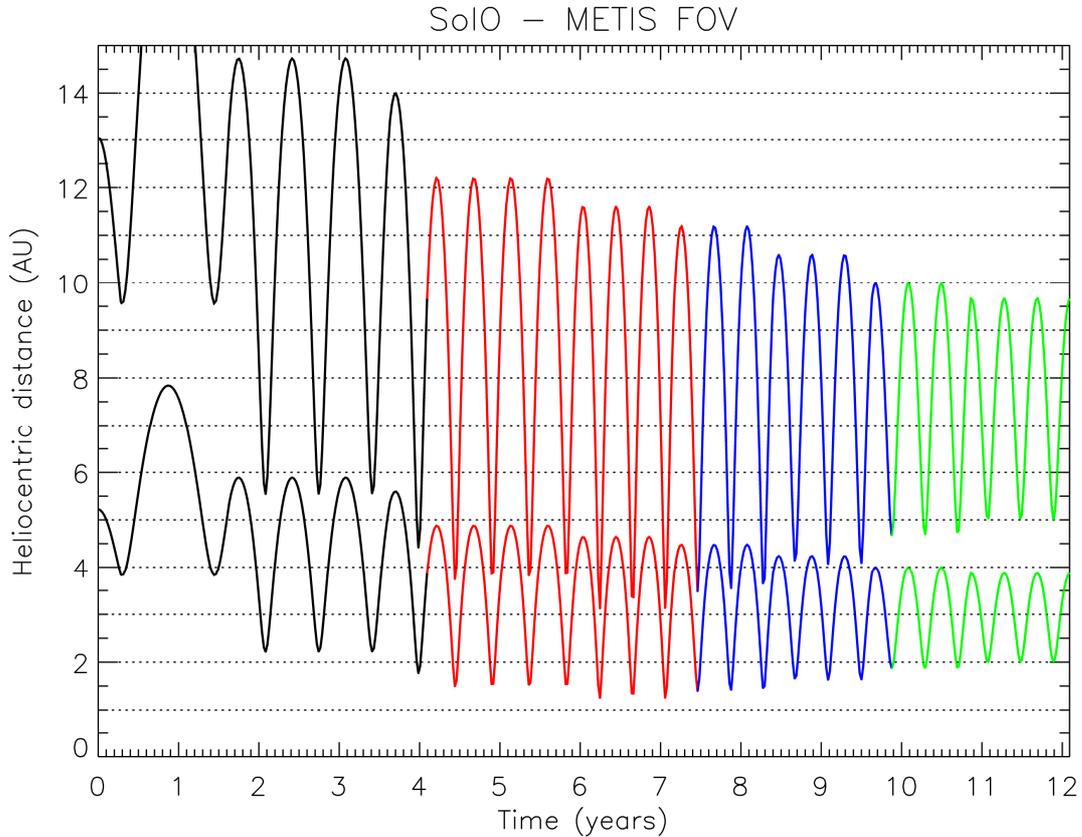


Figure 10: METIS field of view (FOV) as a function of time during the whole mission period. Upper (lower) curve shows the limit of the outer (inner) METIS occulter, different colors refer again to different mission phases.

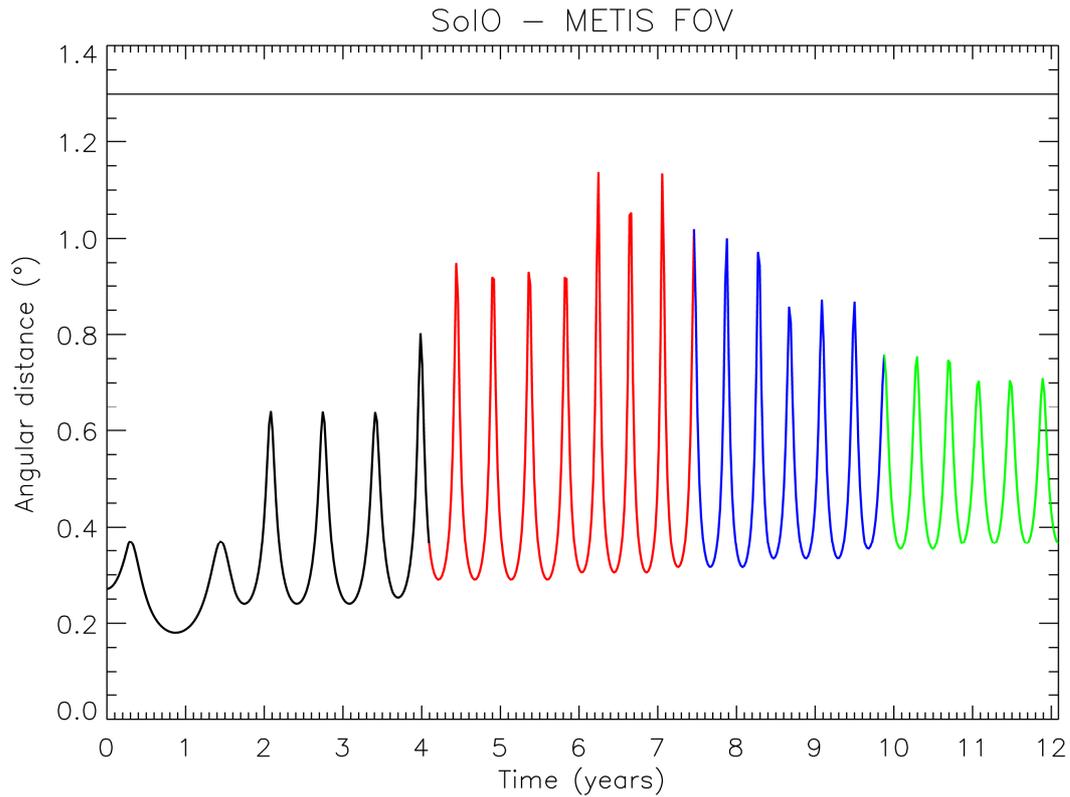


Figure 11: angle over which METIS will observe  $1 R_{\text{sun}}$ ; this angle is obviously smaller at any time than the METIS inner occulter angle of  $1.3^\circ$  (upper straight line).

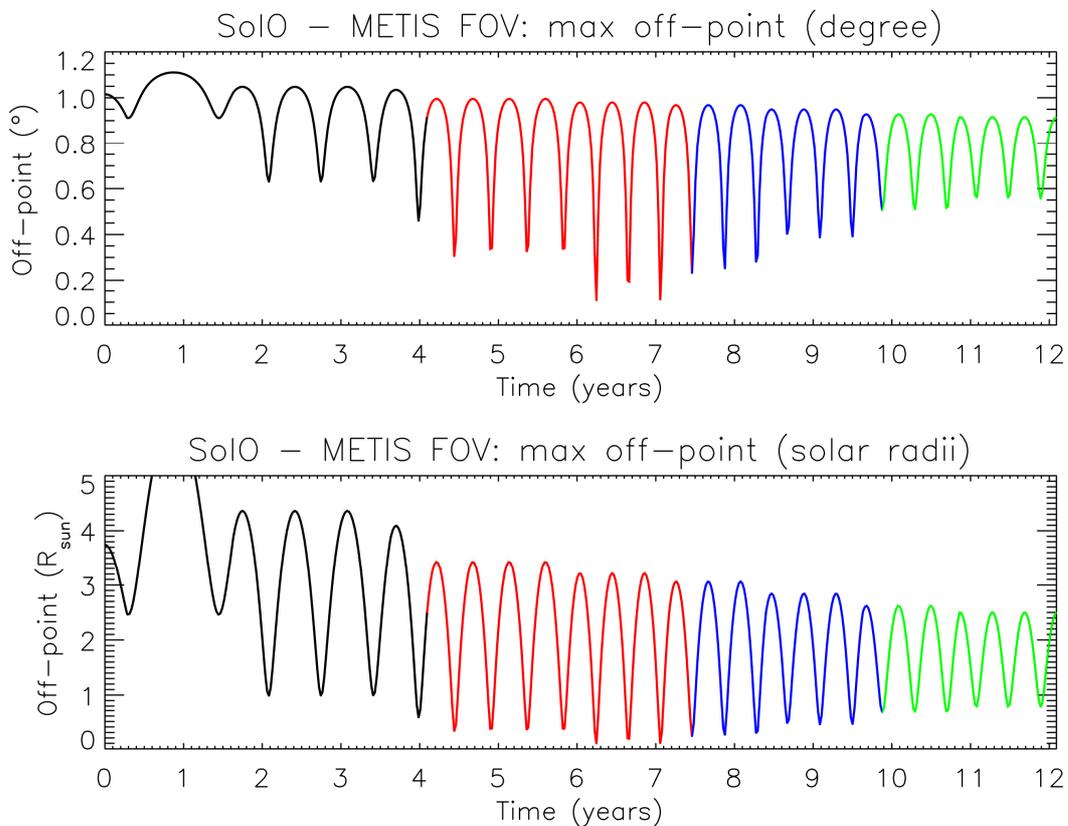


Figure 12: METIS maximum allowed off-pointing in degrees (upper panel) and solar radii (lower panel) during the whole mission period. This plot shows that for an off-pointing of  $1^\circ$  the METIS instrument will have to be turned off at any off-point manoeuvre.