In preparation of ESA's JUICE (Jupiter Icy Moons Explorer) mission we studied the variations of the S/C clock with respect to TDB due to relativistic effects. Figure 1 shows the deviations of the planets taken into account with respect to the S/C throughout the mission. Selected mission events of the trajectory are highlighted with the numbers (0) to (7). After launch in June 2022 (0) JUICE will fly to Jupiter on an interplanetary trajectory, including flybys at Earth in June 2023 (1), Venus in November 2023 (2) and again Earth in October 2024 (3) and October 2026 (4). After leaving the inner planets (5) JUICE will arrive in the Jupiter system around 2030 (6). Two Europa, several Callisto and Ganymede flybys will follow while JUICE is in orbit around Jupiter. Finally JUICE will enter a Ganymede orbit where it remains until mission end in July 2033 (7). Figure 2 shows the absolute velocity of the S/C with respect to the SSB throughout the mission. Large variations in velocity can be seen around the flybys, targeting the trajectory to the Jupiter system and during the orbit phase in the Jupiter system. These changes occur on shorter time-scales than during the interplanetary cruise due to the orbits around Jupiter and its moons.

In order to retrieve the variation of the rate of the clock we used the NAIF SPICE toolkit in combination with JPL planetary ephemerides DE430 and the JUICE nominal mission trajectory kernel. For the calculation of the potential at the clock’s location the Sun, Mercury, Venus, Earth and its Moon, Mars, Jupiter and its moons to Europa, Ganymede, Callisto were incorporated. Saturn was not considered in the analysis because its minimum distance to JUICE throughout the mission is < 8.3 AU. Since TDB was chosen as the reference system, the TDB values of the gravitational parameters were taken from (4). By using the distances of the incorporated bodies to the S/C at a certain point in time \( \varphi \) was calculated for every point along the trajectory. Figure 3 shows the deviation of the S/C clock rate with respect to TDB plotted as \( \frac{d\varphi}{dt} \) in units of \( 10^{-15} \mathrm{s}^{-1} \). The Markers (1) to (6) were derived from this curve and applied to all the other plots, in order to identify the reasons for the largest changes in the S/C clock rate. The jump at (1) is related to the first Earth flyby, while during the peak at (2) the S/C performs a Venus flyby and reaches its closest distance to the Sun throughout the mission. The peak at (3) is related to the second Earth flyby, as well as close approaches of Sun, Venus, Mars and Jupiter during their trajectory variations respectively - cf. (1) (4) marks the third and last Earth flyby while again the Sun, Venus and Mars are close at that time - cf. (1) (5) is interpreted as the point of transition from the inner planets to the Jupiter system along the S/C trajectory. From that point on the influence of Jupiter’s gravitational potential steadily increasing as the S/C is getting closer to it. (6) marks the arrival of the S/C in the Jupiter system. Owing to the short periods of the orbits in the Jupiter System, changes of the rate are on shorter time scales.

Most of the time throughout the mission the S/C clock runs faster than TDB, except around the events (2) and (3) - cf. Figure 4 shows the accumulated offset in time between the S/C clock and TDB, plotted as \( \int \frac{d\varphi}{dt} dt \). At the end of the mission after \( \approx 11.5 \) years, the S/C clock is \( \approx 3.22 \) s ahead of TDB, clearly demonstrating the relevance of general relativistic effects for the mission.

**References:**