PLANNING SCIENCE OPPORTUNITIES WITH THE JUICE MOON COVERAGE TOOL. B. Seignovert[1], N. Altobelli[2], I. Belgacem[2], R. Robidel[3], G. Tobie[1] and C. Vallat[2], [1]Université de Nantes, Univ Angers, CNRS, LPG, UMR 6112, F-44000 Nantes, France, [2]European Space Agency (ESA-SOC), Camino Bajo del Castillo, s/n, E-28692 Villanueva de la Canada, Madrid, Spain, [3]LATMOS/IPSL, UVSQ Université Paris-Saclay, Sorbonne Université, CNRS, Guyancourt, France.

Background: The ESA Space Operations Centre (SOC) is supporting the science activity plan development, in collaboration with the instrument teams and the Project scientist and the Science Working Team (SWT). One of the high science priority of the JUICE mission is to improve the understanding of geological processes on the Galilean icy satellites. To this end, the JUICE SOC needs to analyse what are the best opportunities for the JUICE payload to map the surface of each moon under acceptable geometry conditions. In addition, the JUICE SOC also needs to assess the quality of an observations plan w.r.t the science requirements, to study and visualize the spatial coverage of the Jupiter's 3 main moons (Europa, Ganymede and Callisto) at different scales (global, regional, local).

The moon-coverage tool: To address these requirements, we developed the `moon-coverage` tool. It's a python package, based on `numpy`, `matplotlib` and `spiceypy` [1] and under active development by the CNRS/University of Nantes.

The tool provides an overview of the opportunities (single and cumulated) to observe the surface of the Jupiter's moons. It can identify opportunities to observe a given surface area under specific conditions as well as to provide surface coverage maps.

Most of the kernels management is performed internally and does not require prior configuration by the user. We also provide high level object-oriented APIs on top of the SPICE routines [2] to simplify their usage as much as possible. The trajectory data can be easily represented on various icy moons' basemap and color-coded with any viewing parameters. For example, the Figure 1 showcases the complete set of Callisto's flybys expected during the mission.

When a trajectory calculation is performed, the user can also select a subset of temporal sequences that match its criteria. The Figure 2 represented the evolution of the altitude during the Ganymede orbital phase, and we selected only the segments where the spacecraft is below $500\,\mathrm{km}$ and on the dayside of Ganymede (ie. with an incidence lower than $90°$).

Finally, the tool is also capable of performing surface intersection between the sub-observer trajectory and a designated Region Of Interest (ROI) on the surface. The ROI can be manually defined by the user as a contour with any geometric shape or it can be imported from the Ganymede and Callisto collections of ROIs [3]

that come directly with the tool (see Figure 3).

Usage on ESA DataLabs: This tool is mainly focus on JUICE requirements but can easily be extent for other space mission. We also deployed it on the ESA DataLabs infrastructure in March 2021, to allow the JUICE SWT members to get their hands on the tools quickly, without any prior setup (everything is pre-configured for the user in a JupyterHub environment with the latest set of SPICE kernels).

Limitations and perspectives: Currently, the tool is only able to perform its computations on the sub-observer groundtrack and does not include the spacecraft attitude (only the nadir viewing geometry is implemented). However, we are actively working to support the instruments field of view intersection with the surface to provide a more accurate description of the instrument opportunities. In the near future, we will add additional stereographic and orthographic map projections. Finally, we also plan to include a graphical user interface (with buttons, sliders and menus) to add more interactivity with the data for the user.

Availablity and contributions: The source code is distributed under BSD 3-clauses licence and is available on the JUICE's Gitlab. It is continuously tested on Python 3.6/3.7/3.8/3.9 and regularly deployed on PyPI (currently the latest version of the tool is `0.7.0`). A complete documentation is available on ReadTheDocs and a set of basic examples can be found in this Jupyter Notebook Viewer. Contributions from external users are welcome and feedbacks can already be addressed on our Gitlab instance.

References: [1] Annex A. et al. (2020) *Journal of Open Source Software*, 5(46):2050. [2] Acton C. H. (1996) *Planetary and Space Science*, 44:65–70. [3] Stephan K. et al. (2021) *Planetary and Space Science*, (under review). [4] Kersten E. et al. (2021) *Planet. Space Sci.*, (under review).
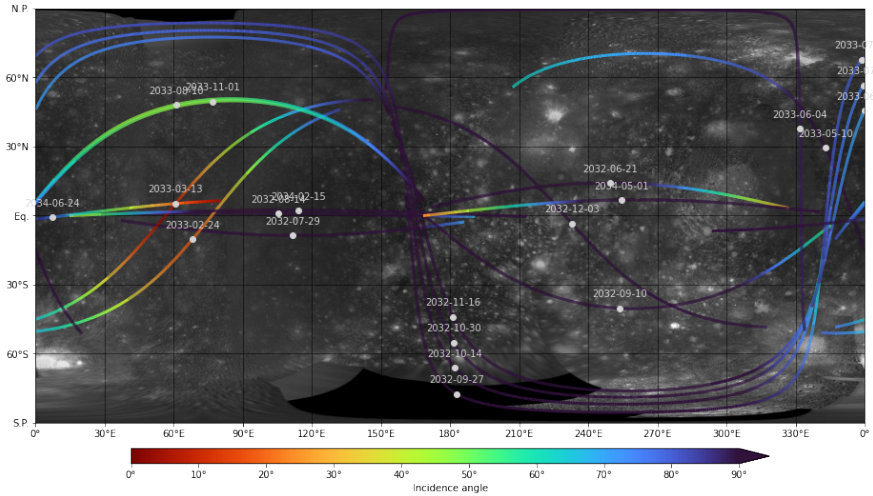
Figure 1: All the Callisto flybys with CReMA `4.2b22.1`. The line is color-coded based on the incidence angle of the sub-observer point between 0° and 90°.
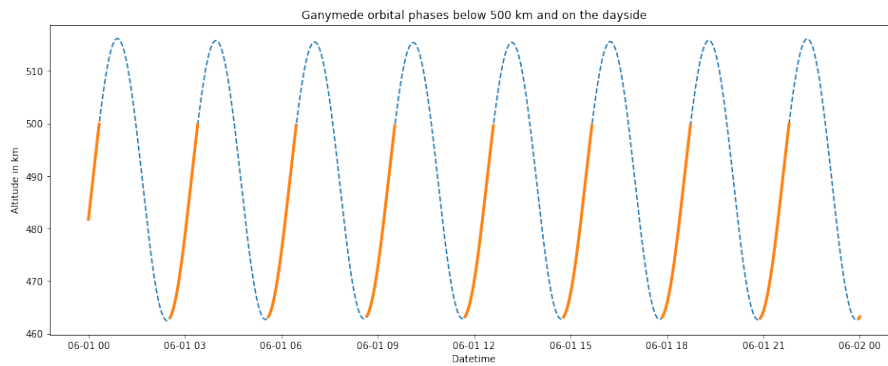

Figure 2: Selection of the segments of trajectory (in orange) where the altitude is below 500 km on the dayside during the Ganymede orbital phase (with CReMA `4.2b22.1` in June 2035). The complete trajectory is represented in blue dashes for reference.
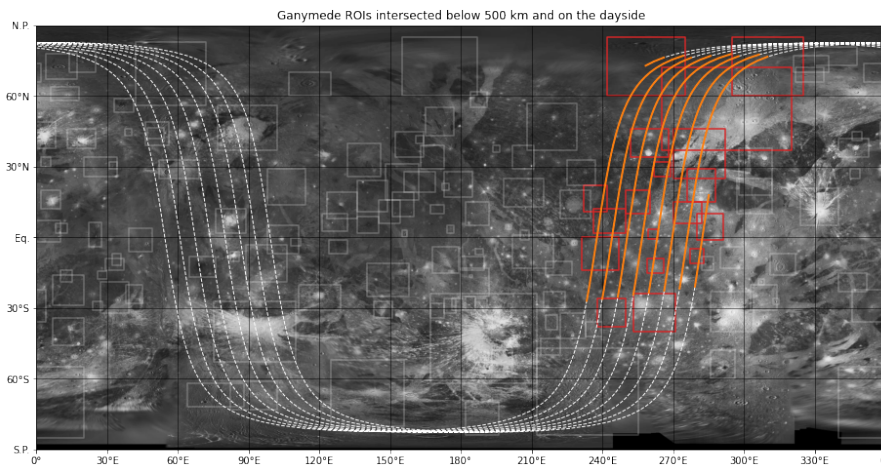

Figure 3: Intersection between Ganymede ROIs [3] and JUICE groundtrack trajectory in June 2035 (with CReMA `4.2b22.1`) when the altitude is below 500 km and on the dayside (in orange). The data are projected on Ganymede latest basemap [4].