THE JANUS CAMERA ONBOARD ESA JUICE MISSION: THE SCIENCE PLANNING STRATEGY.

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Introduction: The Jupiter Icy Moons Explorer (JUICE) mission is the first Large (L-class) mission selected for the European Space Agency (ESA) Cosmic Vision 2015-2025 program devoted to exploring the Jupiter system and investigating the icy Galilean satellites Europa, Ganymede and Callisto [1]. Among the several instruments, JANUS (Jovis Amorum ac Natorum Undique Scrutatator) is the optical camera system onboard the JUICE spacecraft [2], whose scientific objectives are the surface characterization of the icy moons, the study and analysis of geological processes such as cryovolcanism and impact craters formation, the study of Ganymede's rotation and libration, the study of Io's volcanic thermal activity, and the observation and monitoring of Jupiter's atmosphere and its dynamics, rings, small moons, aurorae and the exospheres of its Galilean satellites.

In this work, we report the JANUS preliminary science planning that has been developed to maximize the scientific return based on the instrument capabilities. In particular, we present which type of observations we expect to perform during the mission phases that will occur before entering in orbit around Ganymede, hence highlighting how the achievement of science goals is strictly related to the resources available to the instrument. This preliminary work is pivotal to provide a first estimate of the data volume (DV) that would be generated by the JANUS camera and highlights the targets coverage that will be obtained.

The JANUS camera and the scientific observations: The JANUS camera has a nominal focal length of 467 mm and a pixel dimension of 7 µm; hence it will provide images of the targets with a resolution of 7.5 m per pixel at a distance of 500 km. Moreover, a filter wheel with 13 multiband filters allows JANUS to obtain multi-spectral images in the 380-1080 nm wavelength range. Such characteristics will allow to cover the surfaces of the icy satellites with a spatial resolution ranging from 400 m to 3 m for Europa, Ganymede and Callisto. In addition, Jupiter and other targets, such as Io, small moons and rings, will be observed with a resolution from few km to tens of km.

Scientific observation: we consider the following scientific observations (occurring before the Ganymede orbit insertion) to compute a preliminary estimate of the data volume generated by the JANUS camera required to achieve its science goals:

- Callisto, Ganymede and Europa flybys (FBs);
- Io close and eclipse observations;
- Ring observations;
- Irregular and Minor Moons observations;
- Jupiter atmosphere observation and monitoring during the entire mission, including specific phenomena like aurorae and lightning.

The planning of the required specific observations to fulfill the JANUS scientific requirements, for each of the aforementioned science cases, is performed considering the CREMA 5.0 observation opportunities, i.e. the most updated JUICE trajectory released by ESA to date. Such analysis allows also to determine the coverage of target bodies in terms of resolution and colors obtainable by the JANUS camera.

Below we present the Callisto flyby, Io observation and small moons cases as examples to show the approach we are following in our science planning.

Callisto FBs observations: During a FB, there are two different types of observations: i) *out-of-pushbroom*, i.e. when JANUS will take advantage of the flexibility in satellite pointing, acquiring rasters and ii) *pushbroom*, i.e. when JANUS will acquire only along the ground track being the satellite constrained to nadir pointing. In both cases, JANUS will perform multi-filter observations, with the limitation of the increasing spacecraft – target relative velocity towards the closest approach. Each FB has been designed in a repetitive way: STARE exosphere observations when distant from the target and during nightside, RASTER dayside acquisitions during the *out-of-pushbroom* phase, continuous observations during the *pushbroom* phase. We assume that the *pushbroom* phase duration is ± 30 min around closest approach (the exact duration will be agreed with the other JUICE instrument teams). In Figure 1, we show the surface coverage of Callisto achieved during the *pushbroom* phase of all 21 Callisto's FBs. Figure 2, shows an example of surface coverage obtained during a raster in the *out-of-pushbroom* phase.

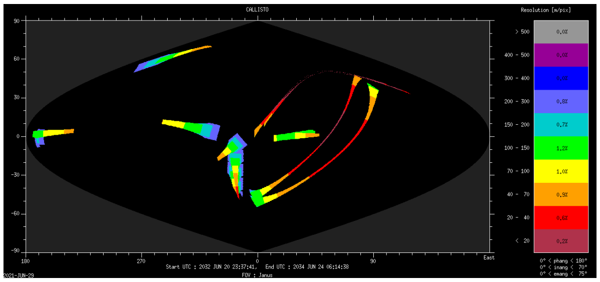

Figure 1 Pushbroom coverage obtained through all 21 Callisto's FBs.

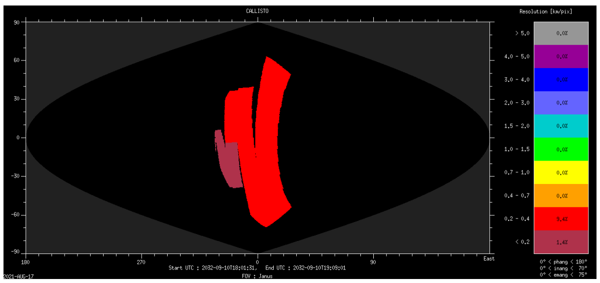

Figure 2: Surface coverage obtained in a 11x5 raster acquired during the out-of-pushbroom phase of the 4th Callisto FB.

Io observations*:* Regarding Io, there are different observation opportunities in CREMA 5.0, in particular there are 50 close opportunities at a distance below 800000 km and about 330 eclipse observations. The close observations are useful for surface change detection and geologic mapping, in addition to plume search and monitoring. The eclipse observations are important for hot spot detection and temperature measurements. To maximize the scientific return, JANUS will acquire (cropped) images in several filters during close observations, while it will use at least 3 filters for eclipse observations. In Figure 3, we show an example of an Io close observation.

Minor moons observations: The mission includes a few approaches of less than 1e6 km to the small inner moons, useful for low-resolution coverage of their surfaces. This will also include the first disk-resolved views on their poles from inclined orbits. Many of the 72 known irregular moons will be observed from remote to derive lightcurves, similar to what Cassini has done at Saturn [3]. Our goal is to obtain rotation periods, pole solutions, shape models, phase curves, and object sizes.

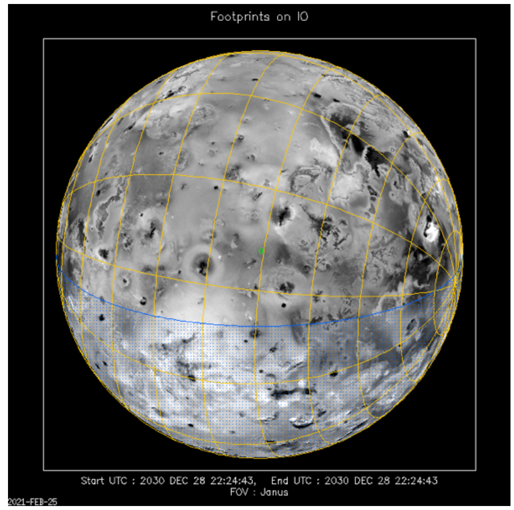

Figure 3: The blue shade corresponds to nightside on Io. This specific observation covers the (i) dayside change detection at Lei-Kung Fluctus and Isum Patera, Volund, Zamama, Prometheus, Culann, Malik, Marduk. (ii) nightside hot spot detection of Tvashtar, Amirani, Emakong, Hi'iaka, Altjirra, and (iii) plume monitoring of Pele and Pillan.

Discussion and Conclusion: In this work, we present the resulting JANUS planning strategy we are developing in order to fulfill the JANUS scientific requirements. In addition to Callisto's FBs and Io observations, we are also currently working on the planning strategy of Europa and Ganymede FBs, rings, minor and irregular moons observations. Stereo opportunities during such FBs have not been assessed yet, but they will soon be evaluated. In addition, the coverage that will be obtained by JANUS at Ganymede and Callisto represents a dramatic improvement when compared to the Galileo observations. Finally, such analysis has been developed at JANUS level and it will be discussed within the JUICE project in the near future.

Such preliminary analysis is pivotal to assess the capabilities of the instrument and provide a preliminary DV required by JANUS during the mission, also including Jupiter atmosphere observations and monitoring. Because the JANUS capability to acquire high resolution data is much larger than the available data downlink, our analysis will be critical to identify the best observation approach for all targets.

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References: [1] Grasset et al., (2013), *PSS,* 78, 1-21. [2] Palumbo et al., (2014), *EGU conference.* [3] Denk, T., Mottola, S. (2019), *Icarus* 322, 80-102.