

JANUS on the JUICE Mission: the Camera to Investigate Ganymede, Europa, Callisto and the Jovian System

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Abstract

The detailed investigation of three of Jupiter's Galilean satellites (Ganymede, Europa, and Callisto), which are believed to harbour subsurface water oceans, is central to elucidating the conditions for habitability of icy worlds in planetary systems. The study of the Jupiter system and the possible existence of habitable environments offer the best opportunity for understanding the origins and formation of the gas giants and their satellite systems. The JUPITER ICY moons Explorer (JUICE) camera system JANUS (Jovis, Amorum ac Natorum Undique Scrutator) will determine the formation and characteristics of magmatic, tectonic, and impact features, relate them to surface forming processes, constrain global and regional surface ages, and investigate the processes of erosion and deposition. Global medium resolution imaging of Ganymede and important parts of the surface of Callisto better than 400 m/pixel (resolution limited by mission data volume) will provide context information. Selected targets will be investigated with high-resolution imaging with spatial resolution from 25 m/pixel down to 3 m/pixel. The camera system has 13 panchromatic, broad- and narrow-band filters in the 0.36 μm to 1.1 μm range, and provides stereo imaging capabilities. JANUS will also allow relating spectral, laser and radar measurements to geomorphology and thus will provide the overall geological context.

Introduction:

The Galilean satellites Io, Europa, Ganymede and Callisto show an increase in geologic activity with decreasing distance to Jupiter [e.g. 1]. Io, nearest to Jupiter, is volcanically active. Europa could still be tectonically and volcanically active today, while Callisto, the outermost Galilean satellite, is geologically inactive. Ganymede holds a key position in the Jovian satellite system in terms of geologic evolution because it features old, densely-cratered

terrain, like most of Callisto, but also widespread tectonically resurfaced regions, similar to most of the surface of Europa. Investigating Ganymede, the largest satellite in the solar system, from an orbiter is essential because of (1) its wide range of surface ages which reveals a geologic record of several billions of years, (2) its great variety in geologic and geomorphic units, (3) its active magnetic dynamo, and (4) the possible presence of a subsurface ocean. The three icy Galilean satellites Callisto, Ganymede and Europa show a tremendous diversity of surface features and differ significantly in their specific evolutionary paths. Each of these moons exhibits its own fascinating geologic history – formed by competition and also combination of external and internal processes. Their origins and evolutions are influenced by factors such as density, temperature, composition (volatile compounds), stage of differentiation, volcanism, tectonism, the rheological reaction of ice and salts to stress, tidal effects, and interactions with the Jovian magnetosphere and space. These interactions are still recorded in the present surface geology. The record of geological processes spans from possible cryovolcanism through widespread tectonism to surface degradation and impact cratering. The huge scientific return of JANUS is not only based on the geology of the Galilean satellites, that in any case represent the driving case for the design, but also on the observation of the Jupiter atmosphere and the satellite exospheres, using specific filters, the Jupiter rings and the minor satellites for astrometric purposes and on the contribution in the determination of the rotational status of Ganymede, to constrain its internal structure.

The JANUS Experiment

Outstanding questions that will be addressed by JUICE Imaging [2]: What are the relative roles of

tectonism and cryovolcanism in shaping the dark and bright terrains on Ganymede? What does the distribution of craters on the Galilean satellites tells us about the evolution of the impactor population in the Jovian system through time? How is the geological evolution of Ganymede and Europa related to the impact, tectonic and cryovolcanic history and how is the geological evolution correlated with differentiation processes and stages? What are the ages of specific geological units on Ganymede and Europa, and how will these findings contribute to our understanding of the origin and evolution of the Jupiter system? What is the rheological response of ices and ice/salt/clathrate mixtures w.r.t. tectonic stress? To what extent are surfaces altered by cosmic weathering and what are the major exogenic surface alteration processes (micrometeorites, radiation, charged particles)? What are the fine-scale characteristics of non-ice materials on Callisto? By which intriguing mechanisms is CO₂-replenishment taking place on Callisto?

Performance of the Instrument Required to Fulfil the Anticipated Goals: JANUS is the next logical step after the impressive successes of the imaging studies by Voyager, Galileo and Cassini of the Jovian system. JANUS will allow orders-of-magnitude steps ahead in terms of coverage and/or resolution and/or time evolution on many targets in Jupiter system. JANUS spatial resolution ranges from 400 m/pixel to < 3 m/pixel for the three main Galilean satellites, and from few to few tens of km/pixel for Jupiter and the other targets in the Jovian system. Based on assumptions on available data volume, JANUS observation will cover about a 100% of Ganymede in 4 colours. About 3% of the surface of Ganymede will be covered with resolutions better than 24 m/pixel and 60 targeted areas will be observed with highest resolution of about 3 m/pixel. Stereo imaging at Ganymede is doable at resolutions between 5 to 10 m/pixel and around 25 m/pixel. Stereo images will be acquired both in nadir pointing and by tilting the spacecraft in a subsequent orbit. For Callisto, assuming only nadir pointing, JANUS will cover 100 % of the surface at ≤ 2 km/pixel, 41 % at ≤ 1 km/pixel, 14 % at ≤ 400 m/pixel, 6.5% at ≤ 200 m/pixel, and some targets at resolutions ~ 10 m/pixel, with 4 colour imaging at medium resolutions. 55% of Europa's surface can be covered at ≤ 3 km/pixel, 42 % at ≤ 2 km/pixel, 25 % at ≤ 1 km/pixel, 11 % at ≤ 700 m/pixel, 3.2% at ≤ 400 m/pixel, 1.1% at ≤ 200 m/pixel and some targets at resolutions ~ 10 m/pixel. Low- to medium-resolution imaging (i.e. km to ~ 100 m-range) is

obtained in four colours. Spatial resolutions at Io will gain 6 to 20 km/pixel with long monitoring time also at NIR wavelengths. The ring and minor satellites can be observed at maximum resolutions of ~ 7 km/pixel. The resolution at Jupiter's atmosphere will reach 9 km/pixel. The SNR > 100 can be maintained in almost all observational scenarios.

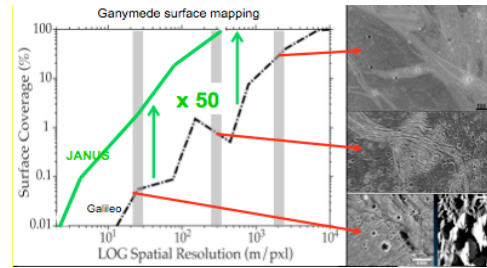


Figure 1: Ground Resolution and surface coverage for Ganymede by JANUS compared to Galileo.

Instrument Design: The JANUS camera consists of three units with physical I/F with JUICE: a) the optical head including the telescope and mounting structure, the filter wheels and the focal plane; b) the proximity electronics; c) the main electronics including camera control, data handling, compression and power supply. The following architectural design was developed: a catadioptric telescope with excellent optical quality is coupled with a framing detector, avoiding any scanning mechanism and, above all, any operational requirement on the S/C. The JANUS design is tuned to have the highest probability to guarantee a great scientific success to the mission by the best usage of the resources allocated on imaging by JUICE through the implementation of a single NAC channel, with WAC capabilities, with high reliability due to the redundancy philosophy. Our proposal has also the advantage to obtain the low to medium resolution Ganymede global coverage earlier during the mission, allowing better choice of observation targets for the high-resolution phase.

References:

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