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The Ganymede Laser Altimeter (GALA) as part of the JUICE payload: instrument, science objectives and expected performance

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Abstract

The Ganymede Laser Altimeter (GALA) has been selected by ESA for the Jupiter Icy Moons Explorer (JUICE) mission payload. GALA will focus on geodetic and geophysical investigations of the icy satellites Europa, Ganymede and Callisto. Here, we describe the scientific objectives, its expected performance, and the status of the instrument development.

1. Scientific Objectives

The icy moons of Jupiter – Europa, Ganymede, and Callisto – are believed to contain global subsurface water oceans underneath their icy crusts. Each of these oceans would contain more water than all Earth's oceans combined. The possibility is intriguing that these large liquid water oceans represent "habitable" environments. Investigation of the latter is one of the main motivations for the Jupiter Icy Moons Explorer (JUICE). The Ganymede Laser Altimeter (GALA) as part of the JUICE payload is one of the instruments focusing on aspects related to the presence and characterizations of subsurface water oceans.

With respect to evolution of the Galilean Moons, the JUICE mission aims at
• an exploration of the morphology and surface geology of Ganymede, Europa and Callisto,
• a determination of their interior structures from a combination of shape, topography and gravitational field data,
• the exploration of their surface chemistry and physical properties,
• and at their formation and evolution especially with respect to subsurface water oceans.
To this end, precise geodetic measurements to determine the figures of the moons and their topography are mandatory. GALA is a powerful instrument in achieving these goals. The topography is needed
• to account for the effects of topographic heights on the gravity field and to account for near surface mass distribution anomalies above the reference figure;
• to support geological studies, e.g. to identify and characterize tectonic and cryo-volcanic regions on the icy moons.

• to identify periodic variations of Ganymede's shape due to tides.

Investigations by GALA will furthermore contribute to determine
• the orientation and rotational states of Ganymede, Europa, and Callisto, in particular the physical librations of Ganymede's outer ice shell in combination with imaging data;
• surface characteristics (roughness, slopes, and albedo) on Ganymede, Europa, and Callisto.

GALA will form an integral part of a larger geodesy and geophysics package, incorporating radio science, VLBI Techniques, stereo imaging and sub-surface radar. Although stand-alone instruments in their right only the synergy between these will allow full use of present-day technology and scientific capability. The synergy will tackle the problems of planetary figure, rotation, gravity field determination, interior structure, surface morphology, geology, and tidal deformation. The latter is crucial for detecting and constraining the depth of a subsurface ocean on Ganymede.

2. Technical Description

GALA uses the "direct-detection" (classical) approach to laser altimetry. Laser pulses are emitted at a wavelength of 1064 nm by using a Q-switched Nd:Yag laser at operational frequencies of 30 and 75 Hz, respectively. The pulse energy and pulse repetition frequency depend on the different JUICE mission phases. The emission time of each pulse is measured by the detector. The beam is reflected from the surface (surface spot size = 20 to 50 m) and received around 3 ms (assuming the 500 km orbit) later at a 25 cm diameter F/1 telescope. The returning laser pulse is refocused onto a silicon avalanche photodiode through a narrow bandpass interference filter. The signal is then sampled and fed to a digital range finder. This system determines the time of flight (and therefore range), the integrated pulse intensity, its width and full shape. The data are passed to a digital processing unit which controls the operation and services the spacecraft interface. The experiment can operate over the day- and night side.

GALA will provide <1 ns time resolution (<15 cm range, <8 cm under optimal conditions). Data return is expected at altitudes up to approx. 1000 km above the surfaces of the moons. In the Ganymede orbit phases, samples will be acquired without gap along-track on ground-tracks separated by a few kilometers on average (better coverage at the high latitudes in the near-polar orbit). The experiment will provide return pulse intensity and wave-form analysis allowing an assessment of surface albedo and roughness at tens of meters scale including un-illuminated areas. Ranging during the Europa and Callisto flybys is possible up to a range of approx. 1300 km and approx. 1000 km, respectively. The laser is suitable to work power-efficiently in the different science scenarios at Europa, Ganymede and Callisto. The digital rangefinder ensures high quality data generation even in difficult operation scenarios. The instrument will be designed with cold-redundant subsystems where applicable (data processing, rangefinder, power converter, laser electronics, laser optics).

GALA will be developed under responsibility of the DLR Institute of Planetary Research, Berlin, Germany. The instrument building consortium consists of institutes and industry from Germany, Japan, Switzerland and Spain. A broad international Science team including ESA member states as well as other countries supports the instrument development and will be responsible for scientific analysis during the mission.