INT-ORB

A self-consistent study of the internal evolution of icy satellites coupled to the evolution of orbital motion and of dissipation in the central planet

DURATION
1/09/20225 – 1/12/2026

BUDGET
393 791 €

PROJECT DESCRIPTION

Satellites orbiting the giant planets are among the most diverse and intriguing objects in the Solar System. Io, the innermost of the four Galilean satellites of Jupiter, is the most volcanically active body of the Solar System. Several of the icy satellites harbour an internal global subsurface ocean. If life were to exist elsewhere in the Solar System than on Earth, icy satellites like Europa (one of the Galilean satellites of Jupiter) and Enceladus (a medium-sized satellite of Saturn) would be the most likely places for it, together with Mars. In those satellites, a thin ice shell with a thickness of some tens of km sits on top of the ocean and hydrothermal reactions occur at the interface between the ocean and the underlying rock layer. Our limited understanding of this structure raises many questions. How does the ocean and ice shell evolve? Can an ocean be maintained for billions of years? Did these satellites always have subsurface oceans? Will Io always be volcanically active? We still do not know.

The aim of this project is to study the internal evolution of the three innermost Galilean satellites, Io, Europa, and Ganymede, and to determine whether the current situation with strong volcanic activity on Io and subsurface oceans on Europa and Ganymede is representative of the entire evolution or a transient state. In studies of the internal evolution of terrestrial planets of the Solar System, the planet can be considered isolated from external effects. Such an approach is, however, incorrect for the three innermost Galilean satellites because their internal evolution is strongly coupled to the orbital evolution, which itself depends on the evolution of tidal dissipation in the satellites and in the evolving Jupiter. Tidal dissipation is at the heart of the coupling between internal and orbital evolution of the Jupiter system. It is an energy source for satellites through conversion of kinetic energy associated with tides into heat by microscopic friction. Since the tidal force depends on the satellite's orbital eccentricity and semi-major axis, the orbit affects the internal evolution and structure through tidal dissipation. Vice versa, tidal dissipation in the satellites and also in Jupiter affects the orbital and rotational motion since it drains energy from either the rotational or orbital energy.

Initial results about the coupled internal-orbital evolution obtained several decades ago demonstrated that satellites could experience periodic, long-term changes in eccentricity, tidal dissipation, and thermal state as a result of these feedback. Thanks to new advances in our understanding of the interior of the Galilean satellites, better ephemerides of the satellites, new insight into Jupiter from the Juno mission, and a new model of tidal dissipation in gas giants recently developed for Saturn, we now have the critical mass of new information to answer questions about the evolution of the Galilean satellites and their habitability. The overarching goal of the project is to advance our understanding of the internal evolution of the three innermost Galilean satellites by, for the first time, consistently and simultaneously evolving the thermal state, interior structure and orbit of these satellites with time, together with tidal dissipation in Jupiter.

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Jupiter and the Galilean satellites are currently at the heart of planetary exploration missions, with the NASA Juno mission actively investigating the Jupiter system and with the ESA JUICE mission (launch foreseen in 2023) and the NASA Europa Clipper mission (launch foreseen in 2024) in their final phases of construction. Results obtained in this project will enlarge the scientific outcomes of the planetary missions to the Jupiter system by providing a theoretical evolution framework for the satellites that can be compared with observations. The project will provide new insight into the evolution of the Galilean satellites and into habitable places in the Solar System, and is expected to create new research perspectives and to identify further questions that could be addressed by JUICE and Europa Clipper. Since the Jupiter system bears strong resemblance to several exoplanetary systems, the project can also provide key insight about how exoplanetary systems work and about whether they might harbour life.

The project will also stimulate the further development of Belgian expertise in the field of the interior structure and evolution of satellites in our Solar System. INT-ORB will also strengthen the international position of Belgium in a time when a detailed exploration of the Jupiter system is ongoing. The scientific results will be published in peer-reviewed journals in planetary sciences and we will communicate them widely at various international conferences.

CONTACT INFORMATION

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