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JUpiter ICy moons Explorer (JUICE): An ESA mission to orbit Ganymede and to characterise the Jupiter system

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ABSTRACT

Past exploration of Jupiter's diverse satellite system has forever changed our understanding of the unique environments to be found around gas giants, both in our solar system and beyond. 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 in general. 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) mission, selected by ESA in May 2012 to be the first large mission within the Cosmic Vision Program 2015–2025, will perform detailed investigations of Jupiter and its system in all their inter-relations and complexity with particular emphasis on Ganymede as a planetary body and potential habitat. The investigations of the neighbouring moons, Europa and Callisto, will complete a comparative picture of the Galilean moons and their potential habitability. Here we describe the scientific motivation for this exciting new European-led exploration of the Jupiter system in the context of our current knowledge and future aspirations for exploration, and the paradigm it will bring in the study of giant (exo) planets in general.

Contents

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1. Introduction

The science incentive for the JUpiter ICy moons Explorer (JUICE) mission is to study the largest giant planet, its extensive magnetosphere, its giant icy moon Ganymede, and to a lesser extent Callisto and Europa, as well as the interactions occurring in the environment. The JUICE mission will perform: a detailed characterisation of the ocean layers; a detection of putative subsurface water reservoirs; a study of the Ganymede's intrinsic magnetic field; topographical, geological and compositional mapping; an analysis of the physical properties of the icy crusts; the characterisation of the internal mass distribution; a study of the dynamics and evolution of the interiors; an investigation of the moons' exospheres/ionospheres. For Europa, where two targeted flybys are foreseen, the focus will be on the chemistry essential to life, including organic molecules, and on understanding the formation of surface features and the composition of the non-water-ice material, leading to the identification and characterisation of candidate sites for future *in situ* exploration. Furthermore, JUICE should provide the first subsurface observations of this icy moon, including the first determination of the minimal thickness of the icy crust over the most recently active regions.

JUICE will study Jupiter's circulation, meteorology, chemistry and structure from the cloud tops to the thermosphere over the long $\sim$3 year duration of the mission. The giant planet is the best and closest example of a gas giant atmosphere, yet several key questions about the physicochemical processes at work on Jupiter remain unresolved. JUICE observations will serve to enhance our understanding of this archetypal planet as a template for giant planets beyond our solar system. These observations will be attained over a sufficiently long temporal baseline to investigate evolving weather systems and the mechanisms transporting energy, momentum and material between the different layers. The focus in Jupiter's magnetosphere will include an investigation of the three dimensional properties of the magnetodisc and an in-depth study of the electromagnetic coupling processes between the magnetosphere, ionosphere and thermosphere. Aurora and radio emissions and their response to the solar wind will be elucidated. The moons' interactions with the magnetosphere and the gravitational coupling and long-term tidal evolution of the Galilean satellites will be studied.

In Section 1, the context in which the JUICE mission has been designed and selected for implementation is described in detail, especially regarding the consistency with the ESA Cosmic Vision 2015–2025 program. Section 2 is devoted to the exploration of the habitable zone, i.e., the three icy Galilean moons, with a special emphasis on Ganymede, around which JUICE will orbit in the final stages of the mission. Section 3 presents our current understanding of the Jovian system, including the giant planet itself, its magnetosphere and the coupling processes at work. The objectives of the JUICE mission in this context are described for each part of the system. Finally, the baseline mission profile, which has been conceived during the assessment phase of the project as a result of the defined science objectives, is detailed in Section 4.

2. Context and science themes

There have been numerous ground and space-based observations of the Jupiter and Saturn systems; flybys by the Pioneer, Voyager, Ulysses, Cassini and New Horizons spacecraft; the orbital tour by the Galileo spacecraft at Jupiter; and the ongoing orbital tour by the Cassini spacecraft at Saturn. Ground based observing facilities (such as the Very Large Telescope) and Earth orbiting telescopes (such as the Hubble Space Telescope) have enabled remote studies of the Jovian atmosphere and related emissions. Galileo made new discoveries in the Jovian system, especially as concerns the four Galilean satellites, which have driven the identification of the next generation of key scientific questions. Many of these relate to our quest for a better