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The ODINUS Mission Concept: a Mission to the Ice Giant Planets to Unveil the History of the Solar System

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Abstract

We present the scientific case and the mission concept for an L-class space mission to the ice giant planets Uranus and Neptune and their satellites with a pair of twin spacecrafts, which we submitted to the call for white papers for the definition of the L2 and L3 missions in the framework of the ESA Cosmic Vision 2015-2025 program.

1. Introduction

The original view of the set of events and mechanisms that characterizes the process of planetary formation was derived from the observation of the Solar System as it is today. This brought to the assumption that planetary formation was a local, orderly process that produce, regular, well-spaced and, above all, stable planetary systems and orbital configurations. However, with the discovery of more and more planetary systems through ground-based and space-based observations, it is becoming evident that planetary formation can result in a wide range of outcomes, most of them not necessarily consistent with the picture derived from the observations of the Solar System. The growing body of evidence that dynamical and collisional processes, often chaotic and violent, can dramatically influence the evolution of young planetary systems gave rise to the idea that also our Solar System could have undergone the same kind of evolution and represent a "lucky" case in which the end result was a stable and regular planetary system. In the context of this debate, it is of primary importance to improve our understanding of the origins and history of the giant planets of the Solar System, and in particular of the still largely unknown ice giants Uranus and Neptune.

2. ODINUS and ESA Cosmic Vision

The mission concept we present is an L-class space mission to the ice giant planets Uranus and Neptune and their satellite systems, with the goal to advance our understanding of the ancient past of the Solar System and, more generally, of how planetary systems form and evolve. The focus of this mission concept is on the first scientific theme of the Cosmic Vision 2015-2025 program:

- What are the conditions for planetary formation and the emergency of life?

In pursuing its goals, the present proposal will also address the second and third scientific theme of the Cosmic Vision 2015-2025 program, i.e.:

- How does the Solar System work?
- What are the fundamental physical laws of the Universe?

The mission concept we will illustrate in the following will be referred to as **ODINUS**, the acronym being derived from its main fields of scientific investigation: **Origins, Dynamics and Interiors of Neptunian and Uranian Systems**. The ODINUS mission is based on the use of two twin spacecraft to perform the exploration of the ice giants and their regular and irregular satellites with the same set of instruments.

3. Uranus, Neptune and ODINUS

The primary information that the ODINUS mission wants to gather by exploring the Uranian and Neptunian systems are:

- What is the atmospheric composition and enrichment respect to solar abundances of the two planets?

- What are the bulk densities and the masses of the two planets and their satellites?
- What are the interior structures and density profiles of the two planets and the satellites?
- What is the surface composition of the (regular and irregular) satellites?
- Which satellites are fully/partially differentiated and which ones are undifferentiated?

Using these data, ODINUS aims to constrain the available theoretical models for the evolution of the Solar System and to shed new light on the path it followed across its ancient past.

4. Mission Design of ODINUS

In order to achieve its goals, the ODINUS mission concept proposes the use of two twin spacecraft (here dubbed Freyr and Freyja from the twin gods of the Norse pantheon) to be put in orbit of Uranus and Neptune. While such a setup presents several challenges in terms of its implementation, it presents the following advantages:

- the exploration of the last two planets in the Solar System will be completed within the lifetime of a single L-class mission instead of two or more;
- the exploration of the two planets and their satellite systems will be performed with the same sets of instruments, allowing for a truly comparative study between the two.

In order to fit the budget of an L-class mission, a conservative, straw-man configuration for the ODINUS mission could be based on two New Horizons-like spacecrafts, i.e.:

- about 6 instruments in the scientific payload + radio science;
- about 500-600 kg of dry mass of each spacecraft;
- Hybrid (ionic and chemical) propulsion;
- Radioisotope-powered spacecrafts.

A similar mission is already doable (even if marginally) with present-day technology, either assuming two separate launches for the Freyr and Freyja spacecraft with Soyuz rockets or a single launch with an Ariane V. The total cost estimates for the New Horizons mission, which we consider as a template for our spacecraft, indicate that ODINUS would fit inside the budget of an L-class mission.

5. Strawman payload of ODINUS

A possible straw-man payload for the two spacecraft would be composed by:

- Camera;
- VIS-NIR Image Spectrometer;
- Magnetometer;
- Mass Spectrometer (Ions and Neutrals);
- Doppler Spectro-Imager (for seismic measurements) or Microwave Radiometer;
- Radio-science package.

Presently, the idea would be to insert each spacecraft on a distant and highly eccentric orbit (irregular satellite-like) around the respective planet and take advantage of the ionic propulsion to spiral inward to the regular satellites and then the planet itself. While the mission concept does not foresee, presently, the inclusion of atmospheric probes, it is under evaluation the possibility to take advantage of the ionic propulsion to slowly spiral the spacecraft inside the planetary atmospheres and therefore use the spacecraft themselves as probes at the end of the mission.

6. Timeline of ODINUS

The ODINUS concept envision the mission as a possible L3 mission in the context of ESA Cosmic Vision, with the indicative launch foreseen for 2034. Assuming an indicative time of flight of about 10 years to reach Uranus and 15 years to reach Neptune, the ODINUS mission would ideally allow to complete the exploration of the Solar System by the first half of the century.

7. ODINUS website

The submitted white paper of the ODINUS mission concept and the full list of supporters are online at the address http://odinus.iaps.inaf.it. To support the ODINUS white paper, you can go to the "Support us!!!" link (http://odinus.iaps.inaf.it/suppus.php) and fill the form.