Kuiper Belt Captured object exploration: the case of Triton

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Overview

The trans-neptunian region is the last frontier of the Solar System exploration. This region is populated by icy bodies that are a relic of the formation process of the Solar System. The largest objects, which joined Pluto in the family of dwarf planets that populate this region, could be geophysically evolved, due to the interplay of the accretional and radiogenic heats, but the smallest ones should represent a preserved record of the original material from which the outer Solar System formed. For this reason, a mission to this region would provide important data to constrain the possible scenarios of the early history of the Solar System. A mission reaching the outer regions of Solar System would also allow for testing the behavior of gravitational interaction in a range poorly sensed, so far, by direct investigation. This would contribute to build a bridge between the smaller scales, where general theory of relativity is well-tested, and the larger scales apparently characterized by 'exotic' phenomenology as dark matter and dark energy.

Exploring the vast depth of the trans-neptunian region provides an unquestionable technological challenge and a large amount of resources is required (due to the extreme environmental conditions, the long travel from the Earth and the large distances between the different targets of interest). However the Solar System evolution delivered some of these bodies to more favorable positions in ancient times. It has long been known that some of the moons of giant planets did not form in their current locations but where captured from heliocentric orbits at a later time. These moons are known as irregular satellites and their orbits around the planets are highly eccentric and inclined, with a large fraction being retrograde.

Neptune hosts the two largest irregular satellites, Triton and Nereid, which represent the ideal candidates for a mission aiming to improve our understanding of the icy body of trans-neptunian region. Triton was visited in 1989 by Voyager 2: the images it supplied revealed one of the youngest surfaces of the Solar System and active geyser-like vents, suggesting the satellite is possibly more active than Europa (Schubert et al. 2010 and references therein). Notwithstanding this, the surface of Triton showed a variety of cryovolcanic, tectonic and atmospheric features and processes (Prockter et al. 2010 and references therein).

The spectra of Triton possess the absorption bands of five ices: N_2, CH_4, CO, CO_2, and H_2O (Dalton et al. 2010). The detection of the HCN ice band has been reported, which could imply the presence of more complex materials of astrobiological interest (see Dalton et al. 2010 and references therein). Triton also possesses a tenuous atmosphere mainly composed by N_2 and CO, which undergoes seasonal cycles of sublimation and recondensation (see Dalton et al. 2010 and references therein).

Science objectives

The analysis of the Voyager 2 shows that the crater coverage of the Triton surface is not uniform. This is evidence of a resurface of part of the moon due to its activity, which also responsible for the jets of dark ice grains suggested to emanate from several locations and to be carried by the feeble wind to form the observed dark streaks (Soderblom et al., 1990). There is also evidence of possible seasonal surface changes by space-based telescope observations (Young & Stern 1999).

For these reasons is important to improve our knowledge of the surface components, of their abundance ratios and spatial distributions. Another objective is the improvement of our data about the morphology of Triton, as just 40% of the surface was observed by Voyager 2, and determine the origins of the specific types of geologic features and terrains. This data would allow to investigate the absolute and relative ages of the surface features and of the moon itself using craters counting. In order to understand the origins of the dark ice grains and their trajectory, it is also important the identification of the possible thermal anomalies and the thermal balance.

The investigation of the internal structure of Triton could be performed by estimating its gravitational mass and momenta via a dedicated radio science experiment.

During the approach and crossing of the planetary system the spacecraft will observe Neptune, giving us informations about the structure of the atmosphere and the composition and dynamics of its layers. The thermal balance of the planet and structure and composition of its rings will be also investigated.

Finally, during the cruise phase, we will perform several observations at different distances of Neptune, focusing on the ice giant as a prototype of the most populated family of exoplanets. In particular, being the spacecraft in this phase basically an ideal gravitational test mass, its orbit could be precisely tracked in order to detect hypothetical deviations of its motion from the predictions of general relativity.

As an optional goal of the mission, we propose to observe Nereid, the second largest irregular satellite of Neptune and of the outer Solar System, performing the same measurements discussed for Triton. The collected data will give us also the opportunity to perform a direct comparison between the two moons.

Suggested payload

To achieve the scientific objectives described in the previous paragraph, and taking in account the mass limitation of a small class mission, we suggest an essential payload formed by only three instruments:

1. **High Resolution Camera;**
2. **Infrared Map Spectrometer;**
3. **Thermal Mapper,**

The High Resolution Camera will perform the morphological study of the targets and the count of the craters. In order to improve the Voyager's data a spatial resolution less then 1 km/pixel is required.

The Infrared Map Spectrometer will be used to obtain the compositional maps and derived products. The suggested range is 400-5700 nm, divided in two channels covering the ranges 400-1000 nm and 1.0-5.7 micron, these being respectively heritages of the ESA missions Venus Express and Rosetta.

The Thermal Mapper, for the study of the thermal anomalies, with a range between 7-14 μm at a high spectral resolution of up to 9nm.

The radio science package will be an integrated part of the telecommunications subsystem.

Mission concept

We propose a direct transfer to Neptune using electric sail or other short time-of flight (ToF) strategies in order to respect the mission constraint. Fly-by of Triton with a minimum slant distance of about 3000 km. Observation of Neptune during transit to the Neptunian system. Possible observation of targets opportunity (Nereid, Chiron, KBO).

Potential areas of collaboration between the two communities

The European and Chinese communities could collaborate in all the phases of the mission like the development of spacecraft and of the instruments. A great effort in the cooperation during the data analysis phase will be warranty of new and important results

Heritage from previous studies/missions

We can take advantage in the development of this mission from the heritage coming from several ESA missions like Venus Express, Rosetta, Juice, Cassini, Dawn e Juno and from some mission studies developed for the recent ESA call for the L2 and L3 missions targeting the ice giants Uranus and Neptune (ODINUS, Uranus Pathfinder and Neptune and Triton).