The OKEANOS: Small Body Exploration to a Jupitar Trojan Asteroid

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Introduction: The OKEANOS (Oversize Kite-craft for Exploration and AstroNautics in the Outer Solar system), which is also known as the Solar Power Sail (or SPS), mission is one of the candidates of the strategic middle-class space exploration to the outer Solar System lead by JAXA [1]. The mission will be launched in late 2020s, and rendezvous for spectral observations and landing for *in-situ* isotope/elemental measurements to a D or P type Jupitar Trojan asteroid of ~20-30 km in diameter on or about 2040. Unique scientific instruments of a high-resolution mass spectrometry (HRMS) together with suits of remote-sensing instruments will be on board. Currently we consider three mission plans for the OKEANOS, plan A is a rendezvous and landing for single asteroid, plan A' is multi-rendezvous and landing for single asteroid, and plan B is a rendezvous, landing for single asteroid and sample return. Note that the sample return is not yet fully developed. More detailed developments of the sample return canister, a plan to prevent sample heating and degradation during capsule reentry will be required.

Scientific Goals: Through in-depth scientific observations with HRMS and spectroscopy, the OKEANOS will provide critical input to the key questions of (1) constraining planet formation/migration theories, (2) inventory and distribution of volatiles (water and organics) in the Solar System.

In-situ HRMS analysis: The HRMS is one of the flagship instruments on the OKEANOS, conducting critical measurements towards the scientific goals of the mission. D/P-type asteroids likely consist of dominant of organics (carbonaceous materials) and anhydrous silicates (hydrated silicates cannot be excluded), possibly with water (ice) in its interiors [2]. We, therefore, plan to analyze volatile materials on the Jupitar Trojan, for their isotopic and elemental compositions using a HRMS (MULTUM: multi-turn ToF mass spectrometer [3]) with a combination of pyrolysis ovens and gas chromatography [4]. This HRMS system allows to measure H, N, C, O isotopic compositions and elemental compositions of molecules. Analyses of light isotopes and molecules of materials on a Trojan asteroid may permit deciphering if the Trojan bodies originate from the cometary reservoir or share similarities with asteroids (or meteorites) from the inner Solar System. Especially isotopic analysis may provide insight into the migration model of giant planets (Jupiter, Saturn) at the early Solar System.

The sample return from the Trojan asteroid: Beside *in-situ* HRMS analysis of isotopic ratios, elements and molecules in surface and subsurface samples on the Trojan asteroid, analysis of returned samples from Trojan asteroidal objects containing non-volatile materials (organics and minerals) as well as water (ice) will open a new insight of the detailed scientific objectives for the Solar System evolution. Since *in-situ* analysis is limited in terms of sample preparations, lack of relationship among components, and mineralogical/petrological contexts, the *state-of-the-art* microanalysis techniques on the Earth will provide these additional information such as isotopic ratios of individual component (organics and associated minerals), trace amount of gaseous species (e.g., Noble gases, CO, CO_2, NH_3, CH_4 gasses in ice), and organic compounds that are hard to be detected under the current *in-situ* HRMS system (e.g., amino acids).

Relationship to other missions: Collaboration with LUCY (multi-rendezvous) of NASA Discovery mission [5] will be enhanced an understanding of origin and nature of a Jupitar Trojan asteroid. Indeed, detailed chemical analysis of single Trojan asteroid by the OKEANOS will support to understand the diversity among other Trojan asteroids by LUCY. The sample return missions of C-type asteroid by Hayabusa2 [6], B-type asteroid by OSIRIS-REx [7] and comet by CAESAR [8] will provide chemical and physical properties of comets and asteroids. These may contribute better understanding of Trojan asteroids in combination with the OKEANOS's *in-situ* analysis and sample return from D/P-type asteroid.

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