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Editorial

Editorial to the Special Issue "Space Missions to Small Bodies: Results and Future Activities"

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Small bodies (asteroids, comets, and satellites) are the most primitive bodies of our solar system and, for this reason, represent the key to understanding its origin and early evolution.

Prior to space exploration, information on small bodies was derived from ground observations and meteorites. The results of ground observations are generally limited to orbital/global properties (such as rotation period and size) and average optical/compositional properties (e.g., derived by spectroscopy and photometry). Space exploration has allowed for high-resolution mapping as well as the study of the interior of small bodies, greatly enhancing their comprehension. Nevertheless, the role of ground observations is still important as a larger number of bodies can be studied and possible targets of future missions identified. Meteorites offer a ground truth, but they are affected by terrestrial environments. Sample return missions are the last frontier of space exploration as they combine the advantages of in situ measurements (no influence from Earth) and meteorite studies (e.g., sample availability and experimental repeatability [1]). Of note, three sample return missions to asteroids were developed and launched in the 2000s (JAXA's Hayabusa and Hayabusa2 and NASA's OSIRIS-REx), and other missions are in preparation.

The following Special Issue focuses on space exploration to asteroids, including the role of ground observations, data analysis, related interpretation from recent missions (i.e., NASA's Dawn mission to Vesta and JAXA's Hayabusa2 mission to Ryugu), and technological preparation for future exploration.

Tian et al. (2024) derived the rotation period of 892 asteroids and studied the photometry of seven main belt asteroids (Kuznetov, Androkinov, Espinette, Lewis, Noel, La Palma, and Fellini) observed by the China Near-Earth Object Survey Telescope (CNEOST). The authors applied convex inversion techniques to derive spin parameters and a shape model of these asteroids. Inversion techniques applied for the OSIRIS-REx mission and their application to the Kamo'oalewa asteroid [2] will be useful for the CNSA's Tianwen2 mission. Approximately 73% of rotation periods derived by Tian et al. (2024) agree with the Light Curve Database [3]; these new data will enhance the understanding of asteroid collisions and non-gravitational effects. The in-depth photometric studies of the seven main belt asteroids identified two possible orientations of the rotational poles and will support future studies of asteroid dynamics and shape distribution.

Massa et al. (2023) took advantage of the new calibration of the data provided by the Visible and InfraRed (VIR) spectrometer onboard NASA's Dawn mission to Vesta and Ceres. In particular, the recalibrated hyperspectral images of Vesta have a better signal-to-noise ratio and facilitated the study of the faint 0.5 μm band, ascribed to pyroxene [4], and the hydroxyl molecule (OH), characterized by low absorption at 2.8 μm [5]. The correlation between the 0.5 μm and 1.9 μm band depths reinforced the attribution of the visible band to pyroxenes. The 2.8 μm band distribution across the Vesta surface was studied in detail, with the authors finding a strong overlap with dark units and anticorrelation with albedo, even in the detections that were questionable in previous works [6]. The results of this study provide further confirmation that carbonaceous chondrites are responsible for

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Vesta's surface darkening. Nevertheless, the OH abundance is not sufficient to observe the 2.2–2.4 μm feature in the NIR spectra of Vesta.

Ota et al. (2023) proposed a formation model of the rubble pile asteroid Ryugu, the target of the JAXA's Hayabusa2 mission. Their work is based on an extensive review of Hayabusa2's geological observations and returned sample analyses. While a rubble pile asteroid is generally thought to consist of reassembled material held by self-gravity following a large impact on a larger asteroid (e.g., [7]), Ota et al. (2023) propose that Ryugu could have originated from a cometary nucleus that successively became a dark asteroid because of water ice sublimation and subsequent resurfacing. This hypothesis would explain the high microporosity of large (i.e., >10 m) boulders (similar to the microporosity of returned samples [8]), the subsurface porosity being higher than the surface one, the occurred loss of volatile materials, the dark surface albedo, and the dynamical evolution of Ryugu and would be in agreement with numerical simulations (e.g., [9]). Moreover, the authors point out that the cometary nucleus hypothesis can be applied to Bennu as well.

Quarta et al. (2023) studied the possibility of a rapid orbit-to-orbit transfer toward a Near-Earth Asteroid in the case of a spacecraft equipped with a next-generation solar electric propulsion system. The considered use case is the Nereus asteroid, while the propulsion system performance (in particular the ion engine throttle table) is based on the NASA Evolutionary Xenon Thruster–Commercial (NEXT-C), i.e., the system used on the DART mission (e.g., [10]). Simulations provided the law that allows for minimization of the orbit transfer time for a defined spacecraft mass and power. For example, in the case of a 100 kg spacecraft and 500 W, orbit transfer would occur in less than one year, which is a reasonable time for a planetary mission. Moreover, simulations showed the possibility of an accurate transfer time assessment using a realistic thruster model.

Quarta and Mengali (2023) performed a similar study in the case of orbit-to-orbit transfer toward an Earth Trojan asteroid in the case of a spacecraft propelled by a solar sail. Numerical simulations were performed with the aim of determining the relationship between minimum transfer time and sail performance. The 2020 XL_5 asteroid was considered as a use case, the optical force model [11] was adopted (according to which the thrust vector includes the optical characteristics of the sail materials), and a flat sail without degradation of reflective materials was assumed. By considering a characteristic acceleration (i.e., the maximum value at 1 AU distance) similar to NASA's Solar Cruiser interplanetary mission (i.e., 0.12 m/s^2), the transfer time is very high (i.e., 8–9 years). This period is reduced to about 500 days in the case of high sail performance in terms of characteristic acceleration (i.e., 1 m/s^2), making solar sail propulsion promising for Earth Trojan exploration.

To summarize, this Special Issue offers interesting insights into asteroid exploration, encompassing both scientific and technological aspects.

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