CURRENT STATUS OF DESTINY+ AND UPDATED UNDERSTANDING OF ITS TARGET ASTEROID (3200) PHAETHON.

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Introduction: Asteroid (3200) Phaethon is the parent of Geminid meteor shower [1,2]. It is an active asteroid, recurrently ejecting dust during the perihelion passage at 0.14 au [3-5]. Phaethon is the flyby target of DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) mission [6]. Detailed understanding of the target asteroid is crucial for the mission planning and science payload design. Here, we present the current status of DESTINY$^+$ and review the updated results of extensive astronomical observations of Phaethon during the close encounter in December, 2017 [7] and observation campaigns for stellar occultation by Phaethon in 2019 [8].

Current status of DESTINY$^+$: DESTINY$^+$ is a joint mission of technology demonstration and sciece observation, which was selected for JAXA/ISAS small-class space program in 2017 [8]. The spacecraft will be launched in 2024 with the enhanced solid-fuel Epsilon rocket into a highly elliptical orbit (270×30000 km) and gradually raise its orbit by electric propulsion for 2 years. After multilple lunar swing-by and subsequent interplanetary cruising, the spacecraft will fly by Phaethon with a distance of 500±50 km at its closest approach and a relative speed of ~35 km/s in January 2028. The flyby point is around the descending node of Phaethon with a geocentric distance of 0.33 au and a heliocentric distance of 0.91 au. After Phaethon flyby, the spacecraft may head to another target asteroid for an extended mission, such as asteroid 2005 UD, which is a possible breakup body of Phaethon [9].

The science observation includes high-speed flyby imaging of Phaethon, and direct measurement of physical and chemical properties of dust particles in the interplanetary space, dust trail and nearby Phaethon. The flyby imaging is performed with a panchromatic telescopic camera (TCAP) with a tracking mirror and a VIS-NIR multiband camera (MCAP) with four bands (425, 550, 700, 850 nm) [10]. In-situ dust analyses with a dust analyser (DDA) which is a combination of impact-ionization dust detector and time-of-flight mass spectrometer enables to analyze mass, arrival direction speed and element composition for dust particle [11].

Updated understanding of Phaethon: Updated results of astronomical observation are reviewed below.
Rotation period: 3.6 hours is verified with refined optical light curves [12,13]. The both studies consistently report 3.603957±0.000001 (hr) [12,13].
Pole orientation: Pole orientation is determined with shape models generated from light curves which were observed with variable phase angles. Results among studies are consistent within uncertainty [12,13,14]. The latest value [14] obtained with light curves and the shape model generated from the Arecibo radar observation [15] shows pole orientation is found to be λ_1= 316.0°, β_1 = -48.7°, indicating a retrograde rotation.
Color: Phaethon is plotted near B, F, C, G-type on the color-color diagrams with slight variation amongst studies [16-19]. Note that they are all slightly shifted from the typical values of the above spectral types.
Absolute magnitude: Due to the lack of observation at small phase angle (20 deg) the absolution magnitude of Phaethon (13.6 - 14.5) is determined with relatively large uncertainty [17,18].
Polarization: Polarimetric observation made during the 2016 apparition [20] and during the 2017 apparition [21-26] all reveal large linear polarization. The large polarization may be attributed to largegrain size (mm size or greater) or large porosity of the surface [e.g. 20]. Rotational variation are reported [23].

Size and shape: Large differences in the size estimate were present in the Arecibo radar images (6 km, dia.) [15] and thermophysical model-ling results of observations from NEOWISE mission (4.6 km, dia.) [29]. The size determined by observations of 2019 stellar occultation by Phaethon is 5.67×4.72 km [27, 28]. The size defined with the occultation observation data shows 5.2km [30] and 5.55 km [31]. The latest shape model generated with a combination of the Arecibo radar data, multiple light curves and the occultation outcome shows that the maximum extent along each axis is 6.4×6.2×5.2km and the volume-equivalent diameter is 5.3km (S. Marshall 2021, personal comm.). A prominent radar dark feature is present near the north pole and km-sized depression-like features are shown near the equator and low latitude regions [15].

Albedo: The variable size estimates with a range of absolute magnitude result in a range of current albedo estimate of 0.079-0.16 [e.g. 20, 29, 32].

Visible reflectance spectra: Visible spectral observation revealed that blue slopes lacking absorption features, with little rotational variation [16, 32], suporintg previous studies. Some observation shows rotational variation [33], in line with observation during that 2007 apparition [34].

NIR reflectance spectra: The NIR observation data of IRTF shows the lack of a 3 µm feature, suggesting the paucity of hydrated silicates on Phaethon [35].

Dust ejection: Neither coma nor m-size dust around Phaethon are detected by optical observation with Hubble Space Telescope [36-37] and thermal infrared observation with VLT [38]. Visibe camera onboard Parker Solar Probe successfully observed dust trail of Phaethon [39].

Composition of Geminids dust: Spectroscopic observation of 2017 and 2018 Geminids show Na depletion and variation [40], supporting the previous studies.

Unanswered questions for Phaethon:

Uncertainty in albedo: Uncertainty in absolute magnitude because of the lack of optical observation at the small phase angles leads to albedo of Phaethon with relatively uncertainty. Light-curve observation during the approach phase and global surface imaging of TCAP with a range of solar phase angle (0-90deg) will resolve this question.

Visible spectral variation: Variation in spectral slope in shorter visible wavelength [33] seems to be related to viewing geometry and may link with semiglobal feature and/or depend on observed latitude. Spetially-resolved imaging by TCAP and MCAP of DESTINY$^+$ will uncover the cause of the visible spectral variation.

Dust ejection and abundance: No dust ejection from Phaethon are not observed by Ground-based and space-based telescope around 1 au heliocentric distance, where DESTINY$^+$ will flyby Phaethon. However, as is the case of Bennu that OSIRIS-REx navigation camera unexpectedly observed ejection of cm-sized dust particles from Bennu during its approach phase [41], DESTINY$^+$ may observe dust ejection from Phaethon with TCAP and/or DDA during the closest flyby.

Mineralogy: CK4 or heated CI/CM chondrites are suggested for analogues of surface materials of Phaethon [42-44]. In such thermally altered carbonaceous chondrites, phyllosilicates are dehydrated and convered to olivine and thus the absorption of olivine centered at 1.05 micron is typically shown [45,46]. Strangely, 1 micron absorption have not been observed among any NIR observation [e.g. 32], while MIR spectra of Spitzer suggest the presence of olivine [J. Hanuš, 2020 submitted]. This enigmatic question of olivine features between NIR and MIR spectra can not be addressed by DESTINY$^+$ observation and only be resolved by sample return. Returned sample by Bennu and Ryugu may provide the clue for it.

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