DESTINY+ TARGET ASTEROID (3200) PHAETHON: RECENT UNDERSTANDINGS FROM 2017 OBSERVATION CAMPAIGN AND THE MISSION SCIENCE OVERVIEW.

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Introduction: DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLyby and dUst Science) was selected in 2017 as a mission for JAXA/ISAS small-class program [1]. It is a joint mission of technology demonstration and scientific observation. It will test high performance electric propelled vehicle technology and high-speed flyby of asteroid (3200) Phaethon and possibly asteroid 2005UD, which a break-up body from Phaethon [2] as an extended mission. Engineering challenges include an up-close encounter at a distance of 500 km from Phaethon with radio-optical hybrid navigation guidance and control, and autonomous imaging based on optical information for target tracking during a high-speed flyby of 33km/sec. The science goal is to understand the nature and origin of cosmic dust brought onto the Earth, in the context of exogenous contribution of carbon and organics for possible prebiotic seeds of the terrestrial life. Phaethon is a parent body of Geminid meteor shower [3, 4], and thus a known source to periodically provide dust to the Earth, via the dust stream. The science objectives are two folded: (1) in-situ analyses of velocity, arrival direction, mass and chemical composition of interplanetary and interstellar dust particles around 1 au, the dust trail, and nearby Phaethon, and (2) flyby imaging of Phaethon to study its geology, for understanding dust ejection mechanism of active asteroid and the surface compositional variation. Planned science observation is illustrated in Fig. 1.

Recent understandings from global observation campaign: Despite numerous studies, the true nature of Phaethon, such as physical properties (size and geometric albedo), dust ejection mechanism [5], chemical makeup (heated CI/CM chondrites [6] or CK4 chondrites [7,8] for the meteorite analogues), and the origin (a Main-belt asteroid (2) Pallas [6,9] or a Jupiter-family comet [10]) have not been well understood. Phaethon passed 0.07 au from the Earth on December 16, 2017, which is the closest approach since 1974 and until 2093. This apparition is a great opportunity to study this intriguing object for better characterization and for further mission planning and payload design for DESTINY$^+$. Global astronomical observation campaign of Phaethon was conducted, including optical, spectroscopic, polarimetric and radar observation with ground and space-based telescopes.

The rotation period of 3.6 hours is verified with refined optical light curves and the shape model has been updated [11, 12]. A likely larger size (D$\sim$5.7 km) than previously reported values (i.e. 5.1 ± 0.2 km [13] was reported from the analyses of delay-Doppler observation of the Arecibo observatory [14]. Note that there is a prominent radar dark feature near one of the poles

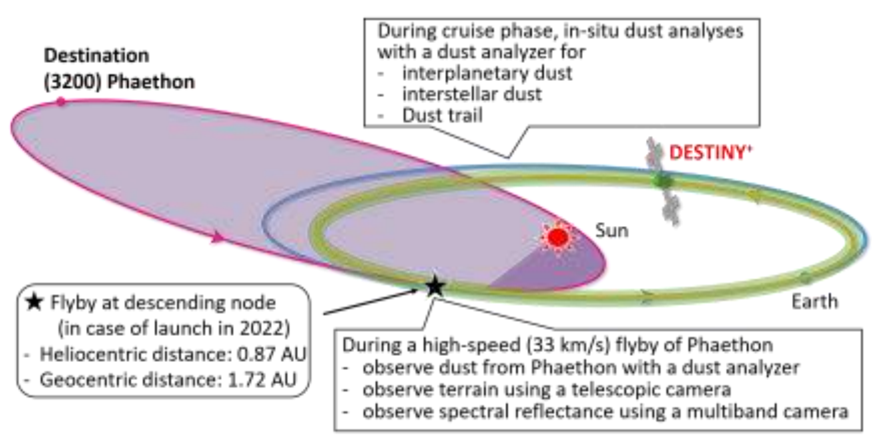

Fig. 1. Overview of DESTINY$^+$ science observation.

and about 1 km-sized depression-like feature near the equator [14]. With the Arecibo radar data [14] and new light curves, the bulk density was estimated to be 1.67 ± 0.47 gcm^{-3} [12], which is somewhat smaller compared to that estimated for Geminids meteoroids (2.9 g/cm^3) [15]. Polarimetric observation made during the 2016 apparition [16] and those during the 2017 apparition [17-20] all revealed that Phaethon exhibits extremely large linear polarization. The large polarization degree with the updated size (5.7 km) led to a significant lower geometric albedo (0.08) than previously reported values (0.11 ± 0.01, IRAS-derived albedo [21], 0.122 ± 0.008, Spitzer-derived value [13]). The similar lower albedo is also reported based on the thermal emission [22]. It is suggested that the large polarization may be attributed to relatively large grain size on the surface [16]. Visible spectral observation revealed that blue slopes lacking absorption features, with little rotational variation [22, 23], in line with previous studies [6-9]. Note that visible spectral observation during that 2007 apparition shows rotational color variation from very blue to neutral [24, 25]. NIR spectral observation at the IRTF revealed concave upwards from very blue to blue-neutral with increasing wavelength with little rotational variation [22]. The NIR data also show the lack of a 3 µm feature, suggesting that the surface is devoid of any hydrated silicates [26]. Recurrent dust ejection has been reported upon the perihelion passage with the STEREO spacecraft [27-29]. Optical observation with Hubble Space Telescope during the 2017 apparition revealed neither coma nor dust ejection from Phaethon around 1 au [30-31].

Mission science overview of DESTINY$^+$: Two sets of camera (Telescopic Camera for Phaethon (TCAP) and Multiband Camera for Phaethon (MCAP)) are used for Flyby imaging of Phaethon [32, 33] [Fig. 2]. The surface of Phaethon can be viewed with a spatial resolution of 5m per pixel during the closest flyby around 500 km distant from Phaethon. The high resolution images are effective to search for geologic features possibly related to dust ejection. TCAP is equipped with a one-axis tracking mirror, which can observe Phaethon with a wide range of solar phase angle (-30 deg to 90 deg). MCAP is used to survey the spectral reflectance with multiple bands (400, 480, 550, 700, 860, 950 nm). Due to the high-speed flyby of 33km/sec, a filter wheel mechanism for multiband observation is not feasible. Instead, a compound-eye camera is adapted for simultaneous multiband observation. With the six bands images, spectral variation in conjunction with local geologic features obtained by TCAP, i.e. craters, cracks, and circular pits, will be studied.

In-situ analyses of dust derived from Phaethon is conducted with DESTINY$^+$ Dust Analyzer is a combination of impact-ionization dust detector and time-of-flight mass spectrometer, which enables to analyze mass, arrival direction speed and element composition for each dust particle [34] (Fig. 2). As implied by the optical observation with Hubble Space Telescope [30-31], dense dust clouds around Phaethon are unlikely. Yet, there might be dust clouds which are generated as impact ejecta by bombardment of micrometeoroids on the surface of Phaethon. Recent numerical simulation suggests 10 dust particles or more can be detected during flyby at the distance of 500 km from Phaethon [35].

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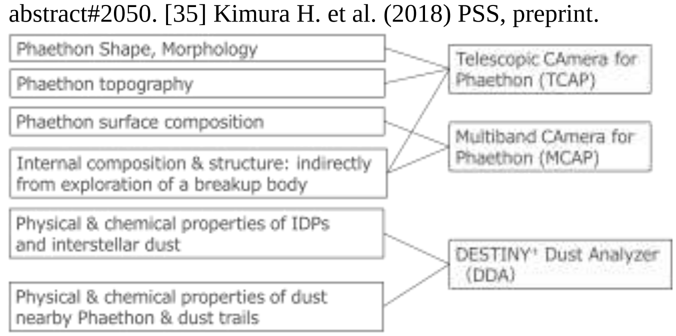

Fig. 2. DESTINY$^+$ science payloads