CURRENT STATUS OF DESTINY+ AND GROUND-BASED OBSERVATIONS OF ITS TARGET ASTEROID (3200) PHAETHON. T. Arai[1], M. Kobayashi[1], K. Ishibashi[1], F. Yoshida[2,1], H. Kimura[1], T. Hirai[1], P. K. Hong[1], N. Okamoto[1], K. Wada[1], H. Senshu[1], M. Yamada[1], H. Akitaya[1], R. Srama[3], H. Krüger[4], M. Ishiguro[5], T. Nakamura[6], H. Yabuta[7], S. Sasaki[8], J. Watanabe[9], T. Ito[9], T. Ootsubo[9], K. Ohtsuka[10,], S. Tachibana[11], T. Mikouchi[11], T. Morota[11], J. Beniyama[11], T. Hiroi[12], T. Sekiguchi[13], S. Abe[14,] S. Urakawa[15], S. Matsuura[16], M. Ito[17], A. Yamaguchi[18], T. Noguchi[19], E. Tatsumi[20], M. Komatsu[21], K. Nakamura-Messenger[22], N. Hirata[23], H. Demura[23], G. Komatsu[1,24], H. Kaneda[25], S. Marshall[26], T. Yanagisawa[27], H. Kurosaki[27], H. Yano[28], M. Yoshikawa[28], N. Ozaki[28], T. Yamamoto[28], H. Toyota[28], K. Nishiyama[28], H. Imamura[28] and T. Takashima[28], [1]Planetary Exploration Research Center (PERC), Chiba Institute of Technology, Chiba, Japan (tomoko.arai@it-chiba.ac.jp), [2]University of Occupational & Environmental Health, Fukuoka, Japan, [3]Institute of Space Systems, University of Stuttgart, Germany, [4]Max Planck Institute for Solar System Research, Germany, [5]Seoul National University, South Korea, [6]Tohoku University, Japan, [7]Hiroshima University, Japan, [8]Osaka University, Japan, [9]National Astronomical Observatory of Japan, Japan, [10]Tokyo Meteor Network, Japan, [11]The University of Tokyo, Japan, [12]Brown University, U.S.A, [13]Hokkaido University of Education, Japan, [14]Nihon University, Japan, [15]Japan Spaceguard Association, Japan, [16]Kwansei Gakuin University, Japan, [17]JAMSTEC, Japan, [18]NIPR, Japan, [19]Kyoto University, Japan, [20]Instituto de Astrofísica de Canarias, Spain, [21]Saitama Prefectural University, Japan, [22]GITAI Japan Inc., Japan, [23]Aizu University, Japan, [24]Università d'Annunzio, Italy, [25]Nagoya University, Japan, [26]Arecibo Observatory & University of Central Florida, USA, [27]Chohu aerospace center, JAXA, Japan, [28]ISAS, JAXA, Japan.

Introduction: DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) is an upcoming flyby mission to Asteroid (3200) Phaethon [1,2]. Phaethon is the parent body of Geminid meteor shower [3,4] and an active asteroid, recurrently ejecting dust during the perihelion passage at 0.14 au [5-7]. It will be launched in 2024 by a solid-fuel Epsilon S rocket and flyby to Phaethon in January, 2028 [8]. DESTINY+ is a joint mission of science observation and technology demonstration. For the science observation, high-speed (36 km/s) flyby imaging of Phaethon at the closest distance of 500±50 km is performed with a tracking telescopic camera (TCAP) and a VIS-NIR multiband camera (MCAP) with four bands (425, 550, 700, 850 nm) [9,10]. Also, direct measurement of dynamical and chemical properties of each dust particle in the interplanetary space, dust trail and nearby Phaethon, using a dust analyzer (DDA) which is an impact-ionization dust detector and time-of-flight mass spectrometer, equipped with a two-axis gimbal [11].

Status of development and operation planning: The Preliminary Design Review (PDR) was complete in 2022 and DESTINY+ is now in Critical Design phase. Functional tests and ground calibration activities using engineering models (EM) are currently underway for science instruments. Preliminary measurement of dust impact ionization TOF mass spectra with the DDA EM and the electrostatic accelerator installed at University of Stuttgart was successful.

For operational planning upon the closest flyby of Phaethon, we plan to observe km-scale large concavities near the equator and low latitude regions identified by the Arecibo radar observation [12]. With the currently available rotation period (3.603957±0.000001 (hr)) [13,14], pole orientation [13, 14] and the updated 3D shape model of Phaethon [15], the flyby timing can be adjusted to be able to observe the targeted areas on the Phaethon during the closest approach.

Ground observation of Phaethon: Imaging of Phaethon will be conducted autonomously during the high-speed flyby. Detailed understanding of its characteristics, especially the size, shape, albedo, and rotation state prior to the flyby is crucial for successful imaging by TCAP with a range of solar phase angle (0-90 deg) [9]. Inspite of the extensive ground-based observations of Phaethon during the close encounter in December, 2017 [16] and observation campaigns for stellar occultation by Phaethon in 2019 [17], there remain moderate uncertainty for the albedo and absolute magnitude [2]. 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 [18,19]. The variable size estimates (4.6 - 6.2 km, dia.) [12, 20-24] with a range of absolute magnitude result in a range of albedo estimate of 0.079-0.16 [e.g. 22, 25, 26]. To better determine the albedo and size, polarimetric observation [27], photometric observation [28], and stellar occultation observation [29] with small solar phase angles were conducted in 2021 and 2022.

Polarimetric observation: Polarimetric observation was conducted at low phase angles of 8.8 - 32.4 deg. from 2021 October to 2022 January and found that Phaethon has a minimum polarization degree Pmin = -1.3 ± 0.1 %, a polarimetric slope h = 0.22 ± 0.02% deg^{-1}, and an inversion angle α_0 = 19.9 ± 0.3° [27]. The derived geometric albedo is P_V = 0.11 (in the range of 0.08–0.13) [27].

Photometric observation: Intensive observations of Phaethon in the optical wavelength (g, r, and i) were performed with the TriCCS camera on the Seimei 3.8m telescope in October and November, 2021 [28]. The derived absolute magnitude Hv and the slope parameter G of Phaethon are Hv = 14.23 ± 0.02 and G = 0.040

± 0.008 from multiple photometric observations including lower phase angles down to about 9◦ with the *H-G* model [28] (Fig.1). With the *H*v value and the geometric albedo of Phaethon derived in the above polarimetric study [27], the Phaethon's diameter is estimated to be within a range of 5.22 to 6.74 km, which is consistent with radar and occultation observations, while *H*v = 14.65 ± 0.02, which corresponds to a diameter range of 4.30 to 5.56 km is obtained with the linear model [28].

Stellar occultation observation: A stellar occultation by Phaethon, which occurred in western Japan and South Korea on 2021 October 3 (UTC) was conducted with a total of 72 observers at 36 stations [29]. Observational reductions show that the apparent cross-section of Phaethon at the time of the occultation could be approximated using an ellipse with a major diameter of 6.12 ± 0.07 km and a minor diameter of 4.14 ± 0.07 km, and a position angle of 117.4 ± 1.5 deg [29] (Fig.2). Another stellar occultation by Phaethon was observed in Hokkaido, Japan on 2022 October 21 (UTC) with a total of 36 observers at 19 stations. The result is shown in Fig. 2.

The latest shape model generated with a combination of the Arecibo radar data, multiple light curves from 1989 through 2021 and the occultation outcome shows that the maximum extent along each axis is 6.4 × 6.1× 5.1 km and volume-equivalent diameter is 5.2 km [15].

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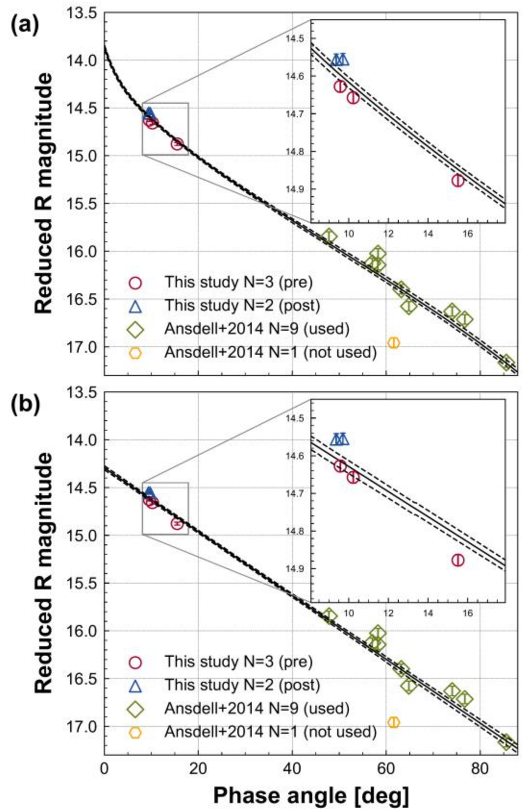

Fig.1. Phase curves of Phaethon with (a) the H-G and (b) the linear model [28].

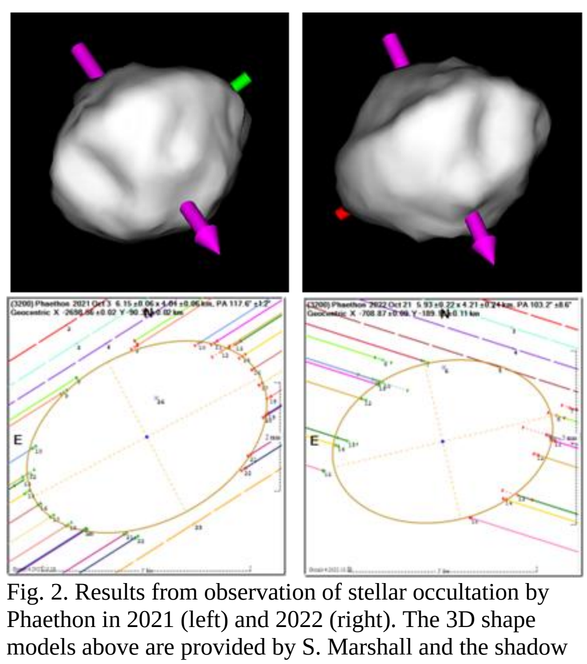

Fig. 2. Results from observation of stellar occultation by Phaethon in 2021 (left) and 2022 (right). The 3D shape models above are provided by S. Marshall and the shadow shapes of Phaethon reduced by Occult4 were provided by T. Hayamizu.