**STELLAR OCCULTATION OBSERVATIONS OF ASTEROID (3200) PHAETHON FOR THE DESTINY+ FLYBY.**

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**Introduction:** DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLyby and dUst Science) is a joint mission of technology demonstration and scientific observation, which was selected in 2017 for JAXA/ISAS small-class program [1]. It will test high performance electric propelled vehicle technology and high-speed (33km/sec) flyby imaging of asteroid (3200) Phaethon and possibly asteroid 2005UD, which a break-up body from Phaethon as an extended mission [1]. Phaethon is a parent body of Geminid meteor shower [3, 4], and still actively ejects dust upon every perihelion passage [5-8]. Phaethon passed 0.07 au from the Earth on December 16, 2017, which is the closest approach since 1974 and until 2093. Durin this apparition, global astronomical observation campaign of Phaethon was conducted [10], including optical, spectroscopic, polarimetric and radar observation with ground and space-based telescopes [11-24]. There are large differences in the size estimate between two-dimensional delay-Doppler radar images of Arecibo (6 km, dia.) [14] and thermophysical modelling results of observations from NEOWISE mission (4.6 km, dia.) [23]. The variable size estimates yield a range of albedo estimate of 0.09-0.16 [14, 24]. To determine the size of Phaethon independently, observations of stellar occulation were conducted in 2019. Here, we report results of stellar occultation, mainly for events in Japan.

**Occultation prediction:** Total 17 events of stellar occultation by Phaethon were predicted by I. Sato, H. Noda, M. Soma and IOTA (Table 1). All predictions were made based on the new Gaia DR2 catalog [25, 26]. Thanks to the results from the Gaia mission, far more precise orbit for Phaethon and star positions than before were obtained, resulting in successful observation of stellar occultation by an asteroid of <10 km dia.

**Observation equipments:** Due to faint stars and short duration for occultation in most events, large telescopes of 20-30 cm coupled with GPS video-rate recording. QHY174M-GPS cameras with CMOS detector and integrated GPS receiver for accurate time tagging of images were used. The readout time was negligible.

**Results:** All results reported to IOTA were summarized [27]. Here are presented two events in Japan.

**2019 August 21 occultation:** Sixteen stations were deployed in southern Hokkaido of Japan across the predicted path at 1-km intervals (Fig. 1a). The observation was not successful due to cloudy weather.

**2019 October 15 occultation:** Ten stations were deployed in Yamagata and Miyagi of Japan across the predicted path at about 1-km intervals (Fig. 1b). The occultation was recorded at two stations by M. Ida and by H. Tomioka et al. (Fig. 1b). Another station farther south had no positive occultation. Observations at other stations failed due to clouds and fog. A preliminary reduction profile and light curve are shown in Fig. 2.

**Size determination:** The best size information came from the July 29 event [27]. The size data from the US event and from Oct. 15 Japan even are broadly consistent with the previous data [14,24], not yet sufficient. Effort of size and shape determination continues with 3D shape model based on light curve and radar observatioin combined with future occultation observation.

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Table 1. List of predicted observation opportunities, modifided from IOTA website. http://iota.jhuapl.edu/2019Phaethon.htm Observations of #1, 2, 5, 10, 11 and 14 were reported to IOTA.

| # | Date/Time (UT) | Star Name | Star mag | ΔMag | Duration (sec) | Location |
|---|---|---|---|---|---|---|
| **1** | **Jul 29, 11:12** | **HIP 24973** | **7.3** | **9.15** | **0.5** | **South western US** |
| **2** | **Aug 21, 18:35** | **TYC 3348-474-1** | **11.9** | **5.06** | **0.5** | **Northern Japan, China** |
| 3 | Sep 13, 02:01 | TYC 3341-00182-1 | 9.3 | 7.7 | 0.4 | Scandinavia |
| 4 | Sep 14, 06:43 | TYC 3340-00407-1 | 9.7 | 7.26 | 0.4 | Southern US, Mexico |
| **5** | **Sep 29, 04:21** | **UCAC4 721-029705** | **12** | **4.91** | **0.3** | **US, Canada** |
| 6 | Oct 07, 18:46 | TYC 3687-02011-1 | 10.2 | 6.64 | 0.2 | Central Asia, Russia |
| 7 | Oct 12, 04:26 | TYC 3306-01824-1 | 10.6 | 6.19 | 0.3 | Alaska |
| **8** | **Oct 12, 06:19** | **TYC 3293-01959-1** | **11.3** | **5.54** | **0.2** | **South eastern US, Mexico** |
| 9 | Oct 12, 19:59 | UCAC4 712-017758 | 11.8 | 4.97 | 0.2 | Russia, Europe, Africa |
| **10** | **Oct 15, 17:38** | **TYC 3292-570-1** | **11.5** | **5.3** | **0.2** | **Northern Japan, China** |
| **11** | **Oct 15, 19:44** | **UCAC4 707-014626** | **11.1** | **5.71** | **0.2** | **Europe, Africa** |
| 12 | Oct 18, 17:22 | TYC 3287-01143-1 | 11 | 5.8 | 0.2 | Russia, Central Asia |
| 13 | Oct 19, 01:16 | HIP 8040 | 9.6 | 7.21 | 0.2 | Africa |
| **14** | **Oct 25, 22:21** | **TYC 3268-00276-1** | **11.3** | **5.58** | **0.2** | **Russia, Europe, Africa** |
| 15 | Oct 28, 13:45 | UCAC4 678-006094 | 11.3 | 5.59 | 0.2 | Australia |
| 16 | Nov 10, 15 53.7 | UCAC4 643-002256 | 9.6 | 7.7 | 0.3 | Indonesia, Philippines |
| 17 | Nov 18 16 12.6 | UCAC4 624-001265 | 9.7 | 7.8 | 0.3 | India, China, Kamchatka |

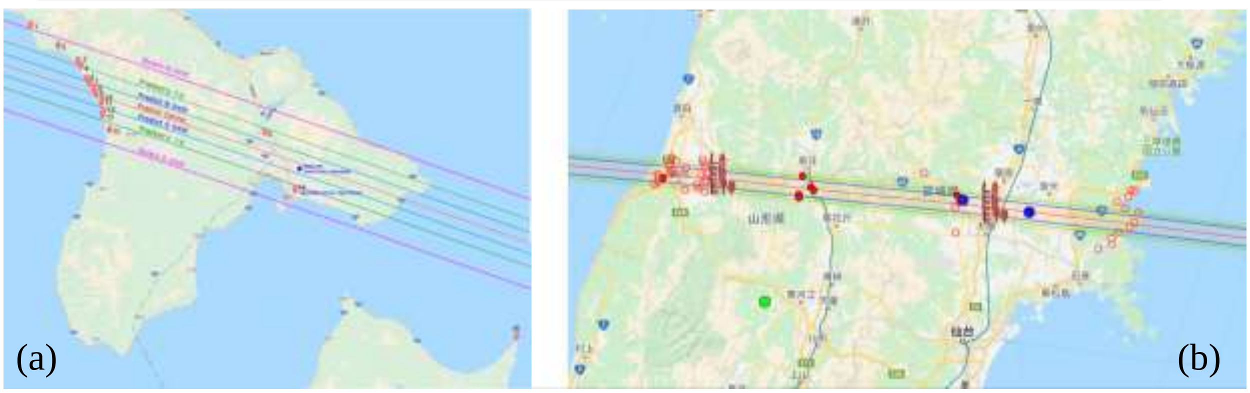


Fig 1. Predicted occultation paths and the observation locations in Japan. (a) August 21, 2019 event and (b) October 15, 2019 event.

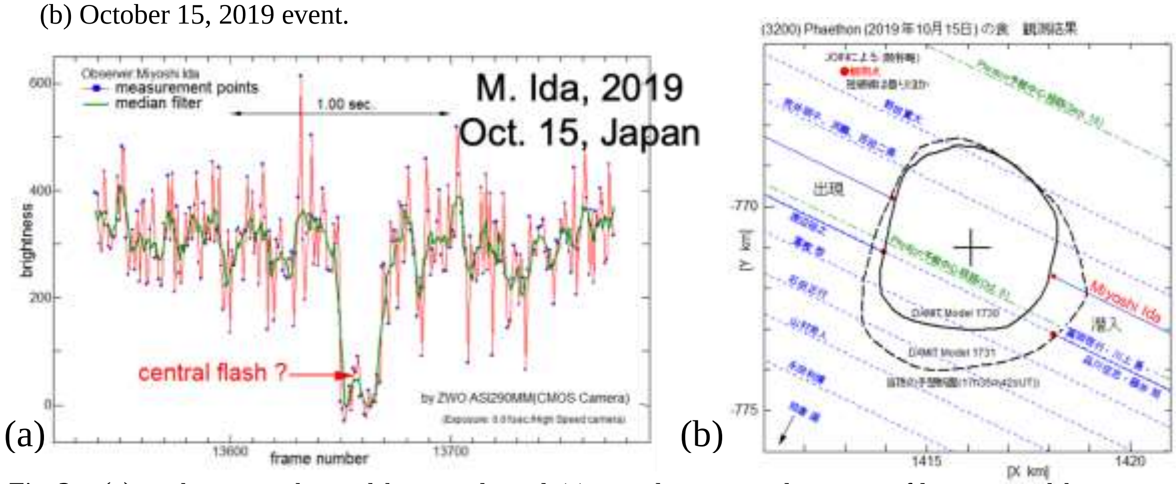


Fig 2. (a) Light curve obtained by M. Ida and (a) a preliminary reduction profile generated by T. Hirose (dashed lines are for the stations which were set up, but failed due to clouds or fog).