3-µm SPECTROSCOPY OF ASTEROID (3200) PHAETHON: IMPLICATIONS FOR B-ASTEROIDS. D. Takir[1], V. Reddy[2], J. Hanuš[3], T. Arai[4], D. S. Lauretta[2], T. Kareta[2], Howell, E.S.[2], Emery, J.P.[5], McGraw, L.[5] [1]SETI Institute, 189 Bernardo Ave., Mountain View, CA 94043, (dtakir@gmail.com), [2]Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ 85721-0092, [3]Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V Holešovičkách, [4] Planetary Exploration Research Center, Chiba Institute of Technology, Japan, [5] Earth and Planetary Science Dept., University of Tennessee, Knoxville, TN 37996.

Introduction: B-type [1] asteroid (3200) Phaethon is an Apollo near-Earth asteroid (NEA) that is thought to be the parent body of Geminids streams [2]. With its diameter of ~5 km [3], Phaethon is considered one of the largest potentially hazardous asteroids (PAHs). JAXA's Destiny+ mission will be launched to Phaethon in 2022 [4]. NASA's OSIRIS-REx mission will also visit another B-asteroid, (101955) Bennu [5]. Here we present the first rotationally resolved spectra of Phaethon to search for the 3-µm absorption feature on this primitive asteroid. The study of the 3-µm band allows us to better understand the hydration state and the association of hydrated minerals with organics on the surface of carbonaceous asteroids, and test the current dynamical and thermal theories of the formation and evolution of the Solar System. Astronomical observations of primitive bodies will also allow us to put the returned pristine samples from these objects in a broader perspective.

Methodology: We measured spectra of Phaethon with the long-wavelength cross-dispersed (LXD: 1.9-4.2 µm) mode of the SpeX spectrograph/imager at the NASA Infrared Telescope Facility (IRTF) [6]. We obtained LXD data during the night of 12 December 2017, using the standard star, SAO 39985 (Table 1). We used the IDL (Interactive Data Language)-based spectral reduction tool Spextool (v4.0) [7] to reduce the data. OH-line emission dominates the background sky through most of the wavelength range while thermal emission from the sky and telescope is important longward of ~2.3 µm. To correct for these contributions, we subtracted spectra of Phaethon and a standard star at beam position A from spectra at beam B. We extracted spectra by summing the flux at each channel within a user-defined aperture. We conducted wavelength calibration at $\lambda > 2.5$ µm using telluric absorption lines. We removed the thermal excess in Phaethon's spectra using the methodology described in [8] and references therein. To constrain Phaethon's model thermal flux, we fitted the measured thermal excess with a model thermal excess. Then, we subtracted this model thermal flux from the measured relative spectrum of Phaethon. To calculate the thermal flux in the 3-µm region, we used the Near-Earth Asteroid Thermal Model (NEATM)[9], which is based on the Standard Thermal Model (STM) of [10]. Figure 1a shows the effect of changing the beaming parameter thermal corrections in Phaethon's spectra. Figure 1b shows the chosen thermal model ($\eta = 1.9$, $p_v = 0.11$) to thermally correct Set 1 spectrum of Phaethon.

Results: Figure 2 shows the LXD spectra (Sets 1 to 10) of Phaethon. We also used Model 1 from [11] to show the shape model of Phaethon as a function of rotation phase (Figure 3).

Discussion: In this investigation, we found that Phaethon is featureless in the 3-µm region, suggesting that its surface is not hydrated. Primitive B-asteroid (142) Polana is the main asteroid in the New Polana Family [12]. This family is the probable source of primitive NEAs including Phaethon and Bennu [13]. These NEAs probably came from the inner belt and made their ways into NEO space via orbital resonances with the giant planets [13]. In this work, we determined that Polana is featureless in the 3-µm region, and its spectra are similar to Phaethon. Furthermore, visible and near-infrared (VNIR: 0.4-2.8 µm) spectra of Polana are similar to those of Bennu and Phaethon [14, 15]. [16] suggested a compositional and dynamical connection between Phaethon and B-asteroid (2) Pallas. However, Pallas exhibits a sharp 3-µm band, attributed to phyllosilicates [9], unlike Phaethon has a dry surface. It is possible that Phaethon had a water-rich surface in the past that became dehydrated due to its proximity to the Sun or due to heating by impact events. Also, it is possible that Pallas is big enough, unlike Phaethon, to allow hydrothermal circulation inside the asteroid that causes water to be replenished on the surface, interacting with silicates.

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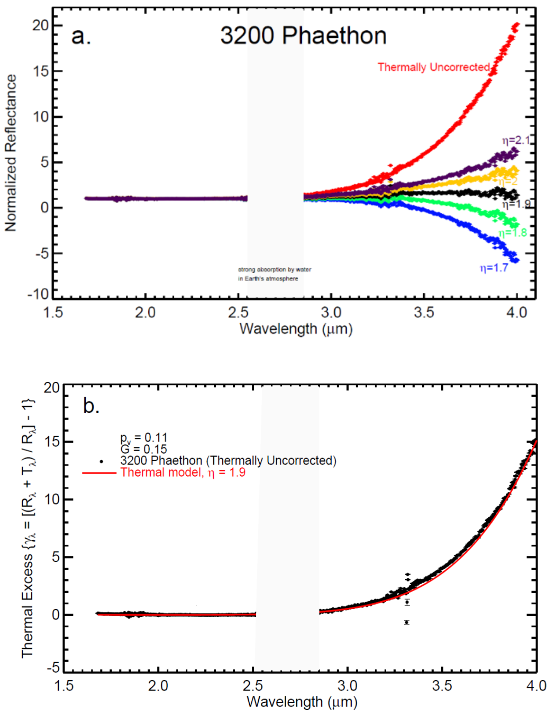

Figure 1 (a) The spectrum of asteroid Phaethon, uncorrected (red) and corrected using thermal models with changing beaming parameter (η) values (1.7-2.1). **(b)** The best fit thermal model (in red with a beaming parameter of η = 1.9) to thermally correct spectra of Phaethon. The gray bar mark wavelength of strong absorption by water vapor in Earth's atmosphere.

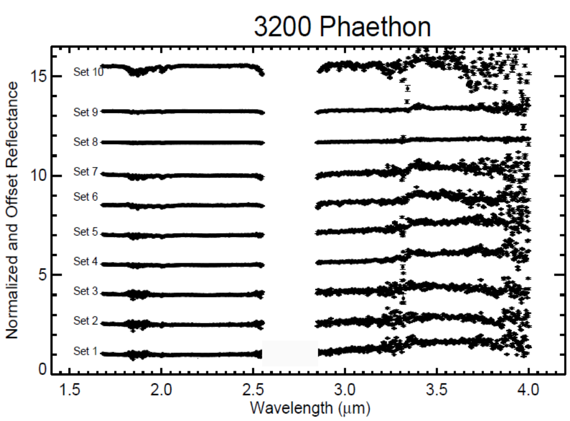

Figure 2. LXD spectra of asteroid Phaethon, which were found to be featureless at the 3-μm region, suggesting that the surface of this asteroid is not water-rich.

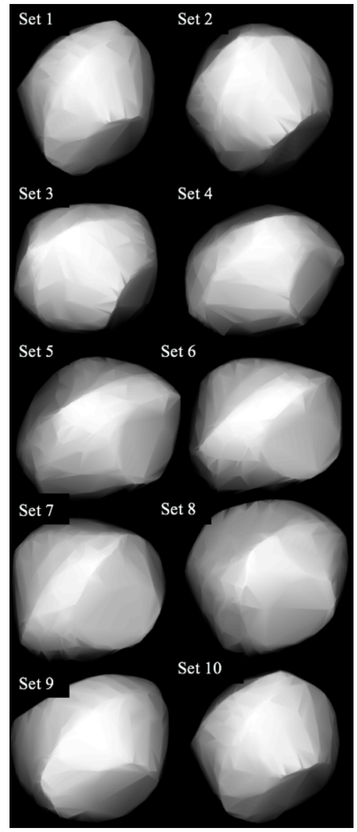

Figure 3. The shape model of Phaethon showing the 10 different rotation phases based on Model 1 from [11].

Table 1. Observational circumstances of asteroid Phaethon. The columns in this table are the observation set, Mid. UTC, V-magnitude, airmass, and rotation phase.

Set #	Mid. UTC	Mag. (V)	Air-mass	Rot. Phase (°)
Set 1	10:17	11.26	1.128	0
Set 2	10:42	11.25	1.153	42
Set 3	11:06	11.25	1.189	82
Set 4	11:38	11.25	1.258	135
Set 5	11:59	11.24	1.320	170
Set 6	12:20	11.24	1.391	205
Set 7	12:36	11.23	1.324	231
Set 9	13:35	11.23	1.849	330
Set 10	14:02	11.22	2.130	15