ROTATIONAL AND SURFACE PROPERTIES OF NEA 3200 PHAETHON.
M.-J. Kim[1], H.-J. Lee[1,2], D.-H. Kim[1,2], F. Yoshida[3], S.-M. Lee[1,2], P. Bartczak[4], G. Dudzinski[4], J. Park[1], Y.-J. Choi[1,5], H.-K. Moon[1], C.-H. Kim[2], H.-S. Yim[1], J. Choi[1], E.-J. Choi[1], J.-N. Yoon[6], A. Serebryanskiy[7], M. Krugov[7], I. Reva[7], K. E. Ergashev[8], O. Burkhonov[8], S. A. Ehgamberdiev[8], Y. Turayev[8], Z.-Y. Lin[9], T. Arai[3], K. Ohtsuka[10,] T. Ito[11], S. Urakawa[12], M. Ishiguro[13], B.-C. Lee[1], D.-G. Roh[1], and H.Seo[1,14], [1]Korea Astronomy and Space Science Institute, 776, Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Korea, skarma@kasi.re.kr, [2]Chungbuk National University, 1 Chungdae-ro, Seowon-gu, Cheongju, Chungbuk 28644, Korea, [3]Planetary Exploration Research Center, Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino, Chiba 275-0016, Japan, [4]Astronomical Observatory Institute, Faculty of Physics, Adam Mickiewicz University, Słoneczna 36, 60-286 Poznan, Poland, [5]University of Science and Technology, 217, Gajeong-ro, Yuseong-gu, Daejeon 34113, Korea, [6]Chungbuk National University Observatory, 802-3 Euntan-ri, Jincheon-gun, Chungcheongbuk-do, Korea, [7]Fesenkov Astrophysical Institute, Observatory 23, 050020 Almaty, Kazakhstan, [8]Ulugh Beg Astronomical Institute of the Uzbekistan Academy of Sciences, 33 Astronomicheskaya str., Tashkent, 100052, Uzbekistan, [9]Institute of Astronomy, National Central University, No. 300, Zhongda Rd., Zhongli Dist., Taoyuan City 32001, Taiwan, [10]Tokyo Meteor Network, Daisawa 1–27–5, Setagaya-ku, Tokyo 155–0032, Japan, [11]National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan, [12]Japan Spaceguard Association, Bisei Spaceguard Center, 1716-3 Okura, Bisei-cho, Ibara, Okayama 714-1411, Japan, [13]Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Korea, [14]Intelligence in Space, 96 Gajeongbuk-ro, Yuseong-gu, Daejeon, 34111, Korea.

Introduction: The near-Earth asteroid (NEA) 3200 Phaethon (1983 TB) is the target of the JAXA's DESTINY$^+$ mission, which is an Epsilon-class program. It is known as a parent body of the Geminids meteor shower that occurs in the middle of December every year. Phaethon is classified as a member of the Apollo asteroidal group with a semi-major axis greater than that of the Earth. It is also called as Mercury-crosser asteroid with the small perihelion distance of only 0.14 au. Therefore, the surface temperature of Phaethon regularly experiences more than 1,000 K [1][2][3]. The spectral type of Phaethon is known as B-type [4][5][6][7], which is a sub-group of C-complex that is attributed to primitive volatile-rich remnants from early solar system. In particular, Phaethon's parent body is assumed to have split into Phaethon and another NEA (155140) 2005 UD that have orbits similar to each other, approximately ~100 kyr ago [1]. For this reason, various investigations of the physical properties of Phaethon have been conducted based on photometric and spectroscopic observations.

Observations: The observation window for Phaethon at the end of 2017 was a good opportunity to acquire high-quality dense photometric and spectroscopic data, as the asteroid passed by the Earth at only 27 lunar distance on 16 December 2017, which was the closest approach in 40 yr. We performed a photometric observation campaign for Phaethon between the Asian and American continents during the 2017 apparition to investigate its rotational properties and refine the pole solution. We also carried out a time-series multi-band photometric observations at Mt. Lemon Optical Astronomy Observatory (LOAO) in Arizona, USA and a visible-spectrometry observations at Mt. Bohyunsan Optical Astronomy Observatory (BOAO) in Korea using the 1.8m telescope, with the 4K × 4K e2v CCD and long-slit spectrograph in order to examine the surface homogeneity of Phaethon.

Table 1. Observatory and instrument details.

Telescope[a]	λ^b	ϕ^b	Instrument [CCD]
SLT 0.4 m	120:52:25	+23:28:07	e2v CCD42-40
OWL 0.5 m	249:12:38	+32:26:32	FLI 16803
SOAO 0.6m	128:27:27	+36:56:04	FLI 16803
CBNUO 0.6 m	127:28:31	+36:46:53	STX-16803
MAO 0.6 m	66:53:44	+38:40:24	FLI IMG1001E
TShAO 1.0 m	76:58:18	+43:03:26	Apogee Alta F16M
LOAO 1.0 m	249:12:41	+32:26:32	e2v 4K CCD
BOAO 1.8 m	128:58:36	+36:09:53	e2v 4K CCD long-slit

[a] Abbreviations: SLT = Lulin Super Light Telescope, OWL = Optical Wide-field patroL, SOAO = Sobaeksan Optical Astronomy Observatory, CBNUO = ChungBuk National University Observatory, MAO = Maidanak Astronomical Observatory, TShAO = Tian Shan Astronomical Observatory, LOAO = Lemonsan Optical Astronomy Observatory, BOAO = Bohyunsan Optical Astronomy Observatory

[b] Eastern longitude and geocentric latitude of each observatory.

Lightcurve and Pole Orientation: We obtained the lightcurve of Phaethon (Fig 1.) and the unique solution for the ecliptic longitude/latitude of the pole orientation (Fig 2.) with two independent methods. With all available lightcurve data obtained via optical observations, as well as our time-series observation data, we derived a convex/non-convex 3D shape model that exhibits a concavity feature [8].

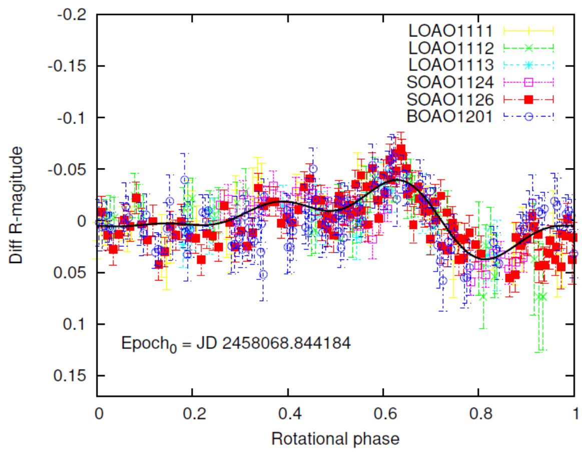

Fig. 1. Phaethon's composite lightcurve folded with the rotational period of 3.604 h at the zero epoch of JD 2458068.844184. The black solid line is a fit to the fourth-order Fourier model using the fast chi-squared method. Each data point represents observatories and observation dates (MMDD) in 2017 (cited from [8]).

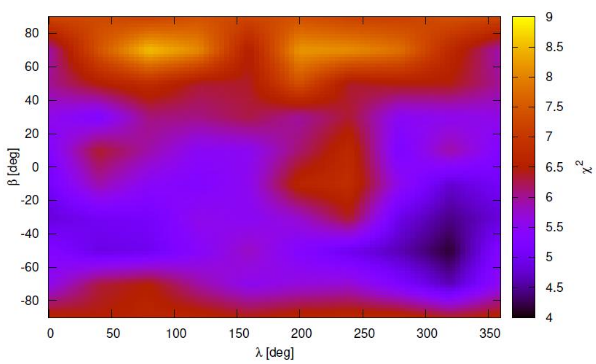

Fig. 2. The distribution of the pole solutions with respect to χ^2. From the lightcurve inversion method, the lowest value near (308, -52) was obtained (cited from [8]).

Surface Homogeneity: We examined the longitudinal color variation using our photometry and spectroscopy data. We found that Phaethon is a B-type asteroid, in agreement with previous studies, and that it shows no evidence for rotational color variation to an accuracy of our measurement (Fig 3.). The sub-solar latitude during our observation period was approximately 55 deg S, which corresponded to the southern hemisphere of Phaethon [3] .

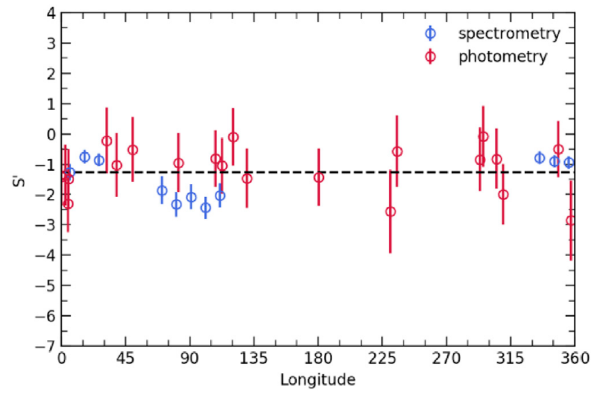

Fig. 3. Spectral gradient S' according to the longitude of Phaeton. The dots indicate S' determined on the observation data, and the dashed lines represent the mean values of S'. The errors in the slope S' for spectroscopy were estimated considering the noise in the spectra (cited from [3]).

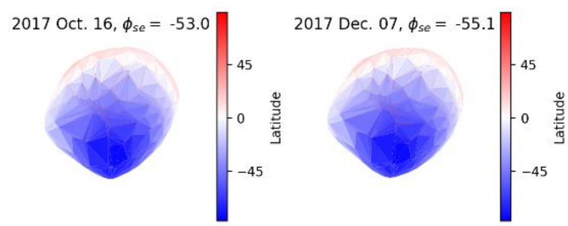

Fig. 4. The aspects of Phaethon at the time of spectral observation. The Symbol ϕ_{se} is the sub-earth latitude (cited from [3]).

We further investigated the newly calculated local surface temperatures by dividing them into six latitudinal regions based on our updated pole-orientation. The result confirmed that the solar-radiation heating effect on Phaethon's mineralogy appears similar at every latitude of the asteroid.

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