IDENTIFYING A KEY TO A SUBLIMATION PHENOMENON ON (162173) RYUGU.

V. V. Busarev[1, 2], F. Vilas[3], [1]Lomonosov Moscow State University, Sternberg Astronomical Institute (SAI MSU), University Av., 13, 119992 Moscow, Russia, e-mail address: busarev@sai.msu.ru, [2]Institute of Astronomy of the Russian Academy of Science (IA RAS), Pyatnitskaya St. 48, 109017 Moscow, Russia, [3]Planetary Science Institute,1700 East Fort Lowell, Suite 106, Tucson, AZ 85719-2395, USA.

Introduction: Based on the shape characteristics of reflectance spectra of some asteroids with H_2O ice sublimation activity having elevated reflectance in the UV-VIS-range [1, 2], we suspected a transient similar activity on (162173) Ryugu, a Cg-type potentially hazardous near-Earth asteroid (NEA) of Apollo's family, observed by F. Vilas in 2007 [3]. Asteroid (162173) Ryugu has been selected as the target of Japan's *Hayabusa 2* space mission, which will return a sample of the asteroid in 2020 (e. g., [4]).

We analyze reflectance spectra of Ryugu obtained by different authors and discuss possible mechanisms of ice preservation on this and similar primitive NEAs.

Observational Data: Taking into account characteristic signs of H_2O ice sublimation seen in an asteroid reflectance spectrum (elevated reflectance in the UV-VIS range and a significant dispersion of points) [1, 2], we consider all obtained to date (published and some unpublished) reflectance spectra of Ryugu (its values of perihelion q = 0.963292 AU and aphelion Q =1.415819 AU):

1) [5]: 17/05/99, heliocentric distance r = 1.311 AU (before aphelion) – one spectrum with positive gradient in the short-wavelength range (Fig. 1);

2) [3]: 11/07/07, r = 1.376 AU (after aphelion) – one very noisy spectrum with a maximum at 0.57 μm (Fig. 1);

3) [3]: 10/09/07, r = 1.241 AU (after aphelion) – one smooth and flat spectrum (Fig. 1);

4) [6]: 01/06/12, r = 1.367 AU (before aphelion) – two spectra, smooth and flat;

5) [6]: 02/06/12, r = 1.368 AU (before aphelion) – one flat spectrum but rise of noise;

6) [6]: 03/06/12, r = 1.370 AU (before aphelion) – three more noisy spectra;

7) Vilas (unpublished): 12/06/12, r = 1.383 AU (before aphelion) – two very noisy spectra with positive gradient;

8) [7]: 24/06/12, r = 1.397 AU (before aphelion) – one noisy spectrum with a small positive gradient;

9) [7]: 26/06/12, r = 1.399 AU (before aphelion) – noisy spectrum with a small positive gradient;

10) [7]: 05/07/12, r = 1.407 AU (before aphelion) – very noisy spectrum with raised short-wavelength reflectance.

11) [8]: 09/07/12, r = 1.410 AU (before aphelion) – one noisy spectrum with a slightly positive gradient in the short-wavelength range;

12) [8]: 10/07/12 (very close in time to the previous spectrum), r = 1.410 AU (before aphelion) – flat noisy spectrum.

Thus, we can see a rise in scatter (dispertion of points) and short-wavelength reflectance in Ryugu's reflectance spectra with its approaching aphelion which could be connected with H_2O ice sublimation on the asteroid. It looks strange because a similar phenomenon was observed in spectra of several main-belt primitive asteroids near perihelion [1, 2].

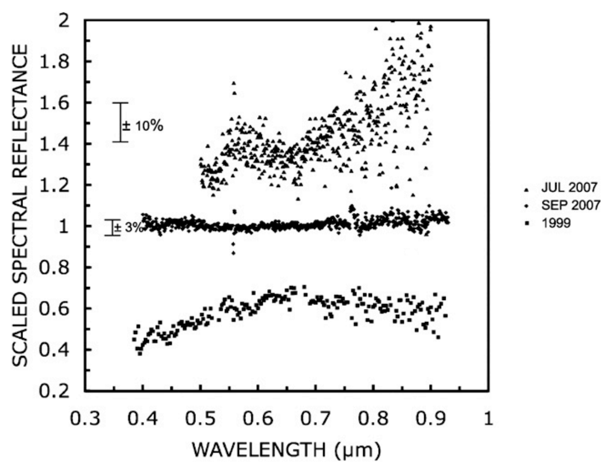

Fig. 1. Normalized at 0.55 μm and offset reflectance spectra of (162173) Ryugu reproduced from [3]. Two upper spectra were obtained on 2007 July 11 and 2007 September 10/11 (composite), respectively. Error bars represent scattering of points in the spectra. The lowermost spectrum of Ryugu was obtained during its 1999 discovery apparition by Binzel et al. [5].

Discussion: When a main-belt primitive asteroid becomes an NEA due to a strong impact event or the action of gravitational resonances, it quickly (after several revolutions around the Sun) loses a considerable amount of ice stored near the surface due to considerable growth of its subsolar and average subsurface temperatures by ~100 degrees (e. g., [9]). Tidal interactions with Earth and other terrestrial planets could raise fractures and breaks in the asteroid body that facilitate venting of any volatiles from its interior and loss of the uppermost regolith. A similar effect is produced probably by a sharp temperature differences between day and night sides of a NEA with its rotation on a time-scale of several hours. As follows from model calculations, the depth of a "desiccated" layer depends on amplitude of the surface diurnal and seasonal temperature variations and characteristics of asteroid regolith and subsurface matter such as the density, structure, porosity, heat conductivity, and so on (e. g., [9-10]). Thus, because of the presence of the desiccated layer, the maximum of the subsolar temperature on an NEA at the moment of passage of perihelion still does not reach its frozen interiors. In other words, we expect a time delay (or "thermal lag") between the time of maximum heating of the asteroid surface and that of the outer boundary of an internal icy reservoir. Moreover, during each passage of perihelion by the asteroid, the outer boundary of the ice core should move deeper, after seeing destructive action of the "heat wave" (an elevation by 50-100 degrees of the internal average temperature) onto the asteroid matter including closed ice traps by means of a mechanism of the formation of numerous new microcracks. A similar thermal mechanism of short-lived outbursts because of formation of deeper cracks and outgassing super volatile compounds was proposed under recent investigations of 67P/Churyumov-Gerasimenko comet [11].

A simpler explanation may also be proposed. A similar observational pattern could originate in the case of residual ice present at one of Ryugu's poles due to considerable change of lighting conditions. According to recent estimations of spin-vector orientation derived from a combined analysis of a data set of visual lightcurves and mid-infrared photometry and spectroscopy [12], Ryugu has a retrograde rotation with the most likely axis orientation of $(\lambda, \beta)_{ecl}$ = (340°, -40°), a rotation period of $P_{sid} = 7.63109^{h}$, and a very low surface roughness (r. m. s. of surface slopes < 0.1). Thus, one could imagine that at the mentioned asteroid parameters some ice-content material preserved in a surface depression at the North Pole of the asteroid would be more sunlit near aphelion then at perihelion. Additional heating of the icy material could produce the observed sublimation activity of Ryugu in the vicinity of aphelion. The simplicity of this explanation renders this exlanation to look more realistic. But it should be emphasized that owing to a relatively quick change of an NEA's orbital parameters under the action of gravitational perturbations from terrestrial planets, this is likely only a temporal phenomenon, and suggests that the residence time of the asteroid in the near-Earth space has not been very long in order to keep the icy matter at the surface.

References: [1] Busarev V. V. et al. (2015) *Icarus 262,* 44–57. [2] Busarev V. V. et al. (2016) *Solar Sys. Res. 50,* 281–293. [3] Vilas F. (2008). *Astron. J. 135*, 1101-1105. [4] Ishiguro M. et al. (2014) *Aph. J. 792*, 74-82. [5] Binzel R. P. et al. (2001) *Icarus 151,* 139–149. [6] Moskovits et al. (2013) *Eprint* arXiv:1302.1199v1 [astro-ph.EP] 5 Feb 2013. [7] Sugita S. et al. (2013) *44th LPSC*, Abs. #2591. [8] Lazzaro D. et al. (2013) *Astron. Astroph. 549*, 2-5. [9] Delbo M., Michel P., (2011) *Astrophys. J.* 728, L42-L46. [10] Delbo M. et al. (2014) *Nature 508*, 233-236. [11] Skorov Yu. V. et al. (2016) *Astron. Astrophys. 593*, 76-85. [12] Müller et al. (2016) *Eprint* arXiv:1611.05625v1.