衝突破片 1999 JU_3のスペクトル特性

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Introduction: Among several hundred asteroids whose visible reflectance spectra have been measured, 1999 JU_3 is among the few C-type asteroids that can be reached with small ΔV from the Earth [1]. This makes this asteroid a very attractive target for a near future sample-return mission. In fact, 1999 JU_3 is currently chosen for the primary exploration target of JAXA's Hayabusa 2 and the secondary target for both OSIRIS-REx mission by NASA and Marco-Polo mission by ESA. Thus, detailed investigation of this NEA is very important for near future planetary mission projects.

In particular, both spatial inhomogeneity and temporal variation in the spectral properties of the mission target NEA would give a large impact on remote sensing strategy and sampling site selection processes. In this study, we observe visible spectrum of 1999 JU_3 over multiple spin phases to examine how much spatial inhomogeneity is present and analyze newly obtained and literature spectrum of 1999 JU_3 closely to infer material properties.

Observations and Data Reduction: A series of visible spectroscopic observations of 1999 JU_3 were conducted with the 8.1-m-aperture Gemini-South telescope in Chili using GMOS instrument on June 24, 26, and July 5. The apparent visible magnitude of 1999 JU_3 was between 19.13 and 19.66 during our observations. The phase angle was relatively small between 22.7 and 30.3°. Two standard stars (HD142801, SA107-998) were used for calibration. Although the three observations cover a wide rotational phases, the observation on July 5th suffered from background star contamination.

Observation Results: Very flat spectra similar to the Sept. 2007 spectrum by [2] were observed in our three observations (Fig. 1). There is no obvious 0.7 μm feature in our spectra. The fact that three flat spectra without clear 0.7 μm absorption were observed at different rotational phases strongly suggest that most 1999 JU_3 surface is covered by material with flat spectrum at least the latitude range seen from the Earth during our observation period.

Data Analyses: We conducted three different analyses: principal-component analysis (PCA) [3], modified Gaussian modeling (MGM) [4], and comparison with spectra of heated meteorite samples [5].

The PCA indicates that the three of our spectra

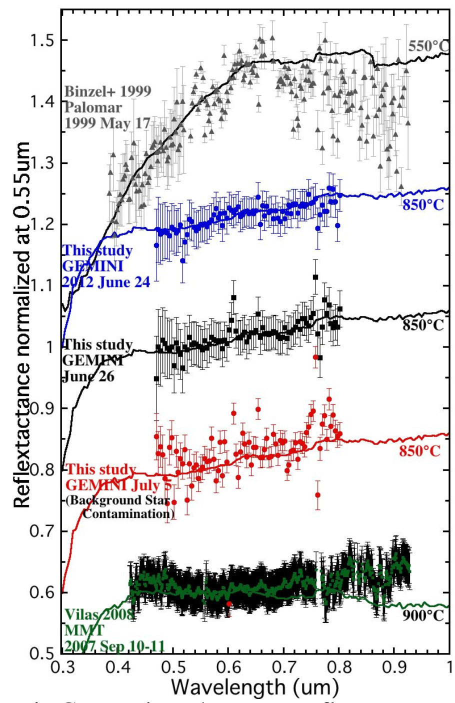

Figure 1. Comparison between reflectance spectra of asteroid 1999 JU_3 and those of heated Murchison meteorite samples at different temperatures [4]. The top and bottom spectra are from [6] and [2], respectively. The middle three spectra are observed in this study.

are clustered together near the spectra obtained in Sept. 2007 by [2] (Fig. 2). The MGM analysis of the July 2007 spectrum reveals that the central wavelength λ_{ctr} and breadth $\Delta\lambda$ of the best-fit Gaussian for the July 2007 spectrum follow the same λ_{ctr}–$\Delta\lambda$ trend for the Ch-type MBA's. This coincidence strongly suggests that the possible 0.7 μm absorption feature in the July 2007 spectrum may be real. Thus, the presence of 0.7μm absorption on 1999 JU_3 should not be ruled out at this point. Nevertheless, the fact that most 1999 JU_3 spectra obtained so far do not exhibit 0.7μm absorption band signatures indicates that material(s) with 0.7μm absorption would cover only a small surface area of 1999 JU_3. Furthermore, the comparison between meteorites and the great variety of 1999 JU_3 spectra reveal that the spectrum observed by [3] in May 1999, that by [2] in Sept. 2007, and those in this study in June to July 2012 can be fit well by Murchison chondrite samples heated at different temperatures (Fig. 1).

Implications for 1999 JU$_3$: If the rotation pole is upright as Müller et al. [7] obtained as the optimal solution, then it would be difficult to understand how a strong 0.7μm absorption feature would be missed by many observers during this observation opportunity in 2012 [8-10]. However, the pole vector determination is not unique yet. There are multiple local minimum solutions to reproduce the light curve observations results because 1999 JU$_3$ has a nearly spherical shape and very small light curve amplitude [e.g., 7].

This apparent contradiction could be resolved if 1999 JU$_3$ has a tilted spin axis and the azimuth of the spin axis is directed to the Earth in summer of 2012 as shown in Fig. 3. In this geometric configuration, we would have seen only a pole of 1999 JU$_3$ in May-July 2012. Then asteroid spin does not change the area visible from the Earth. In contrast, we would have seen the equatorial regions in summer of 2007 in this configuration. Then more variety of spectra could appear as the asteroid rotates. Higher quality light-curve data would be able to answer this question.

A possible Parent body for 1999 JU$_3$: Recent dynamical calculations indicate that 1999 JU$_3$ very likely came from the ν_6 resonance in the main belt [11]. There are only three asteroid families with low albedo (<0.1) near the ν_6 resonance: Sulamitis, Polana, and Erigone. Because the Sulamitis family members are very tightly distributed around the main asteroid 752 Sulamitis, however, kilometer-size fragments from this family are unlikely to have reached the ν_6 resonance [11]. This makes Polana and Erigone families the most likely source families for 1999 JU$_3$. Although both 142 Polana and 163 Erigone possess low albedo and relatively flat visible spectra, they have distinctly different visible spectra. The former exhibits clear blue slope between 0.45 and 1 μm and is classified as B type [12]. None of the 1999 JU$_3$ spectra observed so far is similar to this 163 Polana spectrum.

In contrast, the flat visible spectra observed in this study as well as that in September 2007 are similar to that of 163 Erigone as shown in Fig. 4. Also, the potential 0.7 μm absorption feature suggested from the above MGM analysis of the July 2007 spectrum is also consistent with the 163 Erigone spectrum. These pieces of evidence support the possibility that the parent body of 1999JU3 may be 163 Erigone or its own larger parent body.

Here it has to be noted, however, that the above discussion is based on the premise that 1999 JU$_3$ is a member of a collision family. It may have been a background asteroid near ν_6. Nevertheless, such distinction between a family asteroid near the ν_6 resonance and a background asteroid could be made if its fragmentation age is measured from returned samples.

References: [1] Binzel, R.P. *et al.*, 2004, *MAPS, 39*, 351–366. [2] Vilas, 2008, *Astron. J.*, *135*, 1101-1105. [3] Bus, S. and R. Binzel, 2002, *Icarus*, *158*, 146-177. [4] Hiroi, T. et al., 1996, *MAPS*, *31*, 321-327. [5] Hiroi, T. and F. Vilas, 1995, *LPSC*, *26*, 611-612. [6] Binzel, R. P. et al., 2001, *Icarus*, *151*, 139-149. [7] Müller, T. et al., *A&A, 525*, 1–6. [8] Sugita, S. et al., 2012, *DPS, 44*, 102.02. [9] Moskovitz, N. et al., *DPS 44*, 102.04. [10] Lazzaro, D., *et al.*, 2013, *A&A*, in press. [11] Campins, H. et al., *ACM Mtg*., #6452. [12] Clark, B. E., 2011, *Icarus 216*, 462–475. [13] Abe, M. et al. 2008, *LPSC*, *39*, #1594.

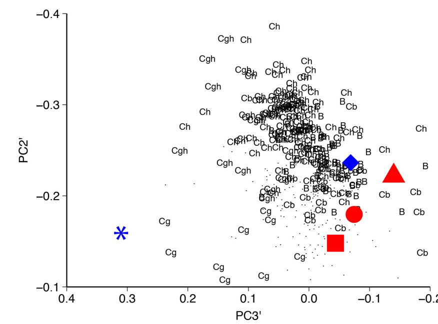

Figure 2. Comparison of principal components, PC2' and PC3', between SMASSII asteroids [3] and 1999 JU$_3$. The blue asterisk and diamond are for [6] and [2], respectively. The red symbols are for our new spectra in June to July 2012 observed with GEMINI-S.

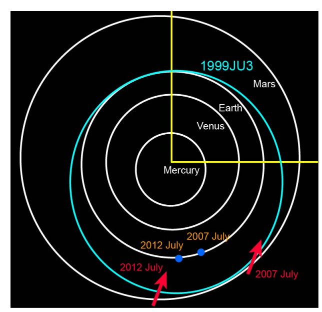

Figure 3. A possible azimuthal direction of the spin pole of asteroid 1999 JU$_3$.

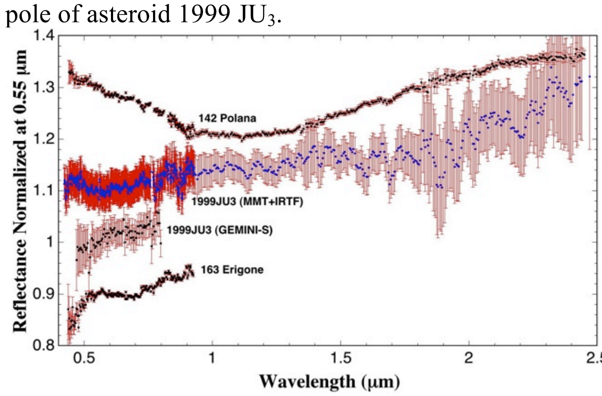

Figure 4. Comparison of reflectance spectra among 142 Polana [3], 1999JU3 [3, 13], and 163 Erigone [3].