

DIFFERENCE IN DEGREE OF SPACE WEATHERING ON THE NEWBORN ASTEROID KARIN.

T. Sasaki¹, S. Sasaki^{1,2}, J. Watanabe², T. Sekiguchi², F. Yoshida², T. Ito^{2,3}, H. Kawakita⁴, T. Fuse⁵, N. Takato⁵ and B. Dermawan⁶, ¹Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; takanori@eps.s.u-tokyo.ac.jp, ²National Astronomical Observatory of Japan, ³Lunar and Planetary Laboratory, University of Arizona, ⁴Gunma Astronomical Observatory, ⁵Subaru Telescope, National Astronomical Observatory of Japan, ⁶Department of Astronomy, Bandung Institute of Technology.

Introduction: “Space weathering” is the term applied to darkening albedo, reddening spectral slope, and obscuring absorption bands of planetary surface materials with time. The mismatch between reflectance spectra of most common asteroids (S-type asteroids) and most common meteorites (ordinary chondrites) might be caused by the space weathering [1-3]. Recent laboratory experiments simulating micrometeorite impact heating [4] confirmed Hapke’s old hypothesis that the spectral darkening / reddening are caused by formation of nanophase iron particles [5,6]. In the meantime, a recent study of celestial mechanics discovered a new-born group of asteroids, “Karin cluster group”, which is thought to be remnants of a collisional breakup only 5.8 million years ago [7]. Indeed recent observation showed Karin family asteroids may have fresh surfaces [8]. Here we report a near-infrared spectroscopy of the brightest asteroid 832 Karin among this cluster group.

Observation: A spectroscopic observation of Karin was carried out on 2003 September 14 UT using a Cooled Infrared Spectrograph and Camera for OHS with the Subaru Telescope. We employed grisms named zJ , JH , and wK for three cycles. In comparison with a light curve obtained by supporting observations [9], rotational phases of Karin in our observation are 0.30-0.34, 0.35-0.38, and 0.45-0.50 (Fig.1). The typical seeing size was about $0''.3$ in the K band during the observation, and the total integration time was 2400 s for each setting ($zJ + JH + wK$). A nearby G2 V star HIP 3990 was observed as a spectroscopic standard. For the cross-check of the cancellation of telluric absorptions, other reference stars (A0 star SAO 165395 and A2 star SAO 165274) were observed during the Karin observation. We used the NOAO IRAF astronomical software package to reduce near-infrared spectra obtained by CISCO. For details refer to Sasaki *et al.*, 2004 [10].

Results: Figure 2 shows the relative reflectance spectra of Karin those are relative to the first, the second, and the last observational sets. Since the range between 1.06 and 1.40 μm was observed both

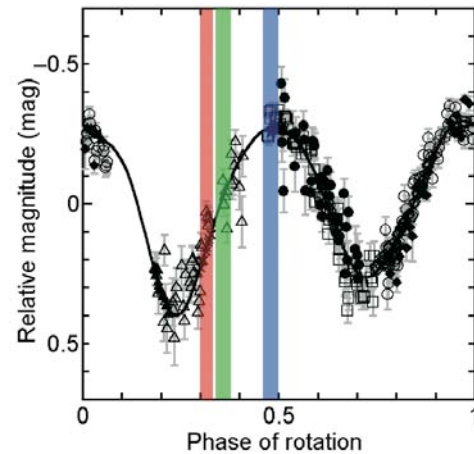


Fig.1: Light curve of 832 Karin. Our observation corresponds to the phase of rotations of red (first set), green (second set), and blue regions (last set). This figure was adopted and modified from Yoshida *et al.* [9].

by zJ and JH bands, actually we have 6 sets of spectra in this region (Fig.2). There is obvious difference between the top two and bottom spectra, suggesting that Karin’s surface is inhomogeneous in each rotational phase. We confirmed that the same difference could be derived using other reference stars, and the SAO 165395 spectra were not changed before the first set and after the second set of Karin observation [10]. The observed spectral change of Karin was not caused by an instrumental, atmospheric, or hour angle effects.

The shape of 0.8-2.5 μm is consistent with an S-type object. Using S subclass classification scheme [11], we identified Karin among the range of S(III), S(IV), and S(V) classes. Figure 4 shows the normalized reflectance spectra of Karin along with previous observations of S(IV) asteroid 584 Semiramis [12] and L6 ordinary chondrite Paranaiba [13]. Whereas the first set’s spectrum matches the spectrum of the S(IV) class asteroid, the last set’s spectrum matches a typical normalized spectrum of L6 ordinary chondrite. The first set seems to be reddened from the last set by space weathering; the trend is consistent with a prediction by laboratory simulations of space weathering [4].

Visible observations of Karin in the same season indicated that the surface at rotational phase of 0.2 is

weathered and the surfaces after 0.3, especially after 0.5, are not weathered [9]. Their results are consistent with our observation.

Discussions: Our results indicate that Karin has inhomogeneous surfaces for each rotational phase, which seems to reflect the degrees of space weathering between the first set and other sets. Difference of surface compositions also can generate the spectral change, however, it is difficult to produce the reddened spectra without space weathering. Hence, we may conclude the differences of Karin's spectra would be caused by space weathering. The mature and fresh surfaces' spectra in one body strongly stand up for the idea that space weathering is responsible for the mismatches between asteroid types and meteorite classes. Our results support the idea that S-type asteroids are parent bodies of ordinary chondrites [2], and also indicate that space weathering should not proceed in a duration as short as 6 million years.

We observed a rapid change of the spectrum around the rotational phase of 0.35 where observing cross section of Karin increased. This spectral change according to the rotational phase could be explained if Karin is one of the cone-shaped fragments at low-velocity impact forming Karin family. Impact disruption experiments suggested that in the low-velocity impact regime ($v < 1$ km/s), the target is shattered into cone-shaped fragments, pointing towards the impact point [14]. In this case, only the base of the cone is composed original mature surface darkened by space weathering. According to the light curve peaks, cone base was observed at a rotational phase of 0.2. This would imply that the surface around 0.2 is mature, which is consistent with our observation.

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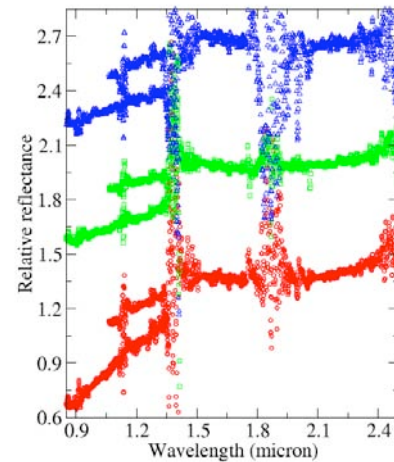


Fig.2: Relative spectra of Karin relative to the first set (red), second set (green), and last set (blue) of the night. Spectral data are smoothed by a running average of 5 pixels, and vertically shifted for clarity.

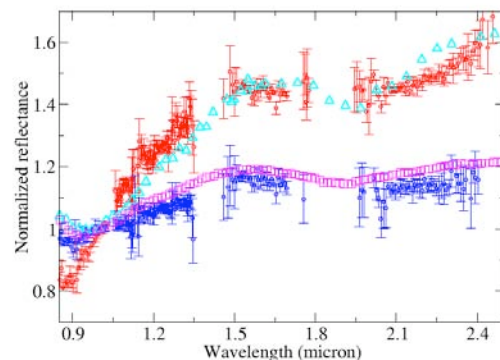


Fig.3: Reflectance spectra of Karin (first set: red; last set: blue) along with the spectra of S(IV)-type asteroid 584 Semiramis (cyan triangle) and L6 ordinary chondrite Paranaiba (magenta square) normalized to the unity at 1.0 μm .