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Young Asteroid 832 Karin shows no rotational spectral variations

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Abstract

We have made near-IR spectral observations of the very young (5.75 Myr) S-type asteroid 832 Karin, well sampled in rotational phase over its 18.35-h period. We find no significant variations in its reflectance spectrum. Karin, the brightest member of the Karin cluster (a sub-family of the larger, older Koronis dynamical family), was shown to be exceptionally young by Nesvorný et al. [Nesvorný, D., Bottke, W.F., Dones, L., Levison, H., 2002. Nature 417, 720–722], using backward numerical integration of orbital elements of cluster members. Their precise dating of the collisional breakup gives us an opportunity, for the first time and without age-dating of physical samples, to monitor time-evolution of processes, like space weathering, that operate on timescales of ∼1–10 Myr. Sasaki et al. [Sasaki, T., Sasaki, S., Watanabe, J., Sekiguchi, T., Yoshida, F., Kawakita, H., Fuse, T., Takato, N., Dermawan, B., Ito, T., 2004. Astrophys. J. 615, L161–L164; Sasaki, T., Sasaki, S., Watanabe, J., Sekiguchi, T., Yoshida, F., Ito., T., Kawakita, H., Fuse, T., Takato, N., Dermawan, B., 2005. Lunar Planet. Sci. XXXVI. Abstract #1590] had made similar measurements of Karin, although more sparsely sampled than ours, and claimed dramatically different colors as a function of rotational phase. Sasaki et al. interpreted their data to be showing the reddish, space-weathered exterior surface of the precursor asteroid, as well as an interior face, which had not had time to become space-weathered. On five nights over 2006 January 7–14 UT, we observed Karin with the SpeX (0.8–2.5 μm) spectrometer of the IRTF. We analyze data in 30° intervals of rotational longitude, some of which we sampled on two different nights. The spectra are consistent with little or no spectral variation as the asteroid rotates; certainly there are no changes as large as previously reported. The previous observations were probably spurious. Our average spectrum resembles the "blue" spectrum of Sasaki et al., which they interpreted to be the "fresh" surface. Karin is not quite as red as typical S-types, yet has rather shallow absorption bands. We surmise that the space-weathering process affecting Karin has had time to reduce spectral contrast, but has not operated long enough to redden its spectrum—an intermediate case of space weathering, which has gone to completion for most main-belt asteroids. This work sets an important constraint on the timescale for the ubiquitous space-weathering process affecting S-types, namely that its effects are evident, but not yet complete, at ∼6 Myr.

Keywords: Asteroids; Asteroids, surfaces; Asteroids, composition; Infrared observations; Spectrophotometry

1. Introduction

A long standing issue in asteroid astronomy concerns the degree to which asteroids exhibit changing colors as they rotate. A related issue concerns the degree of color variation among members of asteroid families. There are two main reasons for interest in such variations: (a) compositional differentiation processes and (b) space weathering processes. First, the observed variety of meteorites demonstrates the existence of many differentiated parent bodies, in which various minerals (within the presumably asteroidal precursor bodies) were spatially segregated due to prior heating and melting. Later, once these bodies cooled and subsequently were fragmented during an energetic collision (catastrophic disruption), one can readily imagine that various fragments might have different mineralogies and that individual fragments might have different mineralogies on different sides. Discovery of such differences could provide insight concerning the interiors of differentiated bodies as well as the mechanics of asteroid collisions.

The second reason to study color variations involves space weathering (cf. Chapman, 2004). This is the process, due to one or more hypothesized mechanisms such as solar-wind and micrometeoritic bombardment of surfaces of airless bodies, that increasingly modifies with exposure to space the inherent spectral characteristics of the constituent rocks. Space weathering

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partially masks and confuses interpretation of reflectance spectra in terms of mineralogy and meteoritic analogs. However, for family members derived from a recent catastrophic break-up, it is possible that some will exhibit the space-weathered exterior of the parent body, while others might be "fresh" or only partially space-weathered fragments of the body's interior. And, as with the differentiated case discussed above, it is possible that an individual fragment might show the space-weathered exterior color on one side, and the less space-weathered interior color on its opposite side. This paper addresses the issue of a single asteroid exhibiting diverse spectral properties on different sides.

Recently, theoretical understanding of the dynamical evolution of a cluster of asteroids within the large Koronis family has presented an excellent opportunity to study space weathering attributes of members of a very young family. Nesvorný et al. (2002) (updated by Nesvorný and Bottke, 2004) demonstrated that this small family-within-a-family, named the "Karin cluster," was formed by catastrophic collision just 5.75 ± 0.05 Myr ago (discussed further below), less than 0.2% the age of the Solar System. This is the first time there has been an alternative to radiometric dating of meteorites to determine precise ages of events in the asteroid belt, and these ages can be ascribed to specific, observable bodies. We have been observing some of the $\sim$90 members of this young cluster, and especially its largest and brightest member, 832 Karin. A principal goal is to determine the degree of space weathering that has developed within less than 6 Myr, and thus measure the absolute rate of space-weathering processes in the asteroid belt. Published estimates of space-weathering rates range from tens-of-thousands to hundreds-of-millions of years.

Although space weathering processes may affect the surfaces of all asteroids, most discussion of space weathering over the last three decades has concerned its effects on S-type asteroids, which is the broad taxonomic class of the Koronis and Karin members. The primary effects on 0.8–2.5 µm spectra of S-types are (1) a generalized reddening of the spectral slope and (2) diminished depth of the strong spectral bands of silicates (i.e., diminished spectral contrast, which is sometimes associated with lowered albedo). Thus this study focuses on central issues in the space weathering debates.

Sasaki et al. (2004, 2005) claimed to have discovered major infrared color changes of Karin during an approximately 1-h period on 14 September 2003, using a spectrograph on the Subaru telescope. They interpreted the observations in terms of preservation of a space-weathered, S-type surface on one side of Karin, and a less-space-weathered, ordinary chondritic surface on the other side. Because Karin rotated less than 20° between the two very different spectra, it is difficult to formulate a shape, illumination geometry, and observing geometry that would permit such drastic spectral changes to occur. Thus we undertook to confirm this claim, which is the biggest regional color difference ever reported for an asteroid.

In this paper, we describe our observing campaign on Karin during January 2006 using the SpeX spectrograph (Rayner et al., 2003) on the 3-m IRTF (NASA Infrared Telescope Facility on Mauna Kea, Hawaii), during which we measured Karin's reflectance spectrum from 0.8–2.5 µm, the same spectral range observed by Sasaki et al. We find no significant color variation as Karin rotates. In an accompanying paper in this journal, submitted simultaneously with ours, Vernazza et al. (2007) report independent visible and infrared observations of Karin and also find no significant rotational color variations.

We begin by providing background discussions of rotational color variations on asteroids, the recent discovery of demonstrably young asteroid families, and summarize the Sasaki et al. result. Then we describe our observations and reductions in some detail, because this is the first publication from our new IRTF SpeX observing program on dynamically young asteroids, which commenced in 2005. We present our final results concerning Karin's virtual lack of rotational color changes. Finally, we assess and discuss the evidence concerning the reflectance spectrum of Karin.

2. Background

2.1. Color variations

A century ago, asteroids were considered to be gray reflectors of sunlight and were occasionally used as solar standards. Bobrovnikoff (1929) undertook the first serious effort to study asteroid colors using a spectrograph on the Lick Observatory 36-inch refractor. Among his results, which seems all the more remarkable today (since it remains the best example), was his discovery of spectral variations, with time, of 4 Vesta. Indeed, Bobrovnikoff used the color variations to determine the rotation period of Vesta, to fair accuracy. This result was subsequently overlooked as observers debated whether Vesta had a 5- or 10-h rotation period, a question not settled until around 1980. Vesta's color variations are correlated with heterogeneity of Vesta's mineralogy (Gaffey, 1997).

There have been attempts (e.g., Degewij et al., 1979) to detect albedo and/or color variations with rotation for some brighter asteroids observed with high photometric or polarimetric signal-to-noise. While real variations have been detected on a few asteroids (6 Hebe, 8 Flora, 44 Nysa, and 349 Dembowska, for example), generally at the level of a few percent, Vesta has remained the principal confirmed case for substantial color variation. One prominent case of reported spectral differences on opposite sides of an asteroid was for 433 Eros (Murchie and Pieters, 1996), who interpreted the differences in terms of significant mineralogical variation across the face of Eros. While the NEAR Shoemaker mission to Eros did reveal statistically significant infrared color variations on Eros (Murchie et al., 2002), the main news was how colorimetrically uniform Eros is; the detected color variations were smaller than the differences inferred from telescopic spectra, which now must be considered as reflecting inherent uncertainties in the telescopic data.

One early explanation for the uniformity of asteroid albedos and colors was that asteroids "painted themselves grey" (or whatever color) with ejecta from large cratering events, enabling localized material to be draped around the entire body due to low gravity on asteroids. While it is true that ejecta travel farther on asteroids than on bodies like the Moon, it is now understood that ejecta velocities are lower than had been thought and total homogenization is not expected. Spacecraft studies of individual asteroids have revealed significant localized non-uniformities in color and spectral traits [cf. Veverka et al. (1996) and Chapman (1996) for Ida, Abe et al. (2006) for Itokawa]. However, even though the localized spectral differences can be large, the spots are often rather small and would yield very modest differences when observed in whole-disk (hemispheric) averages as is done in telescopic observations.

2.2. Young asteroid families

It has been learned over the past decade that asteroid families, produced by catastrophic inter-asteroidal collisions, gradually evolve in various ways. Original families diffuse, with some orbital elements changing on rapid timescales and others on longer timescales, due to resonances, the Yarkovsky Effect, and other forces, so that the original configuration is gradually lost. Other properties of individual family members also evolve with time, including spin state and surface properties. A recent discovery has permitted the identification of several very young asteroid families, which allows us to observe the post-collisional properties of such a break-up before the original conditions have had time to evolve very much. The first case involved identification and analysis of the Karin cluster within the Koronis family (Nesvorný et al., 2002). The cluster is apparently the product of a moderate-sized [32 ± 3 km diameter (Nesvorný et al., 2006)] Koronis family member that was disrupted only 5.75 ± 0.05 Myr ago (Nesvorný and Bottke, 2004).

Nesvorný et al. (2002) applied the Hierarchical Clustering Method (Zappalà et al., 1994) to a new, state-of-the-art proper-element database (Knežević and Milani, 2003) to search for compact families with just 1/10th of the typical dispersion in orbit-element values of most families. They found a prominent, compact cluster of 39 asteroids (including Karin) within the Koronis family (the number known now is $\sim$90); its orbital distribution is diagonal in proper semimajor axis vs proper eccentricity and fits inside a similarly shaped "equivelocity" ellipse expected for a collisional dispersal of fragments. Simulations match the ellipse if the precursor body was near its perihelion when a catastrophic collision and break-up occurred, launching fragments away at $\sim$15 m s^{-1}. Cluster fragments then circled the Sun as a group. But within $\sim$1000 years, they drifted away from each other around their nearly common orbits. Over longer durations, their orbital orientations (longitude of ascending node, argument of perihelion) also drifted apart, around 360°, due to planetary perturbations. After only a few million years, the once-clustered asteroids had dispersed into a torus around the Sun, like the IRAS dust bands. By numerically integrating the orbits back in time to an instant when *all* the orbital elements are clustered, Nesvorný et al. (2002) found the absolute time when the Karin cluster formed: $\sim$5.8 Myr ago [the timing is now dated to better precision, 5.75 ± 0.05 Myr ago (Nesvorný and Bottke, 2004)]. (The chance that such a convergence could happen by happenstance during the full age of the Solar System is $<10^{-6}$!) This first-ever dated event must *not* be confused with the event that created the Koronis family. The age of the Koronis family, based on cratering studies of Ida (a Koronis member) and collisional/dynamical evolution studies, is 2–3 Gyr (Chapman, 2002; Marzari et al., 1995; Bottke et al., 2001), more than *400 times older* than the Karin-cluster event, which is a very recent secondary disruption of an asteroid *within* the Koronis family.

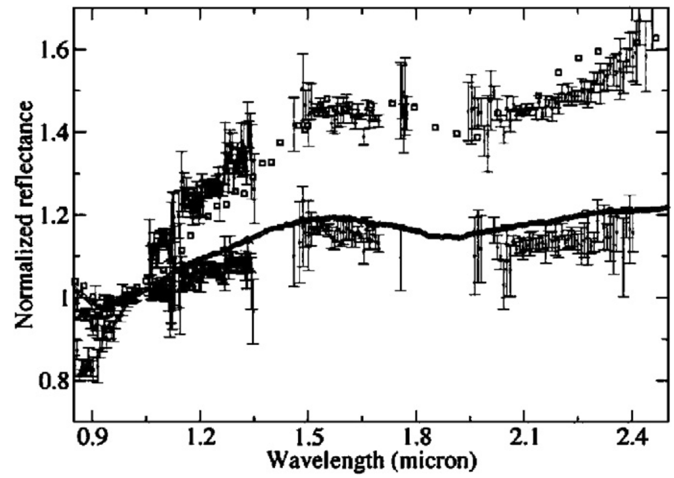

Fig. 1. Reported different IR reflectance spectra on Karin (reproduced in black-and-white from Sasaki et al., 2004). The relevant spectra are the small data points with error bars, which have been normalized to unity at 1.0 µm. The upper spectrum is the "first set" of data by Sasaki et al.; the bottom spectrum is the "third set" (which is very similar to the "second set"). Small squares and solid curve are comparison spectra, not discussed here.

A number of other very young families and clusters have been identified subsequently, using similar approaches. Meanwhile, the Karin cluster has been considered a prime group for telescopic study. In the last few years, additional members of the family have been discovered (Nesvorný and Bottke, 2004), but most of them are very faint. We have observed a number of Karin family members in our overall program (which includes lightcurves, thermal observations, colors, spectra, satellite searches, and other studies), but we concentrate here on the largest and brightest member of the family, 832 Karin itself, which is our most complete data set.

2.3. Sasaki et al. results for Karin

In Fig. 1 we reproduce the chief result of Sasaki et al. (2004) concerning color variations on Karin. The upper data points ("first set") are data taken between UT 7:57 and 8:30 on 14 September 2003, while the lower set of points ("third set") are data taken between UT 10:45 and 11:39. Another set of data ("second set"), which closely resembles the third set, was taken between UT 8:46 and 9:18. The first set of data yields an unusually reddish spectrum, dramatically different from the other two sets. From lightcurve photometry taken near the same epoch (Yoshida et al., 2004), Sasaki et al. show that the first two data sets (which differ dramatically) were taken near average brightness of Karin as it was brightening about 0.1 mag per hour. The third data set was taken near the lightcurve maximum. (The Yoshida et al. colorimetry also hinted at rotational color variations for Karin.) Sasaki et al. interpret their own data as re-

Table 1
Karin spectral data

Date (UT)	Start/end times (UT)	No. of spectra	Sky quality
2006-01-07	11:52–15:29	58	Excellent
2006-01-08	11:20–15:29	84	Excellent
2006-01-12	11:43–15:34	84	Fair
2006-01-13	11:32–15:29	116	Very good
2006-01-14	11:28–15:20	64	Good

flecting a mature space-weathered surface (first set) and fresh, largely un-weathered surfaces (second and third sets), although they do not rule out the possibility that the different colors instead reflect different mineralogies from within a differentiated precursor body. We discuss these data further when we compare them with our own results, in Section 4 below.

3. Our observational program

3.1. Observational procedure

Using the SpeX spectrometer on the IRTF, we concentrated on Karin during clustered nights of two separate observing runs in January 2006. At this time, Karin ($V = 16.5$, RA 11:44, Dec +00:25) had a range from Earth of 2.5 AU, was 3.1 AU from the Sun, and had a phase angle of 17° (98% illumination). With Karin transiting at ∼4:45 local time (14:45 UT), at an elevation of 71°, we were able to obtain good infrared spectra over about 4 h on each of 5 half-nights (2nd halves) during an 8-night span, as shown in Table 1. The tabulated sky quality is a qualitative estimate from our logged notes as well as sky probe records obtained from the nearby CFHT site on Mauna Kea. Seeing was generally good on all nights, typically 0.6 arcsec. During all nights we observed remotely from our Boulder, Colorado, offices, but one of us (EFY) was also present onsite at the IRTF on the last two nights.

SpeX was used in its low-resolution prism mode, with the 0.8 × 60 arcsec slit. In this mode, SpeX delivers a spectrum spanning roughly 0.8–2.5 μm to one quadrant of the 1024 × 1024 InSb array, spanning roughly 512 pixels at an average dispersion of 0.003 μm/pixel, with a resolving power of about 94 (56 at 0.8 μm to 130 at 2.5 μm). The image scale is 0.15 arcsec/pixel, so the image of the 60 arcsec slit is about 400 pixels long.

We employed the usual procedure of making a pair of observations by nodding the telescope along the slit to an offset position ∼50 pixels (7.5 arcsec) away. The two positions are called A and B; a pair of observations is an AB pair. Our exposure time for each observation was 60 s. Because A and B are acquired close in time, differencing them removes most sky background structure, dominated by rapidly varying OH telluric emission lines. Typically, we acquired data in clusters of 2 or 4 AB pairs at a time, taking about 15–30 min for each cluster. Between clusters we observed standard stars or other asteroids and did arc-lamp calibrations. Before each cluster, we adjusted the slit to be aligned with the parallactic angle to ensure that atmospheric dispersion was along the slit; otherwise, spurious spectral slopes could be introduced if the object is cut by the edge of the slit due to imperfect guiding. Both automated- and hand-guiding were used to center the object in the slit due to minor deviations from tracking at the asteroid rate.

Four to six sets of standard star observations were obtained during each half-night, both for determining atmospheric extinction and as solar analogs used to derive spectral reflectances. Our chief standard star, used for our extinction corrections and solar calibration, was HD95868, G2V, $V = 9.7$; we also observed HD89269, G5, $V = 7.5$, and HD28099 (Hyades 64), G2V, $V = 8.1$. Using the SpeX CAL-PRISM macro, argon-arc-lamp spectral calibrations were obtained about 10 times per half-night. A dome-flat-field calibration set was made each night.

3.2. Data reduction

Our data-reduction pipeline generally replicates standard procedures for astronomical spectrophotometry and employs algorithms we and others have previously used to reduce prism-mode SpeX data. In addition, we have checked critical elements of our data reduction against independent algorithms from IRAF and S.J. Bus.

For each observing night, an average flat-field file is produced from the single flat-field calibration set (several images) acquired that night. Because the quartz lamp, used for these dome flats, has a very strong thermal gradient in the near IR, we normalize the flats on a wavelength-by-wavelength basis to remove this gradient before applying the flat to the astronomical data. Bad pixels are identified as outliers in the flat field; these are not included in the eventual spectral extraction. Because of the long slit used, the slit image (hence the spectral lines) exhibits some curvature; to rectify it and put the spectrum on a linear scale, we construct a geometric transformation from raw detector coordinates to a grid that has linear wavelength vs linear position along the slit. This remapping and the fundamental wavelength calibration are done using a 2-D 4th-order polynomial fit to the positions of 10 lines in the arc-lamp between 0.81 and 2.51 μm. The two components of an AB pair are then differenced as a first-order sky subtraction. Finally, the residual sky (sky background that has changed more rapidly than the time separation between the AB observations) is estimated from sky regions above and below (higher and lower on the slit) the spectrum, and is removed on a wavelength-by-wavelength basis. We extract the flux at each wavelength by a simple sum of counts within a rectangular box centered on the spectrum (the box width was about 4 times the FWHM of the spectrum in the cross-dispersion direction). We have made spot comparisons of our results with optimally weighted extraction routines, including one in IRAF. The noise is somewhat greater for our rectangular extractions, but this is only a minor problem for the relatively bright target Karin. Most important, there are no systematic differences between the extraction procedures.

Data that seem to have been badly affected by cirrus clouds, guiding errors, proximity of background stars, or difficulties in background subtraction are omitted from our final results. There are 406 usable spectra of Karin (from 203 AB pairs),

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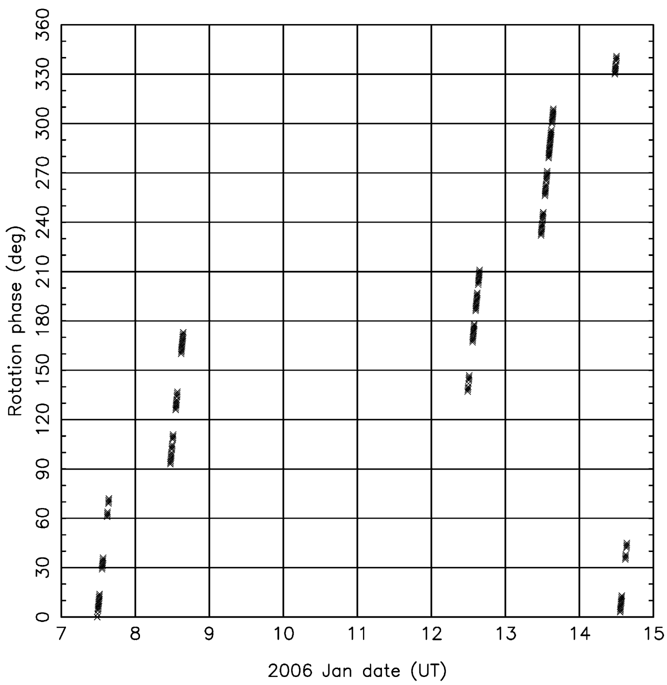

Fig. 2. Timings of our spectral observations of Karin, showing equivalent rotational phase, assuming a rotation period of 18.35 h. The ×'s show times and longitudes for individual spectra that were given non-zero weights in our reductions. The chart demonstrates that our rotational coverage is good, with no gap greater than 20°. More than 80° of the phase coverage is repeated on two different nights.

each of which is assigned a weight based on inherent attributes of the reduced data and on notes in our observing log.

Extinction corrections are determined from observations of our prime star over the widest airmass range, with some modifications (especially for the 12 January data) to avoid data affected by cirrus and to include observations closer in time to the relevant observations of Karin. Generally, our nights were stable enough so that these extinction corrections should be adequate. However, we have also performed spot calculations using, in an unweighted fashion, the approach of S.J. Bus (personal communication, 2006), which leverages the asteroid's smooth spectral shape to estimate the water vapor from the asteroid spectrum itself. A series of ATRAN transmission models (Lord, 1992) generated for the known airmass are compared with the asteroid spectrum after removal of the G-star signature, and the best fit model removed. The two extinction correction techniques show excellent agreement for the features of interest in this analysis.

The resulting 406 weighted spectra are assigned to their respective 30°-bins of rotational phase, adopting the 18.35-h rotation period for Karin (Yoshida et al., 2004), as shown in Fig. 2. In a single step, we average all spectra in each of these 12 bins as well as across 5 pixels (or average $\Delta\lambda = 0.017$ μm) in wavelength to produce the spectra presented in Fig. 3. Extreme outliers are first rejected and then we reject points beyond 1.5 times the standard deviation of the population of remaining points that go into the average (we subjectively judge most such points to be spurious due to irregularities in our observations or reductions). All spectra are normalized to unity at 1.0 μm and are vertically offset from each other by 0.15. Error bars are shown only for the noisiest (210°–240°) and least noisy (180°–210°) averages; they are 3 times the standard errors ($\pm 3\sigma_\mu$) of the plotted means and do not account for any systematic errors.

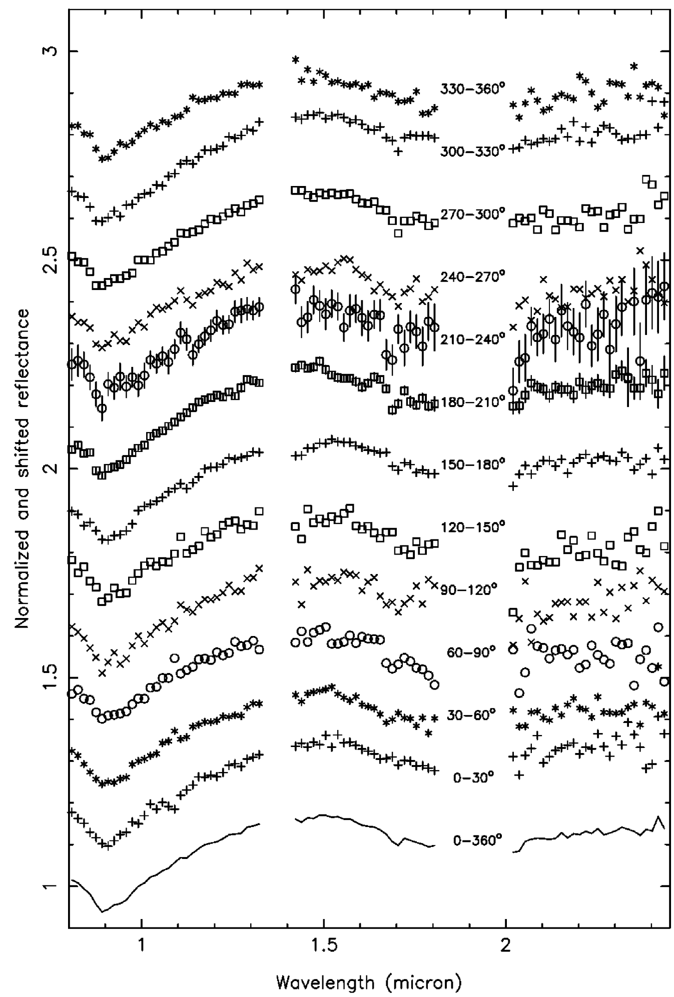

Fig. 3. Symbols show average reflectance spectra for Karin in 12 different 30° bins of rotational longitude, normalized to unity at 1.0 μm and shifted vertically by 0.15. Error bars (3 times the standard errors of the means) are shown for the noisiest (210°–240°) and cleanest (180°–210°) average spectra. Data in the gaps near 1.4 and 1.9 μm are excluded here due to the presence of telluric water bands. It is clear that we could not have missed dramatic color changes, even if they occurred in narrow longitude intervals. The solid curve at the bottom is our best weighted average reflectance spectrum from all five nights of data.

4. Discussion and conclusions

As can be seen in Fig. 3, there are minimal significant differences between the 12 average spectra. Relevant spectral parameters, such as overall slope, depth of the 1 μm absorption band, and center wavelength of the band appear nearly identical within the range of typical errors. Our spectral slopes may be slightly redder in the 180°–210° and 300°–330° intervals and least red in the 120°–150° interval; but the maximum slope difference we see is less than 1/6th that reported by Sasaki et al. (2004) (see Fig. 1).

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Could our results possibly be compatible with the Sasaki et al. results due to different Sun–Earth–Karin geometry? First, we note that we are not (yet) able to determine the rotational phase of our observations with respect to the rotational phases observed $2\frac{1}{2}$ years earlier by Sasaki et al., due to imprecision in the known rotation period of Karin, although this should be possible in the future. Second, the pole of rotation of Karin is not yet known. So conceivably a very reddish large spot on Karin, responsible for the reddish spectrum of Sasaki et al., was located on the opposite hemisphere of Karin when we observed. Such a spot could not be located at or near a pole, however, because the Sasaki et al. observations were made at the same epoch when Yoshida et al. (2004) observed a lightcurve for Karin with an amplitude exceeding 0.6 mag, which suggests a more nearly equatorial presentation in late 2003 when Sasaki et al. observed. We do not have simultaneous lightcurve photometry and our slit spectroscopy techniques are not suitable for deriving a lightcurve, so one might hypothesize that we were observing pole-on and that the reddish spot was at moderate latitudes on the hidden hemisphere. We believe that this is not the case, however, since our observations were made about one-half of a Karin revolution period after the Sasaki et al. observations, so we were observing toward ecliptic longitudes very roughly 180° different from the geometry in late 2003; pole-on geometries, if Karin has a high obliquity, would be closer to 90° and 270° longitude differences from the Sasaki et al. geometry and from our own. Moreover, any spot that could be responsible for the enormous differences seen in Fig. 1 would have to be very large, and it seems very unlikely that it could have been completely hidden from our view.

It is already difficult to imagine a natural shape of Karin, and shape and size of a reddish spot, that would permit the large color differences reported by Sasaki et al. in less than 20° of rotational phase. There would have to be some blending of the two different spectral traits; hence the hypothesized spot would be required to have even more extreme colors than shown by the reddish spectrum. Now that we have observed throughout a Karin rotation period and found only minimal spectral variations at most, we think it is reasonable to regard the reported color changes as disproved and to regard the reddish Sasaki et al. spectrum as spurious. We cannot speculate about what went wrong, not being familiar with the details of the instrument and observing procedures.

At the bottom of Fig. 3, the solid line shows the average reflectance spectrum of 832 Karin from our January 2006 observations, with the same weights applied as in deriving the spectra in the 12 longitudinal bins. Our spectrum closely resembles previously published spectra of Karin (cf. Vernazza et al., 2006). A comparison of our spectrum with Fig. 1 shows that it is similar, but not identical, to the third-set spectrum of Sasaki et al. (the lower spectrum in Fig. 1). In fact, our spectrum is slightly less red than the Sasaki et al. spectrum and exhibits a slightly deeper 1 μm absorption band. (Even our reddest longitudes, 180°–210° and 300°–330°, are very slightly less red than the third-set Sasaki et al. spectrum.) These modest differences could result from (a) different phase angles (although we observed at larger phase angles than Sasaki et al., which often results in slightly reddened spectra), (b) from modestly different systematic errors in the observations and in the data reductions, which are normally encountered, or (c) a slight slope difference between our prime G2V standard star, or the G2V star used by Sasaki et al., and the Sun. Thus we can regard the second and third sets of Sasaki et al. as representing approximately the true infrared spectral traits of Karin, with the first set being spurious.

During 2005 and 2006, we have observed other Karin cluster members, as well as other members of the Koronis and other asteroid families, using the same observing procedures with SpeX. We are not yet at the stage of data reduction to thoroughly compare our Karin spectrum with our other results, but we can make a few general statements. We agree with others (e.g., Vernazza et al., 2006) who have previously reported that Karin is slightly less red, in this spectral region, than other S-types. The depths of Karin's absorption bands also seem slightly weaker than for other S-types and much weaker than for meteoritic analogs like ordinary chondrites. We surmise that Karin, as a very young asteroid, has undergone sufficient space weathering to reduce the spectral contrast of its inherent minerals but that there has been insufficient time to redden its spectrum to the degree exhibited by older S-types. So space weathering processes have only approached intermediate maturity in ~6 Myr.

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