EPSC Abstracts,
Vol. 4, EPSC2009-735, 2009
European Planetary Science Congress,

Small Koronis Family objects as a probe of space weathering

A. S. Rivkin (1), C. A. Thomas (2), D. E. Trilling (3), M. T. Enga (3), and J. A. Grier (4)

(1) Applied Physics Laboratory, Laurel, MD, USA (andy.rivkin@jhuapl.edu), (2) MIT, Cambridge MA, USA (3) Northern Arizona University, Flagstaff AZ, USA, (4) Planetary Science Institute, Columbia MD, USA.

Introduction and Motivation: For two generations, the "S asteroid problem" has occupied and preoccupied asteroid scientists [1]. In brief, the problem concerns the mismatch between the visible-near IR reflectance spectra of the S asteroids (the most common near-Earth and inner-belt objects) and the ordinary chondrite (OC) meteorites (the meteorites most commonly seen to fall to Earth) [2]. OC-like spectra can be found in the NEO population in the Q class, but Q-class asteroids are absent from the population of large main belt asteroids.

In the past decade, spacecraft data from Ida, Eros, and Itokawa [3-5], telescopic spectral surveys, [6-7] new analyses of lunar samples [8], and laboratory simulations of regolith processes [9-11] have all been used to address the S asteroid problem.

As a result of this work, the emerging paradigm holds that the surfaces of S-class asteroids have the spectral signatures one might expect from the mature regoliths of ordinary chondritic bodies. Those processes that change the spectral properties of regoliths, whether observed or hypothesized, often go by the term "space weathering".

As a consequence of this paradigm, it is expected that obects too small to retain substantial regolith or whose surfaces are too young to have had time for their regolith to mature should appear more OC-like (and Q-like). Because smaller objects have shorter dynamical lifetimes, they are expected on average to be younger than larger objects. As a result, smaller S-class objects are expected to have spectra more akin to OC meteorites than their larger kin.

An example of how this is used is an analysis of the spectral slopes of S-class (and related) NEOs [12]. Binzel et al. found that a running-box mean of their spectral slopes gradually changes from near the main-belt S asteroid value for objects of 5 km and larger to the ordinary chondrite value for objects of 1 km and smaller.

However, it can be argued that in the absence of a sample return mission, all of these studies are still providing circumstantial evidence. For instance, many of these studies include an implicit assumption that their sample are all OC composition, despite the fact that that is not demonstrated. The trends seen in the NEO population, or in comparisions between asteroid families, could be caused by differences in composition and still appear consistent with space weathering.

In an attempt to remove that potential stumbling block, we have undertaken a multi-pronged study of small (1-5 km diameter) members of the Koronis asteroid family. By studying members of a single family, we maximize the likelihood of a consistent composition within our sample. Because the Koronis family has been associated with OC meteorites via Galileo studies of Ida, we argue that Koronis objects are undifferentiated, which again will lead to confidence that members of the sample will have identical compositions. This size range was chosen to allow direct comparision to the Binzel et al. results.

As part of the overall program, we have obtained time on Spitzer to obtain albedos of nearly 60 Koronis family objects. Preliminary analyses of those data are underway. Below we report on details from the preliminary results from the other major part of this project: visible-wavelength broadband spectrophotometry from Kitt Peak and Magellan Observatories.

Observations and Data Reduction: Roughly three weeks of observing at the Kitt Peak 2.1-m telescope and roughly one half-night of observing at Magellan Observatory's 6.5-m Baade telescope have been used by this project so far. The KPNO observations are taken through standard *BVRI* filters, with the Magellan observations using the Sloan Digital Sky Survey (SDSS) *g'r'i'z'* filter set [13]. The two observatories have been used in a complementary fashion, with the smaller KPNO

EPSC Abstracts,
Vol. 4, EPSC2009-735, 2009
European Planetary Science Congress,

telescope responsible for surveying the larger members of the sample and Magellan for smaller targets. In all, over 100 objects have been observed through this program so far, with a goal of 200 before the end of 2009.

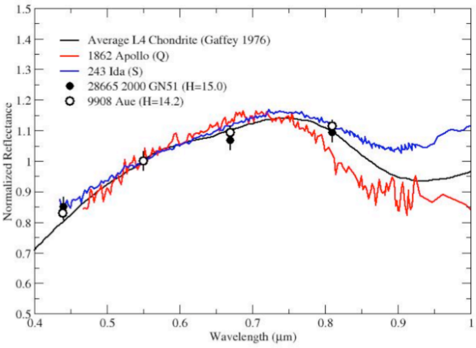

Figure 1: Colors of two objects observed at KPNO in Dec 2008, compared to two asteroids and an OC meteorite [6,15]. Although the wavelength coverage for these data is not optimal for covering the 1-μm band, the observed objects show spectra consistent with the average L4 chondrite. The asteroid data are normalized to the V band, at 0.55 μm.

Data reduction is performed using IRAF, well-known astronomical software with well-established routines for photometry [14]. Standard star observations took advantage of SDSS photometry of on-chip targets where available, otherwise additional standard observations were obtained frequently and over a wider airmass range than the target asteroids.

Discussion: While still in the preliminary stages of data analysis, we can already make some initial observations. Figure 1 shows a comparison of two asteroid spectra from the SMASS survey to the average L4 spectrum presented in Gaffey (1976) [15]. The asteroid spectra include the S-class Koronis family member 243 Ida and the Q-class NEO 1862 Apollo [6].

In addition, two asteroid spectra from this program are shown, 9908 Aue (open symbols) and 28665 2000 GN51 (closed symbols). The data for these latter objects do not have the ideal wavelength coverage for comparison, but they appear slightly more consistent with OC materials. Because the spectral resolution is so low, we turn to color-color diagrams.

Figure 2 shows the average *V-R* and *V-I* colors for the S and Q classes [16] along with the preliminary colors for objects observed at KPNO on 31 December 2008. Although the calculation of observational uncertainties is still underway, it seems clear that most of these small Koronis objects have colors between those of the S and Q classes. As with the Binzel et al NEO study, the evidence that these Koronis family objects span the color range between S and Q is consistent with a space weathering process changing Q/OC-like surfacesto S-like spectra.

These findings, in conjunction with the recent independent discovery by Mothe-Diniz and Nesvorny of a main-belt object with an OC-like spectrum [17], hold promise to provide the final pieces to the S asteroid problem from a remote sensing/spectroscopy perspective.

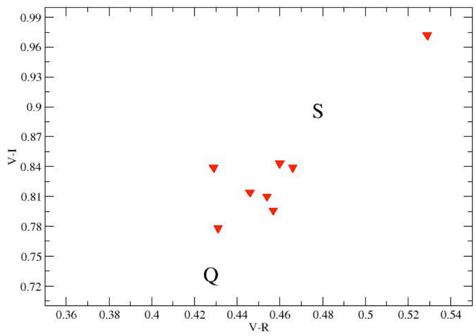

Figure 2: On a color-color digram, the mean S and Q class values are separated from one another (values from 16). While these preliminary colors for objects observed on 31 December 2008 lack observational uncertainties at the time of writing, they clearly span the range of V-R and V-I colors between the S and Q classes. Because these objects belong to the same dynamical family, we are confident that this spread is not due to compositional differences, but is best explained as due to space weathering effects.

References: [1] Bell, J. F. et al. (1989), in *Asteroids II.* [2] Clark B. E. et al. (2002) in *Asteroids III.* [3] Champan, C. R. (1996), *MAPS, 31,* 699-725. [4] Clark, B. E. et al. (2001) *MAPS, 36,* 1617-1637. [5] Hiroi, T. et al. (2006), *Nature, 443,* 56-58. [6] Bus, S. J. and Binzel, R. P. (2002) *Icarus, 158,* 106-145. [7] Lazzaro, D. et al. (2004), *Icarus, 172,* 179-220. [8] Noble, S. (2001) *MAPS, 36,* 31-42. [9] Moroz, L. et al. (1996) *Icarus, 122,* 366-382. 10] Sasaki, S. et al. (2001) *Nature 410* 555-557. [11] Brunetto, R. et al. (2006) *Icarus, 180,* 546-554. [12] Binzel, R. P. et al. (2004) *Icarus, 170,* 259-294. [13] Ivezíc, J. et al. *Astron J, 122,* 2749- 2784. [14] Tody, D. (1986) *Proc SPIE, 627,* 733. [15] Gaffey, M. J. (1976) *JGR, 81,* 905-920. [16] Dandy, C. L. et al. (2003) *Icarus, 163,* 363-373. [17] Mothé-Diniz and Nesvorny (2008) *Astron Astroph, 486,* L9-L12.