OBSERVATIONAL AND DATA REDUCTION TECHNIQUES TO OPTIMIZE MINERALOGICAL CHARACTERIZATIONS OF ASTEROID SURFACE MATERIALS. M. J. Gaffey, Space Studies Department, University of North Dakota, Box 9008, Grand Forks, ND 58202, USA. E-mail: gaffey@space.edu

Introduction: Mineralogy is the key to determining the compositional history of the asteroids and to determining the genetic relationships between the asteroids and meteorites. The most sophisticated remote mineralogical characterizations involve the quantitative extraction of specific diagnostic parameters from reflectance spectra and the use of quantitative interpretive calibrations to determine the presence, abundance and/or composition of mineral phases in a surface material [1]. Although this approach is potentially subject to systematic errors, it provides the only consistent set of asteroid surface material characterizations.

Parametric determinations of asteroid mineralogy are relatively insensitive to "space weathering" processes on asteroids [2]. This is very important because while it is evident that optical alteration (under the general rubric of "space weathering") is occurring on asteroid surfaces, data from spacecraft encounters with asteroids 443 Eros and 253 Ida have made it clear that the process differs from object to object [3]. Moreover the different relative variances of color, albedo and spectral slope between Eros, Ida and the Moon indicate that the asteroid alteration process is not simply an attenuated version of the well-understood lunar-style space weathering (the nanophase iron model - [4,5]).

The spectral parameters used to quantitatively determine mineralogy from an asteroid spectrum are not differentially effected until the degree of space weathering (in any of its proposed forms) is far more extensive than expected (or observed) on asteroid surfaces. By contrast, curve matching depends on factors such as absorption band depth and spectral slope which are often significantly affected by even comparatively low degrees of space weathering [3,6-8].

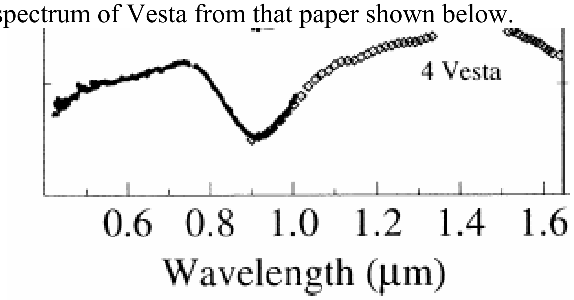
Survey vs. Characterization Spectra: Much of the spectral data obtained for asteroids is not appropriate for compositional analysis. Such spectra lack the spectral coverage, spectral resolution and/or the signal-to-noise required to extract the suite of diagnostic spectral parameters. These survey-mode spectra are useful for providing a broad qualitative picture of asteroid relationships. A contribution of such surveys is to identify specific targets for more detailed quantitative investigation in order to better understand their detailed histories and relationships. To bring the picture into focus, as it were.

Our ability to investigate asteroid compositional histories and genetic relationships is thus dependent upon obtain robust mineralogical characterizations of individual asteroids. However, such characterizations are only possible when spectra have the appropriate wavelength coverage, spectral resolution and signal-to-noise to allow the accurate extraction of diagnostic spectral parameters. The first two criteria (spectral coverage and resolution) are dependent upon the instrument being used. However, even when an instrument with the appropriate wavelength and resolution is employed, the signal-to-noise of the resulting data is critically dependent upon the observing and data reduction procedures.

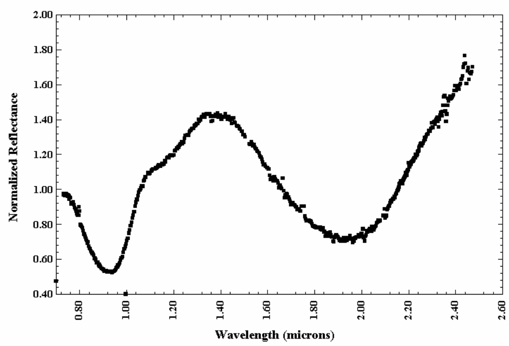
Signal-to-Noise in Asteroid Spectra: Sometimes a low signal-to-noise level is inevitable as when the weather is simply crappy. Short of finding some magical method to control weather and seeing, little can be done to ameliorate that problem. Other times the potential to extract high S/N spectra from good observational data is lost due to inappropriate, incomplete or flawed data reduction techniques. The following discussion will focus on the lessons we have learned in observing with and reducing the data from the low-resolution (asteroid) mode of the SpeX instrument on the NASA Infrared Telescope Facility at Mauna Kea observatory. These concepts can be extended to other instruments and telescopes, but we have focused on the IRTF SpeX system because it is currently the most advanced system for obtaining near-IR asteroid spectra appropriate for compositional investigations.

Basic Spectral Reduction: The basic procedure for converting raw spectral flux measurements to reflectance spectra have been well understood for several decades [e.g., 9]. The raw flux spectrum of the asteroid (or other target) is ratioed to the raw flux spectrum of a standard star observed under identical atmospheric conditions to produce a reflectance spectrum. If the standard star is not a solar analog star, an additional solar analog star must be observed to correct for the non-solar nature of the standard star.

The problem arises with that "identical atmospheric conditions" requirement. A commonly used approach is to ratio the asteroid observation to a standard star observation obtained at near the same airmass (atmospheric path length) as the asteroid. This approach is commonly used to reduce CCD spectra at wavelengths shorter than ~1μm. It generally works well, but often produces spurious results in the spectral interval of the atmospheric water vapor absorption around 0.94 μm. The stronger the atmospheric absorption feature, the more sensitive the final spectrum will be to small differences in the atmospheric path between the asteroid and standard star. In the stronger 1.4 µm and 1.9 µm atmospheric water vapor bands, the correction is so sensitive that these spectral intervals are commonly omitted from published spectra. Burbine et al. [10] state explicitly, "*An atmospheric water band centered at ~1.4 µm causes the points between 1.35 and 1.5 µm to be very suspect and not usable for most asteroids. Due to the problems in correcting for atmospheric water, no corrections have been made and points that appear to have been affected significantly have been deleted. Weaker atmospheric effects are also sometimes present in the spectra at ~0.94 and ~1.15 µm.*". This nissing interval can be seen in the SMASSIR spectrum of Vesta from that paper shown below.



Compare this to the spectrum below of a much fainter asteroid (1459 Magnya) with a similar spectrum shown by Hardersen *et al* at this meeting [11].



The different wavelength coverage is due to the different instruments and is of no consequence for the present discussion. However, the continuous coverage across both the 1.4 and 1.9 µm spectral intervals is of major significance. It is evident that the necessary diagnostic spectral parameters can readily be determined from the Magnya spectrum. Our discussion will focus on the two procedures needed to regularly produce such high quality and well corrected spectra.

Observational Strategies: The major weakness of the data reduction procedure outlined above lies in the problem of matching the airmass of the asteroid and standard star observations. The solution is to observe the standard star repeatedly during the night. If the sky is uniform and stable, the log of the observed flux of the standard star will decrease linearly with increase airmass. A plot of the log flux versus airmass can be fitted with a linear regression to derive the slope and intercept of the distribution. This is repeated for each wavelength in the observations. This STARPACK can then be used to compute the effective flux of the standard star at each wavelength in the spectrum and at the same airmass as each asteroid observation. The presentation will describe the additional steps for processing observations in the real (non-ideal) sky, which is often unstable and non-uniform.

Instrumental Effects: Due to subtle instrumental flexure as the orientation of the telescope changes, photons of any particular wavelength fall onto slightly different locations on the array detector. Offsets in the direction of spectral dispersion typically are one pixel or less along the spectrum (~500 pixels). However, if left uncorrected, these small offsets can produce compositionally significant distortions of the reflectance spectrum [1]. They can readily change the measured band area ratio (BAR) of weakly featured S-asteroids by a factor of two, resulting in a major misinterpretation of the spectrum. These distortions can also significantly shift the apparent position of the 2 µm mafic silicate feature, with similar negative consequences.

To correct this, each group of individual spectra obtained with a common telescope pointing geometry are compared to a reference set to determine the sign and magnitude of pixel offsets. Once the offsets were determined, the data were splined to a common pixel reference set prior to starpack calculations.

The SPECPR (Spectrum Processing Routine) software can carry out both of these operations. The presentation will discuss the availability of this software and will compare the spectra produced with and without these procedures.

Acknowledgements: Various aspects of this work were supported by NASA Planetary Geology and Geophysics Program Grant NAG5-10345 and by NASA Exobiology Program Grant NAG5-7598 (NSCORT: New York Center for Studies on the Origins of Life).

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