FAINT, FUZZY AND 'FEATURELESS' PHAs: MAKING THE MOST OUT OF ALMOST NOTHING. V. Reddy[1,5], M. J. Gaffey[2,5], P. A. Abell[3,4,5] , S. Kumar[2,], and S. K. Fieber-Beyer[1,5] [1]Dept. of Earth System Science and Policy, Box 9011, [1]Univ. of North Dakota, Grand Forks, ND 58202, vishnu.kanupuru@und.nodak.edu; [2]Dept. of Space Studies, Box 9008, Univ. of North Dakota, Grand Forks, ND 58202; [3]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719; [4]NASA Johnson Space Center, Astromaterials and Exploration Science, Mail Code KR, Houston, TX 77058; [5]Visiting Astronomer at the Infrared Telescope Facility, which is operated by the Univ. of Hawai'i under contract from the National Aeronautics and Space Administration, Mauna Kea, HI 96720.

Introduction: Physical characterization (composition, albedo and diameter) of potentially-hazardous asteroids (PHAs) has important implications for impact hazard assessment. Currently only a small percentage of the ~900 known PHAs [1] have detailed compositional information. Over the last decade, attempts [2-5] have been made to taxonomically classify a subset of this population, primarily using the SpeX instrument on NASA IRTF. But many questions regarding their specific origin, geologic history and meteorite affinities remain unanswered.

Due to their inherent faintness, short observing windows and rapid motion across the sky, PHAs are among the most challenging Solar System objects to observe spectroscopically. Given the V mag = 17.5 limit for obtaining good SNR spectra using the SpeX instrument on NASA IRTF, only a handful of PHAs can be observed each lunation. Combined with these factors, spectra of low-albedo 'featureless' objects are challenging to interpret mineralogically due to the lack of diagnostic features. The work presented attempts to interpret faint, fuzzy and 'featureless' PHAs in order to constrain their albedo, composition and diameter. It is part of our expanding effort to physically characterize and understand these objects.

Observations and data reduction: Near-IR spectroscopic observations of PHAs studied here were carried out onsite and remotely using the SpeX spectrograph [6] at the NASA Infrared Telescope Facility on Mauna Kea, Hawai'i. All SpeX data were subsequently reduced using IRAF and the PC-based SpecPR spectral processing program [7]. Spectral parameters such as Band I and II centers, and band area ratios (BARs) [8] were calculated using SpecPR. All spectral parameters have been corrected (where appropriate) for temperature-induced effects based on works by [9,10,11]. Using methods developed by [12] and based on the Standard Thermal Model, the albedos of these objects were estimated using thermal excesses at 2.4 µm, phase angles and heliocentric distance at the time of observation.

Analysis and Results: *(85989) 1999 JD$_6$.* This Aten class PHA was discovered by the LONEOS survey in May 1999. With a rotation period of 7.68 hours, 1999 JD$_6$ has large lightcurve amplitude of 0.7-1.2 magnitude [13,14,15]. Twenty spectra of this PHA were obtained on July 31, 2005, when the object's visual magnitude was 16.8. Figure 1 shows an average of 10 best spectra of 1999 JD$_6$. Visible wavelength data from Small Main-Belt Asteroid Spectroscopic Survey [16] were combined with the SpeX data.

The near-IR spectrum of 1999 JD$_6$ is almost featureless with a neutral slope. Point-to-point scatter in the data increases beyond ~1.9 µm due to decreased sensitivity of the detector coupled with the inherent faintness of the object. Assuming a linear continuum, the estimated mean value of thermal excess at 2.4 µm is ~3±2% given the scatter in the data. The estimated lower limit albedo for the object using the thermal flux calibration curve given the uncertainties is 9±3%. Assuming an H magnitude of 17.1, and an albedo of 9±3% from the thermal model, the estimated upper limit diameter of 1999 JD$_6$ is 1.7±0.3 km.

The visible/near-IR spectrum of 1999 JD$_6$ displays a shallow feature at 0.6 µm (insert in Fig. 2). Near-IR spectrum shows a very weak inflection at ~0.90 µm (Fig. 2) suggesting a possible band I feature. The presence of a feature at 2.0 µm can not be verified given the scatter at longer wavelengths. [2] suggested that 1999 JD$_6$ would be classified as K taxonomic class compositionally similar to CV meteorites. The estimated lower limit albedo of 9±3% would be consistent with such an interpretation. CV3 meteorites typically have albedos ranging from 5% to 10% [17]. Some CV3 meteorites like Allende show a weak inflection shortward of 0.6 µm, a complex broad feature at ~0.90 µm and a very weak shallow feature at 2.0 µm. Given the albedo and weak features at 0.6 and 0.90 µm, we suggest that 1999 JD$_6$ has a composition similar to a CV3 meteorite which is consistent with interpretation by [2].

2005 AD$_{13}$. Spectra were obtained on June 11, 2007 (UT) when this Apollo asteroid was at an apparent V mag of 15.5. Fig. 3 shows the average of 13 best spectra. Apart from the weak inflections at 1.14 and 1.4 µm due to incomplete atmospheric correction, the spectrum is essentially featureless. The spectrum has an overall blue slope (-0.06) and a weak rise in reflectance beyond 2.2 µm due to thermal emission. Based on thermal excess of 3±2% at 2.4 µm, we estimate the albedo of 2005 AD$_{13}$ to be 11±3%. Assuming an H magnitude of 17.9, and an albedo of 11±3% from the thermal model, the estimated upper limit diameter of 2005

AD_{13} is 0.97±0.15 km. The lack of diagnostic features could be due to the presence of an opaque phase (carbon) which leads to low albedo. Some carbonaceous chondrites like Grosnaja (CV3) have a blue slope with an albedo range of 5-10% [17]. While we are not speculating on the causes for the observed blue slope, it would not be unreasonable to suggest Type 3 carbonaceous material as a possible analog for 2005 AD_{13}.

2007 DS_{84}. Twenty spectra of this Amor class PHA were obtained remotely on April 5, 2007 when its apparent V mag was 16.3. An average of 16 best spectra is shown in Fig. 4. The spectrum shows a weak band I feature with a band depth of ~8±1% and a band center at 0.96±0.01 µm. Given the noise level, no band II feature at 2.0 µm could be identified although the presence of a weak feature can not be ruled out. The sharp rise in reflectance beyond ~2.2 µm appears to be thermal emission. Based on a thermal excess of 10±2%, we estimate the albedo of 2007 DS_{84} to be 5±2%. Based on the presence of a 0.9-µm feature along with low albedo, possible meteorite analogs for this asteroid would include CO3 carbonaceous chondrites like Warrenton and Ornans [17] and CM2 carbonaceous chondrites like Cold Bokkeveld. While spectrally 2007 DS_{84} looks similar to Warrenton and Ornans, the estimated asteroid albedo (5±2%) is lower than CO3 meteorites (typically 7-12%). The asteroid albedo is similar to CM2 carbonaceous chondrites which have 3-5% albedos. Using this albedo range we calculate the diameter to be 0.4±0.1 km based on methods by [18].

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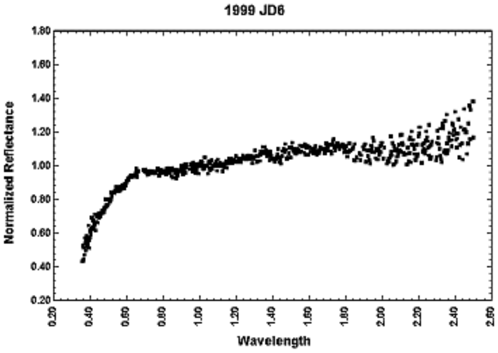

Fig. 1: Average spectrum of Aten (85989) 1999 JD_6.

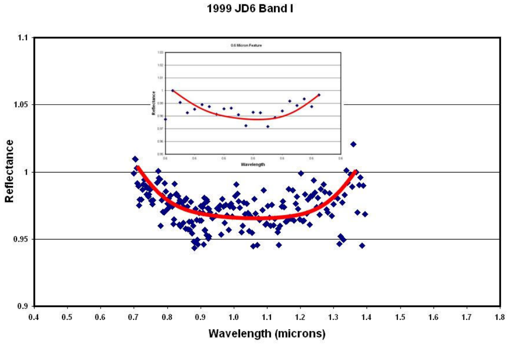

Fig. 2: Continuum-removed 0.6-µm (top insert) and 0.9-µm features (bottom) on (85989) 1999 JD_6.

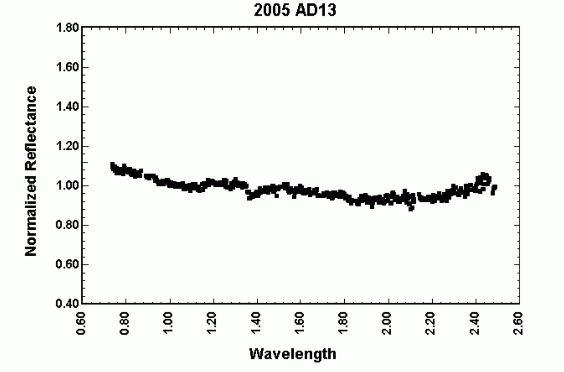

Fig. 3: Average spectrum of Apollo 2005 AD_{13}.

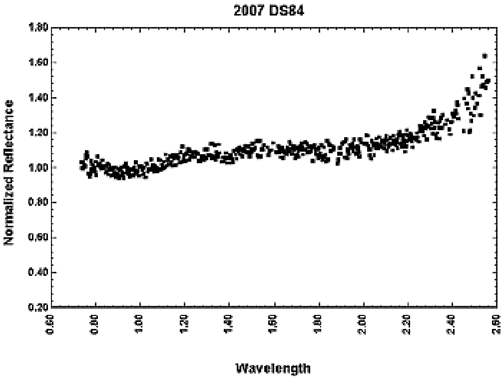

Fig. 4: Average spectrum of Amor 2007 DS_{84}.