MINERALOGICAL INVESTIGATION AND THERMAL MODELING OF NEAR-EARTH ASTEROIDS (11405) 1999 CV_3, 2000 BD_{19}, 2003 SA_{224}, AND 2005 YY_{93}. V. Reddy[1,4], M. J. Gaffey[2,4], P. A. Abell[3,4] and P. S. Hardersen[2,4], Department of Earth System Science and Policy, Box 9011, University of North Dakota, Grand Forks, North Dakota 58202, vishnu.kanupuru@und.nodak.edu; [2]Department of Space Studies, Box 9008, University of North Dakota, Grand Forks, North Dakota 58202; [3]NASA Johnson Space Center, Astromaterials and Exploration Science, Mail Code KR, Houston, Texas 77058; [4]Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawai'i under contract from the National Aeronautics and Space Administration, Mauna Kea, Hawai'i 96720.

Introduction: Constraining composition, albedo and diameter of Near-Earth Asteroids (NEAs) has important implications for impact hazard assessment. Only a small percentage of the ~4500 known NEAs [1] have detailed compositional information. Over the last decade, attempts [2,3,4,5] 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. The work presented here adds to the expanding effort to physically characterize and understand these objects.

Observations and data reduction: Near-IR spectroscopic observations of NEAs studied here were carried out on Jan. 31-Feb. 1, 2006, (UT) 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 like the Band I and II centers, and band area ratios (BARs) [8] were calculated using SpecPR. All spectral parameters have been corrected for temperature-induced effects based on works by [9,10,11].

Analysis and Results: *(11405) 1999 CV_3.* Thirty spectra of 1999 CV_3 were obtained on Feb. 1 (UT) at V mag. of 15.1. An average of 17 best spectra is shown in Fig. 1. [12] classified the object as Sq taxonomic type. The object's spectrum exhibits a broad, asymmetric ~1-μm and a weaker 2-μm feature. The calculated band centers are 0.956±0.01 μm and 2.01±0.01 μm, with a BAR of 0.58±0.05. 1999 CV_3 plots on the pyroxene trend line on the band-band plot [13,14] indicating the presence of an ortho- (OPX) and Type B clinopyroxene (CPX) mixture. Inflection at ~1.1 μm suggests at a possible third pyroxene phase. Type A CPX spectra display two composite bands near 0.95 and 1.15 μm due to Fe^{2+} crystal field transitions located in the M1 site [15]. In contrast, the longer wavelength side lobe of pure olivine has band centers between 1.20-1.30 μm [16]. A weaker inflection at 1.3 μm might be due to plagioclase or high-Fe OPX [17,18].

It is possible to calculate the mean pyroxene chemistry (OPX + Type B CPX) using band I and II centers based on calibration work described in [19]. We estimate the mean pyroxene chemistry of 1999 CV_3 to be $Wo_{19\pm5}$ $Fs_{43\pm5}$. This pyroxene chemistry plots above the basaltic eucrites on the pyroxene quadrilateral suggesting a non-chondritic surface assemblage. Our analysis indicates that the surface is dominated by mixture of OPX and CPX with plagioclase as a minor phase.

2000 BD_{19}. Spectra were obtained on Jan. 31-Feb. 1 (UT) when this Aten asteroid was at an apparent V mag. of 16.7. Fig. 2 shows the preliminary average of 12 best spectra from Feb. 1. Deep band I and II features with band centers at 0.94±0.01 μm and 1.99±0.01 μm respectively, and a BAR of 0.58±0.05 are present indicating the presence of pyroxene. A weaker inflection at ~1.30 μm is also seen. The ~1.30-μm feature has been attributed to olivine, plagioclase feldspar or high-Fe OPX [17,18]. 2000 BD_{19} plots on the pyroxene trend line on the band-band plot (transition region between the ordinary chondrites and eucrites) indicating the presence of OPX and CPX mixture [13,14]. Plotting the object on S-asteroid subtypes diagram from [20], 2000 BD_{19} plots between S(V)/S(VI) region suggesting an orthopyroxene-dominated assemblage with CPX and olivine as minor phases. Using band I and II centers, we estimate the pyroxene chemistry to be $Wo_{14\pm5}$ $Fs_{42\pm5}$ which plots in the region of cumulate eucrites [21] on the pyroxene quadrilateral away from chondritic pyroxenes. Based on the spectral parameters and inferred chemistry, we suggest that 2000 BD_{19} is a thermally-evolved object and experienced at least partial melting temperatures and the most probable meteorite analogs are primitive achondrites [20].

2003 SA_{224}. Thirty spectra of 2003 SA_{224} were obtained on Feb. 1 (UT) when the object was 15.9 V mag. An average of 23 best spectra is shown in Fig. 3 which displays a broad, asymmetric ~1-μm feature and a shallow 2-μm feature. The calculated band I & II centers are 0.99±0.01 and 2.02±0.01 μm with a BAR of 0.52±0.05. 2003 SA_{224} plots above the pyroxene trend line on the band-band plot [13,14] indicating the presence olivine or Type A CPX with OPX and Type B CPX. Correcting the band I center for olivine using calibration in [19] the object plots exactly on the trend line. The asteroid plots at the transition region between the S(III)/S(IV) S-asteroid subtypes suggesting a OPX + Type B CPX mineralogy. Using the olivine-corrected band I center the pyroxene chemistry is $Wo_{12\pm5}$ $Fs_{43\pm5}$.

2005 YY_{93}. Fifty spectra of this Apollo class PHA were obtained on Jan. 31 when its apparent V mag. was 15.9. An average of 20 best spectra is shown in Fig. 4. The spectrum shows a weak band I feature with a band depth of ~6% and a band center at 0.91±0.01 µm. Given the noise level, no band II feature at 2.0 µm could be identified. The sharp rise in reflectance beyond ~2.3 µm appears to be thermal emission. Based on its heliocentric distance (1.17 AU) at the time of observation, the reflectance rise beyond 2.3 µm is due to thermal emission by the asteroid as it is warmed by solar radiation. Using methods developed by [22] one can independently estimate the albedo of the object given the excess thermal emission, the phase angle and heliocentric distance at the time of observation. We estimate the albedo of 2005 YY_{93} to be 4±2% with a thermal excess of 4±2% at 2.4 µm. Based on the presence of a 0.9-µm feature along with low albedo, possible meteorite analogs for this asteroid would include CM2 carbonaceous chondrites like Cold Bokkevelt and Murray [22]. Spectra of these meteorites display a weak 0.9 µm feature attributed to iron-bearing phyllosilicates [23]. Using the albedo we calculate the diameter to be 2.6±0.4 km based on methods by [24].

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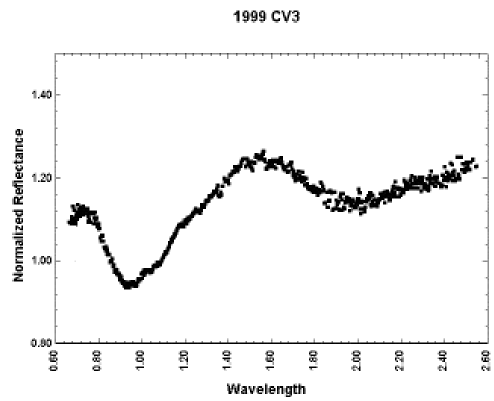

Fig. 1: Average spectrum of Apollo (11405) 1999 CV3.

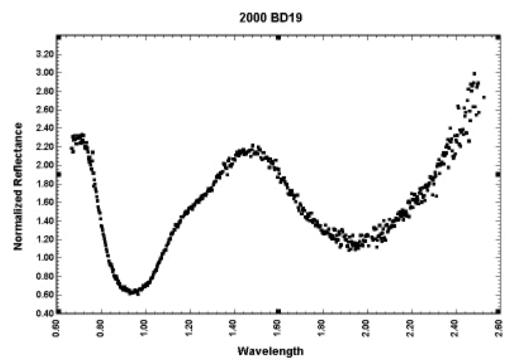

Fig. 2: Average spectrum of Aten 2000 BD19.

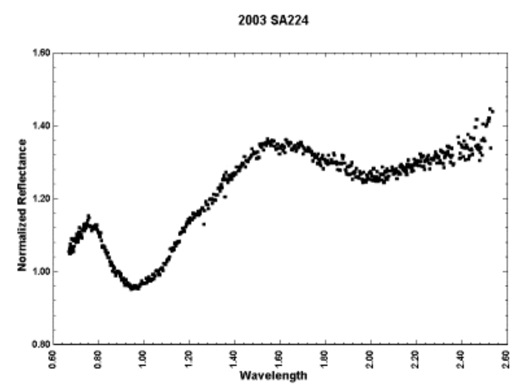

Fig. 3: Average spectrum of Amor 2003 SA224.

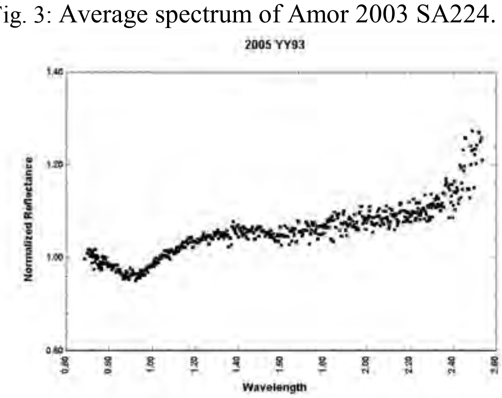

Fig. 4: Average spectrum of Apollo 2005 YY93.