A LARGE 3-MICRON SPECTROSCOPIC SURVEY OF MID-OUTER MAIN BELT ASTEROIDS.
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Introduction: This large 3-µm spectral survey began over a decade ago with a primary goal to search for signatures of H_2O, hydrated silicates, anhydrous silicates, and/or organics on the surface of mid-outer main belt asteroids the (2.5 < a < 5.0 AU). Volatiles and organics are key elements that are relevant to life on Earth and provide important information about the origin and evolution of the solar system, in particular the terrestrial planets, and the conditions in which the solar nebula was active. Because it spans a wide heliocentric range, this survey allows us to place the new observations in the context of the dynamical and thermal evolution models for small bodies and the early solar system.

Previous work: [1,2] previously measured spectra of 35 mid-outer main belt asteroids spanning region and identified four spectral groups on the basis of the band shape and center of the 3-µm feature. We have now increased the total number of the studied mid-outer main belt asteroids to ~100 objects to further investigate the distribution of these asteroids in terms of their hydration state.

New observations: The new observations include asteroids with different classes (e.g., C, B, P, D, G, and T), diameters (~100–400-km), and families/groups (Hygiea, Themis, Cybele, and Hilda). Asteroids were observed using NASA IRTF and SpeX spectrograph/Imager and its two modes, the Prism (0.7-2.52 µm) and long-wavelength cross dispersed (LXD: 1.9-4.2 µm) between 2015 and 2021. We selected our targets from four heliocentric (semi-major axis) bins: 2.5 < a < 2.9 AU, 2.9 < a < 3.3 AU, 3.3 < a < 3.6 AU, and 3.6 < a < 5.0 AU. Here we present the final results of the 3-µm spectroscopic survey that includes a total of ~100 mid-outer main asteroids. The asteroids were observed between 2014 and 2021. We also included previously published visible and prism spectra in this study, to help provide a deeper understanding of the surface composition these asteroids. We used the near-earth asteroid thermal (NEATM) model to model and correct the thermal excess beyond 2.5 microns [3] (Figure 1).

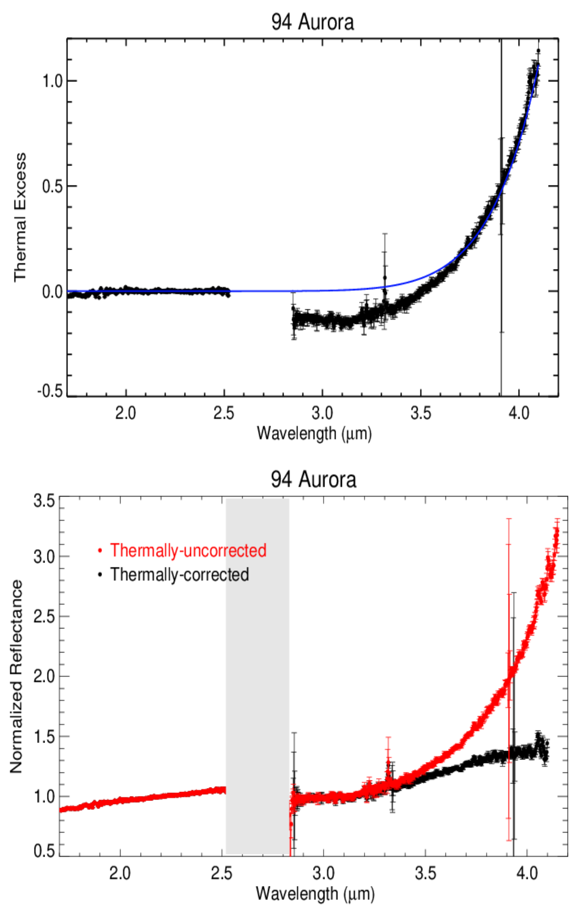

Figure 1: (top) Thermal excess (black) and NEATM's best thermal model (blue) for asteroid Aurora (bottom) Uncorrected (red) and corrected (black) spectra of Aurora.

Results: This 3-µm spectral survey reveals more evidence of dynamical mixing and migration in the main belt. The C-type asteroid (334) Chicago at 3.90 AU is the farthest asteroid in our target list with a CM/CI-like feature (reflectance decreases with decreasing wavelength into the 2.50-2.85 µm spectral region obscured by Earth's atmosphere). The mid part of the main belt (2.7 < a < 3.3 AU) is dominated by CM/CI-like asteroids (e.g., Figure 2), which represent ~65% of our targets. No correlation was found between the 3-µm band depth at 2.90 µm and the heliocentric distance for these asteroids. Asteroids that show no significant 3-µm band or possibly weak ~2.7 µm (e.g., Figure 3) feature like the one found in asteroid Ryugu [4] comprise 15% of our sample. Our observations have also revealed

15 mid-outer main belt asteroids with a 3-µm band that is similar to the band found in the spectra of Ceres and comet 67P/Churyumov-Gerasimenko. All of these asteroids are predominantly concentrated in ~2.7-3.3 AU heliocentric region. No new asteroid was found to have a rounded 3-µm band shape, in which reflectance increases with decreasing wavelength shortward of about 3.07 µm. Some of the objects that were previously found to be part of the 'rounded' group appear to be more consistent with the group that is similar to Ceres or 67P. Both Bamberga (Figure 4) and Interamnia were found to be consistent with CMs/CIs in the 3-µm region. No 3-µm band is detected in Patroclus and Odysseus, two Trojans in our target list.

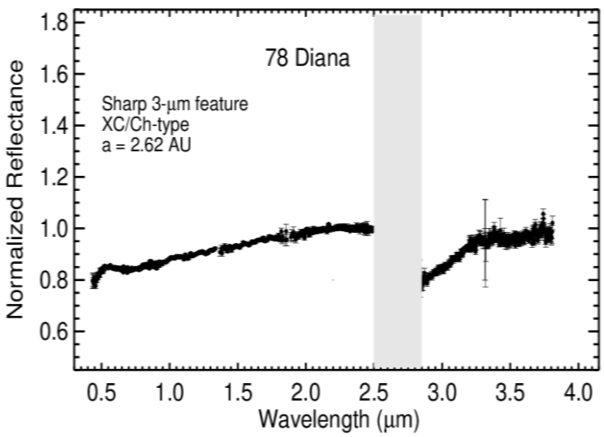

Figure 2. Near-infrared spectrum of asteroid Diana with a CM/CI-like spectral absorption features (0.7 and 3-µm bands).

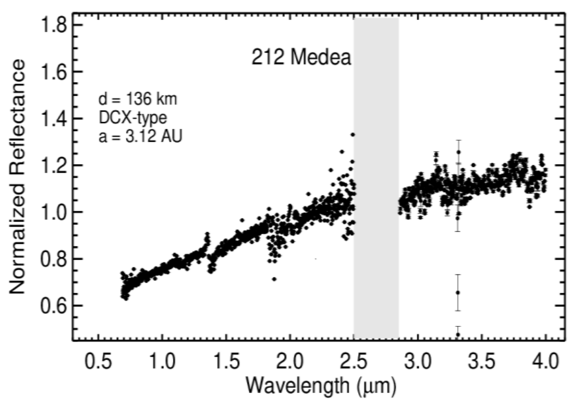

Figure 3. Near-infrared spectrum of asteroid Medea with no significant 3-µm band.

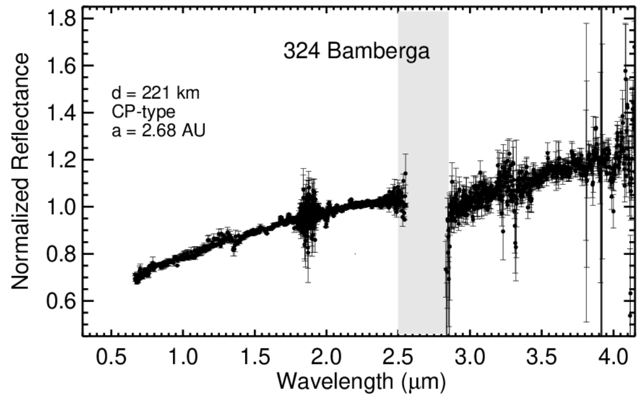

Figure 4. Near-infrared spectrum of asteroid Bamberga with a CM/CI-like spectral absorption features (0.7 and 3-µm bands).

Acknowledgments: All final spectra (Prism and LXD) of the observed mid-outer Main Belt asteroids have been prepared for submission to PDS Small Bodies Node. This study was funded by NASA Solar System Observations Program (NNX17AJ24G).

References: [1] Takir D. and Emery J.P (2012) *Icarus* **219**, 641-654. [2] Takir D. et al. (2015) *Icarus* **257**, 185-193. [3] Harris A.W. *Icarus* **131**, 291-30 (1998).[4] Kitazato K. et al. (2019) *Science* 364, 272–275.