HAPKE MODELING OF SEVERAL KBOS FROM JWST OBSERVATIONS. J. C. Cook[1], R. Brunetto[2], A. C. De Souza Feliciano[3], J. Emery[4], B. Holler[5], A. H. Parker[6], N. Pinilla-Alonso[3], S. Protopapa[7], J. Stansberry[5], I. Wong[8] [1]Pinhead Institute, Telluride, CO., [2]Institut d'Astrophysique Spatiale, Université Paris-Saclay, CNRS, [3]Florida Space Institute, Univ. of Central Florida, Orlando, FL, [4]Northern Arizona University, Flagstaff, AZ, [5]Space Telescope Science Institute, Baltimore, MD, [6]SETI Institute, Mountain View, CA, [7]Southwest Research Institute, Boulder, CO, [8]NASA Goddard Space Flight Center (jasoncampbellcook@gmail.com)

Introduction: For the last quarter century, spectroscopic studies of Kuiper Belt Objects (KBOs) have been limited to the visible to near-infrared wavelengths ($\lambda <$ 2.5 μm), with some photometric studies of KBOs at $\lambda > 2.5$ μm (*e.g.,* [1, 2]). These observations reveal KBOs are a spectrally diverse population. At visible wavelengths, they have spectral slopes from neutral (∼0%/100 nm) to very red (∼50%/100 nm) (*e.g.*, [3]). At the near-infrared wavelengths, CH_4, H_2O, C_2H_6, and CH_3OH-ice have been identified on various targets.

With the successful deployment of the James Webb Space Telescope (JWST), we have entered a new era in spectroscopic studies of the Kuiper belt. JWST's NIRSpec (Near Infrared Spectrograph) instrument is capable of obtaining spectra from 0.7 to 5.2 microns in several different spectral settings/resolutions ($\lambda/\Delta\lambda$) from 30 to 3000. We present Hapke analysis of JWST/NIRSpec observations of Quaoar, Gonggong, Salacia, and 2002 MS_4.

Observations: The observations in this work come from two GTO programs. Quaoar (2002 LM_{60}) is a target in GTO program 1254 (P.I. A. Parker). Quaoar was observed (i) with several medium resolution ($\lambda/\Delta\lambda \sim$ 1000) gratings covering the 1.0-3.2 μm range and (ii) with the prism mode ($\lambda/\Delta\lambda \sim$ 30-300 covering the 0.7-5.2 μm range.). We also present data from GTO program 1191 (P.I. J. Stansberry) including NIRSpec/Prism observations of Gonggong (2007 OR_{10}), Salacia (2004 SB_{60}), and 2002 MS_4.

Analysis: We analyze the spectra using Hapke modeling [4, 5]. Our Hapke routine can examine several multiple arrangements of the surface materials. This includes Mie scattering when the size parameter, $2\pi d/\lambda \ll 1$ (where d is the grain diameter and λ is the wavelength), a two-layer approximation, grains mixtures at either the granular level or sub-granular level (using Maxwell Garnett theory for the latter).

Figure 1 shows the NIRSpec/Prism spectra of Quaoar, Gonggong, 2002 MS_4, and Salacia (bottom to top) and best fit Hapke models. In the spectra, we note the presence of the Fresnel peak of H_2O-ice at 3.1 μm. The exact position and shape of this peak can be used to constrain or determine the crystalline fraction and temperature of the H_2O-ice because the Fresnel peak is sensitive to both of these factors.

We note the presence of an absorption band from 3.3 to 3.5 μm. This region has been associated with the aliphatic CH stretching band of organic molecules. In our Hapke models, we find the inclusion of CH_3OH, C_2H_6, and C_3H_8 make a satisfactory fit, but we are limited by the hydrocarbons with known optical constants.

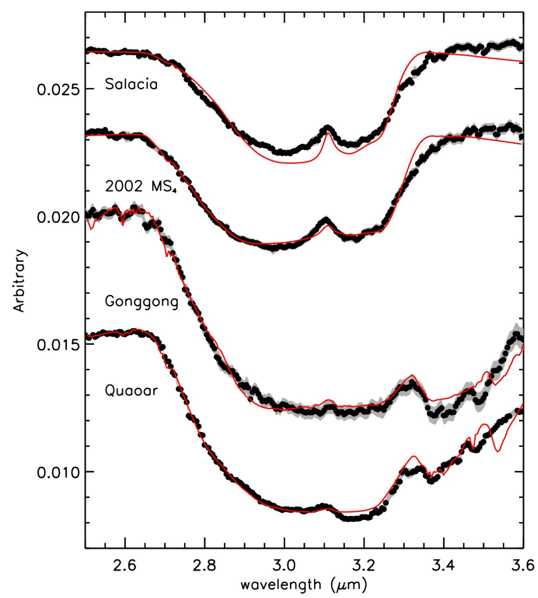

Figure 1: The JWST NIRSpec/Prism spectra of 4 KBOs in the 2.5 to 3.6 μm range. The data are shown as the black points, and 3-σ uncertainty as the grey cloud behind the data points. Hapke models are shown in red. The spectra are scaled and shifted to appear together on the same plot.

Future Work: Our analysis so far has been limited to the wavelength range seen in Fig. 1, but the observed spectral range is much greater. We plan to broaden our analysis to cover the whole range observed by JWST. We will present an in-depth analysis of each target and compare the results to each other.

References: [1] Emery, J. P., et al. (2007) vol. 39 of *AAS/Division for Planetary Sciences Meeting Abstracts* 49.08. [2] Fernández-Valenzuela, E., et al. (2021) *Planet. Sci. J* 2(1):10. arXiv:2011.07121. [3] Hainaut, O. R., et al. (2012) *A&A* 546:A115. arXiv:1209.1896. [4] Hapke, B. (1993) *Theory of reflectance and emittance spectroscopy*. [5] Hapke, B. (2012) *Theory of Reflectance and Emittance Spectroscopy*.