The surface composition of TNOs up to 5 microns before the JWST data era. A. C. Souza-Feliciano[1], N. Pinilla-Alonso[1], M. DePrá[1], B. Harvison[1], and J. Emery[2] .[1]Florida Space Institute/University of Central Florida (12354 Research Parkway, Partnership 1 Building, Suite 214, Orlando, FL, 32826), [2]Northern Arizona University (1900 S Knowles Dr, Flagstaff, AZ, 86011).

Introduction: Trans-Neptunian objects (TNOs) are icy relics, leftovers from the planetary formation that orbit the Sun beyond Neptune, as such the investigation of their properties is essential to understanding the formation and evolution of the Solar System. TNOs conform to a diverse population in reference to their shape, size, surface color, and geometric albedo. Constraining their surface composition through visible and near-Infrared (NIR) spectroscopy from ground-based telescopes is troublesome because of their sizes, relative magnitudes, and the Earth's atmosphere. However, the junction of data from ground- and space-based telescopes all through the longest wavelength-range possible provides us with the best tool to investigate their surface composition. The James Webb Space Telescope's (JWST) launch in December 2021 represents a unique opportunity to validate the compositional studies carried out in the last three decades using ground-based observations. Furthermore, it offers unparalleled access to explore the diversity in the trans-Neptunian belt and interpret it in terms of materials, temperatures, abundances, and phases.

Goals: Our goal is to extend the compositional analysis of TNOs by merging ground-based visible and NIR data with IRAC/Spitzer photometry from 2.5 to 5 microns. The overlapping of our sample with the targets of NIRSpec/Webb programs will allow us to validate our results and extend the number and diversity of TNOs with surface composition information.

Data: Our sample contains two Dwarf Planets, (136199) Eris and (136472) Makemake, one centaur, (2060) Chiron and one plutino, (38628) Huya. Except for Chiron, the visible and NIR spectrum of the sample were obtained with X-Shooter (ESO/VLT) [1,2,3]. The new NIR spectra of Chiron were obtained at the Telescopio Nazionale Galileo (TNG) in 2004 and 2005. For all the targets, we obtained Spitzer fluxes in 2016 on IRAC channels 1 (3.6 microns) and 2 (4.5 microns) during a whole rotational period.

Methodology: We use the fluxes to estimate the geometric albedos and corresponding errors on channels 1 and 2 of IRAC/Spitzer. Then, we use the visible albedo available in the literature [4] to merge visible, NIR, and IRAC/Spitzer data.

After that, we apply the Shkuratov model [5] through a Nested Sampling algorithm for Bayesian inference of the abundances and grain sizes of the materials present on TNOs' surfaces [6]. We select a sample of materials as a starting point for our modeling based on visual inspection of the main features in the 0.5 to 5 microns reflectance and published results. The modeling results are the relative abundances and the particle sizes of the materials in the best fit, as well as the range of values for a collection of statistically indistinguishable solutions.

Results: We confirm the presence of nitrogen ice on the surface composition of the Dwarf-planets in our sample through the absorption in channel 2. Eris needs a higher amount of nitrogen ice than Makemake, as has been suggested before. In both cases, the grain size of the particles of methane ice is in the order of millimeter size. A few percentages of complex organics, included as inclusions in a matrix of amorphous water ice, are needed to fit the visible spectral slope. Our results suggest that these processed materials could be covered under a thin layer of methane and nitrogen, which indicates processes such as transient atmosphere and transport of volatiles acting on their surface.

The best model for centaur (2060) Chiron shows differences in the resulting materials in 2004 and 2005, in agreement with the temporal variability of water ice reported in the literature. Up to about 26% of the surface of Chiron could be covered by water ice in 2004, half of this amount in 2005. According to IRAC/Spitzer light curve, this difference cannot be attributed to rotational variability.

The surface composition of the plutino (38628) Huya is compatible with a highly processed surface covered with a mixture of silicates and complex organics. Up to 22% of water ice is needed to fit the data above 2 microns. The presence of methanol is necessary to improve the overall shape of the spectrum above 2 microns.

Discussion: Our models for Eris and Makemake provide the first detection of Nitrogen in the wavelength domain where this volatile has its fundamental mode absorption. They also show a very young surface, deduced by the lack of complex organics on top of it. All of these factors point to physical processes, such as the transport of volatiles, as the drivers of the surface composition of these dwarf planets.

Chiron, nevertheless, shows a composition typical of other small bodies covered with dust mantles, which could be a result of cometary activity, already suggested for Chiron, or the interaction between the body and the debris orbiting around it.

Huya's surface, otherwise, is what we would expect for a TNO with no atmosphere or cometary activity, a mixture of silicates, water ice and complex-organics that result after the irradiation of simple hydrocarbons.

Conclusions: Extending the analysis of TNOs' surface composition above 2 microns allows the identification of ices, such as H2O, N2, and CH3OH, that could be masked at shorter wavelengths by other materials. Having a broad and deeper understanding of the surface of TNOs points to the physical processes that may be affecting their surface. With JWST, we will be able to conduct the most detailed study of the materials on the surface of the TNOs and infer information on their physical and chemical history.

References: [1] Alvarez-Candal et al. (2011) A&A, 532. [2] Merlin et al. (2017) A&A 604. [3] Alvarez-Candal et al. (2020) MNRAS, 497. [4] TNOs are cool public database website. [5] Shkuratov Y. and Starukhina L. (1999) Icarus, 137, 235-246. [6] DePrá et al. *in prep.* CATUABA: Compositional Analysis Tool Using A Bayesian Approach, preparation for JWST DiSCo-TNOs