Planetary Science with the 0.7 – 5.0 µm SPHEREx Solar System Object All-Sky Spectral Catalog

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Abstract: SPHEREx, the Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer, is a cosmological mission in NASA's Medium Explorer (MIDEX) astrophysics program that will launch in early 2025 and perform a 2-year ***all-sky*** near-infrared spectral survey at WISE sensitivity levels in 106 spectral bands between 0.75 - 5.0 µm with R = 41 to 135 while visiting every 6.2 x 6.2 arcsec pixel on the sky at least 4 times [1-3]. (More details concerning SPHEREx are available at http://spherex.caltech.edu.)

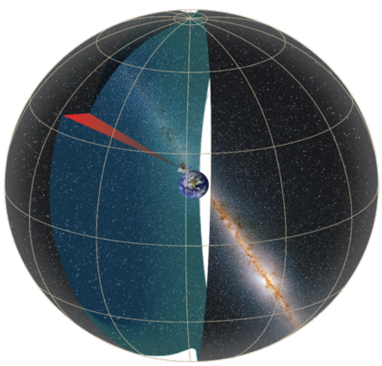
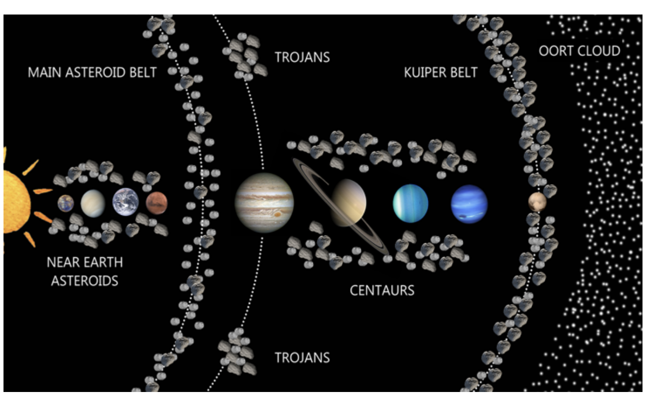


Figure 1: (*above*) SPHEREx all-sky near-infrared mapping. Utilizing a sun-synchronous NEOWISE-like polar orbit, objects in the sky at ~90 deg elongation will be observed in each great circle. The Earth's motion around the Sun advances the great circle's longitude ~1 deg/day; taking data in both the leading/trailing (forward/ behind) directions means that the entire sky's range of longitudes is covered in 6 months, with the ecliptic poles observed every orbit. (***below***) **The rich set of solar system objects available for SPHEREx study** (except for the Sun, Mercury, Venus, and the innermost NEAs).



The upcoming SPHEREx spectral survey provides a fantastic opportunity to detect, spectrally categorize, and catalog hundreds of thousands of solar system objects at WISE/NEOWISE sensitivities [4] using a single stable, well-characterized and calibrated space-based remote sensing platform [Fig.1; 1-3]. The resulting spectra (Fig. 2) could be used for everything from discerning new families of asteroids, comets, Trojans, Centaurs, and KBOs; to characterizing brand new interstellar objects; to mapping the zodiacal light with higher spatial resolution than has ever been done previously while searching for compositional structures; and to augmenting the science return from missions like *DAWN*, *Psyche*, *Lucy*, and NEO Surveyor [5].

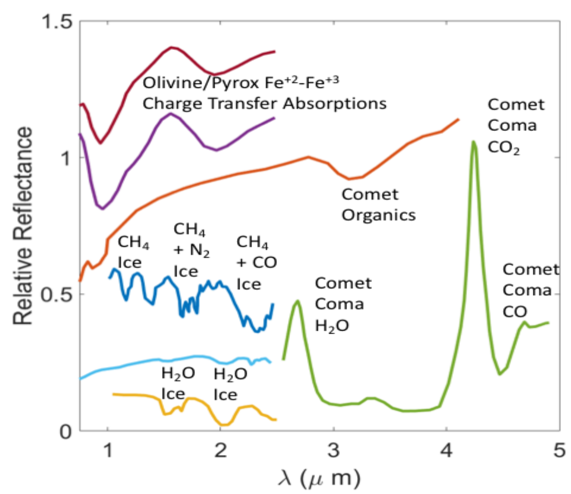


Figure 2 - Representative expected spectral science returns for asteroids (upper left), **comets** (right), and **KBOs & Centaurs** (lower left) from the SPHEREx all-sky survey.

E.g., based on previous mission observational experience [4], important science studies we can expect include:

- Determination of the size, albedo, and ***composition*** of ~10^5 asteroids of different spectral classes (i.e. S vs C/D/P vs V vs M, etc.), aiding in support of the NASA *Dawn* & *Psyche* missions;
- Detailed study of the spectral color groupings of ~10^4 Jovian Trojan asteroids, putting the targets of NASA's *Lucy* mission in sharp delineation;
- Discovery of newly active asteroids and characterization of known episodically active asteroids and Potentially Hazardous Objects (PHOs [6]);

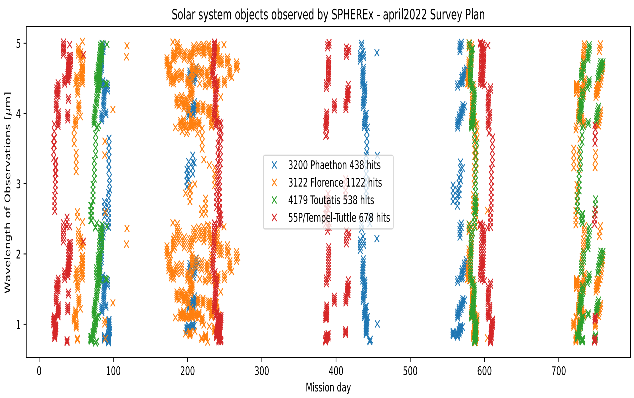


Figure 3 - Expected SPHEREx LVF wavelength of observation versus time "waterfall" plots for known asteroidal PHOs 3200 Phaethon, 3122 Florence, 4179 Toutatis, and cometary PHO 55P/Tempel-Tuttle. Each object is acquired at 3 to 5 different epochs over the course of the 2-year prime mission, and observed 100's of times in individual sky images over the course of ~2 weeks in each epoch. It thus takes ~2 weeks to build up a complete SPHEREx 0.7 – 5.0 μm spectrum of an object.

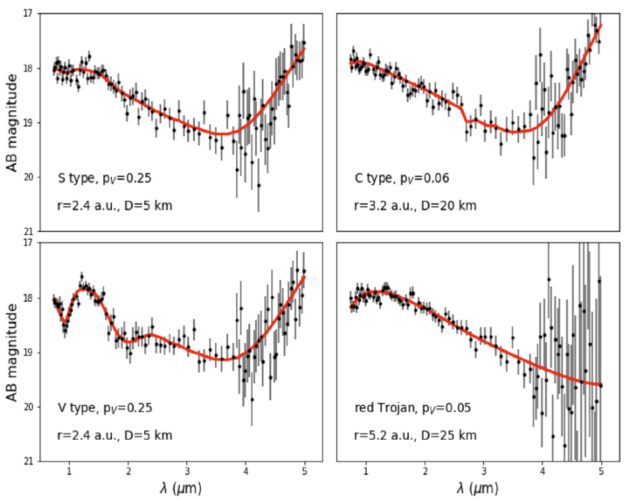


Figure 4 - Expected near worst-case SPHEREx spectral quality after 0.7 – 5.0 μm forced photometry collection and correction [8]. Results shown are for 3 different kinds of ***small*** asteroids and Jovian Trojans**.** Red curves – noiseless object template spectra. Black squares – modeled SPHEREx data, including rotation-induced flux modulation and realistic instrumental error bars. The taxonomic type, visual albedo p_v, heliocentric distance r and object diameter D are listed in each panel. Object sizes are chosen to approximately reproduce a signal-to-noise ratio of 5 at the wavelength of 2.4 μm. Note the significant water absorption feature at ~2.7 μm for the C-type asteroid, the small but detectable 0.7 – 1.5 μm Fe-charge transfer and silicate absorption features for the S-type asteroid, and the pronounced 1-2 μm silicate absorption features for the V-type asteroid. Also note that for main-belt asteroids, scattered light dominates from 0.7 μm out to ~3.5 μm and thermal emission from 4 to 5 μm, while thermal emission is a minor contributor for Trojans at 5.2 au even at 5 μm.

- Characterization from 0.7-5.0 μm of Interstellar Objects passing through the SPHEREx sky survey from a stable, sensitive, above-the-atmosphere observatory;
- Spectral monitoring of the weather on Uranus, Neptune, and Pluto over weeks and years;
- Discovery of 10's, and detection and characterization of 100's of known Centaurs and Comets, leading to better understanding of the origins and evolution of their primordial icy materials (especially CO_2 which is unavailable from the ground), as well as support of the ESA *Comet Interceptor* mission.

There is also great potential for overlapping synergies with results from missions running concurrently in the late 2020's like JWST, WFIRST, Euclid, GAIA, TESS, eROSITA and LSST [3,7].

However, great care will be required to properly convert the millions of individual SPHEREx LVF sky images into calibrated spectra with observational systematics removed (Figs. 3, 4; [6,8]). Providing the planetary science community with an accurate spectral data catalog will require the work of a dedicated team familiar with the SPHEREx mission, science pipeline, and instrument calibtration, time domain astronomical observations, and big dataset archiving at the PDS and IRSA. Here we describe the details of the SSOC's data collection, collation, calibration, and archiving.

References

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