**JWST NIRSPEC SPECTRUM OF ERIS: METHANE, DEUTERATED METHANE, AND NITROGEN.**
W.M. Grundy[1,2], I. Wong[3], C.R. Glein[4], S. Protopapa[4], B.J. Holler[5], J.C. Cook[6], J.A. Stansberry[5], A.H. Parker[7], J.I. Lunine[8], N. Pinilla-Alonso[9], A.C. de Souza Feliciano[9]; [1]Lowell Observatory (w.grundy@lowell.edu), [2]Northern Arizona Univ., [3]NASA GSFC, [4]SwRI, [5]STScI, [6]Pinhead Inst., [7]SETI Inst., [8]Cornell Univ., [9]Florida Space Inst., UCF.

**Introduction:** The solar system is endowed with a large and diverse population of small icy planets that provide rich opportunities for comparative planetology. Those that are massive and cold enough to retain volatile ices such as nitrogen and methane are an especially interesting clan, since phase changes can enable thermal energy to drive geological processes that refresh their surfaces and create diverse landforms. Objects that still retain abundant methane at present include Triton, Pluto, Eris, and Makemake, in order of increasing methane abundance according to ground-based spectra (e.g., [1]).

Eris is an especially interesting target, intermediate in mass between Triton and Pluto but higher in bulk density than both. Eris orbits much further from the Sun, at a mean distance of 68 AU, but its high eccentricity brings it to 38 AU at perihelion and 98 AU at aphelion, resulting in nearly a factor of 7 difference in incident sunlight over its orbit. If Eris's spin axis is aligned with its satellite Dysnomia's orbit pole, that would imply a high obliquity of 78°, with important implications for Eris's seasons [2].

Key questions regarding Eris include the origin of its $CH_4$, and how it refreshes its surface and maintains its high albedo [3], considering that $CH_4$ ice exposed to energetic space radiation is rapidly processed into heavier hydrocarbons and ultimately dark, red tholin-like macro-molecules. A variety of resurfacing scenarios can be imagined. Analogous to Pluto's Sputnik Planitia, convective glacial overturn of a thick $CH_4$ surface deposit could make Eris a "Sputnik planet" [4]. Or seasonal sublimation and condensation could make Eris more of a "bladed planet" [5]. Other key questions involve $N_2$ ice: how much is present, and what is its influence on Eris's resurfacing processes? The existence of $N_2$ had been inferred indirectly from its influence on Eris's $CH_4$ bands ([1][6]), but it had not previously been directly detected.

**Observations:** JWST observed Eris on 2022 August 30 as part of program 1191, led by J. Stansberry. Eris was 95.1 AU from JWST and 95.8 AU from the Sun with a solar phase angle of 0.5°. The observation made use of NIRSpec's IFU with three medium-resolution gratings G140M, G235M, and G395M to cover wavelengths from 0.97 to 5.17 µm at a resolving power of about 1000. The total exposure time was 2422 seconds.

**Results:** The JWST spectrum is consistent with prior results indicating a $CH_4$-dominated surface. Four strong infrared $CH_4$ ice bands have been detected for the first time at Eris at 2.6, 3.3, 3.55, and 3.85 µm. A pair of $CH_3D$ bands at 4.33 and 4.56 µm is also seen. By modeling the $CH_4$ and $CH_3D$ bands together (see [7]), we can estimate the D/H ratio in Eris's $CH_4$ ice, finding that it is higher than the terrestrial SMOW value. Conversely, our derived value is lower than the D/H ratio of methane in comet 67P [8]. This difference may imply that Eris's methane is not primordial, but was produced inside Eris. We find that the D/H ratio of Eris's methane is consistent with inheritance of hydrogen atoms from cometary water under plausible subsurface conditions.

The broad, fundamental vibrational absorption band of $N_2$ is also evident around 4.1 to 4.2 µm. This feature is weak, since $N_2$ is a homonuclear molecule without an intrinsic dipole moment, so the detection of this band implies a substantial quantity of $N_2$, possibly a third as much as $CH_4$ by volume. If Eris's $CH_4$ is not primordial, then its $N_2$ may also not be primordial. Instead, similar subsurface geochemical processes may be implicated to form $N_2$.

No strong ethane ice bands are evident. $C_2H_6$ is readily produced from $CH_4$ via radiolysis, so that observation is consistent with a process that renews Eris's surface rapidly.

**Acknowledgments:** This work is based in part on observations made with the NASA/ESA/CSA James Webb Space Telescope. The data are at the MAST archive at STScI, which is operated by AURA, Inc., under NASA contract NAS 5-03127. These observations are associated with program #1191. We are especially grateful to Tony Roman and Charles Proffitt at STScI for help with program implementation.

**References:**
[1] Licandro et al. (2006) *A&A* 445, L35; 458, L5.
[2] Holler et al. (2021) *Icarus* 355, 114130.
[3] Sicardy et al. (2011) *Nature* 478, 493.
[4] Grundy & Umurhan (2017) DPS #49, 202.02.
[5] Hofgartner et al. (2019) *Icarus* 334, 52.
[6] Tegler et al. (2010) *ApJ* 725, 1296.
[7] Grundy et al. (2011) *Icarus* 212, 941.
[8] Müller et al. (2022) *A&A* 662, A69.