SPECTRAL PROEPRTIES OF DUST ON ASTEROID (101955) BENNU WITH THE OSIRIS-REX VISIBLE AND INFRARED SPECTROMETER (OVIRS). H. H. Kaplan[1], A. A. Simon[1], D. C. Reuter[1], and V. E. Hamilton[2], [1]NASA Goddard Space Flight Center, Greenbelt, MD, USA (Hannah.kaplan@nasa.gov), [2]Southwest Research Institute, Boulder, CO, USA.

Introduction and Background: The Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) spacecraft successfully collected a sample of regolith from asteroid (101955) Bennu on October 20, 2020 [1]. The Touch-and-Go (TAG) spacecraft maneuver used to collect the sample mobilized material, including very fine particles (dust), from up to ~1 m in depth and ~10 m in diameter from the point of contact with the asteroid [1,2]. TAG created a dust plume that intercepted the spacecraft and accumulated on the instruments. As a result, all instruments show degradation in optical throughput, with the degree of degradation depending on their aperture size, orientation, and position on the spacecraft [1]. In this study, we analyzed OSIRIS-REx Visible and Infrared Spectrometer (OVIRS) from before and after TAG to assess the dust on the instrument with implications for Bennu's dust composition and scattering properties, and future visible–near-infrared (VNIR) spectral observations with the OSIRIS-REx spacecraft.

OVIRS is a point spectrometer that measures reflected light at VNIR wavelengths from 0.4 to 4.3 μm with a 4 mrad circular field of view (FOV) [3]. Previous observations with OVIRS revealed widespread hydrated minerals and carbon-bearing materials on Bennu [4,5]. A ~3 μm absorption feature is observed globally in OVIRS spectra, with a band position and depth that is consistent with Mg/Fe phyllosilicates and suggests a similar degree of aqueous alteration to that experienced by some carbonaceous chondrite meteorites [4,6]. A series of weak (<5%) VNIR spectral features, potentially associated with hydrated phyllosilicates and iron oxides, are also found in OVIRS spectra (Fig. 1), though not typically observed in meteorite spectra [7].

OSIRIS-REx Thermal Emission Spectrometer (OTES) spectra are consistent with a very thin accumulation (a few to ~ten microns) of fine particles (<~65–100 microns in size) across the surface of Bennu, and particularly on the roughest boulders, an interpretation that is supported by the dust plume seen during TAG [1,8]. An analysis of TAG contamination on the OTES optics revealed a 15% decrease in throughput, and OTES observations of space with and without that contamination allow a recreation of the thermal infrared spectrum [1]. The spectrum of the contamination lacks volume scattering features and exhibits a stronger Mg-OH absorption (~16.5 μm) than average Bennu, suggesting a Mg-rich phyllosilicate composition [1,6]. Here we present the first compositional analysis of Bennu dust at VNIR wavelengths by analyzing the contaminant on OVIRS.

Methods: OSIRIS-REx conducted multiple global imaging and spectroscopy campaigns of Bennu in the two years leading up to TAG. We selected datasets from the "Baseball Diamond" and "Equatorial Survey" (EQ) mission phases (described in detail in [9]) for analysis. A final set of global observations (the "Bennu Farewell Tour", BFT) was collected after TAG, allowing us to assess instrument performance and possible dust on the optics when compared with the previous datasets.

We ratioed global average spectra from pre- and post-TAG datasets, as well as latitudinally and longitudinally binned data. We also used a small number of spectra from locations with identifiable spectral features, including the exogenic pyroxene-rich boulders [10], to allow for individual footprint comparison at a known ground location.

Results and Discussion: We observed decreased throughput of ~5% with OVIRS after TAG when compared with data at similar, but not identical, phase angle in visible wavelengths. Light entering the OVIRS main aperture is reflected off internal primary and secondary mirrors before entering the detector assembly; the primary mirror is the most likely location for dust accumulation.

OVIRS spectra collected after TAG have stronger absorption features at multiple wavelengths than previous datasets (Fig. 1). These features are consistent in pre- and post-TAG spectral ratios from individual OVIRS footprints at multiple surface locations and average spectra from the entire asteroid surface (Fig. 2), suggesting that the source is instrument contamination (as opposed to changes in surface composition caused by TAG, which would vary with distance from the sample collection site); this interpretation is further supported by evidence of new features in solar calibration observations. Stronger absorptions associated with dust on the OVIRS optics are found at ~0.8, 1.1, 1.3 – 1.4, 1.9, and 2.3 μm (Fig. 1, 2). There may also be absorptions near 3.0 μm and 3.4 μm, but further work is needed to confirm that these features are present. Variations in observation geometry between datasets lead to small differences in absolute absorption strength in ratioed spectra, but absorption position and presence do not vary with latitude or longitude.

All spectral features associated with the dust contaminant were previously noted as weak absorptions on the boulder dominated Bennu surface [7] (Fig. 1). An enhancement of these weak features may result from scattering of fine-grained material, and/or the unique observation conditions for viewing the dust. Absorptions at 1.4, 1.9, and 2.3 µm are indicative of Mg/Fe phyllosilicates (serpentine, saponite). Bennu material dominated by Mg-rich phyllosilicates, like in the most aqueously altered carbonaceous chondrite meteorites, would support the findings from OTES of the contaminant on that instrument [1,6]. However, other absorptions (e.g., 0.8 µm, 1.1 µm, 1.3 µm) and the relative strength of the 1.4 and 1.9 µm features are not consistent with Mg-phyllosilicate alone. The absorptions also do not appear to be consistent with other known components of the Bennu surface (e.g., carbonate, organics [5,11]) or with hydrazine fuel used by the OSIRIS-REx thrusters during TAG. We are currently exploring a wide range of other possible compositions and scattering conditions, as well as the possibility of dust interaction with the OVIRS mirror coating. Further we will use a new thermal correction [12] to better understand changes >2.5 µm, including the increased hydration signature near 3.0 µm.

Implications: The OVIRS observations after TAG include a fine particulate contamination on the primary mirror and are therefore an important datapoint for understanding the spectral properties of dust on Bennu and other carbonaceous asteroids.

A future rendezvous with another asteroid target, (99942) Apophis, is proposed for the OSIRIS-REx spacecraft, and it is important to understand the impact of the dust contaminant on these future observations. Bennu Farewell Tour data collected after TAG show that OVIRS is performing as expected. We derived a correction factor to remove effects of mirror contamination < 2.5 µm and determined the TAG site in Hokioi Crater became darker and had a more positive spectral slope, while the surrounding area remained spectrally unchanged [1]. The work described here supports the full spectrum correction needed for future observations. Future calibration activities will monitor the contamination, its spectral features, and any changes to ensure the possibility of successful data collection with OVIRS at Apophis.

References: [1] Lauretta, D.S. et al. (submitted), *Science*. [2] Walsh, K.J. et al. (submitted), *Science.* [3] Reuter, D.C. et al., (2018) *Space Science Reviews 214*, 54. [4] Hamilton, V.E. et al. (2019) *Nat. Astron., 3*, 332. [5] Simon, A.A. et al. (2020) 10.1126/science.abc3522. [6] Hamilton, V.E. et al. (2022) *LPSC,* this conference. [7] Simon, A.A. et al. (2020), *A&A,* 644, A148. [8] Hamilton, V.E. et al. (2021) *A&A, 650*, A120. [9] Lauretta, D.S. et al. (2021) *Sample Return Missions*, 163. [10] DellaGiustina, D.D. et al. (2020) *Nat. Astron., 5*, 31. [11] Kaplan, H.H. et al. (2021) 10.1126/science.abc3557. [12] Li, S. and Kaplan, H. H. (2022) *LPSC*, this conference.

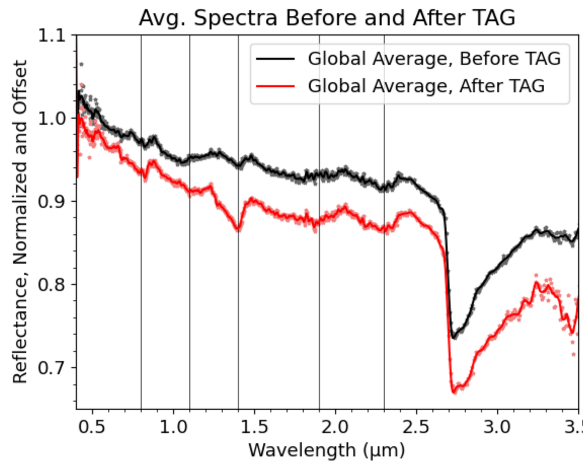

Figure 1. Global averages obtained from observations before the TAG sample collection event (EQ observation, 6182 spectra) and after TAG (BFT observation, 11792 spectra). Vertical lines at 0.8, 1.1, 1.4, 1.9, and 2.3 µm show positions of stronger absorption features after TAG.

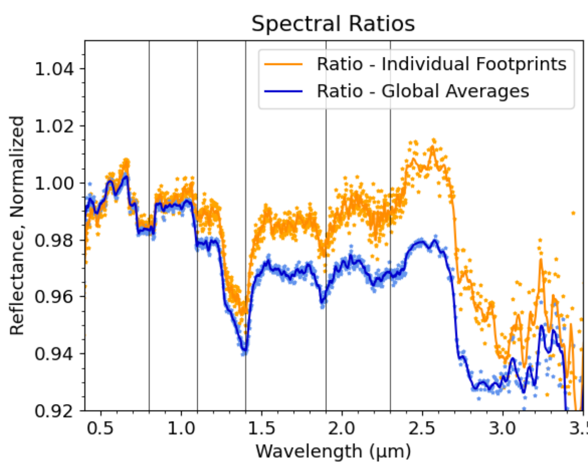

Figure 2. Ratios of OVIRS spectra from before and after the TAG event highlight stronger absorption features that arise from instrument contamination with Bennu material during TAG. Ratios from a single location (orange, pyroxene boulder from [10]), and the entire Bennu surface (blue) have similar features and provide evidence of the Bennu dust spectral properties. Vertical lines at 0.8, 1.1, 1.4, 1.9, and 2.3 µm show positions of stronger absorption features after TAG.