Compositional and petrologic interpretations of olivine-dominated asteroids. S. D. Crossley[1,2], J. M. Sunshine[3,4], R. D. Ash[4], T. J. McCoy[5], and C. M. Corrigan[5], [1]Lunar and Planetary Institute/USRA, Houston, TX 77058 (scrossley@lpi.usra.edu), [2]NASA Johnson Space Center, ARES, Houston, TX, [3]University of Maryland, Dept. of Astronomy, College Park, MD, [4]University of Maryland, Dept. of Geology, College Park, MD, [5]Smithsonian Institution National Museum of Natural History, Dept. of Mineral Sciences, Washington DC.

Summary: We have demonstrated that olivine asteroid FeO content can be reliably determined from hybrid datasets of high-resolution near-infrared reflectance data and broad band visible data while simultaneously accounting for the co-occurrence and composition of pyroxenes. This work doubles the number of interpretable olivine-dominated asteroid spectra and provides further insight into the petrology of olivine-pyroxene asteroids based on equilibrium relationships between olivine and pyroxene in meteorites. Preliminary results indicate that most A-type (olivine-dominated) asteroids are consistent with equilibration in relatively oxidizing environments (>IW-1).

Introduction: Determination of olivine asteroid compositions using reflectance spectroscopy have been previously explored with Modified Gaussian Modeling (MGM) [e.g., 1] and Band Area Ratio (BAR) methods [2], but these investigations were limited by the need for high-resolution visible-to-near-infrared (VNIR) data and/or spectra lacking overlapping absorption features (e.g., pyroxene). High-resolution visible reflectance data are not available for most A-type (olivine-dominated) asteroids identified using Sloan Digital Sky Survey (SDSS) broad band spectral filters, and many also contain pyroxene bands [3] that complicate modeling of olivine absorption bands. To investigate the greater population of olivine-dominated asteroids, we have tested MGM fitting using hybrid SDSS-SpeX datasets, including pyroxene-bearing A-type spectra.

Methods: Sources for telescopic data are reported in [1 and 3]. High-resolution VNIR spectra are produced from combining SMASS/SMASSII UV-visible data [4] with and SpeX visible-to-near-infrared data [5]. Meteorite spectral reflectance measurements were collected at the RELAB facility at Brown University.

Compositions of olivine were remotely determined for meteorites and asteroids following methods in [1]. This involved running three MGM solutions wherein the relative strengths of the three olivine bands were constrained to values appropriate for a given composition (Fa_{10}, Fa_{30}, and Fa_{50}). Model solutions were deemed self-consistent when the olivine band centers and relative band strengths agreed within 10 mol% Fa.

Hybrid-resolution data: To fit broad band filter data using MGM, we normalized datapoints from SDSS spectral filters to corresponding SpeX data after [3]. To assess the accuracy of MGM solutions, we simulated SDSS data by integrating SMASS data (RELAB data for meteorites) using the gaussian profile of each SDSS filter [6], then ran MGM algorithms for both datasets to compare results (Fig. 1).

Accounting for pyroxene occurrence: The 1 µm absorption feature of pyroxene complicates the remote interpretation of olivine composition. However, because parameters of pyroxene bands I and II are correlated and vary predictably with composition [7-8], we were able to constrain the 1 µm band parameters of pyroxene based on the calculated band parameters of the corresponding 2 µm band. We tested this approach with brachinite family meteorites that contain 1-12 vol% pyroxene [9].

Preliminary Results/Discussion: MGM solutions can be reproduced for hybrid-resolution data well within the typical precision of ~10 mol% for Fa (Fig. 1). Low resolution in the visible region precludes fitting of 0.65 µm absorption features identified in meteorite spectra, which are typically associated with Fe^{2+}/Fe^{3+} transitions. Additionally, the center of olivine absorption band I (~0.85 µm), is typically shifted toward shorter wavelengths compared to solutions for continuous data, likely due to the unresolved 0.65 µm band. However, olivine compositions estimated from MGM are derived from the centers of the second and third olivine bands [10], which are negligibly affected by low-resolution visible data.

MGM-calculated asteroid compositions (Fig. 2) indicate many A-type asteroids are consistent with $>Fa_{20}$ and $>Fs_{20}$ and therefore likely equilibrated in relatively oxidized environments (≥IW-1). Among meteorites, these characteristics are most similar to the brachinite family primitive achondrites and some R chondrites. These preliminary findings agree with those of [2] but expand the apparent FeO-rich nature of A-type asteroids to pyroxene-bearing spectra. The dominance of FeO-rich olivine among A-type asteroids may relate to the positive correlation between olivine/pyroxene ratios and oxidation state among chondrites and primitive achondrites [e.g., 11]. This could result in a bias toward FeO-rich compositions for A-type asteroids, given that their taxonomy is defined by spectral features consistent with < 20 vol% pyroxene. Further interpretations will be provided at presentation.

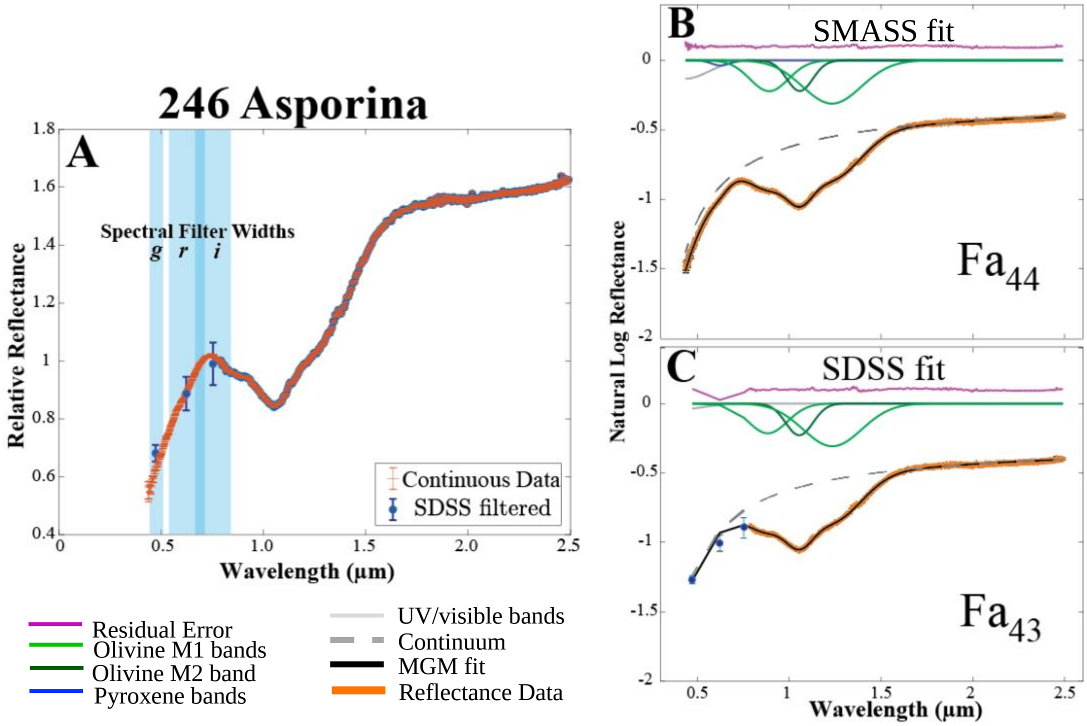

Fig. 1. 246 Asporina (a) reflectance spectrum and MGM solutions for both (b) high resolution and (c) hybrid-resolution datasets. Calculated olivine compositions are within the uncertainty of MGM solutions (±10 mol%), demonstrating that discontinuous data can be used to interpret olivine composition. This capability more than doubles the number of previously interpretable A-type asteroid spectra using MGM.

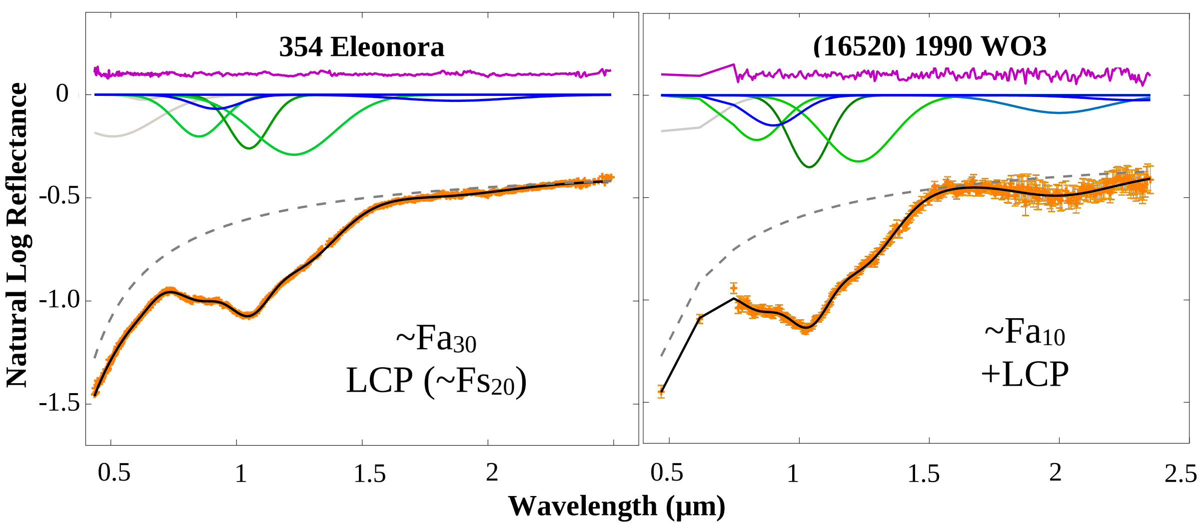

Fig. 2. Example MGM fits for olivine-dominated asteroids. Based on band centers and band strength ratios, asteroid 354 Eleonora is best fit by intermediate ~Fa_{30} olivine models with low-Ca pyroxene (~Fs_{20}, blue bands) within uncertainty of equilibrated mineral assemblages. Asteroid (16520) 1990 WO3 is best fit by low Fa models with both low and high-Ca pyroxene (HCP). Observational uncertainties in the 2 µm region prevent interpretation of Fs content for low-Ca pyroxene in small asteroids like (16520) 1990 WO3. Symbols are the same as in Fig. 1.

References: [1] Sunshine J.M. et al. (2007) *MAPS*, 42, 155-170. [2] Sanchez J.A. et al. (2014) *Icarus*, 228, 228-300. [3] DeMeo F.E. et al (2019) *Icarus*, 322, 13-30. [4] Xu et al. (1995) *Icarus*, 115, 1-35. [5] Rayner J.T. et al. (2003) *Ast. Soc. of the Pacific*, 362-382. [6] York D.G. et al. (2000) *The Astro. Journ.*, 120, 1579-1587. [7] Klima R.L. et al. (2007) *MAPS*, 42, 235-253. [8] Klima R.L. et al. (2011) *MAPS*, 46, 379-395. [9] Crossley S.D. et al. (2020) *MAPS*, 55, 2021-2043. [10] Sunshine J.M. & Pieters C.M. (1998) *JGR*, 103, 13675-13688. [11] Tomkins A.G. et al. (2020) *MAPS*, 55, 857-885.