Visible and Shortwave Infrared Micro-Imaging Spectroscopy of Martian Meteorites

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Motivation

- 196 named Martian meteorites, ranging in age from 4.5 Gyr to 175 Myr [1] and representing ~100-120 distinct falls, provide an opportunity to study variations in the Martian crust and mantle with time.
- Visible/shortwave infrared (VSWIR) spectroscopy allows correlating meteorite spectral properties with remote sensing data [e.g., 2–5].
- However, bulk powders used to date in VSWIR studies are (a) destructive, (b) eliminate valuable textural information on inherent grain size and the relationships between mineral phases, and (c) obscure uncommon phases by mixing.
- We build on prior studies of single Martian meteorites with point-to-point spectra [6] and microimaging spectroscopy [7-9] by conducting a survey of >40 Martian meteorites using VSWIR microimaging spectroscopy. Imaging spectroscopy preserves the petrographic context of mineral phases, requires minimal sample preparation, rapidly (<1 min./meas.) produces tens of thousands independent spectra which can be used to identify minor phases diluted in bulk spectra, and is directly comparable to remote sensing data.
- VSWIR microimaging spectroscopy also may be useful for meteorite classification (looking for more meteoriticists to discuss this with!)

Microimaging Spectroscopy Method

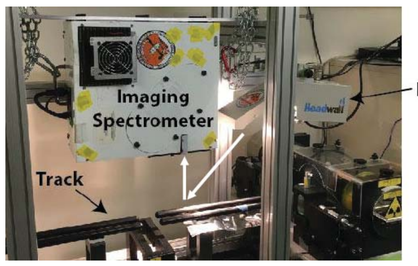


Figure 1. Ehlmann lab imaging spectrometer setup. A halogen lamp illuminates the sample, which is moved by translation stage beneath the spectrometer slit to build an image cube.

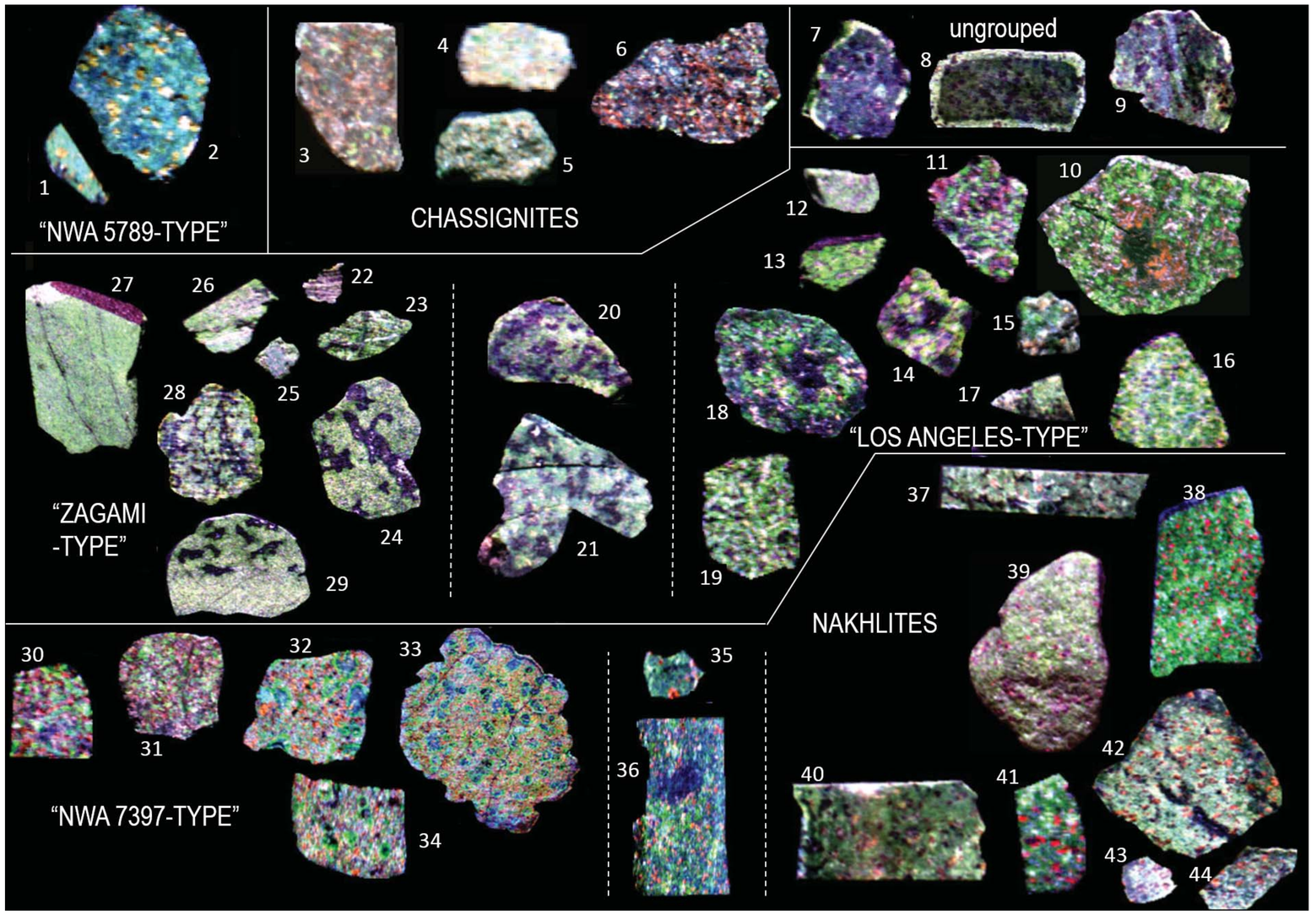
- Two sensors measure reflected light simultaneously at wavelengths of 0.4-1.0 µm (VNIR) and 0.87-2.6 µm (SWIR) at spatial resolutions of 71 µm/pixel (VNIR) and 212 µm/pixel (SWIR) with an effective spectral resolution of 5 nm (VNIR) and 6 nm (SWIR) with SNR >100 at all channels.
- The pair of VNIR and SWIR cubes were calibrated to reflectance with a Spectralon standard, spatially co-registered, and then stacked
- An MNF transform was performed to remove correlated noise.
- Spectral analyses were conducted manually, by parameter mapping, and by semi-automated spectral analysis tools (e.g., n-d visualization, spectral angle mapper) built into ENVI to identify and map absorptions due to specific phases

Meteorite Samples

- Cut meteorite samples, 0.5-5 cm on a side, typically not polished
- 5 chassignites, 7 nakhlites, 55 shergottites (at least 11 were pairs), 7 additional samples provisionally classification as martian
- Prior work had imaged ALH84001 using a flight prototype instrument (UCIS) at JPL [10]

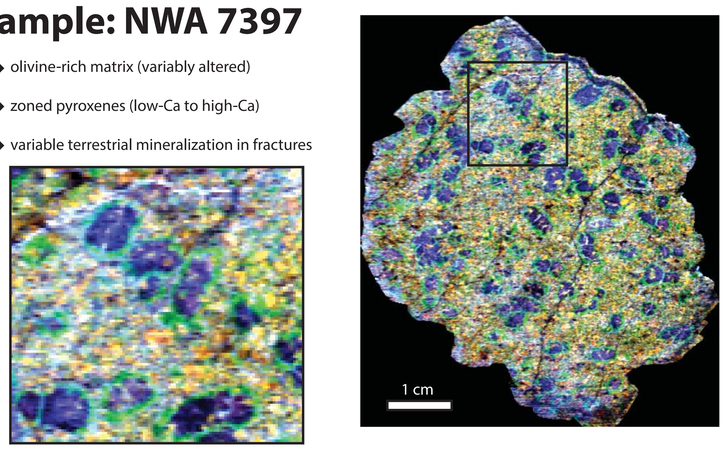
Mars Meteorites in Infrared False Color with Microimging Spectroscopy

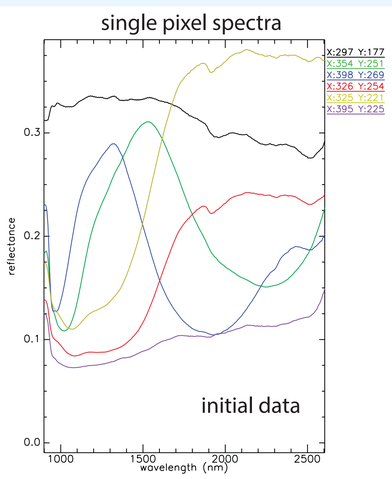
Figure 2. 42 martian meteorites measured as of January 2018. RGB false color infrared composite (R: 2.3 µm; G: 1.6 µm; B: 1.0 µm) of select meteorites from the study, showing similarities in spectral properties that lead to distinctive groupings (scale was not preserved in figure construction). (1) NWA 6162 (2) NWA 5789 (3, 6) NWA 2737 (4-5) Chassigny (7) NWA 4222 (8) NWA 1195 (9) DaG 1037 (10-11) Los Angeles (12-13, 15) Shergotty (14) DHO 378 (16) NWA 10558(17) NWA 1950 (18) NWA 7320 (19) NWA 1460 (20) NWA 1669 (21, 25) Tissint (22-23) NWA 5029 (24) NWA 10441 (26-27) Zagami (28) NWA 2626 (29) NWA 8656 (30) NWA 5990 (31) NWA 7032 (32-33) NWA 7397 (34) NWA 7387 (35) NWA 4480 (36) NWA 817 (37) NWA 1068 (38) Lafayette (39) Nakhla (40) DaG 476 (41) Governador Valadares (42-44) SAU 005

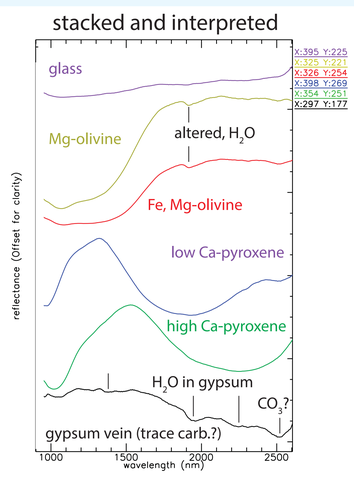


Example: NWA 7397

- olivine-rich matrix (variably altered)
- zoned pyroxenes (low-Ca to high-Ca)
- variable terrestrial mineralization in fractures







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References: [1] Nyquist et al., 2001, Chronol. Evol. Mars [2] Hamilton et al. 1997 JGR [3] Mustard & Sunshine, 1995, Science [4] McFadden & Cline, 2005, MAPS [5] Werner et al., 2014, Science [6] Bishop et al., 1998, Met. Plan. Sci. [7] Cannon et al. 2015, Icarus [8] De Angelis et al., 2014, Planet. Space Sci [9] Greenberger et al., 2015, GSA Today [10] Van Gorp et al., 2014, J. Appl. Remote Sens