THE EMIRATES MARS INFRARED SPECTROMETER (EMIRS) OVERVIEW AND SURFACE RESULTS

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Introduction:

The Emirates Mars Mission (EMM, Amiri et al., 2022) Emirates Mars Infrared Spectrometer (EMIRS, Edwards et al., 2021, **Fig. 1**) currently around Mars is acquiring remote measurements of the martian surface (temperature and composition) and lower atmosphere. EMIRS is a FTIR spectrometer covering the range from 6.0-100 µm (1666-100 cm^{-1}) with a spectral sampling as high as 5 cm^{-1} with a 5.4-mrad IFOV with direct heritage from the Thermal Emission Spectrometer (TES, Christensen et al., 2001) and OSIRIS-REx Thermal Emission Spectrometer (OTES, Christensen et al., 2018). The EMIRS optical path includes a flat 45˚ pointing mirror to enable one degree of freedom while the spacecraft provides the other to build up a 2-dimensional array of observations. The primary goals of EMIRS are to characterize the geographic and diurnal variability of key atmospheric constituents (water ice, water vapor, and dust) along with temperature profiles and surface temperature on sub-seasonal timescales

EMIRS acquires data of the full martian disk and thus provides an integrated view of the martian surface and atmosphere in every spectrum. These observations include complete diurnal, seasonal, and geographic coverage of atmospheric properties, surface temperature, and also surface composition/mineralogy at wavelengths not regularly acquired of the martian surface. Due to the unique nature of the EMM orbit, EMIRS also collects data that

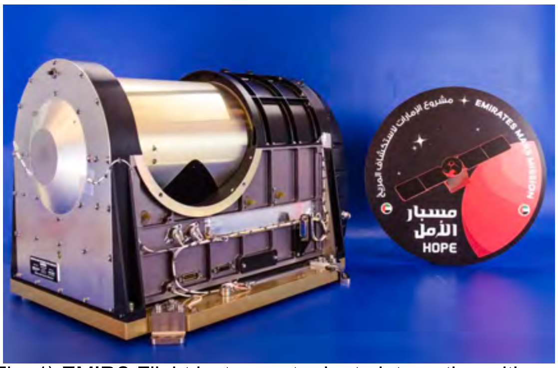

Fig. 1) EMIRS Flight instrument prior to integration with the spacecraft

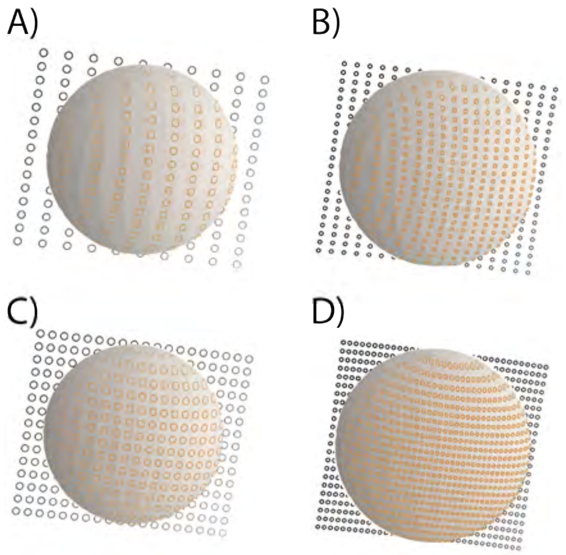

Fig. 1) EMIRS R-OS1 (top, A & B) and R-OS2 (bottom, D & E) synoptic observation strategies observed. These observations are simulated for a S/C altitude of 43,000 km (left, A & C) and 20,000 km (right, B & D). Mars is scaled to the same apparent size.

spans the full local solar time range (all solar incidence angles), at multiple emission angles. These unique observations permit the interrogation of diurnal surface ices/frost, thermophysics (including subsurface layering from both a seasonal and diurnal skin depth), surface roughness, and rock abundance in addition to the primary science goals.

EMIRS Overview and Status:

EMM Concept of Operations (CONOPS, **Fig. 2)** strategy provides opportunities for complete geographic coverage of all times of day in less than 10 days of observations. During the primary science phase, EMIRS acquires data of ~1/2 the martian disk within 1/2 an hour of observing. This observation sequence, which include calibration activities, is carried out ~20 times per orbit and produces data with surface sampling of better than 300 km/px up to 70˚ emission angle, with the highest resolution data being ~100km in diameter. EMIRS uses these data to provide global maps over 8 local time bins of the column integrated dust opacity, column integrated

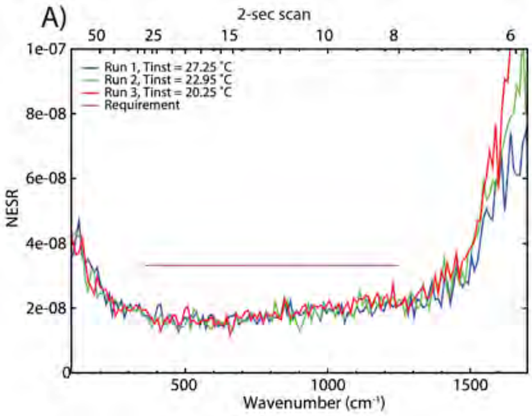

Fig. 3) EMIRS in flight performance exceeds requirements with significant margin

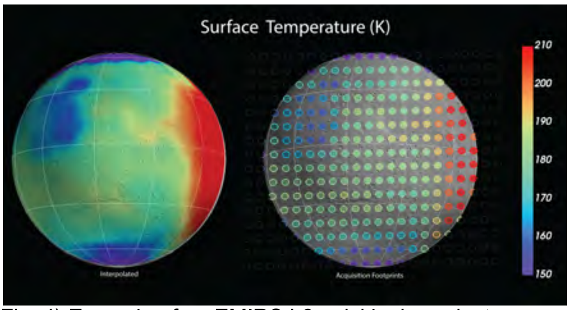

Fig. 4) Example of an EMIRS L2 quicklook product.

ice opacity, water vapor abundance and atmospheric temperature profiles to 60 km altitude.

The calibration pipeline of EMIRS leverages the well-established pipelines of TES and OTES and folds in atmospheric retrievals into the standard process (**Fig. 3**). Level 2 data (calibrated radiance and associated geometry, along with quick look that depict the acquisition geometry, **Fig. 4**) are released on 3 month cadence and lag by ~4 months from the time of collection. Level 3 data (including water vapor column abundance, water ice optical depth, dust optical depth, and atmospheric temperature profiles, including quickook products, **Fig. 5**) lag by an additional 3 months to allow sufficient time for the quality of the data to be assessed.

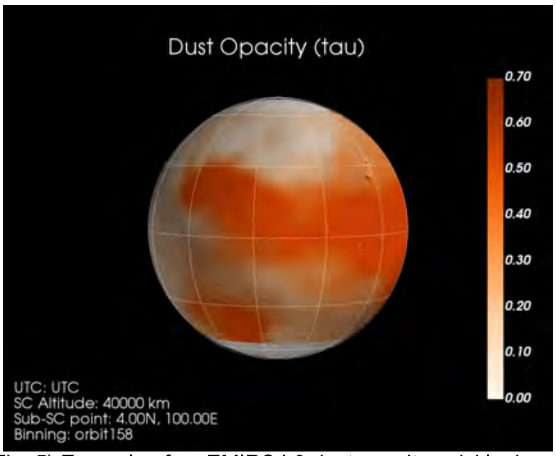

Fig. 5) Example of an EMIRS L3 dust opacity quicklook product.

Surface Results and Associated Challenges:

Due to the unique nature of the EMM observation strategy, nearly every EMIRS pixel covers multiple geologic and thermophysical units, includes a range of local times and incidence/phase angles and is observed from a unique spacecraft viewing geometry (e.g. range of emission angles). This combination of multi-angle viewing when convolved with the multi-time of day observations provide a unique but complicated lever arm on the surface roughness (e.g. Bandfield & Edwards, 2008), rock abundance (e.g. Nowicki & Christensen, 2007) and surface heterogeneity (e.g. Edwards et al., 2018; Wolfe et al., 2021). When compared to the nominally nadir looking TES data of Mars, with a fixed local time, the complexity of the EMIRS dataset becomes apparent (Fig. 6). While good diurnal fits are achievable for

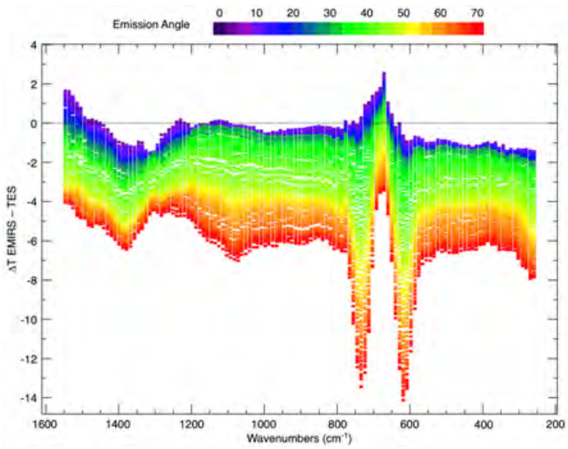

Fig. 6) EMIRS and TES daytime data acquired around the same season and local time vs wavelength and emission angle.

regions with stringent data observation geometry restrictions, the impact of multiple emission angle data on effective surface temperatures can be significant (Bandfield & Edwards, 2008) and necessitates a more sophisticated approach to deriving surface properties/temperatures than most nadir-looking spacecraft. Specifically, we find that during the day, fine-scale surface roughness and macro-scale slopes play an important role in the overall shape of the diurnal curve, while at night the mixing of surface units and rock abundance also plays an important role, causing differential cooling.

Summary and Future Work:

The derivation of an accurate surface radiance is a key input into the atmospheric retrieval used for EMIRS (Atwood et al., 2021; Badri et al., 2021; Smith et al., 2021; Wolfe et al., 2021). As such we are developing a comprehensive parameterization of the EMIRS observation sequence that permits the fitting of anisothermal surface radiance to measured EMIRS radiances using a combination multi-component mixtures that account for the complex viewing geometries and sub-pixel variability.

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