A Sub-millimeter sounder for vertically measuring Mars winds, water vapor, and temperature.

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Introduction: The vertical water vapor and winds on Mars are not well known, yet are critical for understanding fundamental Martian processes and for ensuring safe landing of robotic and human spacecraft.

NASA's Next Orbiter Science Analysis Group [NEX-SAG; 1] recognized the need for these measurements and envisioned a sub-mm instrument aboard a possible Mars orbiter launced in 2022. One of the five compelling science objectives noted was to *"Measure winds and characterize transport and other dynamic processes to understand current climate, water, and dust cycles, with extrapolation to past climates"* and a Finding was *"Observation of wind velocity is the single most valuable new measurement that can be made to advance knowledge of atmospheric dynamic processes. Near-simultaneous observations of atmospheric wind velocities, temperatures, aerosols, and water vapor with global coverage are required to properly understand the complex interactions that define the current climate."*

The various Mars orbiting spacecraft that have been flown to date have characterized the Martian atmosphere fairly well in terms of temperature, pressure, dust and ice aerosols, and column water vapor amount. The ExoMars Trace Gas Orbiter will measure profiles of the abundance of many key trace gases, and MAVEN is studying the upper atmosphere and its interaction with the space environment.

However, measurements of T, aerosol and water vapor are needed simultaneously with wind measurements, to fully understand the impact of thermal forcing on wind, and the consequences for transport.

Sub-millimeter Instrument Design Concept: A passive sub-mm limb sounding instrument is ideally suited to provide the needed wind, water vapor, and temperature profile measurements. The technique has high heritage in Earth-science, and dramatic advances in associated technology in the past decade (driven in part by the communications industry) enable significant reductions in needed power, mass and complexity. Such an instrument can make measurements both day and night, and in the presence of atmospheric dust loading. Our instrument design will be optimized to sample winds, temperature, and water vapor between 0–80 km, at ~5 km vertical resolution.

Our concept [2] for such an instrument builds on prior JPL-led instruments such as the Microwave Limb Sounder currently flying on EOS *Aura* [3], and the MIRO instrument aboard *Rosetta* [4]. The instrument would employ a single, steerable antenna (~23 cm diameter), and observe a diverse set of spectral lines, both weak and strong, from multiple species to cover the full range of altitude desired (Fig. 1).

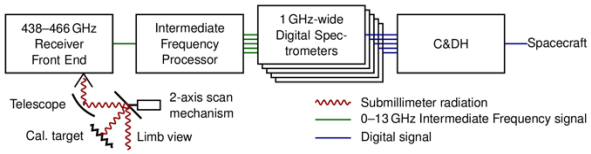

Figure 1: Block diagram of instrument

Performance Analysis. Initial simulations have been undertaken to show performance of our notional sub-mm sounder (Fig. 3). These simulations employed algorithms and software developed for Aura MLS (suitably adapted to the Martian atmosphere) to model performance of the instrument under conditions taken from the Mars Climate Database.

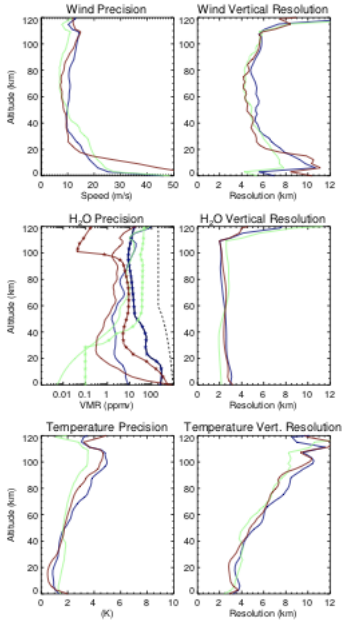

Figure 2: Precision and vertical resolution for a variety of frequencies for wind speed (top), water vapor (middle), and temperature (bottom).

References: [1] MEPAG NEX-SAG Report (2015; http://mepag.nasa.gov/reports.cfm); [2] Read et al., (2018), in revision with *Plan. and Sp. Sci.*; [3] Waters, J.W. *et al.* (2006) *IEEE Trans. Geosci. Remote Sensing 44*, 1075–1092.; [4] Gulkis, S. et al. (2007), *Sp. Sci Rev*, *128*(1-4), 561–597.