A PASSIVE INSTRUMENT TO SEARCH FOR BRINES IN THE SHALLOW MARTIAN SUBSURFACE.

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Introduction: Large amounts of water ice exist on Mars, but the presence of pure liquid water is inhibited by the planet's low temperature [1]. However, liquid saline water or brines can be present because many salts can depress the freezing temperature below current values [1-8]. The Phoenix Mars Mission discovered salts [9] in the soil of its landing site in the martian Arctic capable of depressing the freezing temperature and water vapor partial pressure enough to form liquid brines under today's local environmental conditions [11].

Phoenix found physical and thermodynamical evidence for liquid brines at its landing site [10,11]. Since the Phoenix initial discoveries, independent results suggesting the presence of liquid brines on Mars have been mounting [12-19]. The theoretical idea that freeze/thaw cycles lead to the formation of liquid brines where ice and salts coexist near the surface [11], suggests that liquid brines are common on Mars. The instrument proposed here will test this hypothesis.

Mars Microwave Radiometer (MMR): We propose a high-heritage passive instrument to probe the subsurface of Mars tens of cm deep by making measurements of the 5.2- and 22-GHz brightness temperature. When combined with surface measurements by a Thermal Infrared Radiometer (TIR), the MMR measurements allow: (i) the search for dielectric anomalies caused by near-surface brines; (ii) the search for depth-dependent thermal inertia, indicating the presence of ice layers and associated aqueous processes that could produce trace gases; and (iii) the search for thermal anomalies, which might be associated with trace gas emissions. MMR is capable of detecting thermophysical and compositional anomalies larger than a few 100 kms [20-23] that could be sources of trace gases.

MMR's 5.2-GHz channel offers a good balance between the desire to probe deeper and the need for ~100-km spatial resolution with a constraint on the size of the antenna. The 22 GHz channel is optimun for probing areas just below the surface where brines are likely to be found [11].

The proposed instrument is capable of producing the first global map of Mars' shallow subsurface. Thus it contributes to the understanding of brine formation and the aqueous processes that control the exchange of volatiles between the surface and the atmosphere. MMR is a low mass, low volume, low data rate instrument with direct flight heritage from Juno.

Mars Odyssey revolutionized our understanding of Mars by mapping the hydrogen content of the shallow subsurface and showing evidence that water ice is present globally [24,25]. MMR has the potential to revolutionize our understanding of Mars again by testing the hypothesis that brines are ubiquitous in its shallow subsurface [12].

Searching for Brines on Mars: MMR is capable of searching for evidence of aqueous processes in the shallow martian subsurface such as geothermal activity, and exothermic reactions such as serpentinization. These are potential sources of methane and other trace gases. On Earth, wetlands are the largest sources of methane, and variations in the magnitude of this source are correlated with water table depth and soil temperature. Methanogens have been found on permafrost brines [26]. If similar microbes exist on Mars, they could be producing methane. However, methane can also be released by geothermal process and it can be produced by geochemical processes such as serpentinization [27,28], an exthermic reaction of olivine with water that can raise the temperature by more than 200 K in the absence of heat loss. MMR is capable of detecting evidence for geothermal activity, serpentinization, and other aqueous processes in the shallow subsurface by measuring their thermal and dielectric signatures. MMR can test the hypothesis that the puzzling "frozen sea" measuring ~800 × 900 km [29] contains aqueous processes in the shallow subsurface.

Salts with extremely low eutectic temperatures appear to be common on Mars [9,30,31]. Phoenix recently found evidence for brines a few centimeters below the martian surface (Fig. 1). Renno *et al.* [11] show that, theoretically, freez-thaw cycles concentrate salts into eutectic mixtures and lead to the formation of layers of brines in the shallow subsurface. Zorzano *et al.* [12] show that even sodium perchlorate, a salt with a moderately low eutectic temperature, absorbs water and forms stable liquid solutions under the environmental conditions of Mars' Arctic. Byrne *et al.* [32] shows evidence that recent meteor impacts, hundreds of km apart, exposed clean subsurface ice at Mars' midlatitudes.

The existence of shallow (tens of cm deep) clean ice at midlatitudes is puzzling because it is difficult for the ice to form and be stable there given Mars' current climate [32]. However, eutectic mixtures of salts such as perchlorates could easily melt and form layers of brines and clean ice in this region by the process proposed by Renno *et al.* [11]. Moreover, salts could reduce evaporation by more than 50% and allow subsurface brines to be stable at Mars' midlatitudes, even in its current climate. Therefore, recent impacts might have exposed frozen brines or clean ice formed in the presence of liquid brines. MMR can test this hypothesis by searching for evidence of brines and clean ice in the shallow subsurface.

Fig. 1. Image of millimeter-thick clean, soft ice at the bottom of a trench excavated by Phoenix in the Mars Arctic. Note the cylindrical portion of clean ice at the lower left of the trench. In contrast, pore-filling ice found in other trenches was extremely hard [11].

Mapping the Shallow Subsurface: MMR brightness temperature data observed over hundreds of diurnal cycles, and through at least one annual cycle, can significantly constrain global thermophysical models of Mars' shallow subsurface and can identify broad (~100 km) thermal anomalies that might be associated with sources of trace gases. It can detect the mesoscale dielectric anomalies that would be associated with brine-saturated soils. Therefore, MMR can localize sources of trace gases and identify thermal and moisture conditions associated with these sources.

MMR's microwave weighting functions are sensitive to thermal, dielectric, and stratigraphic properties to 10s of cm below Mars' visible surface, and likely below the penetration depth of Mars' diurnal thermal wave, but well above reflecting horizons detected by the SHARAD or MARSIS radars. MMR specifically addresses the following question: Does Mars possess regional-scale, internally generated thermal anomalies and do these anomalies correlate with terrain features or the presence of brines in the shallow subsurface? TIR data from the Viking Orbiters are not consistent with a homogeneous global thermophysical model [33]. Even a stratified model does not easily explain the "anomalous afternoon cooling" exhibited by some areas having very low thermal inertia [20-24]. Top soils having low thermal conductivity and, thus, low thermal inertia, tend to mask surface expressions of thermal anomalies, but that same low thermal conductivity increases the likelihood that subsurface thermal anomalies will appear in the microwave brightness data. Regions of very low thermal inertia include Olympus Mons, Arabia Terra, Elysium Mons, and large areas polewards of 65° S [34], possible areas of active aqueous processes.

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