AN ACTIVE SOURCE, NIR, REFLECTANCE SPECTROMETER IN A ROVER WHEEL, WATER-WHEEL IR (WIR), FOR SOIL CHARACTERIZATION IN FUTURE MARS SURFACE EXPLORATION.

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Water and water-bearing minerals on Mars: Water and carbon, two essential components for life, both exist on Mars. It is well known that Mars polar caps are made of the mixtures of H_2O-CO_2 ices. Considerable amounts of Water Equivalent Hydrogen (WEH) were sensed by Neutron Spectrometer (Mars Odyssey) at two large equatorial regions on Mars [1], presumably in the forms of water-bearing minerals and ground ice. Minor amount of carbonates in Mars surface soils was suggested by TES (MGS) and MiniTES (MER) thermal emission spectrometers based on spectral deconvolution [2, 3], although not being directly detected by in situ measurements (APXS and MB on MER). Current orbiting Vis-NIR instruments (OMEGA on Mars Express and CRISM on MRO), however, have not found massive carbonate deposits [4, 5]. Both carbonate and organic carbon occur as alteration products in martian meteorites of igneous origin [6]. Hydrated silicates (as clay minerals) and hydrated sulfates were found in martian soils and outcrops by orbital remote sensing and surface explorations [7, 8, 9, 10]. A beautiful example is the sulfate-rich, light-toned soils located within one of the high WEH regions near the Mars equator and exposed serendipitously by the wheels of Spirit rover at Gusev Crater (Fig.1).

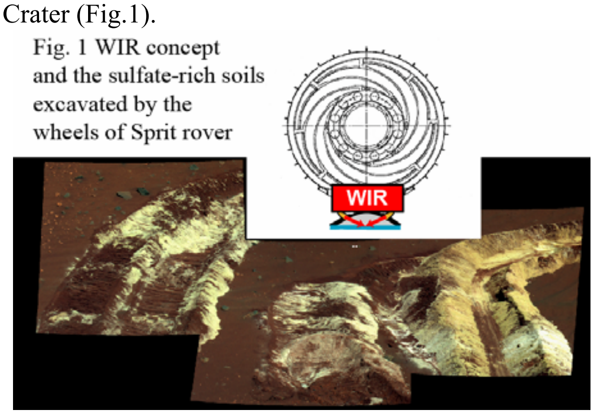


Fig. 1 WIR concept and the sulfate-rich soils excavated by the wheels of Sprit rover

For the next generation of Mars surface exploration missions, frequent and rapid characterization of martian soils, especially for the detection of buried water ice, water-bearing minerals, and carbonates, during the traverse of a rover, will be absolutely essential. We report here an instrument specifically developed for that purpose.

WIR (water-wheel IR) instrument is designed to detect directly water in different forms (liquid, ice, or clathrates, structural H_2O and OH, and water adsorbed on grain surfaces), carbonates, sulfates, clays, as well as C-H & N-H bonds in organic species [11]. WIR will use an active-source, NIR (1-5 μm) reflectance spectrometer installed inside of a well set into the middle wheel of a planetary rover. During rover travel, when the well is at its nadir, the IR sources will irradiate soil disturbed by the front or rear wheel of the rover. Radiation in the 1-5 μm spectral range diffusely scattered from the sample surface will be collected and recorded. The measurement will not interfere with the normal activity of the rover. Information on the spatial distribution of the above-mentioned phases will be obtained along the rover traverses.

WIR is a Contact-Survey experiment. It will observe thousands small (~1 cm^2) patches of soil at near contact range. Examining a small area at a time enables observation of relatively sparse species that are concentrated in a given area, without the spectral background of major materials in a broader area in which the species is a minor or trace component. This enhances the probability of finding rare substances.

WIR instrument development: is supported by a ASTID project (NAG5-12114), a proof-of-concept breadboard was built, and a simulation test on detection limit of various minerals was conducted in our laboratory. During the second ASTID project (NNG05GM95G), our main concentration is to miniaturize and ruggedize the WIR spectrometer and then to install it into a rover wheel.

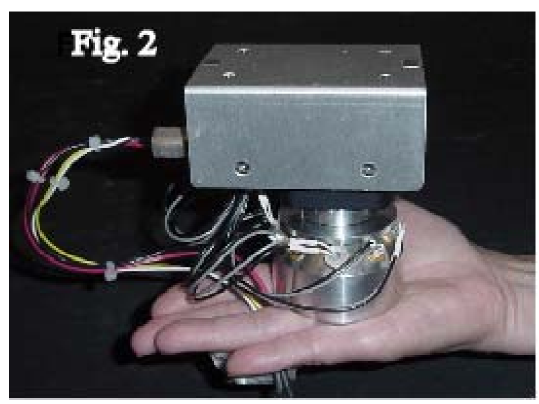
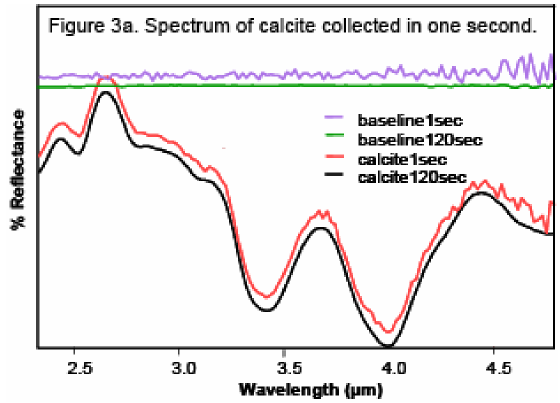
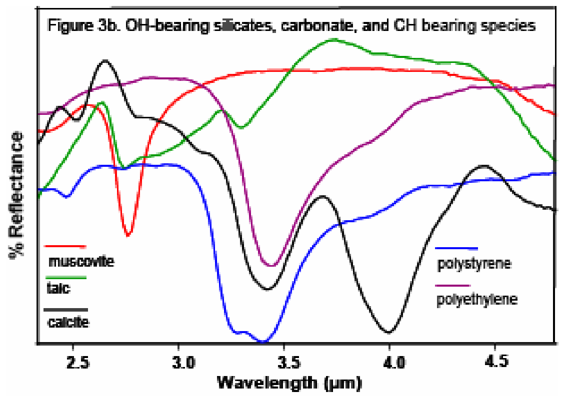


Fig. 2

The major challenges for WIR instrument miniaturization and ruggedization are (1) to have a unit with small size and low mass that can fit into a limited space of a rover wheel (the 26 cm diameter MER wheel, for example); (2) to have a high IR signal col-





lecting efficiency allowing an IR spectrum with good S/N can be obtained in short time; (3) to have enough ruggedness to survive mechanical vibrations; and (4) to have minimal thermal control requirements. The development of this miniaturized WIR system was conducted in collaboration between Washington University in St. Louis and Wilks Enterprises, Inc.

The phase-I WIR spectrometer is 10x7.5x6.5 cm in size, has a mass <200g, and is fitted to a highly efficient sample illumination and light collection head. The phase I system covers a spectral range from 2.4 to 4.8 µm with 128 spectral channels. Figure 3a shows a calcite spectrum with characteristic carbonate overtone bands and sufficient S/N that was obtained in just one second. Figure 3b also shows the characteristic bands of some OH bearing minerals as well as the CH bands of organic species are easily detected with this miniaturized NIR system. Additional experiments on the dilution of powdered calcite in quartz mixtures shows that as little at 5% by weight calcite can be detected in the spectrum of the mixture.

The phase-II WIR spectrometer (Fig. 2) has a similar size and mass, with an improved illumination and collection optical head. It covers a spectral range from 1.25 to 2.5 µm in 128 spectral channels. Figure 4 shows the first set of raw spectra obtained from calcite, talc and gypsum.obtained with this system.

The phase-III WIR spectrometer is now under development, it is designed to provide both the 1.25 to 2.5 µm and the 2.5 to 5.0 µm spectral coverage on one detector, thus a full spectral coverage from 1.25 to 5.0 µm, equivalent to OMEGA and CRISM spectral ranges, will be obtained in one exposure.

The major challenges remaining for the installation of the WIR in a rover wheel are: (1) providing for transmission of power and data through wheel axis; (2) integration of the illumination and collection optics into a well on the rim of a MER wheel; and (3) selection of window material and providing for dust removal from window.

The electro-mechanical design for installing Phase-I WIR on a MER wheel is finished. The assembly and test will be conducted in 2008.

Conclusion: An active-source, NIR reflectance spectrometer has been developed and miniaturized. It covers a spectral range equivalent to those of OMEGA and CRISM, with good spectral resolution and high sensitivity. It can be deployed in three ways: (1) by the wheels of a planetary rover, to characterize thousands patches of disturbed soils in a near-contact distance; (2) by a robotic arm, onto selected soil and rock targets; (3) to reside within a rover-laboratory and to pre-evaluate the samples prepared by SPDS before sending to other payload, e.g. XDR/XRF and GC-MS. In addition, the scientific information provided by WIR is complimentary to those by Mars Microbeam Raman Spectrometer (MMRS) that we have been developing.

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