THE MINIATURIZED MÖSSBAUER SPECTROMETER MIMOS II OF THE ATHENA PAYLOAD FOR THE 2003 MER MISSIONS.

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Introduction: A first-order requirement of spacecraft missions that land on Mars is instrumentation for in situ mineralogical analysis. Mössbauer Spectroscopy is a powerful tool for quantitative analysis of Fe-bearing materials. The Athena Mössbauer spectrometer MIMOS II on the martian surface will provide (1) identification of iron-bearing phases (e.g., oxides, silicates, sulfides, sulfates, and carbonates), (2) quantitative measurement of the distribution of iron among its oxidation states (e.g., Fe^{2+}/Fe^{3+} ratio), and (3) quantitative measurement of the distribution of iron among iron-bearing phases (e.g., the relative proportions of iron in olivine, pyroxene, and magnetite in a basalt) in rocks and soils. Mössbauer data will also be highly complementary with chemical analyses from the APXS and the Mini-TES compositional data. Mars is a particularly good place to do Mössbauer mineralogy because its surface is iron rich (~20% Fe as Fe_2O_3 [1-3]). Mössbauer spectrometers that are built with backscatter measurement geometry require no sample preparation, a factor important for in situ planetary measurements.

The Mössbauer Effect: Iron Mössbauer spectroscopy makes use of the resonance absorption of 14.4 kev γ-rays (the Mössbauer effect) by ^{57}Fe nuclei (2.2% natural abundance) in a solid to investigate the splitting of its nuclear energy levels that is produced by interaction with the surrounding electronic environment. ^{57}Co, which decays to the proper excited state of ^{57}Fe, is normally employed as the source of the γ-rays. In general, the nuclear energy level structure of the absorber will be different from that of the ^{57}Co source (because of different oxidation states, chemical environments, and/or magnetic order), which requires modulation of the energy of the source γ-rays to achieve resonance. This is done using the Doppler effect, by mounting the ^{57}Co source on a velocity transducer and moving it with respect to the absorber. A backscatter (transmission) Mössbauer spectrum is the relative number of γ-rays per second re-emitted from (passing through) an absorbing sample as a function of the relative velocity between the source and sample. Phase and oxidation state identification are determined from peak locations in the Mössbauer spectrum, and peak areas are measures of concentration. The Mössbauer parameters are temperature dependent, and therefore the Mössbauer spectrum will depend on the measurement temperature. In addition the properties of the absorber may vary as a function of temperature and therefore the MB spectrum.

The MIMOS Instrument: The MIMOS II Mössbauer spectrometer system, which is designed and fabricated at the University of Mainz (e.g.[4]), was originally developed for inclusion on the Russian Mars 98 rover mission. Since then, it has gone through several generations of evolutionary prototypes, finally emerging in the built of the flight units for the NASA Mars-Exploration-Rover 2003 twin-mission and the ESA Mars-Express-Beagle-2 2003 lander mission. In preparation of these missions a prototype MIMOS II instrument was successfully tested (data taken under semi-real conditions) on the Rocky-7 Mars prototype rover during the May, 1997, field tests in the Mojave desert [1], and on the FIDO rover during the May 1999 field tests at Silver Lake, California. The MIMOS II system is intrinsically simple, rugged, and has sufficient radiation shielding to protect personnel and other instruments. For Athena, the instrument is split into two parts: the detector head is mounted on a robotic arm and the printed circuit board, which has the circuitry for the instrument control, data acquisition and storage, and communications, is located in the rover's warm electronics box. The main components of the detector head are the ^{57}Co radiation source and shielding, velocity transducer (drive), and silicon PIN diode radiation detectors and their pre- and main-amplifiers. The ^{57}Co source is embedded in a solid rhodium metal matrix which is attached to a titanium holder. The drive has a unique miniature double voice coil electromechanical design. The total weight of the MIMOS II is about 500 g (400 g for the detector head and 100 g for the printed circuit board, not including the harness). The dimensions of the instrument are about 90mm x 50mm x 40mm for the sensor head, and 160mm x 100mm x 25 mm for the electronics board. The power consumption is in the order of 2 W. The instrument has been fully tested over the expected temperature range (operating: -120°C to +40°C Sensor head; -50°C to +40°C electronics board).

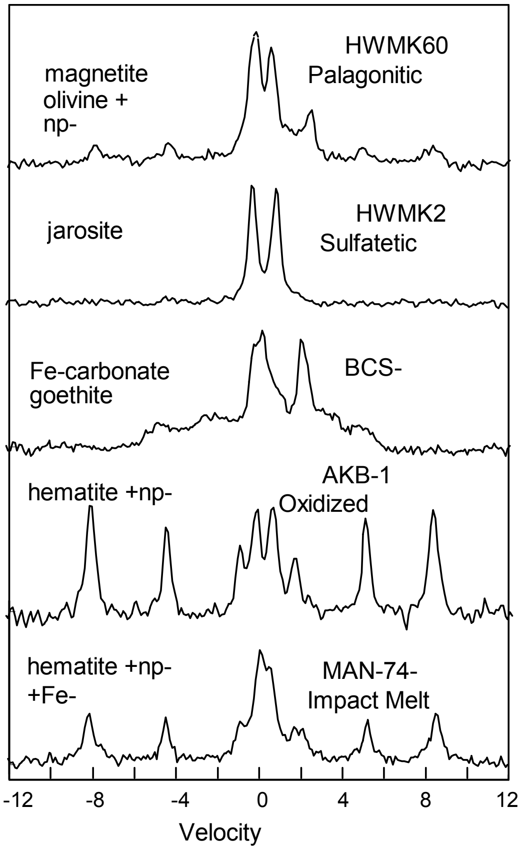

Figure 1. Backscatter Mössbauer spectra (~290 K) obtained with the MIMOS II instrument for Martian surface analogues (after [5]).

The ^{57}Co radioactive Mössbauer source intensity of about 300 mCi at launch will give a 6-12 hr time for acquisition of a standard MB spectrum on Mars, depending on total Fe content and which Fe-bearing phases are present. Measurements will be done by placing the detector head against the rock or soil to be analyzed. Physical contact is required to minimize possible microphonic noise on the velocity-modulated energy of the emitted γ-rays. The field of view of the instrument is circular (diameter ~1.5 cm). The average information depth for Mössbauer data is 200 to 300 µm, assuming basaltic rock composition. The instrument monitors temperature, and adjusts integration periods to assure that the variation in ambient surface temperature during acquisition of a single spectrum is not larger than about ±10 °C, minimizing spectral smearing associated with temperature-dependent mode. Figure 1 shows backscatter Mössbauer spectra obtained with the MIMOS II instrument in the laboratory for five Martian surface analogue samples [5]. Figure 2 and 3 show some of the spectra obtained with the flight instrument during the Athena payload integrated systems test in May 2000 at JPL.

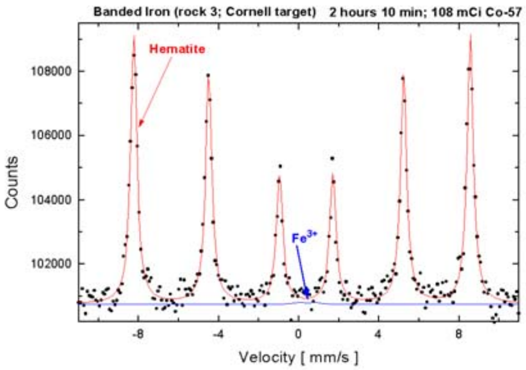

Figure 2. Backscatter Mössbauer spectrum (~290K) of a sample of Banded Iron Formation (BIF), obtained with the MIMOS II flight unit during APEX system test May 2000. The spectrum is dominated by the hematite signal (red six line pattern). A minor contribution (close to zero) of a Fe^{3+} doublet component might be present.

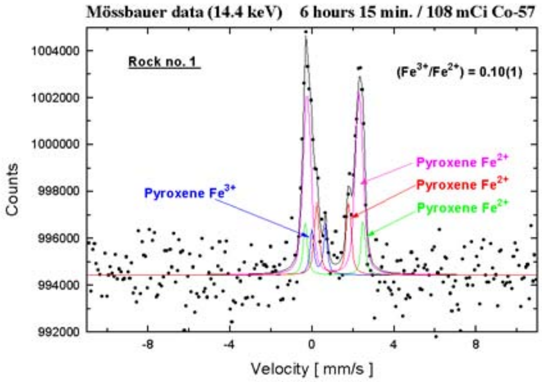

Figure 3. Backscatter Mössbauer spectrum (~290K) of a sample of a rock composed of 40% Fe-rich pyroxene, obtained with the MIMOS II flight unit during APEX system test May 2000. The spectrum is dominated by a pyroxene signal (Fe^{2+}), with a 10% (whole spectrum area) contribution of an Fe^{3+} doublet component, also belonging probably to the pyroxene mineral.

Calibrations: Comparison of Mössbauer spectra (293 K) in backscatter and transmission geometries for Martian analogue samples were performed. An example is depicted in Figure 4. Backscatter spectra (512 velocity channels folded to 256 channels) were obtained using a prototype MER spectrometer, and transmission spectra (1024 velocity channels folded to 512channels were obtained using a laboratory spectrometer. HWMK600 and HWMK24 are the <1 mm size fractions of palagonitic and jarositic tephra from Mauna Kea Volcano (Hawaii). AKB-1 and BCS-301 are an amygdaloidal basalt (Michigan) and an iron ore (Lincolnshire, England). MAN-74-342A is an impact melt rock from Manicougan Crater (Quebec, Canada). Mössbauer spectra depicted in Figure 4 are adapted from *Morris et al.* [6-9].

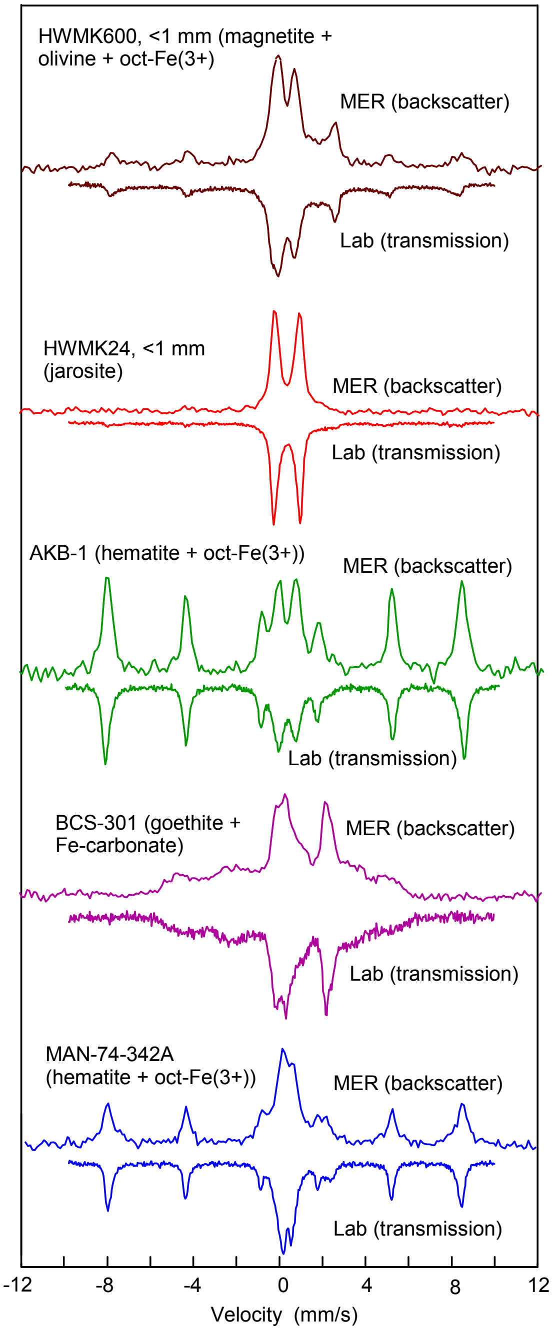

Figure 4. Comparison of Mössbauer spectra (293 K) in backscatter and transmission geometries for Martian analogue samples.

Data Analysis: A very specific Mössbauer data base were build taking into consideration the needs of the Mars Missions. The information published at the literature were carefully analyzed. The most relevant variables that may lead to changes of the Mössbauer parameters of each mineral were reported in the data base records. The stored Mössbauer parameters were used to train an artificial neural network making possible a fast and save mineral identification from its measured Mössbauer parameters [10, 11]. Before the first Mössbauer spectrum being obtained on Mars surface, early in 2004, several and exhaustive tests are planed to be carried out.

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