MAGNETIC PROPERTIES EXPERIMENTS DESIGNED FOR USE WITH A MÖSSBAUER SPECTROMETER AND AN APX SPECTROMETER ON MARS; M.B. Madsen, J.M. Knudsen, S. Faurschou Hviid, H.P. Gunnlaugsson, D.P. Agerkvist, L. Vistisen, J. Madsen, Niels Bohr Institute for Astronomy, Physics and Geophysics, DK-2100 Copenhagen Ø, Denmark; G. Klingelhöfer, E. Kankeleit, Institut für Kernphysik, Technical University of Darmstadt, 64289 Darmstadt, Germany; V.N. Khromov, E. Evlanov, O. Prilutski, B. Zubkov, Space Research Institute, Russian Academy of Sciences, Moscow, Russia.

Experiments have shown that some Mars Sample Analogues may spontaneously separate into more and less magnetic fractions when attracted by a Magnet Array. It is suggested that this effect is used for experiments on the Russian Mars-96 and the MESUR Pathfinder missions. This will give information on the magnetic properties and microscopic structure of the dust grains (multiphase/single phase grains).

Part of the scientific payload of the Russian Mars-96 mission is a ^{57}Fe-Mössbauer spectrometer [1]. Mössbauer spectroscopy will determine the oxidation state of iron as well as the dominant iron-mineralogy in the Martian soil. From the Viking missions we know that there is a magnetic mineral in the Martian soil and dust, the identity of which is not known. Detailed knowledge about the identity of this magnetic phase is important for the understanding of the evolution of the Martian surface. It has therefore been suggested to repeat the Viking Magnetic Properties Experiment with an instrument that includes also weaker magnets [2]. Such an experiment is now in the payload of the MESUR Pathfinder and the instrument (a so called Magnet Array) will provide (semi-)quantitative information on the effective magnetization of the soil. Below we show how the Mössbauer spectrometer on Mars-96 supplemented with a permanent magnet can do three experiments specifically designed to characterize the magnetic phase in the Martian dust and soil.

1. Magnetic separation experiment (concentration of the magnetic phase). Experiments, in which Mars Sample Analogues are blown onto a tilted Magnet Array (a plane containing permanent magnets similar to the ones used in the Viking Magnetic Properties Experiment), have shown that for certain Analogues particularly the weaker magnets are able to attract the most strongly magnetic grains, gravity (tilt) preventing weaker magnetic grains from being held. This effect gives rise to distinct differences between the color of the material adhering to the strongest magnet and that adhering to the weaker magnets. The observed differences show that a (partial) magnetic fractionation takes place. To optimize the separation effect a type of magnet is chosen that is weak enough *not* to attract hematite and paramagnetic material and strong enough to attract material with an effective magnetization of approximately 15 Am^2kg^{-1}.

Figure 1. a) Arrangement of permanent magnets in Magnetic Separator for investigation of Martian dust with the Mössbauer spectrometer and APX-spectrometer b) Spontaneous arrangement of strongly magnetic grains on the surface of the Magnetic Separator.

The magnet arrangement should not be circular as in the Magnet Array designed for using a camera to detect the circular pattern of adhering magnetic material. Instead the Array is composed of linear pieces of magnetic material - in principle arranged as indicated in Figure 1.a. With this arrangement of magnets the magnetic material adhering to the surface of the Magnetic Separator will essentially form a blanket of material, which is well suited for investigation with the Mössbauer spectrometer and the APX-spectrometer.

If there is a significant difference in optical-, APX- and Mössbauer spectra we will have two sets of spectra (from each technique) corresponding to more and less magnetic fractions. These pairs of spectra contain more information than the individual single spectra. From such pairs more detailed information on the spectral components can be extracted. If fractionation is negligible we will have learned that the different mineral phases in the dust/soil are intimately intergrown - and this is an important characteristic of the material. We know that titanomagnetites are present in the SNC-meteorites (~ Martian rocks). An important question is therefore if a connection between the magnetic phase in the soil/dust and that in the rocks can be established. Differences between the X-ray fluorescence spectrum of the material adhering to the magnet and that of the soil are important in this context: *e.g.* Does Ti follow the magnetic phase?

2. Polarization experiment (determination of the type of magnetic order). The blanket of (magnetic) material formed on the surface of the Magnetic Separator described above is not isotropic; magnetic grains will have a tendency to form chains along the field lines on the surface of the instrument as illustrated in Figure 1.b. Hence also the magnetization directions (and thereby the magnetic hyperfine fields of the magnetic components of the grains) will be essentially parallel to the field lines. If the magnetic phase constitutes a sufficient fraction of the material it may be possible to distinguish a *ferrimagnetic* from an *antiferromagnetic* material by a comparison of the signals obtained from two sets of (~ perpendicularly oriented) Mössbauer photon detectors. The experiment is done with exactly the same experimental setup, *i.e.* a tilted Magnetic Separator, as used for experiment 1, described above. The feasibility of this experiment has been demonstrated by detecting the (partial) magnetic polarization of a sample of pure maghemite using Mössbauer spectra obtained from two (almost) perpendicular scattering directions. The polarization is detected by the differences in the relative areas of the $\Delta m=0$ lines (lines 2 and 5) in the Mössbauer spectra. The polarization experiment does not depend (directly) on the possibility of magnetic separation, but of course the quality of the spectra will be better the higher the concentration of magnetically ordered phases.

3. Superparamagnetic Relaxation experiment It will be demonstrated that it may be possible *directly to detect* superparamagnetic behaviour of a superparamagnetic (ferrimagnetic) material present in the soil. This has been demonstrated in the laboratory using two identical samples (of a Mars Sample Analogue exhibiting superparamagnetic relaxation) placed on two horizontally oriented locations and investigated by a Mössbauer spectrometer. One of these locations contained permanent magnets, strong enough to substantially suppress superparamagnetic fluctuations, and the measurement on the other location served as a reference. The experiment shows that a weak external magnetic field (about 50 mT) at the site of the sample induces substantial magnetic splitting in the Mössbauer spectrum, *i.e.* the effect of the field is to move spectral area from a doublet component into a magnetically split component. In this way superparamagnetic relaxation is *directly detected.*

Acknowledgements: The Novo Nordisk Foundation is gratefully acknowledged for supporting the project with a strong Mössbauer source and so is the Danish Natural Science Research Council for financial support.
References: [1] G. Klingelhöfer et.al., *Mössbauer spectrometer for mineralogical analysis of the Mars surface for the Mars-96 mission*, LPSC XXIII (1992) 695-696. [2] M.B. Madsen et.al., *Suggestion for extended Viking Magnetic Properties Experiment on future Mars missions*, LPSC XXIV (1993) 917-918.