MAGNETIC SUSCEPTIBILITY METER FOR PLANETARY REGOLITH COMPOSITION STUDIES (MSM). T. Kohout[1, 2], D. Britt[3] , J. Čuda[4] and MSM team, [1] Department of Physics, University of Helsinki, Finland (tomas.kohout@helsinki.fi), [2] Institute of Geology, Academy of Sciences, Prague, Czech Republic, [3] Department of Physics, University of Central Florida, Orlando, USA, [4] Regional Centre of Advanced Technologies and Materials, Faculty of Science, Palacky University Olomouc, Olomouc, Czech Republic.

Introduction: Magnetic susceptibility is a fundamental material property describing interaction of the material with magnetic fields. In rocks, magnetic susceptibility is sensitive to changes in ferromagnetic mineral concentrations. Thus, magnetic susceptibility reflects initial conditions of rock formation (mainly iron concentration and redox conditions) as well as secondary processes such as weathering and aqueous alterations. It is thus used as one of the main parameters in basic geophysical, paleoclimatic and environmental studies on terrestrial samples.

Magnetic susceptibility is also a reliable, non-destructive tool in distinguishing various types of extraterrestrial materials (Fig. 1) [1], [2], [3] and in searching for compositional variations of meteorite falls [4], [5]. The advantage of a magnetic susceptibility measurement is its rapidity, non-destructivity, and simple instrumentation design.

Magnetic susceptibility of planetary regoliths: We build on the extensive database of magnetic susceptibility measurements of meteorites to use it as a diagnostic tool to characterize the mineralogy and identify the meteorite analogs to planetary regoliths (Fig. 1). Regolith susceptibility measurement methodology is discussed in [6, 7, 8].

Magnetic susceptibility measurements complement reflectance spectroscopy as susceptibility is sensitive to metallic iron, iron oxides and sulfides concentrations while reflectance spectroscopy is sensitive mainly to oxidized iron in silicates and organic materials.

Regolith on an airless body is subject to space weathering. This process is often associated with production of iron nanoparticles. Such iron nanoparticles are in super-paramagnetic (SP) state exhibiting frequency dependence of magnetic susceptibility. Thus, through measurement of magnetic susceptibility at two frequencies we can estimate amount of iron nanoparticles within regolith and determine level of regolith maturity.

Magnetic Susceptibility Meter (MSM) instrument: The design of proposed MSM instrument incorporates a simple LC oscillator with a coil 5 cm in diameter for contact measurements of surface susceptibility. Such susceptibility measurement coil can be incorporated into lander or surface drop probe.

Heritage and current status. The idea of in-situ regolith susceptibility measurements has heritage in similar susceptibility meters built for the Russian PROP-F lander as a part of the Pobos 2 space probe. The MSM instrument is currently at TRL 4 (Technology Readiness Level). The design is based on existing sensor (Fig. 2) from a commercial instrument (SM-30 build by ZH instruments) used for terrestrial applications (geophysical prospecting). Major design changes needed for space qualified version have been successfully tested in the laboratory. TRL 5 is expected to be reached within 1.5 years and TLR 6 is expected to be reached in one additional year (by the end of 2014).

Main instrument parameters.
Mass ~100 g.
Compact and robust design (~5 cm, compact encapsulated coil).
Power consumption <50 mW.
Measurement time ~2-3 s
No moving mechanical parts.
Dual frequency measurement option (1:32 ratio).
Regolith temperature measurement option.

MSM basic functions. The primary function of the MSM instrument is the magnetic susceptibility measurement for regolith mineralogy characterization and identification of the meteorite analogs to planetary regoliths.

The secondary function of the instrument is determination of regolith maturity through detection of iron nanoparticles. This is being achieved through dual frequency measurement feature of the MSM.

A tertiary function of the MSM instrument is measurement of the regolith temperature and its time variation.

Instrument location. The MSM sensor requires direct contact with regolith. Thus, four locations of the instrument are possible. Te instrument can be located either on a main spacecraft if this is equipped with sampling mechanism. It can be also located on a lander on its landing gear or optional robotic arm. Alternatively it can be installed on a rover. The penetration depth of the coil magnetic field is approximately 5 cm. Thus the measurement will be quite localized. This can be turned into advantage when locating the instrument onto robotic arm or rover. In this case multiple locations can be measured and spatial (in)homogeneity of regolith determined.

Detection of space weathering. The MSM instrument will feature dual frequency susceptibility measurement (with frequency ratio 1:32). This will allow detection of iron nanoparticles as described above.

Regolith temperature measurement option. To compensate for the LC oscillator temperature dependence the coil will be equipped with a temperature sensor. The temperature sensor within the coil can also be used to measure regolith temperature and its variation during periods of prolonged contact.

MSM applications: The MSM instrument is currently under one year assessment study for MarcoPolo-R asteroid explorer (ESA) and has been proposed for Lunar Lander (ESA).

Conclusions: Magnetic susceptibility, together with other methods of spectral and mineralogical characterization, can provide diagnostic parameters to determine regolith mineralogy and meteorite analogues. Additionally regolith maturity can be estimated from frequency dependence of asteroid surface susceptibility. The proposed MSM instrument will be able to conduct above mentioned measurements providing us with increased knowledge of planetary regoliths. The advantages of the MSM design are compact design, low mass and low power consumption.

References:

[1] Rochette P. et al. (2003) *Meteoritics & Planet. Sci., 38,* 251-268. [2] Rochette P. et al. (2008) *Meteoritics & Planet. Sci., 43,* 959-980. [3] Rochette P. et al. (2009) *Meteoritics & Planet. Sci., 44,* 405-427. [4] Consolmagno G. J. et al. (2003) *Meteoritics & Planet. Sci., 41,* 331-342. [5] Kohout et al. (2010) *Meteoritics & Planet. Sci.,45,* in press. [6] Kohout et al. (2008) *Meteoritics & Planet. Sci., 43,* 1009-1020. [7] Rochette P. et al. (2004) *Planet & Space Sci., 52,* 987-995. [8] Bentley M. S. (1999) *Planet & Space Sci., 57,* 1491-1499.

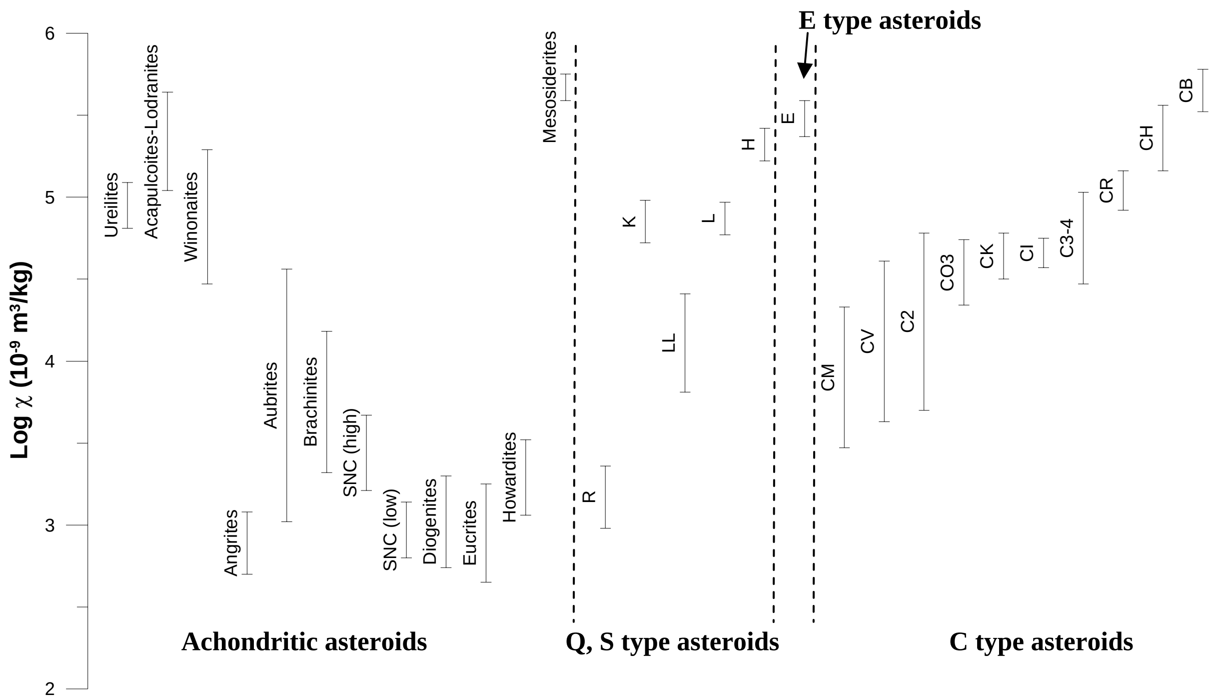

Fig 1. Magnetic susceptibility (logarithm) of basic asteroid clans similar to common meteorite types. Meteorite analogs can be determined from asteroid susceptibility in each clan. Meteorite susceptibility data are compiled from [1], [2] and [3].

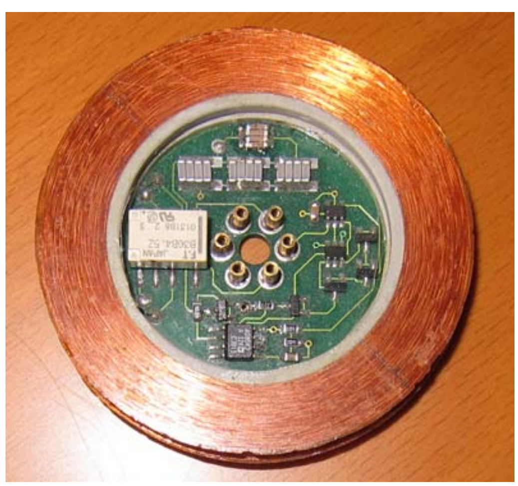

Fig 2. The sensor (coil) with control electronics of the commercial version SM-30 (ZH instruments) is currently being adapted for space aplications as MSM (Magnetic Susceptibility Meter) instrument. The coil diameter is 5 cm.