MAGNETIC CLASSIFICATION OF METEORITES AND ASTEROID PROBING. P. Rochette[1], L. Sagnotti[2], V. Chevrier[1], G. Consolmagno[3], M. Denise[4], L. Folco[5], M. Osete[6], L. Pesonen[7], CEREGE BP80 13545 Aix en Provence Cdx 4 France (rochette@cerege.fr), [2]INGV Via Vigna Murata 605, 00143 Roma, Italy, [3]Specola Vaticana, [4]MNHN Paris France, [5]Antarctic Museum of Siena Italy, [6]Universita Complutense Madrid Spain, [7]University of Helsinki Finland.

Introduction: Magnetic susceptibility (χ) provides a versatile rapid and non destructive way to quantify the amount of magnetic minerals (FeNi metal, magnetic oxides and sulfides) on large volume of material. As petrological studies of meteorites suggest that this parameter should be quite discriminant, we assembled a database of measurements on about 1000 stony meteorites from various European collections: Helsinki, Madrid, Paris, Prague, Roma, Siena, Vatican, and other smaller collections. Thanks to the spread of values over three orders of magnitude, and the narrow range of logχ for a given petrological class, we support the inclusion of a magnetic susceptibility probe on future landing mission on asteroid or other object of the solar system.

Measurements: From 1 to >20 pieces and 1 to >100 cc per meteorite allow to define a representative mean value, using a large coil (8 cm) Kappabridge instrument [1] or its equivalent in case of Helsinky data [2]. The main source of error is the possible anisotropy of the sample, making a variation in logχ up to 0.1. It can be partly corrected by measuring the sample along three perpendicular directions. The fusion crust signal is negligible for strongly magnetic classes but may be significant in a few weakly magnetic meteorites whose fusion crust contains magnetite (case of Chassigny). Multiple samples (> 1cc) measurements show that most meteorites are fairly homogeneous macroscopically except some with high metamorphic grade (6) showing metal segregation (e.g. Portales Valley) and some brecciated meteorites. For a meteorite with multiple pieces measured the average standard deviation on logχ is 0.07. Correlation of logχ obtained on the same meteorite from different collections and different instruments is also fairly good [1,2]. However an important source of outlying specimens especially for historical falls may be misidentification or substitution, as well as differential weathering. Therefore some outliers were skipped when computing meteorite mean values. It appears that a magnetic susceptibility scan even of large collections is a quite efficient way to check how representativ a given specimen is with respect to the bulk of the meteorite, as well as detecting misidentified material.

Magnetic classification: For ordinary chondrites (OC), it appears that weathering is responsible for a systematic bias toward low logχ for Antarctic (Frontier Mountain) and non Antarctic (mainly from Sahara) finds (Table). Once only falls are considered a quite narrow range of logχ is observed for a given class (Figure), with no effect of petrological grade except for LL. This does not support suggested decrease of metal amount with metamorphism for L chondrites. High grade LLs (heated above 400°C) develop the weakly magnetic antitaenite-tetrataenite phases [3] during slow cooling, explaining the difference with low grade taenite-bearing LLs. Outliers from H and L classes are grade 6 material (showing metal segregation) or intermediate types: H/L and L/LL. Once these outliers are excluded from the mean (second row in Table), well defined means for H and L are observed with no overlap at 2 s.d.; this agrees with the lack of overlap on metal amount in [4]. The standard deviation for all falls of a given class is only slightly higher than the averaged standard deviation for multiple pieces of the same fall. This supports the hypothesis that all falls from a given ordinary chondrite class (H or L) may come from the same homogeneous parent body. Magnetic susceptibility cannot be used to classify finds as for example a weathered H give the same value as a fresh L. However, it can be used to probe weathering stage and for pairing purposes.

For non ordinary chondrites analysis of the data is under way (see also [2]). Weakly magnetic classes are HED, Aubrites and SNC (below LL), strongly ones are E (above H) and Ureilites (in the L-H range), while C chondrites are spread in the whole range, again with each class showing restricted variation.

Potential for χ probe on space missions: on objects without intrinsic magnetic field the only way to measure χ is to use a lander able to apply a small coil on the surface to measure. Existing "pocket susceptometer" with a 25 mm radius loop and penetration depth of 30 mm are easily adaptable to such a purpose with a payload of less than 50 g (not counting the mobile arm). Such a petrophysical tool would have the advantage of its penetration depth with respect to all other chemical and mineralogical analysers that obtain essentially surface information prone to bias by space weathering. Moreover pseudo profiles of χ can be obtained to check the magnetic contrast between the surface and interior of a formation. Had such a probe operated on 233 Eros could have answered the pending question of its corresponding meteorite class. However, regolith formation processes could also alter the magnetic mineral content. Increased χ has been observed with increased regolithic maturity in lunar samples [5] due to the impact reduction of Fe silicates. This processes may also be evidenced in our data by the increase of χ from eucrite to diogenite and howardite. Therefore the best in-situ investigation should be provided by a mobile lander able to measure a large number of different rock surfaces to unravel such a process. However the regolithic processes have a negligible signature for most meteorite types which are strongly magnetic.

Integrating a χ probe in "standard" lander mineralogical package, particularly with the MIMOS Mossbauer spectrometer may also be a valuable addition for planetary missions, in particular in the Mars case with implications on identifying oxidation processes in the regolith and magnetic anomalies interpretation.

References: [1] Rochette P. et al. (2001) *Quaderni di Geofisica* 18, 30 pp. [2] Terho M. et al. (1993) *Studia Geoph. Geod.. 37*, 65-82. [3] Rancourt D.G. and Scorzelli R.B. (1995) *J. Magn. Magn.Mat. 150*, 30-36. [4] Jarosewitch E. (1990) *Meteoritics 25*, 323-337 . [5] Fuller M. and Cisowski S. (1987) *Geomagnetism vol 2.*, 307-455.

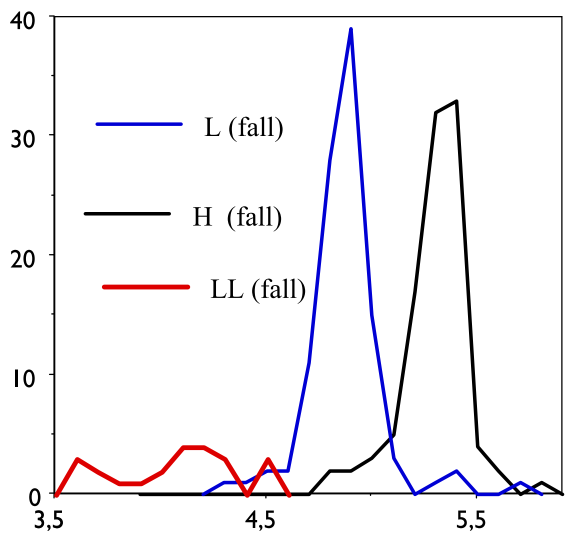

Figure: histograms of logχ (in 10^{-9} m^3/kg) for LL,L and H falls.

Table : mean and standard deviations of logχ (in 10^{-9} m^3/kg) observed in LL, L and H groups separated between falls, Antarctic and non Antarctic finds. Meteorite number in brackets. Preliminary values after [1] (Madrid and Paris data not included).

class:	LL	L	H
Falls (all)	4.06 ± 0.28 (23)	4.87 ± 0.18 (110)	5.29 ± 0.21 (104)
selection id.		4.87 ± 0.11 (100)	5.32 ± 0.11 (97)
grade 3-4	4.27 ± 0.20 (4)	4.90 ± 0.11 (8)	5.32 ± 0.09 (21)
grade 5	4.12 ± 0.32 (7)	4.91 ± 0.11 (15)	5.31 ± 0.09 (49)
grade 6	3.95 ± 0.24 (12)	4.87 ± 0.10 (75)	5.33 ± 0.16 (26)
Antarctic finds	4.34 ± 0.16 (5)	4.68 ± 0.25 (52)	5.12 ± 0.17 (173)
Non Antarctic finds	3.79 ± 0.24 (6)	4.47 ± 0.28 (80)	4.89 ± 0.31 (105)