Remote magnetic classification of asteroids

Gunther Kletetschka[1], Mario H. Acuna[2], Peter Wasilewski[2], Vilem Mikula[1], Tomoko Adachi[1], and Tomas Kohout[3]
Catholic University of America, Washington DC, USA, NASA's Goddard Space Flight Center, Greenbelt, Maryland, USA, University of Helsinki, Finland

Introduction

The objective of asteroid and comet investigation is to establish with remote data acquisition systems the characterization and classification of these bodies. Among other parameters, we focus on the presence of magnetism, its global characteristics and geometry. It is generally accepted that asteroids are the parent bodies for most meteorites reaching the Earth (Wasson and Wetherill, 1979; Feirberg et al, 1982). The composition of asteroids mostly matches ordinary chondrites. Ordinary chondrites,, which are commonly undifferentiated conglomerates of primitive material, contain intermixed grains of olivine, pyroxene, feldspar and metallic Fe-Ni compounds and reflect the parent body composition. The iron content of undifferentiated meteorites is both within the silicates and in the form of fine magnetic grains. Magnetic properties of ordinary chondrite meteorites (Figure 1) suggests that magnetism is mostly related to Fe-Ni compounds, namely α-kamacite (<7% Ni), γ-taenite (>7% Ni), and γ"-tetrataenite (43-52% Ni) capable of carrying remanent magnetization (Morden and Collinson, 1992; Wasilewski, 1988).

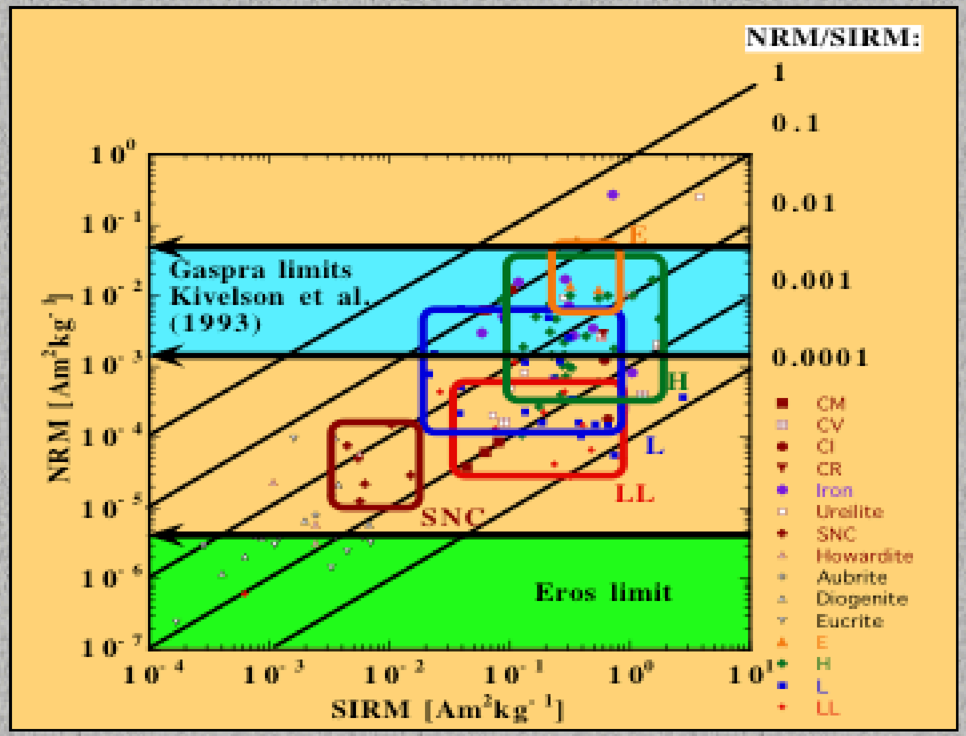
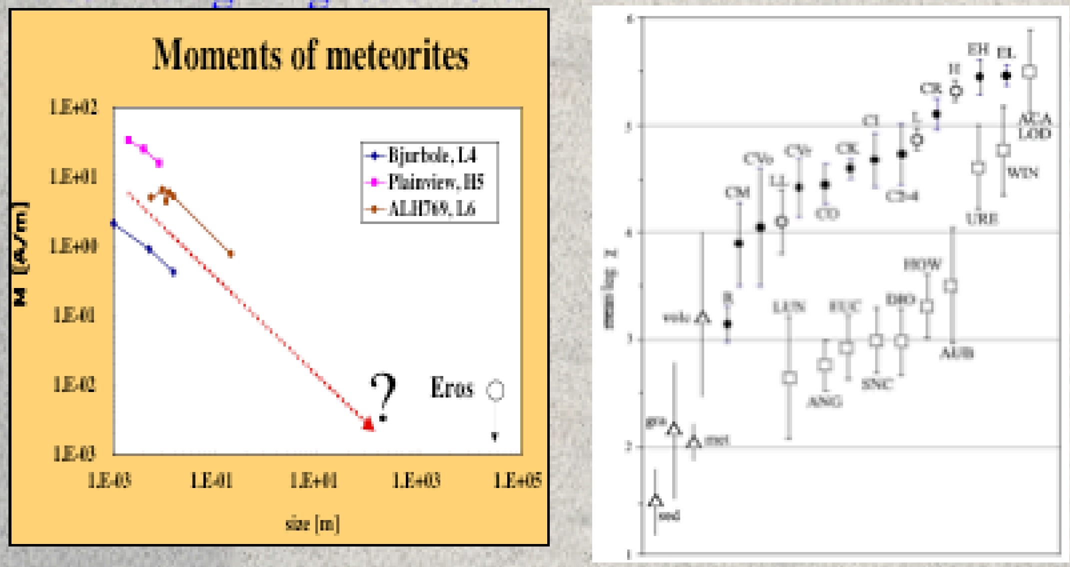


Figure 1: Magnetic characteristic of numerous meteorites. Solid lines represent NRM/SIRM ratio and indicate magnetized levels of meteorites (details in Wasilewski et al., 2002; MAPS, 37, 937-950.)

Material and method

We identified three meteorites (Bjurbole - L4, Plainview - H5, and ALH769 - L6) for which we had various sizes available, from gram size to (ALH76009 – 23.7 kg, Allende – 17.2 kg, Canyon Diablo – 454 kg) and large piece of lodestone (600 kg that had been struck by lightning and consequently strongly magnetized). The samples were assigned a coordinate system and placed at the center of the 40 foot "Helmholtz" coil array housed at NASA GSFC Magnetic Test Facility, fully within the region where intensity and gradient of the magnetic field can be fully controlled. Two three-axis fluxgate magnetometers record the field intensity of the fixed x, y, and z meteorite coordinate system as it is rotated through 360°. Magnetic remanence was measured in pristine state (NRM) and also after demagnetization by a 5 mT alternating magnetic field.



A. B.

Figure 2: A. Size dependence of various magnetic moments of three types of meteorites (see Wasilewski et al, 2002 ; MAPS, 37, 937-950.). Similar observation reported from LL meteorites (Morden and Collinson, 1992); B. Decimal logarithm of magnetic susceptibility in 10-9 m3/kg (mean with s.d.) for different classes of meteorites (open circles: ordinary chondrites, solid circles: non ordinary chondrites, boxes: achondrites) and various sedimentary, granitic, metamorphic and volcanic rock samples from northern Victoria Land (triangles). Meteorite values are from falls only. Weathered metal bearing meteorites show slightly lower values (Rochette et al., 2003; MAPS, 38, 251-268).

Magnetic Remanence

Large sample studies reveal that the orientation of the bulk remanent magnetization may be random with respect to sample geometry and internal composition structure. This is confirmed with the 433 Eros asteroid which had no detectable remanent magnetic field. Eros asteroid is likely an example of a parent body for LL and/or L types of meteorites and thus their magnetic properties may help us in interpretation of the absence of remanent magnetic field on 433 Eros. Our unique size-dependent measurements (Figure 2A) indicate decay of magnetic intensity with the increase of

Discussion, Implications

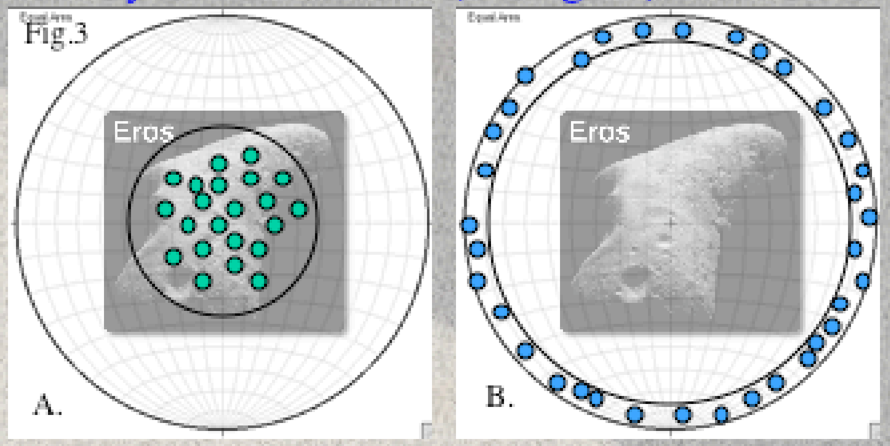
Common characteristic of meteorites is randomness of their natural remanent magnetization (NRM) (Morden and Collinson, 1992; Collinson 1987). The overall moment is still much stronger (~1A/m) than the one implied for 433 Eros (<1e-2 A/m). The smallest scale for which the magnetization is homogenous and is on the order of chondrule size(~1mm). Some of these chondrules acquired very intense NRM compared with the maximum they can acquire (saturation isothermal remanent magnetization = SIRM) (Wasilewski and Dickinson, 2000). These chondrules, however, seem to have their magnetic directions randomly oriented. Thus smaller samples have intense magnetic remanence because the amount of chondrules in small samples is not large enough to randomize completely the remanence direction. This effect of randomized magnetic moment can be illustrated by plotting the moment vs. grain size of mateorite (see Figure 2A). When the size of the meteorite reaches the size of a chondrule (1mm), samples have a large distribution of remanent magnetism reflecting the acquisition properties of chondrules which were magnetized most likely before they became part of the meteorite (or .asteroid). A compaction from suspension, responsible for genesis of the asteroid body, resulted in remanent magnetization with randomized magnetic moments.

Magnetic Susceptibility

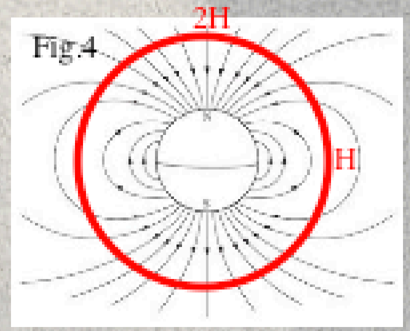
Magnetic susceptibility can be shown as a powerful tool to magnetically classify meteorites (See Figure 2B). We ask ourselves a question: "Can the susceptibility of the whole asteroid be measured?". Such data could aid the magnetic classification scheme and identify the metallic nature of the asteroid interior without direct access.

Proposed concept

Stereonets below indicate the orientation of magnetic vectors measured on board of the satellite. All data is collected as due to three sources: A.Vector along asteroid- satellite (Fig.3A.)
B.Vector tangential to asteroid-satellite (Fig.3B.)
C. Any other direction (no Figure)



Dipole has magnetic field H twice as intense at the pole direction (2H) as it is perpendicular to the pole direction (H), see Fig.4.



Magnetic susceptibility directly relates to induced magnetization due to oscillation of the magnetic field carried by solar wind. The separation of the data according to the rules above will generates data sets containing induced magnetization that allows an estimate of magnetic susceptibility, parameter important for classification of asteroids. Solar wind interaction with the surface is a complex process that has to be considered during such estimate of magnetic susceptibility (Omidi et al, 2002, JGR, 102, 1487).