

**MAGNETIC PROPERTIES OF COMETARY BODIES AND DETECTION LIMITS OF THE ROSETTA SPACE MISSION.** T. Kohout<sup>1,2</sup>, A. Kosterov<sup>3</sup>, J. Haloda<sup>4</sup>, P. Halodova<sup>4</sup> and R. Zboril<sup>5</sup>, <sup>1</sup> Institute of Geology, Academy of Sciences, Prague, Czech Republic, <sup>2</sup> Department of Physics, University of Helsinki, Finland, <sup>3</sup> Institute of Physics, St. Petersburg University, Russia <sup>4</sup> Czech Geological Survey, Prague, Czech Republic <sup>5</sup> Centre for Nano-material Research, Palacky University, Olomouc, Czech Republic.

**Introduction:** Launched in 2004 launched ESA (European Space Agency) Rosetta mission is due to arrive to comet 67P/Churyumov-Gerasimenko in May 2014 and to conduct observations during the approach the comet to the Sun. Both orbiter and cometary lander are equipped with magnetometers (Rosetta Plasma Consortium Magnetometer (RPC-MAG) and Rosetta Magnetometer and Plasma Monitor (ROMAP) respectively). The preliminary studies [1, 2] take into account FeNi alloys as the magnetic mineral present in cometary material.

Iron, chromium and manganese bearing sulfides have been reported in interplanetary dust particles (IDP's) [3, 4] and cometary dust [5, 6]. Moreover, the sulphides in these extraterrestrial materials are more abundant than FeNi metallic phase.

Thus magnetic properties of these sulphides must be considered while interpreting magnetic observations of cometary bodies.

**Magnetic properties of sulphides:** Iron nickel (FeNi) alloys are dominant magnetic phase in most extraterrestrial materials. Additionally carbides, phosphides and sulfides can be found in some achondritic and chondritic or martian meteorites. While most of these sulphides (with the exception of monoclinic pyrrhotite  $\text{Fe}_{1-x}\text{S}$ ) are antiferromagnetic or paramagnetic at room temperature, various magnetic transitions occur at lower temperatures enhancing their induced or remanent magnetization. In table 1 we provide review of available low-temperature magnetic data of alabandite (Fe,Mn)S, daubreelite ( $\text{FeCr}_2\text{S}_4$ ) and troilite (FeS).

Such a review is beneficial for understanding of the magnetic properties of primitive extraterrestrial materials at low temperatures typical in their environment.

**Temperature state of the comets:** Thermal modeling of comet 46P/Wirtanen or 67P/Churyumov Gerasimenko [7] shows that the cometary surface is subject of temperature variations in range of 100 to 200 K up to depth of several meters while the cometary interior is thermally stable at several tens of Kelvin. This is within temperature region where alabandite, daubreelite or troilite are "magnetic". Thus not only FeNi alloys, but also sulphides have to be considered in interpretation of magnetic data of cometary objects.

**Magnetic modeling of comets:** Let us now model a cold icy cometary body containing dispersed 10 wt%

fine-powder fraction of alabandite, daubreelite, troilite or FeNi metal. From table 1 we can estimate the magnetic susceptibility of such a body to be  $\sim 10^{-8} \text{ m}^3/\text{kg}$  for alabandite or troilite. This is below the magnetic susceptibility of most meteorites (only some HED or SNC meteorites have such low values) while presence of 10 wt% of daubreelite will result in magnetic susceptibility  $\sim 1000 \times 10^{-8} \text{ m}^3/\text{kg}$  what is comparable to most carbonaceous or LL and L ordinary chondrites or aubrite or ureilite achondrites (fig. 1). Thus, such a cometary body will show similar magnitude of interactions with IMF (Interplanetary Magnetic Field) as with parent bodies of these meteorites. A comet with 10 wt% of finely dispersed FeNi metal would produce even order of magnitude higher induced magnetization.

Based on [8] the induced magnetization measured on the orbit around such a comet containing 10 wt% of finely dispersed daubreelite in 10 nT IMF will be in range of  $10^{-1} - 10^0 \text{ nT}$ . This is low but, within the resolution limit of Rosetta's RPC-MAG instrument (31 pT, [1]). The ROMAP instrument on the lander (resolution 10 pT, [2]) should provide stronger signal and might detect those interactions more reliably.

**Conclusions:** Magnetic interactions between comets containing iron-bearing sulphides and IMF will be difficult, but not impossible, to detect from orbit. The magnitude of the interactions is expected to be similar to those with achondritic or chondritic parent bodies. The lander present on the cometary surface should provide even stronger signal.

Moreover, the approach of the comet towards Sun and rotation of its nuclei causes variations in the surface temperature. This may cause detectable changes in the magnetic properties of the comet as various sulphides are changing their magnetic ordering states at their characteristic transition temperatures.

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Table 1. The review of the magnetic properties of the sulphides considered in this study with corresponding temperature intervals of increased magnetism.

Magnetic mineral	Magnetic susceptibility (10 <sup>-8</sup> m <sup>3</sup> /kg)	Induced magnetization in 10 mT field (Am <sup>2</sup> /kg)	Saturation remanence (Am <sup>2</sup> /kg)
Alabandite (below 150 K)	10	0.003-0.004 0.01-0.1 (below 50 K for MnS slightly enriched in Mn)	
Daubreelite (below 165 K)	10000	3.5-5	~ 4-12
Troilite(below 70 K)	10	0.1-0.3	~ 0.3
FeNi metal (20 wt% of Ni)	100000	~ 10	~ 2-3

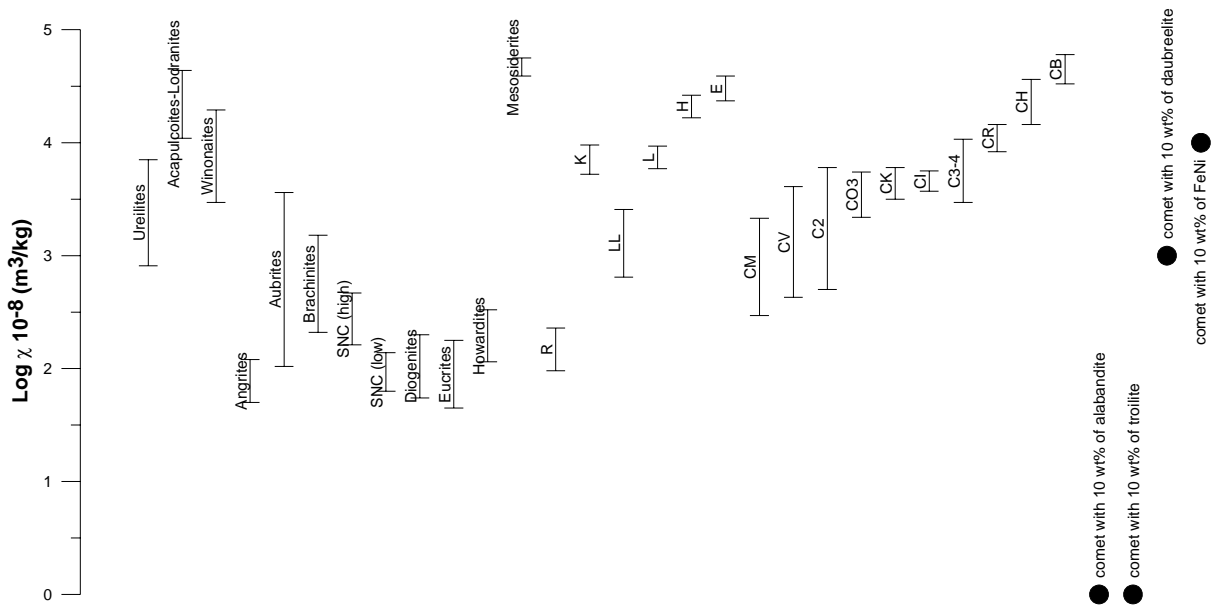


Figure 1. Model magnetic susceptibility of an icy comet containing dispersed 10 wt% fine-powder fraction of alabandite, daubreelite, troilite or FeNi metal and its comparison to susceptibility of meteorites. The temperature of the cometary body with sulphides is supposed to be within temperature interval specified in table 1. Meteorite data are from [8, 9, 10].