PHYSICAL PROPERTIES AND X-RAY MICROTOMOGRAPHY OF THE MICROMETEORITES FROM NOVAYA ZEMLYA, RUSSIA. T. Kohout[1, 2], J.-P. Suuronen[1], A. Kallonen[1], J. Čuda[3], D. D. Badjukov[4] and R. Skála[2], [1] Department of Physics, University of Helsinki, Finland (tomas.kohout@helsinki.fi), [2] Institute of Geology, Academy of Sciences, Prague, Czech Republic, [3] Regional Centre of Advanced Technologies and Materials, Departments of Physical Chemistry and Experimental Physics, Palacky University Olomouc, Czech Republic. [4] V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Moscow, Russia

Introduction: Cosmic dust recovered on Earth in the form of interplanetary dust particles (IDPs) and micrometeorites is, together with larger meteorites, valuable source of primitive extraterrestrial material. Reliable determination of cosmic dust's bulk and grain density and porosity is an issue of key importance in planetology. Cosmic dust represents material released from asteroids and probably also comets into interplanetary space. It carries important information about the composition and structure of cometary dust or coma as well as of asteroid surfaces. Thus, knowledge of cosmic dust's physical properties is essential in the interpretation of ground-based or space-based observation of comets and asteroids. Some cosmic dust particles experience significant atmospheric processing during their entry while others survives almost unaffected. Thus, comparison of the physical properties of pristine cosmic dust particles to these significantly affected by atmospheric entry can give us insight into changes related to their atmospheric entry.

Physical properties of cosmic dust: Physical properties and internal structure of cosmic dust in the form of six ~100 µm-sized micrometeorites, collected in the Novaya Zemlya glacier in Russia [1] were investigated using x-ray microtomography (XMT) at the Department of Physics, University of Helsinki. Due to its high-voltage (20-180 kV) nanofocus x-ray tube, and variable imaging geometry, the XMT equipment allows scans of samples sized from10 cm down to 50 µm, with sub-micron resolution (i.e. voxel size below 1 μm^3) in the case of small samples.

XMT results from Novaya Zemlya micrometeorites are summarized in table 1 and indicate their predominantly silicate composition. The internal structure is influenced by re-melting during atmospheric entry and varies from glassy to barred or porphyritic olivine structure (fig. 1). Additionally to internal structure imaging, XMT allows bulk particle shape, volume and porosity determination. Quantitative volumetric 3D calculations of various compositional fractions as well as of pore space within scanned particles were done in similar was as by [2] and [3], but with higher resolution. The micrometeorites were found to be quite compact with porosity mostly below 3% (with up to 1 um pore size resolution). Such low porosity values are most likely a result of pore space reduction during atmospheric entry. Unmelted cosmic dust particles [4, 5] as well as compositionally similar meteorites [5, 6] are generally found to have slightly higher porosities.

The bulk and grain densities were derived using particle bulk and grain volumes derived from XMT scans, and mass determined by a microbalance. Average bulk and grain density of the particles were calculated to be 3.4 and 3.5 g/cm^3, respectively. Te grain density is close to the grain density of mineral olivine and silicate rich chondritic meteorites [6].

One particle was found to have a large metal inclusion amounting almost 5% of its volume (fig. 1). This is also reflected in its higher bulk and grain densities of 5.6 and 5.7 g/cm^3 respectively. Its grain density is similar to stony iron meteorites [6].

Magnetic studies of all micrometeorites revealed further ~4 wt% fraction of submicron-sized ferrimagnetic material (magnetite or iron) which is too finely grained to be detected in the XMT scans.

Conclusions: The porosity of the studied micrometeorites was reduced during their atmospheric entry while their grain densities are consistent with their predominantly olivine compositions.

XMT proved to be a capable 3D non-destructive investigation tool suitable for extraterrestrial material studies and for quantitative evaluation of its physical properties. and represents a significant improvement over the SEM based methods used in earlier studies [7, 8].

References:

[1] Badjukov D. D. and Raitala J. (2003) *Meteoritics & Planet. Sci., 38,* 329-340. [2] Tsuchiyama A. et al. (2004) *Meteoritics & Planet. Sci., 39,* A107. [3] Taylor S. et al. (2011) *Meteoritics & Planet. Sci., 46,* 1498-1509. [4] Rietmeijer F. J. M. and Nuth J. A. (2000) *Earth, Moon and Planets, 82-83,* 325-350. [5] Corrigan C. M. et al. (1997) *Meteoritics & Planet. Sci.,32,* 509-515. [6] Consolmagno G. et al. (2008) *Chemie der Erde, 6*8, 1-29. [7] Flynn G. J. and Sutton S. R. (1991) *LPSC XXII,* 541-547. [8] Love S. G. (1994) *Icarus, 111,* 227-236.

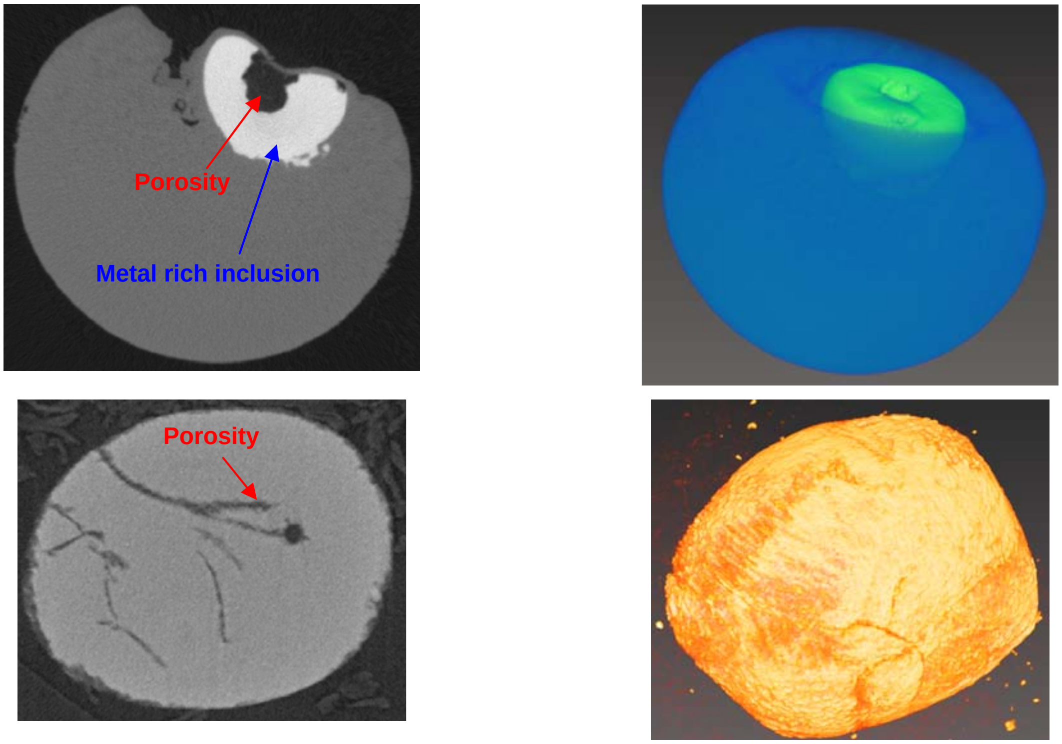

Fig. 1. Left – XMT scans of two ~100 µm individual micrometeorites – a metal rich inclusion (white) and large voids (black) can be seen. Right – shape models of the two micrometeorites suitable for volume and density determination. The grain density and porosity of the upper particle was calculated to be 5.66 g/cm^3 and 0.3% respectively and of the lower particle 3.37 g/cm^3 and 2.9% respectively. This is in agreement with the observed structure. The upper particle is more compact (lower porosity), but include large metal inclusion (density similar to stony iron meteorites composed of silicate and metal). The lower particle is more porous and its density is similar to silicate rich chondritic meteorites and mineral olivine (3.27 – 3.37 g/cm^3).

Table 1. Physical properties of the Novaya Zemlya micrometeorites derived from XMT. The achieved resolution is expressed as voxel size.

Sample	Bulk volume (mm^3)	Grain volume (mm^3)	Mass (µg)	Porosity (%)	Bulk density (g/cm^3)	Grain density (g/cm^3)	Voxel size (µm)
1	0.0150	0.0149		0.8			1.0
2	0.0237	0.0233	86	1.6	3.63	3.68	0.6
3	0.0272	0.0270	93	0.6	3.42	3.44	0.8
4	0.0321	0.0320	181	0.3	5.64	5.66	0.7
5	0.0186	0.0181	61	2.9	3.27	3.37	0.9
6	0.0377	0.0372	125	1.3	3.32	3.36	0.6