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Detection of magnetic anisotropy of a single grain crystal orientated to investigate the origin of dust alignment.

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Distribution of magnetic fields in inter- and circum-stellar regions is commonly estimated from the observation of visible and infrared polarization, which is caused by the magnetic alignment of the dust particles. The origin of alignment in the diffuse interstellar region is explained by a paramagnetic relaxation model assumed for the grains. However in the high-density regions, efficiency of the above mechanism is still unclear since the dust is in thermal equilibrium with the gas molecules. An alternative possibility was proposed on the mechanism, which was based on the balance between the rotational Brownian energy and the magnetic anisotropy energy induced in the dust. Here the magnetic anisotropy are caused by paramagnetic anisotropy and/or by diamagnetic anisotropy.

A new principle to detect magnetic anisotropy of a small crystal is experimentally examined by measuring the anisotropy of paramagnetic apatite crystals having sub-millimeter sizes. The new method is based on a rotational oscillation of magnetically stable axis with respect to field direction. Here the crystal is released in a diffused area using a short microgravity condition. The method is hence free of mass measurement; anisotropy can be measured for a limitlessly small crystal grain, in condition that the oscillation is observable. In a conventional method to detect anisotropy, existence of a sample holder and difficulty of mass measurement had prevented the detection of small samples. A chamber-type drop shaft was newly developed to observe the field-induced oscillation; duration of microgravity was below 0.6s. Volume of drop box was as small as 100 cmˆ3, weight was below 1kg. The compact size of apparatus was realized by introducing a small NdFeB magnetic circuit with dimensions of 2.5 cm x 2.0 cm x 0.6 cm (B<0.6T).

Rotational oscillation was observed for 4 apatite crystals with different sizes, and the anisotropy value was determined in terms of a formula established for the period of harmonic oscillation. The obtained values of anisotropy both agreed fairly well with the published values. It was confirmed from the experiment that the position of the sample stage, located at the center of N and S pole, was effective to spontaneously release the sample by an attractive field gradient force. In previous micro-g experiments, release of sample was often prevented by a Coulomb attractive force between sample and holder deriving from the electric charges. The above-mentioned field-gradient force is effective to reduce the interference of the attractive force.

The mass independent property of the above oscillation was examined in wide range of sample size; namely between 1.0 and 0.1mm in diameter. The present technique of observing anisotropy of a sub-millimeter-sized crystal is a step toward realizing anisotropy measurements of micron-sized grains. Precise anisotropy values of single micron-sized grains can be used to examine the validity of a dust alignment model based on magnetic anisotropy energy induced in the dust particles.

[1] C.Uyeda et al: Jpn. Phys. Soc. Jpn. 79, 064709 (2010).

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