Detection of Magnetic Anisotropy Using a Wide Field Area Produced by Ferrite Magnets

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Polarization data in the visible and infrared region caused by partial dust alignment is commonly used to determine the direciton of magnetic field in various glactic area [1]. Observational studies has concluded that partially aligned silicate-grains can be he cause of the polarization. However, the physical mechanism of the aformentioned alignment in the dense region (i.e., the surrounding areas of the proto-planetary discs) leaves room for discussion, because dust and gas are in a thermo-dynamically equilibrium condition.In this study, it was assumed that partial alignment in the dense region was caused by anisotropy of magnetic susceptibility $\Delta\chi$ that was assigned tothe dust material [2]. In this case, the field-induced anisotropy energy induced in the dust should be larger than the Brownian energy (Uyeda et al., 1991, 2004a). Using a conventional torque method, value of $\Delta\chi$ per unit mass was generally difficult to measure when its mass *m*was below several milligrams [3], because *m*measurement of sample was difficult;note that the obtanable size of a single crystal is below sub-milimeter in dimaeter in many materials, and reliable $\Delta\chi$ values aredifficut to obtain in these materials. Therefore a new method that was proposed and practicalized in which**[A1]** $\Delta\chi$ was determined from period of harmonic oscillation τ of stable axis of crystal with respect tomagnetic field ***B***; here oscillation was induced by a field-induced anisotropyenergy$\frac{1}{2}\Delta\chi mB^2$, and τ followed an equation

$$\tau = 2\pi\ (I/m\Delta\chi)^{1/2}|\boldsymbol{B}|^{-1}. \quad (1)$$

where*I*denote moment of inertia of the crystal. It is seen that τ is independent to *m*in the above equation, and$\Delta\chi$ is determined form τ ,*I*/*m andB*no matterhowsmallcrystalmay be, in condition that the oscillation is observable [3].

Here we introduced a pair of ferrite magnetic plate (10cm x 5cm x 1cm) was used to generate ***B***to increase the volume of homogeneous field area with respect to previous researches [3]. Accordingly, the mm-size sample released in μgarea was allowed to translate in a wide sperical area of ~3 cm in diameter during the observation of field-indused oscillation. The diameter of homogeneous area in the previos setup was less than ~1.5cm, and the sample frequently moved away from the homogeneous field area; success rate of τ measurement was less than 20% due to this distervance. In the presentexperiment, $\Delta\chi$ values were obtained in milimetre sizecrystals of a paramagnetic chrorite and a diamagnetic graphite following the aforementioend propcedure. It is generally considerd that dynamic motions are not induced in diamagneitc and paramagnetic materials bya low field intensity produced by a ferrite magnet. The crystals used in the experiment were separated from bulk samples using a wire saw and a titanum knife. The sample was placed on a sample stage that was located at the the field center of two magnetic plates. A short microgravity condition (duration< 0.5s) was applyed to the setup by conducting a free fall [3][4].Shortly after the biginning of the free fall, the sample stageslowly lifted from its initial position, which was effectiveto release the small sample in a diffuse area.The rotational-oscillation of the samples were observed by a high-speed camera (ZWO ASI290MC) that was newly adopted in the experiment; the camera was capable to observe and presere the motion of the sample with a time resolution of 0.033 fps and a spatial resolution of 0.004 cm.

[1] *for example,* R. Spitzer Jr., Physical Processes in the Interstellar Medium (1978). [2] C. Uyeda, et. al., A & Ap (2001). [3] C. Uyeda et. al., (2010)*J. Phys. Soc. Jpn.*32, 164079. [4] Yokoi et al., Planet., Space Sci., 28, 094103.

[A1]Alternatively,

"in the sub-milligram range".

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