MANIPULATION OF PROTISTS USING STATIC MAGNETIC FIELDS

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Introduction

Protists adjust their swimming behavior in response to mechanical perturbations. A Paramecium, for example, performs an avoiding reaction, backing up and swerving, upon bumping into an obstacle. More subtly, Paramecium and other protists adjust their swimming direction and speed in response to earth’s gravity. In earlier work, we have shown that Paramecium alter their swimming in intense magnetic fields. Paramecium align their swimming with a magnetic field and, to a first approximation, seem to respond to magnetic body forces in the same way they respond to the body force of gravity. We performed experiments at the NHMFL, during the past year, to study whether these alterations in their swimming is a passive or active response to the body forces and torques that magnetic fields exert on Paramecium.

Experimental

Videos of Paramecium Caudatum swimming in a range of intense magnetic fields were acquired. The experiments were carried out in the 50 mm bore, 27 T, resistive magnet in Cell 5. A commercially made borescope (ITI) served as the optics and the light from a high luminosity LED illuminated the samples through three fiber optic lines. Solutions containing Paramecium were placed in custom made sample cells made of plexiglass and glass. Paramagnetic impurities were added to the solutions for investigations of the response of the Paramecium to magnetic forces. The effective buoyancy, $b_{eff}$, of Paramecium in magnetic field relative to zero magnetic field, $b$, is given by:

$$ \frac{b_{eff}(z)}{b} = \left(1 - \frac{(\chi_c - \chi_s)}{\rho_c - \rho_s} gb \right) \frac{dB}{dz} \tag{1} $$

where $\rho_s$ and $\rho_c$, $\chi_s$ and $\chi_c$ are the densities and magnetic susceptibilities of the solution and Paramecium, respectively.

Results and Discussion

Paramecium swimming in a wide range of uniform magnetic fields and strong magnetic force fields were observed. We have measured the distribution of their swimming directions and speeds and are characterizing those distributions to determine how they systematically change with magnetic field parameters. We established that magnetic forces can be used to simulate an environment with 4.5 times earth gravity and to simulate an inverted gravity environment up to 2.5 times earth gravity (see Figure). The figure also illustrates the nearly 100% alignment of the swimming Paramecium in fields in excess of 10 T.

Conclusions

The magnetic forces and torques that can be applied to swimming Paramecium in resistive magnets are sufficient to dramatically alter their swimming behavior. This result suggests that magnetic fields can be used as a tool to perturb and thus probe their natural physiological responses.

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