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Multicellular Magnetotactic Bacteria under an Applied Magnetic Field Form Active Crystals

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Multicellular Magnetotactic Bacteria under an Applied Magnetic Field Form Active Crystals

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Abstract

Multicellular Magnetotactic Bacteria (MMB) of the species ***Magnetoglobus multicellularis*** live in spherical colonies composed of 10-50 individual bacteria. These bacteria are the only known obligately multicellular bacteria. The colony swims as a single unit parallel to the Earth's magnetic field. When a magnetic field is oriented normal to a glass surface, aggregates accumulate into a monolayer on the glass surface. As the magnitude of magnetic field increases, the density of the colonies increases. At a critical field strength, the mean free path of the colonies shrinks to the radius of a single colony. The colonies display a crystalline packing. Unlike previous examples of active crystals (e.g., with colloids and fast swimming bacteria), these bacteria spontaneously detach and reincorporate into the structure at rates dependent on the strength of the applied field. As a result, active crystals composed of MMB display numerous vacancies. We describe the dynamics is this new state of active matter and compare them to active crystals and active super-critical fluids.

Introduction

Figure 1: Site of collection of Magnetoglobus multicellularis samples

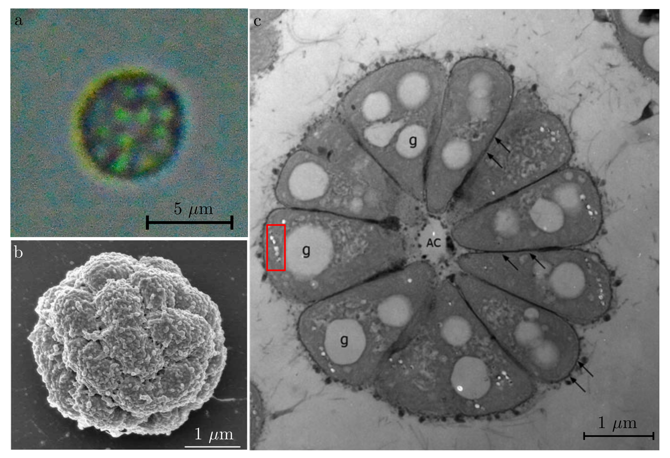

Figure 2: Images of Magnetoglobus multicellularis bacteria.

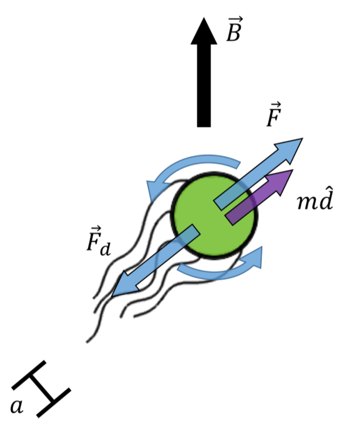

Figure 3: Multicellular magnetotactic bacteria aligning with a magnetic field.

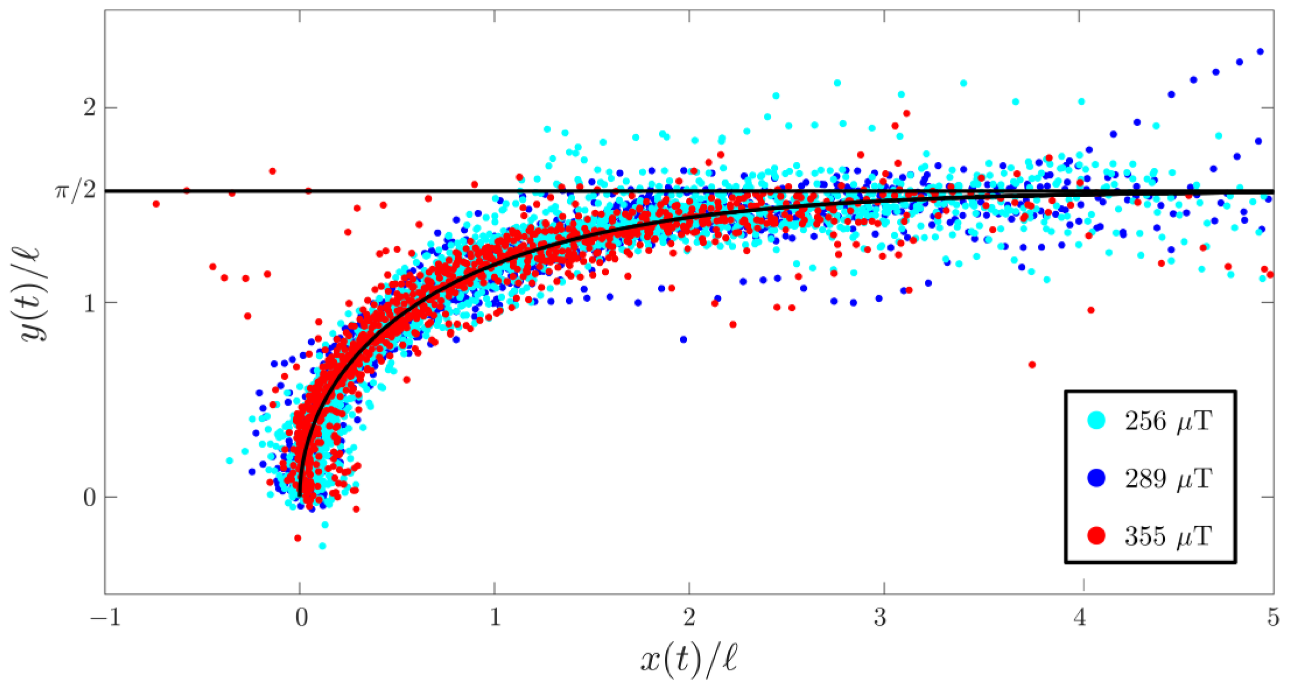

Figure 4: Alignment of cells with different magnitudes of applied magnetic fields.

$$k = \frac{mB}{8\pi\mu a^2}$$

Methods

Video Analysis with Matlab

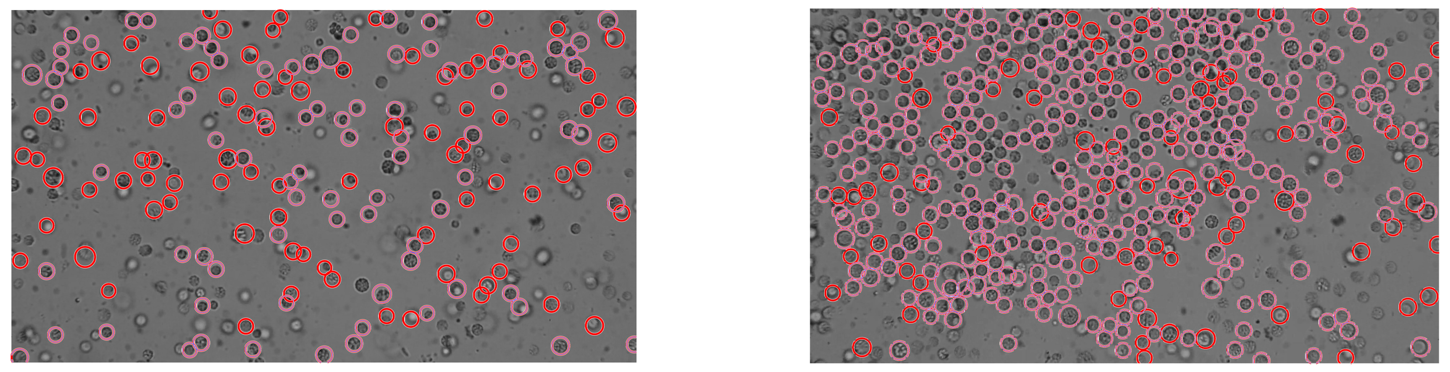

Figure 5: Algorithm to track cells and select those which are bound to the glass slide.

Distribution of Velocities

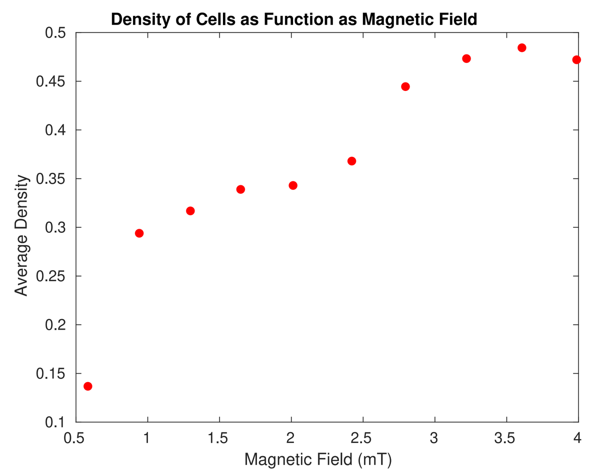

Figure 6: Average density of cells in the slide across frames.

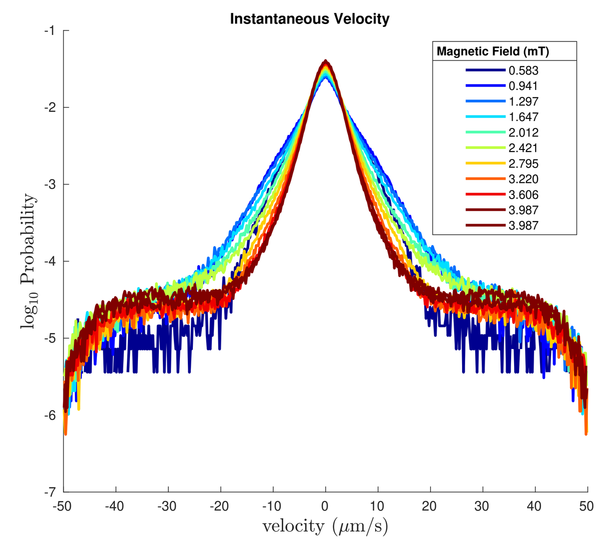

Figure 7: Velocity distribution of the bacteria under different magnetic fields

$$d\theta = -k\theta dt + \sqrt{2D}dW$$

$$\langle\theta^2\rangle = \frac{D(8\pi\mu a^2)}{mB}$$

Delaunay Triangulation

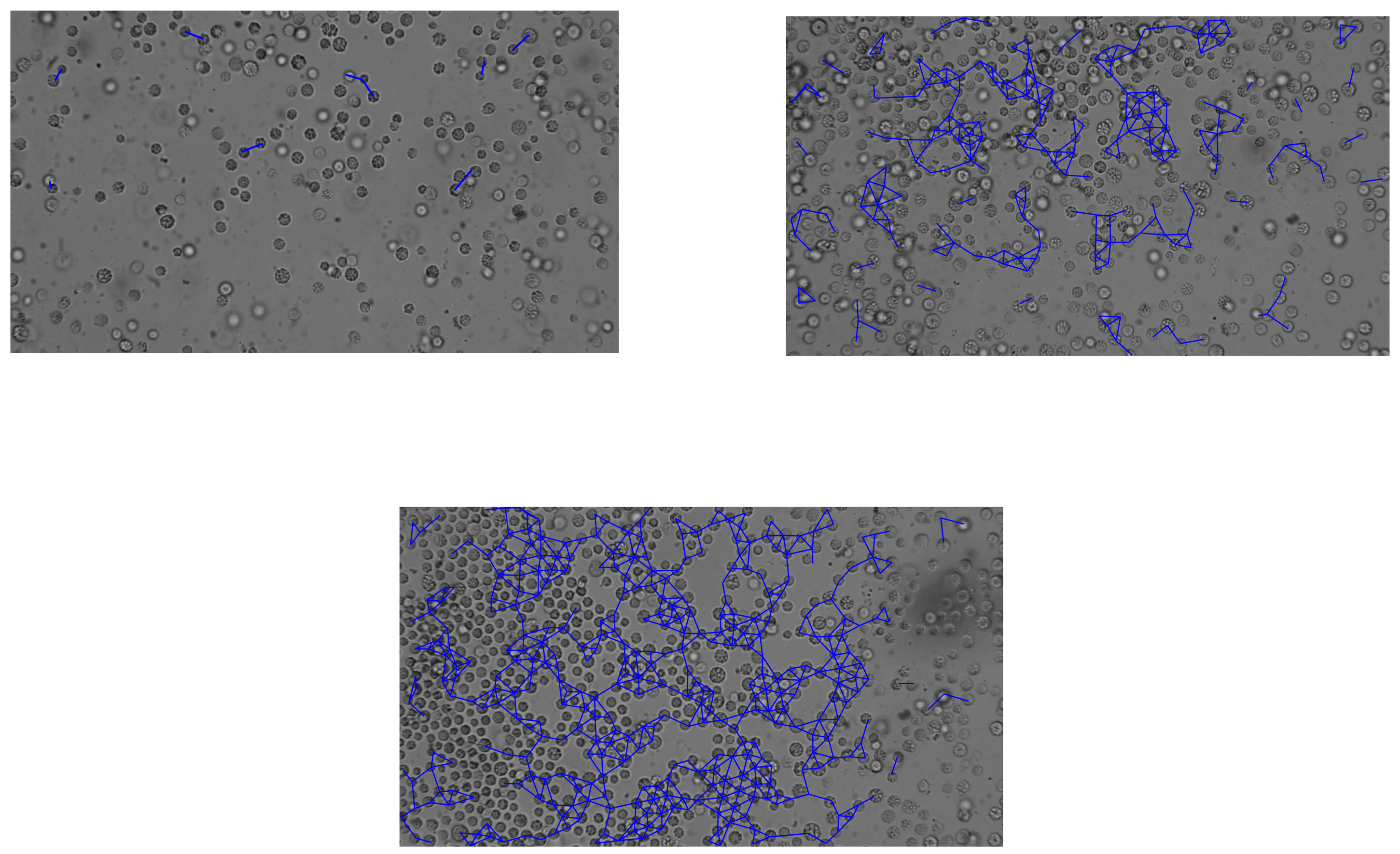

Figure 8: Clustering algorithm for a low, medium and high magnetic field.

Results

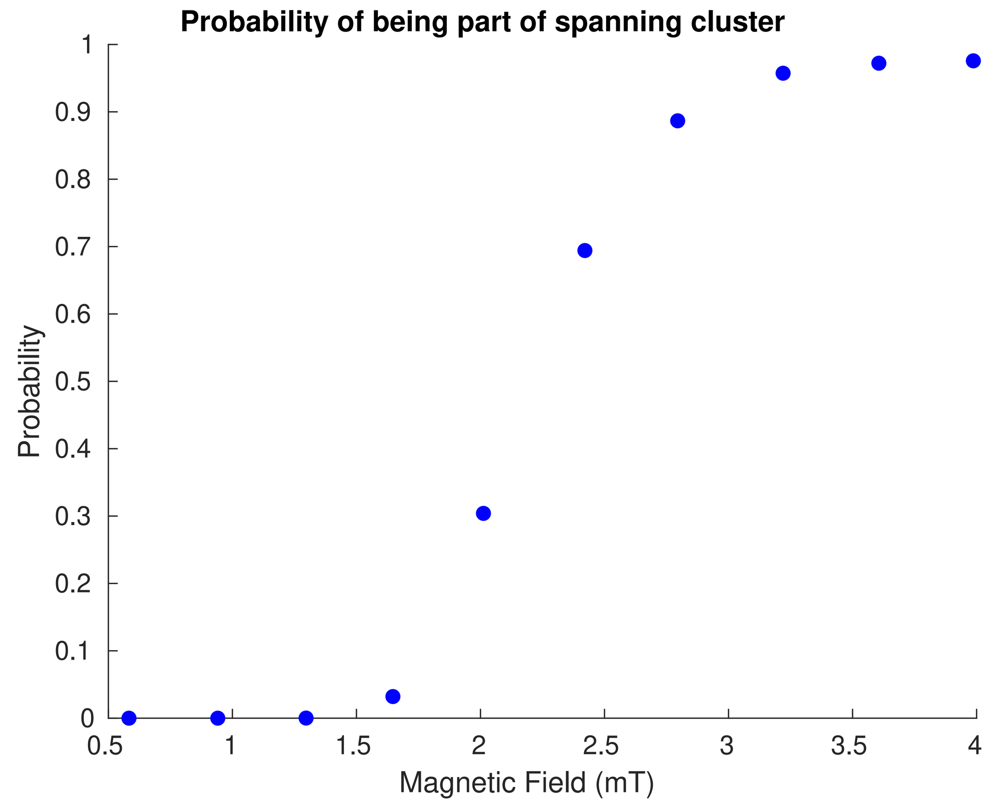

Figure 9: Probability that a cell is part of the spanning cluster

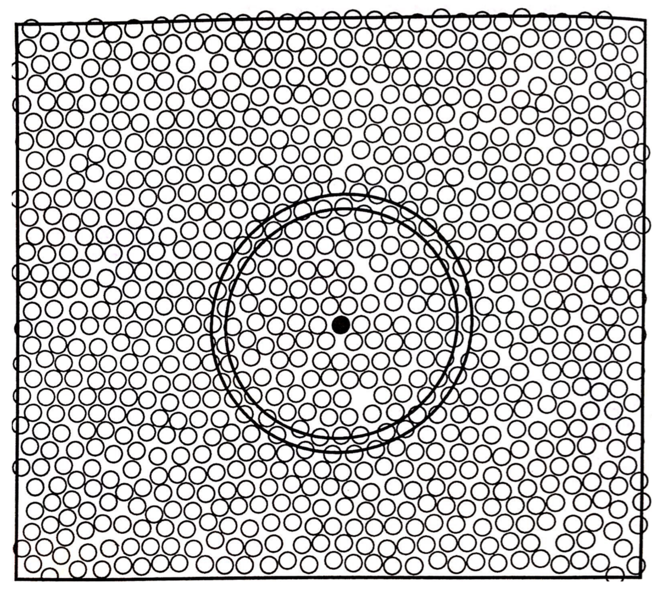

Figure 10: Graphic representation of the calculation of correlation function.[1]

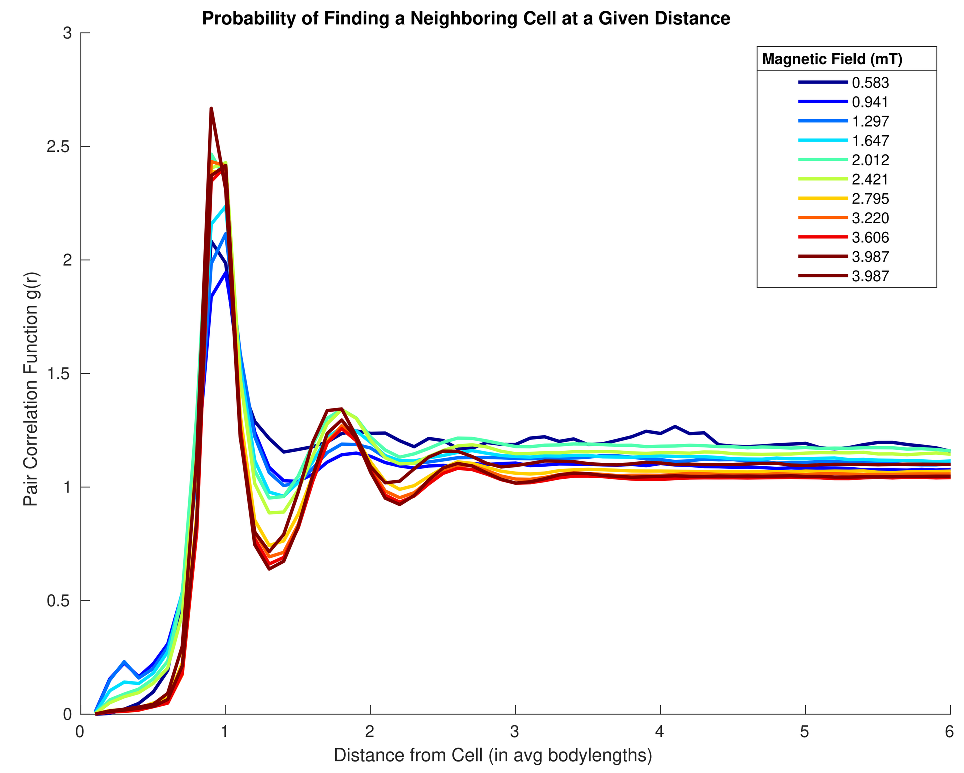

Figure 11: Pair correlation function g(r) as magnetic field increases

References

[1] P.M. Chaikin T.C. Lubensky *Principles of Condensed Matter Physics*. Cambridge University Press, 1995.