Magnetic-like model for chemotactic navigation in ants

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Self-propelled individuals, from single cells to animals, continuously convert internal energy into directed motion. As they move, they respond to environmental cues, so that their trajectories reflect a feedback between self-propulsion and sensing. Ants provide a particularly clear example of this type of behavior through chemotaxis (the navigation along chemical gradients).

Motivated by this process, we recorded the motion of individual *Aphaenogaster senilis* ants following externally imposed pheromone trails. Our aim was to isolate the minimal ingredients of chemotactic guidance to characterize the feedback between the chemical signal and motion (see figure 1 and [1]). Our analysis of the trajectories reveals a distinctive pattern: once an ant finds the trail, it navigates along it while oscillating around the trail direction (see figure 1b and [1]).

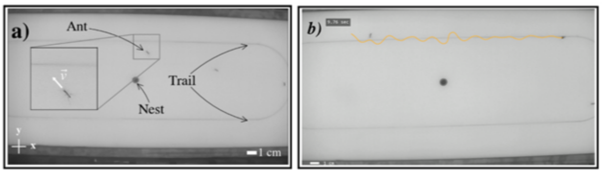

Fig 1. Caption: a) Experimental plate where the experiment is conducted, with relevant regions highlighted. b) Example of a trajectory showing oscillatory motion around the trail.

To investigate whether this movement pattern arises directly from the interplay between self-propulsion and chemotaxis, we introduce a physical model based on the Inertial Spin Model (ISM) [2]. Originally developed to describe collective alignment in bird flocks, here it is adapted to a single-agent scenario, treating the chemotactic interaction as an external magnetic-like field coupled to the particle's velocity. Analytical treatment of the model predicts underdamped oscillations while navigating the trail for a specific parameter regime, and the decay of this oscillations matches the experimental observations in both amplitude and frequency. Notably, simpler active-matter models, such as the Vicsek model, fail to reproduce this oscillatory regime.

Taken together, these results show that oscillations around the trail in chemotactic ants may emerge from physical coupling mechanisms, without invoking higher-order cognitive processes. This approach illustrates how minimal models can capture essential features of complex biological behavior, providing a bridge between experimental observations and theoretical frameworks in active matter.

References:

[1] Flaquer-Galmés, R., Campos, D. and Cristín, J., Magneticlike model for chemotactic navigation in ants, PRR, 8 (1), 013116, 2026.

[2] Cavagna, A. et al, Flocking and turning: a new model for self-organized collective motion, Journal of Statistical Physics 158, 601, 2015.