Insect dynamics: motion and fluctuations

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Understanding the collective dynamics of living systems composed of many interacting individuals remains a central problem in active matter and biological physics. With this goal, we investigate insect dynamics through a set of controlled experimental systems focusing on ants and moths.

For ants, we study dense collectives confined in quasi-two-dimensional arenas. Under these conditions the system exhibits activity cycles in which it alternates between low-activity states, characterized by the formation of long-lived stationary clusters, and highly active states where most individuals move simultaneously. By analysing spatial number fluctuations within subregions of the system we observe giant number fluctuations characterized by $\langle(\Delta N)^2\rangle \sim \langle N\rangle^{\alpha}$ with $\alpha \approx 1.6$-1.7, in both regimes. Although the scaling behaviour is similar, we hypothesize that the underlying physical mechanisms are different. In the low-activity regime the large fluctuations appear to originate from the spatial heterogeneities introduced by clustering, whereas in the highly active state they may be related to alignment interactions between individuals and the possible emergence of a collective-motion state. This interpretation, however, remains tentative.

Also with ants, we are beginning to explore how the geometry of the substrate influences insect dynamics. To this end, we perform experiments with ants in curved arenas produced by 3D printing, including spherical and toroidal surfaces. In these systems, which are not yet in the dense regime, we vary the total number of individuals and use image analysis to reconstruct trajectories and characterize insect dynamics on curved spaces.

In parallel, we study moths in a cubic cell where individuals typically walk on the flat walls of the system. In this case our aim is to understand and model the encounter dynamics associated with sexual communication by varying the female-male ratio and analysing the resulting trajectories and interaction patterns.

Keywords:
active matter, insect dynamics, giant number fluctuations