



Seminar/Talk

How Curvature Shapes Active Systems

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Biological systems are typically not flat, with curvature appearing across a wide range of length scales, from the subcellular structures and individual cells to tissues and organs. The presence of curvature is tightly linked to biological function, shaping processes from morphogenesis to cellular organization. With active matter providing a powerful framework for understanding the physics of living systems, a natural question arises: how does curvature influence collective behavior in active matter? To address this question, we study both polar active particles and semiflexible active filaments. For non-interacting particles, curvature alone produces a striking effect: it bends their trajectories in a manner reminiscent of gravitational lensing. This deflection can lead to intermittent trapping of particles, which profoundly alters their flocking behavior. In this sense, curvature acts as a geometric torque that reshapes collective dynamics [1]. Interestingly, this picture changes significantly when we move from particles to extended objects such as active filaments. Active filaments have intrinsic curvature, so their energy-minimizing configurations generally do not align with geodesics, except in special cases such as spherical surfaces. On surfaces with non-uniform curvature, however, their motion emerges from a subtle interplay of activity, bending rigidity, density, and geometrical constraints. Whereas particles may become trapped by geodesic trajectories, including closed loops or long, recurrent paths, filaments instead localize in particular regions of the surface. These results show how curvature and topology can be harnessed to guide or constrain filament organization [2]. Together, these results highlight how surface curvature affects active system behavior, with broad implications for biological function and the design of synthetic active materials. Figure 1: Each filament is shown in a different grayscale shade, while the surface is color-coded by curvature. On a sphere, filaments follow geodesics, but on closed surfaces with non-uniform curvature, they become trapped in specific regions. REFERENCES [1] E. D. Mackay, G. Janzen, D. Fernandez, and R. Sknepnek, arXiv preprint arXiv:2505.24730 (2025). [2] G. Janzen, E. D. Mackay, R. Sknepnek, and D. Matoz-Fernandez, arXiv preprint arXiv:2507.23616 (2025).

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