Curvature-controlled defect dynamics in active systems

Abstract

We have studied the collective motion of polar active particles confined to ellipsoidal surfaces. The geometric constraints lead to the formation of vortices that encircle surface points of constant curvature (umbilics). We have found that collective motion patterns are particularly rich on ellipsoids with four umbilics where vortices tend to be located near pairs of umbilical points to minimize their interaction energy. Our results provide a perspective on the migration of living cells, which most likely use the information provided from the curved substrate geometry to guide their collective motion.

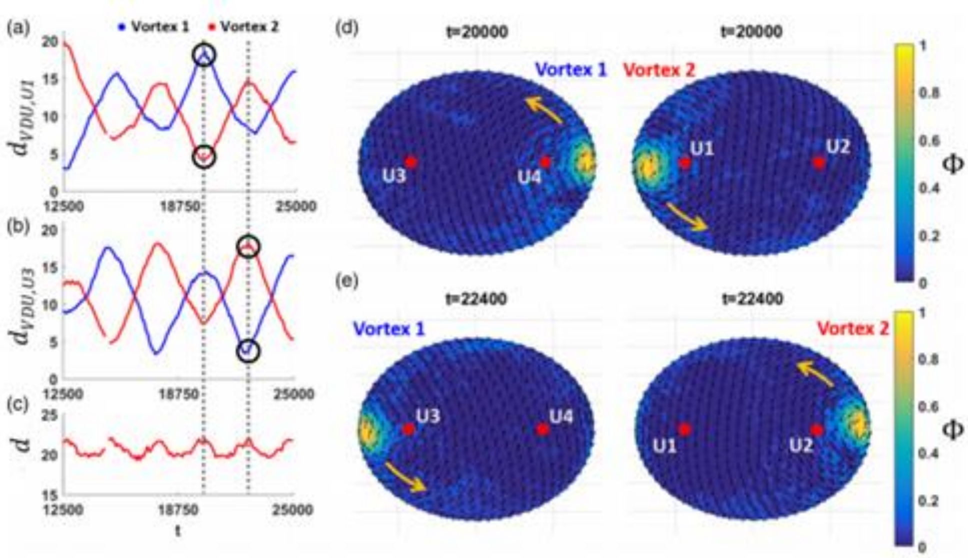

FIG. 6. Vortex dynamics on a triaxial ellipsoid with axis ratios $x/z = 2$, $x/y = 1.14$, and $v_0 = 0.1$. d_{VDU} for vortices (a) 1 and (b) 2 (blue and red curves) as a function of time measured from two different umbilical points (U1 and U3). The circles indicate the maximum distance of the vortices at $t = 2(\times 10^4)$ (a) and $t = 2.24(\times 10^4)$ time steps (b), which are peak values of the vortex to vortex distance shown in (c). Images depicted in (d) and (e) are the corresponding mapped values of Φ and director fields. On triaxial ellipsoids with pairs of close umbilical points the vortices encircle the two closest umbilics whereas they switch positions when umbilics are farther apart. All cases lead to stable oscillations in distance as illustrated in (a) and (b). The distance between vortices is maximized close to the umbilical points and switches between the two symmetric configurations (c).