Electronic Supplementary Material (ESI) for Soft Matter.

Supplementary Information

Active microfluidic transport in two-dimensional handlebodies

Jérôme Hardoüin, Justine Laurent, Teresa Lopez-Leon, J. Ignés-Mullol and Francesc Sagués

Supplementary Figures

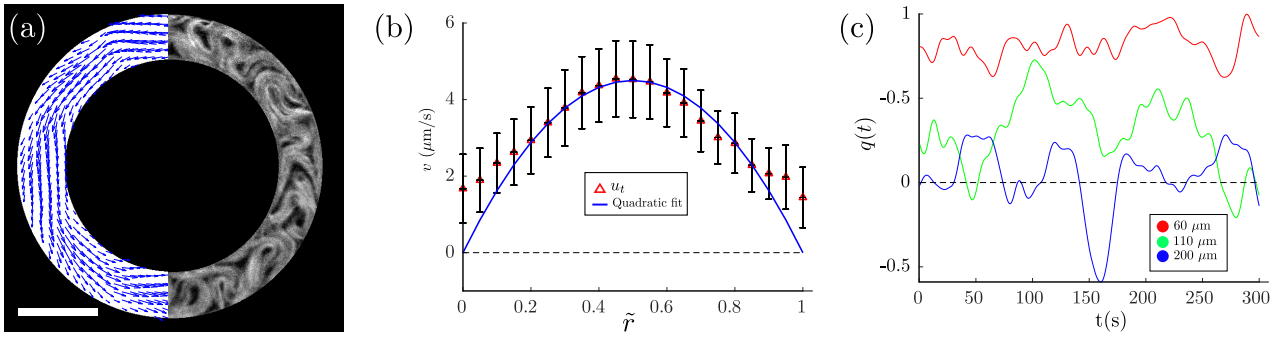


Fig. S1 Particle Image Velocimetry of active flows confined in annuli. (a) Fluorescence micrograph of an active nematic confined in a $60\ \mu$m annulus, with the corresponding velocity field overlaid in blue. The velocity field is averaged over 600 frames at 2 frames per second. The image is overlapped with a black mask around the region of interest, for a better visualization. (b) Tangential velocity u_t fitted with a Poiseuille-like velocity profile. The quadratic fit has the form $u_t = u_0 \cdot \tilde{r}(1-\tilde{r})$. (c) Transport coefficient $q(t) = V_t/V$, for three different annulus widths. In the transport state (red line), the ratio remains close to 0.8. This is coherent with the average profiles described in Fig. 1 (d) showing that the radial component of the velocity is negligible. Furthermore, the time dependence is weak compared to the other signals: the ratio typically fluctuates about 0.82 ± 0.09. In the switching state (green line), this ratio drops significantly, and the fluctuations are larger (0.31 ± 0.22). Sometimes, the transport velocity changes sign, which attests for occasional flow reversals. Finally, in the turbulent state (blue line), the transport is almost negligible, with oscillations about 0.05 ± 0.2. Note that, in the particular experiment displayed here, a large fluctuation is observed at time $t = 160$s, with the ratio shooting down to -0.6.

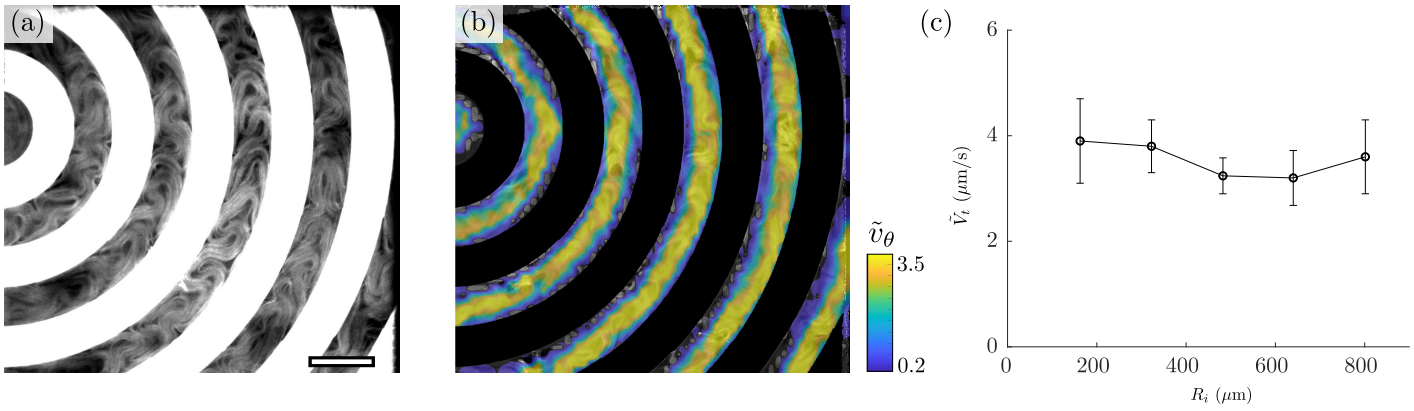


Fig. S2 Role of the average channel curvature. (a) Fluorescence micrographs of concentric annuli with the same width, $60\ \mu$m, corresponding to the transport regime, and different inner radius, R_i. *Scale bar:* $100\ \mu$m. The image is overlapped with a black mask around the region of interest, for a better visualization. (b) Corresponding intensity maps with the time-averaged absolute value of the azimuthal component of the velocity. Only values above 0.2 μ s^{-1} are represented. (c) Mean azimuthal speed as a function of R_i.

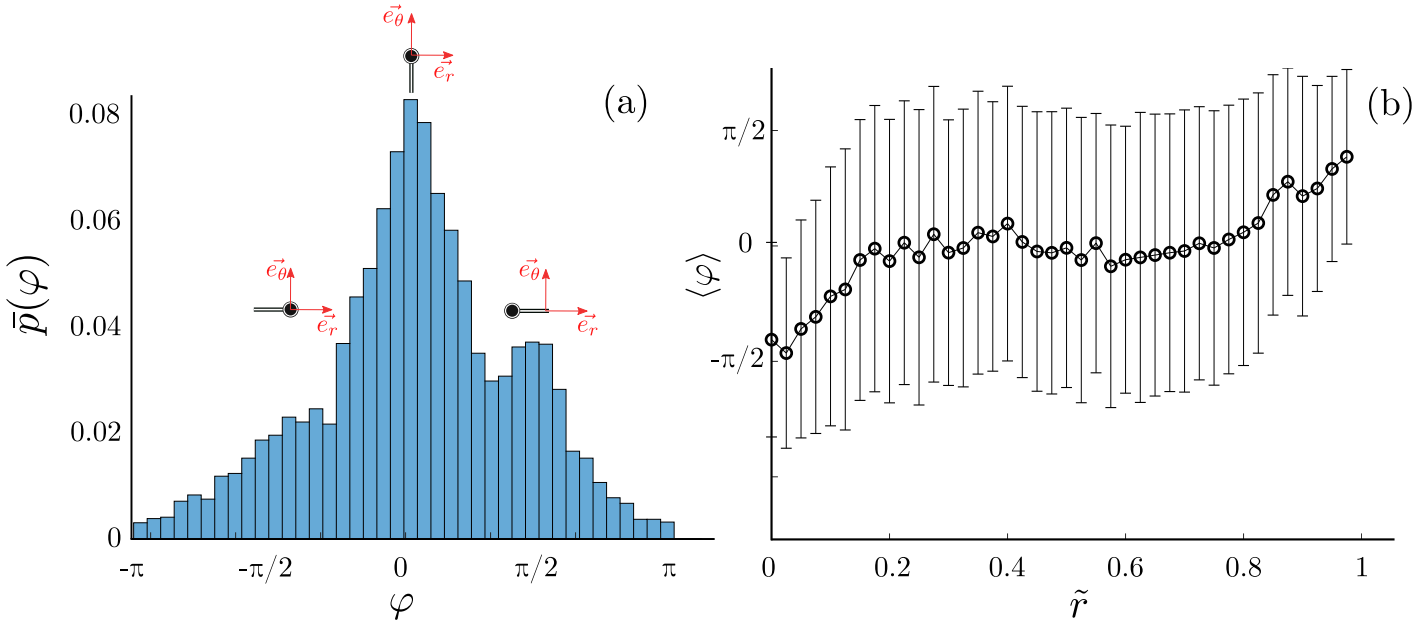


Fig. S3 Distribution of defect orientations. Defect positions and orientations are computed with Matlab routines (see Methods). The orientations are then projected onto the azimutal direction θ. Statistics are obtained from a video of 600 frames at 2 frames/s. See Methods section. (a) Distribution of defect orientations in a 80 μm wide annulus. (b) Average defect orientation as a function of the radial coordinate. Error bars correspond to the standard deviation of the measurements.

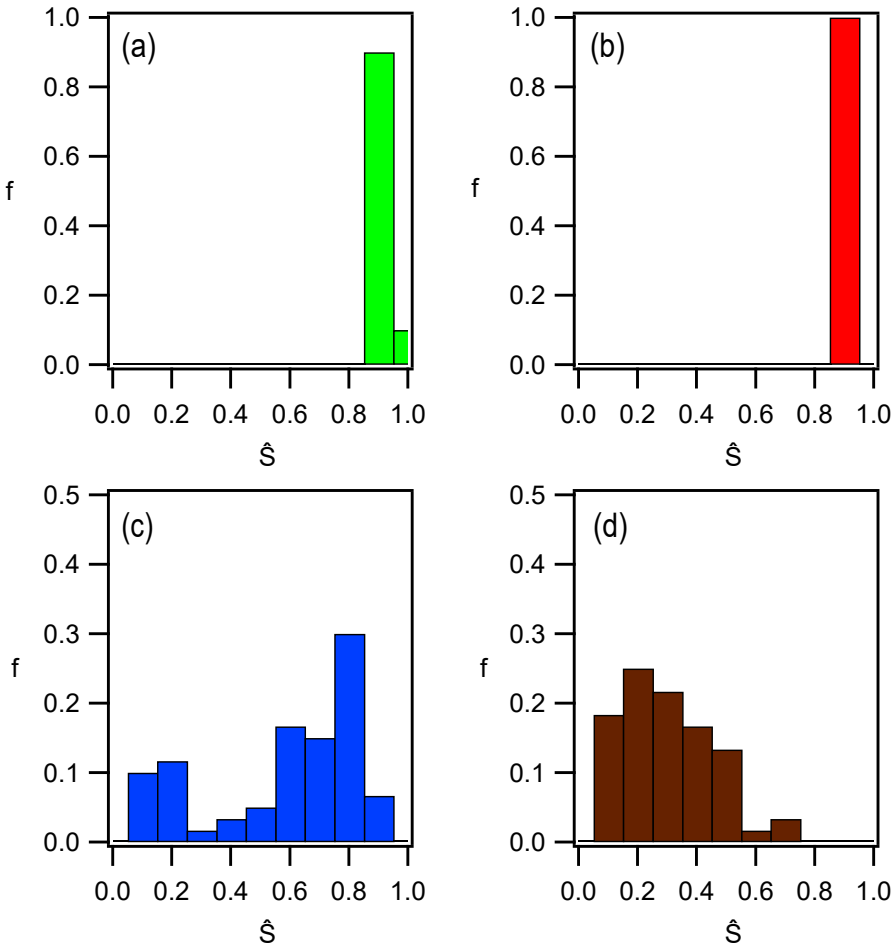


Fig. S4 Time distribution of the flow order parameter. Normalized frequency distribution (f) of the flow order parameter, $\hat{S}$, for active flow in annuli of width $60\ \mu$m (a), $80\ \mu$m (b), $110\ \mu$m (c), and $200\ \mu$m (d).

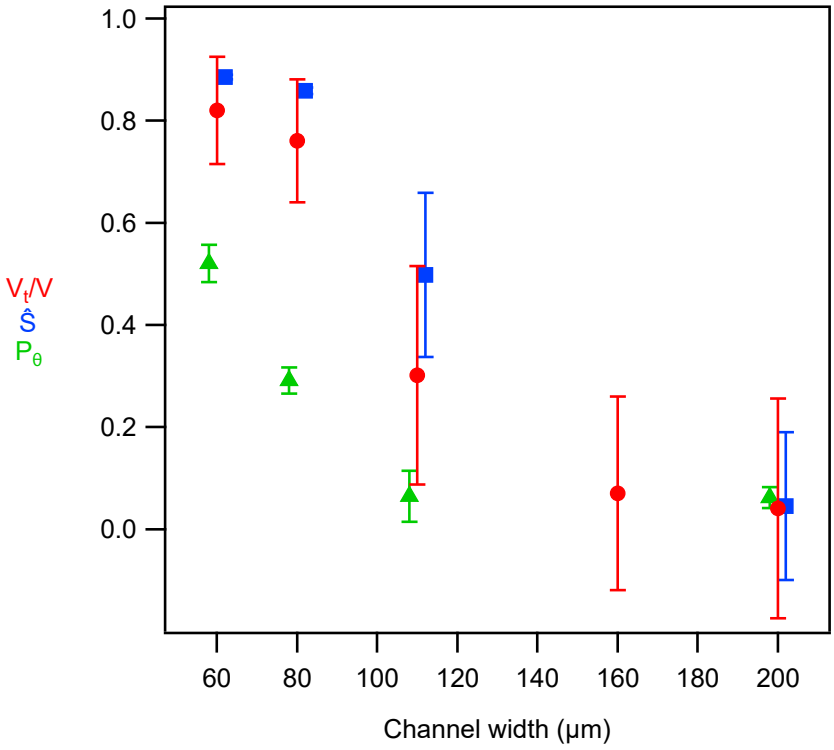


Fig. S5 Comparison between different order parameters. Different order parameters of active flows, averaged over time, as a function of the annulus width: tangential velocity, V_t, divided by the total speed, V (○); flow order parameter, $\hat{S}$ (□); defect orientational order parameter, P_θ (△).

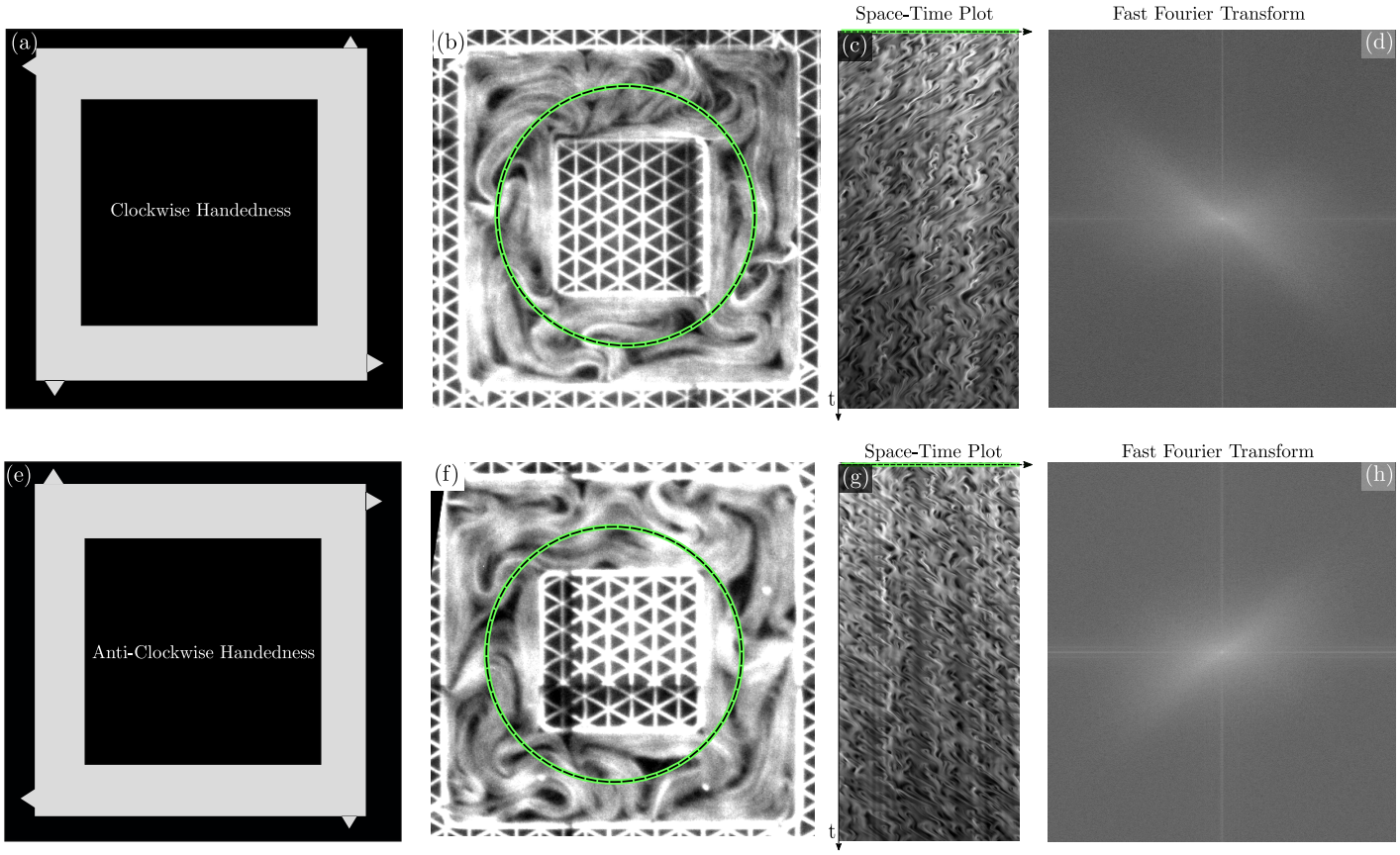
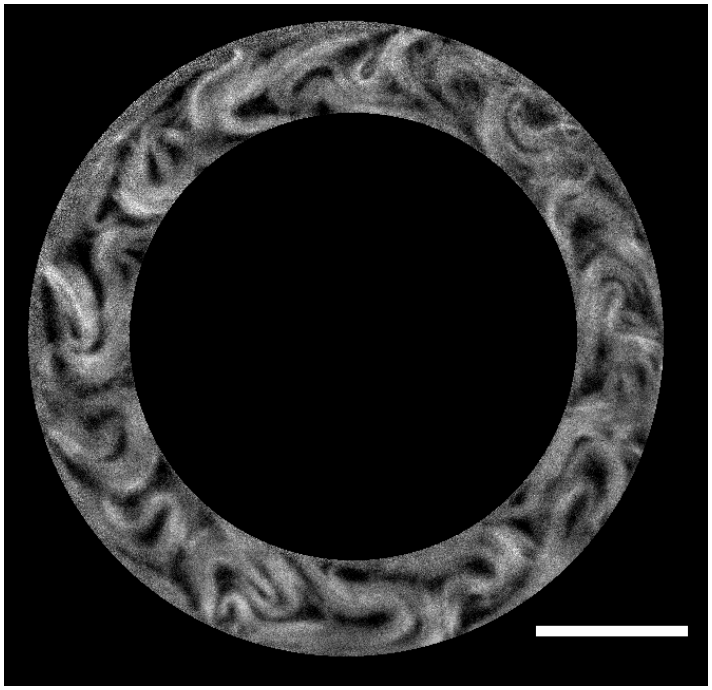
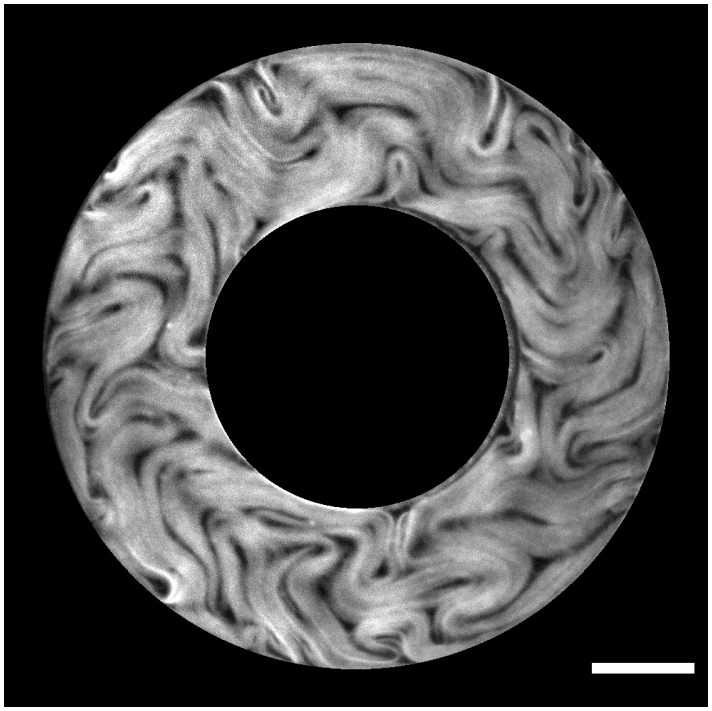


Fig. S6 Wall-induced rectification in asymetric annuli. (a,e) Sketches of square annuli with asymetric outer boundaries. (b,f) Fluorescence micrographs of active nematics confined in asymetric square annuli. (e,g) Time-series of a pixel ring at the center of the annuli. (d,h) FFT computation of the times series (e,g) showing clockwise (resp. counter-clockwise) transport.

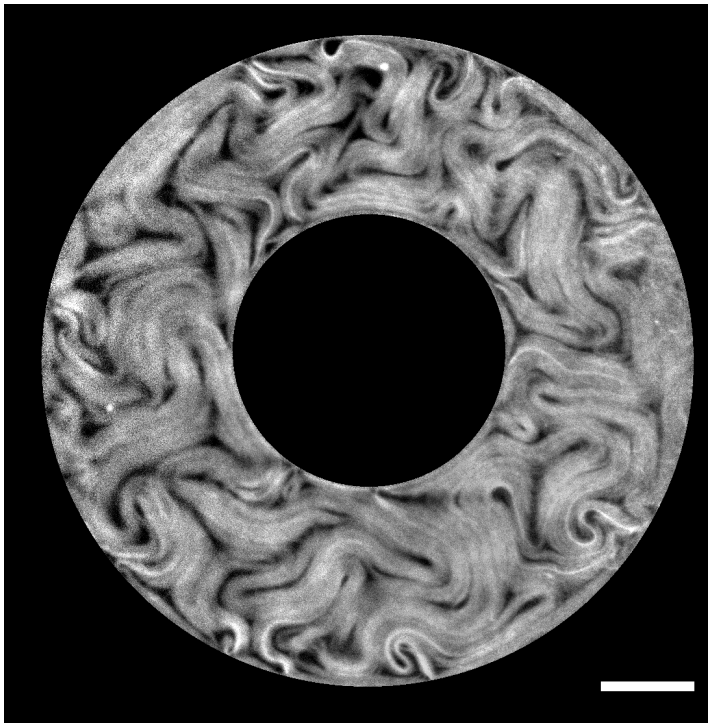
Supplementary Video Captions



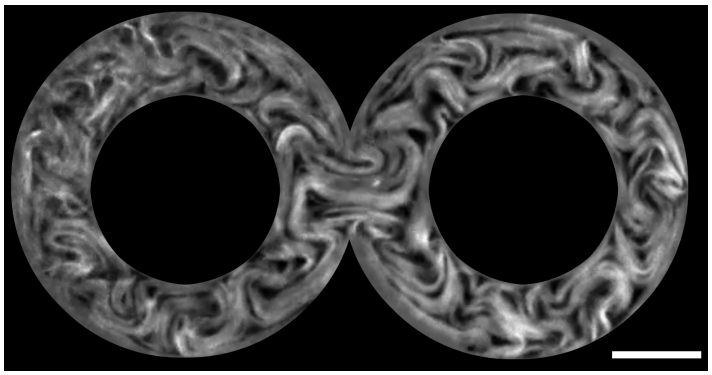
Movie S1 Symmetry Breaking. Confocal fluorescence video of active nematics confined in a $60\ \mu\mathrm{m}$ wide annulus. The image is overlapped with a black mask around the region of interest, for a better visualization. *scale bar:* $100\ \mu$m.



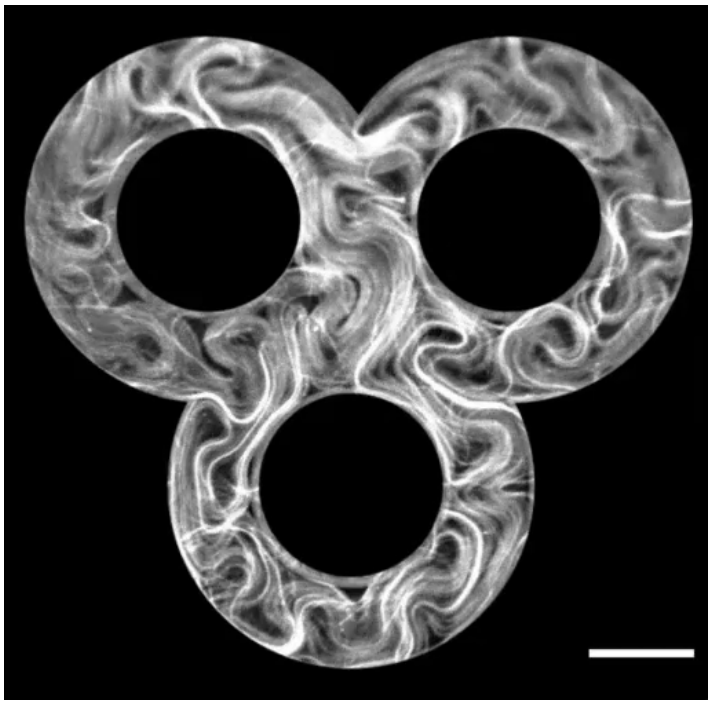
Movie S2 Switching state. Confocal fluorescence video of active nematics confined in a $110\ \mu\mathrm{m}$ wide annulus. The image is overlapped with a black mask around the region of interest, for a better visualization. Scale bar: $100\ \mu$m.



Movie S3 Turbulent state. Confocal fluorescence video of active nematics confined in a $200\ \mu\mathrm{m}$ wide annulus. The image is overlapped with a black mask around the region of interest, for a better visualization. Scale bar: $100\ \mu$m.



Movie S4 Synchronisation in a Genus 2. Confocal fluorescence video of active nematics confined in a genus 2 handle-body, with an overlapping distance of $D/2R_0 = 0.94$. The width of each annulus is $w = 80\ \mu$m. The image is overlapped with a black mask around the region of interest, for a better visualization. Scale bar: $100\ \mu$m.



Movie S5 Frustration in a Genus 3. Confocal fluorescence video of active nematics confined in a genus 3 handle-body. The width of each annulus is $w = 80$ μm and the overlapping distance is $D/2R_0 = 0.83$. The image is overlapped with a black mask around the region of interest, for a better visualization. Scale bar: 100 μm.