Electronic Supplementary Material (ESI) for Soft Matter.

Supplementary Information for

Emergence and Dynamics of Unconfined Self-Organised Vortices in Active Magnetic Roller Liquids

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Legends for Movies S1 to S7

Movie S1. Complete evolution of a stable multi-vortex state in a system of size 128 × 128 particle diameters showing the vorticity of the particle vorticity as iso-surface and the fluid velocity as streamlines. Fig. 1 shows a snapshot of this simulation. The system was discretized on a regular grid of 1024 × 1024 points and integrated over 150000 time steps, corresponding to about 2 sec real time. The field frequency is 45Hz.

Movie S2. The same simulation as in Movie S1, but the particle density, ρ, is shown as iso-surface and particle velocity as streamlines.

Movie S3. Emergence of a macroscopic vortex structure from a group of rollers. The first column: experimental observation; The second column: the corresponding color-coded visualization retrieved from single-particle tracking; The last column: the corresponding vorticity map calculated from particle image velocimetry (PIV). f_H = 40 Hz, H_0 = 35 Gauss. The movie is at 0.5× speed.

Movie S4. The movie shows the process of merging two vortices with same chirality as close-up of a small region as shown in Fig. 3a. Visualized are the particle vorticity as iso-surface and particle velocity as streamlines (also beyond the region used to in Fig. 3a).

Movie S5. The movie shows the process of annihilation two vortices with opposite chirality as close-up of a small region as shown in Fig. 3c. Visualized are the particle vorticity as iso-surface and particle velocity as streamlines (also beyond the region used to in Fig. 3b).

Movie S6. Steady multi-vortex state with opposite chirality. The left column: experimental observation; The right column: the corresponding vorticity map calculated from PIV. f_H = 40 Hz, H_0 = 35 Gauss. Real-time playback.

Movie S7. Role of magnetic interactions in the macroscale dynamics of multi-vortex state. The first column: experimental observation; The second column: the corresponding PIV velocity map; The last column: the corresponding PIV vorticity map. At H_0 = 30 Gauss (0~5 sec), the aggregation of rollers is observed in the vortex core as a result of the weak magnetic repulsion that often prevents the emergence of large stable vortices. When the field amplitude is increased to H_0 = 35 Gauss (5~10 sec), the increase in the magnetic repulsion eliminates the roller aggregation that allows the growth in the vortex size. A H_0 = 40 Gauss (10~15 sec), the stronger magnetic repulsion facilitates the further incrase in the vortex size. f_H = 40 Hz. The movie is at 2× speed.

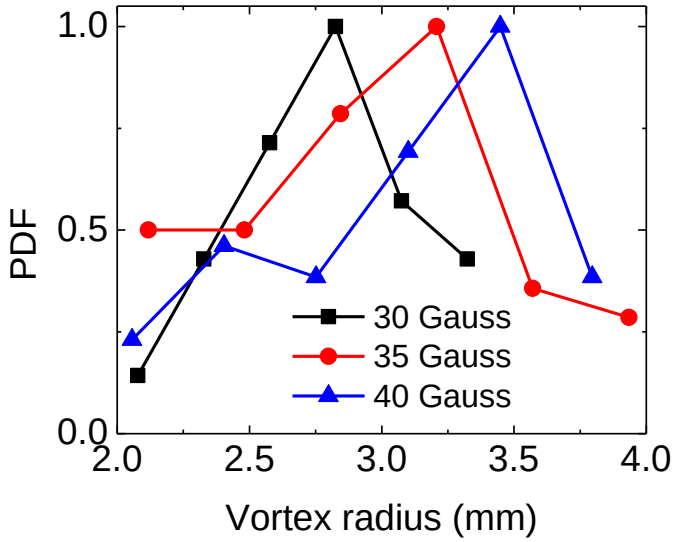

Figure S1. Probability distribution function (PDF) of the vortex size depending on the field amplitude. The number of observed vortices is about 20 for each amplitude condition. PDF is normalized by the most probable vortex size at each amplitude.