# Active microrheology in two-dimensional magnetic networks
# Supplementary Information

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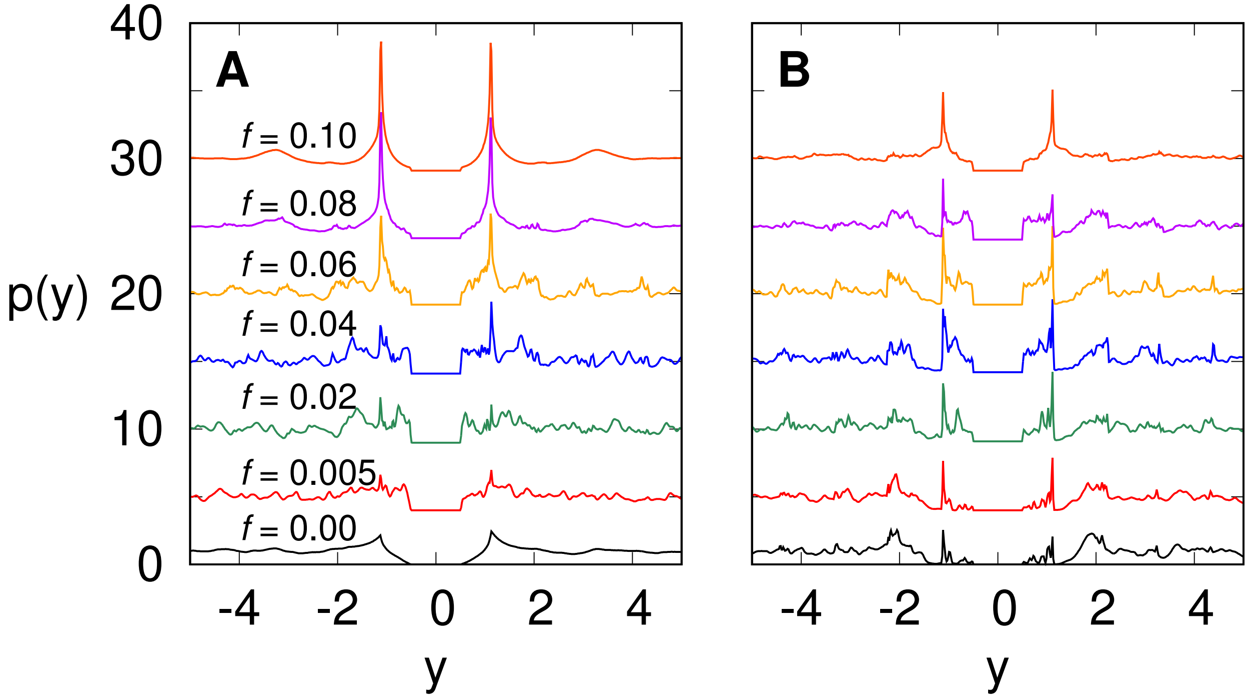


Fig. S1: Partial correlation function in the direction orthogonal to pulling force direction, $p(y)$, around the **A** non-magnetic and **B** magnetic tracer particles. Colors correspond to values of the pulling force $f$, from the top to the bottom: $f = 0.10$ (oragne-red), 0.08 (dark-magenta), 0.06 (orange), 0.04 (blue), 0.02 (drak-green), 0.005 (red) and 0.00 (black). For the purpose of clarity, the curves are vertically shifted.

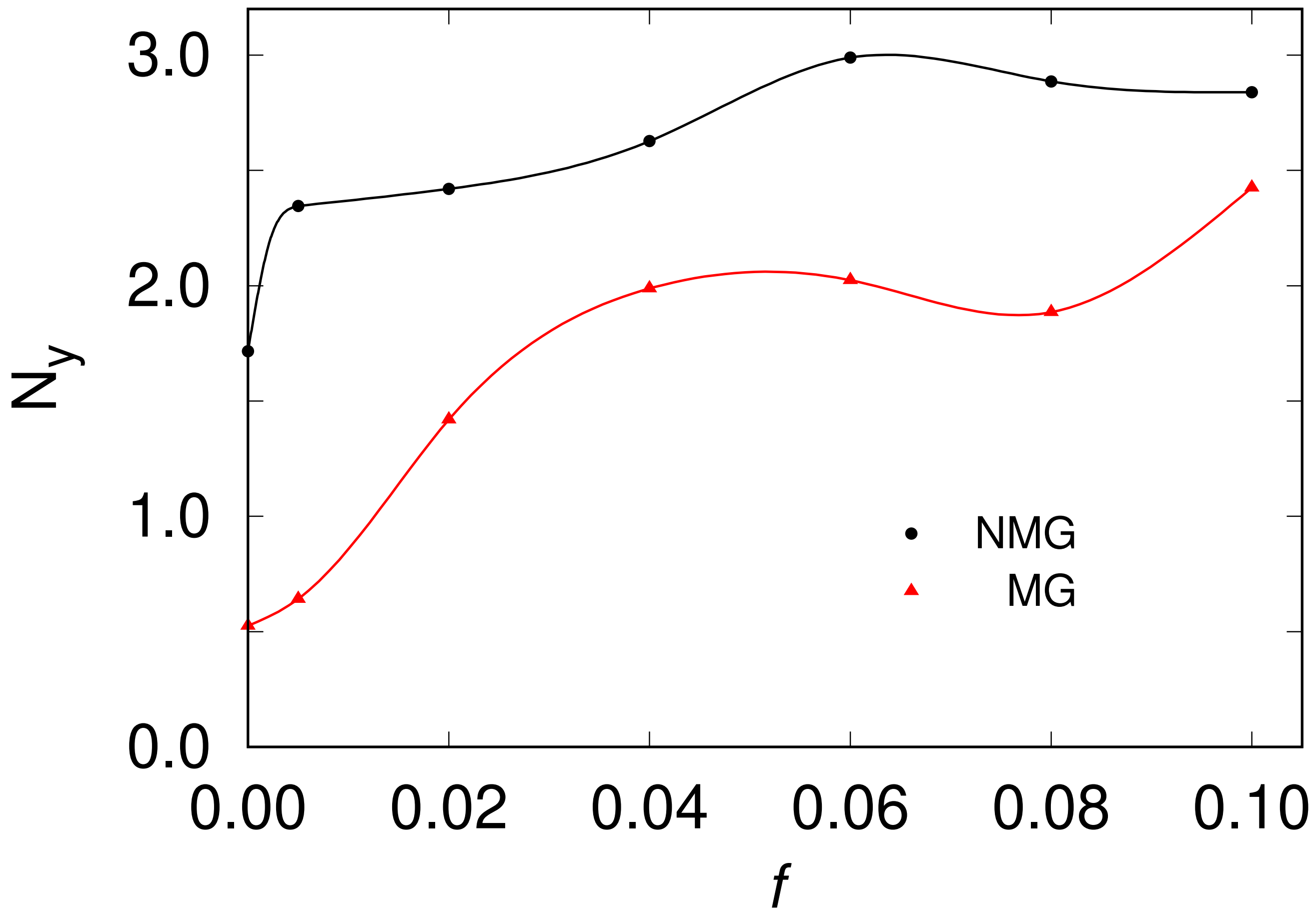


Fig. S2: The number of nearest matrix particles in the direction orthogonal to force direction for both non-magnetic(black circle) and magnetic(red triangle) tracer particles as a function of force $f$. The curves are guide to the eye.

Fig. S1 presents the matrix structure changes around tracer particles in the direction orthogonal to pulling force direction. For both non-magnetic and magnetic tracer particles, $p(y)$ is symmetrical around $y = 0$ at all pulling force strengths. The number of nearest matrix particles in the direction orthogonal to pulling force direction(the nearest peak size in Fig. S1) as a function of pulling force $f$ which is shown in Fig. S2 in order to clarify this tendency. For non-magnetic tracer particle, when pulling force $f$ increased from 0 to 0.005, see Fig. S2 black curve, the number of nearest matrix particles of non-magnetic tracer particle increased from 1.716 ($f = 0$) to 2.346 ($f = 0.005$). Then for $0.005 \leqslant f \leqslant 0.06$, it slowly increase to 2.989 ($f = 0.06$). These phenomena indicate non-magnetic tracer particle first cling on the edge of a network cell and then deform the cell's shape until break it and cling on the contact point of three network cells. When pulling force $f$ increase to 0.08, the number of nearest matrix particles of non-magnetic tracer particle decrease to 2.878 because a channel structure formed behind of non-magnetic tracer particle. For magnetic tracer particle, see Fig. S2 red curve, the number of nearest matrix particles of magnetic tracer particle remain constant for $f \leqslant 0.005$ indicating that magnetic tracer particle remain its position in this situation. Then it increase from 0.641 to 1.988 for $0.005 \leqslant f \leqslant 0.04$. Here magnetic tracer particle cling on the edge of network cell and deform the cell's shape. The number of nearest matrix particles of magnetic tracer particle remains constant until pulling force $f > 0.06$ indcating that magnetic tracer particle begin replace the contact point of three network cells until a new contact point formed by itself at $f = 0.08$ (cf. Fig. 1 (**E**)).

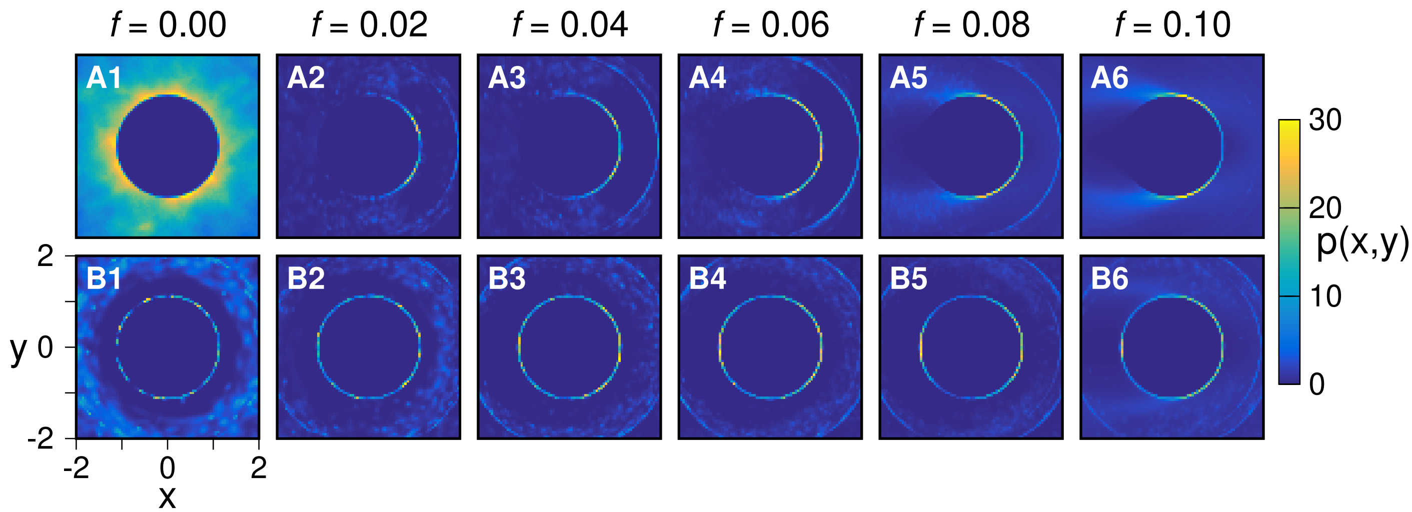


Fig. S3: Two-dimensional correlation function around tracer particles, $p(x, y)$. Panels **A1** to **A6** give the results for non-magnetic tracer particle, while panels **B1** to **B6** present magnetic tracer particle results. Different columns are shown the results for various pulling forces $\boldsymbol{f}$. The pulling force on a tracer particle is applied in $+\mathbf{x}$ direction.

Two-dimensional pair correlation function($p(x, y)$) is used to deeply understand local matrix structure changes around tracer particles. It is defined by

$$p(x, y) = \kappa \sum_i \delta\left(x - dx_{tr,i}\right) \delta\left(y - dy_{tr,i}\right) \tag{1}$$

with $\kappa = \frac{N_x N_y}{\rho L^2}$, $\rho$ the number density, $L$ the simulation box length and $N_x$, $N_y$ the number of bins in $x$ and $y$ direction, respectively.

The two-dimensional correlation function $p(x, y)$ is shown in Fig. S3. The top panel gives the results for non-magnetic tracer particle, while the bottom panel presents magnetic tracer particle results. Absence of pulling force, non-magnetic tracer particle result show a rough ring(Fig. S3 **A1**) but perfect ring formed surrounding the magnetic tracer particle(Fig. S3 **B1**). For non-magnetic tracer particle, at a small pulling force strength($f = 0.005$), peaks in $p(x, y)$ result appeared symmetrically for $y > 0$ and $y < 0$ and at $x = 1$. It means non-magnetic tracer particle start cling on the edge of a network cell. For intermediate forces(e.g. $f = 0.04$) the peak for non-magnetic tracer particle become smaller at y = 0, indicating that non-magnetic tracer particle is trying to break a network cell. For the second largest force which shows in Fig. S3($f = 0.08$), matrix particles around the non-magnetic tracer particle exhibit peaks at the top and bottom side of the tracer particle, which shows a channel structure is formed in this situation (cf. Fig. 1 (**D**)). Matrix particles around magnetic tracer particle, on the other hand, exhibit peaks also behind the tracer's posiiton($x < 0$), which suggest the magnetic tracer particle trapped into the center of a network cell for all situations. At pulling force strength equals 0.08, matrix particles around the magnetic tracer particle exhibit peaks in front of($x > 0$) and behind of($x < 0$) the tracer particle's position($(0, 0)$), which means the magnetic tracer particle broke the contact point of three network cells and formed a new contact point by itself (cf. Fig. 1 (**E**)). From Fig. S3, we can get qualitative information about critical channel formation force $f^{\mathrm{C}}_{\mathrm{channel}}$ for two types of tracer particles. For non-magnetic tracer particle, $f^{\mathrm{C}}_{\mathrm{channel}} \approx 0.80$ while $f^{\mathrm{C}}_{\mathrm{channel}} > 0.80$ for magnetic tracer particle.

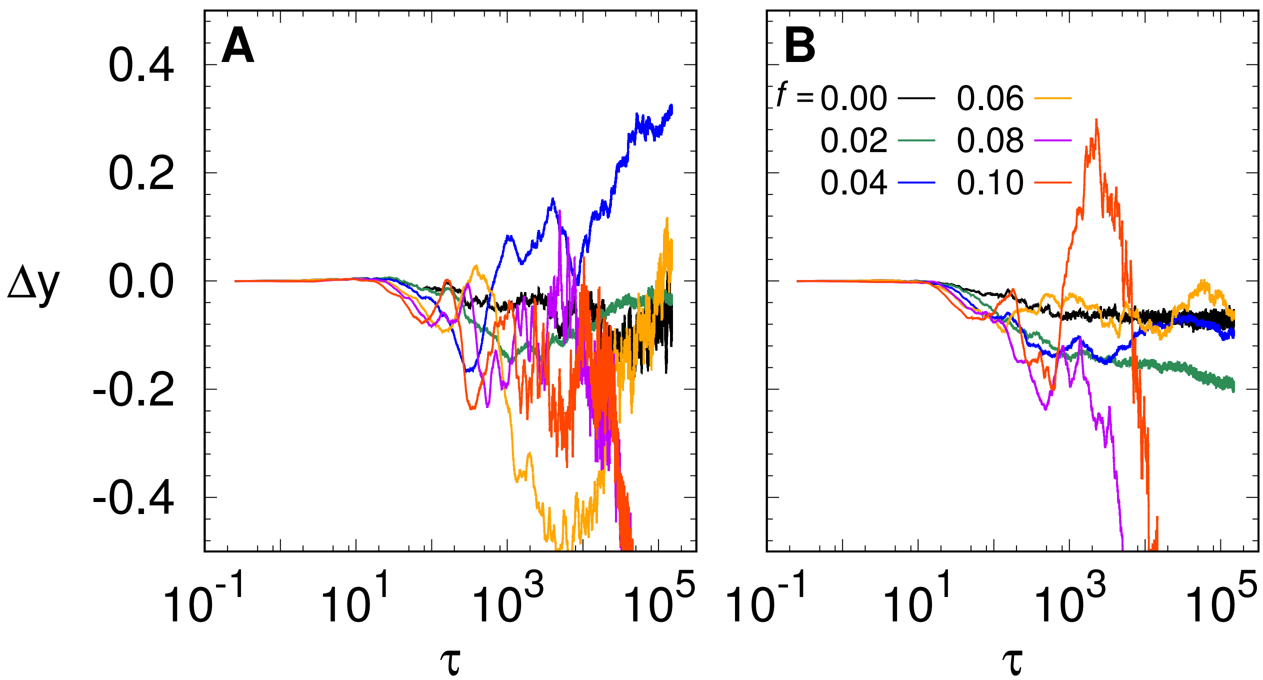


Fig. S4: Time dependent displacement orthogonal to the force direction $\Delta y = \langle y(t) - y(0) \rangle$ for nonmagnetic (**A**) and magnetic (**B**) tracers. Colors correspond to values of the pulling force $f$. $f$ = 0.10 (oragne-red), 0.08 (dark-magenta), 0.06 (orange), 0.04 (blue), 0.02 (drak-green) and 0.00 (black).

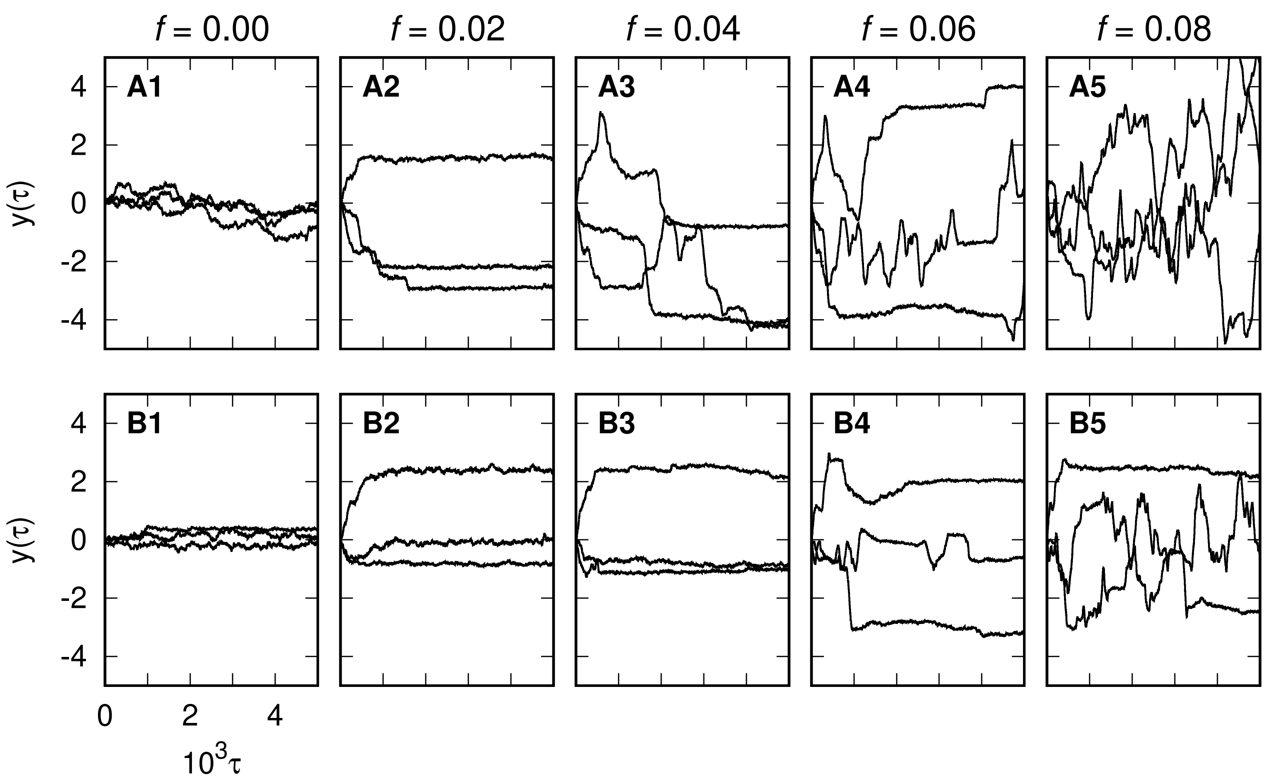


Fig. S5: Typical trajectories of tracer particles in the direction parpendicular to the force direction. Panels **A1** to **A5** give the results for non-magnetic tracer particle, while panels **B1** to **B5** present the results for magentic tracer particle. Different columns correspond to different pulling force $f$.