Electronic Supplementary Material (ESI) for Soft Matter

Slow and anomalous dynamics of collective cell migartion

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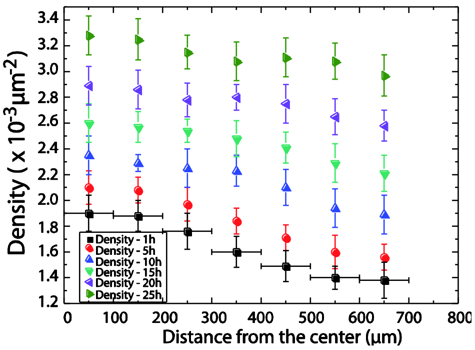

Fig. S1. A) The spatial density distribution of the cell density for the first data set from the center of the monolayer to the edge of the monolayer for various times (Mean ± SD). The density was determined within areas of sizes (100 x 100) μm^2. The times plotted from bottom (black) to the top (green) are 1, 5, 10, 15, 20, and 25 h. On short times, there was a density gradient from the center of the monolayer to the edge of the monolayer. However, over times, the gradient vanished and the monolayer became denser as a result of cell division.

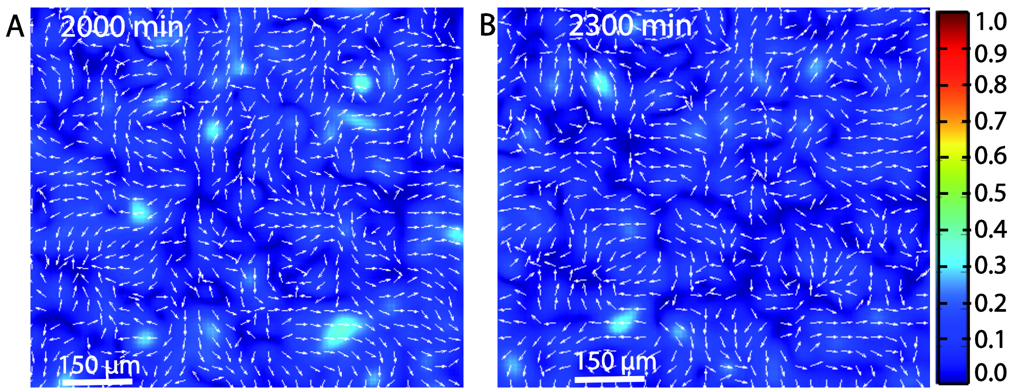

Fig. S2. The speed distribution and displacement field of the MCF-10A monolayer for the time 2000 min and 2300 min. The displacement fields are generally random while the velocity is almost zero. The velocity is color coded as in Fig. 1 b and 1c.

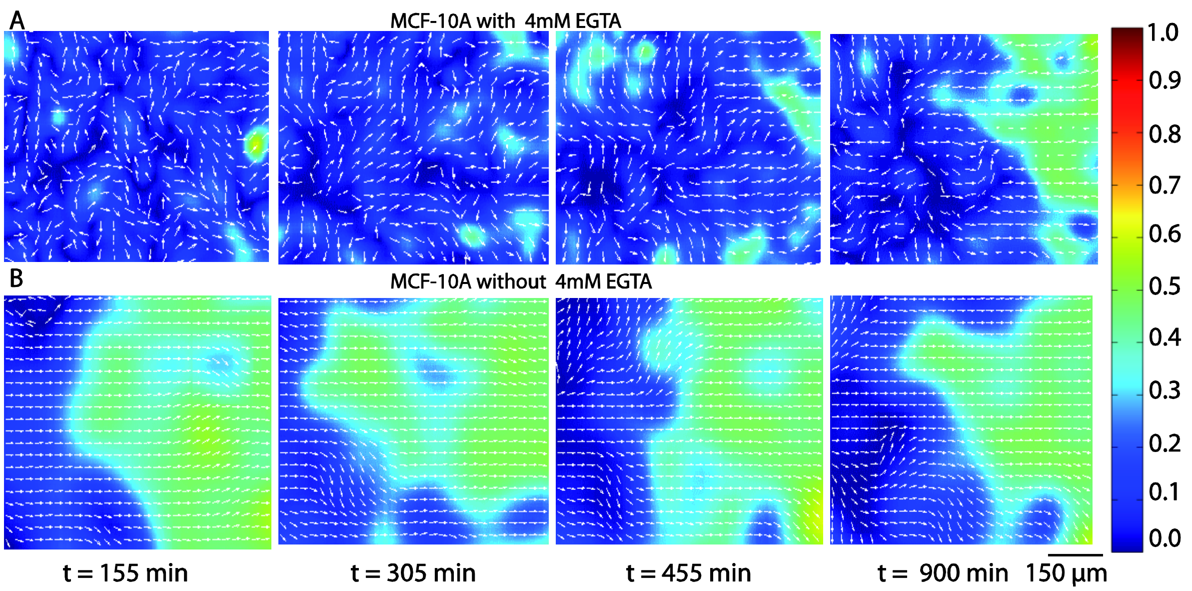

Fig S3. The time evolution of the velocity of an MCF-10A monolayer treated with 4mM EGTA (A) and without EGTA (B). This distribution of the velocity is from the center towards the edge of the monolayers (from left to right). The arrows are the displacement fields while the velocity is color coded. The color code is the same as in Fig. 1b and C of the paper.

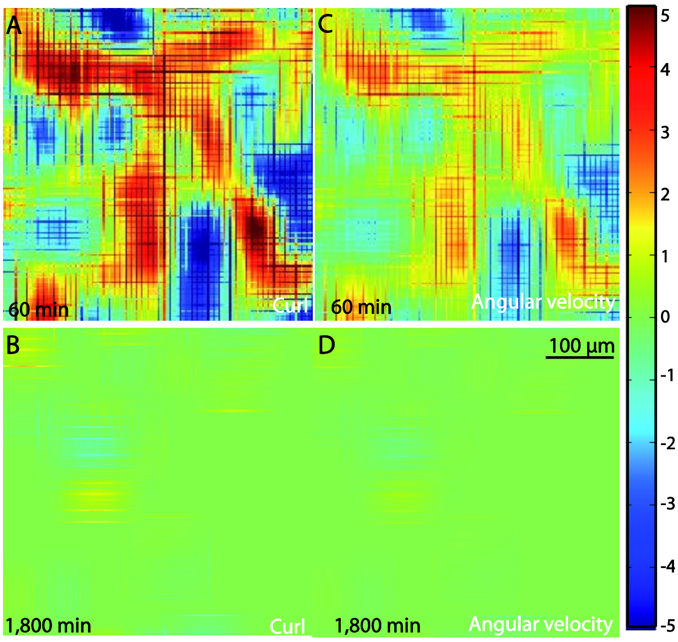

Fig S4. The curl of the velocity vector fields of an MCF-10A monolayer after 60 (A) and 1800 (B) minutes of migration. C) and D) are the corresponding angular velocity at the times 60 and 1800 minutes respectively. The scale bar (x 10^{-3}) is the same for A-D. For the angular frequency, the units of the color bar are in rad/min. A radian is 57.2°.

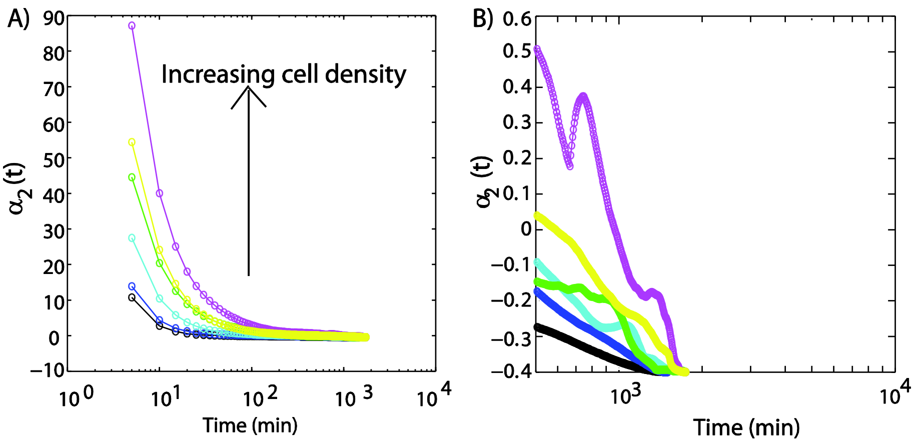

Fig. S5. A) The Non-Gaussian parameter for various cell densities as a function of time. On short times, $\alpha_2(t)$ increased with higher cell density thereby indicating that single cell dynamics is more anomalous on short time as the density increases. B) is the magnification of the A) showing that the non-Gaussian parameter peaks in the vicinity of the cage breaking time. At higher densities $\alpha_2(t)$ peaks at the cage escape times thereby confirming the intermittent nature of caging and cage escape processes. $\alpha_2(t)$ was derived from the mean squared displacement and was defined as $\alpha_2(t) = (3[\Delta r^4(\Delta t)]/5[\Delta r^2(\Delta t)]^2)-1$, where [...] indicates the ensemble and time step averages.

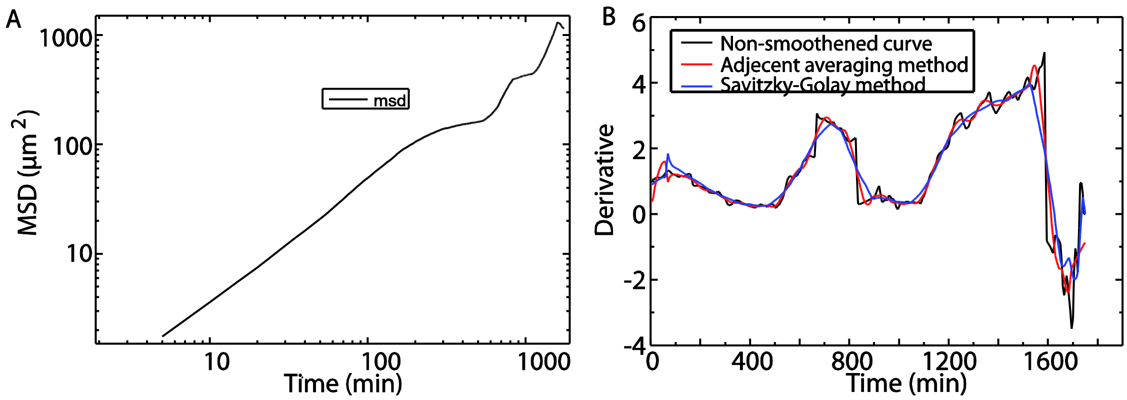

Fig. S6. A) A plot of the mean square displacement (Msd) at the highest cell density as shown in Fig. 4 in the main article. B) A plot of the logarithmic derivative of the Msd after smoothening the Msd using the adjacent averaging method (red) and the Savitzky-Golay method (blue).

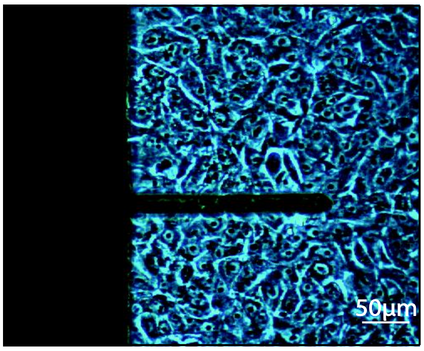

Fig. S7. A phase contrast image of a cell monolayer showing the cantilever. The cell density was determined from the snapshots by counting the cell nuclei within an area.

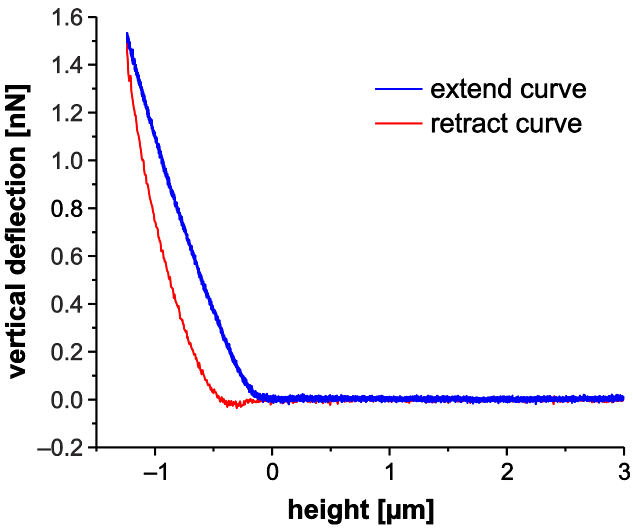

Fig. S8 shows a typical force-distance curve showing the cantilever's vertical deflection depending on the height during one scanning cycle at one point on the cell-monolayer. The vertical deflection has been converted into the corresponding force using the calibration of the cantilever's sensitivity and spring constant. For elasticity analysis, only the extend curve was of importance. The origin of the height-axis was set to that height at which the cantilever just touched the sample (contact height). Typically the indentation depth of the cell-monolayer was below 1.5 μm.

Movie S1. This movie shows an example of a measurement, that is, an MCF-10A cell monolayer migrating outward over time. The movie shows 40 hours of a measurement.

Movie S2. This movie shows how the velocity distribution of an MCF-10A monolayer varies over time and space. The displacement fields (white arrows) are uni-directional and the cooperative velocity spans several cell diameters. Moreover, the velocity is lowest at the center of the monolayer and highest at the edges of the monolayer.

Movie S3. This movie shows the spatial and temporal evolution of an MCF-10A monolayer treated with 4 mM EGTA. The displacement fields of the monolayer are more random on short times although the velocity remains spatially and temporally heterogeneous. However, on longer time, the displacement fields becomes uni-directional. Thus, EGTA effects a more random motion on short times time scales.