Droplet coarsening in an active biomimetic fluid

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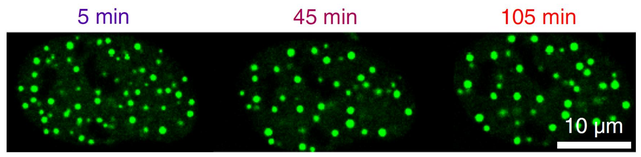
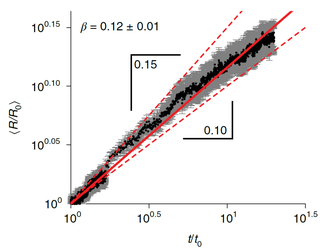
Abstract

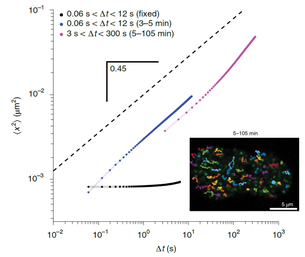
In this work, we design a 3D composite system which elucidates how the advective environment of the cell cytoplasm contributes to organelle coarsening. We employ two separate model systems: phase separating DNA structures, and microtubule-based active fluids. We find that active fluid flows generate an enhanced diffusion type of droplet motion. Upon performing droplet coarsening measurements, we observe that large droplets form more quickly at high ATP concentration. The scaling exponent of the organelle coarsening is shown to not depend on ATP concentration, however. Going forward, this system will be leveraged to design a composite system to control active stresses internally through active phase separating droplets.

Organelle coarsening in cells



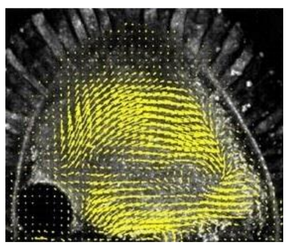
Fused in sarcoma condensates in the cellular nucleus[1]





Coarsening: $\langle R \rangle = (Kt)^{\beta}$ Motion: $\langle x^2 \rangle = D_{eff} t^{\alpha}$

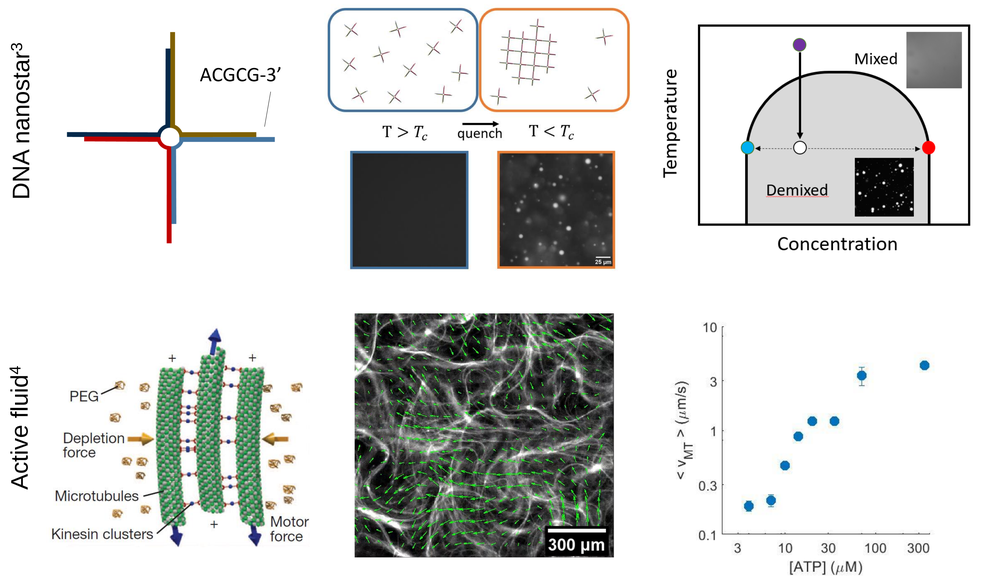
β modulated by diffusive exponent α



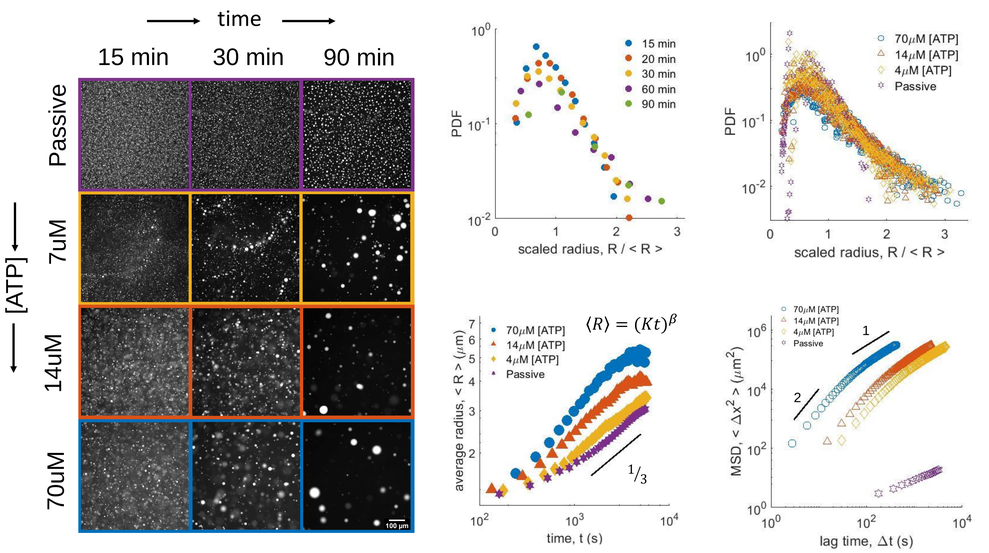
How does advection affect droplet coarsening?

Streaming in *Drosophila* oocyte[2]

Tunable composite model system



Droplet coarsening under advection



Conclusions/Future Work

- We have designed a composite system which couples advection to organelle phase behavior via two model systems
- Coalescence rate (β) indicates advective coarsening is a diffusive-like process regardless of ATP concentration
- Droplet motion is timescale dependent, with diffusion at long time scales
- In the near future, we plan to vary the active fluid correlation length and inspect the droplet distribution scaling

IRG2 Goals

- Our active composite system is a step towards mimicking organelles in a cytoplasmic environment
- In the future, we will leverage this system to attempt to control active stresses internally
- We will attempt to design a system which couples active fluid activity to the phase separating system (active droplets)

References

1. C. Brangwynne et al. "Germline P. granules are liquid droplets that localize by controlled dissolution/condensation." *Science*. 2009, 324:1729-1732
2. S Ganguly et al. "Cytoplasmic streaming in drosophila oocytes varies with kinesin activity and correlates with the microtubule cytoskeleton architecture." *PNAS*. 2012, 109:15109–15114.
3. S. Biffi et al. "Phase behavior and critical activated dynamics of limited-valence DNA nanostars." *PNAS*. 2013, 110:15633-15637.
4. Tim Sanchez et al. "Spontaneous motion in hierarchically assembled active matter." *Nature*. 2012, 491:431–434.

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