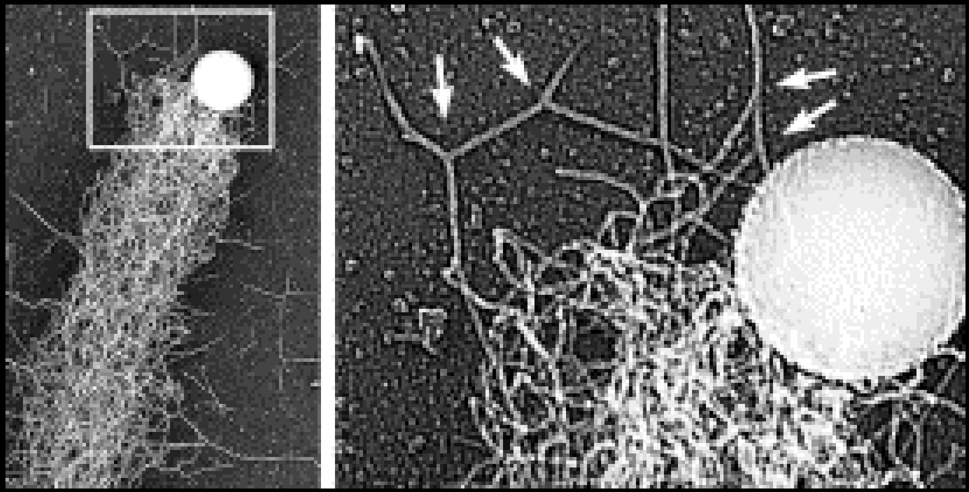
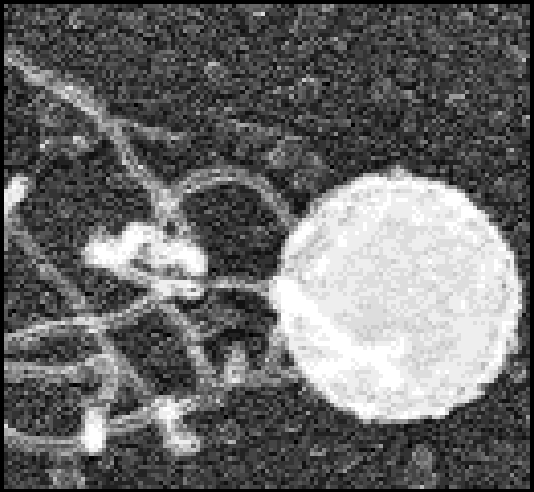
Mathematics & Neurobiology

University of California at Davis

Mesoscopic Model of Actin-Based Propulsion

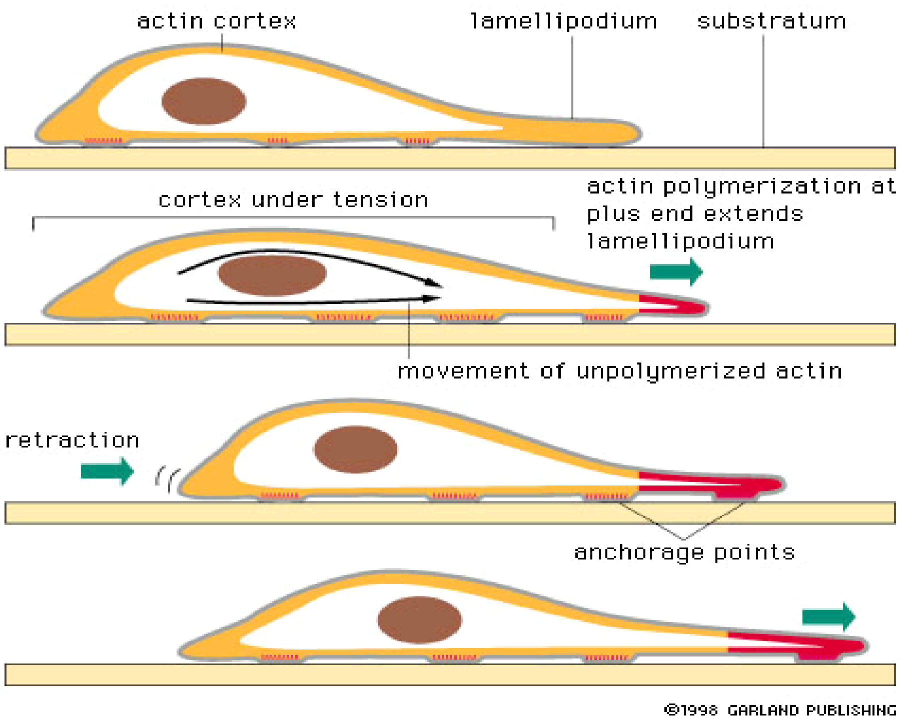
Alex Mogilner

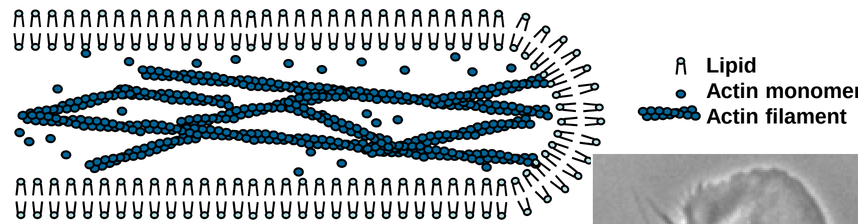


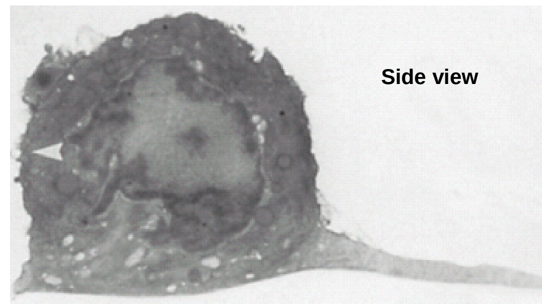


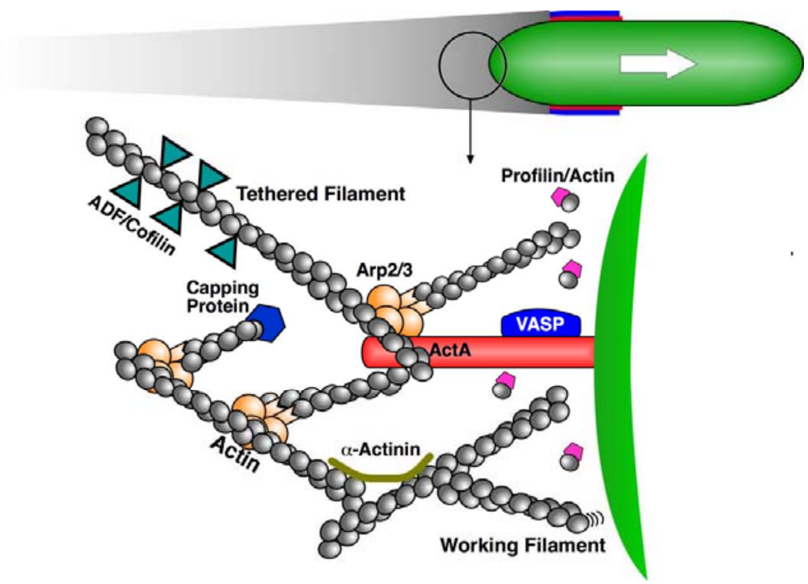
Cameron et al, 2001

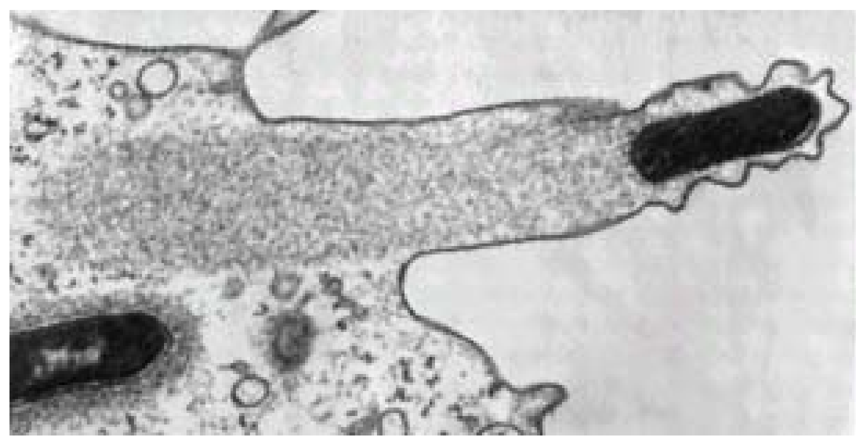
Actin based protrusion





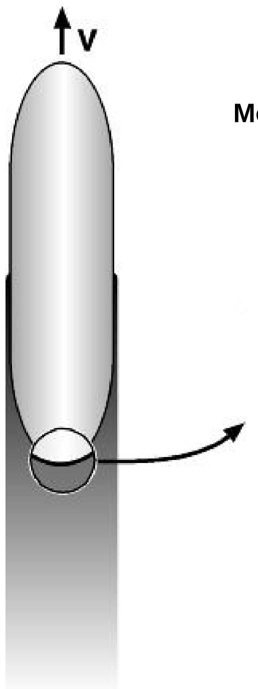




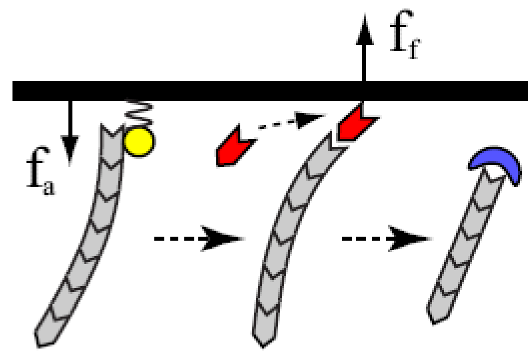


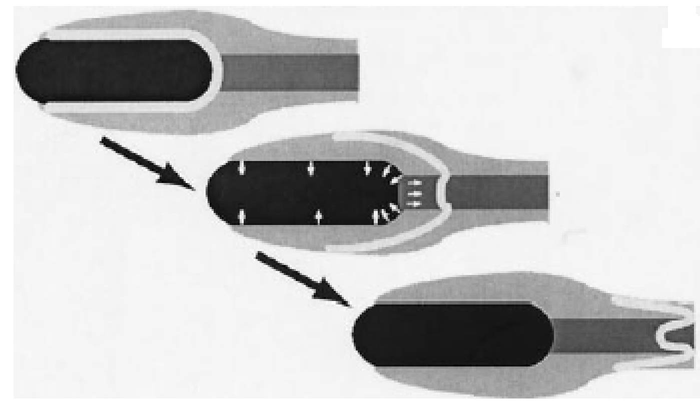
Two theories of force generation

Polymerization Ratchet vs Elastic Propulsion

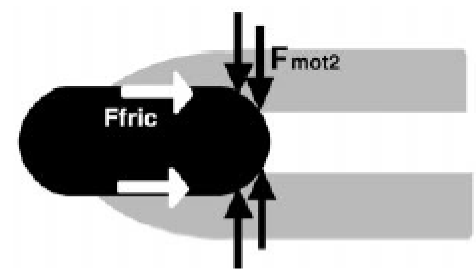


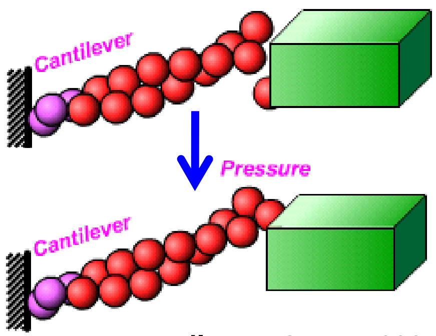
Mogilner & Oster, 2003





Gerbal, Prost et al, 2000 –



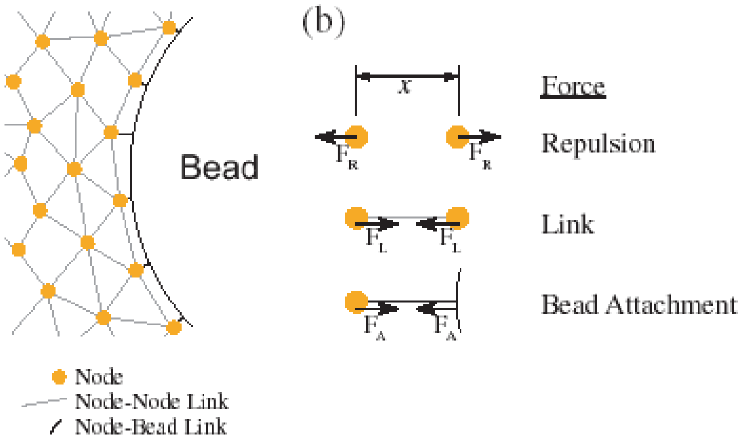


Mogilner & Oster, 1996

Agent-based computational models

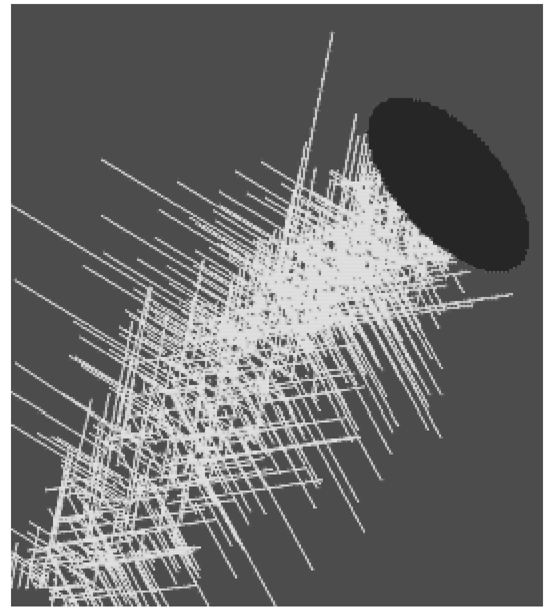
Dayel et al PLoS Biology 2009
Zhu et al 2011, In Preparation

Viscoelastic propulsion model:

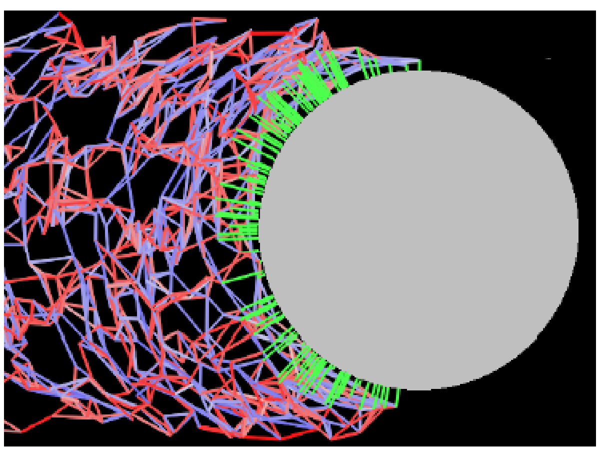


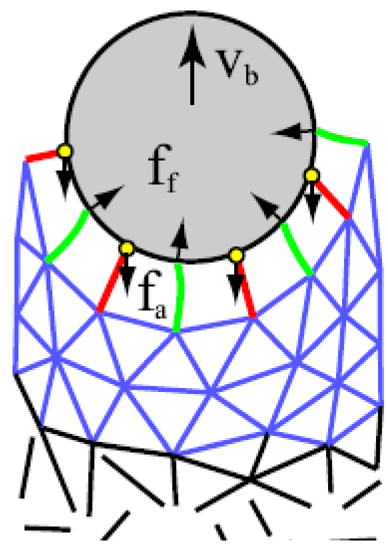
1) Nodes appear at the surface with constant rate and establish links with nearest neighbors with a given probability, decreasing linearly with distance; up to a given number of links.
2) The links are springs appearing in the unstressed state; if they are compressed, the neighboring nodes repel each other; if they are stretched, the neighboring nodes attract each other.
3) When the critical strain is reached, a link breaks irreversibly.
4) The bead attachments (also elastic) break with stress-dependent rate.

Polymerization ratchet model:



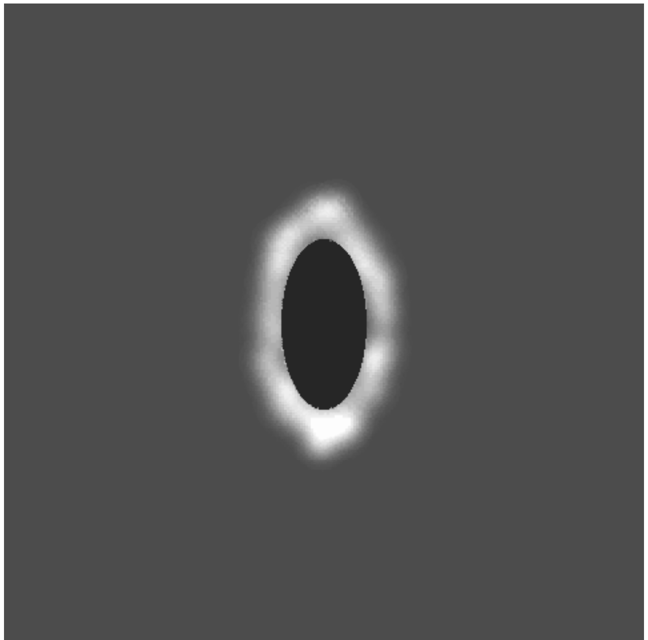
Hybrid model:

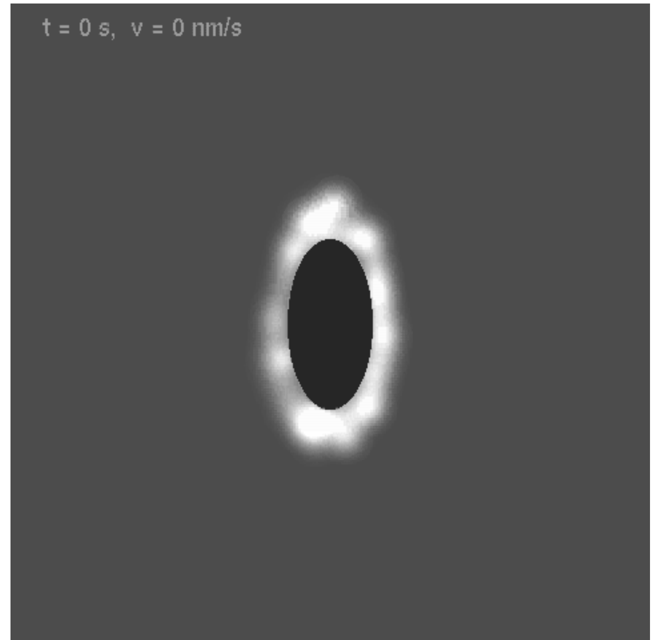




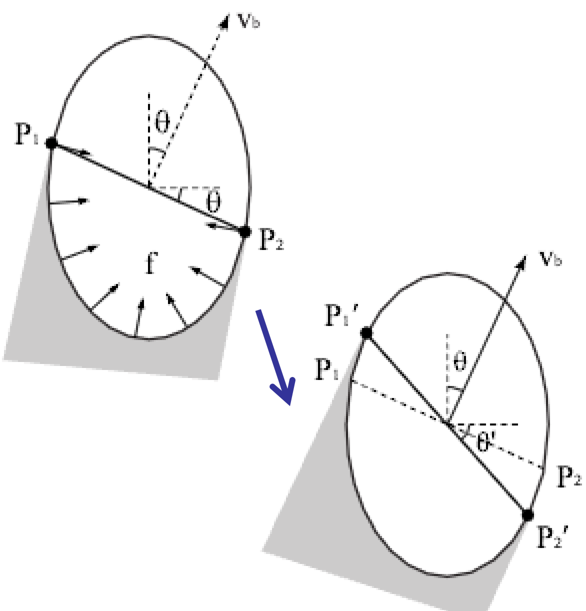
Different predictions for ellipsoidal beads:

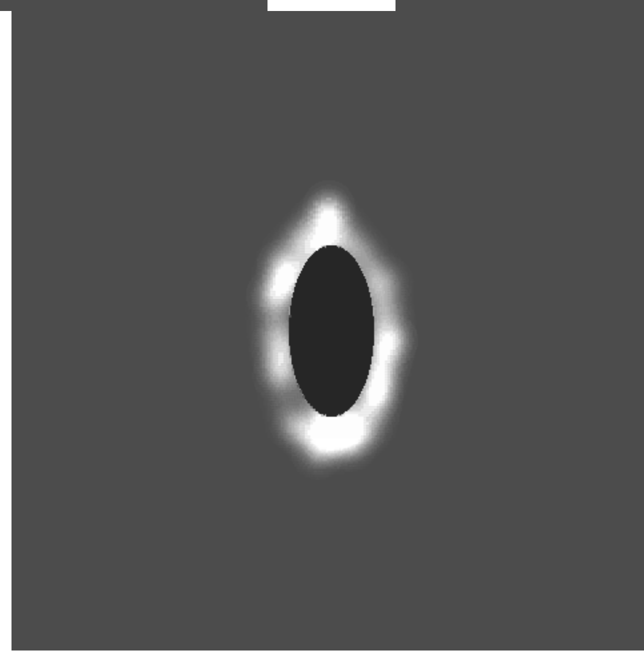
Growing viscoelastic actin network

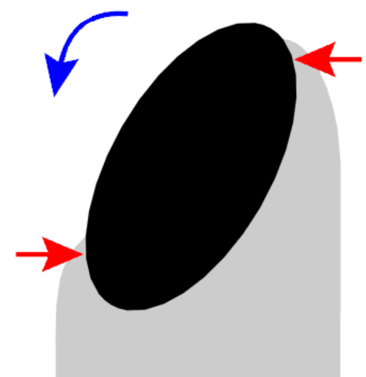




Rigid actin ratchet network



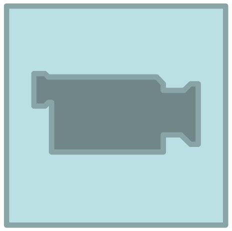


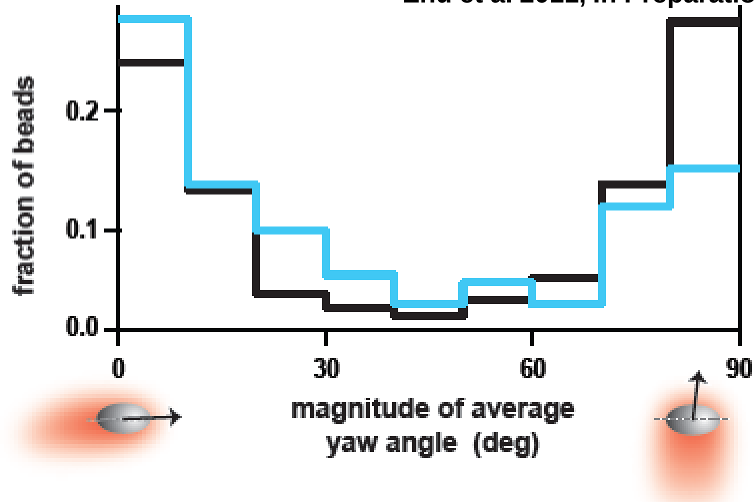


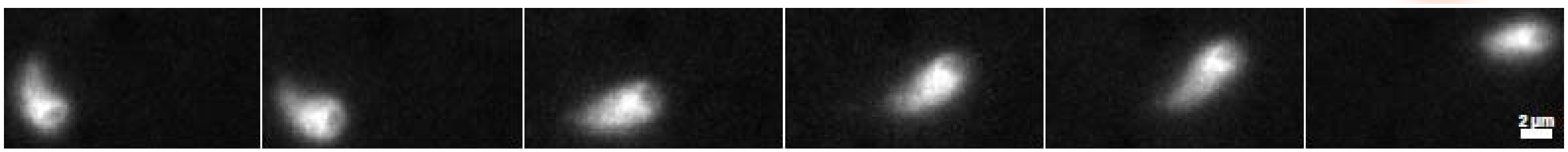
Viscoelastic-ratchet network

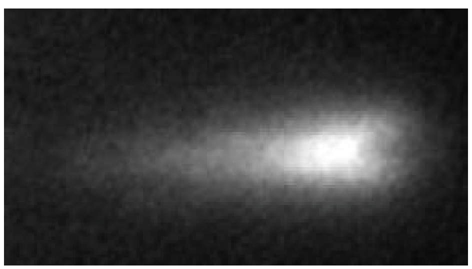
Experiment with ellipsoidal beads

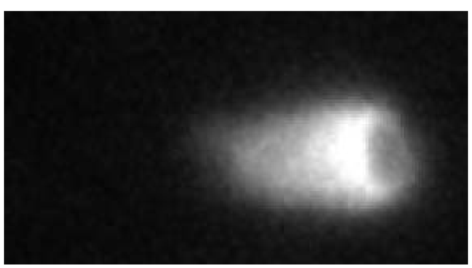
Lacayo et al 2011, PLoS Biology, submitted
Zhu et al 2011, In Preparation

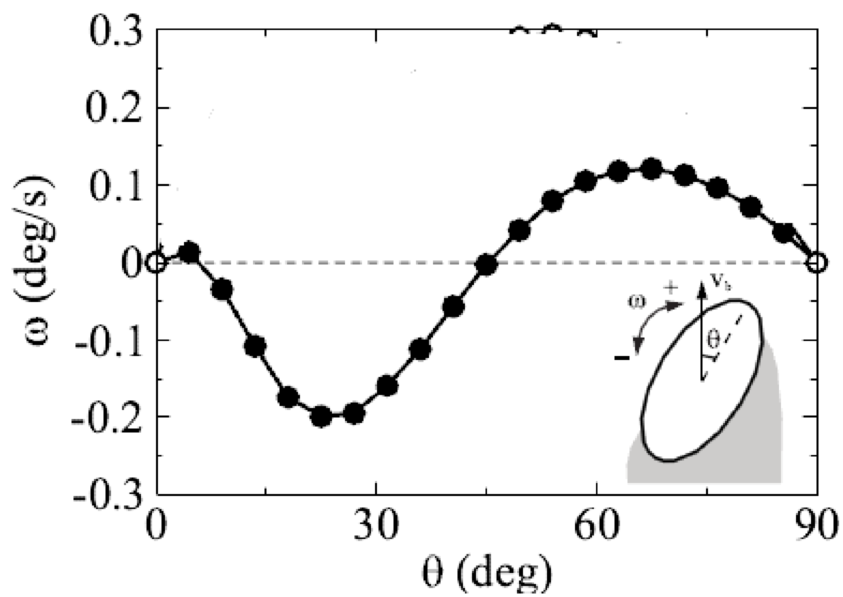


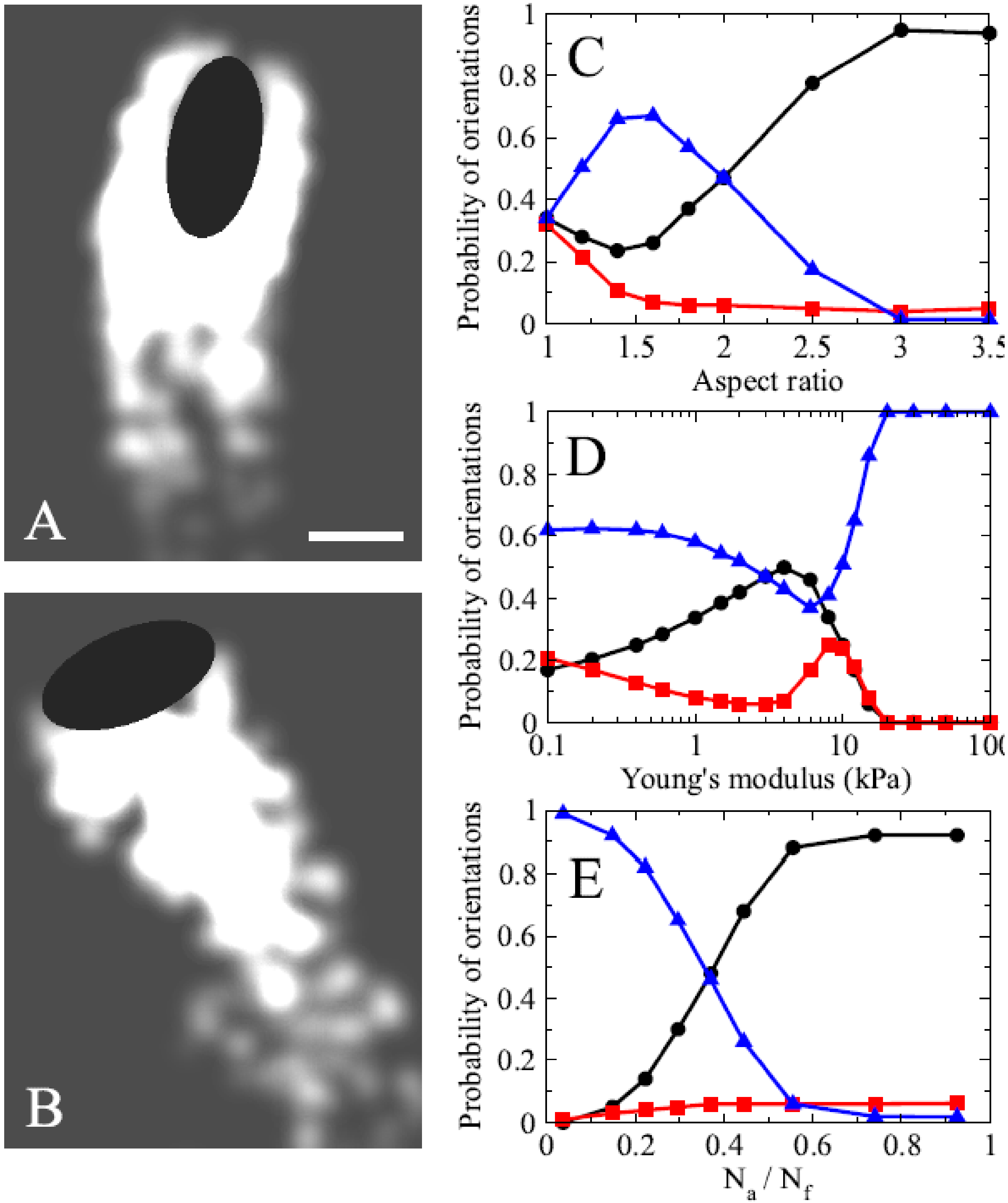








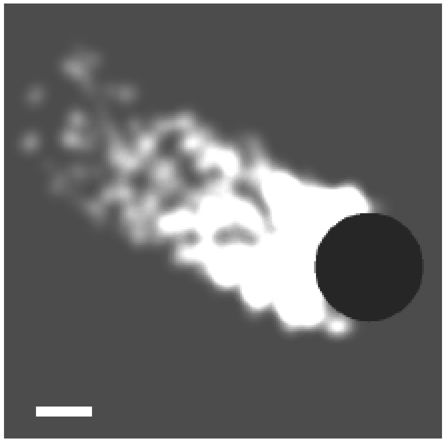


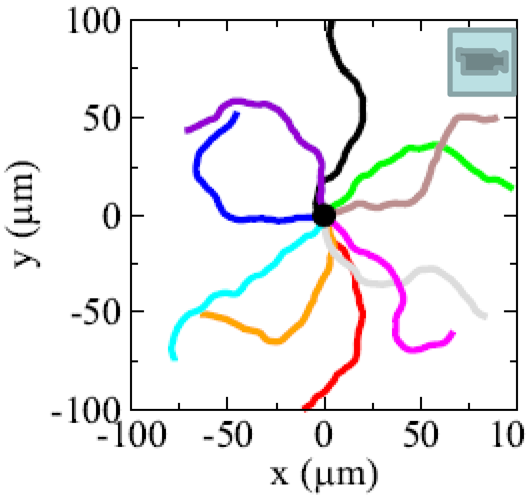


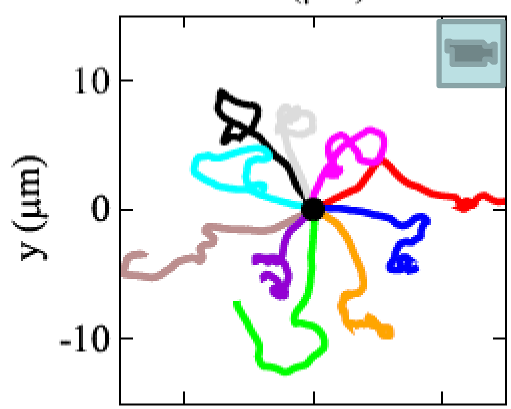
Zhu et al 2011,
In Preparation

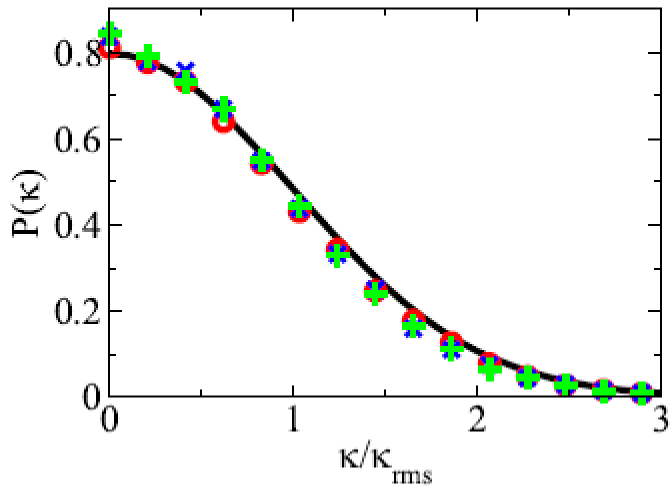
Curvature of the spherical beads' trajectories

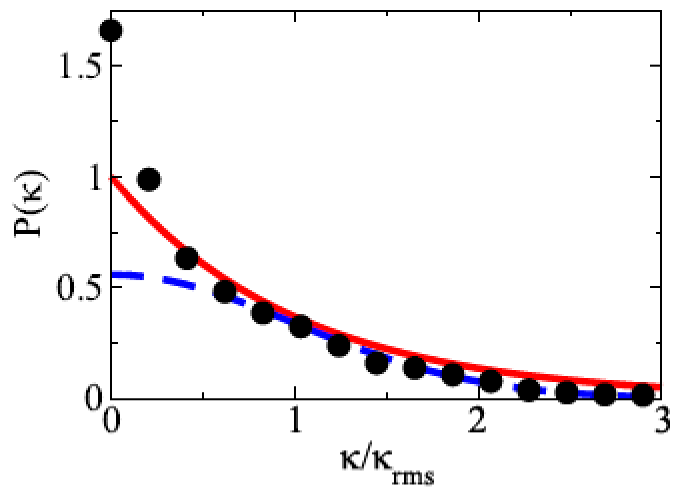
Zhu et al 2011, In Preparation



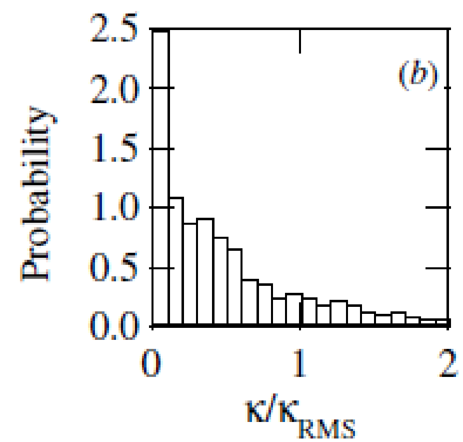




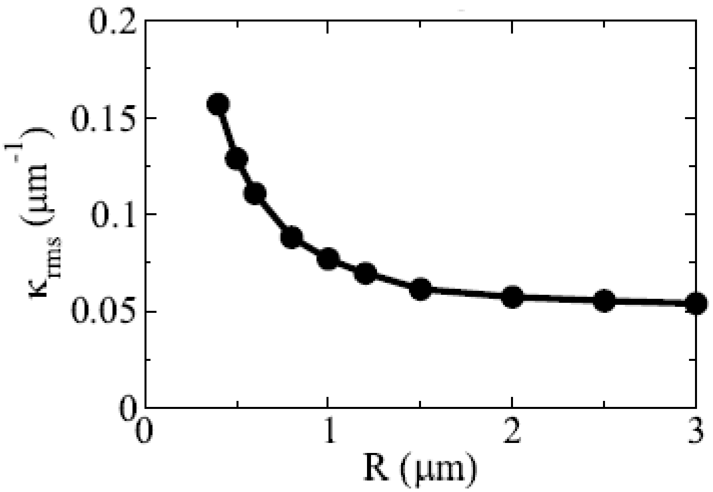




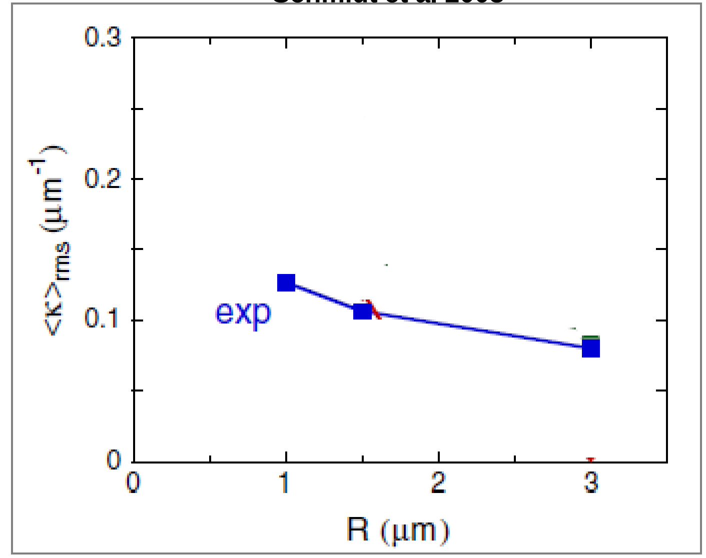
Shaevitz and Fletcher, 2008



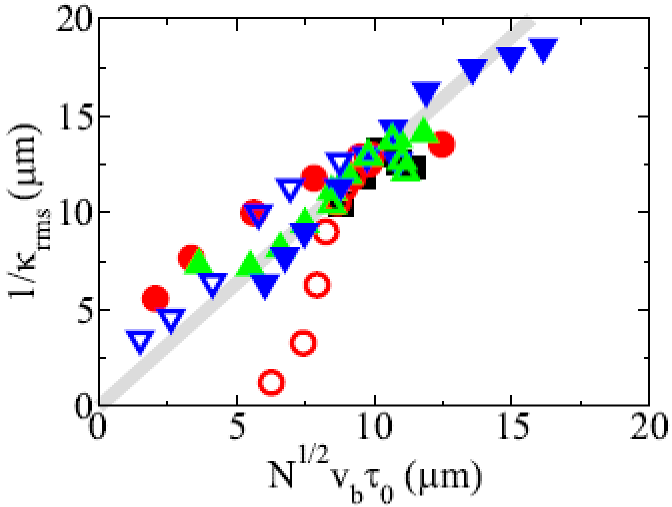
Zhu et al 2011, In Preparation



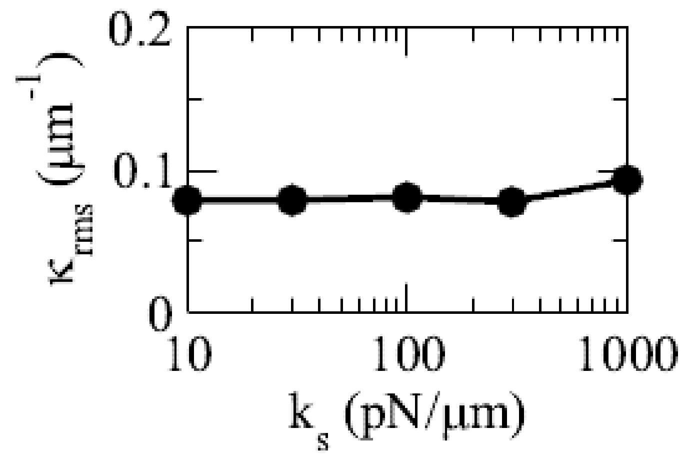
Schmidt et al 2008



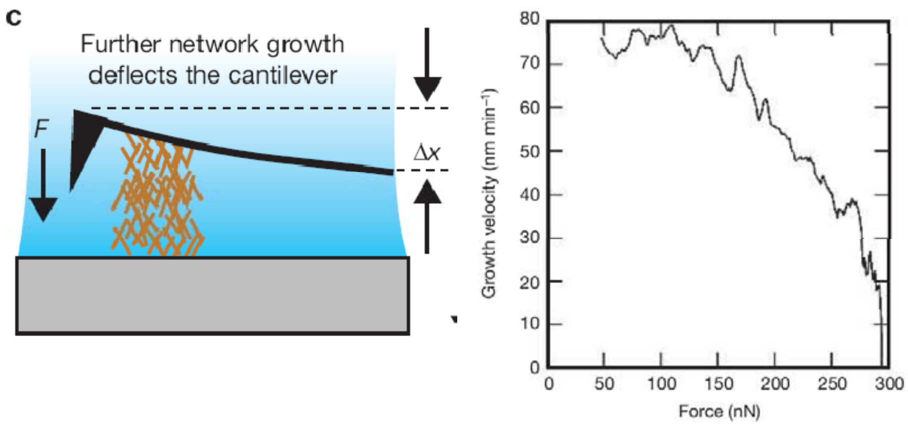
Nature of the curvature is random fluctuations of the filament density:

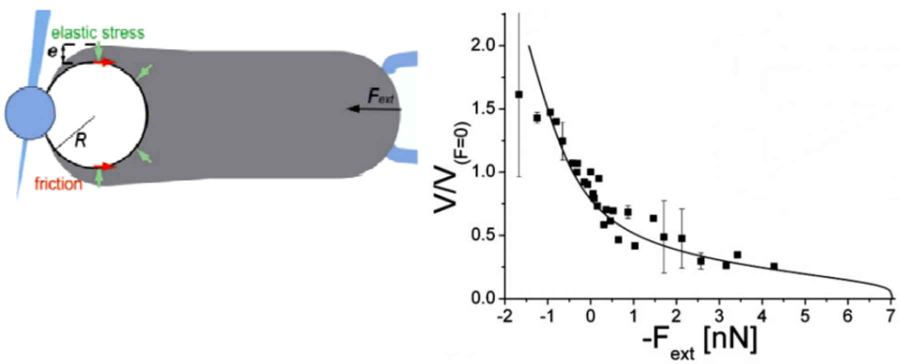


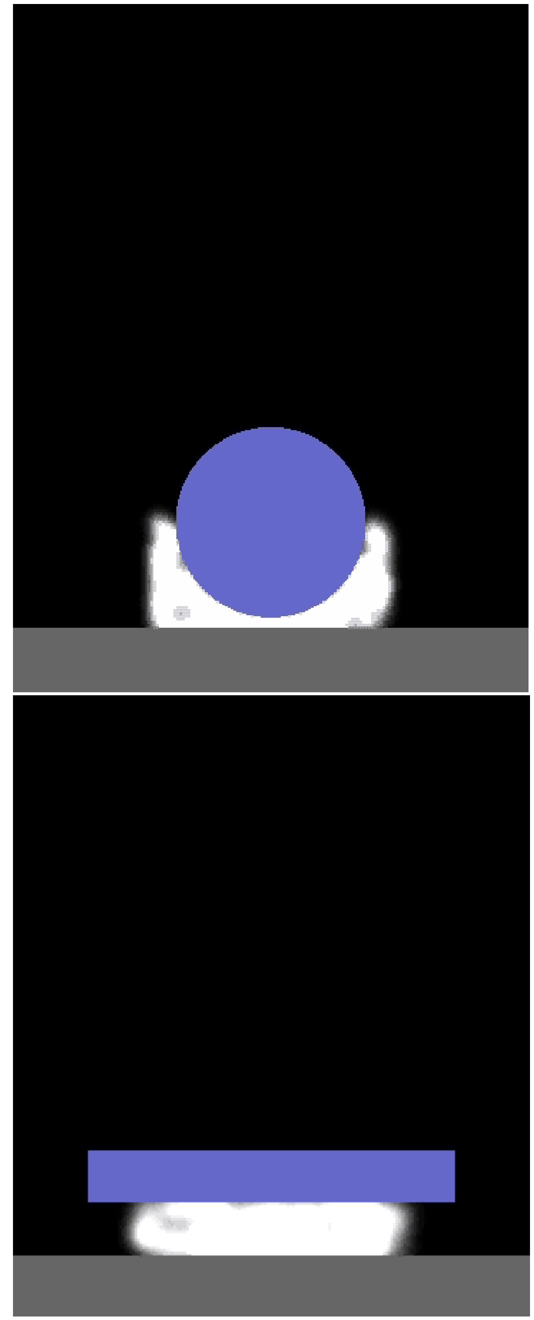
Elastic effects do not affect the curvature:



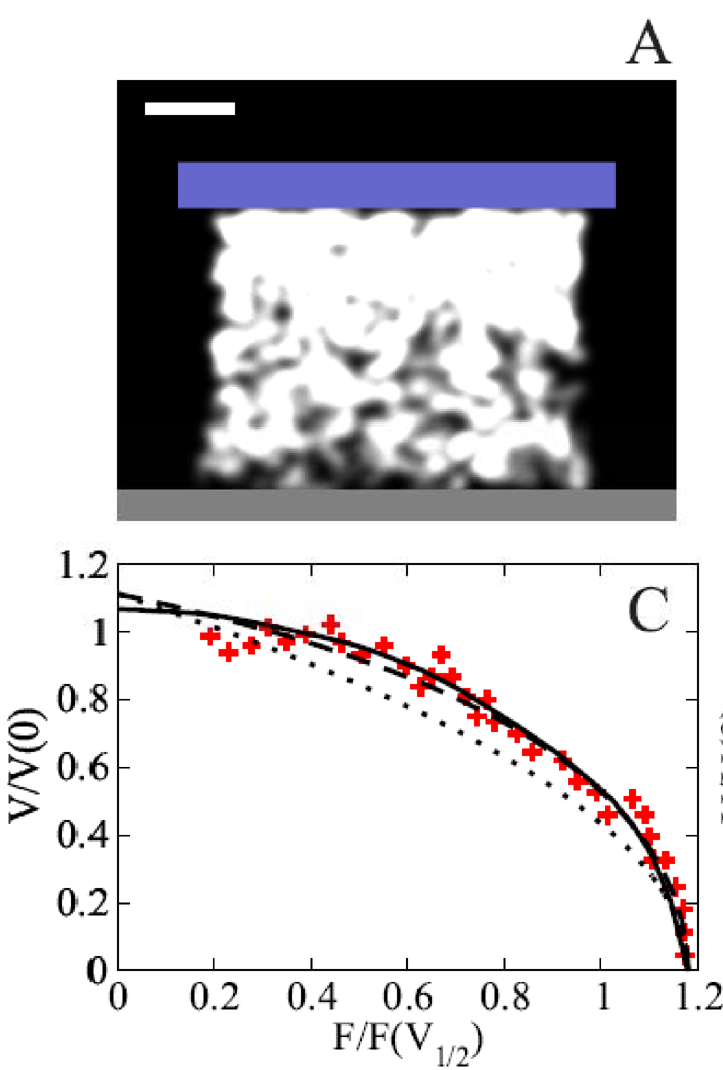
Force-velocity properties of growing actin networks



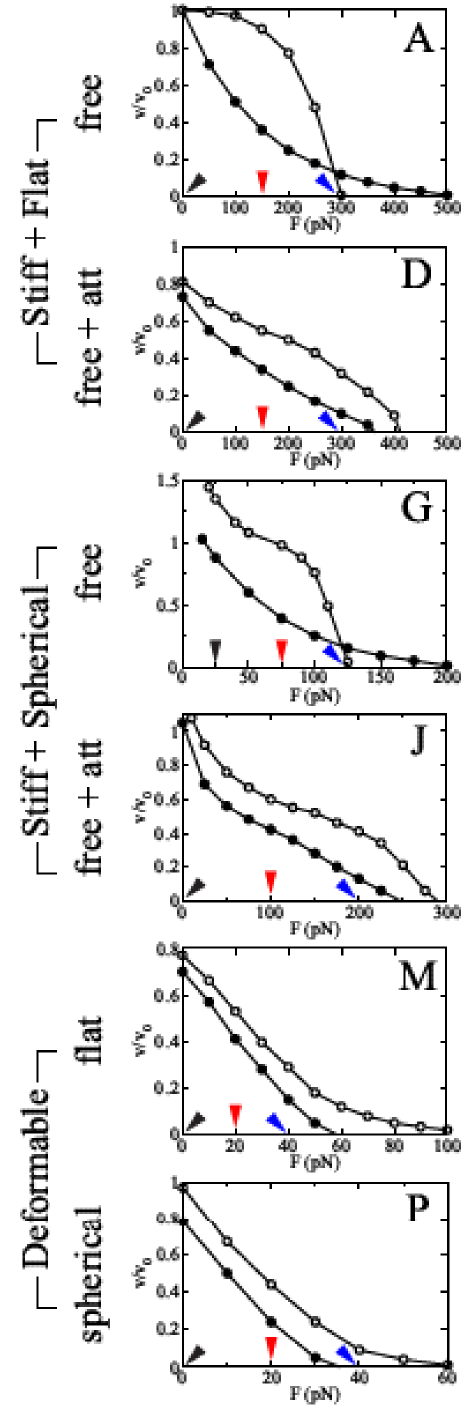




Different shapes of measured
force-velocity relation:
Concave-down (Parekh *et al*. 2005)
Concave-up (Marcy *et al*. 2004)



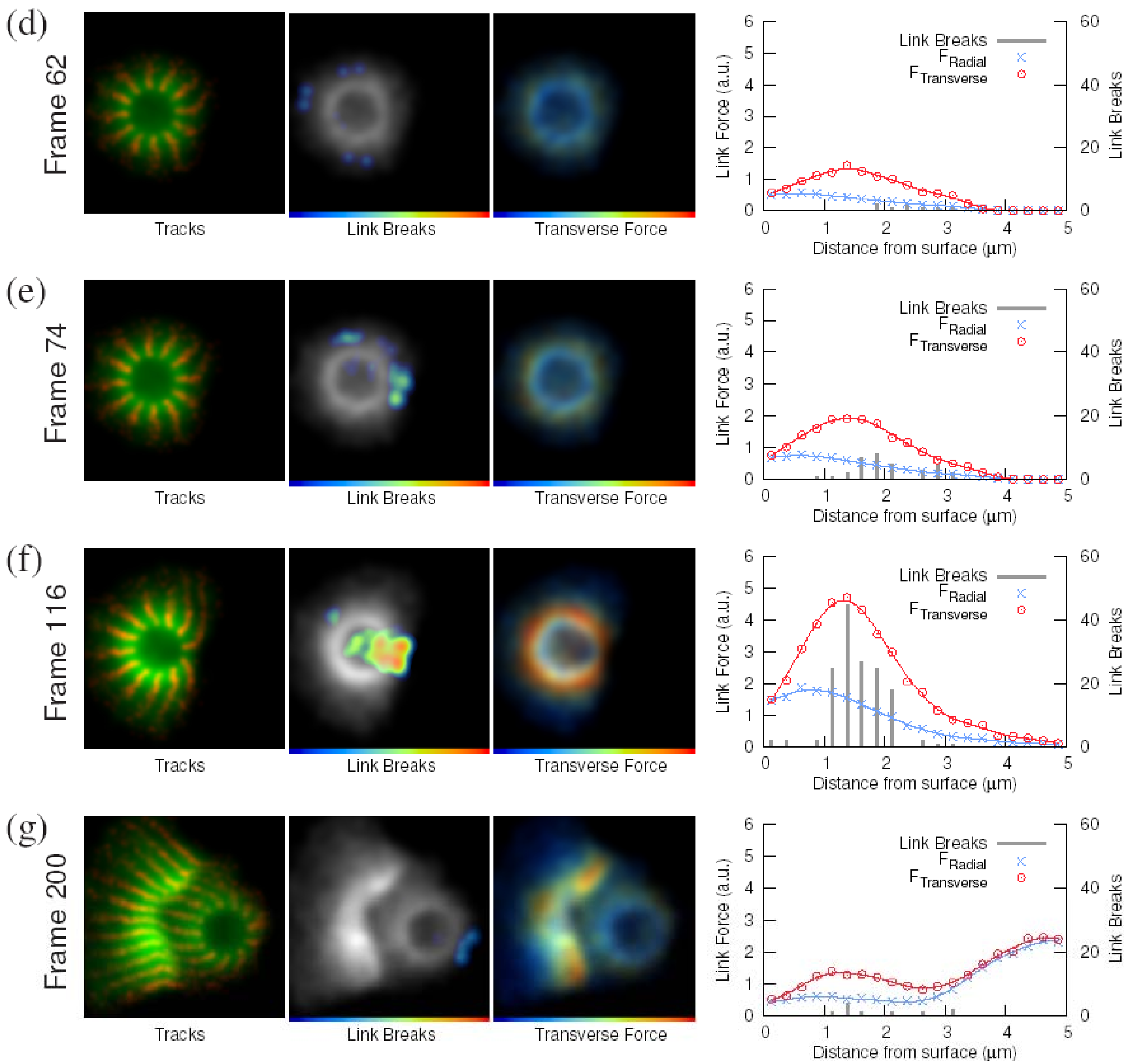
A
B
C
D
V/V(0)
F/F(V1/2)
0
0.2
0.4
0.6
0.8
1
1.2
-1
1.5
0.5
2
3



Stiff + Flat
free
free + att
Stiff + Spherical
free
free + att
Deformable
flat
spherical
A
D
G
J
M
P
v/v0
F (pN)

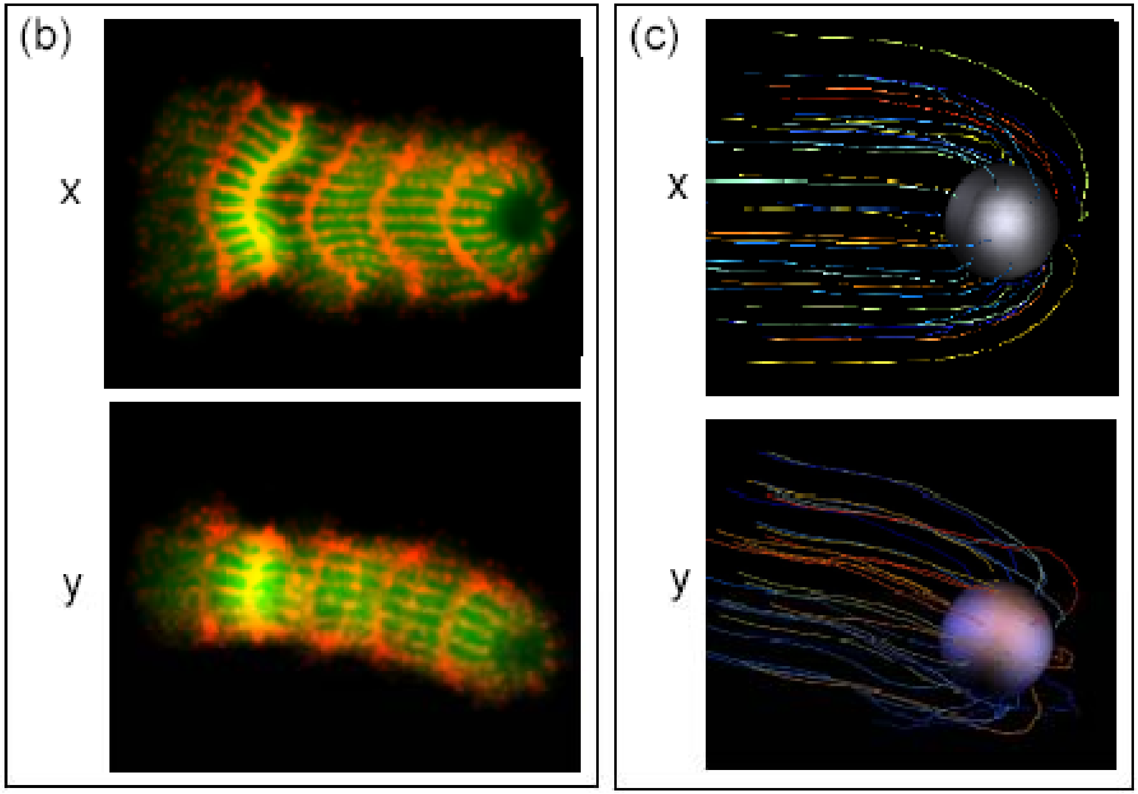
Mechanics of symmetry breaking: stress distribution; positive feedback; inner vs middle vs outer shell

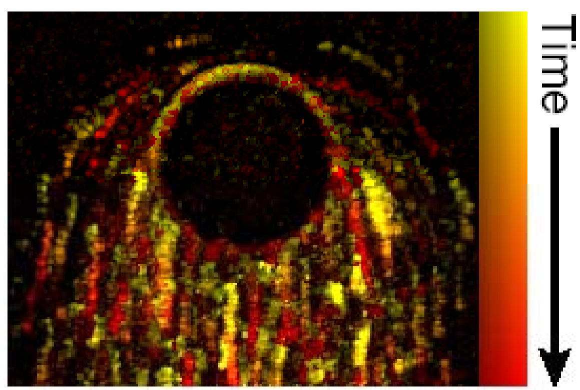
Dayel et al PLoS Biology 2009



Motility: no 'soap-squeezing', but 'sustained rip'

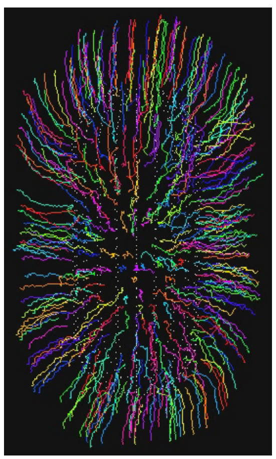
Dayel et al PLoS Biology 2009

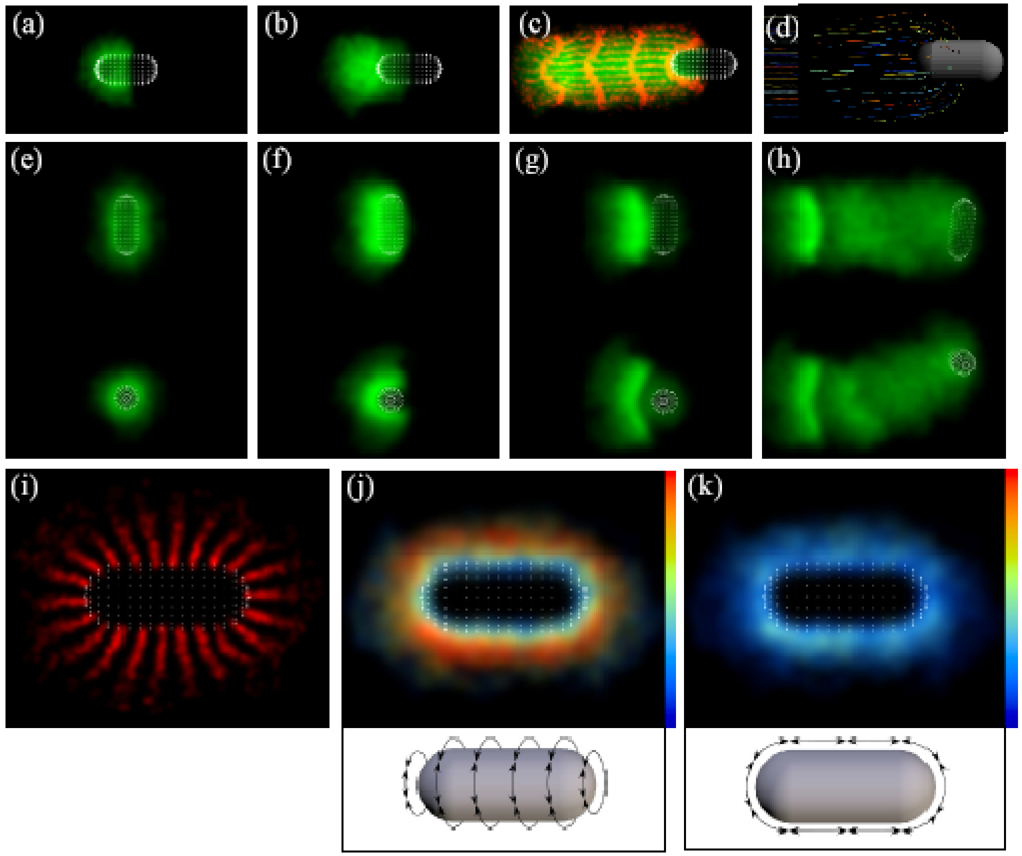




Motility of Listeria-like shape

Dayel et al PLoS Biology 2009





Gel ‘oozes’ from Listeria

Capsule breaks and moves sidewise

Summary:

Microscopic ratchet and macroscopic elastic models do not predict behavior of ellipsoidal beads correctly;

Mesoscopic hybrid model combines ratchet and elastic models;

Explains 1) bi-orientation of ellipsoidal beads;
2) Distribution of curvatures of spherical bead trajectories;
3) Force-velocity properties of growing actin networks in two regimes

UC Davis:

Jie Zhu

UCSF:

Mark Dayel, Dyche Mullins + others

Stanford:

Catherine Lacayo, Julie Theriot + others

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