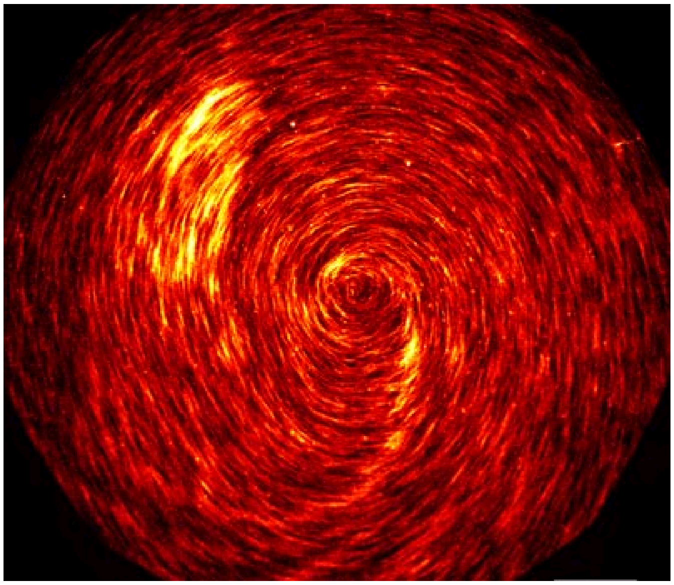
Filaments swarm and swim in circles

Sep 6, 2010 2 comments



Swirling actin shows collective motion

Swarms of insects and flocks of birds are examples of natural systems in which individual components act independently, yet together display complex collective motion. Scientists have extensively modelled such systems theoretically but have lacked the experimental apparatus to put their theories to the test. Now, a group of biophysicists in Germany has studied a simple biological "active system" in the laboratory and has shown that collective motion kicks in when the system becomes dense enough.

Active systems occur when a source of energy keeps groups of particles away from thermal equilibrium. Those of greatest interest consist of entities that are self propelled and orientable, such as the actin filaments that make up the skeleton of biological cells. Powered by myosin proteins, these filaments allow cells to move and divide coherently.

In 1995 the theoretical physicists John Toner and Yuhai Tu put forward a model to describe the collective motion of large groups of organisms, and other researchers have since expanded it to cover active systems more generally. However, experimentalists have so far been unable to create systems in the laboratory that are simple and adjustable enough to test the models.

Thrusting proteins

Now Andreas Bausch of the University of Technology, Munich (TUM) and colleagues have created such a system in a sample made up of actin and the myosin. One end of each of the myosin molecules was connected to a glass slide immersed in water with the other end free to bind with 10 µm long actin filaments. A thrusting movement of the myosin then set the actin in motion.

Such samples have been prepared by biologists since the 1970s, but these studies have focused on the behaviour of the myosin. This latest breakthrough came one Friday afternoon when Bausch and colleagues decided to see what would happen when they increased the density of actin filaments in the sample by up to a factor of 1000.

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The researchers found that the filaments move around randomly in samples with an actin density less than about five per square micron. But above this critical density, the filaments form distinct clusters between 20–500 µm across that move around erratically and endure for several minutes.

Spiral and bands

Things get even more interesting at densities greater than about 20 filaments per square micron, where the filaments group together in bands that move across the sample as waves. These bands remain stable for as long as the observations are carried out (up to half an hour) and span several centimetres. In addition, the researchers found that at all densities above the critical density the filaments can also create spiral patterns lasting up to 10 minutes.

To try and understand the origin of this collective motion Bausch, together with Erwin Frey of the Ludwig Maximilians University in Munich and colleagues, carried out a computer simulation of the system. This involved the simple assumptions that filaments repel each other when they get close enough – without specifying the mechanism responsible for the repulsion – and that filaments tend to align themselves along the average direction of neighbouring filaments. The simulation successfully reproduced the cluster motion and the waves but not the spiral patterns. They think that the spirals are caused by longer-range interactions brought about by the flow fields set up in the water by each of the filaments, and which were not included in the simulation.

The work is reported in *Nature* **467** 73. Writing in the "News and views" section of the journal, physicists Jean-François Joanny of the Institut Curie in Paris and Sriram Ramaswamy of the Institute of Science in Bangalore, India, describe the work as a "crucial quantitative, experimental demonstration" of collective motion in a biological system.

The physicist's approach

The researchers maintain that the close similarity between the patterns seen in the experiments and those predicted by simple theoretical models underlines the value of what they call "the physicist's approach" to studying such systems; in other words, the strategy of ignoring chemical and biological details. They propose building up a phase diagram of filament behaviour by systematically varying the density and activity of the motor molecules in future experiments, and then testing the universality of this diagram by comparing it to the results of experiments carried out on real systems.

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1 **m.a.king**
Sep 11, 2010 6:27 AM
Toronto, Canada

Physicist's approach...

Interesting model... In the proposed development of a phase diagram, I wonder whether the researchers have considered a more biological dimension - variation of amino acid sequence in actin and/or myosin by genetic origin?
mk

Offensive? Unsuitable? Notify Editor

2 **yhrfews34fr**
Sep 29, 2010 4:27 AM

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