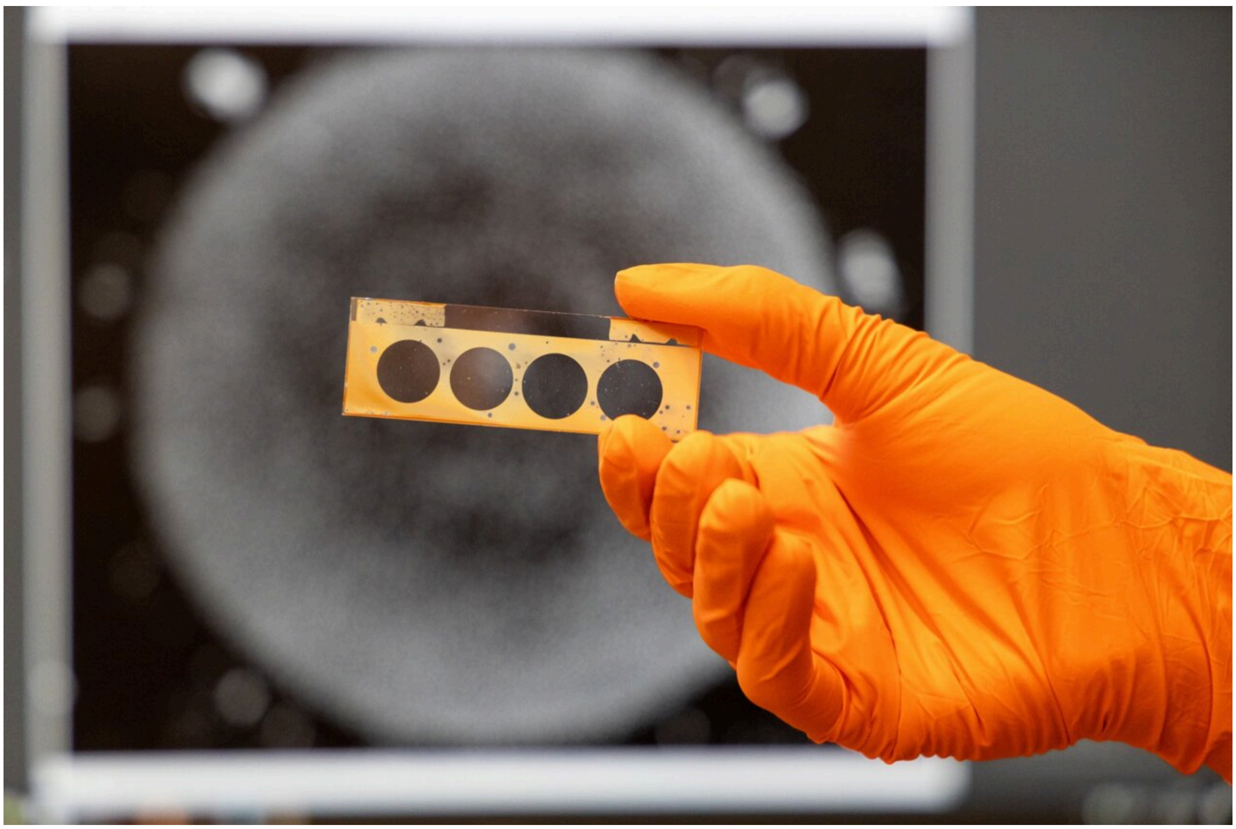
Why do birds flock? Shedding light on collective motions in heterogeneous populations

October 26 2023



The circular well in which the microbeads are placed, with an image of the experiment on the background. Credit: Leiden University

Electrifying plastic beads in a laboratory setup creates flocking behavior similar to that observed in birds. And if you mix beads of two sizes, they will automatically separate. This seemingly simple observation by Alexandre Morin and Samadarshi Maity teaches us about collective motion at all scales. "It's beautiful that something as complex as birds can be understood at its essence through beads."

A single bird can fly in any direction it wants. But a group of birds moves in the same direction as if they are one without following a leader: they flock. This spontaneous flocking is the phenomenon that Morin studies, though not by observing animals. Instead, he uses plastic microbeads.

What beads teach us about flocking phenomena

"We study collective motions," Morin starts. "People expect that an object will always behave the same, no matter how many there are. But that is not the case above a certain density. Not for birds and not for beads. The principle is the same."

Using microbeads ten times smaller than the thickness of hair, the researcher mimics flocks in the lab. This way, they can control a single unit and manipulate huge flocks. Something that is not possible with animals. "With flocks that fit under the microscope, we can learn so much more."

Ph.D. candidate Maity describes the experiment. "We have two types of beads of different sizes. We place them in a circular well with a fixed speed in a random direction. If there are enough beads, a collective vortex motion arises." Morin adds, "In other words, the beads behave like a flock even though they have no brain or cognition. That's simply amazing to me."

Unexpected self-sorting

The flocking of a single species is understood well, but the Leiden researchers pushed this understanding by mixing two species. They observed something unexpected. "By introducing two sizes of beads, we added complexity that represents natural systems better," Maity explains. "We saw that the small beads quickly migrated to the center and the big ones to the edge. They spontaneously sort themselves."

"And of course, we want to understand why," Morin adds.

To answer this question, they developed a theoretical model. "With a mathematical model, we can discover general rules. These describe all the interactions in the system and track where individual beads are at any time, says Morin."

"I did a lot of smaller experiments and fed that data into the model," Maity says. "And it worked remarkably well. Our model can predict how a system will move. We learned that the main influence on the sorting behavior is the beads' speed, not their size."

Their article, "Spontaneous Demixing of Binary Colloidal Flocks" has now been published in the journal *Physical Review Letters*.

Swarms of robots

Typically, it is easy to separate particles of different sizes by centrifugation. This technique is used widely, from pharmaceutics to the food industry. Morin and Maity's work offers an alternative. "We can even separate particles of the same size and density with our method," Morin says.

Understanding flocking has other benefits too, according to Maity. "A different example is autonomous swarms of robots, like in a warehouse or the Starlink satellites. Our work can help program such robots better.

The swarm becomes more reliable than the individual robots. If one fails, the swarm still functions."

Now that Morin's group has understood the system of flocking beads, they will explore other collective phenomena. "We will continue looking at self-organization but with deformable units. This mimics human tissues better, so we get even closer to understanding natural systems."

More information: Samadarshi Maity et al, Spontaneous Demixing of Binary Colloidal Flocks, *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.131.178304

Provided by Leiden University