Lead-flapping objects experience less wind resistance than their trailing counterparts

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It is commonly known that racing cars and bicyclists can reduce air resistance by following closely behind a leader, but researchers from New York University and Cornell University have found the opposite is true with flapping objects, such as flags.

Their study, published in the most recent issue of the journal *Physical Review Letters*, discovered that in a series of flags, the leading flag faces significantly less resistance than do succeeding flags. The finding may alter our understanding of how living flapping creatures, such as birds or fish, move through the air and water.

"Inspired by schooling fish and flocking birds, we studied how flapping flags alter fluid drag forces, or resistance that moving objects face, on one another when grouped together," said Jun Zhang, an associate professor in NYU's Physics Department and its Courant Institute of Mathematical Sciences and a co-author of the study. "To our surprise, we discovered that the leading flag enjoys a drag reduction of up to 50 percent while its downstream neighbor suffers a significant drag increase. If this effect applies to fish schools and bird flocks, the leaders would also have a reduced burden and spend less energy as they swim or fly."

The finding is the first of its kind on fluid flow. All previous studies on rigid objects in a moving fluid show the exact opposite result: the leading object must overcome greater drag forces than the followers.

"Our finding is thus a dramatic violation of our common sense about fluids and structures," Zhang explained.

In the study, the researchers sought to simulate flags flying under windy conditions by inserting flexible filaments ("the flag") to a wire ("the flagpole"). To model wind, they placed the model flag into a flowing soap film. Because the filaments are flexible and massive, they spontaneously flap under the fluid, reacting as flags would in a natural breeze.

Under different flow conditions, Zhang and his co-author Leif Ristroph, a doctoral candidate in Cornell's Department of Physics, first calculated the resistance faced by a single flag. They subsequently determined the resistance faced by two flags in tandem.

They found that the leading flag always suffered less drag, or resistance, than did the trailing flag. In addition, they also reported that the leading flag in a tandem of flags experienced less drag than a flag in isolation. Both results are contrary to existing research on fluid force.

The trailing flag acts as a splitting plate that restricts the lateral motion of the oncoming flow, the researchers said in explaining their results. This effect indirectly reduces the motion of the leading flag, which makes the appearance of the leader smaller than usual, yielding less drag. By contrast, the trailing flapping body, which flaps in the oscillating wake of the first, has greater flapping amplitude due to the resonate effect of this wake. This larger appearance in a flow translates to a greater drag.

Source: New York University