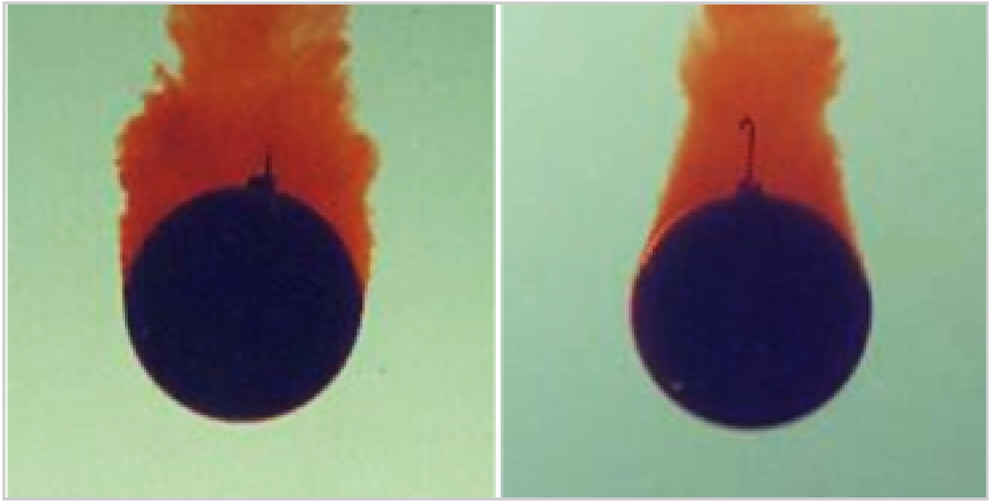

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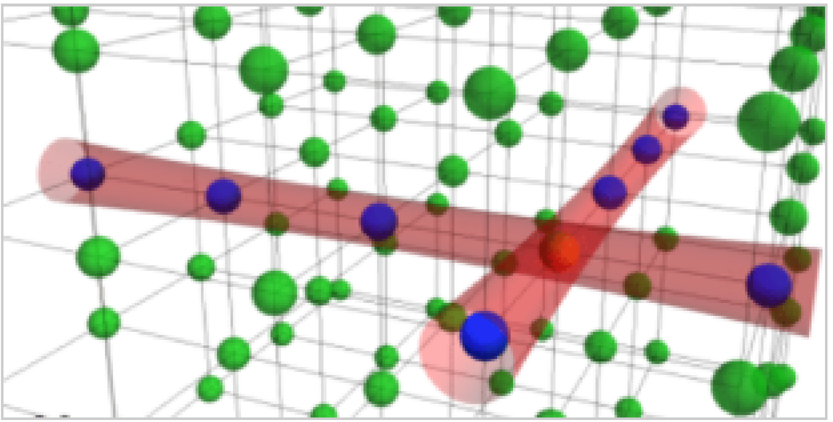

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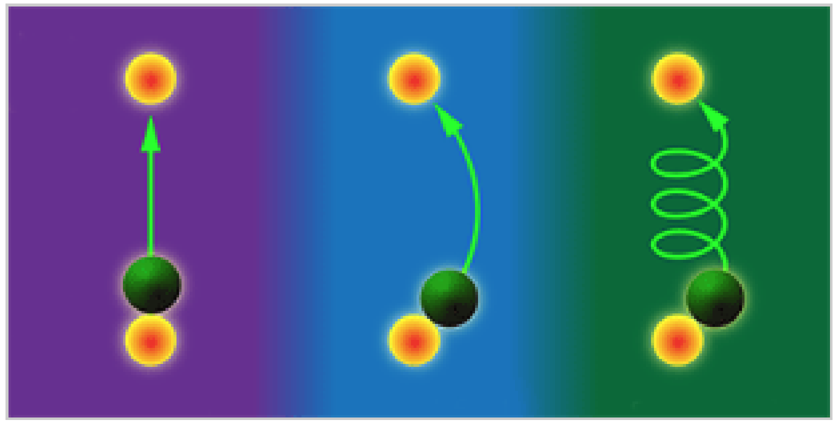

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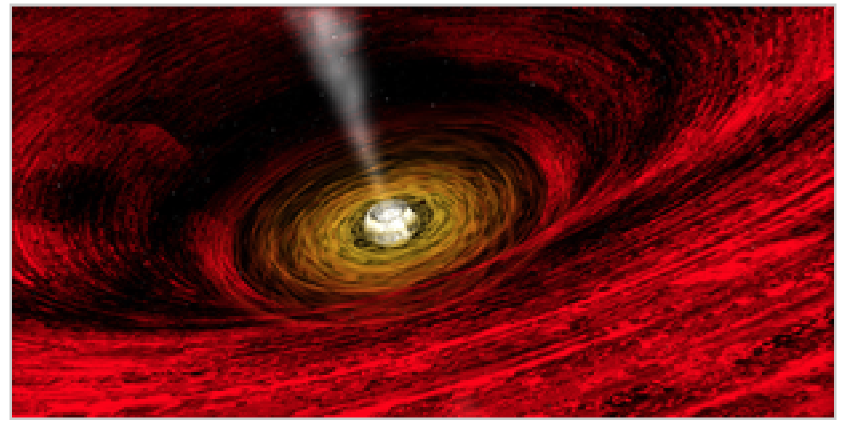

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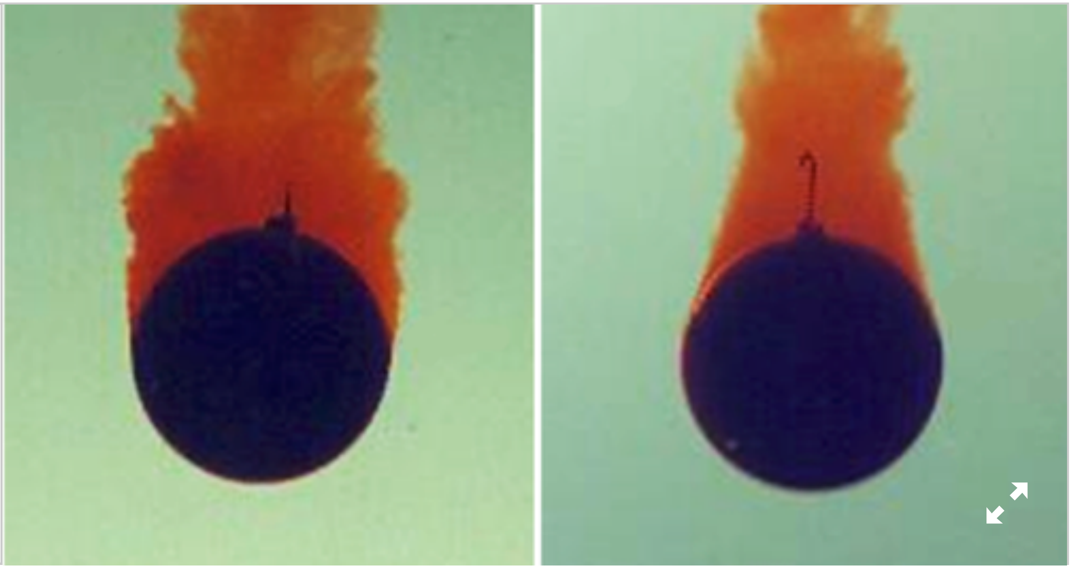

I. U. Vakarelski *et al.*, Phys. Rev. Lett. (2015)

Dropping the ball. The wake of a falling metal-cored ice ball is wider at lower speed (left) and narrower at higher speed (right), as visualized using red dye in the ice. The narrower wake corresponds to a reduction in drag.

Ice that isn't too cold is covered with a thin layer of water that allows a solid, such as a hockey puck, to slide smoothly. Now a team of researchers has found that an ice surface also facilitates the motion of an ice-covered object through water. They dropped ice-covered spheres into a column of water and measured a substantial drag reduction, compared with metal or ceramic balls of the same size and average density. The melting of the ice surface reduces the turbulent wake behind the sphere, they found, a result that could be important for understanding the motion of icebergs and ships traveling in icy waters.

When an object is moving fast enough through liquid, the drag (slowing force) is controlled by the size of its turbulent wake. If the body accelerates above a certain threshold speed, the turbulent region abruptly narrows, leading to a reduced drag. This transition is called the drag crisis.

To lower the drag—often desirable for ships, airplanes, and golf balls—engineers can force the drag crisis to happen at lower speeds by texturing the surface with dimples or with other tricks. Ivan Vakarelski of the King Abdullah University of Science and Technology in Thuwal, Saudi Arabia, and colleagues have now found another way to promote the drag crisis. They observed that it occurs at lower speeds for a ball of ice falling through water, compared with a solid metal ball, thanks to the thin water layer at the ice surface produced by melting. The team believes that this effect not only provides insight into the imperfectly understood physics of the drag crisis but also might have some practical consequences in nature and in technology.

A pure ice ball would float in water, so the researchers froze a 10-mm-thick shell of ice around a 40-mm-diameter steel or tungsten carbide ball at $-10\,^{\circ}\mathrm{C}$. “We adopted some ideas from commercial cocktail-drink ice ball makers,” says Vakarelski.

Loading

I. U. Vakarelski *et al.*, Phys. Rev. Lett. (2015)

An ice-coated ball with a heavier core (right) falls faster with less drag and a narrower wake than an ice ball with a lighter core.

They dropped these balls into a 2.4-m-high tank of water and recorded their descent with a high-speed video camera. For comparison, they also watched the descent of steel or steel/aluminum balls of the same size and average density as the heavy-cored ice balls.

Balls of different density fall with different speeds, and Vakarelski and colleagues found that every ball showed an abrupt decline in drag at a certain speed, marking the onset of the drag crisis. But this threshold was lower for the ice balls than for the metal balls. At speeds between the two thresholds, the ice ball drag could be more than 50% lower. The team also put dye in the ice layer to image the flow and could see the narrowing of the turbulent region behind the spheres when the speed went above the drag crisis threshold.

From the typical thickness of the melted layer at the surface, the researchers calculated that the lower-speed drag crisis comes from the transfer of water from the surface film into the surrounding fluid. When the team reduced the surface melting rate by dropping ice balls into colder water, they fell more slowly, further supporting the connection between melting and the drag crisis threshold.

This influence of the melted surface layer of ice seems surprising, Vakarelski says. “There is no *a priori* reason to expect that the hydrodynamic drag of icy bodies in water should be different from that of other solid bodies,” because the surface film is the same as the ambient water, unlike the case of a solid sliding on ice in air. But this intuition is wrong, according to the team’s results.

Vakarelski says the results might imply that ships with frozen hulls would experience lower drag, and they may also be relevant for modeling drifting icebergs, which may be more common in a warming climate. More generally, he says, the work makes a new connection between microscopic and macroscopic phenomena (melting and drag).

Lydéric Bocquet, a specialist in fluid dynamics at the Ecole Normale Supérieure in Paris says that the shift of the drag crisis for ice is substantial and unexpected. And regardless of any practical applications of the results, problems where there is a high-speed flow of fluid past a solid surface “remain to a large extent very mysterious, and any new information on this is fundamentally interesting.”

This research is published in **Physical Review Letters**.

–Philip Ball

Philip Ball is a freelance science writer in London and author of *Curiosity: How Science Became Interested in Everything* (2012).

Subject Areas

Fluid Dynamics

Drag Moderation by the Melting of an Ice Surface in Contact with Water

Ivan U. Vakarelski, Derek Y.C. Chan, and Sigurdur T. Thoroddsen

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