Dancing beads on surface waves cluster in surprising ways

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Leaves floating on water waves. Credit: Fundamental Research on Matter (FOM)

(Phys.org) —FOM researchers have discovered that objects floating on surface waves behave differently than expected. If a small number of floating objects is present on a water surface, these will drift to the locations where waves peak. However, a large number of floating objects will gather where the water is stationary. This finding might lead to new, efficient methods for cleaning up litter from the sea. The study

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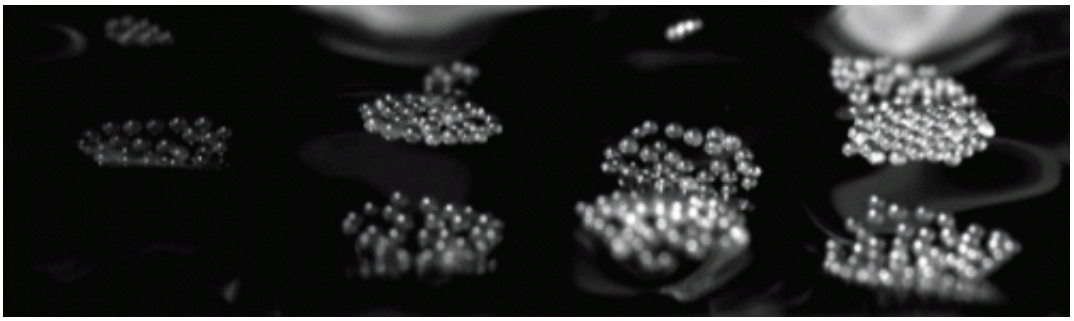
Floating objects are found everywhere: from the bubbles in our drinks to marine plants on the sea surface. We partly understand how things float thanks to Archimedes' principle, which explains the upward force on an object. However, this principle does not account for horizontal drift and so it cannot explain why bubbles in a drink drift to the wall of a glass or how marine plants bob along the waves of the sea.

Former FOM PhD student dr. Ceyda Sanlı, supervised by prof.dr. Detlef Lohse and prof.dr. Devaraj van der Meer of the University of Twente, investigated these floating mechanisms. Sanlı looked at plastic beads floating on water. In her experiment, the water surface was a so-called standing wave: a steady wave pattern with locations where the water is stationary (nodes) and positions where the waves peak (anti-nodes). Sanlı systematically increased the number of the beads on the surface. She found that when a small number of beads is present, these drift to the anti-nodes. Surprisingly, increasing the number of beads completely changes their floating behaviour: when their number exceeds a certain value, the beads drift to the nodes instead.

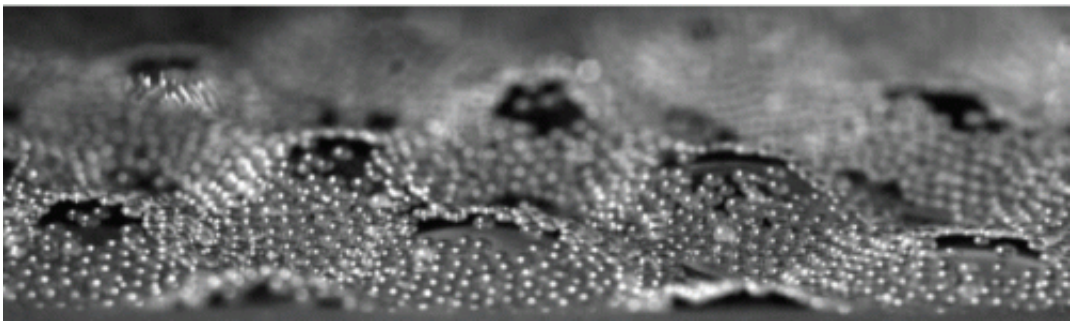
Breathing

The strange behaviour of the floating beads can be explained by a phenomenon known as 'breathing'. As a result of the periodic wave motion, the beads in the antinodes move towards and away from each other, as if they are breathing. This motion creates space between the beads, which raises their potential energy. If there are only a few beads present, the displacement due to the 'breathing' is small and so the increase in potential energy is minor. However, if there are many beads on the water, the breathing motion will cause a significant rise in potential energy. In that case, it is energetically favourable for the beads to move towards the nodes. In the nodes, there is no 'breathing'. Instead,

the closely packed beads are gently rocked back and forth by the wave, like a baby in a crib. The potential energy is therefore low.



A small number of beads on the surface will drift towards the wave maxima (anti-nodes).



A large number of beads accumulates at the wave minima (nodes).

Sanlı observed that the beads indeed spontaneously self-organise to occupy the position of lowest energy. Using this insight, the researchers could explain the limits of the clustering around nodes and anti-nodes, as well as predict the number of beads required to invert the pattern.

The team's success in explaining the floating behaviour in terms of the

energy and 'breathing' is a breakthrough. According to Sanlı, this method might also be useful when studying other self-organising systems, from biological systems such as brain networks, to swarms such as bird flocks and crowds of people.

Cleaning the sea

The results could also be used to design methods to remove impurities in a melted metal surface or to remove plastic contaminants from a paper pulp. Another potential application involves cleaning sea surfaces. Marine pollution is a worldwide problem that threatens marine life. Scientists are currently seeking to develop effective and less energy consuming methods to clean the sea surface. In this project, the researchers found that creating surface waves can actually cause floating objects (such as floating litter) to cluster in an organised manner, which could facilitate a clean-up. Different types of contaminants could also be separated, as different objects can experience the wave drift in opposite directions.

More information: From antinode clusters to node clusters: The concentration-dependent transition of floaters on a standing Faraday wave, Ceyda Sanlı, Detlef Lohse & Devaraj van der Meer, *Physical Review E*, Vol.89, No.5. DOI: 10.1103/PhysRevE.89.053011.

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