SLAM Seminar

Self-propulsion and self-oscillations of Leidenfrost droplets

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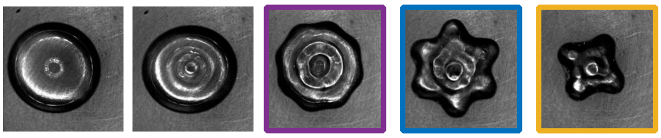
Host: Scott Waitukaitis

A water droplet placed on a hot solid levitates on a cushion of its own vapor. This is known as the so-called Leidenfrost effect, discovered in 1756. This gas layer, continually renewed, mechanically and thermally isolates the liquid, which, by limiting its evaporation and suppressing boiling, enables the drops to survive quietly for minutes. This levitation state also prevents the liquid from wetting its substrate, giving the droplet a pearl-like shape, and creating a friction-free situation. This makes Leidenfrost droplets very sensitive to any external perturbations, such as gravity or air flow, and therefore, as has been widely accepted, explains their extreme mobility.

However, we have observed that droplets deposited without initial velocity on strictly horizontal substrates self-propel in random directions. In this seminar, I will first discuss the origin of Leidenfrost droplets' mobility and show that their motion is generated by confinement. PIV measurements reveal that, as the drop aspect ratio of the drop becomes of order unity, the (intense) internal motions of liquid switch from symmetric to asymmetric rolling. Such a flow reshapes the vapor cushion and tilts it, as evidenced by interferometric measurement. Hence, this leads to propulsion. Droplets are thus found to generate their own dynamics and self-propel even in the absence of external field, which contributes to their legendary mobility.



In the second part of the talk, I will discuss another spontaneous dynamic occurring during Leidenfrost drops' life. Above a certain size, Leidenfrost puddles often suddenly and unexpectedly start to oscillate with star shapes, a phenomenon first reported about 140 years ago, but not yet understood. It is known that similar deformations can be triggered when a liquid is subjected to an external periodic forcing. However, a periodic forcing could not be identified in the context of the Leidenfrost phenomenon. I will show that Leidenfrost bodies are subjected to an internal periodic forcing, which unravels the origin of Leidenfrost stars. I will then discuss the frequency of the vibrations and show that they can excite Faraday-like surface standing waves. Drops being close cavities, deformations only get amplified when their polar perimeter can accommodate an integer number of wavelengths. This resonance condition explains the discrete and sporadic response of the liquid and, more generally, how the drop natural modes can be locked on throughout the drop's life.

These two dynamics, orchestrated by evaporation-driven confinement, highlight the richness of this system that involves capillarity, phase changes, thermal effects, aerodynamics, and hydrodynamics.

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Thursday, November 16th, 2023 11:00 - 12:00

Seminar Room F / Moonstone Bldg / Ground floor

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