Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **66** Type: **Oral not-in-competition (Graduate Student) / Orale non-compétitive (Étudiant(e) du 2e ou 3e cycle)**

Droplet creation in the walking droplet pilot wave system and in Bose-Einstein condensates: walking droplets, vortex molecules, and Faraday instability

Tuesday 10 June 2025 11:30 (15 minutes)

Condensed matter systems such as superfluids can simulate phenomena in every major area of physics, from gravitational to cosmological to high-energy physics, including an analog for quark confinement known as "vortex molecules"(Eto, Ikeno & Nitta, 2020). On the other hand, in the last twenty years the field of Hydrodynamic Quantum Analogs (HQA), which studies the walking droplet pilot wave system, has provided deep insights into the nature of quantum behaviours. This field was reviewed in 2021, including longstanding misinterpretation of Bell's work (Bush & Oza, 2021).

Walking droplets exhibit uncanny analogs for many quantum effects of electrons and photons, such as diffraction through slits, tunnelling, entanglement, multi-modal statistics, quantized orbits, Landau levels and Zeeman splitting in a magnetic field, spin states, and spin-spin correlations. Although their behaviour is most like de Broglie's original (and never completed) double solution theory, walking droplets'behaviour is unique, described by a hydrodynamic pilot wave theory in which a chaotic, non-Markovian dynamics –dynamics with a memory –plays a key role.

In this system, the bath is vertically driven, causing Faraday waves to break out on the surface at large enough acceleration. The droplets'quantum-like behaviours are strongest in what is known as the "high memory" regime, near the Faraday threshold, where the effects of viscous damping are mitigated and the pilot-wave is most long-lived. At accelerations far above the Faraday threshold, waves break and droplets are created.

We investigate droplet creation in a Bose-Einstein condensate (BEC) system hosting vortex molecules, a Rabi-coupled system of two different hyperfine spin states. Droplet creation has been shown numerically for a BEC of two immiscible components driven towards each other by an oscillating force, with droplets generated at their interface along with quantum vortices. We expect a similar result in the Rabi-coupled case, where the Rabi coupling itself serves as the periodic driving.

Keyword-1

hydrodynamic quantum analogs

Keyword-2

condensed matter analogs

Keyword-3

Bose-Einstein condensate

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Session Classification: (DQI) T1-11 | (DIQ)

Track Classification: Technical Sessions / Sessions techniques: Division for Quantum Information / Division de l'information quantique (DQI / DIQ)