Dynamics of formation and decay of oblique dark solitons in polariton quantum fluids

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The demonstration of polariton superfluidity [1] has underlined the huge potential of semiconductor microcavities for studying the physics of quantum fluids. As in everyday fluids, waves and turbulence are also expected at the quantum scale. Similar to a boat sailing across calm waters, an obstacle flowing a quantum fluid can leave turbulences in its wake and generate waves. A large variety of quantum hydrodynamic effects are expected to appear in a polariton fluid at the breakdown of superfluidity under different perturbations [2, 3]. Presently, there is growing interest around solitons, especially in condensed matter systems [4]. Solitons are solitary waves, which propagate in the medium while maintaining their shape. The stability of their shape is the result of the exact compensation of the dispersion by the interparticle interactions. For the case of repulsive interaction, dark solitons may appear, having the shape of density depressions in the fluid. Nucleation and stability of dark solitons depend on particular conditions which are basically set out by the density and the velocity of the fluid, together with the nature of the obstacle that provides the perturbation.

In our experiments we create dark solitons by perturbing a polariton quantum fluid with an engineered attractive potential called mesa. Using a time and phase resolved setup we image the formation dynamics [5] of hydrodynamically nucleated dark solitons and their eventual decay and breaking into vortex streets [6].

We assess quantitatively the formation and the decay process of dark solitons and our results are scaled against parameters such as the formation speed as well as the fluid density during the hydrodynamic transient. The variation of the formation velocity and the stability conditions are quantified and traced back to an effect of the local density distribution of the fluid. We propose an explanation in terms of the conditions for the convective instability of dark solitons.

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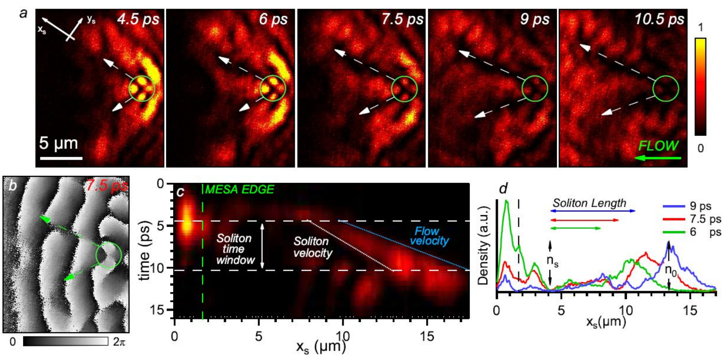

Fig.1: a- Time evolution of the density of a polariton wavepacket scattering on an engineered circular obstacle (green circle). Dark solitons (white arrows) are visible few picoseconds after the polaritons injection and are characterized by dark straight lines in the density and a phase shift (b). The velocity of formation of dark soliton can be extracted from the time evoulution of the polariton density along the soliton grow direction (c). d- Density of dark solitons ns with respsct to the polairotn fluid n0 at different times.