Flashtalk : vortices and solitons in a Quantum Fluid of light

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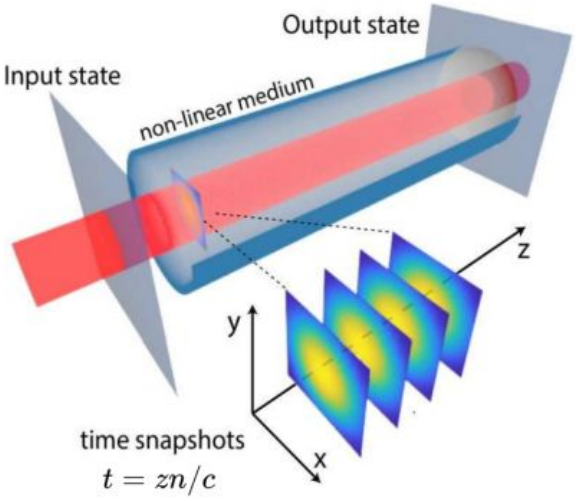
Fluids of light



Nonlinear Schrödinger Equation

$$i\frac{\partial}{\partial z}E = \left(-\frac{1}{2k_0}\nabla_\perp^2 - \frac{\delta\epsilon(\mathbf{r})}{2n_0}k_0 - \frac{n_2}{n_0}k_0|E|^2\right)E$$

Gross-Pitaevskii Equation

$$i\hbar\frac{\partial}{\partial t}\psi = \left(-\frac{\hbar^2}{2m}\nabla^2 + V + g|\psi|^2\right)\psi$$

Kinetic energy

External potential

Non-linear interaction

$$n_2 \propto \frac{N_{at}}{\Delta^3}$$

Two control knobs for the interactions

N_{at} atomic density (controlled by the temperature)

Δ detuning (controlled by the laser frequency)

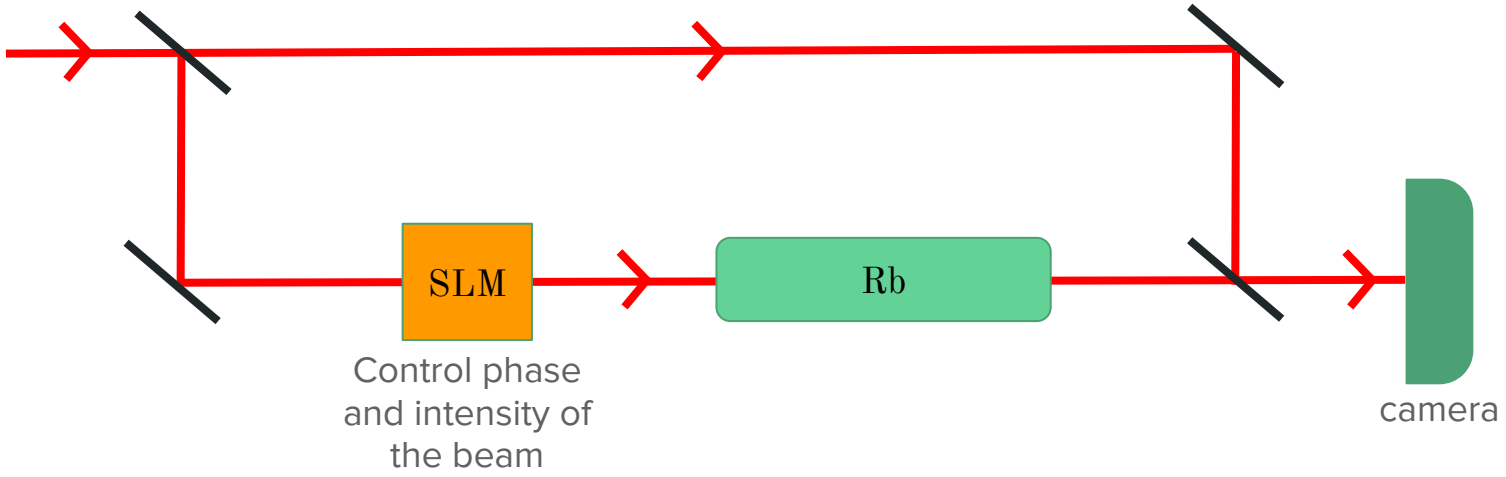
GPE can be reformulated by a transformation → hydrodynamics equations

$$\psi = \sqrt{\rho}e^{i\theta},\ \rho = |\psi|^2 = |E|^2$$

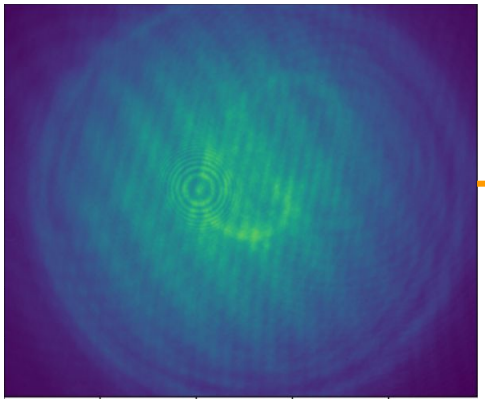
Experiment

We want to study the hydrodynamical behavior of the fluid of light.

We deduce the phase and density by interferometry.

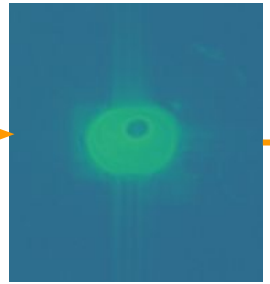


Extracting phase and density

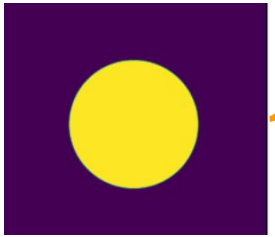


Raw camera image

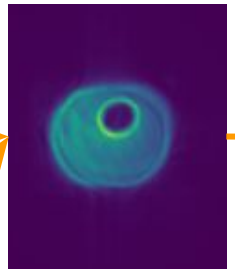
$\mathcal{F}$



x

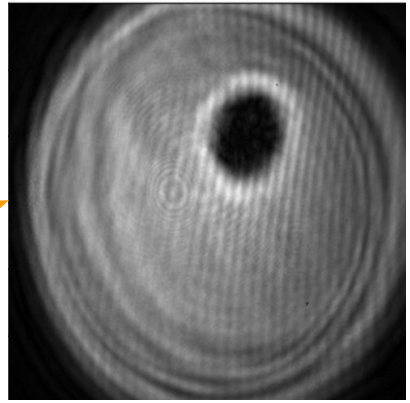


Mask



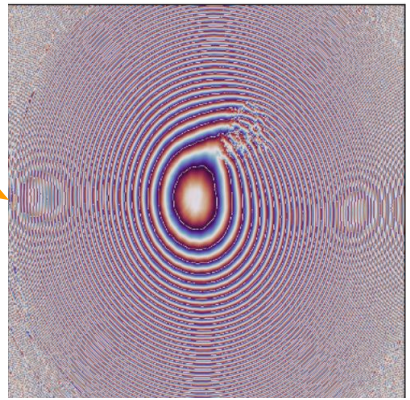
$\mathcal{F}^{-1}$

modulus



Density

phase

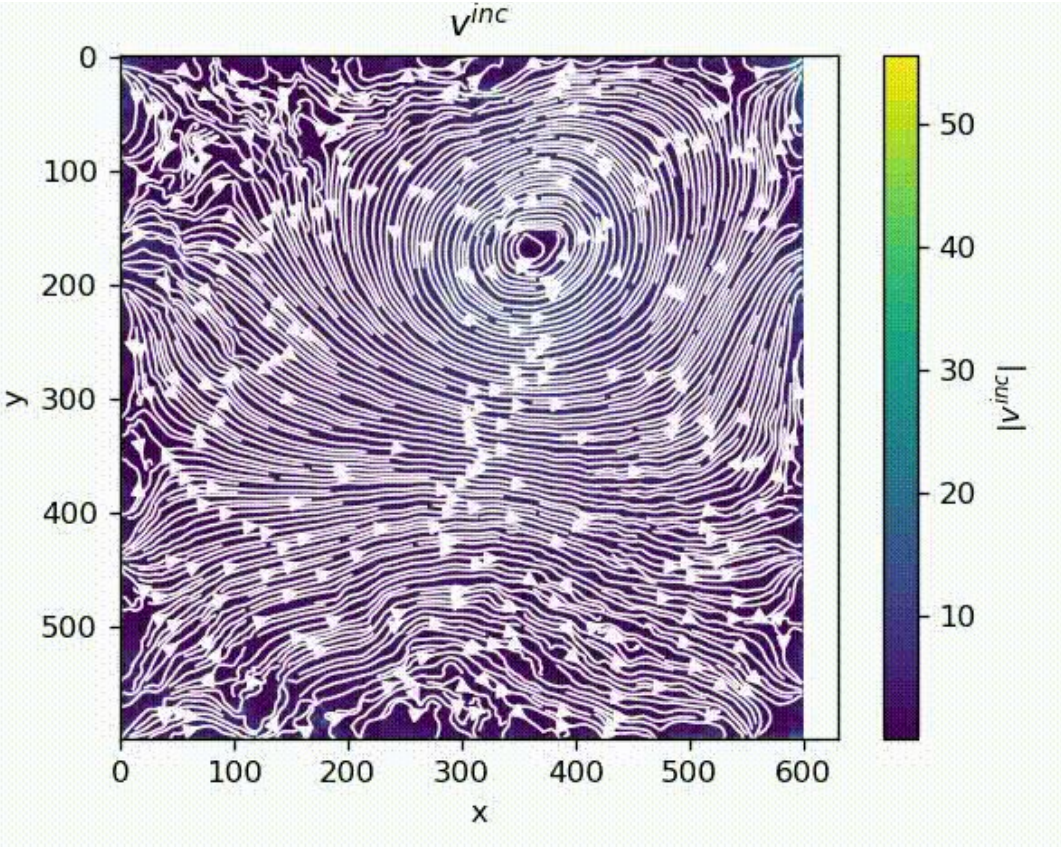


Phase

Vortices

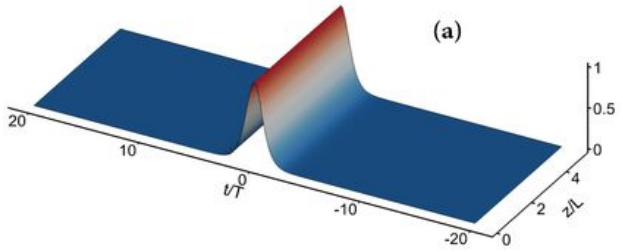
We imprint a phase pattern in the SLM to generate vortices

Vortices with a charge greater than 1 are unstable and break

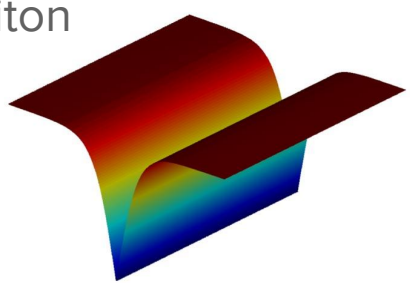


Solitons

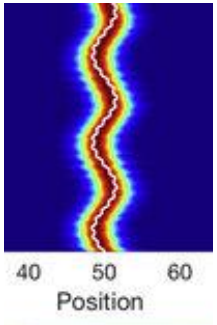
Soliton



Dark soliton



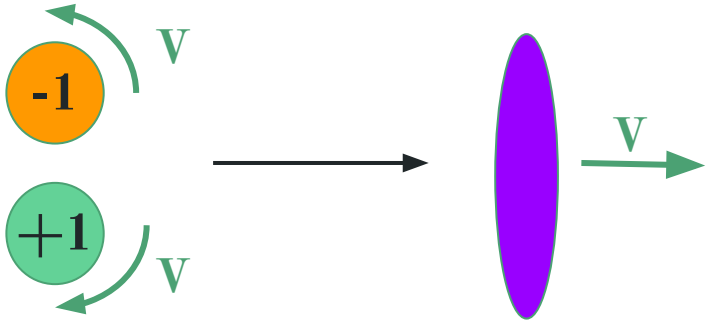
Ex of “snaking” instability :



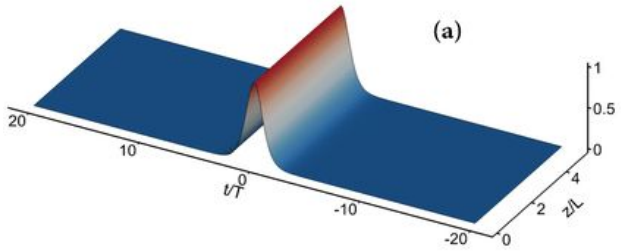
Jones Roberts Solitons

JRS : stable solutions to the NLSE (immune to instabilities)

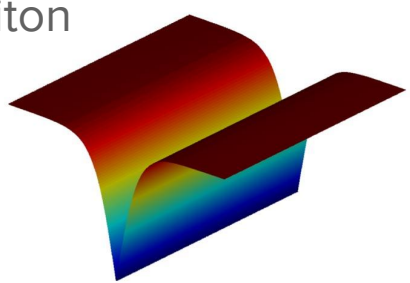
It is generated by the fusion two vortices of opposite sign : (a dipole)



Soliton



Dark soliton



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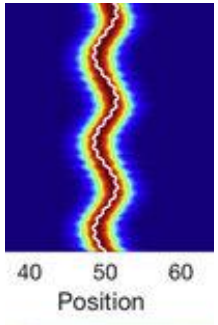
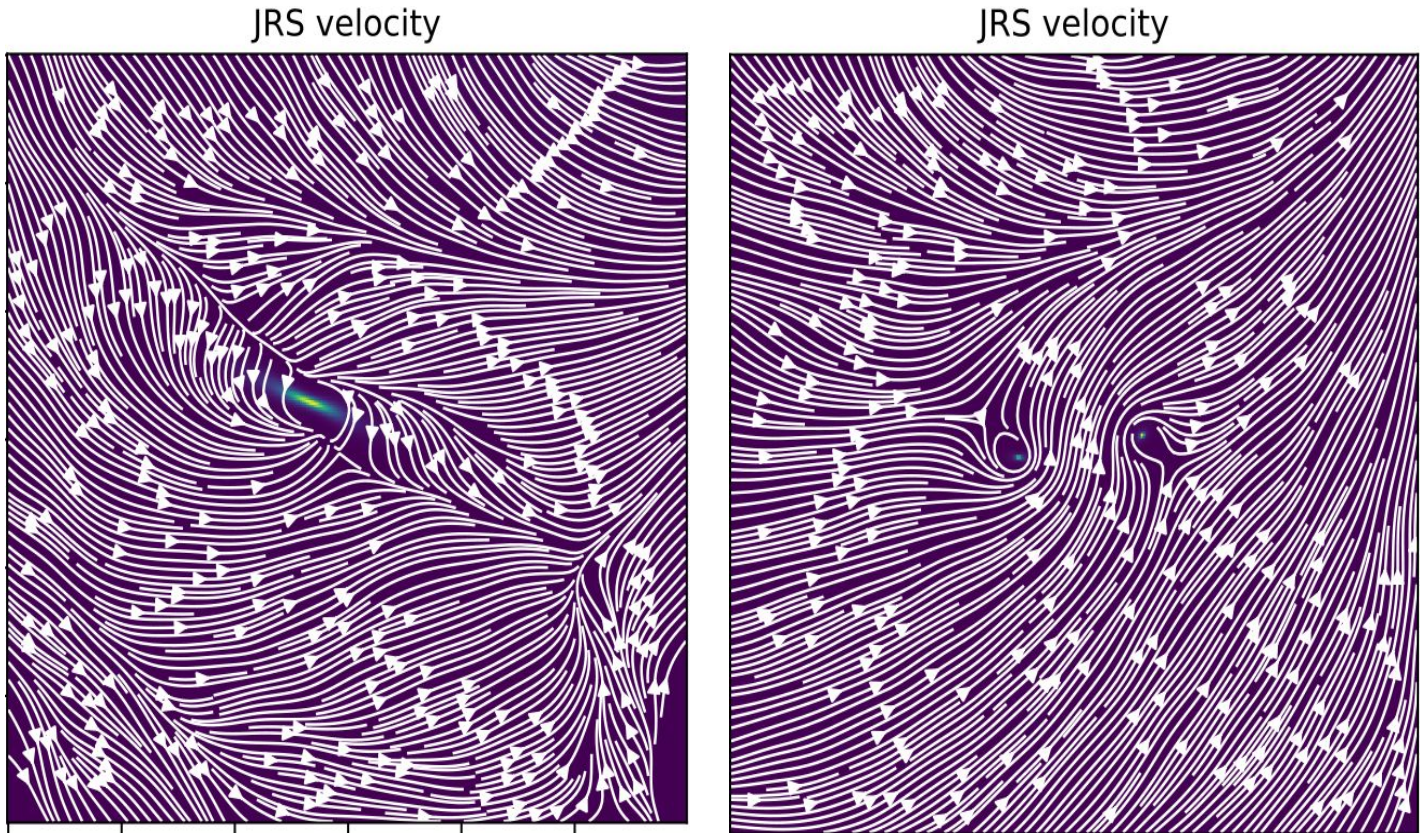


Velocities



Outlook

- how do they form ?
- how do they interact ?
- dipole - vortex collision
- dipole - dipole collision
- ...