Master degree internship position

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Optical analogue of self-gravitating systems

General context.— Many interactions in nature are long range. As long range interactions, we refer to those in which parts of the system far away from each other interact considerably. An historical example of such systems are stars inside a galaxy or globular clusters. Typically, in such a system, a star is subjected to a force dominated by the ensemble of the other stars (long range) rather than, for example, the neighboring ones (short range). As a consequence, one expects a very different behaviour (and often counter-intuitive) compared to what happens in the short-range interacting regime usually encountered in statistical physics textbooks. For example, in the thermodynamic equilibrium, there is inequivalence of ensembles or a possible apparition of negative specific heat in the micro-canonical ensemble [1, 2]. The macroscopic dynamics is also very different: starting from arbitrary initial conditions, the system forms "rapidly" a quasi-stationary state (like a galaxy) and then relaxes towards a thermodynamic equilibrium.

Recently, it has been observed that a laser beam propagating in a nonlinear, nonlocal medium presents a behavior very similar to the formation of a quasi-stationary state of self-gravitating bosons in the non-relativistic regime [3, 4], which is a serious candidate for dark matter, which constitutes the halos of galaxies.

Objectives.— During this internship, we will study theoretically and numerically such an optical analogue of a self-gravitating system. Preliminary experiments will be performed to determine the most suitable platform for this study. The targeted objectives are listed below.

1. Derivation of simple analytical scalings as done in the classical case for the early time of the collapse.
2. Study the evolution of the system for various initial conditions (formation of a quasi-stationary state, energy ejection, cold collapse, Landau damping, mixing) by writing a code to solve the Schrödinger-Newton equation [5].
3. Full description of the analogy between self-gravitating systems and nonlinear optical propagation.
4. Preliminary experiments to characterize the nonlinear thermal response of various materials (lead glass, sapphire, etc.).

Profile.— We are looking for a highly motivated candidate interested in at least one of the aspects of the project (statistical physics and/or non-linear optics). The grant is about 500 euros/month. The candidate will have the possibility to apply for a PhD thesis on this subject.

Contact.— If you are interested, please contact :

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[1] A. Campa, *et al.*, Phys. Rep. **480**, 57 (2009).
[2] Y. Levin, *et al.*, Phys. Rep. **535**, 1 (2014).
[3] R. Bekenstein, *et al.*, Nature Phys. **11**, 872 (2015).
[4] T. Roger, *et al.*, Nat. Commun. **7**, 13492 (2016).
[5] F. S. Guzman and L. A. Urena-Lopez, Appl. J. **645**, 814 (2006)