

INTERNSHIP PROPOSAL

Laboratory name: Institut d'Astrophysique de Paris

CNRS identification code: UMR7095

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Internship location: Institut d'Astrophysique de Paris, CNRS & Sorbonne Université

Thesis possibility after internship: YES

Funding: YES -- either via ED127 Doctoral School [application needed], or via ANR funding [guaranteed]

Resonance broadening in self-gravitating systems

Context

Gravity is a long-range interaction. As a result, stellar systems are generically (i) inhomogeneous (stars follow intricate orbits), (ii) self-gravitating (stars self-consistently define the gravitational potential), (iii) resonant (orbits introduce orbital frequencies). On long timescales, these systems unavoidably evolve through finite-N effects, with N the total number of particles.

Such a relaxation is generically described by the inhomogeneous Balescu-Lenard equation (BL) [1,2], which captures the lasting effects of two-body resonances. Yet, BL is ill-posed in the presence of flat frequency profiles, i.e. within "over-resonant" systems. In that case, one must resort to "resonance broadening theory" [3,4] to include the contributions from nonlinear effects -- neglected in BL -- to self-consistently regularise BL's (sharp) resonance condition [5].

Upshot

This internship focuses on exploring, analytically and numerically, the effect of resonance broadening in low-dimensional long-range interacting systems. For that purpose, we will focus on the model of classical Heisenberg spins [6,7] evolving on the unit sphere with different external profiles, in the limit of weak collective amplification. In practice, we will explore analytically the nonlinear origin of resonance broadening, using stochastic theory, emphasising the existence of anomalous scaling with respect to N. In parallel, we will use extensive numerical simulations with varying total number of particles and dynamical temperature, to explore the extent of resonance broadening, and its possible saturation. Ultimately, this program of research will offer new clues on the validity of the different quasilinear assumptions on which BL relies.

References

- [1] Heyvaerts, 2010, MNRAS, 407, 355
- [2] Chavanis, 2012, Physica A, 391, 3680
- [3] Dupree, 1966, Phys. Fluids, 9, 1773
- [4] Weinstock, 1969, Phys. Fluids, 12, 1045
- [5] Fouvry+, 2025, Arxiv, 2505.07332
- [6] Barre+, 2014, J. Stat. Mech, 2, 02017
- [7] Fouvry+, 2019, Phys. Rev. E, 99, 032101

Requirement

Strong interest in theoretical astronomy, dynamics, analytical and numerical work

Framework

The internship will be supervised by Jean-Baptiste Fouvry (IAP, Paris), and co-supervised by Pierre-Henri Chavanis (LPT, Toulouse)