Balescu–Lenard equation and marginal stability crossing

Niveau : M1 ou M2 physique.

Subject

The Balescu–Lenard equation [1, 2] describes the long-term evolution of plasmas under the effect of fluctuations in the electric field originating from the finite number of particles. This "collisional" evolution typically occurs on timescales much slower than the (fast) evolution induced by the mean electric field, as governed by the Vlasov equation. Building upon the same theoretical ground, a more general kinetic equation now allows one to describe the long-term evolution of systems governed by long-range interactions, as for example stellar clusters [3, 4].

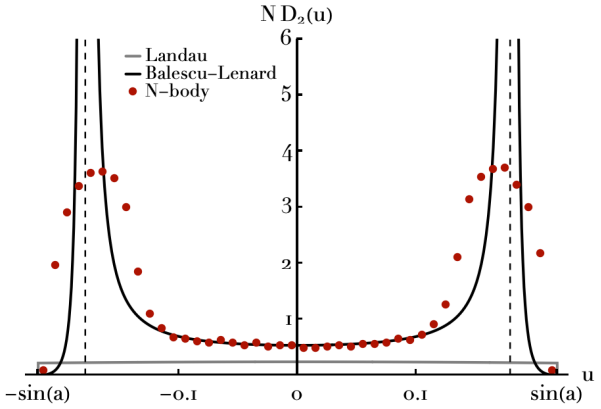

Figure 1: From [5]. Numerical measurement in N-body simulations of the orbital diffusion coefficient in a simplified long-range interacting system, compared with the theoretical predictions from the Landau and Balescu–Lenard equations.

In practice, the Balescu–Lenard equation diverges when the system approaches an instability. This description is not appropriate anymore: the fast and slow timescales are mixing up. Nonetheless, such a situation can occur in astrophysics, where the attractive nature of gravity naturally tends to trigger instabilities. Figure 1 presents one such example of the divergence of the Balescu–Lenard kinetic theory, while the real system has a fully regular behaviour. By what should one then replace the Balescu–Lenard equation?

The goal of the internship will be first to study the derivation of the Vlasov and Balescu–Lenard equations. Then, we will focus our interest on

the Rogister&Oberman theory [6], and translate it for simplified astrophysical models. Simultaneously, the intern will also consider a (much) simpler system of stochastic differential equations, reproducing some of the features of this problem within a framework more accessible analytically.

Requirement

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

Localisation and supervision

This internship will be co-supervised by Julien Barré (Institut Denis Poisson, Orléans – julien.barre@univ-orleans.fr) and Jean-Baptiste Fouvry (Institut d'Astrophysique de Paris – fouvry@iap.fr). The localisation of the internship (Orléans or Paris) is to be determined with the intern. The internship can be adapted to both M1 and M2 levels.

References

[1] Balescu R., 1960, Phys. Fluids, 3, 52

[2] Lenard A., 1960, Ann. Phys., 10, 390

[3] Heyvaerts J., 2010, MNRAS, 407, 355

[4] Chavanis, P.-H., Physica A, 391, 3680

[5] Fouvry, J.-B., Bar-Or, B., and Chavanis, P.-H., Phys. Rev. E, 99, 032101

[6] A. Rogister and C. Oberman, 1968, J. Plasma Phys., 2, 1, 33-49