Evolution of spherical self-gravitating collisionless systems in phase-space

Anaëlle Hallé[1,2], S. Colombi[2], S. Peirani[2]
[1] MPA, Garching, Germany. [2] IAP, Paris, France.

Vlasov-Poisson in spherical symmetry

$$\begin{cases} \dfrac{\partial f}{\partial t} + v_r \dfrac{\partial f}{\partial r} + \left(\dfrac{j^2}{r^3} - \dfrac{\partial \phi}{\partial r} \right) \dfrac{\partial f}{\partial v_r} = 0 \\ \triangle \, \phi = 4\pi G \rho \end{cases}$$

j : angular momentum (conserved),

gravitational force $-\dfrac{\partial \phi}{\partial r} = -\dfrac{GM(<r)}{r^2}$

Simulations

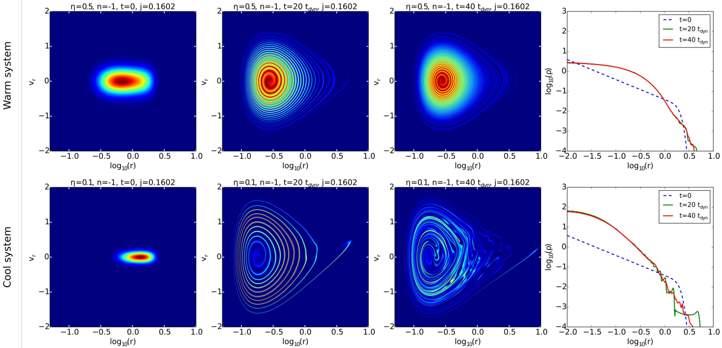
Initial phase-space density: $f(r,v) = \dfrac{\rho_0(r)}{(2\pi\sigma_r^2)^{3/2}} \exp\left(-\dfrac{1}{2}\dfrac{v^2}{\sigma_r^2} \right), r \leq R_0$

Density profiles $\rho_0(r) \propto r^n$ with n=0, -0.5, -1, -1.5.

Initial virial ratios $\eta = \dfrac{2T}{|W|}$ of 0.5 ("warm" case) or 0.1 ("cool" case).

T : kinetic energy, W: potential energy. Isotropic velocities.

Simulations on a 2048 x 2048 x 128 grid in $\ln(r), v_r, \sqrt{j}$, using the semi-Lagrangian Vlasolve code by T. Sousbie (Colombi et al 2015).



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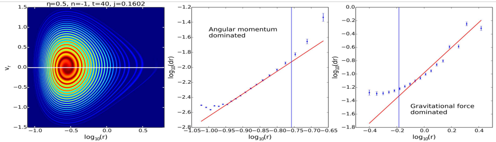
Self-similarity properties of the spiral

Analytic prediction (Alard 2013) for interfold distance as a function of fold position, using self-similar solutions of the Vlasov-Poisson system:

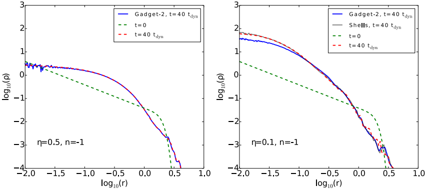
$$\mathrm{d}r \propto r_0^{\frac{3-\gamma}{2}} \text{ for a power-law force } F = \left(\frac{j^2}{r^3} - \frac{\partial \phi}{\partial r}\right) \propto r^\gamma$$

At fixed angular momentum, the repulsive force force dominates at low radii: $\gamma = -3 \Rightarrow \mathrm{d}r \propto r_0^3$,

while the gravitational force dominates at large radii.



Comparison with N-body codes



Comparison with the N-body Tree code Gadget-2 (Springel et al 2005) is performed in Colombi et al 2015 for the Hénon sphere (n=0), using correlators and entropic estimators.
Convergence obtained in the warm case, but collective effects induced by shot noise of the particles prevent convergence in the cold case.

In this work, comparison with Gadget-2 and a spherically symmetric shell code (Hénon et al 1964). Radial orbit instability in the "cool" n=-1.5 and n=-1 case lowers the central density.