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THE GRAVITATIONAL DRAG FORCE FELT BY A PLUMMER-TYPE PERTURBER IMMERSED IN A GAS

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In this work we use axisymmetrical numerical simulations with the Flash Code to calculate the gravitational drag force felt by a gravitational Plummer sphere when moving in a homogeneous medium. We revisit the linear scenario studied by Ostriker (1999) as well as the nonlinear scenario studied by Kim & Kim (2009) focusing in the hydrodynamics and in the integrated force.

In 1943 Chandrasekhar worked the problem of gravitational drag force in the context of stellar motion. The process of dynamical friction is defined as momentum loss by a massive moving object due to its gravitational interaction with its own gravitationally induced wake. This problem arises in many astronomical systems ranging from stars in clusters or galaxies, galaxies in galaxy clusters, binary star cores in the common envelope phase of evolution, as well as in accretion discs (Ostriker 1999).

Following Ostriker (1999), a gravitational perturber moving through a gaseous background creates a density wake in the medium. The gravitating object induces small disturbances in the far-field ambient medium and, consequently, the far-field density structure of the wake can be derived in linear perturbation theory. In this case, the drag force is usually written as

$$F_{DF} = \frac{4\pi\rho_\infty (GM)^2}{V_0^2}\ln\Lambda, \qquad (1)$$

where $\ln\Lambda$ is the Coulomb logarithm. For subsonic and supersonic perturbers respectively, it has the next values: (i) $\ln\Lambda = \frac{1}{2}\ln\left(\frac{1+\mathcal{M}}{1-\mathcal{M}}\right) - \mathcal{M}$ and (ii) $\ln\Lambda = \frac{1}{2}\ln\left(1-\mathcal{M}^{-2}\right) + \ln\left(\frac{\mathcal{M}c_\infty t}{r_{\rm min}}\right)$. $r_{\rm min}$ is the minimum radius of the effective gravitational interaction of a perturber with the gas. Salcedo & Brandenburg (1999) show that $r_{\rm min} = 2.25$. We show numerical results using the Flash method (Fryxell 2000) of a perturber moving in a gas in both, linear and nonlinear regimes (Bernal & Salcedo 2013) which have been compared to the results of Kim & Kim (2009).

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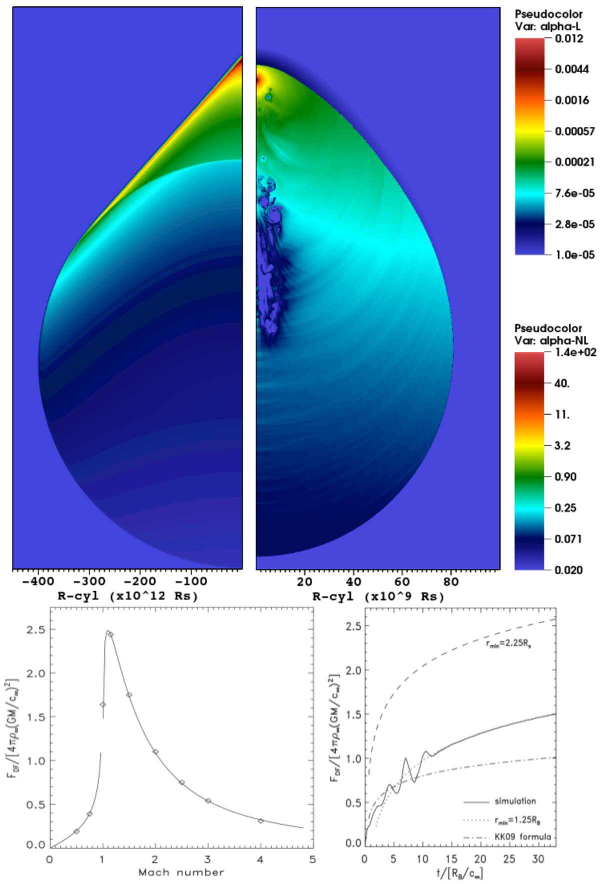

Fig. 1. Up – Color maps of the perturbed density, in logarithmic scale, for the linear and nonlinear cases. For the linear case the flow is very smooth while for the nonlinear case a rich morphology is present. Down – (left) Dimensionless drag force as a function of Mach number in the linear regime ($A = 0.01$). The solid line corresponds to Ostriker's formula. (right) Dimensionless drag force in the nonlinear regime using three analytical formulae.

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