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A Study of Transient Dynamics of Perturbations in Keplerian Discs Using a Variational Approach

D. Razdoburdin[1,2]

[1] Sternberg Astronomical Institute
nikolai.shakura@gmail.com

[2] Lomonosov Moscow State University

The behavior of hydrodynamic fluctuations in the gaseous component of astrophysical disks is of primary importance for understanding their observed properties. It is also related to the major problem of the enhanced angular momentum transfer and the nature of the effective viscosity in Keplerian disks. Having a significant gradient of angular velocity, these disks are capable of substantial transient effects in perturbation dynamics. In our study, we consider such effects employing a variational formulation of the optimization problem, which allows one to obtain optimal initial perturbations that exhibit the highest possible growth on a specified time interval. In particular, we use our method to study the transient dynamics in the shearing sheet approximation. We show that the most rapidly growing shearing harmonic has azimuthal wavelength of the order of the disc thickness. Moreover, its initial shape is always nearly identical to a vortical perturbation having the same potential vorticity. We also extend our study to a global spatial scale taking into account the background vorticity gradient and the disc cylindrical geometry. We show that global vortices with azimuthal wavelengths more than an order of magnitude greater than the disc thickness are still able to attain the growth of dozens of times in a few Keplerian periods at the inner disk boundary. We argue that if the disk is already in a turbulent state with small effective viscosity, then these large-scale vortices have the most favorable conditions to be transiently amplified before they are damped. At the same time, turbulence is a natural source of the potential vorticity for this transient activity. Thus, we conclude that transiently growing vortical structures on scales above the disc thickness should provide an additional angular momentum transfer in disks and should affect their variability properties as well.