INSTABILITIES OF UNIFORMLY ROTATING DISKS

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We explore a series expansion method to calculate the instabilities and the structure of the perturbations for a variety of uniformly rotating finite stellar disks. This survey focuses on the role of the distribution function in stability analyses. Although the potential does not show differential rotation, it will in many cases be a reasonable approximation for the disk in the central regions of galaxies without massive central mass concentration.

1. Method

In order to find normal mode perturbations, we have to find simultaneous solutions for the linearized Boltzmann equation and the Poisson equation. We use a power series expansion in the radius. The velocity coordinates enter as power series as well, choosing stars on circular orbits as the zero point. In addition, the angular and time dependence are combined in a rotating harmonic function. These expansions can be substituted in the linearized Boltzmann equation in order to collect the terms with equal powers, resulting in a linear set of equations for the unknown response. The method (Vauterin & Dejonghe, 1994) is very well suited for uniformly rotating disks, since these do not show any local resonances. Coupling this way of solving the Boltzmann with Hunter's (1963) set of potential-density pairs, self-consistent modes were calculated using a matrix method.

The described scheme can be used to study the stability of a wide variety of uniformly rotating stellar disks. The calculations start with an unperturbed distribution written as a linear combination of (nonintegral) powers of binding energy E and angular momentum J. Most of the unperturbed models which we have studied feature an inert, spherical halo.

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2. Results

All examined models which are isotropic in a rotating frame and have a distribution which is everywhere increasing with increasing binding energy were found to be stable, regardless the halo strength or the rotation speed. The simple analytical form of the perturbed distribution allows to quantify the vertex deviation due to the presence of a rotating bar.

We superimposed two components with opposite rotation speeds, which are on themselves stable. The result turns out to be unstable for modes with higher order of symmetry, resulting in somewhat patchy perturbations. Since the individual components are stable for all perturbations, these instabilities are clearly two-stream.

In the self-consistent isotropic case (Maclaurin disk), the distribution is proportional to $E^{-1/2}$. By adding an angular momentum dependence to this distribution, we constructed self-consistent unperturbed models which are not isotropic. The dominating mode, which was perfectly bar-shaped in the isotropic case, now shows a spiral structure. Other inverted models also show spiral instabilities. The disks become more unstable for increasing rotation Ω and increasing disk-to-halo proportion f.

3. Conclusions

It turned out that *the structure of the distribution has a big influence on the stability.* Even the "simple" quadratic potential we applied allows the construction of disks varying from totally stable to violently unstable ones. In addition, *this potential can generate bar instabilities as well as spiral structures.* It is reasonable to assume that most of these instabilities correspond to so-called "edge-modes" (Toomre, 1981).

All of the examined distributions which have an increasing number of stars for increasing binding energy are stable in a quadratic potential, even for a small halo component (some 20 % in mass). This might indicate that disks in the central parts of galaxies (where the potential is almost quadratic) are usually stable.

References

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