ON THE EVOLUTION OF PERTURBED GAS DISKS

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Numerical experiments have shown that axisymmetric shearing gas disks will develop a spiral pattern when a non axi-symmetric contribution is introduced. This mechanism initially seems to be a prime candidate as the source of galactic spiral arms. The experiments have, however, failed to explain the formation of more than the most open systems and the smooth transition in the morphological sequence does not indicate any change in the physical mechanism between Sa and Sc types.

In order to study the evolution and persistence of these spiral arms, experiments have been performed on a disk of gas rotating in equilibrium in a Toomre potential.

$$\phi = c^2/a \ (a^2+r^2)^{-3/4} \tag{1}$$

This disk is perturbed by a point mass passing along a parabolic trajectory.

$$r = p/(1+\cos f) \tag{2}$$

where p is the semilatus rectum and f the true anomaly. If p is assumed to be independent of the mass of the perturber, the system can be determined by five independent parameters: The Toomre constants (a,c), the isothermal sound speed in the gas and two parameters for the perturber (p,m) where m is the mass ration perturber/disk. In the extremes this model has well known solutions. For small values of p the perturbation is reduced to a short tidal jolt and the spiral system is formed when differential rotation. winds up material arms. For large p and m values the system will resemble the well studied case where the potential has a bar superimposed [Sanders 1977; Matsuda and Isaka 1980; Sørensen and Matsuda 1982], and a quasi-stationary open pattern, correlated with the major resonances will result. Neither of these types of arms are entirely satisfactory as candidates for the observed spirals, being either too short lived or too open to fit the observations.

Here we concentrate on a third type which previously has been discussed only briefly [Sørensen 1979]. In the perturbation experiments tightly wound arms forms in the density distribution. Although the

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amplitude of the pattern depends on the strength of the perturbation, the rest of its attributes including the degree of winding is independent of both p and m. The principal wavefronts have been traced in both the density distribution and the velocity field. In the velocity field the basic mode, simple epicyclic waves, can easily be identified. These wave fronts have no simple geometrical form for this type of potential and their pitch angle varies with radius as well as time [Nelson, 1976]. For illustration purposes, however, a mean pitch angle was defined by fitting the best logaritmic spiral to each arm, and the measured variation in pitch angle with time is shown in fig 1 (solid) with the evolution of a retrograde epicyclic wave (dotted). A similar procedure was followed for the density. Due to non-linear effects the density response is quite different from that of the velocity field and the arms fit a logaritmic spiral to a very high degree as seen in fig 2. The density pattern seems considerably tighter wound and less prone to further winding than the velocity mode as can be seen from fig 1 (dashed). Further experiments indicate that the the two modes follow the same evolutionary track although their position on this track is displaced. The evolutionary track is closely correlated with the radial variation in the potential, represented here by the Toomre a-constant, being progressively steeper with increasing central concentration. The pattern persists until the winding of the velocity response matches that of the density response.

References

Matsuda, T. and Isaka, H.,1980. Prog. Theor. Phys., 64, 1265.

Nelson, A.H.,1976. Mon. Not R. astr. Soc., 177, 265.

Sanders, R.H.,1977. Astrophys. J., 217, 916.

Sørensen, S.-A.,1979. In Photometry, Kinematics and Dynamics of Galaxies, ed. Evans, D.S.

Sørensen, S.-A. and Matsuda, T.,1982. Mon. Not. R. astr. Soc., 198, 865.

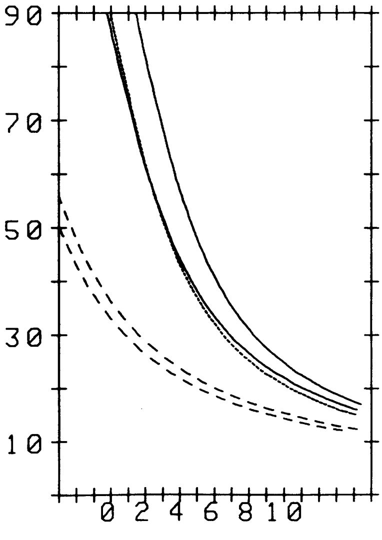

Fig. 1

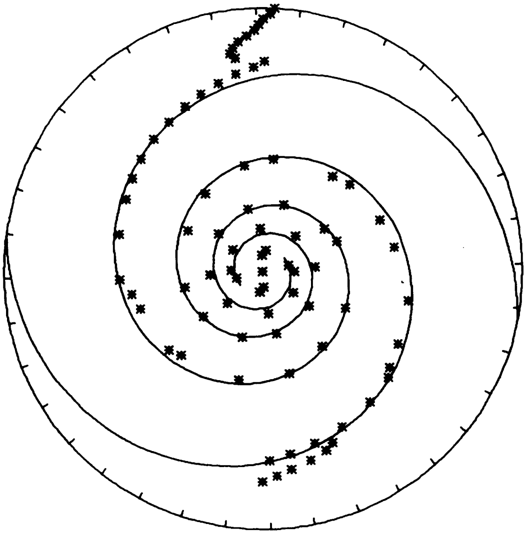

Fig. 2