VERTICAL STRUCTURE OF SPIRAL SHOCKS IN A CORRUGATED GALACTIC DISC

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Numerical calculations of spiral shocks in the gas discs of galaxies (1,2,3) usually assume that the disc is flat, i.e. the gas motion is purely horizontal. However there is abundant evidence that the discs of galaxies are warped and corrugated (4,5,6) and it is therefore of interest to consider the effect of the consequent vertical motion on the structure of spiral shocks. If one uses the tightly wound spiral approximation to calculate the gas flow in a vertical cut around a circular orbit (i.e the θ-z plane, see Nelson & Matsuda (7) for details), then for a gas disc with Gaussian density profile in the z-direction and initially zero vertical velocity a doubly periodic spiral potential modulation produces the steady shock structure shown in Fig. 1. The shock structure is independent of z, and only a very small vertical motion appears with anti-symmetry about the mid-plane.

Now if instead of an initially flat gas disc we impose an initial perturbation of density and velocity derived from linear corrugation wave theory (8), and assume that the corrugations are spirals congruent to the potential spirals, then the response of the gas to the same spiral potential as for Fig. 1 is shown in Fig. 2. Note that there is now no steady state since the corrugation will in general have a different phase velocity from the stellar density wave producing the potential, hence the corrugation moves in the rest frame of the spiral potential. The main feature produced by the corrugation is a splitting of the main shock peak into two peaks as in Fig. 2, a phenomenon which appears and disappears periodically. The period between succesive splittings in this case is 10^8 years, and the duration is 4×10^7 years. The reason for the splitting is that the corrugation carries its own doubly periodic density modulation (8), and when the corrugation and spiral shock are out of phase the total density modulation becomes quadruply periodic around a full galactic orbit.

The main conclusion to be drawn from this calculation is that, while the overall doubly periodic density modulation due to a two-armed stellar spiral (or bar) persists, the detailed structure of the density is significantly modified by a corrugation of the gas disc. This is true even if the corrugation amplitude is relatively small (maximum gas ridge z deviation ≈ 30 pc, and z velocity ≈ 6 km/sec in Fig. 2), and hence the existence of higher harmonics in spiral galaxies (9), leading to such features as

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secondary filaments and gaps and asymmetries in arms, might easily be explained by corrugations.

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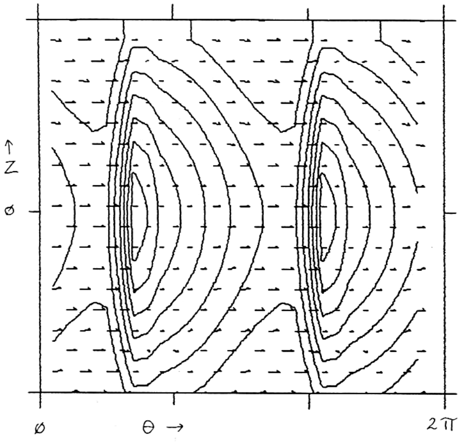

Fig. 1 Contour plot of gas density in the θ-z plane in response to a spiral potential alone. The contours start at a density (relative to the unperturbed ridge density) of 0.4 and the step is 0.2. The arrows show the velocity component perpendicular to the spirals. The z thickness of the box is 200 pc, and the θ length is 31 kpc.

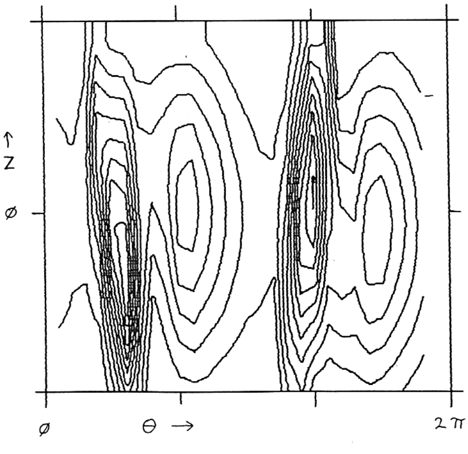

Fig. 2 Contour plot of gas density in the θ-z plane in response to a spiral potential and an initial corrugation of the gas layer. Contours are as for Fig. 1.