3-DIMENSIONAL PARTICLE SIMULATION OF VERTICAL OSCILLATIONS IN GAS DISCS

T.C. Johns and A.H. Nelson
Department of Applied Mathematics and Astronomy,
University College, P.O. Box 78, Cardiff CF1 1XL. UK

The problem of the persistence of warping in the outer regions of many galactic HI discs is now well known. Such a warp is observed in the Milky Way, where further deviations from a flat plane are seen in the form of a systematic tilt of the gas disc near the centre, with a short-wavelength (approximately 2 kpc) corrugation at intermediate radius.

A kinematical model for warped HI discs suggests that in the absence of external influences such features should rapidly wind up by differential precession and dissipate for a realistic rotation law. However it was argued by Nelson (1981) that in reality the kinematical tilted-ring model may be an oversimplification, and a more complete analysis of the vertical wave modes available to the galactic gas disc including the pressure term revealed the existence of two distinct classes of wave mode, the so-called "fast" and "slow" corrugation waves. In practice we expect only the lowest-order modes to be dynamically important. The fast mode winds up rapidly over the whole disc being closely related to the kinematical model, but Nelson demonstrated that the retrograde slow wave has the property that the line of nodes winds up slowly or not at all in the central and outer regions, giving a persistent central tilt and outer warp.

Since the properties of the slow and fast wave modes were derived using a local approximation, it is desirable to test the global properties of such waves by numerical simulation. To this end a 3-dimensional quasi-particle code has been developed, based on a non-self-gravitating version of the quasi-particle hydrodynamics technique due to Lucy (1977) and Gingold and Monaghan (1977). In the problem of interest the only interparticle forces involved are short-range pseudo-pressure forces, and consequently it has been found to be convenient to introduce a rectangular mesh of 63x63x7 cells and make use of an indirect particle-mesh scheme for evaluation of pressure forces. This enables a large number of particles to be handled efficiently - approximately 30 000 in the simulations reported.

The gravitational potential used in the calculations was of the form

H. van Woerden et al. (eds.), The Milky Way Galaxy, 503–504.

https://doi.org/10.1017/S0074180900243027 Published online by Cambridge University Press

$$\phi(\underset{\sim}{r}) = \phi_1(r) + \phi_2(r,z)$$

where the rotation law for the models was

$$\Omega(r) = \Omega_c(1+(r/a)^p)^{-q}\ , \ q = (1+2^{-p})/p,\ p=4 \text{ for Model 1 (Figs 1,2)}$$

and $\Omega(r) = \Omega_c(1+r^2/a^2)^{-3/4}$ for Model 2 (Fig 3).

The vertical potential is modelled as

$$\phi_2(r,z) = \tfrac{1}{2}\nu(r)z^2$$

with $\nu(r) = k\Omega^2(2a)\exp(1-r/2a)$, k = 16.4 respectively for Models 1,2;

$\Omega_c{-1} = 1.22\text{x}10^7$, $1.82\text{x}10^7$ yr respectively for the two models and a = 6 kpc.

Figures 1 to 3 below show the wavefronts corresponding to the crossing of the galactic midplane for models in which the gas disc was initially tilted at an angle of about 2 degrees with respect to the plane of the potential. In all figures the sense of rotation is anti-clockwise and shaded areas indicate gas above the midplane.

In Figures 1 and 2 the initial velocity was chosen so that the gas was in approximate centrifugal equilibrium. In Figure 1 the z-velocity was chosen so that initially the gas was moving in the plane of the tilted disc; in Figure 2 the z-velocity was reversed. Note the different sense of the wind-up in the two cases and the reversal that occurs in the centre in Figure 2. In Figure 3 the velocity field was similar to that in Figure 2, but with an additional asymmetric perturbation in the plane of the disc, which caused large-scale deviations from circular motion and shocks in the gas disc. In this case the wavefront does not wind up significantly in the centre, perhaps evidence for the presence of a retrograde slow wave mode.

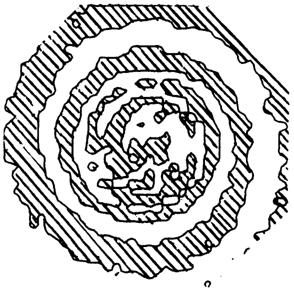

Figure 1.

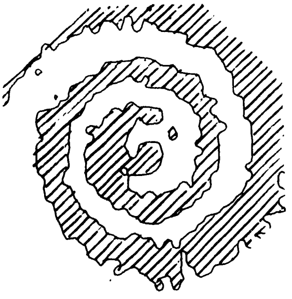

Figure 2.

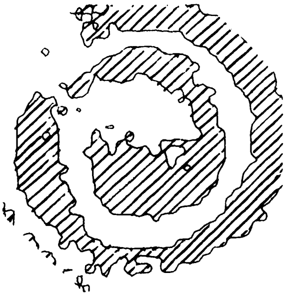

Figure 3.

REFERENCES

Gingold, R.A., Monaghan, J.J.: Monthly Notices Roy. Astron Soc. 181, 375.
Lucy, L.B.: 1977, Astronomical J. 82, 1013.
Nelson, A.H.: 1981, Monthly Notices Roy. Astron. Soc. 196, 557

https://doi.org/10.1017/S0074180900243027 Published online by Cambridge University Press