SPIRAL INSTABILITIES AND DISC HEATING

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Heating-Cooling Equilibrium of a Disc

Many simulations of disc galaxies exhibit a succession of transient spiral patterns when sufficient halo is included to suppress the global bar instability (Hohl 1970, Hockney and Brownrigg 1974, Sellwood and James 1979). This behaviour causes the velocity dispersion to rise secularly which in turn reduces the intensity of the patterns. Spiral activity usually ceases altogether as Q tends asymptotically to a value somewhat greater than 2.

Such simulations however, take no account of star formation which continually injects low velocity dispersion stars into the disc. In our current simulations, we mimic this process by adding particles at a constant rate. The new particles are chosen randomly from the same density distribution as the original disc and their initial velocities are purely tangential at the local circular speed. The mass in the stabilising halo, initially 70% of the total, is steadily reduced to conserve mass. The halo density profile was chosen in such a way that the rotation curve is independent of the disc to halo ratio in order that the mass transfer does not affect the centrifugal balance of the disc.

The Q of the disc rises from its initial value of 1, quickly reaching a steady equilibrium value after 2 or 3 rotation periods. Spiral structure is continuously present for the duration of the experiments, 35 rotation periods. However, as in previous work, any one pattern lasts typically for less than a rotation period. The patterns are large scale and have a fair degree of symmetry, often two armed but frequently more. A logarithmic spiral Fourier analysis of the particle distribution shows that leading features are continually being "swing amplified" (Toomre 1981) into strong trailing waves which propagate for a short time before fading.

The equilibrium Q of the disc is dependent on the rate of addition of $\dot{s}$tars. From three different experiments we $\dot{f}$ind Q = 1.9, 1.7 and 1.7 for $\dot{f}$ = .006, .015 and .03 respectively, where $\dot{f}$ is the fraction of the

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 127–128.

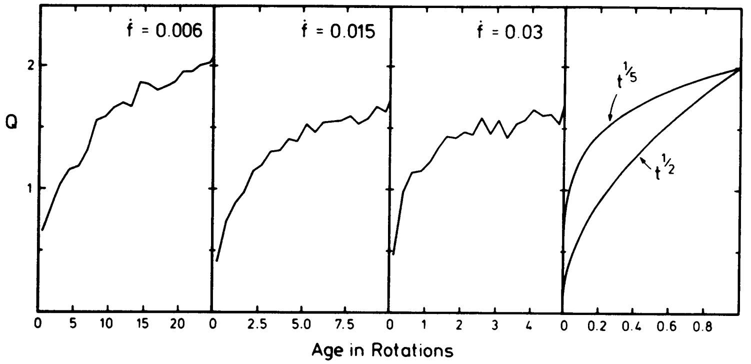

Figure 1. The age-velocity dispersion relation for stars in three models having different star formation rates. The fourth plot gives two fiducial curves indicating the range of power laws spanned by the models.

total mass added to the disc per rotation period, measured at the half mass radius. The mass of the disc reaches twice its initial value after 50 rotation periods when $\dot{f}$ = .006, which represents the best scaling to a roughly constant star formation rate in the Galaxy.

Thus the steady addition of cool stars balances the heating caused by the transient spirals at an equilibrium Q low enough for spiral activity to be maintained practically indefinitely.

The Age-Velocity Dispersion Relation

Particles are divided into groups by their age, that is the time since they were inserted into the simulation. The local velocity dispersion of each group is computed and expressed as a Q, i.e. a fraction of the local $\sigma_{u,min}$. The measured Q is found to be almost independent of radius, so we average the whole disc together and obtain the relations shown in figure 1.

The experimental results substantially agree, both in form and magnitude, with that observed in the solar neighbourhood (Wielen 1974).

References

Hockney, R.W. & Brownrigg, D.R.K. (1974) M.N.R.A.S. 167, 351.
Hohl, F. (1970) NASA TR R-343.
Sellwood, J.A. & James, R.A. (1979) M.N.R.A.S. 187, 485.
Toomre, A. (1981) "Normal Galaxies" Eds. Fall, S.M. & Lynden-Bell, D. Cambridge Univ. Press.
Wielen, R. (1974), Highlights of Astronomy 3, 395.

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