Spiral Heating of Galactic Discs.

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Abstract. We have investigated the combined effects of transient spiral waves and giant molecular clouds in heating stellar discs by solving the Fokker-Planck equation with a Monte Carlo simulation. By using obervations of the velocities of local stellar populations we are able to estimate the product of the mean surface density and the mass-weighted mean mass of the clouds and the RMS potential fluctuations associated with the spiral waves. The estimates show good agreement with observations of giant molecular clouds in our galaxy and HI observations in other spiral galaxies. We make predictions of the vertical and radial velocity distributions of two disc populations.

Method.

The heating of a stellar disc by transient spiral waves and giant molecular clouds can be described by the Fokker-Planck equation. We have solved this equation by Monte Carlo simulation using the diffusion coefficients derived by Binney and Lacey (1988). We have assumed spiral waves with similar temporal and spatial behaviour to those observed in numerical simulations.

At the beginning a sample of stars were chosen with a small velocity dispersion. The system was evolved by simulating diffusion of the stars in a two-dimensional space corresponding to the vertical and radial epicycle energies of the stellar orbits. For full details of the methods used and the assumptions made see Jenkins and Binney (1990).

Results.

The Fokker-Planck equation was solved for a range of strengths of spiral heating in relation to cloud heating. The ratio the vertical velocity dispersion to radial velocity dispersion σ_z/σ_R decreases as the contribution from spiral heating increases. Except for pure cloud heating the velocity ellipsoid is expected to grow faster in the radial direction than the vertical direction. Although ephemeral spiral waves are ineffective in vertical heating we found that the enhanced radial heating due to the spiral waves also led to a significant increase in the effective vertical cloud heating.

We have fitted our results to the observations of the kinematics and ages of nearby stars by Wielen (1977) and Strõmgren (1987). We are able to estimate the product of the mean surface density of molecular hydrogen with $\int N(m)m^2\,\mathrm{d}m/\int N(m)m\,\mathrm{d}m$, where $N(m)\,\mathrm{d}m$ is the number of clouds with masses in the interval $(m, m+\mathrm{d}m)$. Our estimate agrees with estimates of this quantity made using mm CO observations of giant molecular clouds in the Galaxy. We predict that the mean RMS potential fluctuations associated with transient spiral waves should be $[9-13\,\mathrm{km\,s^{-1}}]^2$ in good agreement with 21 cm observations in near by spirals which show deviations from circular motion of this order. Figure 1 shows the expected velocity distributions for a coeval population and for a population with a constant birth-rate. The shapes of the distributions change little over galactic time-scales. The distribution for a population with a constant birth rate is remarkably

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 400–401.

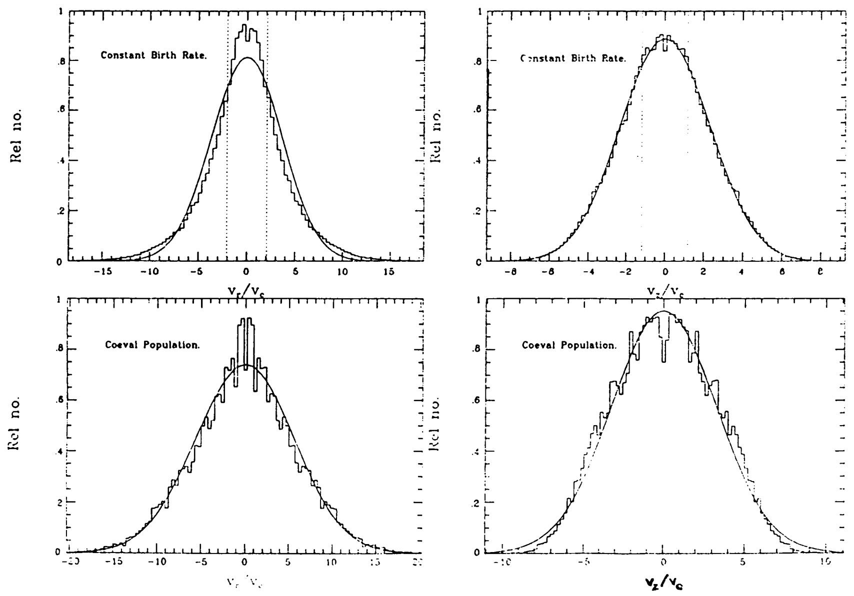

Figure 1. Predicted histograms of the numbers of stars with given v_R and v_z normalized by a velocity v_c defined in Jenkins & Binney (1990). The full curves are best-fitting Gaussians. Since the initial velocity distribution of young stars is not well determined, we have excluded from the constant star-formation panels the very youngest stars. The dotted lines mark the root mean square velocity of the youngest stars included.

Gaussian. By contrast the v_R-distribution is more highly peaked and has a more extended tail than the Gaussian fitting curve. For the constantly forming population we calculated the dependence of the velocity dispersion on distance from the mid-plane of the disc. The radial dispersion was found to increase with distance and the vertical dispersion to show a smaller decrease with distance. The full results are in Jenkins and Binney (1990).

Conclusions.

The combined effects of transient spiral waves and giant molecular clouds appear to be adequate to explain the heating locally observed. However larger samples of stellar motions and ages are badly needed in order to put stronger constraints on any future models of the disc heating. Only with new data will it be possible to conclude whether or not any other heating process may be important.

References.

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https://doi.org/10.1017/S0074180900244677 Published online by Cambridge University Press