PROPERTIES OF THE GALACTIC BAR FROM HYDRODYNAMICAL SIMULATIONS

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It is well known that the existence of H I and CO gas at "forbidden" velocities in longitude-velocity (l–V) diagrams of the inner Galaxy (*e.g.* Liszt & Burton 1980, Liszt 1992) is inconsistent with circular motion in an axisymmetric potential. Gas flow in a barred potential could be consistent with the observations, however. We have compared the observations to 2-D hydrodynamical simulations of gas flows in a family of barred potentials. The gas flow pattern is very sensitive to the assumed potential, and the l–V distribution of cool gas in the inner Galaxy places strong constraints on several parameters of the Milky Way bar.

We use a 2-D grid-based hydrodynamical code (kindly provided by E. Athanassoula) to model the gas flow (van Albada 1985, Athanassoula 1992). This is an Eulerian grid code for an isothermal gas in an imposed potential, taken to be due to the stellar component and halo. We use a mass model with three components: a modified Hubble bulge, a Rybicki disk (representing both the disk and the halo), and a prolate Ferrers $n = 1$ bar. Each model is specified by seven parameters for these components, and the pattern speed of the bar. The velocity field of the gas reaches a steady state by about 0.15 Gyr; we continue the simulation to roughly 0.4 Gyr, and then project the density and velocity data into l–V diagrams as would be seen by an observer at the solar radius, at various viewing angles to the bar.

We concentrate our attention on the shape of the extreme–velocity envelope of the Galactic H I l–V diagram (see Liszt 1992, Fig. 2); the H I should probe the maximum velocity attainable and the outer contour is unaffected by clumpiness. As the band of emission at $|v| < 80$ km s^{-1} is due to foreground (Liszt, private communication), we compare only to the shape of the contour at higher velocities. Notable features of the l–V diagram are (1) sharp peaks at $l = +3°$ and $-4°$, which require either a peak in the rotation curve or strong non-axisymmetric motions, and (2)

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emission in the "forbidden" quadrants – there is gas at positive longitude, out to $l = 6°$, with negative (approaching) velocities, and vice versa; this is impossible in a stationary axisymmetric system.

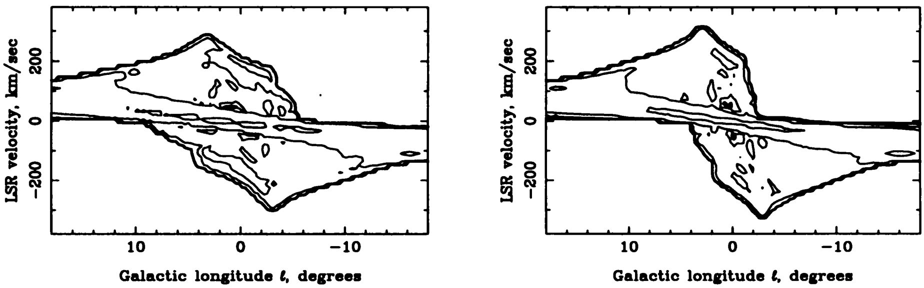

Figure 1. (a) Longitude-velocity diagram for our best-fitting model of the Galactic bar, viewed at 35° to the major axis of the bar. The contours are stepped logarithmically by a factor of 10. (b) The same model viewed at 20° to the major axis.

We have run over 40 models, varying the parameters of the potential, and constructed l–V diagrams. The l–V diagram of our best model is shown in Figure 1(a); this model has a bar with semimajor axis 3 kpc, axis ratio 4:1, mass $8 \times 10^9 M_\odot$, and Lagrangian radius 3.6 kpc, and best matches the data when viewed at 35° to the major axis of the bar. The emission at the peaks in the l–V diagram tends to come from gas streaming along the bar, relatively close to the center. The model has straight shocks at an angle to the major axis of the bar, as in many of Athanassoula's (1992) models. The emission in the forbidden quadrants comes from gas which is approaching these shocks from behind. Hence the lengths of the shocks limit the angular extent of the emission in the forbidden quadrants. If the bar is too small, or too close to end-on, the shocks subtend a smaller angle in longitude and the emission in the forbidden quadrants is cut off, as seen in Figure 1(b).

In order to match the data we have had to do considerable fine–tuning of the parameters; we do not claim that ours is a unique model for the Galactic potential. However the sensitivity of the l–V diagram to the assumed potential and the need for fine-tuning suggest that large regions of parameter space are inconsistent with the observations. In particular we suggest that a bar which is closer than 20° to end-on cannot generate the emission observed in the forbidden quadrants of the l–V diagram.

References

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