THE CO ROTATION CURVE OF THE MILKY WAY : ACCURACY AND IMPLICATIONS

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The CO rotation curve exhibits an increase in circular velocity beyond R = 12 kpc (Blitz, Fich, and Stark 1980) which may be as much as 50 km s^{-1} at R = 18 kpc. Recently, Blitz and Fich (1983) have examined the uncertainties in the rotation curve at large R and have concluded that : 1) Of all the uncertainties, small changes in R_o and θ_o have the most serious effect on the rise at large R. However, unless $\omega_o < 20$ km s^{-1} kpc^{-1}, a value smaller than that accepted by all observers, the rotation curve rises beyond R = 12 kpc. 2) Systematic errors in stellar distances and non-circular motions might have an effect on the magnitude of the rise. Both effects are thought to be small, but probably work to make the rotation curve even steeper. 3) The global value of the Oort A constant is < 12.5 km s^{-1} kpc^{-1}, and the local value of 15 km s^{-1} kpc^{-1} is most likely due to a local velocity perturbation.

One of the implications of a rising rotation curve is that most of the mass in the outer Milky Way can be shown observationally to reside outside the disk. This may be done as follows : Spitzer (1942) has shown how the scale height of a gas layer in a flattened system is related to the velocity dispersion of the gas and the density. This can be generalized to include all sources of gas pressure by substituting the ratio of the total gas pressure to gas density for the square of the velocity dispersion (Kellman 1972). If one assumes that all of the mass implied by the rotation curve is in the disk, and if the stellar scale height is much larger than the gas scale height, it can be shown (Kulkarni, Blitz and Heiles 1982) that

$$\frac{Z_2^2}{Z_1^2} \leqslant \left(\frac{R_2}{R_1}\right)^{\alpha} \frac{H_{*2}}{H_{*1}} \quad . \tag{1}$$

where Z is the rms scale height of the gas, R is galactic radius, H_* is the stellar scale height, and the subscripts 1 and 2 refer to different radii. The equality holds if the gas pressure is independent of radius. The exponent $\alpha = 1$ for a flat rotation curve, and is < 1 for a rising curve. If $H_* \ll Z$, equation (1) becomes

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$$\frac{Z_2^2}{Z_1^2} \leqslant \left(\frac{R_2}{R_1}\right)^{\alpha} \qquad (2)$$

with the same conditions on α and the inequality.

Locally $H_* >> Z$. Either this condition continues to be satisfied at $R > R_o$ or there is a distance R_c beyond which $H_* << Z$. In the former case, equation 1 is valid at all $R > R_o$. In the latter case, equation 2 is valid at $R > R_c$. Kulkarni, Blitz and Heiles (1982) have shown that the HI scale height increases almost linearly from $\sim$ 200 pc at R = 10 kpc to $\sim$ 2 kpc at R = 30 kpc. Thus if equation 1 is appropriate, the left hand side is $\sim$ 100 for these two values of R and $H_{*2}/H_{*1} > 30$. This implies that the stellar scale height at R = 30 kpc is comparable to the radius of the Galaxy, a notion inconsistent with the concept of a thin disk. If equation (2) is valid, there is no location beyond R_c at which equation (2) can be satisfied. This is due to the linear increase of Z with R_2 which makes the left hand side of equation (2) proportional to R^2. Since the right hand side is proportional to R, the inequality cannot be satisfied for $R_2 > R_1$. Thus, it is not possible to satisfy either equation (1) or (2) with all of the galactic mass at large R in a thin disk.

By relaxing the condition that all of the mass implied by the rotation curve resides in the disk, it is possible to avoid these difficulties. Thus, without any assumptions about the mass-to-light ratio or the form of the disk mass distribution, the CO rotation curve and the run of HI scale height imply that a significant fraction of the mass of the Milky Way lies outside the disk.

References

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