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Vertical scaleheights of stars and gas in the galaxy

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Abstract. The vertical scaleheight of atomic hydrogen gas is observed to be nearly constant with radius in the inner Galaxy (< 8.5 kpc). This has been a long-standing puzzle (Oort 1962) because the gas scaleheight should increase exponentially with radius as a response to the decreasing gravitational potential of the stellar disk alone. We treat the stars, H I and H_2 as three gravitationally coupled components in the Galactic disk and find their scaleheights as a function of galactocentric radius. This approach not only explains the near-constancy of H I scaleheight but also reproduces the observed scaleheight variation for H_2 and stars in the Galaxy.

We show in this paper that the gas gravity needs to be taken into account to get the correct physical description for the observed vertical scaleheights of the disk components. This is because the interstellar gas in the Galaxy constitutes a significant fraction (15%) of the total disk mass. A large fraction of the mass of atomic hydrogen is located in the outer Galaxy ($R > 8.5$ kpc), which is also the region where the stellar disk potential drops down. In contrast, most of the molecular hydrogen gas (~ 80 %) is concentrated in the form of a ring between $4 - 8.5$ kpc. Thus, we expect the large scale distribution of H I and H_2 gas combined, to constrain the vertical distribution of matter, over the entire Galactic disk.

We solve for the density distribution of each component, perpendicular to mid-plane, using the equation of the hydrostatic equilibrium as well as the joint Poisson equation. The density distribution of each component is solved for by taking into account the gravitational potential of other components as well. The half-width-half-maximum of the density distribution is taken to define the scaleheight. The model surface densities of stars (Mera et.al. 1998), observed surface densities of H I and H_2 gas (Scoville & Sanders 1987) and their corresponding observed velocity dispersions are used as input parameters to determine the scaleheights for all the three components.

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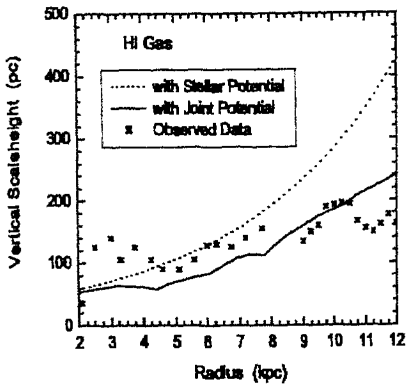

Figure 1. Results for H I scaleheight versus Radius. The results obtained using the joint potential are compared with the observations as well as those obtained using stellar potential alone.

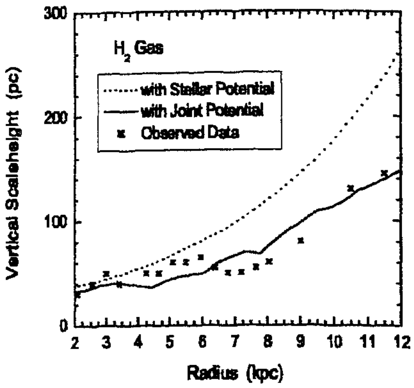

Figure 2. Results for H_2 scaleheight versus Radius. The results obtained using the joint potential are compared with the observations as well as those obtained using stellar potential alone.

1. The resulting H I scaleheight variation is compared with observations of Lockman (1984) and Wouterloot et.al. (1990) (see Figure 1). On using the joint potential, the scaleheight reduces significantly at large radii and show a better overall agreement with observations. The agreement improves significantly if H I velocity dispersion is taken to decrease with radius.

2. The H_2 scaleheight values obtained are compared with observations of Sanders et.al. (1984) and Wouterloot et.al. (1990) (see Figure 2). The curve predicted by using joint potential agrees very well with observations in the entire region studied.

3. The resulting stellar scaleheights is in agreement with a small linear increase in scaleheight between 5-9 kpc, as observed by Kent et.al.(1991).

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