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Large Scale Characteristics of the Galactic HI Distribution

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Abstract. Using the new LAB HI survey, a combination of the Leiden/Dwingeloo and the Argentine Surveys processed in Bonn, we study the morphology of the HI distribution in the Milky Way. Assuming circular motions of the gas and hydrodynamical equilibrium we fit a z-density distribution law to extract scale height z_h, deviation from the plane $z_\circ$ and peak density $n_\circ$. We find that the galactic disk flares from 0.3 kpc at R=9 kpc up to 1 kpc at R=30 kpc without discernable dependence on azimuth. The warp of the galactic disk is also clearly visible, with a symmetric part up to R=17 kpc where the deviation reaches a maximum of 1 kpc, and an asymmetric part where in quadrants 1&2 the deviation reaches a maximum of more than 5kpc at R=28 kpc while in quadrants 3&4 the deviation from the plane drops back to zero. Finally we discuss spiral structure in the peak density plots. Applying the linear density-wave theory we try to model the spiral structure of the Galaxy.

1. Introduction

For the understanding of the large scale morphology of galaxies it is crucial to find answers to contemporary problems like the nature of dark matter or the dynamical evolution of galaxies. For our galaxy, the Milky Way, optical observations can be used only within a few kpc around the Sun due to interstellar absorption. Molecular clouds are difficult to utilize because they are sparsely distributed in the outer parts of the Galaxy. So we use HI observations to probe the galactic large scale structure. The new LAB HI survey is ideal for this purpose. Its improved characteristics give us the opportunity to attack the question of the large scale structure of the HI distribution in the Milky Way.

2. Method

For a determination of the characteristics of the HI distribution we have to convert the original heliocentric temperature distribution of the survey $T(l,b,v)$ (Kalberla et al. 2004) into a galacto-centric density distribution $n(R,\ z,\ \theta)$. Assuming circular motion of the gas around the center we do this with the help of a rotation curve (Kalberla 2003). Assuming that the Milky Way is in a steady

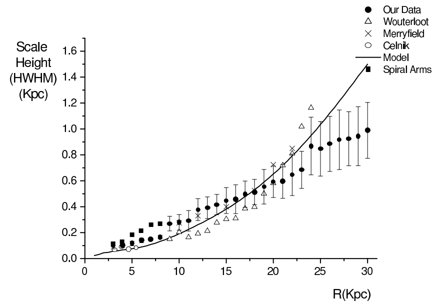

Figure 1. A diagram of scale height z_h (HWHM) vs galacto-centric radius R. Scale heights are averaged over azimuth for a constant radius. The bars represent the scatter in the scale height values.

state, we use a hydrostatical approach. From the Euler equation we obtain a z-distribution law:

$$n_{HI}(z) = n_o \cdot sech^a(\frac{z - z_\circ}{z_h}) \quad (1)$$

This formula is fitted to the z-density profiles for α=2 (isothermal case), extracting the values of z_h, $z_\circ$, $n_\circ$. For the modeling of the spiral arms we follow the method by Burton(1972). Using the linear-density wave theory we calculate the perturbation in the radial velocity due to the spiral waves. We generate synthetic profiles and compare these with the LAB Data.

3. Results

Scale Height At R=6kpc z_h=150 pc becoming z_h=500 pc at R=12 kpc (Fig. 1). No correlation between azimuth and scale height was found. Our result is somewhat in disagreement with previously published scale heights. Most probably this is due to the fact that a correction for the local gas was not applied, thus affecting scale heights.

Warp There is no evidence for a warp in the inner galaxy. The warp starts at R=10kpc where the deviation from the plane is $z_\circ$=0.1kpc. Until R=17kpc the warp is symmetric, reaching a maximum deviation of 1kpc. In the outer galaxy the warp becomes highly asymmetric. In the first and second quadrants it reaches a maximum of more than 5kpc at R=28kpc while in the third and fourth quadrants it drops back to lower values and eventually zero. The direction of the maximum warp is that of 90-270° (Fig. 2&3). Our results are in good agreement with Burton(1988).

Spiral Arms In the plots of column density vs azimuth (Fig. 4) for the inner Galaxy we found pronounced spurs. What is more interesting is that we find anti-correlation between scale height and column density in the region of spiral

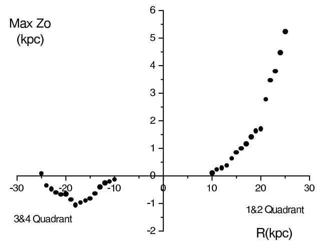

Figure 2. A diagram of maximum deviation z_o vs radius R showing the amplitude of the warp.

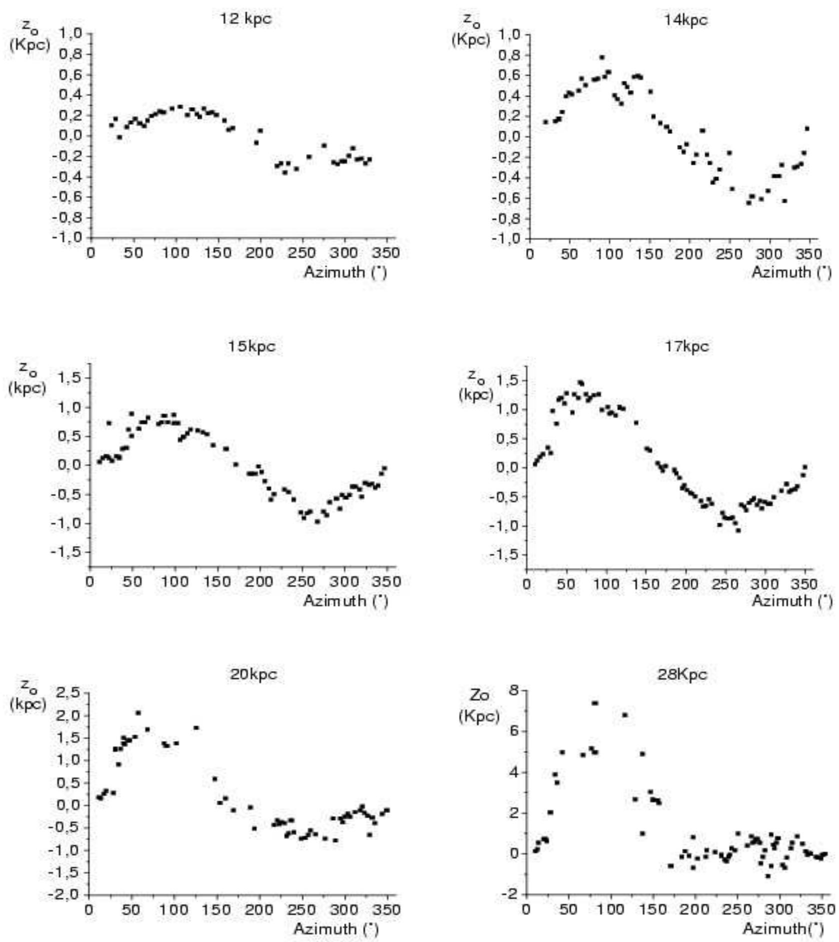

Figure 3. Six diagrams of deviation z_o vs azimuth θ.

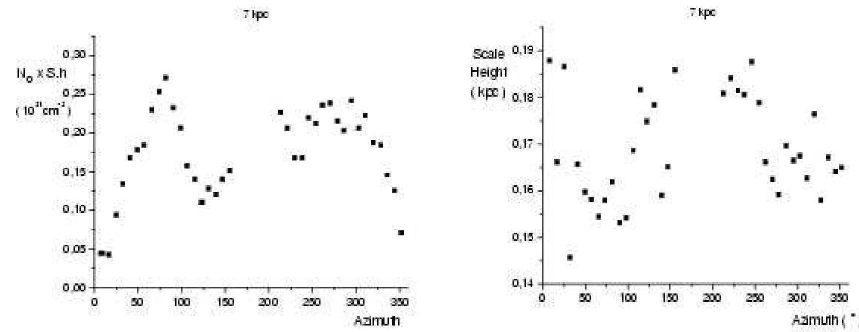

Figure 4. Two diagrams of column density and scale height vs azimuth θ for R=7kpc.

arms when comparing scale heights vs azimuth. In modeling spiral arm structure we are only partially successful so far. We are able to reproduce and match distinct spiral features (Fig. 5-10) but we find no model that is able to explain the global structure of the HI emission.

4. Discussion

Our aim is to separate the emission from the disk and the disk-halo interface (Kalberla et al., these proceedings). We found it critical to first construct models of the galactic disk emission for a better understanding of the Galactic density distribution. Our parameterization of the Galactic warp is successful, leading to significant improvements in the emission models. We intend to follow this up with modeling of the corresponding perturbations in the gravitational field of the Milky Way. Density waves and their response to the HI surface density distribution need to be studied in more detail.

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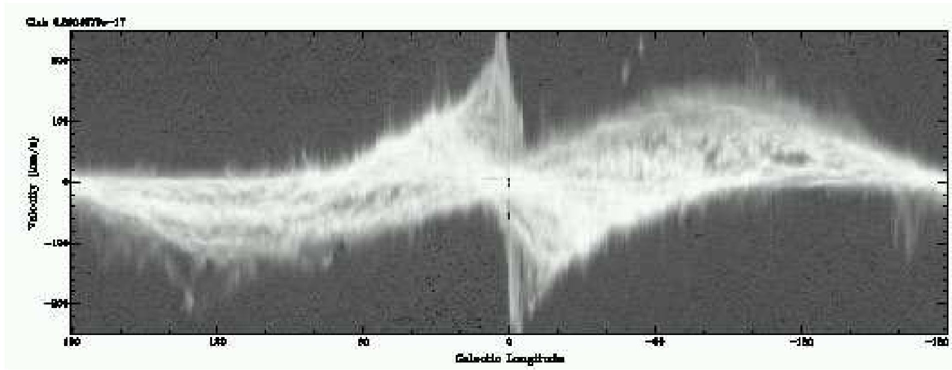

Figure 5. LAB Survey: A velocity versus longitute diagram along the Galactic Equator, b=0° displaying the HI emission intensities (T_b in K).

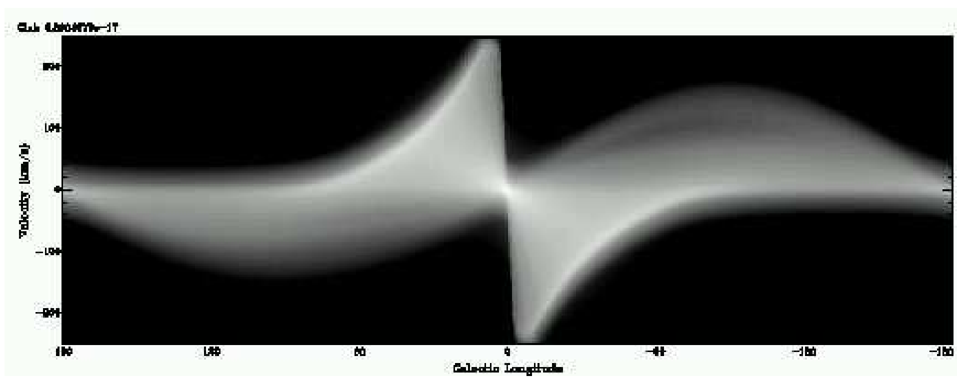

Figure 6. Model with no spiral arms

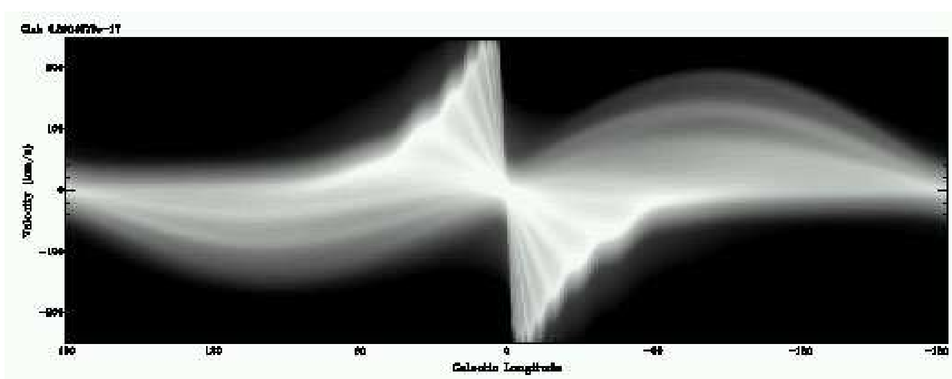

Figure 7. Model 2: m=2, i=7°, $\Omega_p = 0.024$ km/sec/kpc, R_o=3.5kpc

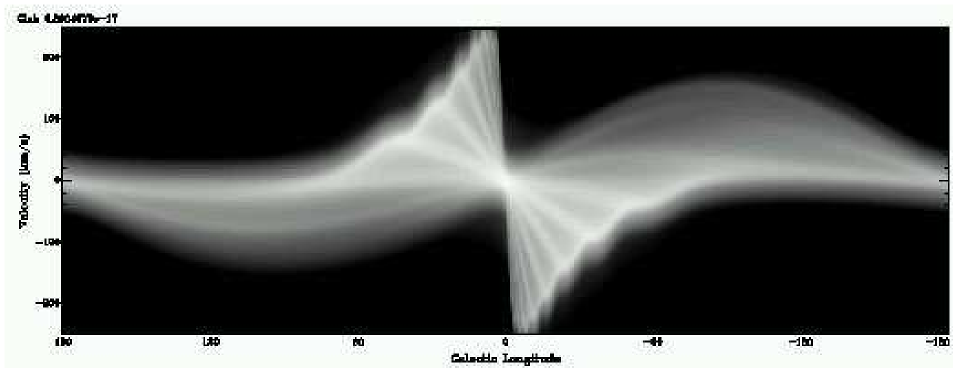

Figure 8. Model 3: m=2, i=7°, $\Omega_p = 0.013$ km/sec/kpc, R_o=3kpc

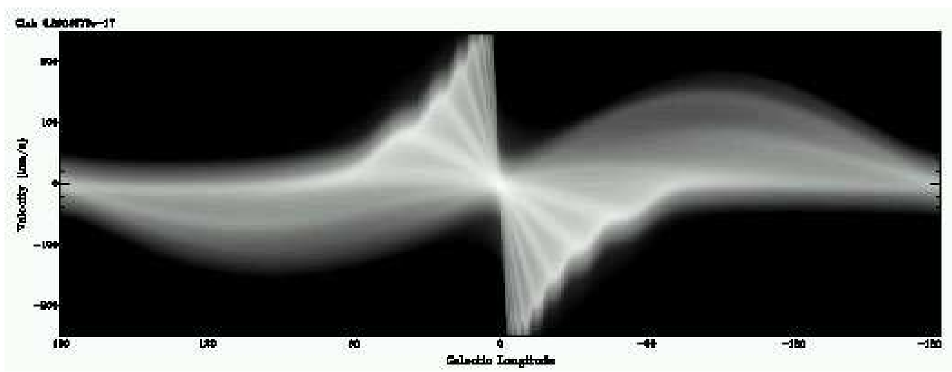

Figure 9. Model 4: m=2, i=7°, $\Omega_p = 0.013$ km/sec/kpc, R_o=4kpc

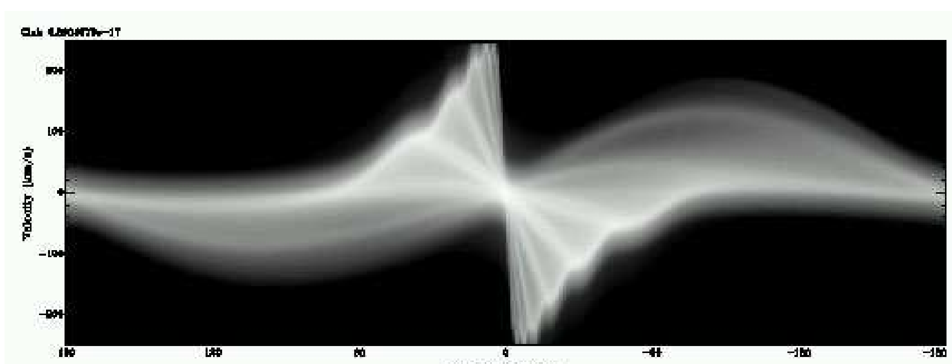

Figure 10. Model 6: m=2, i=9°, $\Omega_p = 0.013$ km/sec/kpc, R_o=3.5kpc