Galactic Spiral Structure in H I Emission and Self-Absorption

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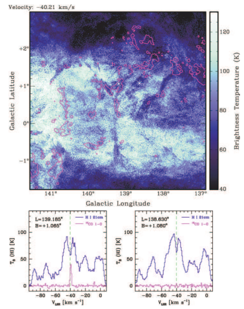
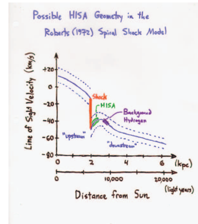
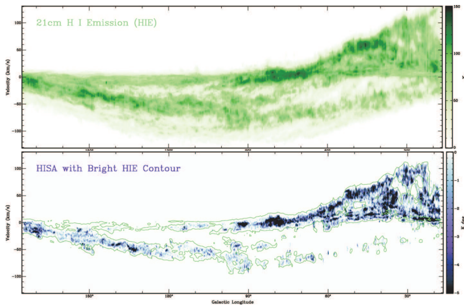
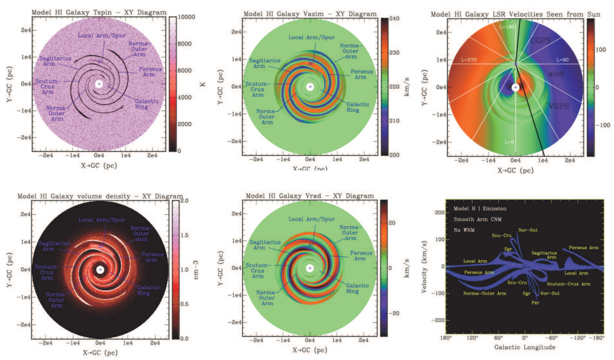


H I Self-Absorption (HISA) occurs when cold H I lies in front of warmer H I emission (HIE) at the same radial velocity. The map and spectra **AT LEFT** show HISA in the Perseus spiral arm in the Canadian Galactic Plane Survey (CGPS; Taylor et al. 2003). This HISA cannot arise from simple Galactic rotation, which allows gas at only one distance for a given radial velocity in the outer Galaxy. But spiral shock models (e.g. Roberts 1969, 1972) like that **AT RIGHT** give natural HIE backgrounds for any cold H I downstream of the shock, where it may be condensing into molecular clouds prior to new star formation.

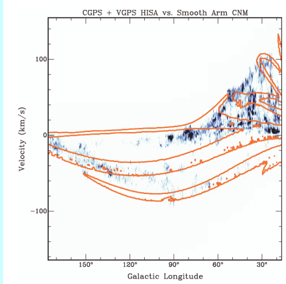


The *(l,v)* projections **AT RIGHT** show HIE and HISA in the CGPS and VLA Galactic Plane Survey (Stil et al. 2006). The contour outlines the bright HIE background needed for HISA to be detected. An automated method was developed for this purpose (Gibson et al. 2005a,b). Faint HISA occurs in most areas where it can be seen, and may arise from ambient cool gas made visible by turbulent eddies. Strong HISA is concentrated into cloud-like complexes that may trace spiral arm shocks. Since spiral structure is difficult to constrain in the Milky Way, the utility of HISA for tracing spiral arms should be assessed.

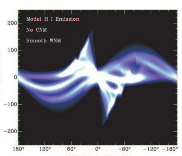




A simple radiative transfer model was developed to study HISA effects on a Galactic scale. The model is 2-D, consisting of *(x,y)* cells with assigned density, temperature, and velocity vectors. A cell can be either Cold Neutral Medium (CNM; 40 K) or Warm Neutral Medium (WNM; 8000 K), with densities inversely related, but also scaled in proportion to a Wolfire et al. (2003) H I disk model with arm density perturbations. The velocity field uses a flat rotation curve (220 km/s) perturbed by the spiral shock model of Roberts (1969, 1972). The arm template is adapted from Taylor & Cordes (1993). All *(x,y)* cells are WNM unless assigned CNM for various reasons. Models were run with CNM inserted downstream of spiral shocks (covering 5% of the spiral phase), placed randomly in the Local Arm (which was not given a shock), or scattered more sparsely throughout the disk, in order to compare the effects of arm-shock-induced HISA vs. ambient HISA. All cells were allowed both a "smooth" velocity dispersion (line broadening) and a "lumpy" dispersion (intercloud scatter) that could be turned on or off. Smooth dispersion is implemented with a velocity spread function during radiative transfer. Lumpy dispersion is realized by adding random velocities to each *(x,y)* cell. After the *(x,y)* model is constructed, it is "observed" from the Solar position to construct an *(l,v)* brightness temperature map. The basic components of the model are shown **AT LEFT** with all 3 types of CNM cells (shock-induced, local, ambient disk), but without lumpy dispersion in the velocity field. The observed $v_{LSR}(x,y)$ map indicates Galactic longitude, including the CGPS+VGPS coverage. A companion *(l,v)* map shows how the spiral arms translate into observed coordinates. The same smooth-dispersion CNM arms are plotted **AT RIGHT** as contours on top of real CGPS+VGPS HISA.



The grid of model $T_B(l,v)$ maps **AT RIGHT** examines combinations of different kinds of CNM contributions and varying CNM and WNM velocity dispersions, focusing on longitudes of 0 – 180 degrees to compare to observed HISA. The model is *not intended* to be a fully accurate representation of the Galaxy, but merely to test the *plausibility* of various HISA mechanisms. All maps show brightness temperature ranging linearly from 0 to 100 K. Results:



* Spiral shocks are able to make HISA quite easily, in both the inner and outer Galactic disk. Arm shocks on the Galactic far side can also produce HISA, but it is often harder to identify due to foreground confusion.

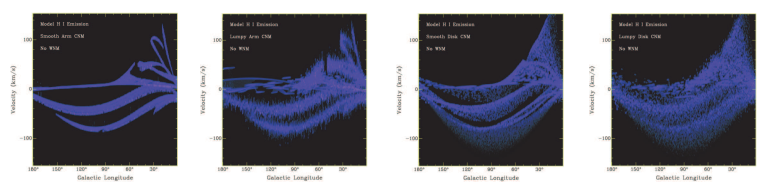
* Although given no shock of its own, the Local arm's ambient CNM cells easily produce considerable HISA, perhaps from velocity crowding.

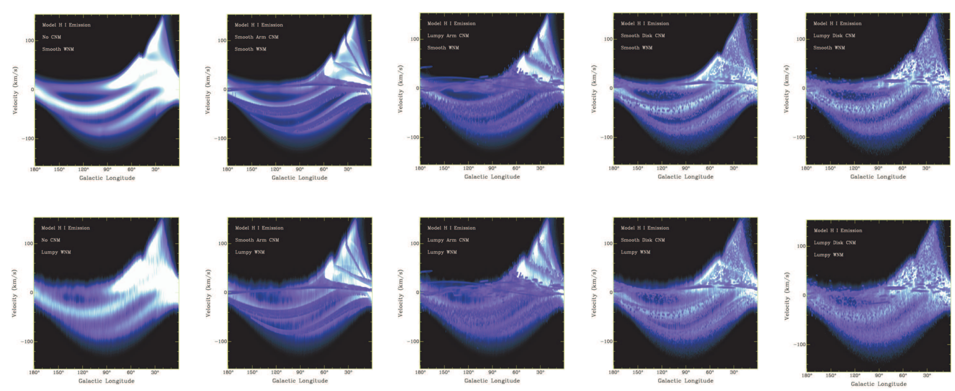
* Neither the arm shocks nor the Local arm are able to make HISA in all the areas it is observed, even allowing for some uncertainties in arm positioning. Some level of ambient disk HISA appears necessary for this.

* At the same time, the disk HISA is able to mimic some arm features simply by following the shock velocity field, but it does not produce arm features of the same strength or extent as arm-shock CNM gas. Thus both ambient-disk and arm-shock HISA appear to be present.

* HISA arm features are visible in all of the models at right, but lumpy dispersion in the CNM, and especially in the WNM, make these features harder to identify reliably.

* A large quantity of CNM gas appears in emission instead of absorption, often changing from one to the other against HIE background gradients. In addition, HIE *foregrounds* can raise background CNM brightness significantly, even if that CNM is itself HISA against more distant HIE! These foregrounds become more prevalent as the WNM dispersion is increased, especially with a lumpy WNM.





For more details, please see www.naic.edu/~gibson/hisa

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