Galactic Spiral Structure in H I Emission and Self-Absorption
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H I Self-Absorption (HSA) 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 HSA in the Perseus spiral arm in the Canadian Galactic Plane Survey (CGPS; Taylor et al. 2003). This HSA 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.

A simple radiative transfer model was developed to study HSA 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 HSA vs. ambient HSA. 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 position to construct an \((l,v)\) 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 left as contours on top of real CGPS+VGPS HSA.

The grid of model \(T_B(x,y)\) 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 HSA. The model is not intended to be a fully accurate representation of the Galaxy, but merely to test the plausibility of various HSA mechanisms. All maps show brightness temperature ranging linearly from 0 to 100 K. Results:

* Spiral shocks are able to make HSA quite easily, in both the inner and outer Galactic disk. Arm shocks on the Galactic far side can also produce HSA, 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 HSA, perhaps from velocity crowding.

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

* At the same time, the disk HSA 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 HSA appear to be present.

* HSA 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 HSA 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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