Dark Gas in the Interstellar Medium

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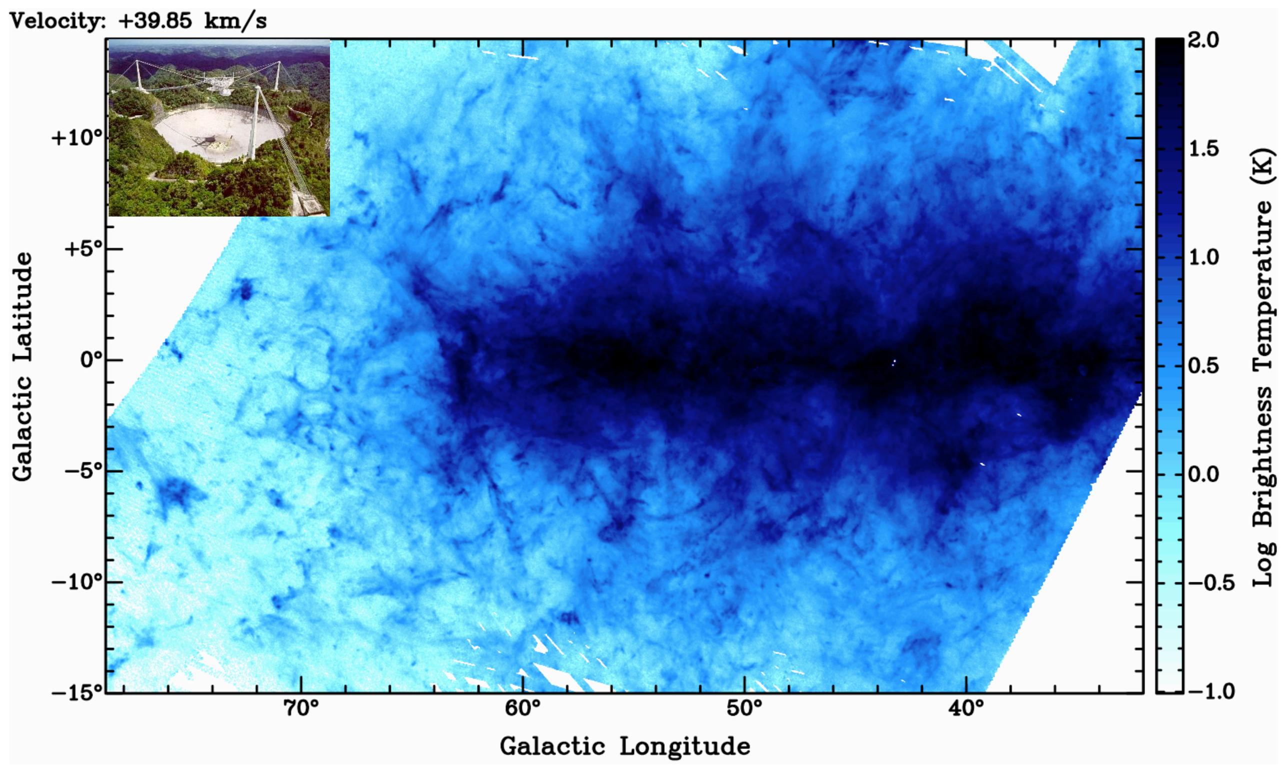


Figure 1. Neutral atomic hydrogen (H I) gas 21cm line emission from interstellar clouds, knots, and filaments extending up to 500 parsecs above and below the Galactic plane (Arecibo 305m radio telescope survey; Gibson et al. 2012). Many of these features are cold and may contain ``dark'' gas -- either narrow-line, opaque H I emission or molecular hydrogen (H_2) gas without visible emission from carbon monoxide (CO) or similar molecular tracers.

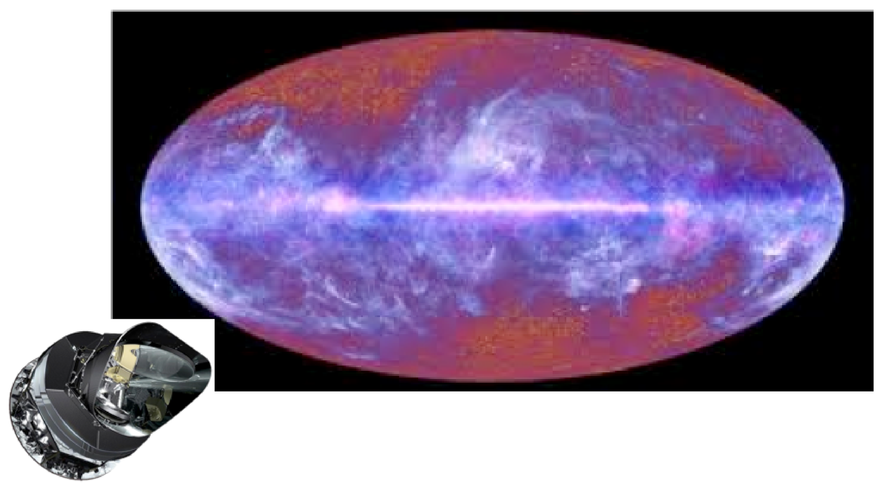


Figure 2. *Planck* satellite all-sky survey map of far-IR thermal emission from cold interstellar dust, which can help identify ``dark'' gas not visible through normal radio line spectroscopy.

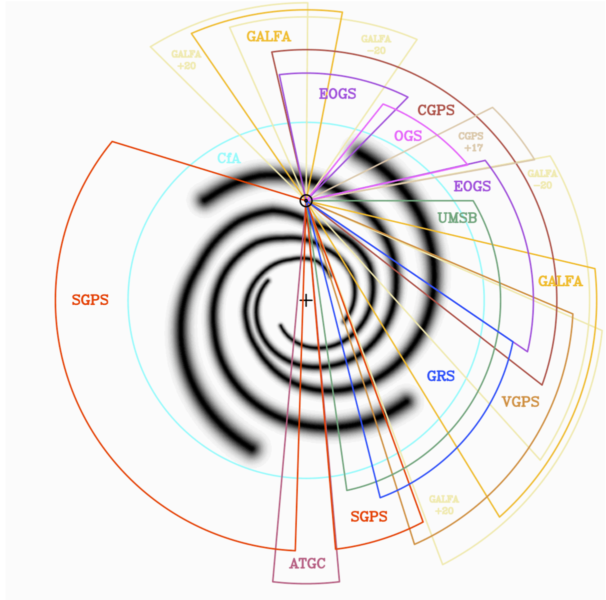


Figure 3. Parts of the Galaxy covered by various radio H I and CO surveys.

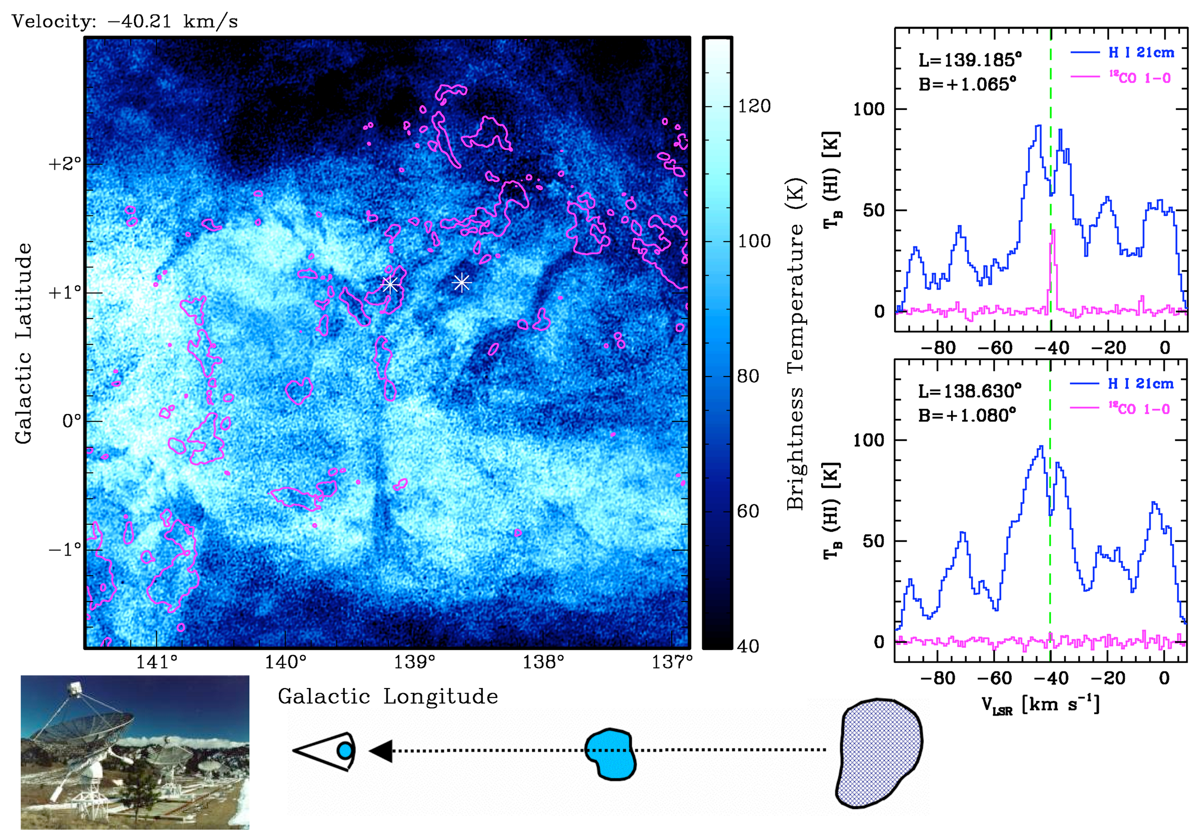


Figure 4. H I maps and spectra in radio interferometer surveys like the Canadian Galactic Plane Survey (blue; Taylor et al. 2003) show cold atomic gas as H I self-absorption (HISA) against warmer background H I emission (sketch). The HISA gas often appears separate from common molecular gas tracers (e.g., ^{12}CO J=1-0;magenta; Heyer et al. 1998), even though it is too cold to be stable outside of molecular clouds (Wolfire et al. 2003). Dark H_2 may be abundant here.

Overview

Most of the interstellar material in disk galaxies, including our own, is too warm and tenuous to form new stars. Yet somehow, clouds cold and dense enough to collapse under their own gravity occasionally coalesce. This mysterious process is enabled by the gas changing from predominantly free atoms to molecules that enhance radiative cooling. Molecular association is not directly observable, and the gas itself is often ``dark" to standard probes like spectral line emission from neutral atomic hydrogen or carbon monoxide (hydrogen molecules do not radiate when cold, as they are symmetric and lack rotational transitions). But under the right circumstances, this dark gas can be revealed, e.g., as opaque hydrogen emission or absorption, or as infrared continuum radiation from dust grains mixed with hidden molecular hydrogen. We have mapped tracers of such gas over large areas of the Galactic disk at high resolution. We find dark gas clearly revealed in many areas. We present maps of sample features and discuss our ongoing investigation.

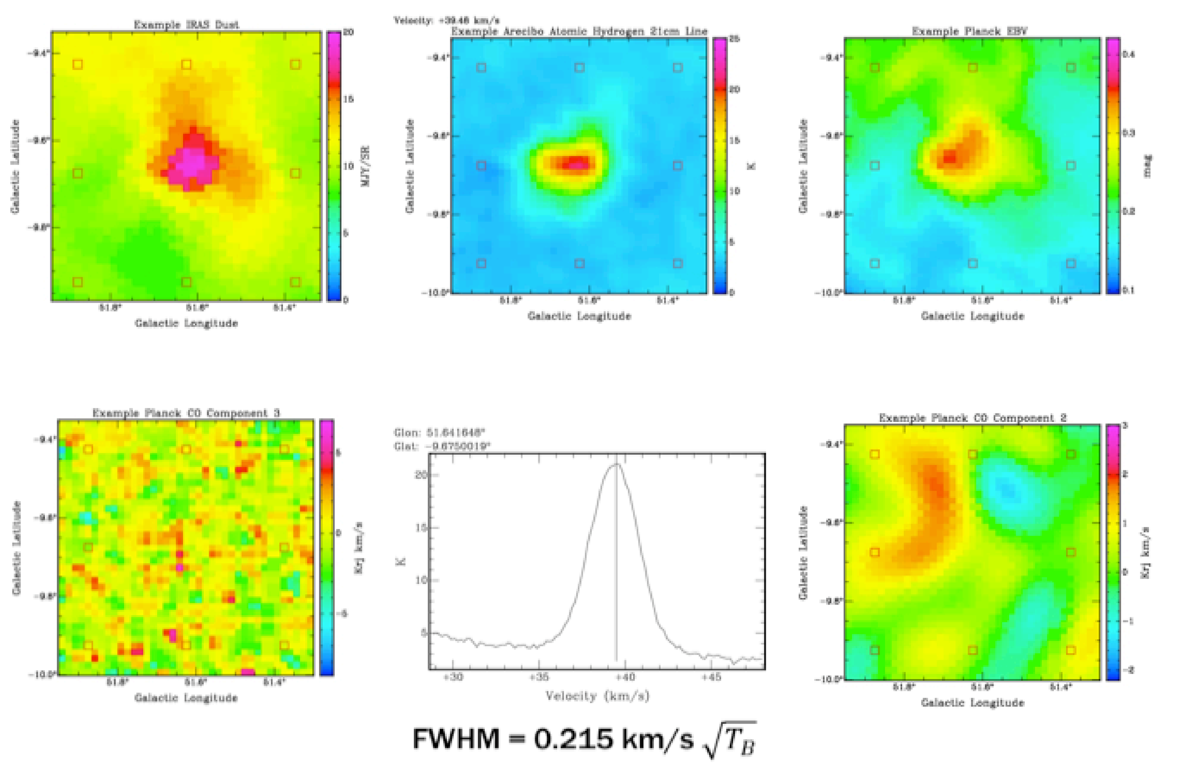
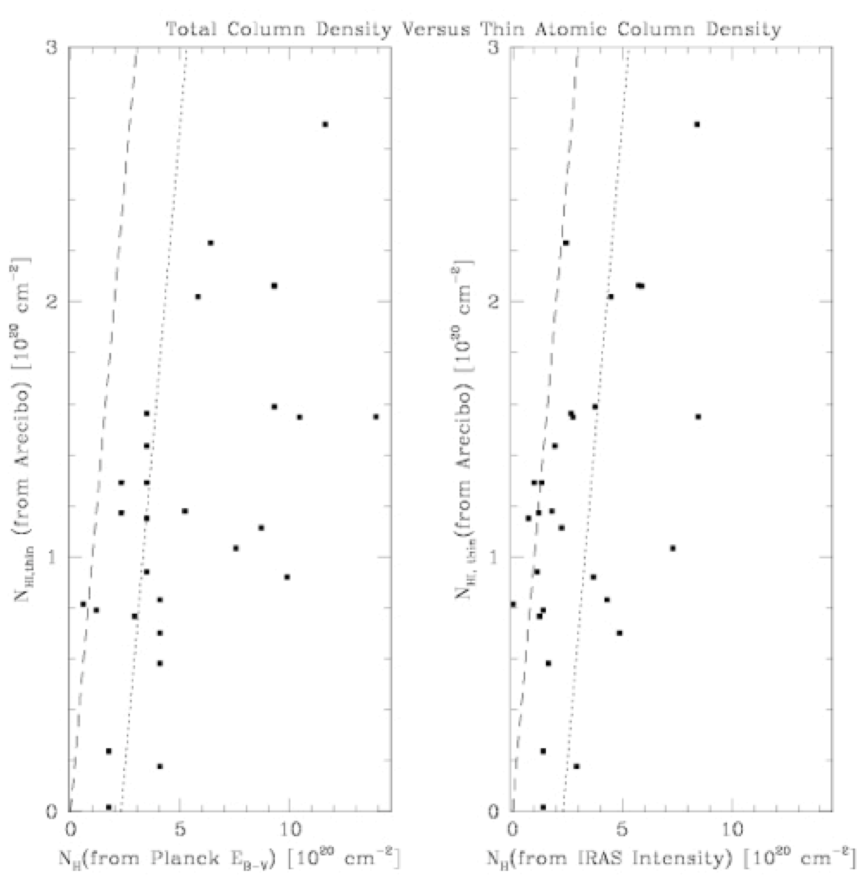


Figure 5. We have undertaken a survey of ~ 20 small, cold, narrow-line H I emission (NHIE) in the Arecibo data and have compared them to *Planck* ^{12}CO 1-0 and dust emission, as well as shorter-wavelength *IRAS* dust emission (Miville-Deschenes & Lagache 2006). Most of these NHIE clouds have little or no CO. Their column densities from dust, compared to those for optically thick H I below, are mostly near or below the threshold for CO photodissociation (Snow & McCall 2006), but high enough to imply significant dark gas, with greater columns detected for colder dust. NHIE line shapes imply most of the dark gas is H_2.



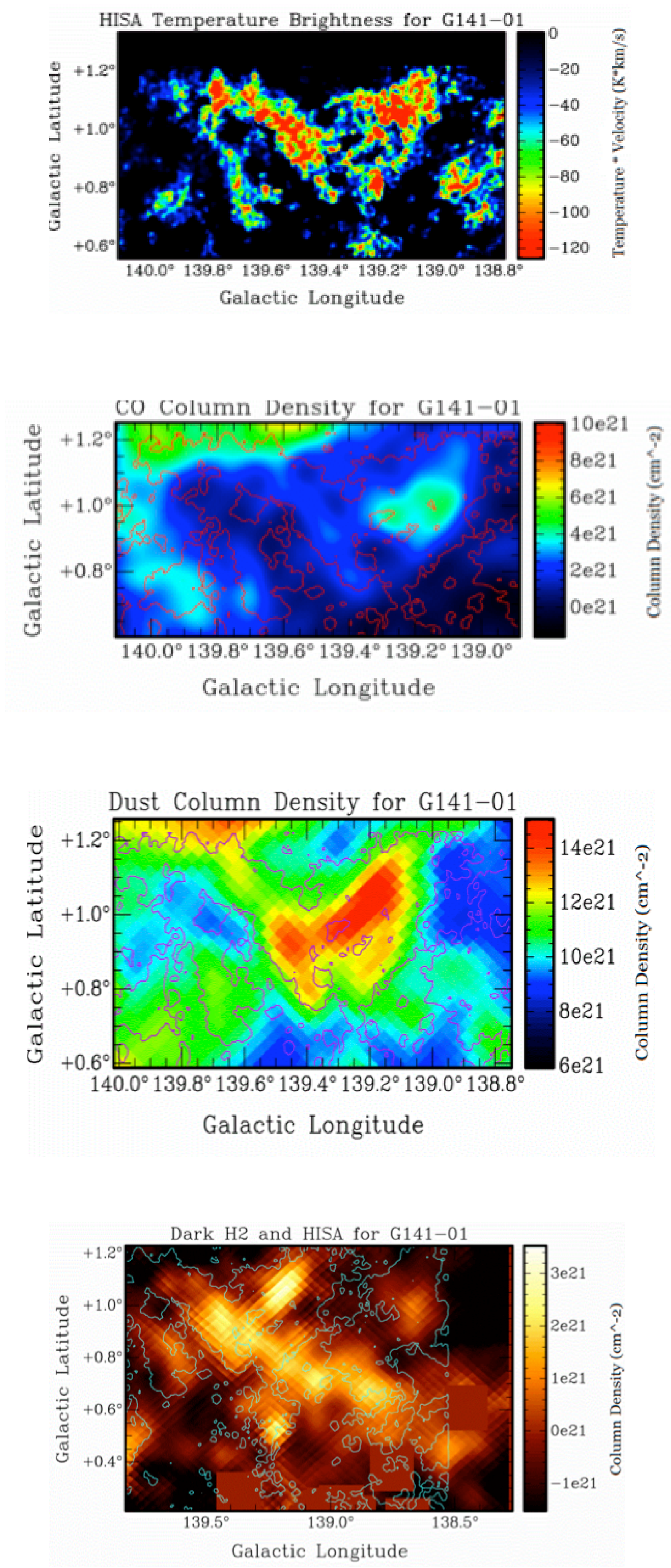


Figure 6. We extracted maps of different components of the HISA cloud: *Top:* Cold atomic gas traced by HISA, measured as a brightness contrast ON and OFF the cloud (Gibson et al. 2005); *Upper middle:* Line integral of CO emission, translated into the equivalent column density of H nuclei in accompanying H_2; *Lower Middle:* Total column from all forms of gas, via the proxy of *Planck* far-infrared dust emission; and *Bottom:* ``dark'' gas, estimated as the total gas column minus optically thin H I emission (not shown) and the H-column traced by CO. The dark gas column could be due to HISA or H_2, or both, but the two contributions are separable with careful analysis, which we are now undertaking. After some testing, we plan to apply this method in an automated way to map out dark gas content and properties in large areas of the Galactic disk.

References

Compiegne, M., et al. 2011, A&A, 525, 103
Dame, T. M., et al. 2001, ApJ, 547, 792
Gibson, S. J. 2010, ASPC, 438, 111
Gibson. S. J., et al. 2012, AAS, 219, 349.29
Gibson, S. J., et al. 2005, ApJ 626, 195
Gibson, S. J., et al. 2000, ApJ, 540, 851
Heyer, M. H., et al. 1998, ApJS, 115, 241
Kalberla, P. M. W., et al. 2005, A&A, 440, 775
Miville-Deschenes, M.-A., & Lagache, G3. 2005, ApJS, 157, 302
Reach, W. T., Koo, B.-C., & Heiles, C. 1994, ApJ, 429, 672
Snow, T. W., & McCall, B. J. 2006, ARA&A, 44, 367
Taylor, A. R., et al. 2003, AJ, 125, 3145
Taylor J. H., & Cordes, J. M. 1993, ApJ, 411, 674
Wolfire. M. G., et al. 2003, ApJ, 587, 278

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