IAU Colloquium 164: Radio Emission from Galactic and Extragalactic Compact Sources
ASP Conference Series, Vol. 144, 1998
J. A. Zensus, G. B. Taylor, & J. M. Wrobel (eds.)

Mapping Small Scale Structure in Galactic H I with the VLBA

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Abstract. We present the first VLBA maps of Galactic H I opacity towards the QSO 3C 138. The maps show significant opacity structure down to angular scales of 20 mas, which implies density structures in the cold neutral medium on physical scales of 10 AU or less.

Recent observations of Galactic H I in absorption using VLBI techniques (Diamond et al. 1989; Davis et al. 1996) have confirmed previous observations of very small scale structure in cold Galactic neutral hydrogen. Davis et al. have published the first maps of small scale atomic structure observed in absorption against the extragalactic continuum sources 3C 138 and 3C 147 using the MERLIN array. They found significant variations of the H I optical depth over angular scales of about 150 mas. Here we present intial results from a project to use the high angular resolution and sensitivity of the Very Long Baseline Array (VLBA) to image Galactic H I along many additional sight-lines.

Integrating the central component in the opacity spectrum gives an average column density of $5 \times 10^{20}\mathrm{cm}^{-2}$, assuming $T_{spin} = 50\mathrm{K}$. These observations were made in dual polarization mode, allowing us to place an upper limit on the component of the interstellar magnetic field parallel to the line of sight. Averaging the circular polarization (V) spectrum over the bright northeast component yields an upper limit of 350μGauss, and averaging the V spectrum over the weaker southwest component yields an upper limit of 250μGauss.

The opacity maps show significant optical depth variations in the 6.4 km/s component on angular scales down to the resolution of the opacity maps, 20 mas. At the assumed distance of 500 pc to the absorbing gas, this corresponds to a linear scale of order 10 AU. Assuming the gas is structured in roughly spherical "cloudlets", dividing the column density by the linear scale gives the implied volume density. In this case, $5 \times 10^{20}\mathrm{cm}^{-2}/1.5 \times 10^{14}\mathrm{cm}$ yields $3 \times 10^{6}\mathrm{cm}^{-3}$, a volume density several orders of magnitude above that observed for the average cold neutral ISM, implying pressures several orders of magnitude higher. Heiles (1996) has suggested that the volume densities could be much less if the small scale structure is the result of filamentary or sheet-like structure see edge on.

Acknowledgments. The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under a cooperative agreement by Associated Universities, Inc.

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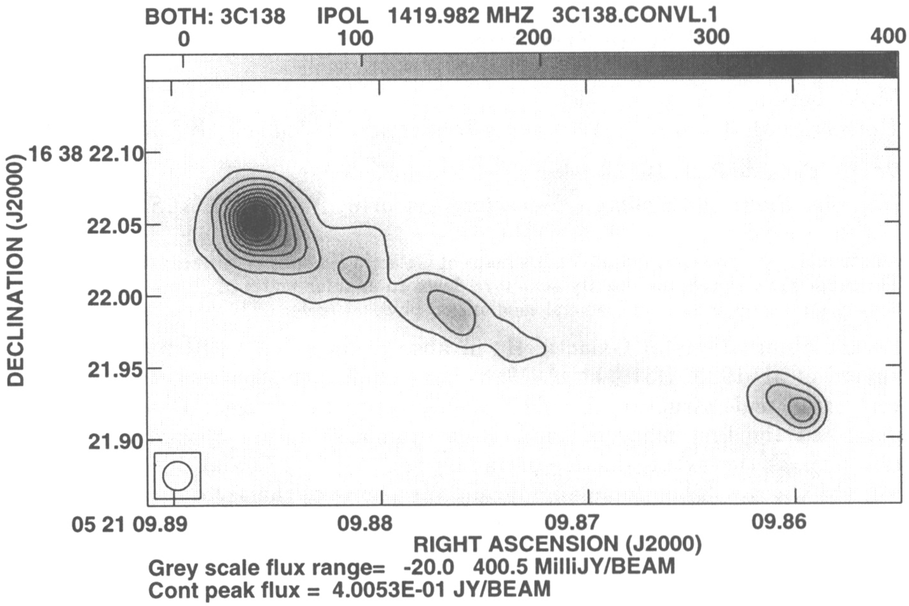

Figure 1. Continuum image for 3C 138 at 1420 MHz, made with the VLBA including the phased VLA over 250 kHz bandwidth. The map has been convolved with a 20 mas FWHM Gaussian function to improve the signal-to-noise ratio in the opacity images.

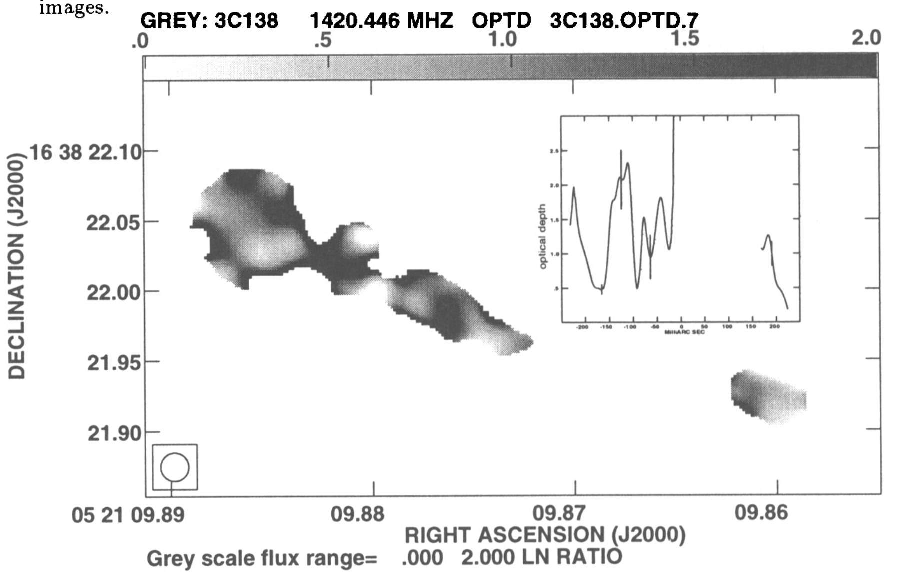

Figure 2. An opacity image for the deepest H I absorption component in the 3C 138 spectrum at +6.4 km/s LSR velocity. The inset plot shows a slice in opacity along the axis of the source, with 1σ errorbars shown at several values. Significant variations in opacity are seen down to the smallest angular scale represented.

https://doi.org/10.1017/S0252921100045607 Published online by Cambridge University Press