Results from the Allen Telescope Array: HI in Galaxy Groups

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ABSTRACT

With only the current reservoir of molecular gas, galactic star formation will cease much sooner than the decline of the observed star formation rate suggests. This is the molecular gas depletion problem. One aspect of the solution to this problem is including atomic hydrogen in the reservoir of gas for star formation. However, to form stars, the gas must be transported to the inner regions of galaxy disks: through inflow of HI from the outer disk or infall of intergalactic HI. We propose a mechanism for this is angular momentum loss through weak tidal interactions between galaxy group members. To constrain the contribution from this effect, we are imaging galaxy groups in the Local Volume (within 10 Mpc) in the 21 cm line with the ATA. This survey will look for extensions of the HI disks as well as intergalactic HI.

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SETI Institute

Allen Telescope Array

The Gas Depletion Problem

If we consider only molecular gas as the reservoir for star formation, the observed star formation rates cannot be sustained! Compare the evolution of the star formation rate (SFR) that we observe with the molecular gas depletion rate (GDR), the rate at which molecular gas is consumed:

• **SFR:** Though the exact forms vary, studies of the cosmic star formation rate produce curves similar to that shown in Figure 1. From this, we estimate dlogSFR/dt ~ -24% Gyr^{-1} today.

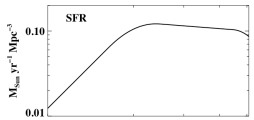


Figure 1: Smoothed SFR(z) fit from Hopkins & Beacom 2006.

• **GDR:** Leroy et al. 2008 find a constant molecular star formation efficiency ($SFE_M = \Sigma_{SFR} / \Sigma_{H2}$) in regular spirals: GDR = $SFE_M \times \rho_{H2}$. Thus, the time derivative of the gas depletion rate is dlogGDR/dt = -SFE_M ~ -53% Gyr^{-1}.

At the present epoch, the star formation rate is declining only half as fast as the molecular gas depletion rate! Therefore, the gas reservoir for star formation must extend beyond the molecular gas: we must consider the atomic hydrogen as well.

Moving HI into the Star-Forming Center

To add to the reservoir for star formation, the HI must move into the star-forming centers of galaxies. We propose weak tidal interactions between group members as a mechanism for removing the angular momentum of the HI so that it may move inward.

We are **surveying galaxy groups in the 21 cm line within the Local Volume** using the catalog of Karachentsev et al 2004, looking for evidence of these tidal interactions, such as disk extensions or distortions and intergalactic HI.

Why we use the ATA

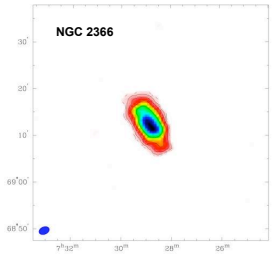
• **Sensitivity:** About 40 hours of observation allows us to get down to an HI column density of ~4 x 10^{19} cm^{-2}. This comes close to the expected minimum column of intergalactic HI due to the intergalactic radiation field.

• **Large Beam:** A FWHM of 2.5 degrees at 1.4 GHz means we can mosaic entire groups with a small number of pointings.

Reduction and Analysis

• RFI cleaning and calibration are done using the RAPID software (Garrett Keating).

• We map each channel individually within ~ 1000 km/s of the systemic velocity of the main galaxy of the group to look for intergalactic HI and other tidal features.



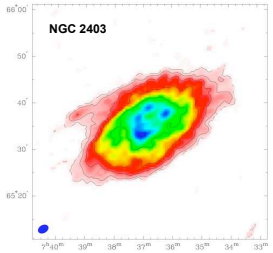


Figure 2: Moment 0 maps of NGC 2403 and NGC 2366, the two main members of the NGC 2403 galaxy group. Color indicates column density, ranging from 0 to ~ 3 x 10^{21} cm^{-2}. Contours are (8 x 10^{19} cm^{-2}) x 2^n.

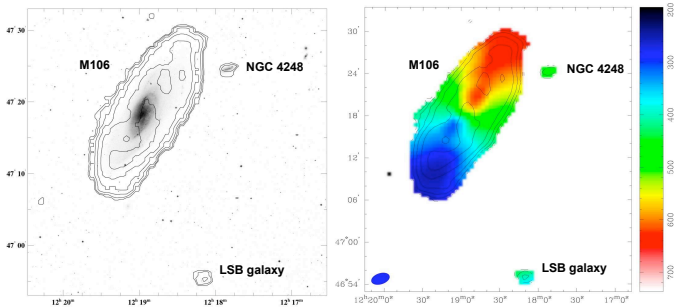


Figure 3: Moment 0 and moment 1 maps of M106 and vicinity. On the left, the moment 0 map contours are overlaid on the DSS image. On the right, moment 0 map contours are overlaid on the moment 1 map, with color indicating the velocity in km/s. Moment 0 map contours are (4 x 10^{19} cm^{-2}) x 2^n.

Progress

We have mapped 4 groups of galaxies so far, with good detections of the group members but no previously undetected intergalactic gas. We expect that as our understanding of the instrument and data reduction processes improve, we will be able to get down to the expected column density limit of intergalactic HI and our observations will yield constraints on the amount of gas in the groups.

References

Hopkins, A. M., & Beacom, J. F. 2006, ApJ, 651, 142

Karachentsev, I. D., Karachentseva, V. E., Huchtmeier, W. K., & Makarov, D. I. 2004, AJ, 127, 2031

Leroy, A. K., Walter, F., Brinks, E., Bigiel, F., de Blok, W. J. G., Madore, B., & Thornley, M. D. 2008, AJ, 136, 2782