PROCEEDINGS OF SCIENCE

Westerbork ultra-deep HI imaging of galaxy clusters at z=0.2

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We report here on results from our completed ultra-deep blind HI survey of two galaxy clusters at redshift z=0.2, performed with the Westerbork Synthesis Radio Telescope. The field of the X-ray bright, massive Butcher-Oemler cluster Abell 963 was observed with a total of 117x12hrs integration time. Additionally, Abell 2192 was observed as an example of a more diffuse cluster, at similar distance, with a total of 73x12hrs integration time. In both fields, sampling a total volume of 7x10^4 Mpc^3, the expected noise levels of 19 and 24 μJy/beam respectively, at a velocity resolution of 44km/s, were achieved. These HI measurements are part of a multi-wavelength survey including ultraviolet(GALEX), optical(INT), infrared(Spitzer), and rest frame 1.4 GHz radio-continuum data(WSRT).The goal is to study the gas content of galaxies in various environments at a redshift of 0.2 and in particular the gas content of the blue galaxies that are responsible for the Butcher-Oemler effect in Abell 963.

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1. Motivation

The morphological mix of galaxies in the Universe is known to depend strongly on environment. Dense environments are dominated by early-type galaxies, while spiral galaxies form the majority of the field population. This dependence evolves over cosmic time. Since redshift 0.5 the fraction of spirals in clusters has dropped significantly, while a bulk of S0 galaxies has appeared (Dressler et al. 1997). This raises the question whether it is the field population that evolves with redshift, and hence changes the morphological mix in clusters as it is being accreted, or whether it is the cluster environment that forces morphological transitions during the accretion process. The HI content of galaxies plays an important role in their morphological transformations as it represents the reservoir of fuel for star formation and is easily affected by tidal interactions and ram-pressure stripping. Until recently, the limited sensitivity and bandwidth of synthesis imaging radio telescopes prohibited the observation of HI emission at intermediate redshifts. However, the new receiver system on the Westerbork Synthesis Radio Telescope has made such an observation practically possible for the first time and allows us to study the HI content of galaxies in and around the nearest Butcher-Oemler clusters at z=0.2.

2. The targets

Abell 963 is a massive and unusually relaxed (less than 5% substructure), X-ray detected, lensing cluster with a velocity dispersion of 1350 km/s. At z=0.206, it is one of the nearest Butcher-Oemler (Butcher and Oemler, 1984) clusters with a blue fraction of 19%. Some interesting results from Verheijen et al.2007 show that although those galaxies are blue, and have been forming stars recently, they all appear to have lost their cold neutral gas! Abell 2192, at z=0.188, has a velocity dispersion of 650 km/s. So far it hasn't been detected in X-rays and the fraction of blue galaxies has not yet been determined. By observing these very different clusters and the large scale structure in which they are embedded, a variety of environments can be blindly and uniformly surveyed, ranging from voids to cluster cores.

3. The data

The data for the survey were collected with the WSRT between 2005 and 2008, including a successful pilot study (Verheijen et al. 2007). In total 2280 hours of integration time were collected, 876 in the field of Abell 2192 and the rest in the field of Abell 963. With a continuous frequency coverage between 1160 and 1220 MHz, the observed velocity range is 49,246 - 67,300 km/s, corresponding to a depth of 326 Mpc. At 1190 MHz the FWQM of the WSRT primary beam is 11.6 Mpc at the distance of these clusters. The total combined surveyed volume with a single pointing is 70x10^3 Mpc^3, which is equivalent to the volume of the entire Local Universe out to a distance of 25 Mpc! The resolution of the survey is 21x31 arcsec and 39 kHz or 54x86 kpc and 12 km/s. In order to be able to detect galaxies with HI masses down to 2x10^9 $M_\odot$ over a global HI profile width of 120km/s, with S/N=4 in each of 3 independent spectral resolution elements, the required rms noise levels are 24μJy/beam for the field of A2192 and 19μJy/beam for the field of

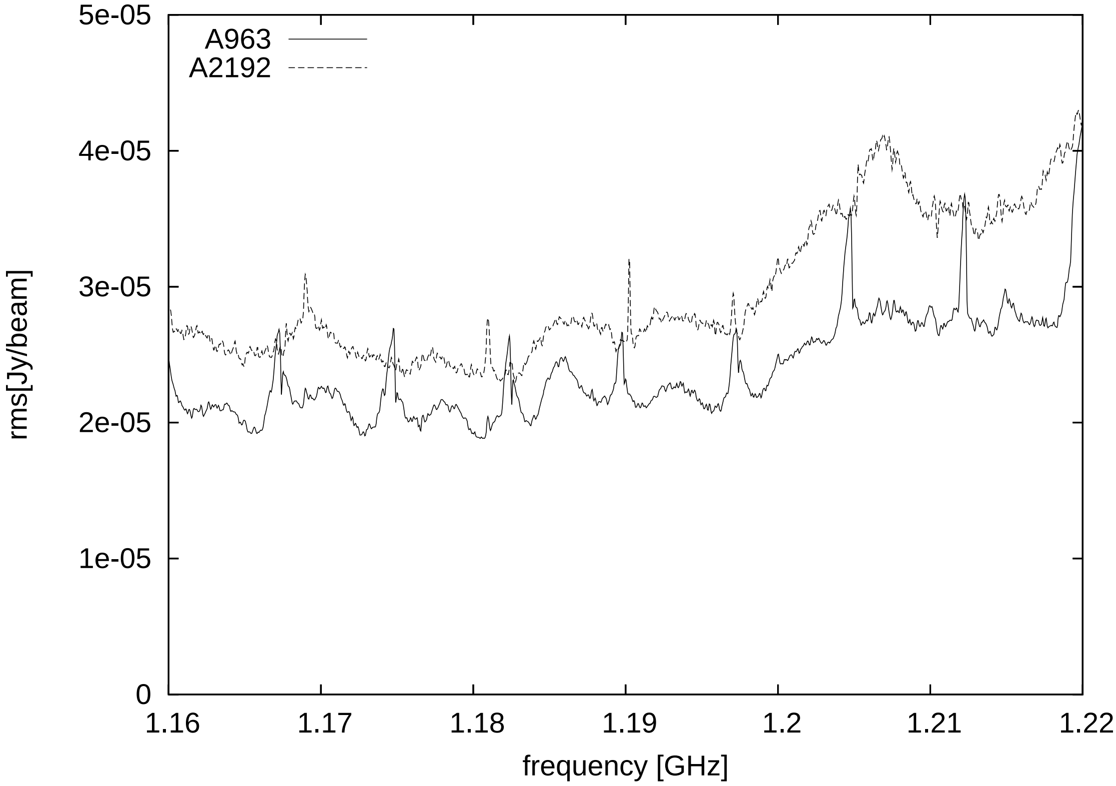

Figure 1: The rms noise in the two data cubes, after velocity smoothing down to 44km/s.

A963. For galaxies with known optical redshifts, a 3-sigma detection would be sufficient, corresponding to an HI mass of 8x10^8 $M_\odot$, similar to that of the Large Magellanic Cloud.

Figure 1 shows the noise levels in the two data cubes after velocity smoothing down to 44km/s. The desired levels were achieved for most of the frequency range. At the high frequency end, a significant amount of data was lost due to radio frequency interference, hence the higher noise. Figure 2 shows examples of HI detections. The three galaxies possibly belong to an infalling group of gas rich galaxies, situated at a projected 2.9 Mpc north-west from the cluster center. The spectra show that the three galaxies are also grouped in velocity.

4. Outlook

Based on the HI mass function for the local universe (Zwaan et al. 2003), the achieved noise levels and the size of the surveyed volume, we expect to have approximately 200 detections in the two data cubes. In addition to estimating the role of the environment in the galaxy evolution, and the fate of the blue galaxy population in A963, those detections will be used to estimate the cosmic neutral hydrogen density Ω_{HI}, and also to construct an HI-based Tully-Fisher relation at z=0.2.

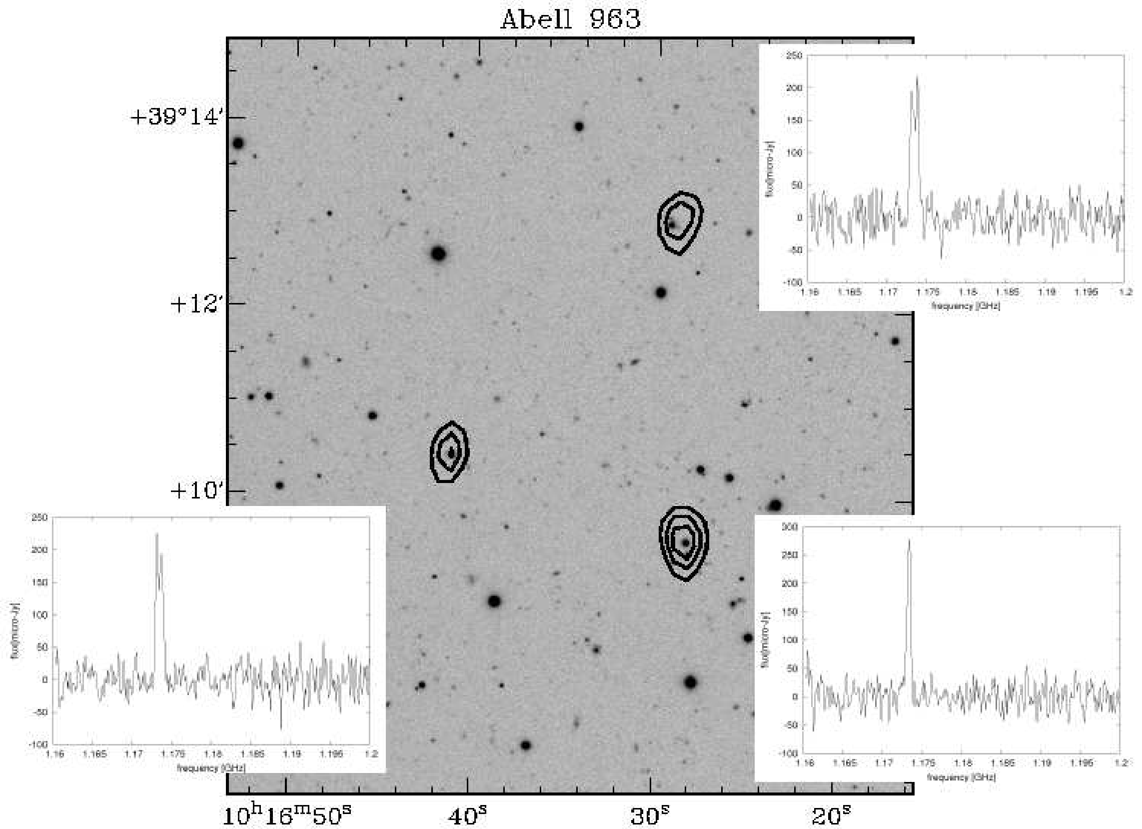

Figure 2: Three of the detections in the field of Abell 963. Total HI emission overlayed on a B-band image, and spectra extracted from the HI data cube containing the emission line. Note the double-peaked line profiles of the northern and eastern sources.

References

[1] H.Butcher & A.Oemler, 1984, ApJ, 285, 426B

[2] M.Verheijen et. al, 2007, ApJ, 668L, 9V

[3] Dressler,A. et al, 1997, ApJ, 490,577

[4] Zwaan, M. et al., 2003, AJ, 125, 2842