The Universe at Low Radio Frequencies
IAU Symposium, Vol. 199, 2002
A. Pramesh Rao, G. Swarup and Gopal-Krishna, eds.

Probing H I in the Universe with SKA

J.M. van der Hulst

Kapteyn Astronomical Institute, Postbus 800,NL-9700 AV Groningen, The Netherlands

Abstract. This paper briefly describes the capabilities of a new generation large telescope such as the Square Kilometer Array (SKA) for imaging H I in a one degree field out to $z \approx 3$

1. Introduction

The fascinating observations of the few thousand galaxies in the Hubble Deep Field show that there is already significant evolution detectable in the comoving star formation rate density by looking back to a redshift of 1 (Madau et al. 1998). Already between $z = 0.5$ and $z = 1$ ($4 - 6$ h^{-1}Gyr) there should be a noticeable increase of a factor $2 - 3$ in SFR density.

Little is known, however, about the evolution of the H I in galaxies out to redshifts of 1 and beyond, because present day instruments lack the sensitivity and resolution to directly measure the H I in galaxies at these redshifts. Damped Lyα studies (Lanzetta et al. 1995, Storrie-Lombardie et al. 1996) indicate that the comoving H I mass density is roughly $5 - 10\times$ the present beyond $z = 1$ and out to $z = 3$. This is also the period during which metal-rich gaseous halos appear, confirming that this is an era of strong evolution, where it is imperative to have good insight into the evolution of the H I content of galaxies.

SKA will be able to measure the H I in galaxies out to redshifts of $z \approx 3$ directly and will revolutionize this area of research. The great potential of SKA is that it will be able to find galaxies independent of effects of extinction and color using the H I , with the additional advantage that once a an object has been found found the H I line provides an accurate redshift at the same time. The associated continuum emission will furthermore provide an independent estimate of the star formation rate.

2. An example: A "Pencil Beam" Survey

Consider a 360 hour integration on a single field of one square degree. For H I studies one requires high surface brightness sensitivity: a 1 km^2 array with baselines up to 100 km will provide a resolution of 1" at 610 MHz ($z = 1.3$) corresponding to a linear size of 4.4 kpc (for $H_0 = 75$ km/s/Mpc and $\Omega = 0.3$). L_* galaxies (which typically have H I masses of $3.5 \times 10^9 h^{-2} M_\odot$) can be detected out to redshifts of $z \approx 3$, i.e. beyond the redshift where the universe shows considerable evolution. Using the H I mass function of Zwaan et al. (1997) and assuming no evolution of the H I properties of galaxies with redshift one can calculate how many galaxies one would expect to detect per redshift interval in a one square degree field of view. Table 1 gives a brief summary.

Table 1. Detectable HI Masses as a function of redshift

Red-shift	Look Back Time (h^{-1} Gyr)	HI Mass Limit (h^{-2} $M_\odot$)	Number of Detections
0.5 - 1.0	4.2 - 6.2	1.7 10^8	6.6 10^5
1.0 - 1.5	6.2 - 7.3	4.7 10^8	2.3 10^5
1.5 - 2.0	7.3 - 8.0	1.1 10^9	1.0 10^5
2.0 - 2.5	8.0 - 8.5	2.2 10^9	4.4 10^4
2.5 - 3.0	8.5 - 8.9	4.1 10^9	3.0 10^4
3.0 - 3.5	8.9 - 9.1	6.7 10^9	1.0 10^4
3.5 - 4.0	9.1 - 9.2	1.2 10^10	9.5 10^3
4.0 - 4.5	9.2 - 9.3	1.6 10^10	7.0 10^3

Out to a $z \approx 2$ one will be able to resolve a fair fraction of the galaxies so one can obtain rotation curves, mass distributions, gas fractions for more than 10^5 galaxies between now and 8 h^{-1}Gyr ago. One then is in a unique position to trace the evolution of the ISM in galaxies over a substantial fraction of the age of the universe, from the era of strongest evolution and star formation activity until the present. In addition one would learn whether and how the evolution depends on the dark matter content and environment.

In addition one can use the continuum emission to probe the star formation rates of the detected galaxies, independent of the effects of extinction using the radio continuum-FIR correlation (Helou et al. 1985, Helou 1991, Condon et al. 1991, Condon 1992, Sauvage and Thuan 1992). This information can be used to link the star formation rates to the HI contents of galaxies as a function of redshift and environment. So such a survey will provide an independent estimate of the evolution of the comoving star formation rate density to be compared with the optically determined funtions (Madau et al. 1998).

References

Condon, J.J. 1992, ARA&A, 30, 575

Condon, J.J., Anderson, M.L., & Helou, G. 1991, ApJ, 376, 95

Helou, G., Soifer, B.T. & Rowan-Robinson, M. 1985, ApJ, 298, L7

Helou, G. 1991, ASP Conf. Ser. Vol. 18, The Interpretation of Modern Synthesis Observations of Spiral Galaxies, ed. N. Duric and P. C. Crane, 125

Madau, P., Pozetti L., & Dickinson, M. 1998, ApJ, 498, 106

Lanzetta, K., Wolfe, A., & Turnshek, D. 1995 ApJ, 440, 435

Storrie-Lombardie, L.J., McMahon, R.G., & M.J. Irwin, M.J. 1996 MNRAS, 283, L79

Zwaan, M.A., Briggs, F.H., Sprayberry, D. & Sorar, E. 1997, ApJ, 490, 173

Sauvage, M., & Thuan, T.X. 1992, ApJ, 396, L69

https://doi.org/10.1017/S0074180900168639 Published online by Cambridge University Press