NEUTRAL HYDROGEN AT THE PRESENT EPOCH: A CONSTRAINT ON THE EVOLUTION OF HIGH REDSHIFT SYSTEMS

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Introduction

Damped Lyman α and metal absorption lines in the spectra of quasars indicate the presence of intervening gas-rich systems at high redshift ($z > 2$). These systems have characteristic size scales, velocity dispersions and neutral hydrogen column densities (N(HI)) similar to present day spirals and are thus thought to be their progenitors (cf. Wolfe 1988). Constraints on galaxy evolution can be derived by comparing the H I properties of high redshift systems to the present galaxy population.

Good observational statistics on high redshift absorbers specify the number of these systems along the line of sight as a function of N(H I), the column density of neutral hydrogen per absorber (cf. Lanzetta et al. 1991). Here, we derive similar statistics for nearby ($z = 0$) galaxies of which spirals are the only gas-rich systems that provide a significant cross-section for the interception of light from quasars.

The N(HI) distribution function at $z = 0$

A complete sample of spiral galaxies selected for optical diameters greater than 7′ and by the range in declinations observable at Arecibo was used to determine absorption cross-sections as a function of N(HI). The probability distribution for interception specifies the number of systems intercepted per unit distance along the line of sight at a given column density, N. This can be determined from the integral over all magnitudes of the product of the luminosity function of spiral galaxies, $\phi(M)$, and the effective cross-sectional area of a galaxy, $A(M,N)\Delta N$, in a range of column densities ΔN centered on N. The results of this analysis are presented in Fig. 1 in a form comparable to the results of Lanzetta et al. (1991). For $z \sim 2.5$ they plot $f(N)$, a quantity described in the figure caption. Also plotted is the value of $f(N)$ at a column density of $10^{19.5}$ cm^{-2} as determined by Tytler (1987).

The conclusion is that the number of nearby absorbers per unit distance along the line of sight is at least a factor of 4 less than that at high redshifts. It thus appears that substantial evolution has taken place since a redshift of 2 or 3. The improved determination of the effective cross-sectional

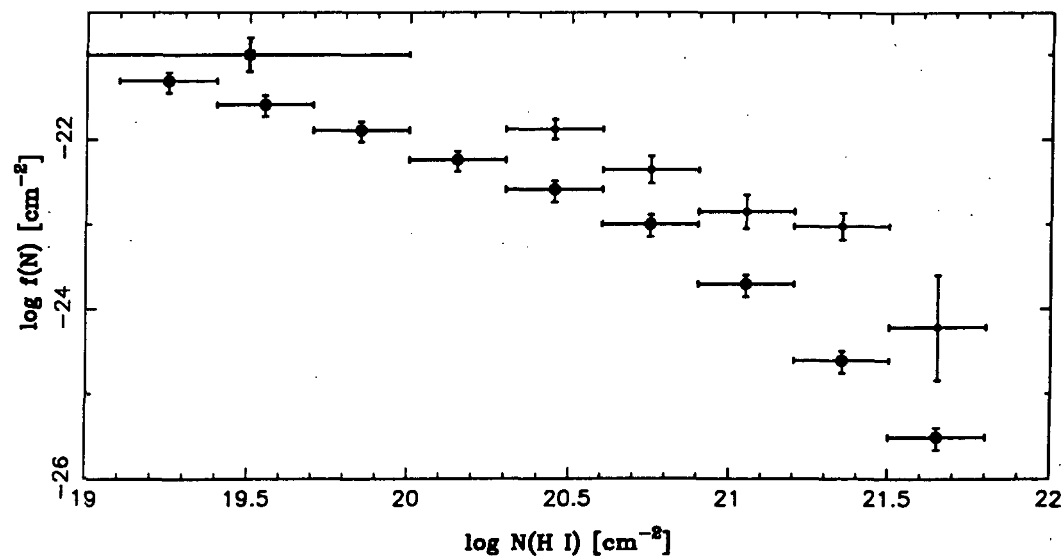

FIG 1. HI column density distribution function for high z systems and nearby galaxies.
• Lanzetta et al (1991), □ Tytler (1987): high z data. Horizontal bars indicate bin sizes and vertical bars indicate 1σ uncertainties.
○ This calculation: data from nearby galaxies. Horizontal bars indicate bin sizes and vertical bars are errors mainly due to the uncertainty in the mean density of nearby galaxies.
The product $f(N)dNdX$ specifies the number of absorbers in an absorption distance dX with HI column density in the interval between N and $N + dN$, where $dX = \frac{H_o}{c}dl$, with l in Mpc.

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areas at the present epoch over previous estimates confirms the discrepancy in $f(N)$ and strengthens the implication that a) there were a greater number of them at high redshifts and/or b) they were larger. The discrepancy appears to increase with column density. This could be a result of poor sampling of high column density lumps due to inadequate resolution in the H I data (van Gorkom 1992, private communication). It could also be the effect of higher column density material forming stars more efficiently, thus depleting it faster than lower column density gas.

The cosmological mass density at $z = 0$

A comparison of the H I content and luminosity function of different galaxy types shows that over 90% of the neutral hydrogen cosmological mass density (Ω_{HI}) at the present epoch is associated with spiral galaxies (Rao and Briggs, in preparation). S0 galaxies, irregulars and ellipticals contribute the other 9%. Ω_{HI} at $z = 0$ is plotted in Fig. 2 along with $\Omega_D(z)$, the H I mass density at high redshifts derived by Lanzetta et al. (1991) from statistics of damped Ly α absorbers. It is reassuring that the local value of Ω_{HI} is consistent with the decreasing trend with time that is seen at high redshifts. The contribution of spirals to Ω_{HI} was computed using the isolated galaxy sample of Haynes and Giovanelli (1984). The mean M_{HI}/L_B ratio of their sample is larger than that of our sample of 27 nearby, large diameter spirals by about 30%. Preliminary calculations indicate that the value of Ω_{HI} determined from our sample is also smaller than that determined from the Haynes and Giovanelli galaxies. Thus in order to better determine an H I mass density that is representative of the local universe, larger samples that include a larger volume of space must be used.

Also plotted in Fig. 2 is the cosmological mass density of luminous matter, Ω_{lum}, at $z = 0$. It is determined by the sum of the luminous matter density in spirals and ellipticals. As galaxies evolve, neutral gas can disappear as a result of ionization or by being converted into stars. The sum of the present mass densities of luminous matter and of neutral hydrogen is ~ 3 times the HI mass density at the earliest epoch probed by the damped Lyman α surveys ($z \sim 3.5$).

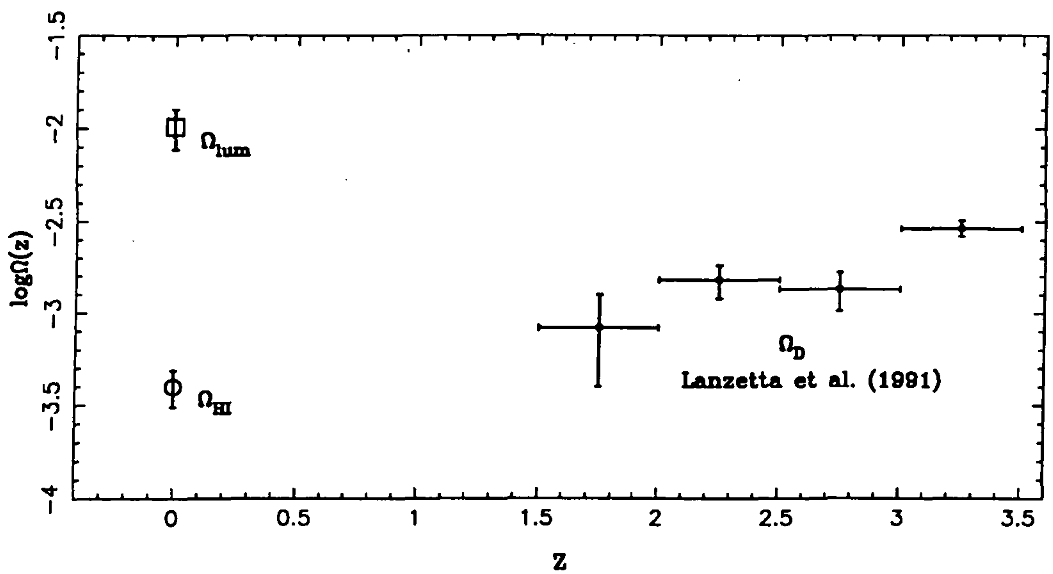

FIG 2. The cosmological mass density as a function of redshift.
• from the work of Lanzetta et al. (1991).
○ $\Omega_{HI}(z = 0)$, □ $\Omega_{lum}(z = 0)$

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