Complete Ionisation of the Neutral Gas in High Redshift Radio Galaxies and Quasars

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Abstract. Cool neutral gas provides the raw material for all star formation in the Universe, and yet, from a survey of the hosts of high redshift radio galaxies and quasars, we find a complete dearth of atomic (H I 21-cm) and molecular (OH, CO, HCO^+ & HCN) absorption at redshifts $z \gtrsim 3$ (Curran *et al.* 2008). Upon a thorough analysis of the optical photometry, we find that all of our targets have ionising ($\lambda \leqslant 912$ Å) ultra-violet continuum luminosities of $L_{\mathrm{UV}} \gtrsim 10^{23}$ W Hz^{-1}. We therefore attribute this deficit to the traditional optical selection of targets biasing surveys towards the most ultra-violet luminous objects, where the intense radiation excites the neutral gas to the point where it cannot engage in star formation (Curran & Whiting 2010). However, this hypothesis does not explain why there is a critical luminosity, rather than a continuum where the detections gradually become fewer and fewer as the harshness of the radiation increases. We show that by placing a quasar within a galaxy of gas there is *always* a finite ultra-violet luminosity above which *all* of the gas is ionised. This demonstrates that these galaxies are probably devoid of star-forming material rather than this being at abundances below the sensitivity limits of current radio telescopes.

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For a cloud of hydrogen containing an ionising source, the equilibrium between photoionsation and recombination of protons and electrons in a nebula is given by

$$\int_{\nu_{\mathrm{ion}}}^{\infty} \frac{L_\nu}{h\nu}\, d\nu = 4\pi \int_0^{r_{\mathrm{ion}}} n_{\mathrm{p}}\, n_{\mathrm{e}}\, \alpha_A\, r^2\, dr = 4\pi\, \alpha_{\mathrm{A}}\, n_0^2 \int_0^{r_{\mathrm{ion}}} e^{-2r/R}\, r^2\, dr,$$

for a gas density $n_{\mathrm{p}} = n_{\mathrm{e}} = n = n_0\, e^{-r/R}$, where n_0 ($= 10$ cm^{-3}) is the value at $r = 0$ and R is a scale-length describing the rate of decay of this with radius. For the observed critical value of $\int_{\nu_{\mathrm{ion}}}^{\infty} (L_\nu/h\nu)\, d\nu = 3 \times 10^{56}$ ionising photons sec^{-1} ($L_{\mathrm{UV}} \sim 10^{23}$ W Hz^{-1}), this gives a scale-length of $R = 3$ kpc, which is the value found for the H I in the Milky Way, which has an exponential profile with a similar $n_0 = 13.4$ cm^{-3} (Kalberla & Kerp 2009). That is, the observed critical luminosity is sufficient to ionise all of the gas in a large spiral galaxy, thus explaining why neutral gas is not detected in high redshift optically selected sources (Curran & Whiting 2012). Therefore, even the SKA is unlikely to detect 21-cm absorption within the host galaxies of these objects.

References

Curran, S. J. & Whiting, M. T. 2010, *ApJ*, 712, 303
Curran, S. J. & Whiting, M. T. 2012, *ApJ*, in press (arXiv:1204.2881)
Curran, S. J., Whiting, M. T., Wiklind, T., Webb, J. K., Murphy, M. T., & Purcell, C. R. 2008, *MNRAS*, 391, 765
Kalberla, P. M. W. & Kerp, J. 2009, *ARAA*, 47, 27