Highlights of Astronomy, Volume 14
IAU XXVI General Assembly, 14-25 August 2006
Karel A. van der Hucht, ed.

doi:10.1017/S1743921307010484

Implications for the cosmic re-ionization from the optical afterglow spectrum of GRB 050904 at $z = 6.3$

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Abstract. We discuss the implications for the cosmic re-ionization from the optical afterglow spectrum of GRB 050904 at $z = 6.3$

Keywords. cosmology: observations, cosmology: theory, early Universe

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The gamma-ray burst GRB 050904 at $z = 6.3$ provides the first opportunity of probing the intergalactic medium (IGM) by GRBs at the epoch of the reionization. Here we present a spectral modeling analysis of the optical afterglow spectrum taken by the Subaru Telescope, aiming to constrain the reionization history. The spectrum shows a clear damping wing at wavelengths redward of the Lyman break, and the wing shape can be fit either by a damped Lyα system with a column density of $\log(N_{\rm HI}/{\rm cm}^{-2}) \simeq 21.6$ at a redshift close to the detected metal absorption lines ($z_{\rm metal} = 6.295$), or by almost neutral IGM extending to a slightly higher redshift of $z_{\rm IGM,u} \simeq 6.36$. In the latter case, the difference from $z_{\rm metal}$ may be explained by acceleration of metal absorbing shells by the activities of the GRB or its progenitor.

However, we exclude this possibility by using the light transmission feature around the Lyβ resonance, leading to a firm upper limit of $z_{\rm IGM,u} \leqslant 6.314$. We then show an evidence that the IGM was largely ionized already at $z = 6.3$, with the best-fit neutral fraction of IGM, $x_{\rm HI} = 0.00$, and upper limits of $x_{\rm HI} < 0.17$ and 0.60 at 68 and 95 % C.L., respectively. This is the first direct and quantitative upper limit on $x_{\rm HI}$ at $z > 6$. Various systematic uncertainties are examined, but none of them appears large enough to change this conclusion.

To get further information on the re-ionization, it is important to increase the sample size of $z \gtrsim 6$ GRBs, in order to find GRBs with low column densities ($\log N_{\rm HI} \lesssim 20$) within their host galaxies, and for statistical studies of Lyα line emission from host galaxies.

See Kawai *et al.* (2006) and Totani *et al.* (2006) for details of our work.

References

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