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LETTER

Re-ionizing the universe without stars

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Abstract Recent observations show that the measured rates of star formation in the early universe are insufficient to produce re-ionization, and therefore, another source of ionizing photons is required. In this *Letter*, we examine the possibility that these can be supplied by the fast accretion shocks formed around the cores of the most massive haloes ($10.5 < \log M/M_{\odot} < 12$) on spatial scales of order 1 kpc. We model the detailed physics of these fast accretion shocks, and apply these to a simple 1-D spherical hydrodynamic accretion model for baryonic infall in dark matter halos with an Einasto density distribution. The escape of UV photons from these halos is delayed by the time taken to reach the critical accretion shock velocity for escape of UV photons; 220 km s^{-1}, and by the time it takes for these photons to ionize the surrounding baryonic matter in the accretion flow. Assuming that in the universe at large the baryonic matter tracks the dark matter, we can estimate the epoch of re-ionization in the case that accretion shocks act alone as the source of UV photons. We find that 50% of the volume (and 5-8% of the mass) of the universe can be ionized by $z \sim 7$–8. The UV production rate has an uncertainty of a factor of about 5 due to uncertainties in the cosmological parameters controlling the development of large scale structure. Because our mechanism is a steeply rising function of decreasing redshift, this uncertainty translates to a re-ionization redshift uncertainty of less than ±0.5. We also find that, even without including the UV photon production of stars, re-ionization is essentially complete by $z \sim 5.8$. Thus, fast accretion shocks can provide an important additional source of ionizing photons in the early universe.

Keywords Galaxies: formation · Galaxies: halos · Cosmology: theory · Cosmology: early universe · Ultraviolet: ISM · Shock waves

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1 Introduction

An understanding of what re-ionizes the Universe at the end of the "Dark Ages" has so far eluded us. Thus far, two sources of ionizing photons have been suggested; stars and quasars (Loeb and Barkana 2001). Both of these present difficulties. In the case of quasars, Mortlock et al. (2011a) find very few QSOs at $z \sim 6$, and only one is found above (Mortlock et al. 2011b; see also note is proof). More importantly, if there were many fainter quasars producing sufficient UV to reionize the universe at $z = 10$, then they would overproduce the present-day unresolved soft X-ray background (Dijkstra et al. 2004).