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X-rays and hard UV radiation From the First Galaxies: Ionization Bubbles and 21 cm Observations

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The first stars and quasars are known sources of hard ionizing radiation in the first billion years of the Universe. We examine the joint effects of X-rays and hard UV radiation from such first-light sources on the hydrogen and helium reionization of the intergalactic medium (IGM) at early times, and the associated heating. We study the growth and evolution of individual HII, HeII and HeIII regions around early galaxies with first stars and/or QSO populations. We find that in the presence of helium-ionizing radiation, X-rays may not dominate the ionization and thermal history of the IGM at redshifts, z, of 10-20, contributing relatively modest increases to IGM ionization, and heating up to about 10^3--10^5 K in IGM temperatures. We also calculate the 21 cm signal expected from a number of scenarios with metal-free starbursts and quasars at these redshifts. The peak values for the spin temperature reach about 10^4 to 10^5 K in such cases. The maximum values for the 21 cm brightness temperature are around 30-40 mK in emission, while the net values of the 21 cm absorption signal range from about a few to 60 mK on scales of 0.01-1 Mpc. We find that the 21 cm signature of X-ray versus UV ionization could be distinct, with the emission signal expected from X-rays alone occurring at smaller scales than that from UV radiation, resulting from the inherently different spatial scales at which X-ray and UV ionization/heating manifest. This difference is time-dependent, and becomes harder to distinguish with an increasing X-ray contribution to the total ionizing photon production. Such differing scale-dependent contributions from X-ray and UV photons may therefore "blur" the 21 cm signature of the percolation of ionized bubbles around early halos (depending on whether a cosmic X-ray or UV background built up first), and affect the interpretation of 21 cm data constraints on reionization.

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