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Finding the stars that reionized the Universe

Mahavir Sharma, Tom Theuns and Carlos Frenk

Institute for Computational Cosmology, Department of Physics, Durham University, South Road, Durham, UK, DH1 3LE, email: mahavir.sharma@durham.ac.uk

Abstract. We study the abundance of the remnants of stars that reionized the Universe in galaxies in the present day Universe using the EAGLE cosmological hydrodynamical simulation. High mass galaxies contain most of these 'reionizers'. The fractional number of galaxies that do not host reionizers increases with decreasing stellar mass, $M_\star$. For the galaxies that host reionizers, the fraction of mass of the galaxy in reionizers increases with decreasing $M_\star$, such that the fraction is low ($\sim 10^{-4}$) for high mass galaxies and can be as high as 0.1 in low mass galaxies, $M_\star \leqslant 10^7$ M$_\odot$. In Milky-Way like galaxies, the distribution of reionizers is spatially more extended than that of normal stars.

Keywords. cosmology: theory, galaxies: evolution, Galaxy: formation, stars: statistics

1. Introduction

Metal poor stars allow us to track the assembly history of our galaxy, and allow us to constrain the nature and abundances of stars that reionized the Universe. It has been a challenge to identify the descendants of reionizers and first stars in metal poor stellar population in the Milky Way, though considerable progress has been made in this direction at the observational front in recent years (Frebel & Norris 2015).

We use the EAGLE cosmological hydrodynamical simulation to track descendants of reionizers. EAGLE is a suite of Smoothed Particle Hydrodynamic (SPH) simulations that follow the formation and evolution of galaxies (Schaye *et al.* 2015; Crain *et al.* 2015). In this work we use the high resolution run 'L0025N0752', that simulates a cubical region of the Universe with comoving size of 25 Mpc.

In a recent study (Sharma *et al.* 2017a) we developed a model of reionization in which we used the idea that winds from starbursts open up channels through which the ionizing photons escape and ionize the Universe. In particular, we assumed that when the local surface density of star formation, $\dot{\Sigma}_\star > \dot{\Sigma}_{\star,\rm crit}$, a wind is launched that opens up a channel. Following on that work, we define reionizers as the stars that formed before redshift 6 in regions of high $\dot{\Sigma}_\star$. The later criterion is automatically satisfied for most of the star particles at $z > 6$ since $\dot{\Sigma}_\star$ is typically very high during those early times. Galactic winds played a major role in reionization and might also have led to peculiar distribution and abundance patterns in the metal poor stars that formed during such episodes and may still be visible today (Sharma *et al.* 2016, 2017b).

In this work, we study the present day distribution of the descendants of reionizers in galaxies and in particular in the Milky Way type galaxies, which can be compared with existing catalogues of metal poor stars and with upcoming data from GAIA (Gaia Collaboration *et al.* 2016).

2. Results: distribution of reionizers

In the hierarchical structure formation galaxies grow via mergers and accretion. For example the Milky Way is formed of a number of progenitors that merged with the main

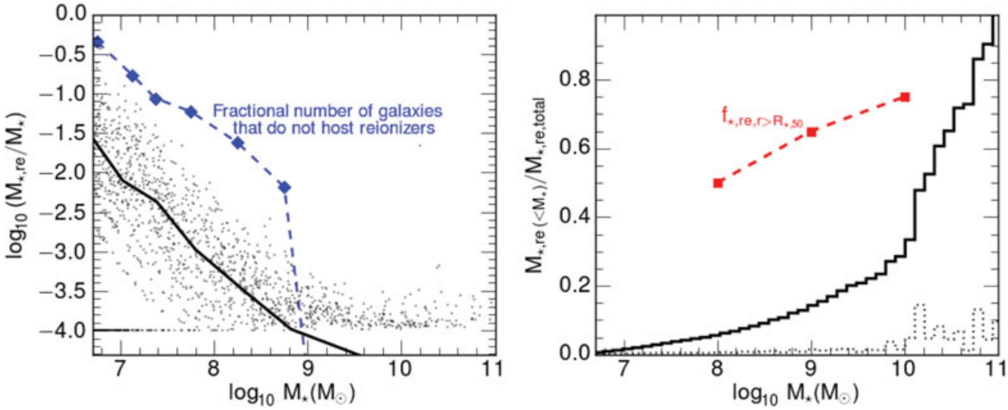

Figure 1. Left panel: fraction of reionizers to normal stars for an individual galaxy is shown as a function of the stellar mass, $M_\star$, for galaxies from the EAGLE simulation. Each dot represents a galaxy, and, the solid curve is the median of galaxies that host reionizers. The galaxies that do not host reionizers have been assigned a value of 10^{-4} and their numerical fraction increase with decreasing stellar mass (dashed blue curve). Right panel: fraction of the total stellar mass of reionizers in the Universe that resides in galaxies below a given $M_\star$ is plotted as a solid line. The corresponding differential histogram is shown as a dotted line. The dashed red line shows the fraction of reionizers in a galaxy that reside outside the stellar half mass radius ($f_{\star,re,r>R_{\star,50}}$).

progenitor during its lifetime. Therefore, the descendants of first stars and reionizers may end up in a galaxy that is not necessarily the galaxy in which they were born. In fact we find that 70 percent of the reionizers live in high mass galaxies with stellar mass, $M_\star > 10^{10}$ M$_\odot$, in the present day Universe (Fig. 1, right panel), however, they formed in low mass galaxies in the early Universe.

For Milky Way type galaxies the fraction of stars that are reionizers is typically 10^{-4}–10^{-3}, while for a low mass galaxy ($M_\star \sim 10^7 \mathrm{M}_\odot$) the fraction can be in the range 0–0.1. This fraction has a considerable scatter from galaxy to galaxy, particularly at the low mass end. The fractional number of galaxies that do not host reionizers increases with decreasing stellar mass (dashed blue curve in the left panel of Fig. 1)

We also find that the reionizers have a shallower spatial distribution when compared to normal stars and the shallowness increases with $M_\star$ (dashed red line in the right panel, see also Sharma *et al.* 2017b), which implies that the relative abundance of reionizers to normal stars is higher in the Galaxy outskirts (right panel). Therefore it may be easier to detect reionizers in the solar neighbourhood rather than in the bulge of the Galaxy.

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