

Unveiling the evolution of the most extreme overdensities in the first billion years of the Universe

Extremely overdense regions in the early Universe are likely engines for the production of hydrogen ionising radiation in the early Universe. The copious number of UV-faint galaxies and the idealistic environment for driving AGN activity means the most overdense environments, protoclusters, should drive some of the first ionised bubbles. As such, characterising the properties of these protoclusters is crucial in understanding their role in the Epoch of Reionisation. We present NIRSpec and NIRCам/Grism spectroscopic observations of galaxies resident within three protoclusters at $z=7.66-10.6$. One protocluster shows evidence of a dusty, metal-enriched and evolved core and low metallicity, high temperature, young galaxies in the outer regions. Such constraints on the build-up of dust and metals in overdense regions are unsurprising in the context of hierarchical growth, however the detection of Ly α emission from one of the galaxies on the outskirts of the protocluster allows for constraints on the formation of an ionised bubble. We also provide the first spectroscopic confirmation of a $z=7.66$ protocluster, the first such structure identified by JWST in its first weeks of operation. This NIRCам Grism data allows for a complete sample of bright emission-line galaxies in the structure as well as strong constraints on the distribution of star formation. Finally, we provide evidence that one of the brightest $z>10$ galaxies, GNz11, lies at the centre of an overdense structure of UV-faint Ly α -emitters, likely representing an early protocluster core. Moreover, we will discuss the differences in the evolutionary phases of these three protoclusters that likely results in their differing Ly α transmission. Finally, we compare these results with state-of-the-art simulations to understand the interplay between protocluster-resident galaxy properties and their environments. JWST has opened a new era in understanding the properties and evolution of these most overdense structures in the early Universe. We exploit this capability to unveil our most in-depth understanding of protoclusters at high redshifts.