Probing the Circumgalactic Gas Around high redshift galaxies with VUDS

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Context

Our current understanding of galaxy formation is based on studies of i) stars ii) star formation and iii) multi-phase gas, but the link between all these components is missing, providing us an incomplete and fragmented view of all the involved processes. Several studies based on simulations and theoretical analysis suggest that galaxies acquire most of their baryons by funneling cold gas, through cold filamentary streams deep inside dark matter (Birnboim+2003; Keres+2005;Keres +2009), moreover these cold streams should be detectable by absorption or emission, covering 25% of the area around galaxies ($z \geq 2.5$) at radii between 20 and 100 kpc, and flowing in with velocities >200 kms-1 (Dekel+09). Studying the interface between galaxies and the Intergalactic Medium: the circumgalactic medium (CGM) can help to understand how gas flows in and out of galaxies. A way to probe the CGM around star-forming galaxies is to look for absorptions that the CGM around foreground galaxies imprints in the spectra of bright background galaxies (Figure 1).

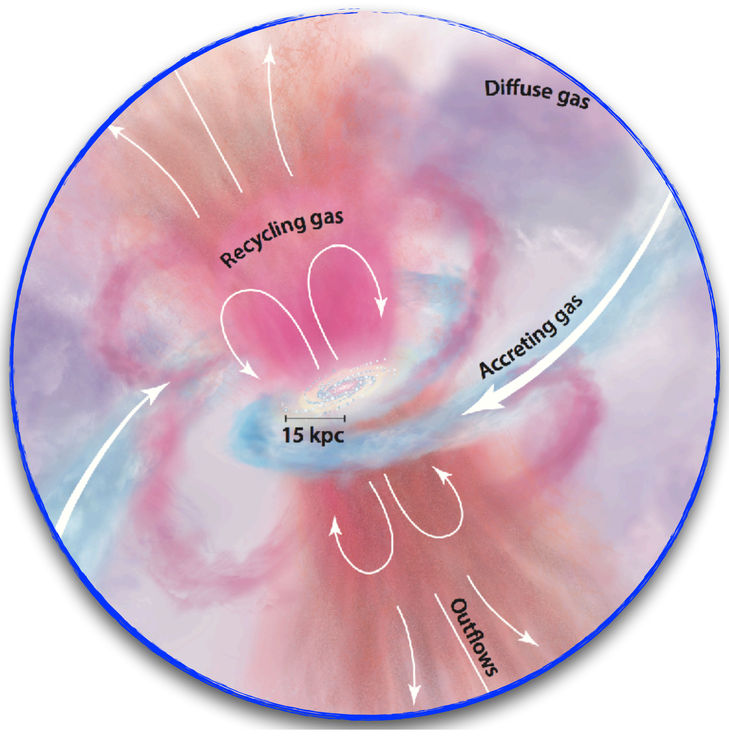

Figure 1: CGM diagram showing the inflows and outflows between the IGM and CGM recycling the baryonic material Tumlinson et al 2017.

Aim

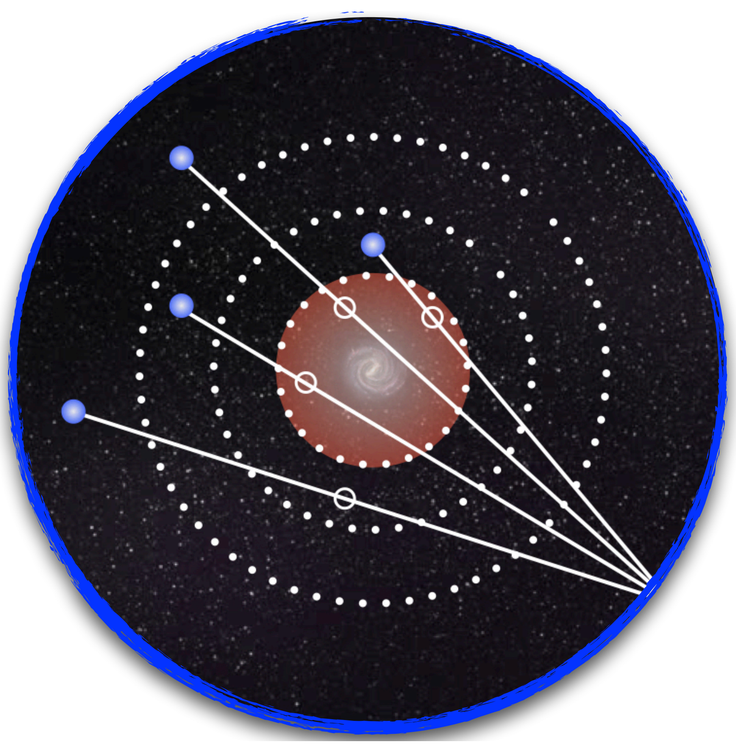

Figure 2: Sketch of close pairs of galaxies formed by a foreground galaxy (red) and four background galaxies (blue circles) probing its surrounding medium thorugh different line of sights.

By using deep spectroscopy of different lines-of-sight around a foreground galaxy (see Fig 2) we can get useful information on the overall kinematics, chemical abundances, and (in some cases) estimates of the mass flux of cool material entrained in an in-outflow. In particular, we selected close galaxy pairs, and identified in the spectra of background bright galaxies the faint imprints left by the circumgalactic gas surrounding the foreground galaxies. Stacking analysis provide a powerful way to extract faint signal from absorptions lines data sets, by enabling measurements of these weak absorptions.

Sample and Methods

In order to probe the circumgalactic medium (CGM) around galaxies at $2 < z < 4$ We have selected a sample of 7646 close (0-250 kpc) galaxy pairs from the Vimos Ultra-Deep Survey (VUDS). Each galaxy pair was selected by $0.01 \leq \Delta z = z_{bg}\text{-}z_{fg} < 1.0$, ensuring that their geometry is unambiguous and guaranteeing that the spectra contain a significant rest-wavelength interval in common after both are shifted to the rest frame of the foreground object, resulting into a final sample of 1244 pairs of galaxies.

Results

1. We have detected strong absorption features in both individual (see fig 2) and stacked background galaxies spectra (see fig 3). The pairs were gathered in three different separation bins: 0 <5", 5"<r<10",10" < r < 15" and 15" < r < 20" which at the mean redshift of the foreground galaxies of $\langle z \rangle = 2.6$, the angular bins correspond to projected physical distanced of (b :) 39, 78,115,154 kpc respectively. By doing this, we are able to trace the average absorptions line strengths (i.e. Ly$_\alpha$, OISiII, CIV, OISiII, CIV, AlII) out to galactocentric radii of $\sim$150 kpc on stacked spectra, and absorptions line strengths up to $\sim$250 kpc in some individual cases.

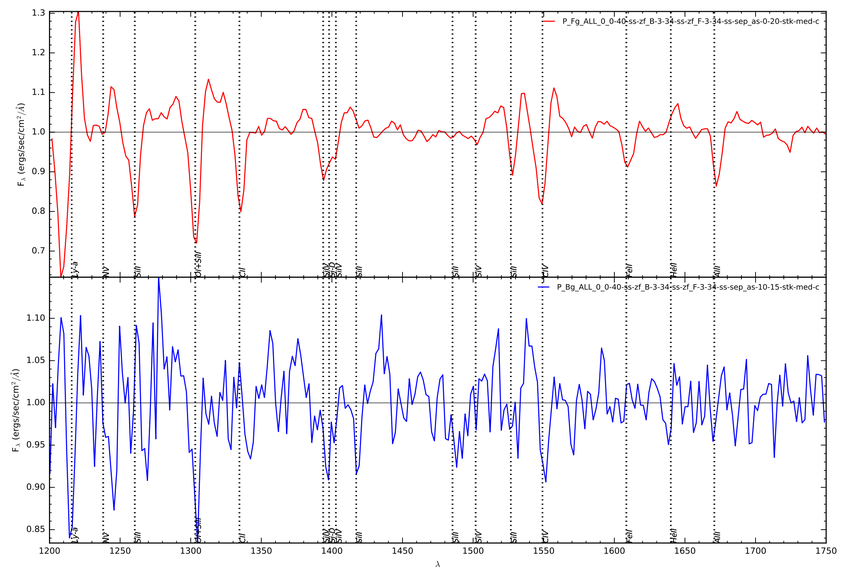

Figure 3: Stacked composite spectra of foreground galaxies (upper panel) and background galaxies.

2. We constructed radial profiles for Ly$_\alpha$, CIV detected from 10 kpc and upto 140 kpc, although other IS absorption lines could be detected in only one or two separations. Our results agree well with those presented by Steidel et al 2010, where the radial profile shape of IS absorption and Ly$_\alpha$ emission lines, show a variation of absorption line strength with the galactocentric impact parameter b. The former matches a model of circumgalactic gas, where cool gas is distributed symmetrically around every galaxy, accelerating radially outward with v$_{out}(r)$ increasing with r.
3. The CGM of galaxies at $2 < z < 5$ are rich in metals even at $\sim$150 kpc away from the galaxies.

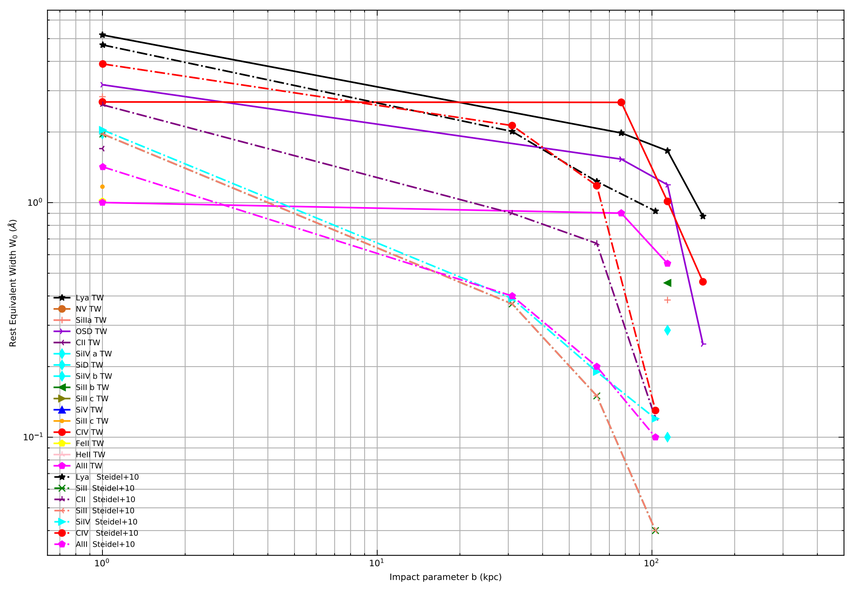

Figure 4: Radial profile of different IS absorption lines.

References

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