Absorption Gas Kinematics

Introduction & Motivation

Inflowing and outflowing gas in galaxy halos is important in star formation and therefore galaxy evolution. Background quasar spectra provide sensitive absorption lines from these gaseous halos, known as the circumgalactic medium (CGM). The Mg II \( \lambda \lambda 2796, 2803 \) doublet is ideal since it samples galaxies over the redshift range where the galaxies can be studied in detail. Mg II is observed in outflowing winds (e.g., Wu et al. 2009) and in infalling accretion (e.g., Balsan et al. 2012). Other studies have reported trends between Mg II absorption and star formation rate, B-band luminosity, and/or stellar mass of the host galaxy (e.g., Chen et al. 2010; Ménard et al. 2011). Recent works indicate that the gas is preferentially located along the minor axis or the major axis of the host galaxy (e.g., Kacprzak et al. 2012), suggesting bipolar outflowing winds and coplanar accretion are the dominant structures traced by Mg II absorption.

As such, increasing the sample size of known Mg II absorbers and their host galaxies holds the promise of furthering our understanding of gas flows in galaxies. Many previous surveys have been published with samples no larger than ~80 galaxies. In many cases, magnitudes, colors, and quasar-galaxy projected separations are not directly comparable between samples due to differing cosmologies and magnitude systems. It is desirable to standardize previous surveys to form a large uniform sample of Mg II absorption-selected galaxies.

Mg II Absorber-Galaxy Catalog

We built a catalog of 182 isolated Mg II absorption-selected galaxies (median \( z = 0.36 \)) from our work and a literature search. Figure 1 presents the quasar-galaxy offsets for most galaxies in MGGC2CAT. We standardized all galaxy impact parameters and photometric properties to the current ACDM cosmology and placed all B- and K-band absolute magnitude limits on the AB system using uniform K-corrections (see Kim et al. 1996) of the SEDs of Bozonenza et al. (2008). We also determined rest-frame B-K colors and B- and K-band luminosities. For details, see Nielson et al. (2013).

Additionally, we applied halo abundance matching using the Bolshoi cosmological simulations (Trujillo-Gomez et al. 2011) to obtain halo masses, \( M_\text{h} \), from absolute \( r \)-band magnitude. We measured virial radii, \( r_\text{vir} \), from the formula of Bryan & Norman (1998). See Churchill et al. (2013) for details.

Luminosity Scaling

The outer boundary of absorbing gas is commonly assumed to follow a Holmberg-like relation, \( R(1) \equiv R(1, 2796) \). We examined whether the B- and K-band halo gas radius also depends on \( \Delta v \). We apply four \( \Delta v \) cuts and cut all \( R \) by maximising the number of galaxies with \( \Delta v \) where \( \Delta v \) falls below the fitted line and maximising the number of galaxies with \( \Delta v \) above the fitted line. In Figure 4, B-band results are presented. The scaling with \( \Delta v \) steepens from \( \beta > 0.3 \) to \( 0.6 \) at \( R = 0.6 \) kpc within uncertainties. The covering fraction decreases from \( f_{\text{cov}} = 0.6 \) to 0.3 with increasing \( \Delta v \). For the K-band (not shown), \( f_{\text{cov}} \) plateaus slightly from 0.2 to 0.15 and \( R \) decreases from 75 kpc to 60 kpc. The covering fraction behaves similarly to the B-band.

Cloud-Cloud Velocity Clustering

Using the sample of 42 Mg II absorption profiles in HiRES/UVES spectra associated with MGGC2CAT galaxies presented in Figure 3, we determine the two-point velocity correlation function (TPCF), which is the probability of finding any two clouds separated by a particular velocity difference \( \Delta v \). We calculated the TPCF for various sub samples sliced by galaxy rest-frame color, redshift, halo mass, impact parameter, and pixel radius and impact parameter as shown in Figure 9. In every case, statistical tests (Che-square test on binned data, and the t-test and Kolmogorov-Smirnov test on unbinned data) between the two subsamples show that the TPCFs of the two subsamples are not drawn from the same population to greater than the 10% level.

Figure 9 presents the TPCF for red and blue galaxies. Blue galaxies have a more extended high velocity separation tail while red galaxies are peaked at low velocity separations and this difference is accentuated when velocities are normalized by \( v_\text{vir} \). In Figure 9b, higher redshift galaxies have more extended tails than low redshift galaxies, which are dominated by low velocity separations.

Figure 9 – TPCFs for Various Subsamples Split by Galaxy Properties

Solid lines are the TPCF while the shading around the solid line represents the 1 x Pearson uncertainty. Left panels present the TPCF for 20 separations while right panels present the TPCF for velocity separations \( \Delta v \) normalized by \( v_\text{vir} \) to account for the halo mass.

References

- Balsan et al. 2012
- Bryan & Norman 1998
- Churchill et al. 2013
- Chen et al. 2010
- Kim et al. 1996
- Ménard et al. 2011
- Nielson et al. 2013
- Wu et al. 2009