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Skewering the Cosmic Web with Quasars

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Abstract

This is a progress report on a STIS spectroscopic survey of 13 bright ($V < 18$) QSOs contained in a 22 square degree region that lies within the coverage of the 2dF Galaxy Redshift Survey. Our unique asterism of quasars will yield about 150 Lyman-α absorbers, with rest equivalent widths complete to 0.2 Å. The goal is 3D "tomography" of the low redshift IGM, using adjacent sightlines to detect absorber-galaxy correlations 10-20 times weaker than galaxy-galaxy correlations.

1.1 Introduction

Quasars are extremely sensitive probes of the low redshift IGM. Absorbers of the Lyman-α "forest" can trace neutral HI columns that are 10^6 times lower than the gas that has fallen into galaxies. This neutral component is the most easily detectable phase of gas that is highly ionized and not closely associated with luminous galaxies (Rauch 1998). By $z = 0$, the Lyman-α "forest" has thinned out into a "savannah," due to IGM gas draining onto galaxies, and due to the competing effects of cosmic expansion and the lower UV photoionizing background. Hydrodynamic numerical simulations indicate that the low redshift Lyman-α "forest" contains about a third of the baryons (Davé et al. 2001).

UV spectroscopy with the Hubble Space Telescope enables absorbers to be found at low redshift, and related to large scale structure seen in the well-studied galaxy distribution. We are acquiring and analyzing Cycle 10 STIS observations of 13 QSOs in a region of sky centered on $\alpha = 00^{\mathrm{h}}50^{\mathrm{m}}$, $\delta = -29°30'$. The data use the FUV MAMA and the G140L grating, with a setting that is sensitive to Lyman-α out to $z = 0.4$. The data have a mean S/N of 15-20 per 250 km s^{-1} resolution element. Absorber clustering will be reported in terms of the two-point correlation, nearest neighbor analysis, and various void statistics.

1.2 The Galaxy Distribution

The region of sky skewered by our 13 sightlines intersects the 2dF Galaxy Redshift Survey (Fig. 1.1), which will execute its final data release in the middle of 2003 (Colless et al. 2001). We will measure the 3D clustering signal between absorbers and galaxies on scales where clustering is detected in the galaxy distribution, since the redshift depth of the absorber survey is $\sim 600\ h_{100}^{-1}$ Mpc. The average number of absorbers per sightline (10-12) is well matched to the number of walls and voids in the galaxy distribution out to $z = 0.2$.

This experiment will yield the most sensitive test yet for absorber-absorber and absorber-galaxy clustering on scales of 1-2 h_{100}^{-1} Mpc. With correlated sightlines, the sensitivity to

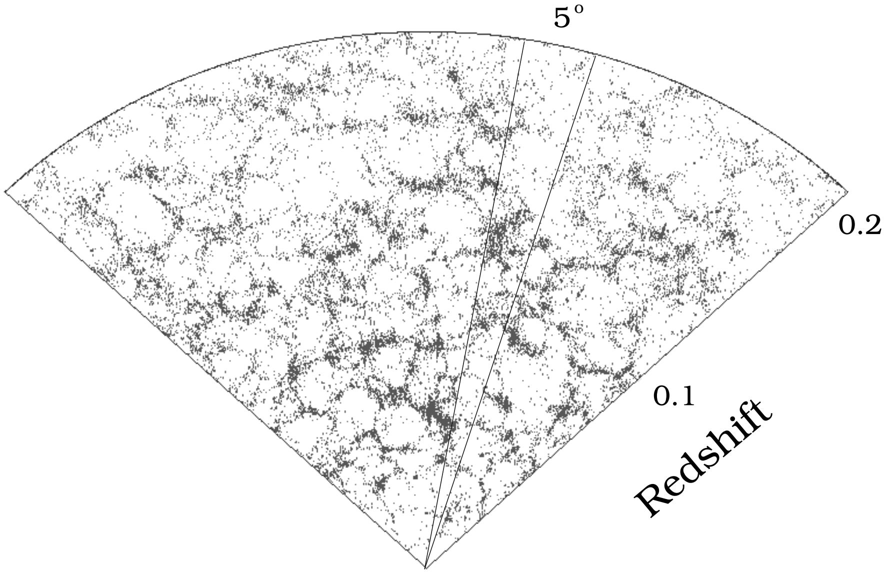

Fig. 1.1. This mock 2dF survey slice shows the 5 degree span of the region encompassing the 13 sightlines (credit: 2dF Galaxy Redshift Survey Team). The transverse distance corresponds to 2 h_{100}^{-1} Mpc at $z = 0.1$.

absorber-absorber clustering goes as the square of the number of sightlines and linearly with the number of absorbers per sightline. We expect to measure the amplitude of the correlation function to a 2σ limit of $\sigma(\xi) = 0.5$ on scales of 1-20 h_{100}^{-1} Mpc. The direct relationship between luminous galaxies and absorbers can be studied with the 2dF redshift data.

1.3 Comparison with Simulations

We use high resolution SPH simulations of the low redshift IGM to make direct comparisons with our spectra. The most basic checks are the number of absorbers and their two-point correlation function. We measure lines in spectra extracted from simulations that have been processed to exactly mimic the observations (Petry et al. 2002).

With the absorber statistics from this survey, augmented by data with similar resolution from the HST archive, we will attempt a spectral inversion to derive the mass spectrum of fluctuations on scales of 1-10 h_{100}^{-1} Mpc, for direct comparison with analogous meausures from galaxy redshift surveys. Another key cosmological probe is the velocity dispersion in low density regions. We will measure the quiescence of the large scale velocity field using the line-of-sight velocity difference of coincident absorbers with transverse separations of 1-2 h_{100}^{-1} Mpc.

1.4 Future Directions

In addition to the analysis previously described, we will derive a new measurement for dN/dz for Lyman-limit absorbers at low redshift, using deep imaging from CTIO to identify the galaxies that can potentially cause such absorption. The STIS sightlines thread several dozen voids in the galaxy distribution so we will be able to measure the proportion of Lyman-α absorbers in voids. We will also carry out a sensitive search for metals, by shifting and stacking the estimated ~ 80 Lyman-α systems with $z < 0.12$. When metallicities are also in hand, we will be able to account for the cycling of baryons from the IGM through galaxies.

The STIS absorbers have cosmic overdensities of $\delta\rho/\bar{\rho}$ = 10-30 and their relationship to the underlying dark matter distribution can be understood through simulations that incorporate gas dynamics. The STIS absorbers span a column density ranging from the strongest absorbers, which are often associated with galaxies to the weakest absorbers, which trace the filaments of large scale structure.

This project is a precursor to more ambitious surveys that can be carried out using COS and the SDSS database, that will improve the sensitivity to absorber-absorber and to absorber-galaxy power on scales of 1-10 h_{100}^{-1} Mpc by an order of magnitude. Combining the dense sampling of galaxies with correlated QSO sightlines will provide a means to extend and deepen our understanding of the relationship between the visible baryons in galaxies and the dim baryons in the IGM.

References

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