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Abstract. Hydrodynamic cosmological simulations predict that the average opacity of the Lyα forest should increase in the neighborhood of galaxies because galaxies form in dense environments. Recent observations (Adelberger et al. [1]) confirm this expectation at large scales, but they show a *decrease* of absorption at comoving separations $\Delta_r \lesssim 1h^{-1}$ Mpc. We show that this discrepancy is statistically significant, especially for the innermost data point at $\Delta_r \leq 0.5h^{-1}$ Mpc, even though this data point rests on three galaxy-quasar pairs. Galaxy redshift errors of the expected magnitude are insufficient to resolve the conflict. Peculiar velocities allow gas at comoving distances $\gtrsim 1h^{-1}$ Mpc to produce saturated absorption at the galaxy redshift, putting stringent requirements on any "feedback" solution. Local photoionization is insufficient, even if we allow for recurrent AGN activity that keeps the neutral hydrogen fraction below its equilibrium value. A simple "wind" model that eliminates all neutral hydrogen in spheres around the observed galaxies can marginally explain the data, but only if the winds extend to comoving radii $\sim 1.5h^{-1}$ Mpc.

BASIC PREDICTIONS

In a recent paper [2], we discuss a variety of predictions for galaxy-Lyα forest correlations from hydrodynamic simulations. In this proceeding, we focus on the "galaxy proximity" effect on small scales ($\leq 2h^{-1}$ Mpc comoving). Using smoothed particle hydrodynamics simulations (SPH) of a ΛCDM universe ($\Omega_m = 0.4, \Omega_\Lambda = 0.6, h = 0.65, \Omega_b = 0.02h^{-2} = 0.0473$, $\sigma_8 = 0.80$), we generate synthetic Lyα forest spectra from the temperature, gas density, and velocity at each spatial location in skewers through the simulation box. Once we have created synthetic spectra, we use the known positions of the simulated galaxies to compute the mean flux decrement, $\langle D \rangle = \langle 1 - e^{-\tau} \rangle$, as a function of comoving separation from the galaxy, Δ_r.

Figure 1a shows the basic predictions for the mean flux decrement, computed for the 150 galaxies with the highest star formation rates within a simulation $50h^{-1}$ Mpc on a side. We see a clear trend of increasing decrement (absorption) with decreasing Δ_r, a signature of the dense environments these galaxies occupy. The observed points, from [1], show a similar trend at large scales, but the trend flattens at $\Delta_r \lesssim 2.5h^{-1}$ Mpc, and absorption *decreases* for $\Delta_r \lesssim 1h^{-1}$ Mpc. The innermost point, $0 \leq \Delta_r \leq 0.5h^{-1}$ Mpc is in especially severe conflict with the theoretical prediction. We investigate several possibilities for resolving this conflict below. Similar investigations have been carried out by [3], [4], and our results are compatible with theirs to the extent that they overlap.

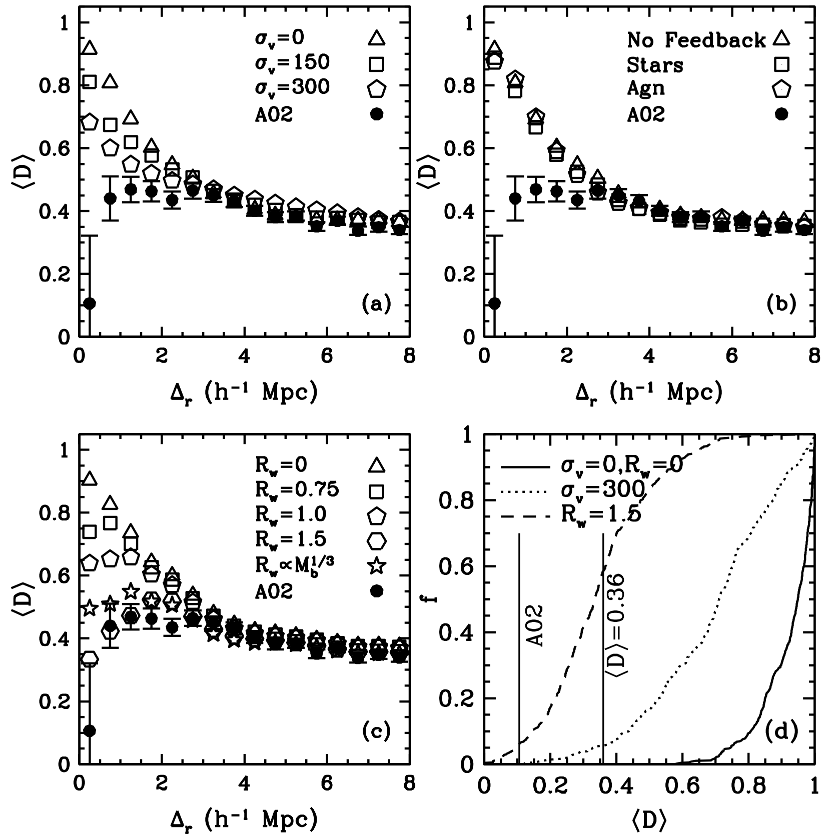

FIGURE 1. The Conditional Mean Flux Decrement. (a) The conditional mean decrement compared with the baseline calculation, and calculations with redshift errors as indicated in panel and described in text, (b) Effect of photoionization feedback from stars or AGN on the numerical predictions, (c) Effect of spherical winds/gas removal on the predictions, (d) Cumulative distribution of 3-tuples at $\Delta_r = 0.25$ Mpc as a function of $\langle D \rangle$. Vertical lines at $\langle D \rangle = 0.11$ and 0.36 correspond to the Adelberger et al. [1] value for this separation and the global mean respectively. Symbols are as indicated in the panel.

REDSHIFT ERRORS

Since we expect galaxies to occupy peaks in the density distribution, if the redshift of the galaxy is incorrectly estimated, then one may compute an artificially low value of $\langle D \rangle$ at small Δ_r because one samples a region of lower density than the region around the true galaxy redshift. We estimate the size of this effect by adding a redshift error, drawn from a Gaussian distribution, to each galaxy redshift. Squares and pentagons in Figure 1a show the result for rms redshift errors $\sigma_v = 150$km s^{-1} and $\sigma_v = 300$km s^{-1}, respectively. The sign of the effect is as expected — increasing the redshift errors does decrease the values of $\langle D \rangle$ at small Δ_r, pushing them towards the global mean. It is clear, however, that even with significant redshift errors (Adelberger et al. estimate ~ 150km s^{-1}) the difference between the theoretical curves and the observations remains substantial.

LOCAL PHOTOIONIZATION

There is some evidence that a significant amount of Lyman continuum radiation is leaking from the interstellar media of Lyman Break Galaxies (LBGs) [5]. It is then plausible that these galaxies may affect their immediate surroundings in the form of photoionization from the stars within them. There is also evidence indicating that $\sim 3\%$ of LBGs host AGN [6]. If the timescale between AGN outbursts is sufficiently short, then, in contrast to the stellar case, the gas surrounding the galaxies can remain out of photoionization equilibrium between outbursts, and the neutral hydrogen fractions around galaxies that have recently hosted AGN may be further suppressed. We have incorporated simple models for these two scenarios within the simulations by including the non-uniform ionizing background near galaxies in each case, as well as the additional effect of non-equilibrium neutral fractions in the AGN case. For details of these models see [2]. Figure 1b compares the results of these two calculations to the original, no-feedback, calculation. Photoionization has minimal impact on the mean decrement even at small Δ_r. It is tempting to think that increasing either the AGN luminosities or the escape fraction of ionizing photons could produce a larger effect, but this is not the case because the total output of the sources cannot exceed the UV background, which is itself constrained by the mean (unconditional) flux decrement. The models we have presented are close to maximal, with the observed galaxies or their AGN assumed to produce 50% of the entire UV background.

WINDS

Outflows have been detected in LBGs by looking at the difference between absorption and emission features within these systems [7]. Strong winds from supernovae are a generic property of starburst galaxies and have the effect of shocking and sweeping up the material in their wake, both of which lead to decreased absorption inside the “sphere of influence” of the wind. We have constructed very simple “wind” models in which we eliminate all neutral hydrogen in a spherical region of radius R_{wind} around each galaxy in the simulation sample. We note that this model is highly optimistic since it assumes either *perfect* entrainment of the material in the volume out to R_{wind} or sufficient energy injection to completely ionize hydrogen within this radius. Neither condition is necessarily expected to hold for realistic winds ([3], [4]).

Figure 1c shows the result of the wind model for the 40 galaxies with the highest star formation rates in a simulation box of side $22.22h^{-1}$ Mpc (comoving). Here the squares, pentagons, and hexagons correspond to models with constant comoving radii $R_{wind} = 0.75, 1.0$, and $1.5h^{-1}$ Mpc respectively. Stars show a model in which the volume of the wind around a galaxy is proportional to the baryonic mass of the galaxy, normalized such that the $40th$ brightest galaxy has a wind radius of $1h^{-1}$ Mpc and including winds around all 641 resolved galaxies in the box. The largest winds in this model extend to $R_{wind} \sim 2h^{-1}$ Mpc, requiring an average propagation speed $V \sim 750\text{km s}^{-1}(1\text{Gyr}/t)$ for a wind duration t and $h = 0.65$. Only the most extreme wind models come close to matching the observational results. Note, in particular that $1h^{-1}$ Mpc winds do not

eliminate, or even drastically reduce, absorption at $\Delta_r \leq 1h^{-1}$ Mpc because much of the absorption at these separations in *redshift space* comes from infalling gas that is further than $1h^{-1}$ Mpc in *real space*. These peculiar velocity effects are also the reason that photoionization has such a tiny impact; even for near maximal models, the ionization does not strongly affect gas at such large distances.

STATISTICAL FLUKE?

Since the innermost data point comes from only three galaxy-los pairs, we must also ask whether it could just be an anomalous statistical fluctuation. We have done a Monte Carlo calculation in which we draw 500 sets of 3 galaxies from our population of $z = 3$ simulated galaxies and compute the value of $\langle D \rangle$ at $\Delta_r \leq 0.5h^{-1}$ Mpc for each 3-tuple. Figure 1d shows the cumulative distribution of the flux decrement from these samples. We see that our baseline calculation can virtually never get to decrements as low as those observed. Even with a redshift error of 300km s^{-1}, one sees decrements below 0.36 only $\sim 5\%$ of the time. For the most extreme wind model, we find decrements as low as the observed one, $\langle D \rangle = 0.11$, $\sim 5\%$ of the time. Despite the limited size of the current data set, the observed “LBG proximity effect” stands as a striking result, not easily explained.

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