Do galactic winds affect the Lyα forest?

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Abstract

We investigate the effects of galactic winds on the Lyα forest in N–body simulations complemented by a semi–analytic model of galaxy formation, which includes recipes for the long–term evolution of winds. We find that the main statistical properties of the Lyα forest, namely the power spectrum $P(k)$ and the flux probability distribution function PDF, are not significantly affected. However, hot bubbles and shells do produce individual signatures in the forest, e. g. regions of high Lyα flux transmissivity and narrow, saturated absorption lines. We show that the enhanced Lyα flux transmissivity found by Adelberger et al. (2005) in close proximity of a large fraction of LBGs can be explained by the presence of winds.

1 Pressure Driven Bubbles and Momentum Driven Shells

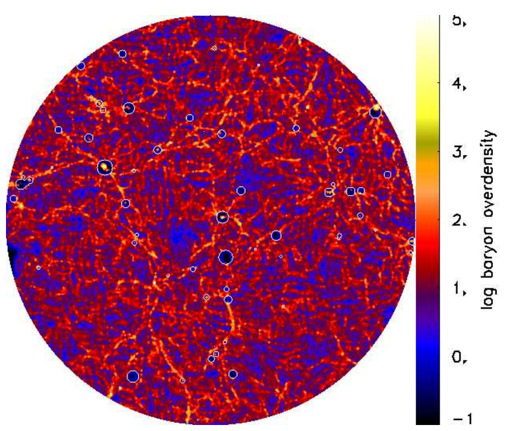

Fig. 1: Density slice at $z = 3$ for the e03 model.

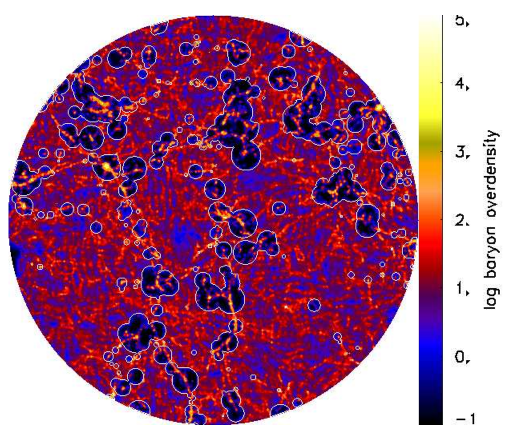

Fig. 2: Density slice at $z = 3$ for the e01 model.

The N–body simulation "M3" (Stoehr 2003) has diameter 52 h^{-1} Mpc and assumes: $M_{\rm DM} = 1.7 \cdot 10^8 h^{-1}$ M$_\odot$, $N_{\rm p} = 7 \cdot 10^7$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, $h = 0.7$, $n = 1$ and $\sigma_8 = 0.9$. The most innovative feature of the SA model for the long–term evolution of winds of Bertone et al. (2005) is the description of the dynamics of outflows as a two–phase process: a pressure–driven adiabatic expansion followed by a momentum–driven snowplough. The model contains one free parameter, ε, which defines the fraction of mass swept up by winds while crossing the ambient medium. We examine two wind models: the e01 model with $\varepsilon = 0.1$ and the e03 model with $\varepsilon = 0.3$.

2 The Flux PDF

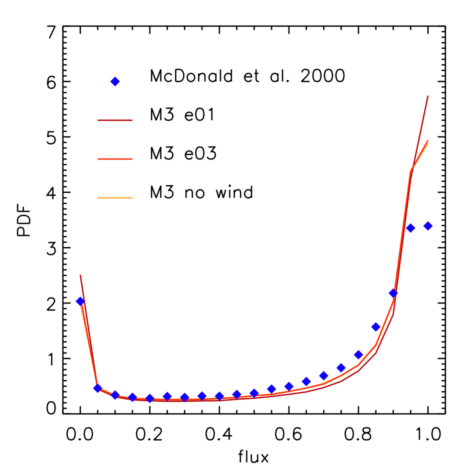

Fig. 3: Flux PDF at $z = 3$. Numerical results compared to the observations of McDonald et al. (2000).

Comparison with the observed PDF of McDonald et al. (2000). The prediction of the e03 model agrees well with the "no wind" model and the flux PDF is not significantly affected. More efficient winds as in model e01 sensibly modify the PDF and show the largest discrepancies with the observations.

3 The Flux Power Spectrum

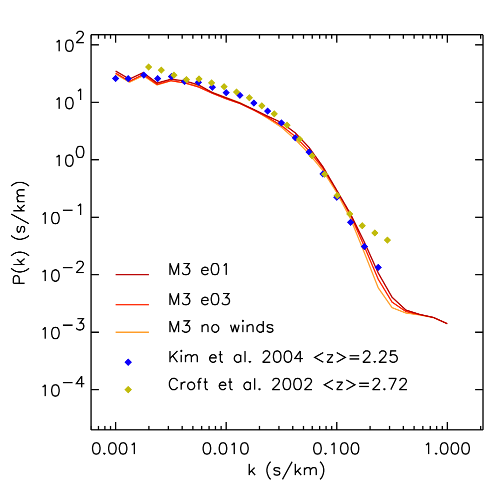

Fig. 4: The flux $P(k)$ of a combination of synthetic spectra at $z \sim 3$ and $z \sim 2$. Results are compared to the data of Kim et al. (2004) at $\langle z \rangle = 2.25$ and Croft et al. (2002) at $\langle z \rangle = 2.72$.

Good agreement with the data of Kim et al. (2004), but deviations are significant for $0.005 < z < 0.02$ s km^{-1}. Substantial agreement of the "no wind" model with the two e01 and e03 wind models at $k < 0.01$ s km^{-1}: this indicates that the presence of winds in the IGM should not affect the estimation of cosmological parameters, as long as the filling factor is small.

4 Flux Transmissivity around LBGs

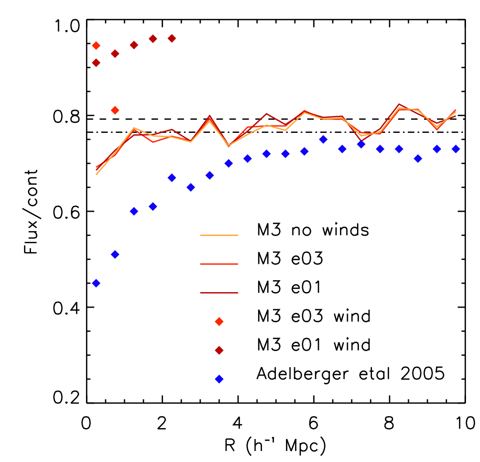

Fig. 5: The mean flux transmissivity as a function of R. Results for samples of galaxies with random impact parameters and for subsamples of galaxies blowing winds with $R_{\rm wind} > R$.

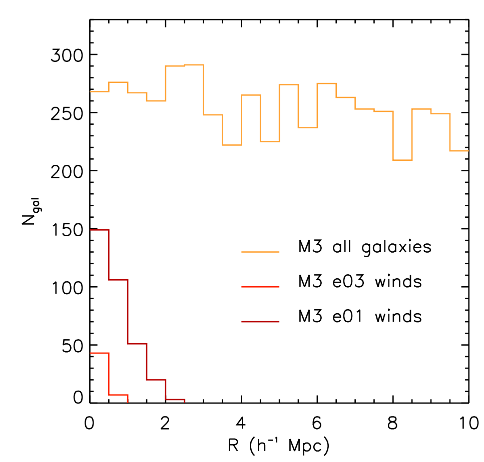

Fig. 6: Number of galaxies and number of wind–blowing galaxies with $R_{\rm wind} > R$ as a function of R. e01 produces a larger number of wind–blowing galaxies than the e03 model.

We find that, although the mean Lyα transmissivity decreases in proximity of LBGs, around a significant number of galaxies the Lyα flux is almost completely transmitted, in excellent agreement with the finding of Adelberger et al. (2005). The high flux level in our spectra is due to the assumption in the SA model that gas in haloes is at the virial temperature.

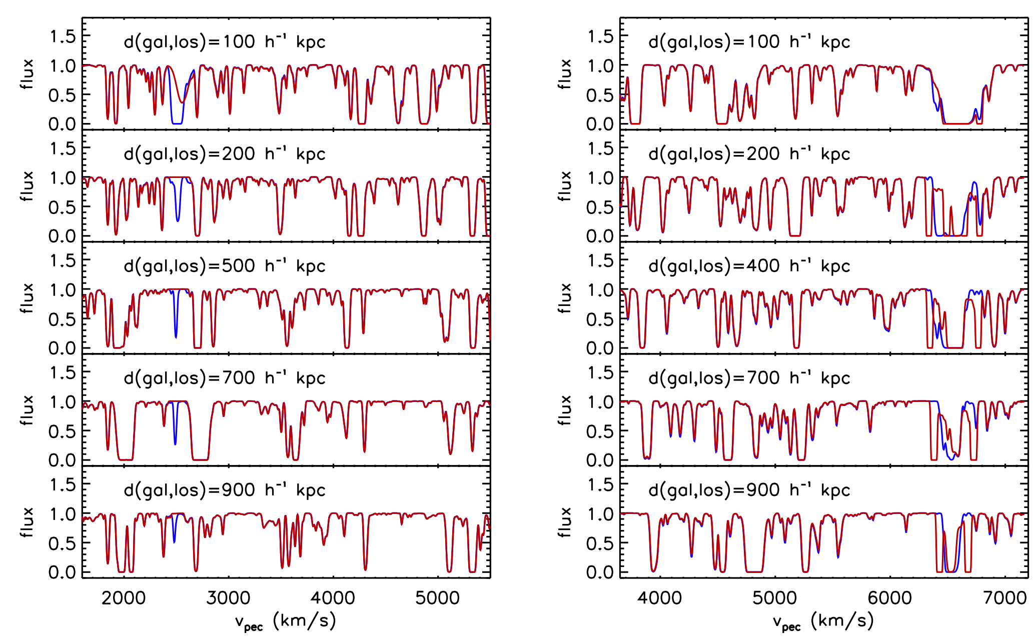

Fig. 7: Example of bubble (left) and shell (right) signatures in the Lyα forest at $z = 3$ for different impact parameters. From the e03 model. The source galaxies have $M_\star = 1.6 \cdot 10^9$ h^{-1} M$_\odot$ and $M_\star = 9.2 \cdot 10^9$ h^{-1} M$_\odot$ respectively.

Despite the different physics of pressure–driven and momentum–driven winds, when a LoS crosses a bubble or a cavity, the optical depth of the gas inside the wind is reduced and the flux increased.

5 Conclusions

1. Good agreement between all numerical models and the observed flux PDF at $z = 3$.
2. Good agreement between the numerical $P(k)$ and observations at $2 < z < 3$. Winds do not produce significant effects on $P(k)$: the estimation of cosmological parameters using the Lyα forest power spectrum should not be sensitive to the presence of galactic winds.
3. Enhanced Lyα flux transmissivity in proximity of wind–blowing galaxies. Our numerical results are in excellent agreement with the observations of Adelberger et al. (2005).

References

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