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COSMOLOGICAL CONSTANT AND Lyα FOREST STATISTICS

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Abstract. We investigate the impact of recent discovery of a large positive vacuum energy density ("cosmological constant") on our interpretation of the Lyα forest cloud statistics. It has been known for some time that, contrary to the usual situation in cosmology, the impact of non-zero Λ on the cloud population is larger in the low-redshift limit than in the high-redshift one. We show that this offers a significant circumstantial support to the theory that Lyα clouds are gravitationally confined (in mini-haloes as well as large galactic haloes).

Great progress has recently been made in studies of the structure and evolution of the baryonic content of the universe. New observational techniques (deep fields, gravitational microlensing, QSO absorption spectroscopy, etc.) have successfully been coupled with tremendous advances in theoretical methods and numerical modelling, enabling unprecedented improvement of our knowledge on this difficult issue. At the time of writing, new generation of instruments (fronted by *Chandra* X-ray observatory) is gathering data, to be analyzed with ever-improving computational facilities. It seems, therefore, that we are already in a position to draw some general conclusions on the evolutionary status of baryonic matter, even if the details are still elusive, and probably will remain so for years to come. It is well-known that most of the baryons at high redshift are located in the highly-ionized intergalactic clouds, known as the Lyα forest, seen in absorption against all known QSOs (Rauch 1998; Weinberg et al. 1997). These clouds are diffuse, very weakly clustered, (in conventional language) intergalactic structures of predominantly low-column density sheets and filaments, usually shown as a "cosmic web". However, as cosmic time passes, a different population of highly-clustered, compact objects confined by gravity becomes dominant. This population is physically associated with "minihaloes" of Rees (1986) or "dark galaxies" of Trentham et al. (2001) on one hand, and haloes of normal luminous galaxies (Chen et al. 1998) on the other. Thus, we expect that, physically speaking, baryons in hot, diffuse intergalactic plasma are gradually incorporated in this confined state, at much lower temperature. It is important to understand that the "two populations hypothesis" (Tytler 1987) meant different things to different authors. On the top of that semantical problem, it seems clear that even the classical notion of distinct absorbing populations got increasingly complicated in recent years, especially after realization that the Lyα forest absorbers almost always contain small metal abundances (Cowie et al. 1995; Burles & Tytler 1996). This circumstance presents a grave problem for those who wish to achieve unity of the two populations in intergalactic models, as was the original proposition of Tytler (1987). As suggested by Lake (1988), the Tytler's choice of "site of unification" is largely arbitrary; today we have even more arguments for such a conclusion. One of them follows from analysis of Ćirković & Samurović (2000), who show that observations of the neutral hydrogen absorption around luminous galaxies are consistent with the index of the power-law column density distribution derived from statistical analysis of large samples of high-redshift Lyα forest lines. If we wish to reject the interpretation of this as a sheer coincidence, we are forced to conclude that realistic samples of absorbers represent statistical mixtures of two distinct physical populations. The dramatic difference between the conventional, Einstein-de Sitter CDM-dominated universe ($\Omega_m = 1$, $\lambda = 0$) which has dominated in studies and textbooks until several years ago, and the current understanding in which the dark energy is the dominant component ($\Omega_m \approx 0.3$, $\lambda \approx 0.7$) is exhibited in the Lyα-forest studies. It has been noted, more than a decade ago, that the nonzero cosmological constant can influence Lyα-forest statistics, notably the line-of-sight redshift distribution of absorption lines (Fukugita & Lahav 1991; Turner & Ikeuchi 1992; see also Van de Bruck & Priester 1998). The basic idea is to recover observed redshift distribution statistics by taking into account changes in the geometrical line element due to the dark energy, by using absorption lines as a particularly weird "standard candles". As noted by these authors, particularly interesting is the circumstance that, contrary to our intuitive expectations and contrary to most examples in observational cosmology, we are in position to obtain more information on the dark energy at low than at high redshift. There were several important developments since the two pioneering studies of Fukugita & Lahav (1991) and Turner & Ikeuchi (1992) have been published. The most important, of course, is the spectacular success of two observational projects on cosmological supernovae (e.g. Riess et al. 1998), as well as independent evidence for dark energy from the CMB fluctuations (e.g. Lineweaver 1998). Thus, in a sense, we have the answer to the original puzzle. However, it is worth attempting to check the method itself, since a lot of data has accumulated on the low-redshift Lyα-forest, which was essentially a *terra incognita* at the beginning of 1990s (e.g. Weymann et al. 1998). This is our goal in this study. Furthermore, it is interesting to outline the *inverse problem*: how, if we know the line element *exactly*, to quantify the evolution of the low-redshift Lyα-forest. In Fig. 1 we plot non-evolving absorption-line counts for various cosmological models. That this situation is unrealistic is seen in Fig. 2, where effective redshift distribution index α at low-redshift ($\frac{\mathrm{d}N}{\mathrm{d}z} \propto (1+z)^{\alpha}$) is compared with observational data. It is hard to escape the conclusion that intrinsic evolution of Ly-α clouds occurs even in the low-redshift regime.

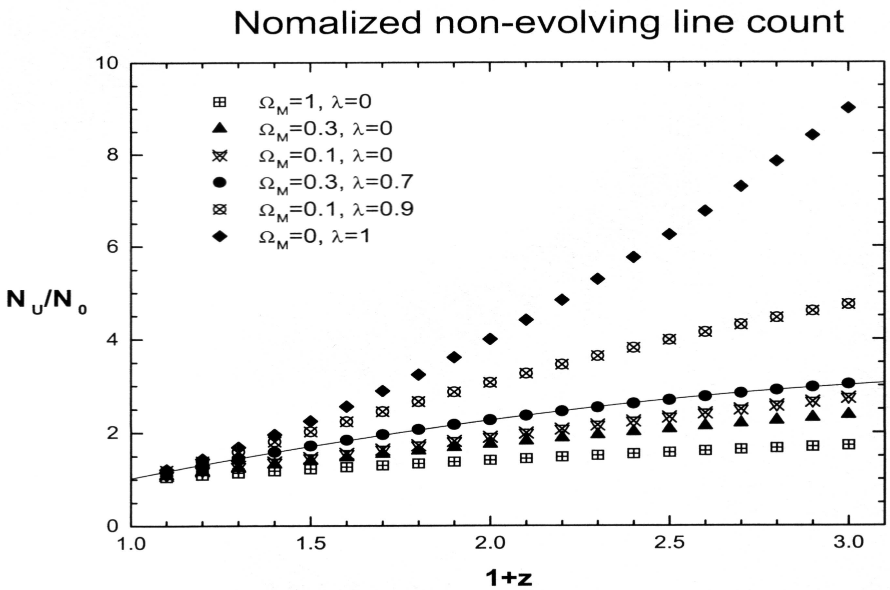

Figure 1: Normalized, non-evolving Ly-α absorption line count for various cosmological models.

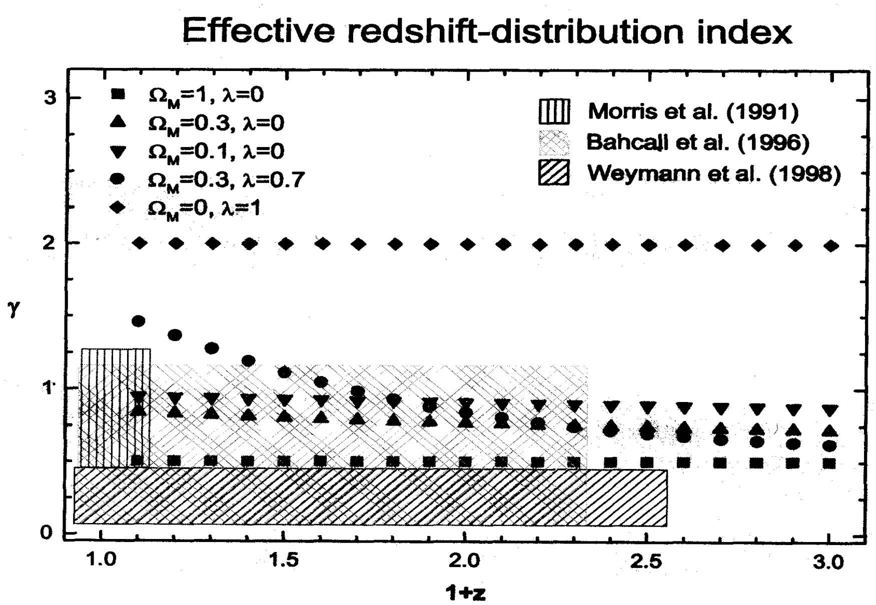

Figure 2: Effective redshift distribution index γ for non-evolving population of absorbers in various cosmologies; still rather scarce observational data are represented by boxes.

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