On the Origin of Very Wide Lyα-Absorption-Lines in Quasar Spectra

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Abstract

We present a new explanation for the very wide absorption features in quasar spectra. In our model, a very wide absorption feature will originate, when the line of sight crosses a bubble wall tangentially. We demonstrate this on the quasar pair (2138-4427), (2139-4434). Both show two very wide absorption lines in their spectra at the same redshift. The bubble wall model can explain these observations in low density Friedmann-Lemaitre models with spherical metric. It contradicts models with euclidean or hyperbolic metric.

1 Introduction

The Lyα absorption systems have been analysed with the complete Friedmann equation (i.e. including the Λ-term) by using two approaches: 1) A bubble wall distribution of hydrogen absorbers and 2) a cloud model with homogeneously distributed absorbers (Hoell, Liebscher, Priester (1994), hereafter HLP). The observations of high-resolution spectra can be explained in both cases by the same Friedmann-Lemaître model \( \Omega_0 = 0.014, \lambda_0 = \Lambda c^2/3H_0^2 = 1.080 \). A simple explanation for this agreement is the fact, that the observed line counts for the cloud model are usually averaged over redshift intervals \( dz = 0.2 \). This implies averaging over more than twenty bubble walls. Thus, a homogeneous distribution of clouds is compatible with clouds situated in the walls of a bubble structure.

The bubble wall model is based on the assumption that the void-structure observed in the distribution of galaxies in our cosmological neighbourhood \( (z < 0.05) \) is a universal phenomenon and is expanding with the Hubble flow only. This predicts a characterestic pattern in the statistical distribution of absorption lines in the Lyα-forest (i.e. single lines or close blends \( \Delta v \leq 300 \text{ km/s} \) representing hydrogen-filaments in the walls either inside galaxies or in intergalactic clouds). High-resolution spectra of numerous quasars in the redshift range \( 1.8 < z < 4.5 \) show this characteristic pattern (see e.g. Pettini et al. (1990)).

The aim of this letter is to show that the very wide Lyα-absorption features can also be explained with a universal, spongelike bubble wall distribution of hydrogen absorbers. We shall demonstrate this on the pair of quasars (1) 2138-4427 (\( z_{em} = 3.17 \)), (2) 2139-4434 (\( z_{em} = 3.23 \)). They are separated by 8 arcmin on the sky. Both show two very wide absorption lines in their spectra at the same redshift \( z_{abs} = 2.380 (4110 \text{ Å}) \) and \( z_{abs} = 2.853 (4685 \text{ Å}) \),
see Francis and Hewett (1993). Our interpretation of these observations is presented in 2. Conclusions are presented in 3.

2 The interpretation with the bubble wall model

The fact, that the two spectra of the quasar pair show similar absorption features at the same redshifts, leads to the conclusion, that there are two large objects which cross both lines of sight. In a Einstein-de Sitter (flat) universe ($\Lambda \equiv 0$) the diameters of these objects would be about $6 \cdot h_0^{-1}$Mpc ($H_0 = h_0 \cdot 100$km/(s·Mpc)). It was pointed out by Peacock (1993), that these objects can not be explained in the standard model of structure formation (CDM, HDM or MDM).

An obvious explanation for this astonishing finding is provided by the bubble wall approach. It is assumed that the wide features originate when the lines of sight from the two quasars to the observer cut tangentially through the wall system on opposite sides of a void. This is shown schematically in Fig. 1 and Fig. 2. The spectra centered at the absorption maximum at 4110 Å and 4685 Å were taken from Fig. 4 of Francis and Hewett (1993). The spectral resolution (1.3 Å) is not large enough to show a clear pattern. Furthermore, the spectrum (A) is contaminated by possible Ly$\beta$ absorption (quasar (1) Ly$\beta$(emission) at 4278 Å and quasar (2) at 4340 Å) and both could be disturbed by metal lines.

Coinciding very wide absorption features can be expected in close quasar pairs if the separation of the lines of sight corresponds to the expected average size of bubbles at a certain redshift. In the case of the quasar pair here we even have this occurrence twice at two redshifts. Does the separation at $z = 2.380$ and $z = 2.853$ agree with the expected size? We shall see that this is the case sufficiently well for low density Friedmann-Lemaitre models with spherical space metric. It contradicts, however, models with euclidean or hyperbolic metric (details see below). The separation $d(z)$ between the lines of sight at redshift $z$ is given by

$$d(z) = \frac{\alpha D_r(z)}{1+z}$$

with $\alpha =$angular separation between the two quasars and $D_r(z) =$metric distance, given by

$$D_r(z) = R_0 \cdot r(z)$$

with

$$R_0 = \frac{c}{H_0} \sqrt[3]{\frac{k}{\Omega_0 + \lambda_0 - 1}}$$

and

$$r(z) = \begin{cases} \sinh \chi(z) & \text{for } k = -1 \\ \chi(z) & \text{for } k = 0 \\ \sin \chi(z) & \text{for } k = +1 \end{cases}.$$

The radial distance $\chi(z)$ along the line of sight is given by

$$\chi(z) = \sqrt[3]{\frac{\Omega_0 + \lambda_0 - 1}{k}} \int_1^{1+z} \frac{d\zeta}{\sqrt[3]{\Omega_0 \zeta^3 - (\Omega_0 + \lambda_0 - 1)\zeta^2 + \lambda_0}}.$$
Table 1: Redshift intervals $\Delta z(z)$ in the line pattern obtained from the spectra (A) and (B) (2nd column) and the typical average values $\Delta z(z)$ obtained by the Friedmann regression analysis (HLP 1994) (3rd column)

| $z$  | $\Delta z(z)$     | $\Delta z(z)$     |
|------|--------------------|--------------------|
| 2.380| 0.47 $\cdot 10^{-2}$ | 0.67 $\cdot 10^{-2}$ |
| 2.853| 0.52 $\cdot 10^{-2}$ | 0.63 $\cdot 10^{-2}$ |

Table 2: The parameters of the four models for comparison ($c/H_0$ in Gpc)

| Model          | $h_0$ | $\Omega_0$ | $\lambda_0$ | $c/H_0$ |
|----------------|-------|------------|--------------|---------|
| Einstein-de Sitter (EdeS) | 0.5   | 1.00       | 0.0          | 6.00    |
| Ostriker-Steinhardt (O-St)  | 0.65  | 0.35       | 0.65         | 4.62    |
| Sandage-Tammann (Sa-Ta)     | 0.5   | 0.05       | 0.0          | 6.00    |
| Bonn-Potsdam (BN-P)         | 0.9   | 0.014      | 1.08         | 3.34    |

(Note, that for $k = 0$ the quantity $R_0 \cdot \chi(z)$ remains finite!). The metric distance for four models is shown in Fig. 3. In the bubble wall approach it is assumed that the size of the bubbles (or voids) expands with the Hubble flow only. For the comparison with the size of the Harvard voids in our neighbourhood we transform $d(z)$ to the present-epoch $t_0$:

$$d_0 = d(z) \cdot (1 + z). \quad (6)$$

In addition we calculate the typical average bubble size $R_0 \Delta \chi$ at the present-epoch, given by

$$R_0 \cdot \Delta \chi = \frac{\Delta z(z) \cdot c}{H(z)}. \quad (7)$$

The spectral resolution (1.3 Å) and the possible contamination by $Ly\beta$ absorptions prevent us from deriving the typical seperation $\Delta z(z)$ between the absorption lines from the given spectra with sufficient reliability. We therefore use the average $\Delta z(z)$ derived by HLP based on numerous quasar spectra. We have, however, attempted to count the line numbers in the spectra of the two quasars, whenever it appeared possible, in order to derive the $\Delta z(z)$-values directly. They could be considered as approximate lower limits. In this sense we shall use it for calculating the bubble size along the line of sight $R(z)\Delta \chi$ directly as approximate lower limit. The values for the present-epoch are then obtained by multiplication with $(1 + z)$. The values of $\Delta z(z)$ and $\Delta z(z)$ are given in Tab. 1.

Here we use four representative models given in Tab. 2. The calculated separations $d_0$ are given in Tab. 3 for spectrum (A) ($z_{abs} = 2.380$, given in Fig. 1) and in Tab. 4 of spectrum (B) ($z_{abs} = 2.853$, given in Fig. 2). One can see, that only the BN-P-model gives a sufficient agreement between the present diameters $d_0$ and $d_{void} = \Delta z(0) \cdot c/H_0$, where $\Delta z(0) = 0.009 \pm 0.002$, see deLapparent, Geller and Huchra (1986).

The other three models, however, can not explain the wide absorption features in the bubble wall interpretation. This is evident in particular if we compare the bubble sizes along the line of sight $R_0 \cdot \Delta \chi$ or $R_0 \cdot \Delta \chi$ (column 3 and 4) with the Harvard void size $d_{void}$ (column 5) in Tab. 3 and Tab. 4.
Table 3: Calculated values for the four representative models in the case of spectrum (A) 
\(z_{abs} = 2.380\)

| Model  | \(d_0\) Mpc | \(R_0\Delta \chi\) Mpc | \(R_0\Delta \chi\) Mpc | \(d_{\text{void}}\) Mpc |
|--------|--------------|------------------------|------------------------|------------------------|
| E-dS   | 13           | 4.5                    | 6.4                    | 54 ± 12                |
| O-St   | 14           | 5.7                    | 8.2                    | 42 ± 10                |
| Sa-Ta  | 21           | 8.0                    | 11.4                   | 54±12                  |
| BN-P   | 19           | 21.5                   | 30.7                   | 30±7                   |

Table 4: Calculated values for the four representative models in the case of spectrum (B) 
\(z_{abs} = 2.853\)

| Model  | \(d_0\) Mpc | \(R_0\Delta \chi\) Mpc | \(R_0\Delta \chi\) Mpc | \(d_{\text{void}}\) Mpc |
|--------|--------------|------------------------|------------------------|------------------------|
| E-dS   | 14           | 4.3                    | 5.2                    | 54±12                  |
| O-St   | 15           | 5.5                    | 6.7                    | 42±10                  |
| Sa-Ta  | 24           | 7.8                    | 9.5                    | 54±12                  |
| BN-P   | 22           | 24.8                   | 30.1                   | 30±7                   |

3 Conclusions

We have seen, that a very wide absorption feature in quasar spectra can originate, when the line of sight cuts tangentially through a bubble wall in a universe in which a bubble structure expands with the Hubble flow. The wide Ly\(\alpha\) features consist of blends of many lines produced in hydrogen clouds. We have demonstrated this on the quasar pair (2138-4427), (2139-4434). We find a sufficient agreement in closed low density cosmological models, here the BN-P model, derived by Hoell, Liebscher and Priester (1994). Models with euclidean or hyperbolic metric fail to explain the wide absorption lines with the bubble wall approach.

We note that the metal lines (e.g. \(^{16}\)O, see, for example Turnshek et al. (1989)) corresponding to the wide Ly\(\alpha\) features are usually small. This is due at first to their larger atomic weight and second to the finding that only a small portion of the hydrogen clouds are already sufficiently enriched with elements produced by stellar evolution, for example in the inner parts of galaxies.
References

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Figure Captions

**Fig. 1:** Spectrum (A) of quasar (1) and (2) centered at 4110 Å \( (z_{abs} = 2.38) \) taken from Francis and Hewett (1993). Our interpretation of this observation is shown schematically.

**Fig. 2:** The same as in Fig. 1 for spectrum (B) of both quasars centered at 4685 Å \( (z_{abs} = 2.853) \)

**Fig. 3:** The metric distance for the four representative models (see Table 2).