OUTFLOWS IN GALAXIES AND DAMPED LY\textalpha\ SYSTEMS

Céline Péroux\textsuperscript{1}

Abstract

Although quasar absorbers, and in particular Damped Lyman-alpha systems (DLAs) have proven a valuable tool to study the early Universe, their exact nature is so far poorly constrained. It has been suggested that outflows in galaxies might account for at least part of the DLA population. Observational evidences and models in support of this hypothesis are reviewed, including recent observations of Lyman Break Galaxies (LBGs). Observational counter-arguments and theoretical limitations are also given. Finally, implications of such a model for the environment of galaxies at high-redshifts are discussed.

1 Quasar Absorbers

Several observational techniques allow for the detection of high-redshift galaxies, e.g. the Lyman-Break method, narrow band Ly\textalpha\ imaging, and selection in other wavebands (radio, sub-mm, etc). A complementary method is the detection of systems in absorption in the spectra of background quasars. Since quasar are now detected to $z \sim 6$ (Fan et al. 2001), quasar absorbers can be detected at very early epochs. The quasar absorbers with the highest H I column density are called Damped Lyman-alpha systems (hereafter DLAs) since their line shapes show evidences for damping wings (Wolfe et al. 1986). These systems have proven powerful tools to study the abundances of high-redshift objects (e.g. Péroux et al. 2002a), in terms of H I column density, ionic and molecular content (e.g. P. Petitjean’s contribution to these proceedings). The detection of absorbers differs from more traditional techniques since it is independent of the morphology and luminosity of these systems. DLAs in particular can be used to trace the neutral gas (Péroux et al. 2001 and reference herein) and metal abundances over cosmological scales (e.g. Péroux et al. 2002b). The limitations of studying galaxies using absorbers

\textsuperscript{1} Osservatorio Astronomico, Via Tiepolo, Trieste, Italia
is that only one-dimensional information is available (with the exception of the growing body of transversal informations now available from quasars groups and lensed system, e.g. B. Aracil’s contribution to these proceedings) and the fact that their exact nature is unknown.

Several hypotheses have been proposed to explain DLAs, but imaging of low redshift systems has shown that a variety of objects are at the origin of the absorbers. Therefore the main questions are: which population of galaxies dominates DLAs at high redshift? How does this evolve with cosmological time? Several approaches have been suggested to answer these questions: i) comparing observations with models of galaxy evolution (e.g. Boissier, Péroux & Pettini, 2002); ii) direct imaging of the systems giving rise to DLAs (e.g. Le Brun et al. 1997); iii) comparison with other types of high-redshift galaxies (e.g. Bouché & Lowenthal 2000). It is the later which is described here.

2 Lyman-Break Galaxies

Lyman-Break Galaxies (hereafter LBG) are selected using deep imaging in 3 bands. This technique is particularly efficient to select star forming galaxies at $z > 2.5$. Several hundreds of these galaxies have been found at $z \sim 3$ (Steidel et al. 1999). Their star formation rate is typically between $1-100 \, M_\odot \, yr^{-1}$ and their metallicities range from $1/10$ to $1/2$ solar. In addition, the velocity offsets of the interstellar absorption lines and of the Ly$\alpha$ emission line relative to $[O \, iii]$ and H$\beta$ indicate that many of these objects possess high velocity outflows ($100-1000 \, km \, s^{-1}$) (Pettini et al. 2001). Such winds are important: they might play a role in the feedback process required to regulate star formation, they might be at the origin of metal pollution of the interstellar medium (Ferrara et al. 2000), and could create cavities through which photons would escape and reionise the Universe at high-redshift (Pettini et al. 2001). Indeed, recent simulations shown that outflows might be responsible for metal pollution without destructing the filaments producing the Lyman-\alpha forest (Theuns et al. 2002).

One particular LBG, MS 1512-cB58 ($z = 2.72$) which has its flux amplified by gravitational lensing due to a foreground cluster, has been studied in details (Pettini et al. 2000 & 2002). Pettini et al. (2002) derived the chemical content of MS 1512-cB58 using 48 UV lines. They deduce that the metal enrichment took place some 300 Myr ago, indicating that the galaxy is rapidly transforming its baryonic mass in stars (probably leading to the formation of a galactic bulge or an elliptical). The Ly$\alpha$ absorption of that galaxy can be fitted with a damping profile with a hydrogen column density $N(HI) = 7.5 \times 10^{20} \, cm^{-2}$ (Pettini et al. 2002), revealing an asymmetric emission line. The complex structure of the Ly$\alpha$ line is interpreted as the signature of photons scattered by outflowing material.
3 Are Outflows Responsible for DLAs?

3.1 Evidence in Favour

Using geometrical arguments, Schaye (2001) has shown that at $z \sim 3$ the observed number density of DLAs ($dN/dz = 0.20$) can be explained by the comoving observed number density of LBGs ($0.016h^3\text{Mpc}^{-3}$) assuming plausible shell’s radius ($19h^{-1}\text{kpc}$) and luminosity ($\ll L^*$). Other observational evidences have been provided by Rauch et al. (2002) who have studied Mg ii absorbers along three adjacent lines of sight and find that the signature of these systems is consistent with such an expanding shell.

Other authors have directly compared the properties of galaxies with those of DLAs. Heckman et al. (2001) used Na i lines to study local near-IR bright galaxies. From the Na i equivalent width, they deduce a column density of about $\sim 10^{21}\text{cm}^{-2}$ in the outflows. Therefore, if a luminous quasar were located behind such line of sight, its spectrum would contain a damping profile as well as low-ionisation metals spanning velocity range up to few km s$^{-1}$, similar to what is observed in high redshift DLAs. Moller et al. (2002) compared the properties of 3 spectroscopically confirmed HST-imaged DLAs ($z_{\text{abs}} = 1.92, 2.81 & 3.15$) with those of LBGs. They find that the half-light radius, the radial profile, the optical-to-near-IR colour, the morphology, and the Ly$\alpha$ emission equivalent width and velocity structure match well those of LBGs. They thus conclude that a least part of the DLAs could be linked to LBGs.

3.2 Evidence Against

Nevertheless, three important observational characteristics appear extremely different in DLAs and in LBGs, as pointed by Pettini (2001). These are:

1. an important difference in their inferred star formation rates (around $50 M_\odot$ yr$^{-1}$ for LBGs; less than $10 M_\odot$ yr$^{-1}$ for DLAs)

2. a difference in terms of metallicities (1/3 solar in LBGs; 1/20 solar in DLAs)

3. a difference in the velocity of the outflows (around 500 km s$^{-1}$ for LBGs; while less than 200 km s$^{-1}$ for DLAs)

It has been suggested (Theuns et al. 2001) that LBGs are more metal rich and thus more dusty, occulting their presence along the line of sight to a background quasar. Schaye (2001) also proposed that, for geometrical reasons, DLAs preferentially occur in the external part of the outflows with higher cross-section and where the star formation rate is lower, thus explaining the observed discrepancies. Finally, Pettini (2001) argue that LBGs are quickly transforming their baryonic mass in stars, while DLAs have a slower star formation rate, suggesting that the two populations probe different types of galaxies.
4 Summary

Recent observations have shown that outflows might be common amongst high-redshift galaxies. The nature of quasar absorbers, extensively studied in the past years, is not as yet strongly constrained. It is suggested that at least part of the DLA population is due to the outflows in galaxies, although some evidence seems to disfavour such an hypothesis. Therefore these may have important consequences for regulating star formation, polluting the intergalactic environment with metals and indirectly to the reionisation of the Universe.

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