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Optically identified QSO absorption systems and galaxy evolution

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Appendix: Notes on individual publications

In the following we briefly comment on each paper from which we have compiled data. Numbers of sub-subsections (1) ... 17)) correspond to the identification number (id. no.) in Table 1 and Figures 2 – 4 as well. In particular we discuss some points which are important to our purposes.

1) Lanzetta & Bowen 1990

In their paper entitled *Intermediate redshift galaxy halos: Results from QSO absorption lines* K.M. Lanzetta and D. Bowen list optically identified MgII absorption systems in their TABLE 1 for the purpose to study correlations between equivalent widths of MgII absorption lines and impact parameters. We assume that TABLE 1 in this paper contains all data on optically identified (MgII) absorption systems available up to this time and thus we take it as the starting point for our search for further data in the literature until now. All $m_r(z)$ data listed in TABLE 1 are reported also in later papers and we took them from these more topical sources.

2) Yanny *et al.* 1990

In their paper entitled *Emission–line objects near QSO absorbers. I. Narrow–band imaging and candidate list* B. Yanny, D.G. York and T.B. Williams report on a search for emission–line objects (predominantly from [OII]) in the environment of 8 QSOs with previously known associated MgII absorber systems using narrow–band imaging. Data for 37 objects are given but in 14 out of the 37 cases only lower limits for R magnitudes could be derived from the detection limit.

In a subsequent study (Yanny 1990) 8 of the 37 absorber candidates in 4 QSO fields have been investigated using long–slit spectroscopy confirming their incidence with the absorber redshifts ($0.4 \leq z_{\rm abs} \leq 0.7$). It turns out that all 8 spectroscopically studied objects are absorbers, i.e. $z_{\rm gal} = z_{\rm abs}$.

3) Bergeron & Boissé 1991

In their paper entitled *A sample of galaxies giving rise to* MgII *quasar absorption systems* J. Bergeron and P. Boissé present imaging and spectroscopic observations aimed at detecting intervening galaxies responsible for low redshift ($z \sim 0.5$) MgII absorption line systems in quasar spectra. This paper represents a pioneering study on optical identifications of absorber systems confirming the intervening galaxy hypothesis. 14 confirmed identifications, 4 candidates and 3 “negative cases”, i.e. galaxies closest to the QSO line of sight but without any absorption system at galaxy redshift are presented. The authors give luminosities of galaxies as well as sizes and shapes of the absorbing regions.

We include the 14 spectroscopically confirmed absorber galaxies and 4 candidates in Figure 2 and 4. The three “negative cases” from their Table 6 are included as “candidates” as well.

4) Bechtold & Ellingson 1992

In their paper entitled MgII *absorption by previously known galaxies at* $z \approx 0.5$ J. Bechtold and E. Ellingson report on an investigation of 9 QSO spectra using the Multiple Mirror Telescope to search for MgII absorption from intervening galaxies. This is the reverse procedure: galaxies and their redshifts ($0.2 \leq z \leq 0.7$) are known from previous studies of the QSO environment and now, the possible absorption systems are searched for. These data are as useful to us as those from studies aimed to find intervening galaxies near QSOs with absorption line systems.

It should be noted that a considerable fraction of the data comes from galaxies in high density environment, i.e. galaxy clusters. This is reflected by the fact that many redshift values are close each other. In the cases where $z_{\rm gal} \neq z_{\rm QSO}$ is not confirmed by spectroscopy a physical influence on the galaxies from the quasar cannot be excluded.

In their TABLE 4, the authors give r(z) data for 21 galaxies in the environment of 9 quasars. Photometric data are taken from Green & Yee (1984), Yee, Green & Stockman (1986), and unpublished images from Yee. Spectroscopy is from Ellingson, Green & Yee (1991) and Ellingson & Yee (1992). Only two MgII absorption–line systems are identified with corresponding galaxy redshifts. Consequently most of the r(z) data from this paper do not belong to optically identified QSO absorbers and consequently they are not included to our compilation.

In TABLE 5 of their paper the authors list previously known identified absorber galaxies (most from Bergeron & Boissé 1991) and some new candidates. The latter ones are included in our compilation.

5) Bergeron *et al.* 1992

In their paper entitled *Discovery of $z \sim 1$ galaxies causing quasar absorption lines* J. Bergeron, S. Christiani and P.A. Shaver report on the first identification of intervening galaxies responsible for four MgII absorption–line systems at redshifts of about 1 in two QSO fields. There are three candidates in each field assumed to be responsible for the MgII doublets in the QSO spectra. Five galaxy redshifts have been measured showing incidence with three of the four absorption line redshifts. Two galaxies are not at any absorber redshift and one galaxy without measured redshift is assumed to be at the remaining absorption redshift. The two confirmed non–absorbers are marked with open bold line symbols in Figure 2.

6) Nelson & Malkan 1992

In their paper entitled *A photometric search for* [OII] *lines in* MgII *quasar absorption systems* B.O. Nelson and M.A. Malkan report on results obtained by narrow– and broad–band photometry of 336 objects near the line of sight to 22 quasars showing MgII absorption lines in their spectra. The attention is focused to [OII] emission–line objects which are claimed to undergo enhanced star formation and these galaxies are searched for using narrow–band photometry. Gunn g magnitudes for 52 objects are given in their TABLE 4. The corresponding absorber redshift can be derived from their list of observed QSO fields in TABLE 1. Some quasars have not been imaged in the Gunn g bandpass but e.g in "Spinrad Red". These data are not included and finally 43 g magnitudes remain in our compilation.

In 6 cases redshifts of identified galaxies had previously been measured spectroscopically by other authors (Bergeron & Boissé 1991, Bergeron *et al.* 1988, Christiani 1987, Miller *et al.* 1987, see also references in TABLE 4 of Nelson & Malkan). In most other cases (without spectroscopy) more than one candidate is given for each absorber redshift. They are all included in our compilation. In five cases we are able to adopt r magnitudes from the papers mentioned to derive (g-r) colors. These colors are used in Figure 3b.

7) Steidel & Dickinson 1992

In their paper entitled *The unusual field of the quasar 3C 336: Identification of three foreground* MgII *absorbing galaxies* C.C. Steidel and M. Dickinson present imaging and spectroscopic observations of the field of 3C 336 ($z_{\rm em} = 0.927$) which reveals at least 3 MgII absorption systems with $z_{\rm abs} < z_{\rm em}$. Data for 6 galaxies with spectroscopically measured redshifts and $\mathcal{R}$ ($\lambda = 6930$, $\Delta\lambda = 1500$), g ($\lambda = 4900$ and $\Delta\lambda = 700$) and i ($\lambda = 8000$ and $\Delta\lambda = 1450$) AB magnitudes are given in their TABLE 1. 3 galaxies seem to be the absorbing galaxies. 3 further objects with $\rm z_{gal} \neq z_{abs}$ are marked with open bold line symbols in Figure 2 and 4 as usual.

In this paper Steidel & Dickinson give apparent AB–magnitudes $\mathcal{R}_{\rm AB}$ (6930/1500) together with $(g{-}\mathcal{R})_{\rm AB}$ and $(\mathcal{R}{-}i)_{\rm AB}$ colors. Because we restrict our comparison of observations with models to Thuan & Gunn and Johnson bandpasses as discussed in §2.2 we cannot take the AB colors from Steidel & Dickinson (1992) into consideration.

8) Steidel & Hamilton 1992

In their paper entitled *Deep imaging of high redshift QSO fields below the Lyman limit. I. The field of Q0000-263 and galaxies at $z = 3.4$* C.C. Steidel and D. Hamilton present results for the first field completed in a new survey involving very deep imaging of the fields of high redshift quasars with optically thick Lyman limit absorption systems. In their TABLE 1 the authors list U_n, G and $\mathcal{R}$ magnitudes for 33 objects within 30" of Q0000-263 ($z_{\rm em} = 4.106$). The moderately under–luminous galaxy at $z = 0.438$ was previously suggested to be at $z = 3.408$ (Turnshek *et al.* 1991), but now Steidel & Hamilton suggest that the line previously identified as Lyman α is probably [OII]. The $z = 0.438$ and $\mathcal{R} = 22.5$ galaxy is added to our list and is an interesting case for a late type absorber. Another galaxy is assumed to be a candidate for the DLA system at $z = 3.39$.

9) Yanny & York 1992

In their paper entitled *Emission–line objects near Quasi–stellar object absorbers. III. Clustering and colors of moderate–redshift* HII *regions* B. Yanny and D.G. York report on three deep narrow–band images corresponding to [OII] at the redshift of known QSO absorption–line systems which show evidence for enhanced star formation occurring in groups of giant HII regions spread over 100 – 300 h^{-1}kpc. This paper extends their earlier investigation (Yanny *et al.* 1990, cf. 3)). For the three QSOs under study the authors list all galaxies in the field. From these tables we picked up 7 absorber candidates as suggested by the authors.

10) Drinkwater *et al.* 1993

In their paper entitled *On the nature of* MgII *absorption line systems in quasars* M.J. Drinkwater, R.L. Webster and P.A. Thomas present the results of a large R–band imaging survey of 71 bright (m_v < 18) quasars revealing MgII absorption lines in their spectra. For 21 QSO fields possible absorber candidates are found, however, no galaxy redshifts have been measured. A statistical approach is used to identify galaxies likely to be associated with the absorption systems. In TABLE 5 and 7 of their paper the authors give z_{abs} and R magnitudes for possible absorber candidates. For some galaxies two possible z_{abs} are given.

11) Le Brun *et al.* 1993

In their paper entitled *A deep imaging survey of fields around quasars with* $z < 1.2$ MgII *absorption systems* V. Le Brun, J. Bergeron, P. Boissé and C. Christian report on an imaging survey of 12 fields around quasars with 17 MgII absorption systems in the r band at the CFH telescope. They give a list (Table 3. in their paper) of altogether 19 absorber candidates with 6 galaxy redshifts being spectroscopically confirmed. It turned out that two of them are not absorber galaxies ($z_{gal} \neq z_{abs}$). The authors emphasize that some of the candidates are rather uncertain.

12) Spinrad *et al.* 1993

In their paper entitled *Hydrogen and metal absorption lines in PKS0405–123 from the halos of low redshift galaxies* H. Spinrad, A.V. Filippenko, H.K.C. Yee, E. Ellingson, J.C. Blades, J.N. Bahcall, B.T. Jannuzi, J. Bechtold and A. Dobrzycki report on HST ultraviolet and ground–based optical spectra of the bright quasar PKS 0405–123 which has two absorption–line systems. Spectroscopically measured redshifts and Gunn g and r magnitudes are given for 9 galaxies. One redshift is very uncertain. The values of galaxy redshifts are grouped near two different absorber redshifts ($z_1 = 0.1670$ and $z_2 = 0.3516$) indicating small groups of galaxies or outskirts of clusters of galaxies.

In the z_2 system only Lyα absorption is observed whereas in the z_1 system metal lines (CIV and probably MgII) are detected as well.

The authors give r–magnitudes and (g–r) colors (Thuan & Gunn (1976) g and r) in their TABLE 1 and thus g–magnitudes can be derived.

13) Steidel *et al.* 1993

In their paper entitled *A dwarf galaxy near the sight line to PKS 0454+0356: A fading "faint blue galaxy"?* C.C. Steidel, M. Dickinson and D.V. Bowen report on the discovery of a dwarf galaxy at $z = 0.072$ which is only 4" in projection from the line of sight to the quasar . Fortuitously the spectrum of a second galaxy was recorded simultaneously from several moderately strong emission lines revealing $z \approx 0.2$. Here we are not interested in dwarf galaxies and therefore only data from the latter object are included in our compilation. By now no appropriate absorption lines are found in the QSO spectrum. Future observations (using HST) in search of MgII resonance lines would be very meaningful for the study of the gas associated with an intrinsically faint, star–forming dwarf galaxy.

14) Aragon-Salamanca *et al.* **1994**

In their paper entitled *The nature of distant galaxies producing multiple* CIV *absorption lines in the spectra of high-redshift quasars* A. Aragon-Salamanca, R.S. Ellis, J.-M. Schwartzenberg and J. Bergeron demonstrate that luminous L* galaxies up to $z \simeq 2$ which cause CIV absorption in the spectra of quasars can be detected by deep infrared (K band) imaging.

The authors use a statistical approach to identify the absorbers from photometry alone because at these faint limits spectroscopy is very difficult. A sample of 11 QSOs with clustered CIV absorption line systems is investigated. In some cases, several suitable complexes at different $z_{\rm abs}$ are present within a single QSO spectrum. As the redshift of possible absorbers we take from their TABLE 1 the mean values $\langle z_{abs}^{\rm CIV} \rangle$ weighted by the appropriate rest–frame equivalent width for each system.

A subset of the QSO fields has also been imaged in R and I. Thus, 19 K magnitudes and 9 $(R-K)$ colors are given in TABLE 2 of the paper. From these data we obtain R magnitudes as a function of redshift for 9 absorber candidates.

15) Ellingson *et al.* **1994**

In their paper entitled *Metal–line absorption at* $z_{\rm abs} \sim z_{\rm em}$ *from associated galaxies* E. Ellingson, H.K.C. Yee, J. Bechtold and A. Dobrzycki report on deep optical imaging and limited spectroscopy of 10 fields around quasars with $0.15 < z_{\rm em} < 0.65$ revealing CIV absorption predominantly at the emission redshift of the QSO. The aim of their investigation is not the optical identification of absorber systems but the study of the interaction of quasars with galaxies from the surrounding clusters. Some of their data, compiled in TABLE 2. are also useful to our purposes. We select 7 candidates from their list, one galaxy with spectroscopically confirmed redshift.

We want to caution that the rich cluster environment and the proximity to the quasars might be influential on the evolution of these galaxies.

16) Steidel *et al.* **1994a**

In their paper entitled *The* $z = 0.8596$ *damped lyman alpha absorbing galaxy toward PKS 0454+0356* C.C. Steidel, D.V. Bowen, J.C. Blades and M. Dickinson present HST and ground–based data on a new DLA system at $z_{\rm abs} = 0.8596$ along the line of sight to PKS 0454+0356. Optical images were obtained as part of a large survey for galaxies producing MgII absorption line systems, including a very deep $\mathcal{R}$ (6930/1500) image from which we take the $\mathcal{R}$ magnitude as a function of redshift for this galaxy. The authors only gave a faint limit ($K > 20.5$) for the K magnitude.

17) Steidel *et al.* **1994b**

In their paper entitled *Imaging of two damped lyman alpha absorbers at intermediate redshift* C.C. Steidel, M. Pettini, M. Dickinson and S.E. Persson report on observing the fields of the QSOs 3C 286 and PKS 1229–021 in the I and K_s bands. Under good seeing conditions they resolve faint galaxy images close to the QSO sight–lines. We adopt I and K magnitudes as a function of redshift for three absorber candidates from this paper.