Is the Probability of Occurrence of Absorption Lines in QSOs a Function of Redshift?

#14

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It has been noted[1,2,3] that the occurrence of absorption lines in quasi-stellar objects appears to increase with increasing redshift. From this, the conclusion has been drawn that QSOs with high redshift have intrinsically different properties than those of low-redshift QSOs. McCrea[2], for example, finds that 53% of the QSOs with emission redshift, $z_{em} > 1.8$, have absorption lines; 18% have them between $1.0 < z_{em} < 1.8$; and only 8% have them for $z_{em} < 1.0$. However, this correlation has been found using all the observed absorption lines, and one might ask if the correlation is merely the result of stronger lines being brought into the observable spectrum as the redshift increases. To properly test for such a correlation one ought to use a single line, or else allow for the difference in strengths of lines in different parts of the spectrum.

In the first case, the C IV λ 1549 resonance line was chosen, and evidence of a correlation between its occurrence and z was sought. This line was used because it is the absorption line which has been observed in the most QSOs and because it is available over a relatively large range of z. Ideally, we would like to test whether there is a correlation between the equivalent width of the absorption lines and the emission redshift. Data on equivalent widths are not available however, and we have therefore assigned the value 1.0 to a quasar in which λ 1549 is seen in absorption and the value 0.0 if it is not reported as being present. The minimum equivalent width necessary for detection is, of course, dependent upon the equipment used, but this is not significant as long as the distribution in z is similar for all observers. The limits on z_{em} for the sample must be chosen so that for any observer the minimum detectable equivalent width is substantially independent of z for z anywhere between these limits. A variety of effects all tend to cause the far ultraviolet to be underexposed, but we are probably quite safe in adopting $z > z_{min} = 1.4$, corresponding for the C IV line, to $\lambda > 3720$ Å. This may be unduly pessimistic and we have also considered cutoffs of $z_{min} = 1.3$ ($\lambda = 3565$) and $z_{min} = 1.2$ ($\lambda = 3410$).

Most of the data used has been tabulated by Burbidge and Burbidge[1], who list 102 QSOs with redshifts. The identity of one object in their table, PKS 0056-17, is open to question[4], and we therefore have omitted it. To this list we have added 13 QSOs observed by Braccesi, Lynds and Sandage[5], seven by Lynds and Wills[6], and one by Schmidt and Olsen.[7]

The sample with $z_{min} = 1.4$ consisted of 33 objects which have been reported with $z_{em} \geq 1.4$; 13 of these have C IV in absorption. The correlation coefficient for the occurrence of C IV absorption vs. z was computed by means of the standard formula,

$$r = \frac{\sum_{i=1}^{33} (z_i - \bar{z})\ (p_i - \bar{p})}{\sqrt{\sum_{i=1}^{33} (z_i - \bar{z})^2 \ \sum_{i=1}^{33} (p_i - \bar{p})^2}}$$

(where P_i is the quantity assigned a value of one or zero), and was found to be 0.060 for this sample. One thousand sets of 13 objects randomly distributed among a total of 33 objects, having the same values of z as the 33 QSOs, were then generated and the correlation coefficient calculated for each set. It was found that in 75% of these cases a correlation coefficient greater than 0.060 resulted purely by chance from such a random distribution. The use of Student's t distribution is not rigorously justified in such a situation but showed that for $z \geq 1.4$ the correlation coefficient is zero to a 75% level of confidence. The samples with $z_{min} = 1.3$ and $z_{min} = 1.2$ contained 13 C IV absorptions out of 36 QSOs in the former and 14 out of 38 in the latter case. The correlation coefficients and confidence levels were .152, 40% and .108, 50%, respectively.

It therefore appears that no correlation between the occurrence of absorption lines and redshift is indicated by the present sample of QSOs using the C IV line alone.

As a second test we have used the Mg II λ 2798 and Si II λ 1265, 1816 lines to compare the presence of absorption lines at low and high z. Magnesium and silicon have about the same cosmic abundance, and the ionization poetentials are 15.03 eV for Mg II and 16.34 eV for Si II. Moreover, the continuum f values differ by only a factor of two for these ions, and the f values for the three lines are nearly identical. The higher ionization potentials differ considerably, however, and if the ionization is moderate, there might be considerably more Mg II than Si II. It would be of interest to check the relative strengths of λ 2798 and λ 1816 when either of these appear in absorption and the other is accessible to an observer. The QSOs 3C 309.1 and PKS 0237-23 are candidates for such a test. A qualitative estimate of the line strengths for the latter object shows λ 2798 to be somewhat stronger than λ 1816.[8] In the sample used for the C IV test there are five QSOs with Si IV in absorption and two with Si II. From this and the fact that the Si II lines are weaker than the Si IV lines we assume the ratio of Si IV to Si II to be between 2.5 and 25. Using a power law with spectral index, $\alpha = -1$, for the ionizing radiation field, rough calculations of the ionization show that the amounts of Si II and Mg II are nearly the same. Thus we shall assume that Mg II λ 2798 and Si II λ 1265, λ 1816 shall all be approximately of equal strength in QSOs. If there is no dependence on z, it would then be expected that Mg II and Si II would be seen in absorption about equally often. They should be seen less often than C IV since carbon is more abundant by a factor of 10 and because most of the Si and Mg is ionized beyond the 2nd stage. Taking $.3 < z < .8$, corresponding, for Mg II, to a high wavelength plate cutoff at λ = 5000 Å and a low wavelength cutoff at λ = 3640 Å, we find that three of 49 objects have Mg II in absorption. Increasing the high wavelength cutoff to 6700 Å ($z_{high} = 1.4$) gives four of 70. Thus about 6% of the low z QSOs have Mg II absorption lines. Since at least one of the two Si II lines is in the proper wavelength region whenever C IV is, we may use the same sample for Si II as for the C IV test. Si II absorption is found in two of 33 and two of 38 high z QSOs, for the samples with $z_{min} = 1.4$ and 1.2 respectively. This is also about 6%. The statistics are of course too small to establish that there is definitely no correlation. Our point is simply that the Mg II - Si II comparison demonstrates that there is nothing particularly anomalous about the small number of absorption lines in QSOs of small z.

Our results here lead us to the conclusion that there is no evidence that the true occurrence of absorption lines in quasi-stellar objects is a function of redshift, and that the higher percentage of absorption line objects at high z is probably an effect due simply to the limited region of the spectrum which is accessible to observation.

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Ray J. Weyman
Richard C. Wilcox

Steward Observatory
University of Arizona
Tucson, Arizona

1. Burbidge, G. R. and Burbidge, E. M., Quasi-Stellar Objects, (Freeman, San Francisco and London, 1967).

2. McCrea, W. H., Nature, 218, 257, (1968).

3. Burbidge, E. M., Tucson Conference on Seyfert Galaxies and Related Objects, A. J., (in press).

4. Lynds, C.R., (private communication).

5. Braccessi, A., Lynds, C. R., and Sandage, A., Ap. J., 152, L105, (1968).

6. Lynds, C. R. and Wills, D., Ap. J., (July, 1968).

7. Schmidt, M. and Olsen, E. T., A.A.S. Meeting, (April, 1968).

8. Burbidge, E. M., Lynds, C. R., and Stockton, A. N., Ap. J., 152, 1077, (1968).