ABSORPTION STRUCTURE IN THE BL LAC OBJECT 0215+015 AT 20 km s^{-1} RESOLUTION

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The origin of the narrow metal absorption lines in the spectra of QSOs remains uncertain despite the large amount of high-quality data obtained at high resolution over the past decade. Recently, statistical tests of a uniform sample of C IV absorption systems have shown that their redshift distribution is consistent with the view that these lines arise in randomly distributed intervening galaxies in a Friedmann Universe (Young, Sargent and Boksenberg 1982, hereafter YSB). In a complementary approach we consider in detail the physical properties of the absorbing material in cases of particular interest. We have chosen the high-redshift BL Lac object 0215+015 (Blades et al. 1982, hereafter BHMP) for detailed spectroscopic study because it is currently in a bright phase (V ~ 14.5 - 16.5) and because it has several strong absorption systems with differing ionization structure. From our medium-resolution spectra of 0215+015 (BHMP) it appears that the density of C IV systems per unit redshift in this object is somewhat higher than, but not inconsistent with, the average density in the YSB sample.

Following the high-resolution (0.65 Å FWHM) observations obtained by BHMP in 1979 and 1980, we have now reobserved the C IV systems at z_a = 1.549 and 1.649 at a resolution of 0.27 Å FWHM (20 km s^{-1}). These observations were made in 1981 using the IPCS and RGO spectrograph on the 3.9m Anglo-Australian Telescope. A red-blazed 1200 line mm^{-1} grating was used in second order to provide a dispersion of 5 Å mm^{-1} with the 82cm camera. The z_a = 1.549 C IV system is shown in Figure 1 with the corresponding "low-resolution" (1.5 Å FWHM) profile superimposed. It is interesting to note that what appears as a simple C IV doublet at 1.5 Å resolution breaks up into many narrow components at 0.27 Å. There is also a clear detection of Galactic Ca II K absorption with W_λ = 0.12 Å. The z_a = 1.649 C IV system shows even greater complexity. We have

G. O. Abell and G. Chincarini (eds.), Early Evolution of the Universe and Its Present Structure, 359–364.

https://doi.org/10.1017/S0074180900039322 Published online by Cambridge University Press

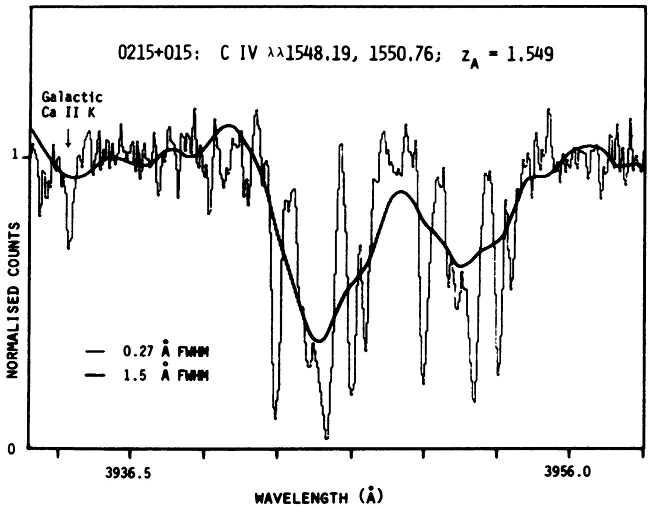

Figure 1. C IV absorption in 0215+015 at high and "low" resolution.

applied a model-fitting procedure to the profiles to determine the absorption parameters of individual clouds. Since there is only minimal blending in the profiles at this very high resolution, the velocity dispersions and column densities are much better defined than is usually the case. For the $z_a = 1.649$ system we fit 9 components over a velocity range of 910 km s^{-1} with *b* values from 8 to 25 km s^{-1} and column densities N ranging from 1 to 13 x 10^{13} cm^{-2}. For the $z_a = 1.549$ system there are 7 components spread over 300 km s^{-1} with *b* ranging from 6 to 15 km s^{-1} and N from 3 to 20 x 10^{13} cm^{-2}. It is worth noting that for the majority of components the *b* values are now directly comparable with that due to thermal broadening alone for gas at T = 10^5K, namely *b* = 12 km s^{-1}.

Such complex absorption can hardly be due to a single intervening galaxy, but can it be explained by a cluster of galaxies? To test whether this is plausible we have considered as an example the Coma cluster for which the luminosity function and surface density of galaxies versus radial distance are known (Godwin 1976, Abell 1977). By assuming galactic C IV cross-sections implied by the QSO absorption-line statistics of YSB and an average of two C IV velocity components per galaxy, we can reproduce the observed multiplicity of C IV components in 0215+015 with a line of sight passing within 0.3 Mpc(H_0=100 km s^{-1} Mpc^{-1}, $q_0 = 0$) of the cluster centre. This estimate only includes galaxies brighter than $M_V = -16.9$ and the impact parameter could be larger if fainter galaxies are considered. The likelihood of two such encounters with a rich cluster (corresponding to $z_a = 1.549$ and 1.649) is difficult to assess because the distribution of matter at these redshifts is not known. On the other hand, there are serious difficulties with interpreting these complex C IV systems as due to material ejected by the BL Lac object. The redshift of 0215+015 is likely to be of order 1.7, based on

https://doi.org/10.1017/S0074180900039322 Published online by Cambridge University Press

the highest absorption redshift identified (z_a = 1.719) and the lack of a Ly α forest (Blades, Hunstead, Murdoch and Pettini, in preparation). Thus, ejection velocities ≳ 5000 and 16000 km s^{-1} are required for the 1.649 and 1.549 systems, respectively. Current models for the intrinsic formation of narrow absorption-line systems in QSOs (Falle et al. 1981) cannot at present accommodate such large ejection velocities.

As part of the programme to obtain high-resolution spectra of 0215+015 we have also observed ions from the rich mixed-ionization system at z_a = 1.345 with resolution of 20 - 30 km s^{-1} FWHM. In BHMP it was pointed out that the derived ion column densities matched very closely those observed in Galactic halo sight-lines, making this system a highly plausible candidate for an intervening galaxy. At high resolution the line profiles are complex with at least four components spanning 250 km s^{-1}. The pair of lines Fe II λλ 2586, 2600 was observed on 1981 Nov 6.7 UT and again on 1981 Dec 1.5 in order to improve the signal to noise ratio. Clear differences in the absorption profiles are apparent when the spectra are superimposed, indicating substantial changes in the column density of some components. The two spectra are shown in Figure 2(a). Since changes in absorption structure on such a short time-scale (11 days at z_a = 1.345) are completely unexpected, a third spectrum of the same region was obtained on 1982 Jul 16.8. This spectrum is shown in Figure 2(b) superimposed on the 1981 Dec 1.5 spectrum and again there has been a clear change. As an analogous change is also seen in Fe II λ2586, there can be little doubt that the variations are real. Since this system is unlikely to be intrinsic (ejection velocity ~ 40,000 km s^{-1}) we have explored some of the more obvious mechanisms for producing variations. Using typical sizes for interstellar clouds in the Galaxy (0.1 - 10 pc), it is impossible to explain the variations by transverse motion of either the source or the absorber, unless by chance the line of sight has intersected a transient event in the absorber, such as a supernova.

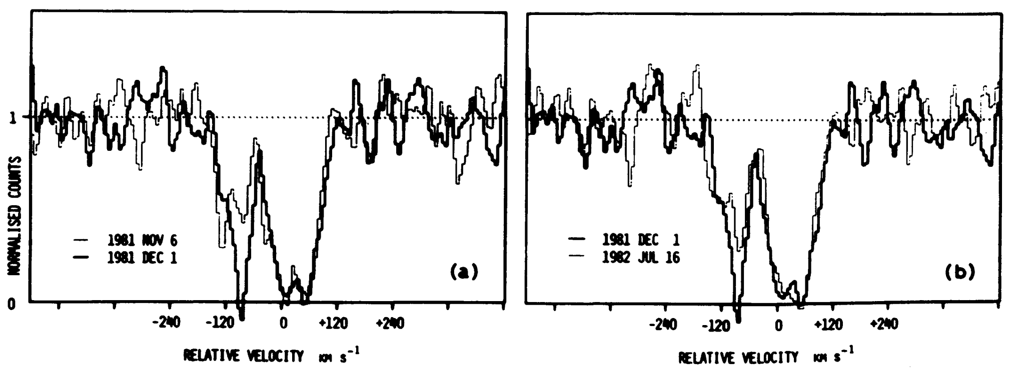

Figure 2. Time variation in the Fe II λ2600 absorption profile in the z_a = 1.345 system; the resolution at each epoch was 27 km s^{-1} FWHM (after smoothing with a gaussian of 10 km s^{-1} FWHM).

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We are led therefore to a scenario in which the source is composed of several components of varying brightness and the absorption variability arises from the integrated effect of multiple sight lines through the absorbing galaxy or galaxies. The multiple source components may be intrinsic to the BL Lac object or alternatively may be gravitational lens images, perhaps formed by one of the absorption regions detected. In the latter case, the known variations in the BL Lac object combined with path differences through the lens galaxy will lead naturally to non-coherent variations in the images. It should be possible to test this hypothesis using VLBI mapping and by looking for correlations between the apparent magnitude of 0215+015 and the characteristics of the absorption profile.

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Discussion

Boksenberg: I would like to comment on the observed frequency of multiple heavy element absorption systems seen in QSO and BL Lac spectra. I believe these are much rarer than the literature would lead us to believe. Most published absorption systems have been discovered in low-resolution spectral surveys, when the complex systems, of large equivalent width, are more evident than simple systems. The discovered systems then are studied at high resolution and the complex multiple structure is revealed. An unbiased survey I have begun with Sargent, in which we do not pre-select "interesting" QSOs for study at high resolution, so far suggests that most heavy-element systems in fact are single, not multiple. This is entirely consistent with these being due to intervening galaxies.

Wolfe: Your detection of variations in Fe II line strength in 0215+015 is very exciting. The only other case in which such variability is observed is in the z = 0.5, 21-cm absorption spectrum in another BL Lac object, AO 0235+164 (Wolfe, Davis, and Briggs, 1982, Ap. J., 259, 495). The latter system also exhibits strong Fe II absorption, and I suggest that you look for Fe II variations there. This is important since it is highly unlikely that the 21-cm variations are due to passages of gravitational lenses across the beam because the radio beam diameter is at least $\sim$ 20 pc compared to optical beam sizes of less than $\sim$ one light week. So I believe that the detection of Fe II variations in 0235+164 would eliminate the lens model.

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Hunstead: The H I variability in AO 0235+164 certainly calls for high-resolution optical observations at several epochs.

Baldwin: Are the differences seen between the three observations outside the absorption line to be taken as typical? Some look as large as those visible in the absorption line itself. Are they confined to one of the days?

Hunstead: In general, the continuum fluctuations are consistent with photon statistics. We believe the claimed variation is highly significant, especially in view of the correlated variation seen in the Fe II λ2586 line.

Dressler: The interpretation that the various absorption components occur in intervening galaxies in rich clusters like Coma seems inconsistent with the small velocity spread you find of several hundred km/sec. A typical spread of velocities in a dense cluster is of order 2000 - 3000 km/sec.

Hunstead: We would not necessarily expect a single sight of line intersecting a small number of galaxies to sample the full velocity spread of the cluster.

Wampler: I would like to emphasize the unusual nature of 0215+015. First, in August of 1981 it was approximately 14th magnitude. With a redshift of $z = 1.7$ it would be the brightest known object in the universe if it is at the Hubble distance.

Second, the polarization is very high 20% - 30%. I don't know the effects of gravitational lensing on polarization, but perhaps time delays in the light path or some other effect would give additional constraints on the system.

Peterson: How many photon counts do you have in the continuum bins in each of the three spectra that you used to detect variability?

Hunstead: About 50 counts, with a sky count of about 20.

Schallwich: On your question "Can such absorption arise in intervening clusters of galaxies?" mentioning the Coma cluster, Sholomitskii, Sunyaev, Wielebinski and Schallwich observed a QSO with absorption line systems with the 100-meter radiotelescope to search for hot gas (clusters of galaxies) via the Sunyaev-Zeldovich effect, which adds up on the line of sight.

We could not detect such an effect at λ 6 cm or at λ 2.8 cm on a level of $\Delta T/T \sim 10^{-4}$ (I have a positive detection on this level for the cluster Abell 2218).

So no "Coma clusters" (I mean rich clusters) should be expected to be responsible for the absorption.

Hunstead: This question bears on the general question of the origin of QSO absorption lines and not simply on 0215+015. We put forward the cluster absorption hypothesis simply to see whether it is at all plausible.