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H II REGIONS AND QSO ABSORPTION LINES

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RESUMEN. En este artículo discutimos la posibilidad que las líneas de absorción metálicas en los objetos cuasiestelares se originen en las galaxias que se interponen en la línea de la visual.

ABSTRACT. In this paper we discuss the possibility that metal absorption lines from QSOs originate in star forming regions in intervening galaxies.

Key words: **GALAXIES–HALOES — NEBULAE–H II REGIONS — QUASARS**

I. INTRODUCTION

In the last years, several large-scale surveys have contributed to our understanding of QSO absorption lines (Foltz et al. 1986, Lanzetta et al. 1987, Sargent et al. 1980, 1988, Tytler et al. 1987, Weyman et al. 1978, Young et al. 1982). The observed lines include the so called $Ly\alpha$ forest, which corresponds to $Ly\alpha$ absorption lines observed at wavelengths smaller than the observed $Ly\alpha$ emission line from the QSO, and metal lines. Among these, we find $CIV\lambda1548$, and $\lambda1550$, $CII\lambda1334$, $NV\lambda1238$ and $\lambda1242$, $OI\lambda1302$, $MgII\lambda2795$ and $\lambda2802$, $SiIV\lambda1393$ and $\lambda1402$, $SiIII\lambda1206$, $Si\lambda1260$, $\lambda1596$ and $\lambda1304$, $FeII\lambda1146$, $\lambda1608$ and $\lambda2599$.

For a given QSO, several absorption redshift z_a are found, corresponding to different absorption systems. The relative velocity of an absorption line system with respect to the QSO with redshift z_e, is given by $\beta = [(1+z_e)^2 - (1+z_a)^2]/[(1+z_e)^2 + (1+z_a)^2]$. In general, it is assumed that systems with $\beta > 0.1$ are not ejected from the QSO and correspond to intervening material (Weyman et al. 1979). There is evidence that the $Ly\alpha$ forest is produced by intergalactic clouds and the metal absorption lines by intervening galaxies (Sargent et al. 1988). It is generally assumed that the metal line systems originate in the galactic halo of the intervening galaxies, where the gas is photoionized by the radiation field due to the integrated contribution of the QSOs (Bechtold et al. 1987, Bergeron and Stasinska 1986). Recently, an analysis of high resolution data suggests an analogy with the absorption lines of gas-rich dwarf galaxies, leading to a different origin for the metal absorption lines of QSOs, i.e., they could originate in the star forming regions of the intervening galaxy (York et al. 1986, 1988). In this paper, this possibility is analysed, considering photoionization models for HII regions. The method used to analyse the QSO absorption lines is described in §II. The results are shown and discussed in §III.

II. METHOD OF ANALYSIS

Several photoionization models for HII regions are available in the literature, covering a large range of densities and different spectra of the ionizing radiation (Evans and Dopita 1985, McCall et al. 1985,

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Stasinska 1982). However, in order to study the QSO absorption lines we need the column densities of the different ions at different distances from the central star, which are not available. Thus, we built a grid of models using a photoionization code (see Gruenwald and Viegas-Aldrovandi 1988 and Péquignot 1986), where the calculation of the column density of the ions has been included. We consider a spherically symmetric HII region, divided in several concentric slabs, where the diffuse radiation is treated in the "outward only" approximation. The gas is composed of H, He, C, N, O, Ne, Mg, Si, S, $C\ell$, A and Fe. The coupled equations of ionization and thermal balance are solved for each slab, starting from an inner radius. The calculation stops when hydrogen becomes neutral.

The models were built with a black body spectrum for the ionizing radiation, with temperatures $T/10^3K = 50., 41., 36.5$ and 30.9, characteristic of stars $O4$, $O6$, $O8$ and $B0$, respectively. The hydrogen density is taken to be $n_H = 1., 10., 10^2$ and $10^3 cm^{-3}$ and the chemical abundances vary from the solar values $Z_\odot$ (Grevesse and Anders 1988) to $Z\odot/100$. For each model, the ionic column density as well as the emission line fluxes have been calculated for different lines of sight, corresponding to different distances from the central stars and expressed as a fraction r of the Stromgren radius. The general results of these models, including the emission line fluxes and the column density of several ions, will be published elsewhere (Gruenwald and Viegas, in preparation).

In order to explain the metal absorption lines of QSOs, we assume that the high ionization lines are produced in an HII region of a galaxy lying along the line of sight to the QSO, whereas the neutral interstellar gas can also contribute to the low ionization lines. Thus, the characteristics of the absorbing HII region are obtained from the observed CIV and $SiIV$ absorption lines, using a diagram of the column densities $N(SiIV)$ versus $N(CIV)$. In this diagram, models corresponding to a given type of ionizing star define a "theoretical region". On the other hand, the observed column densities are obtained from the observed equivalent widths of CIV and $SiIV$ absorption lines as a function of the line width (parameter b), using the curve of growth. The observed column densities correspond to a curve on the diagram. The superposition of this curve on a theoretical region defines the characteristics of the absorbing HII region and the value of b. Then, using similar diagrams of $N(X_i)$ versus $N(CIV)$ for other ions (CII, $SiIII$, $SiII$, OI, $FeII$), the agreement between the observed values of $N(X_i)$ and the theoretical ones corresponding to the HII region defined previously is verified.

III. RESULTS

Using the method described above we are analyzing the absorption systems observed by Sargent et al. (1988). We have chosen the systems showing at least CII and $SiII$ absorption lines in addition to those of CIV and $SiIV$. Here, to illustrate the method, we present the results for the system z_a =1.6724 of $Q0237$-233, which in rich in absorption lines.

In Figure 1, the theoretical region is shown for an $O4$ star and for a $B0$ star, for models with $n_H = 10cm^{-3}$. Solid lines correspond to different chemical compositions ranging from $Z_\odot$ (top curve) to $Z_\odot/100$ (bottom curve). Dashed lines, limiting the solid lines, correspond to different lines of sight with $r = 0$ (right side) and $r = 0.7$ (left side). The observed values are plotted with the error bars obtained from the errors listed by Sargent et al. The column densities of CIV and SIV were obtained from the observed equivalent widths of $\lambda1548$ and $\lambda1393$, respectively. The points correspond to $b = 20$, 25, 30, 40, 50, 60, 80 and $100km/s$. For $30 \leq b \leq 40km/s$, the observed points are in the theoretical region, for models with abundance between $Z_\odot/30$ and $Z_\odot/100$, corresponding to $5. \times 10^{14} \leq N(CIV) \lesssim 2 \times 10^{15} cm^{-2}$ and $1.\times^{14} \lesssim N(SIV) \lesssim 2.6\times^{14}$. Thus, assuming $N(CIV)$ in this range, we determine the column densities for other ions using the diagrams $N(X_i)$ versus $N(CIV)$ and compare to the column densities obtained from the observed equivalent widths using $30 \leq b \leq 40km/s$ (Table 1). The observed values listed in Table 1 for CII, $SiII$ and $FeII$ were obtained from the lines $\lambda1334$, $\lambda1526$ and $\lambda1608$ respectively. On the other hand, the lines $SiII\lambda1304$ and $OI\lambda1302$ should have been observed, since their wavelengths are in the observed range but they are not listed by Sargent et al. Using $z_a = 1.6726$, the observed wavelengths for these lines are, respectively 3486Åand 3480Å, and the observed equivalent widths, in the rest frame, calculated from the column densities listed in Table 1, should be $W(1304) \simeq 0.22$ and $W(1302) \simeq 0.30$. A glance at Table 3 of Sargent et al., shows two unidentified lines (No.

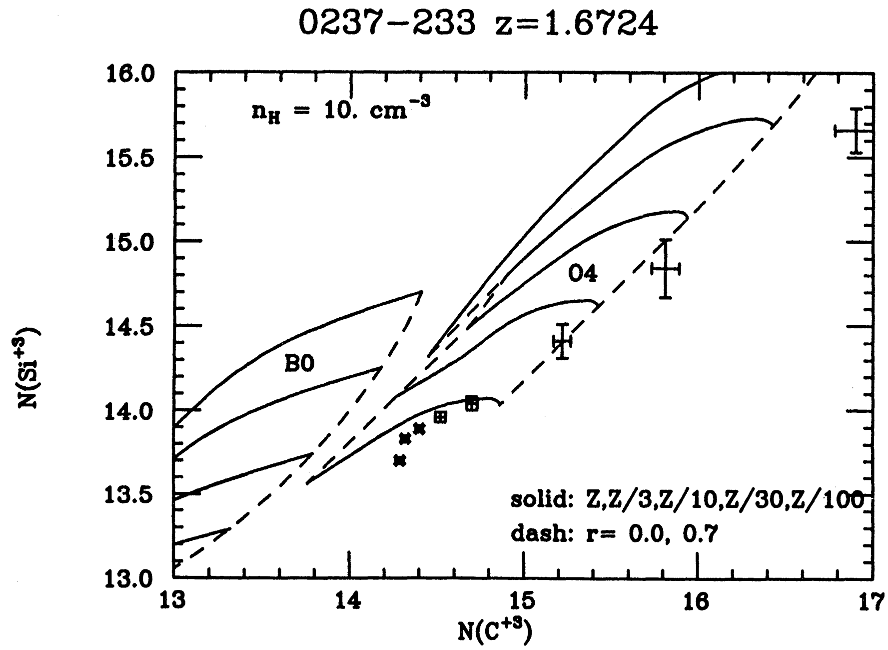

Fig. 1 - $N(SiIV)$ versus $N(CIV)$. Observed results are for the z_a =1.6724 absorption system of Q0237-233.

Table 1 - Log of the column densities

ion	CII	SiII	FeII	OI
Observed	14.99–15.57	14.21–14.34	13.96–14.00	
Model	15.02–15.22	13.82–14.22	13.62–14.00	14.70–14.92

20 and 21) with observed wavelengths λ3480.30Åand λ3486.03 and observed equivalent widths 0.75 and 0.60, leading to equivalent widths in the rest frame of 0.28 and 0.22, respectively. This leads to the conclusion that lines No. 20 and 21 correspond to $OI\lambda1302$ and $SiII\lambda1304$ of the absorption system analysed and reinforces the conclusion that the z_a =1.6724 system of Q0237-233 originates in an HII region of an intervening galaxy, with $n_H \simeq 10cm^{-3}$ and chemical abundances in the range $Z_{\odot}/30 < Z < Z_{\odot}/100$.

The density of the HII Region is limited to $n_H \leq 10cm^{-3}$ by the fact that absorption lines from the excited states of CII and $SiII$ are not observed. Although the results presented in this paper correspond to $n_H = 10cm^{-3}$, models with $n_H = 1cm^{-3}$ do not change the main conclusions, in particular, that the HII region is underabundant in metals. Furthermore, high dispersion observations could find a smaller value of b than those given by our models. However, this could indicate that the absorption lines are produced by a complex of close HII regions lying on the line of sight.

Although absorption systems could also originate in galactic halos photoionized by the background radiation as suggested before, our results indicate that some absorption systems originate in star forming regions. At present, other absorption line systems are being studied and a more detailed analysis will be published elsewhere (Viegas and Gruenwald, in preparation).

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