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ELEMENTAL ABUNDANCES AND HIGH REDSHIFT QUASARS

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RESUMEN

Hemos observado el ultravioleta en el sistema local de reposo para 70 cuasares de alto corrimiento al rojo ($z \geq 3.5$). Los flujos de varias de las líneas en emisión ultravioleta se usaron para estimar la composición química del gas emisor de líneas y para fechar la primera época de formación estelar. Se analizaron los cocientes de línea en el contexto de los modelos de fotoionización más recientes. Hemos estimado una abundancia promedio de $Z/Z_\odot = (5.1 \pm 0.3)$ para el gas emisor de líneas. Suponiendo una escala de tiempo de evolución de ~ 0.5 Gyr, la primera época de formación estelar violenta tiene que haberse dado a $z_f \gtrsim 8$ lo que corresponde a una edad del universo de varios 10^8 años ($\mathrm{H}_o \simeq 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_M \simeq 0.3$, $\Omega_\Lambda \simeq 0.7$). Los cuasares de alto corrimiento al rojo indican que la metalicidad aumenta hacia altas luminosidades.

ABSTRACT

We observed the rest frame ultraviolet for 70 high redshift quasars ($z \geq 3.5$). The fluxes of several ultraviolet emission lines were used to estimate the chemical composition of the line emitting gas and date the first star formation epoch. The line ratios were analysed within the frame work of the most recent photoionization models. We estimated an average abundance of $Z/Z_\odot = (5.1 \pm 0.3)$ of the line emitting gas. Assuming an evolution time scale of ~ 0.5 Gyr, the first violent star formation epoch should start at a redshift of $z_f \gtrsim 8$ corresponding to an age of the universe of several 10^8 yrs ($\mathrm{H}_o \simeq 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_M \simeq 0.3$, $\Omega_\Lambda \simeq 0.7$). The high redshift quasars provide indications for increasing metallicity towards higher luminosities.

Key Words: **QUASARS: EMISSION LINES, ELEMENTAL ABUNDANCES — QUASARS: STAR FORMATION HISTORY**

1. INTRODUCTION AND OBSERVATION

Quasars, among the most luminous objects in the universe, are excellent tools to probe their galactic environment and star formation history up to early epochs. Redshifts of $z \gtrsim 3.5$ correspond to $\sim 10\,\%$ of the current age of the universe ($\mathrm{H}_o = 65\,\mathrm{km\,s^{-1}}$ $\mathrm{Mpc^{-1}}$, $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$; cf., Carroll, Press, & Turner 1992; Carlberg et al. 1999).

The prominent emission-line spectrum of quasars contains valuable information to estimate the chemical composition of the gas (Hamann & Ferland 1999; Hamann et al. 2002). Studies of luminous quasars at high redshift provide evidence for metallicities enhanced up to an order of magnitude compared to solar metallicity (cf., Hamann & Ferland 1992, 1993; Ferland et al. 1996; Korista et al. 1996; Dietrich et al. 1999; Dietrich & Wilhelm-Erkens 2000; Warner et al. 2002). These high metallicities require a violent star formation phase.

We have compiled a sample of 70 high redshift quasars ($3.5 \lesssim z \lesssim 5.0$) to study the chemical enrichment of the gas closely related to quasars (Constantin et al. 2002; Dietrich et al. 1999,2002). The high redshift quasar sample was complemented by observations which were kindly provided by Sargent et al. (1989), Schneider et al. (1991a,b), Storrie-Lombardi et al. (1996), Steidel & Sargent (priv.comm.), and Steidel (priv.comm.).

2. RESULTS AND DISCUSSION

We corrected the quasar spectra for Fe-emission and also for the weak contribution of the Balmer continuum emission. For the Balmer continuum emission we calculated a template spectrum following Grandi (1982). The Fe-emission was given by an Fe-emission template kindly provided by Vestergaard & Wilkes (2001).

We used the C IVλ1549 emission line profile, which was fitted with a broad and narrow Gaussian component, as a template to measure emission line fluxes. The O VIλ1034 emission line flux was corrected for absorption shortward of Lyα assuming a continuum slope of $\alpha = -1.6$ for $\lambda \leq 1200$ Å (Telfer et al. 2002).

We estimated the relative metal abundance based on a detailed study of the metallicity dependence of emission line ratios (Hamann et al. 2002). The most robust indicators, N III]λ1750/O III]λ1663 and N Vλ1240/(O VIλ1034+C IVλ1549), were measured to estimate the metallicity, as well as N III]/C III], N IV]/O III], N IV]/C IV, N V/He II, N V/C IV, and N V/O VI (Dietrich et al. 2002).

In Figure 1 we present the mean metallicity of the

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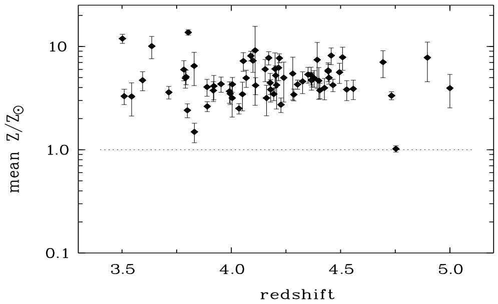

Fig. 1. Mean metallicity of the high-z quasars vs. redshift. The dotted line indicates solar metallicity.

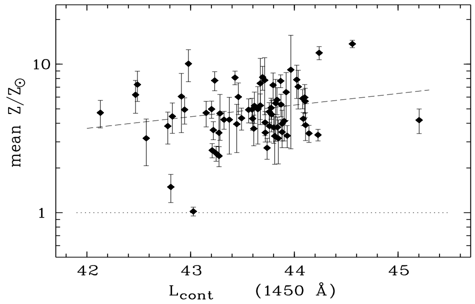

Fig. 2. Mean metallicity of the high-z quasars vs. luminosity. The dotted line indicates solar metallicity.The dashed line is a linear fit to the data.

gas as a function of redshift based on the photoionization calculationss using a segmented power law continuum (Hamann et al. 2002). The mean metallicity for each quasar was calculated using the line ratios given above. The errors indicate the scatter caused by the individual line ratios used for each quasar to derive the metallicity. The mean relative abundance amounts to $Z/Z_\odot = 5.1 \pm 0.3$ for the high redshift quasar sample.

The supersolar metallicities at $z \gtrsim 4$ require previous intense star formation. Stellar populations in galactic nuclei can reach several times solar metallicity on time scales of ~ 0.5 Gyr with a flat IMF (e.g., Hamann & Ferland 1993; Friaça & Terlevich 1998). This places the onset of first star formation at $z \gtrsim 8$, corresponding to a cosmic age of several 10^8 yrs. This result provides further indications for a violent star formation episode and for the close connection of quasar activity and the formation of massive spheroidal systems (e.g., Gnedin & Ostriker 1997; Kauffmann & Haehnelt 2000; Granato et al. 2001).

For each quasar we calculated the intrinsic continuum luminosity $L_{cont}(1450\text{Å})$. In Fig. 2 the average metallicity of the quasars is shown as a function of $L_{cont}(1450\text{Å})$. A weak trend of increasing $Z/Z_\odot$ towards higher luminosity is visible. Similar to the mass–metallicity relation of the spheroidal component of galaxies, Figure 2 suggests that more luminous quasars tend to show higher metallicities (Hamann & Ferland 1993, 1999).

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