Cosmochemistry, Cosmology, and Fundamental Constants High-Resolution Spectroscopy of Damped Lyman-Alpha Systems

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Spectroscopy of QSO absorption lines provides essential observational input for the study of nucleosynthesis and chemical evolution of galaxies at high redshift. But new observations may indicate that present chemical abundance data are biased due to deficient spectral resolution and unknown selection effects: Recent high-resolution spectra reveal the hitherto unperceived chemical nonuniformity of a molecule-bearing damped Lyman-alpha (DLA) system, and the still ongoing H/ESO DLA survey produces convincing evidence for the effect of dust attenuation. We present a revised analysis of the H_2-bearing DLA complex toward the QSO HE 0515–4414 showing nonuniform differential depletion of chemical elements onto dust grains, and introduce the H/ESO DLA survey and its implications. Conclusively, we aim at starting an unbiased chemical abundance database established on high-resolution spectroscopic observations. New data to probe the temperature-redshift relation predicted by standard cosmology and to test the constancy of fundamental constants will be potential spin-offs.

1. CHEMICAL UNIFORMITY AT HIGH Z?

In stark contrast to many interstellar lines-of-sight in the Milky Way or the Magellanic Clouds, high-redshift DLA systems usually appear to be chemically uniform [1]. But despite their chemical uniformity, for any redshift the observed metallicities are different by up to two orders of magnitude [2].

The known DLA systems make a heterogeneous population involving very different physical environments – a very unfavorable precondition for tracing nucleosythesis and the chemical evolution of galaxies. But the physical environments of molecular clouds are less diverse. In fact, for the known H_2-bearing DLA systems the metallicity-redshift distribution may exhibit less variation than for the regular DLA systems [3].

Molecular hydrogen is detected in DLA components exhibiting high particle densities and low kinetic temperatures [4, 5]. The metallicity of DLA systems is usually calculated by averaging ad hoc radial velocity intervals, i.e. by averaging several absorption components. But the depletion of chemical elements in H_2-bearing components may surpass the average by up to one order of magnitude [4, 5]. Moreover, narrow components arising from cold gas are blurred in the usually complex absorption profiles.

In fact, high-resolution (55 000) and exceptionally high signal-to-noise (90-140) spectra of the H_2-bearing DLA system toward the QSO HE 0515–4414 indicate the hitherto unperceived chemical nonuniformity of individual metal absorption profile components, similar to the interstellar lines-of-sight intersecting Galactic warm disk and halo clouds (Figs. 1, 2). In addition, for the H_2-bearing components the calculated [6] fraction of iron in dust of 98 percent is close to that of Galactic cold disk gas. Is the DLA system toward HE 0515–4414 just a rare case, or are compact high-metallicity dust clouds systematically missed in present spectroscopic observations due to insufficient resolution or low signal-to-noise ratio?

2. FAINT QSOS OBSCURED BY DUST?

The possibility that present surveys of DLA systems are affected by dust is an ongoing concern: If the extinction of DLA absorbers is high enough, optical surveys will miss the QSOs behind them. However, present samples of DLA absorbers toward radio-selected and SDSS QSOs do not indicate any distinct selection bias due to dust [8, 9].

In contrats, the new H/ESO survey of DLA systems toward a complete subsample of 182 HE QSOs produces convincing evidence for the effect of dust attenuation: Four new DLA systems were discovered toward the bright half of the QSO subsample, but 14 were detected toward the faint. The probability for both numbers being drawn from the same Poissonian is less than 2.5 percent (Fig. 3). Do the DLA systems toward the fainter QSOs exhibit more dust than those toward the bright?

3. FUTURE AIMS

In order to study the possible biases and selection effects involved with duts, we aim at starting a sound abundance database established on high-resolution and high signal-to-noise spectroscopy of the complete sample of DLA systems discovered by the H/ESO survey. The database will

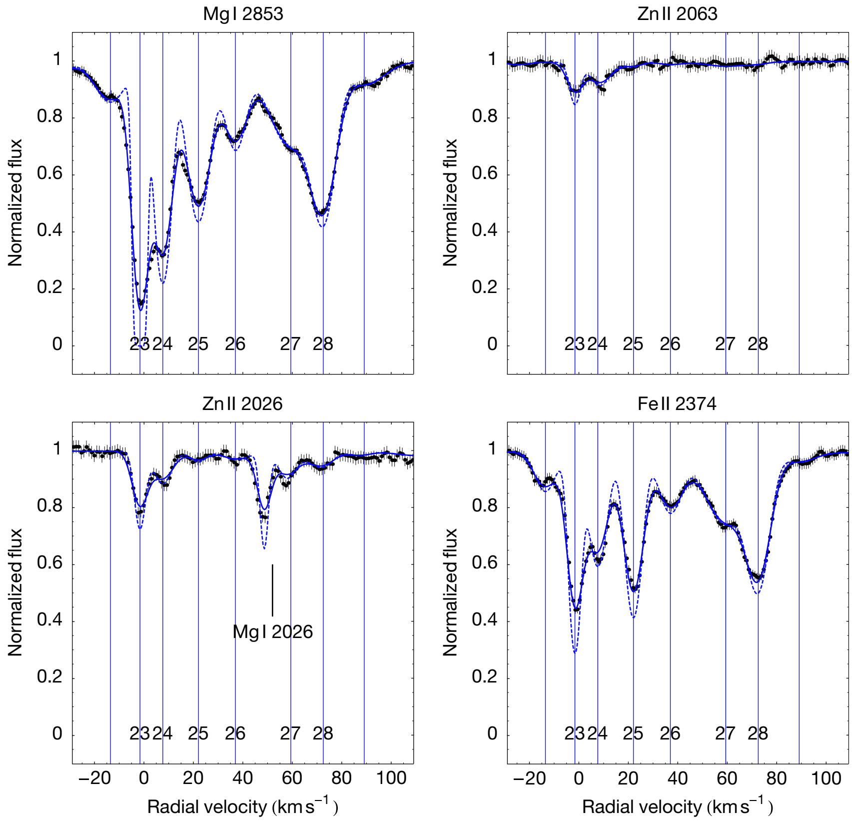

Figure 1: Selected metal absorption profiles associated with the DLA system toward HE 0515–4414. The blue curves indicate the optimized profile decomposition and its deconvolution. Individual components are labeled by numbers 23-28. Note the different optical depths of Fe II and Zn II for the H_2-bearing componets 23/24 and component 28. Component 23 also exhibits rare neutral species (S I, Si I, Fe I). Radial velocity zero corresponds to the redshift $z = 1.1508$.

be extremely useful for studying the physical conditions in DLA systems, and may shed some light on the star formation history of the universe and the problem of missing metals [10, 11].

As spin-off product, newly detected C I and C II fine-structure absorption lines may be used to test the temperature-redshift relation predicted by the standard big-bang cosmology. A further potential spin-off will be a homogenous sample of Fe II lines suitable for probing the hypothetical variation of the fine-structure constant α by means of the regression many multiplet method [12, 13].

Acknowledgments

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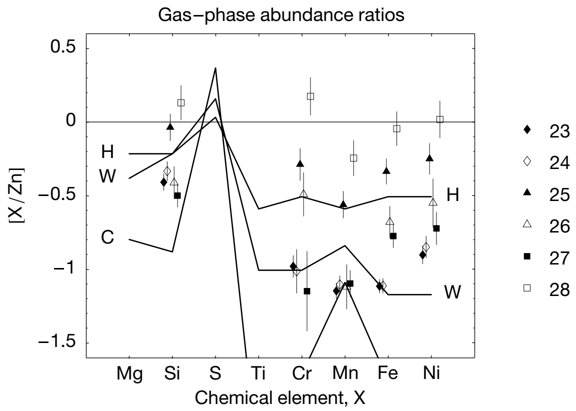

Figure 2: Evidence for chemical nonuniformity at high redshift. Gas-phase abundance ratios (relative to solar ratios) for the absorption components shown in Fig. 1 compared with typical values found for Galactic cold (C) and warm (W) disk and halo (H) clouds [7]. Since the volatile element Zn is only mildly depleted, the abundance ratios reflect the differential depletion of chemical elements into dust. Note that Cr, Mn, Fe, and Ni are strongly depleted in the H_2-bearing components 23/24 but appear essentially undepleted in component 28.

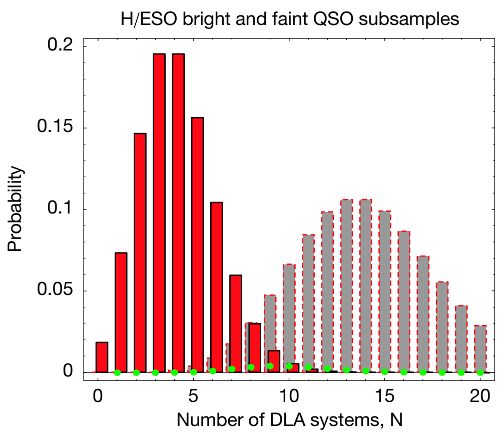

Figure 3: Evidence for attenuation of fainter QSOs by dust. The number of DLA systems detected toward the bright (faint) half of 182 HE QSOs is 4 (14). The absorption paths of both subsamples exhibit almost the same length. Two Poissonians with means 4 and 14 are marked by, respectively, the red and gray vertical bars. The probability for both numbers being drawn from the same Poissonian with mean *N* is indicated by green dots.