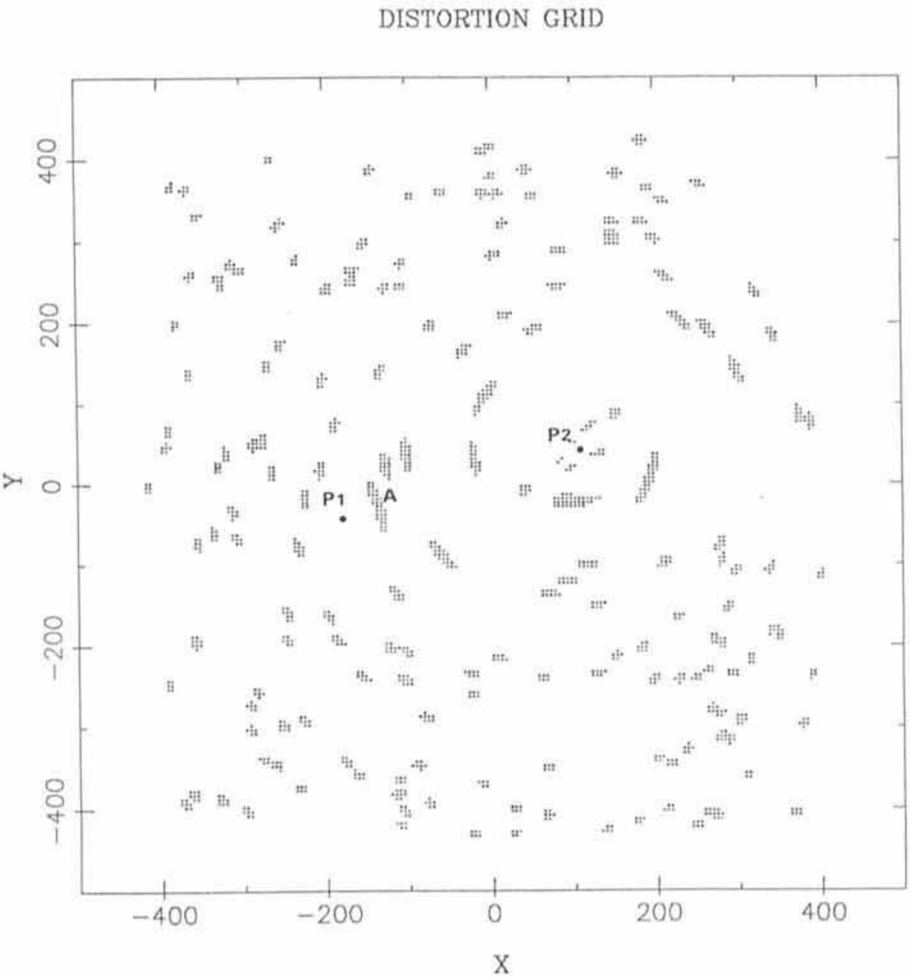

Figure 3: *Simulation of the gravitational distorsion of a population of galaxies randomly distributed at z=1.2. The cluster-lens is at redshift 0.23 with standard structural and dynamical parameters as expected for a rich cluster of galaxies. The cluster is composed of two potential wells located at P1 and P2. One should note the simulated "straight arc" located in A.*

ratio D_{ol}/D_{ls} where D_{ol} is the angular-diameter distance between the observer and the lens and D_{ls} is the distance lens-source. This ratio is independent of H_o and slowly varies with q_o. But a large number of arclets in the same cluster could possibly constrain the deceleration parameter. On the contrary, constraints on H_o are not evident. As was suggested by Kovner and Paczynski (1988), one should wait for a supernova occurring in the source, and measure the short time delay between the event in the two or three images in the arc. Another possibility was suggested recently (Soucail and Fort, 1991). A velocity gradient was detected along the giant arc in A2390 (Pello et al. 1991), and was interpreted as an intrinsic rotation of the source. Applying the Tully-Fisher relation on this galaxy, they deduced an absolute magnitude of the source and consequently determined H_o for a large distance modulus.

It is clear that this observational programme calls for large telescopes with sub-arcsecond seeing. It is extremely time-consuming, both for ultra-deep imaging in multi-band photometry (B, V, R, I, K) and for the spectroscopic follow-up of the most luminous arcs. The future European VLT will give new insight into the domain opened by this Key Programme. Observations with the VLT of the images produced by these Very Large Natural Telescopes are likely to open a completely new window to the early Universe.

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PROFILE OF A KEY PROGRAMME

High Resolution Studies of Quasar Absorption Lines

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The Key Programme described here intends to study the physics, chemistry and chemical composition of diffuse gas clouds between a redhift z~0.6 to redshifts beyond z=4. With long integration times, it is now possible with CASPEC, and, for the first time, EMMI (1), to observe quasars fainter than 17.5 mag with a spectral resolution of 10 km s^{-1}, and signal-to-noise ratios as high as 50 from the UV to the near IR. High quality spectra of a selection of bright quasars will probe several long cosmic sight lines. This will permit detailed astrophysical analyses of the diffuse gas in intervening galactic disks and halos, gas clouds in the intergalactic medium and, for those clouds in the physical vicinity of quasars, it will be possible to study the interactions between the quasar radiation and the absorbing clouds.

The immediate first goal of the research will be an understanding of the ionization conditions, cloud temperatures, velocity structures, ionic abundances, and dust content for those clouds with sufficient column density that they produce observable absorption lines from enough metallic ion transitions that these cloud parameters can be constrained.

Past attempts to study the narrow line clouds relied on low-resolution spectra and curve of growth analyses. Since these earlier spectra achieved only comparatively poor S/N ratios, or had limited wavelength coverage, it was often difficult to produce definitive, accurate results. High S/N ratio spectra are required in order to model convincingly the weak absorption lines and determine the b values and wavelengths of the principal clouds in a redshift system. Once the weak lines are modeled it is possible to extend the model to the stronger lines in the system and determine the column densities with fair confidence. The strong line column densities are needed to determine the abundances of the prevalent C, N, O group of elements relative to those of the less abundant metals. If the metal line clouds have low velocity dispersions (as a few radio studies of the hydrogen 21-cm line in particularly strong clouds and isolated high resolution optical studies have shown to be the case) then data from transitions with a wide range of oscillator strengths will be needed before the physical and chemical properties of the clouds are clearly understood. Careful measurements of lines with different λf values for the same ion and the investigation of the relative abundances of the elements as a function of their grain volatilities are required before the chemical composition of these distant clouds can be settled. Observations of several ionization stages for key elements, such as N, C, Si and S can lead to accurate models of the ionization structure of the clouds. It is important that the spectra have sufficient wavelength coverage that many spectral lines of different strengths are available for analysis.

When the observations have sufficient spectral resolution, it is possible to measure the gas kinetic temperature for metal line clouds with low turbulent velocities by comparing the doppler widths of the metal lines to those of the hydrogen lines. For low ionization clouds that have damped hydrogen Lyman lines, fine structure excitation of low ionization metal ions often produces measurable fine structure lines that, in addition, can give an excitation temperature. CASPEC spectra of UM-402 gave very different temperatures for different cloud systems (2). In the z=2.523 redshift complex C II fine structure lines suggest an excitation temperature T<15 K, a typical temperature for cool interstellar clouds in our Galaxy. At high redshift this temperature provides a useful check on the Cosmic background temperature, since theory predicts that the background temperature will scale as 1+z. Other metallic fine structure lines and measurements at other redshifts can sample the background radiation at different wavelengths relative to the peak of the Planck curve. In marked contrast to this low temperature cloud, a second cloud in a high redshift complex seems to be interacting with the radiation field of UM-402, and gives a doppler temperature for one hydrogen Ly-α cloud that exceeds 5×10^5 K.

The dust content of the high redshift clouds can be estimated by comparing elements with small (Si, Mn, Zn) and high (Cr, Fe, Ni) depletion factors onto grains in Galactic interstellar clouds. Absorbing clouds with large H I column densities, i.e. the damped Ly-α systems, are the best candidates to estimate abundances because their H II content is frequently negligible, as shown by the low ionization level of the gas (3) and from photoionization model calculations (4). When the hydrogen Ly-α line is damped, the estimate of N(H I) is independent of the velocity dispersion b, of the gas. Absorption lines from elements with low cosmic abundances are optically thin, even in clouds with high column densities. Since their transitions are unsaturated, the corresponding ionic column densities are then also independent of b. At high redshift ($z \sim 2$) the important ions to be studied are Cr, Ni and Zn. At lower redshift ($z \sim 0.8$) Ca and Mn can be used, or the more abundant Fe^+ ion if the Fe II $\lambda\lambda$2366, 2373 lines which have very small oscillator strengths are used. The dust grain depletion factors in the Galactic interstellar medium are of order unity for Zn, 10^{-1} for Mn, 10^{-2} for Cr, Fe and Ni, and a few 10^{-4} for Ca. There is presently no damped Ly-α system known at $z < 1.3$, but such systems will be detectable with the HST (one of us, J. B., is Co-I in the HST key programme on "Quasar Absorption Line Survey"). Dusty clouds should also show detectable amounts of H_2 absorption; molecular hydrogen absorption has now been reported in PKS 0528-250 (5). For this study the maximum spectral resolution was 5000, 1/6 the resolution now achievable with ESO instrumentation for this quasar.

In several cases with z<1 metal line absorbing clouds are clearly associated with an identified host galaxy (6, 7, 8). We therefore know that at least in these cases the absorbing clouds are part of very extended gaseous halos associated with the intervening galaxies. Cir-

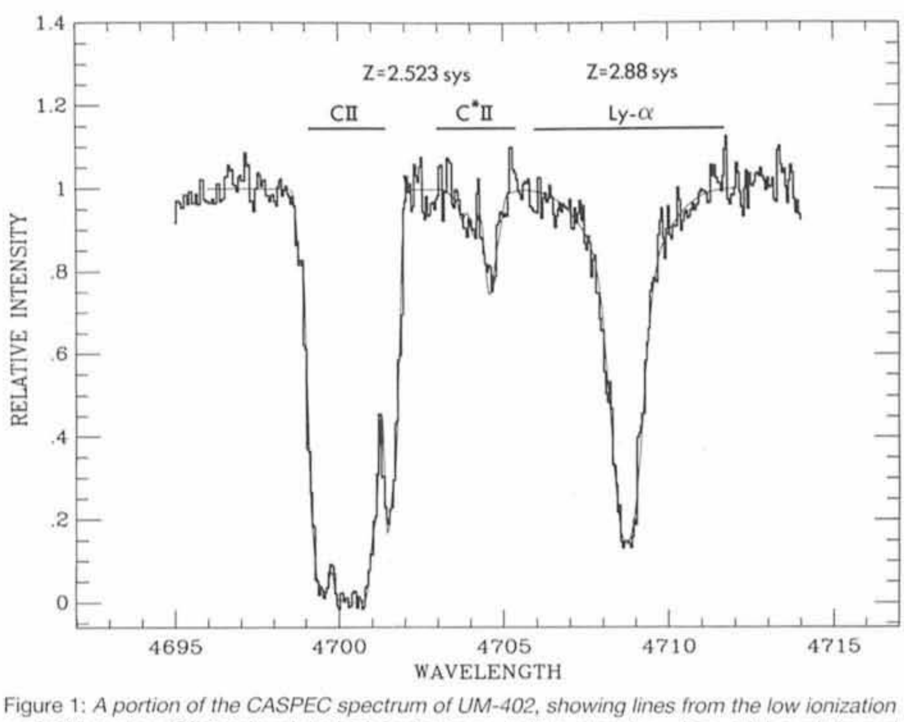

Figure 1: *A portion of the CASPEC spectrum of UM-402, showing lines from the low ionization z=2.523 system (C II lines) and the high ionization z=2.88 system (Ly-α line with broad thermal wings). The thin line shows a model fit.*

cumstantial evidence suggests that most of the dense clouds, those having absorption systems with damped Ly-α lines, are also galactic disk complexes, despite their surprisingly frequent occurrence in high redshift quasar spectra (9). The study of the conditions and evolution of these cloud systems can tell us much about the evolution and conditions in the host galaxy itself. The ionic abundances and dust content in disks and outer gaseous envelopes of moderate to high redshift galaxies are important parameters for the study of primeval galactic evolution. Also, the dust content of distant galaxies strongly affects the opacity of the early Universe.

CASPEC observations of the BL Lac object 0215+015, aimed at studying the ionization level of absorption systems with $N(HI) \sim 10^{18}-10^{20} cm^{-2}$, have permitted an estimate of the column densities of Mg II, Mn II and Fe II in the $z=1.345$ absorber (10). In this system the derived abundances of Mg, Mn and Fe are all equal to 0.15 ($\pm$0.5) times the solar values, implying no depletion onto dust grains. The abundance of Ni II has been derived in the $z=2.811$ system toward PKS0528-250 (11), suggesting that much less Ni is depleted in this system than in Galactic interstellar clouds. In these two absorbers the abundances are about 0.10 and 0.05 times the solar values and the dust-to-gas ratio is approximately one order of magnitude lower than the Galactic value. In contrast, the damped Lyα ($N(HI) \sim 10^{19} cm^{-2}$) system at $z=2.523$ toward UM-402 has metal abundances close to solar. Obviously, while there is a spread in the abundances in these high redshift clouds, some high redshift galaxies are able to process hydrogen into heavy metals in short cosmic time scales.

Often the high column density, damped Ly-α line, clouds are accompanied by much lower column density satellite lines (2, 12).These satellite lines may arise from clouds in a turbulent halo phase or in an accompanying galaxy cluster. The total velocity spread of the individual components of the damped Ly-α line rarely exceeds one hundred km s^{-1}, appropriate for a galactic disk, while the satellite lines span a velocity range of several hundred km s^{-1}, and in a few cases up to one or two thousand km s^{-1} comparable with velocity dispersions in galaxy clusters. The evolution of such complexes of lines with z (if any) may give insight into the beginnings of galaxy clusters.

The brighter high redshift quasars can now be studied with high spectral resolution using ESO telescopes and echelle spectrographs. For these studies ESO has some important advantages over its competitors. These include: (a) the EMMI spectrograph is somewhat more efficient (1) than comparable instruments at other observatories and (b) the observing conditions at La Silla are quite good. Furthermore, the Barbieri Key Programme and the Hamburger Sternwarte Key Programme will increase the number of bright, Southern Hemisphere quasars that will be available for study. Together, these advantages represent a significant capability that should be exploited. The experience gained in these initial studies will point the way to future work and give valuable experience in the extraction of the peak performance from the telescopes, their instrumentation and the data reduction facilities. European astronomers will then be in a good position to fully exploit the revolutionary possibilities represented by the future availability of the VLT and its powerful complement of instruments.

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Discovery of the Most Distant "Normal" Galaxy

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Normal galaxies at epochs about one third or less the present age of the universe, t_H, are extremely difficult to detect directly since they are very distant from us and thus have very faint apparent luminosities. However, it is crucial to search for young normal galaxies at high redshift for understanding the formation and evolution of galaxies. The existence of high redshift gas-rich galaxies has already been inferred from the absorption signatures that their interstellar and halo gas imprints on the spectra of more distant objects which may happen to lie on the same line of sight. Such absorption features, due to hydrogen atoms and heavier elements, have been detected in the spectra of distant quasars (see e.g. the first surveys of Weymann et al., 1979, Sargent et al., 1980 and Young et al., 1982). In these studies, quasars are used as background candles to probe all the intervening matter between us and them.

The first identification of a galaxy giving rise to a Mg II absorption system, at a redshift $z = 0.430$ or about $\frac{2}{3}\, t_H$, was obtained in 1985 at the ESO 3.6-m (Bergeron, 1986). This first identification has been followed by a dozen of others for similar redshifts in a survey done by Bergeron and Boissé (1990). These galaxies have huge gaseous halos, roughly three times larger than the extent of the stellar components and their centres are separated from the quasar image usually by 5 to 10 arcsec. Comparing these observed impact parameters, an average close to 3 Holmberg radii R_H ($R_H = 22$ kpc with $H_o = 50$ km s^{-1} Mpc^{-1}), to those predicted from statistics of Mg II absorption line samples, Bergeron and Boissé conclude that all field galaxies at $z \sim 0.4$, brighter than 0.3 L^* should have extended gaseous halos of roughly spherical geometry. Furthermore, there is also a similar level of [O II] λ 3727 emission, thus of star formation activity, in the absorbing galaxies and in those of faint (field) galaxy surveys at $z \sim 0.3$ (Broadhurst et al., 1988, Colless et al., 1990) which is higher than that observed in local galaxies (Peterson et al., 1986). Consequent-