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# The Absorption and Emission Kinematics of a $z = 0.745$ Mg II Absorber

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**Abstract**

We present QSO absorption line spectroscopy of the $z = 0.745$ Mg II system towards Q1331+17 and complementary galaxy emission line spectroscopy of its candidate absorbing galaxy 3.9 arcsec away. Our objective is to spectroscopically confirm the galaxy causing absorption and to study the synergy between absorption and emission line kinematics. We confirm the galaxy counterpart of the absorber as a $0.3L_{\star}$ edge on disk galaxy 28 $h_{70}^{-1}$ kpc from the QSO and determine a rotation velocity $v \geq 230$ km/s. An extrapolation of the disk rotation curve does not match the absorbing gas velocity, evidence against a simple disk rotation model. We also study the symmetries and column densities of absorption line components in the context of expanding gas shells or superbubbles.

## 1.1 Introduction

Moderate redshift ($z \sim 0.5$) Mg II absorbers are known to be associated with relatively bright galaxies at impact parameters $< 40$ kpc (Steidel, Dickinson, & Persson 1994). These systems therefore offer excellent opportunities to study the relationship between galactic emission and absorption properties. This is a particularly useful synergy to understand in order to provide a foothold for the interpretation of higher redshift systems where galaxy identification is more challenging. In this contribution, we focus on a Mg II absorber at $z_{\rm abs}$=0.745 for which we have obtained echelle spectroscopy of the QSO and moderate resolution spectra of galaxies in the field to study the absorption and emission line kinematics.

## 1.2 Data

We have obtained UVES spectroscopy of the QSO Q1331+17 which is known to exhibit a Mg II system at $z_{\rm abs}$=0.745, as well as several C IV systems and a higher redshift DLA. The high spectral resolution of the UVES spectrum ($\sim$ 7 km/s) permits a detailed study of the absorption kinematics of the Mg II system and determination of component column densities via Voigt profile fitting. Unfortunately, the Lyman limit of the higher redshift DLA sets in redward of Ly$\alpha$ at $z = 0.745$, so it is impossible to determine the N(HI) of this system. However, as argued by Bond et al. (2001), this absorber is unlikely to be a DLA.

In addition, we have obtained FORS multi-object spectroscopy of all the galaxies close to the QSO, including the favored counterpart candidate of Le Brun et al. (1997), which we will refer to as G5. Detection of the [O II] $\lambda$3727 Å line in G5 at $z = 0.745$ in our FORS

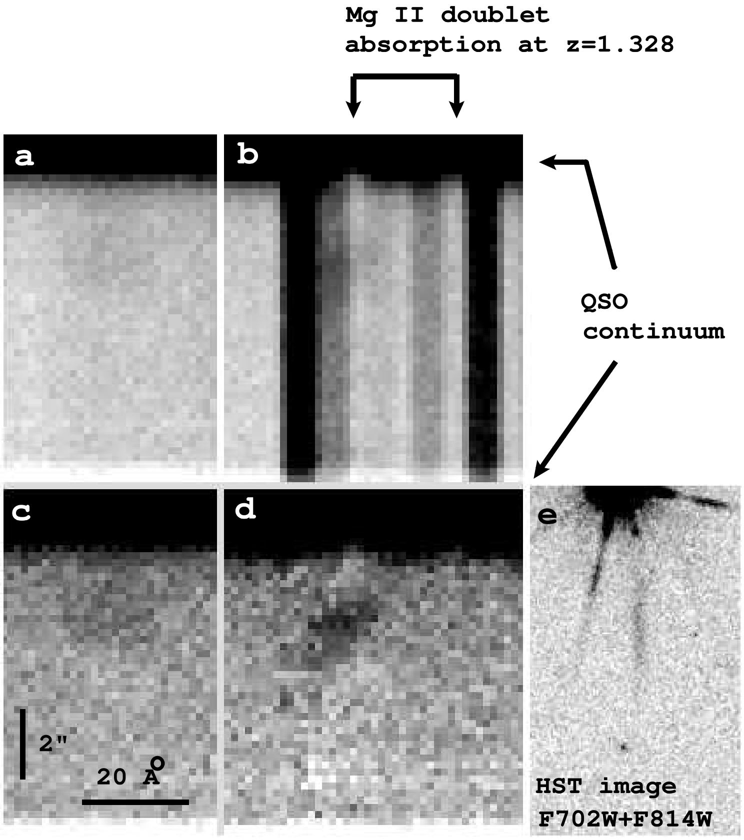


Fig. 1.1. Panels (a) and (b) show two postage stamps from the reduced 2-D spectrum from the slit covering G5. The wavelength ranges are 5654.58 – 5693.88 Å and 6485.12 – 6540.14 Å for panels (a) and (b) respectively and show the [O II]$\lambda$3727 line at $z = 0.745$ and another unidentified emission line believed to occur at a different redshift (see Ellison et al. 2003 for discussion). The QSO continuum appears at the top of the slit and the Mg II absorption system at $z = 1.328$ is marked. Panels (c) and (d) have the sky background removed. Panel (e) shows the WFPC2 image on the same spatial scale.

spectra confirms this identification. This galaxy is separated from the QSO by 28 $h_{70}^{-1}$ kpc ($\Omega_M = 0.3, \Omega_\Lambda$=0.7) and has an edge-on disk morphology, so that by aligning the slit with the major axis we can obtain a rotation curve from the detected [O II] $\lambda$3727 Å line, see Figure 1.

Finally, we perform a re-assessment of the HST archival images of the Q1331+17 field obtained with the WFPC2 camera. A photometric analysis leads to a determination of $L \sim 0.3 L_\star$, significantly lower than had been previously reported by Le Brun et al. (1997).

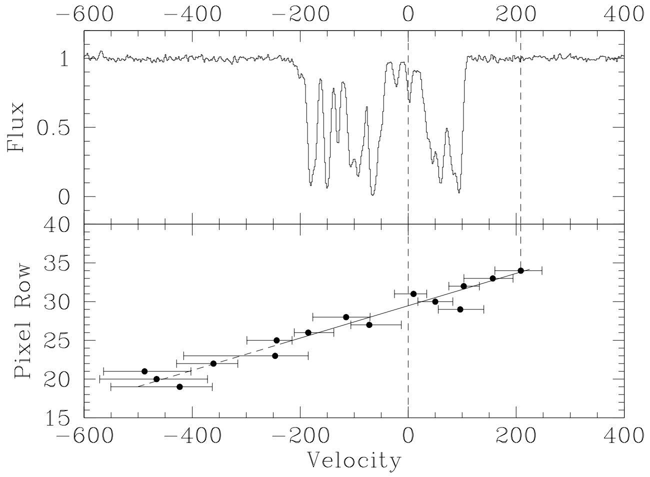


Fig. 1.2. Emission and absorption kinematics shown on a common velocity scale relative to $z = 0.7450$. A least squares fit for pixels 25-35 is shown by the solid diagonal and extrapolated to pixels 19-24 (which are more affected by sky subtraction) in the dashed line. The vertical dashed lines indicate zero velocity $v = 208.5$ km/s at the limit of the detected rotation curve.

## 1.3 Kinematic Analysis

In Figure 2 we show the emission line rotation curve of G5 with the QSO absorption on the same velocity scale. We determine a rotation velocity $v_{rot} \geq 230$ km/s, a value that is inconsistent with the Tully-Fisher relation (TFR). This discrepancy is exacerbated by including effects of evolution and the possible superposition of a second galaxy (see Ellison, Mallen-Ornelas, & Sawicki 2003 for details). If caused by dust, approximately 2 magnitudes of extinction would be required to reconcile the TFR. If the absorbing gas were part of the rotating disk, we would expect to see a velocity match at the extrapolation of the disk. Indeed, Steidel et al. (2002) have recently also performed a similar analysis and found that in 4/5 of their low redshift Mg II systems the absorption is well aligned with the rotation curve velocity. In the Mg II absorber towards Q1331+17, we find that the absorption components fall approximately central to the systemic redshift of the emission line, but with a large spread ($\sim$ 100 km/s) to either side (Figure 2). Therefore, in this case, we do not find that the absorption kinematics are dominated by rotation, as is the case for one of the Steidel et al. (2002) systems and one further system studied by Lanzetta et al. (1997).

## 1.4 Superbubbles

Bond et al. (2001) have previously suggested that this Mg II system may be associated with expanding shells of gas due to symmetries in the absorption line components. We can study this hypothesis in more detail with our higher quality UVES data. The symmetries are even more striking in the UVES data (as can be seen from Figure 2) but, in contrast to Bond et al. (2001) we find the pairwise separations have $\Delta v \sim 150$ km/s. By performing Monte Carlo simulations based on the two-point correlation function and column density distribution function of Mg II systems, we find that the probability that these symmetries arise by chance is vanishingly small. Further evidence for superbubbles comes from the large Mg I/Fe II ratios, indicative of high densities, Figure 3 (see also Rauch et al. 2002), Extending the Bond et al. (2001) analysis of superbubbles, we infer that the gas is likely to be enriched to a level of at least 1/10th solar metallicity and caused by OB associations comparable to the largest observed at $z = 0$ (see Ellison et al. 2003 for further details).

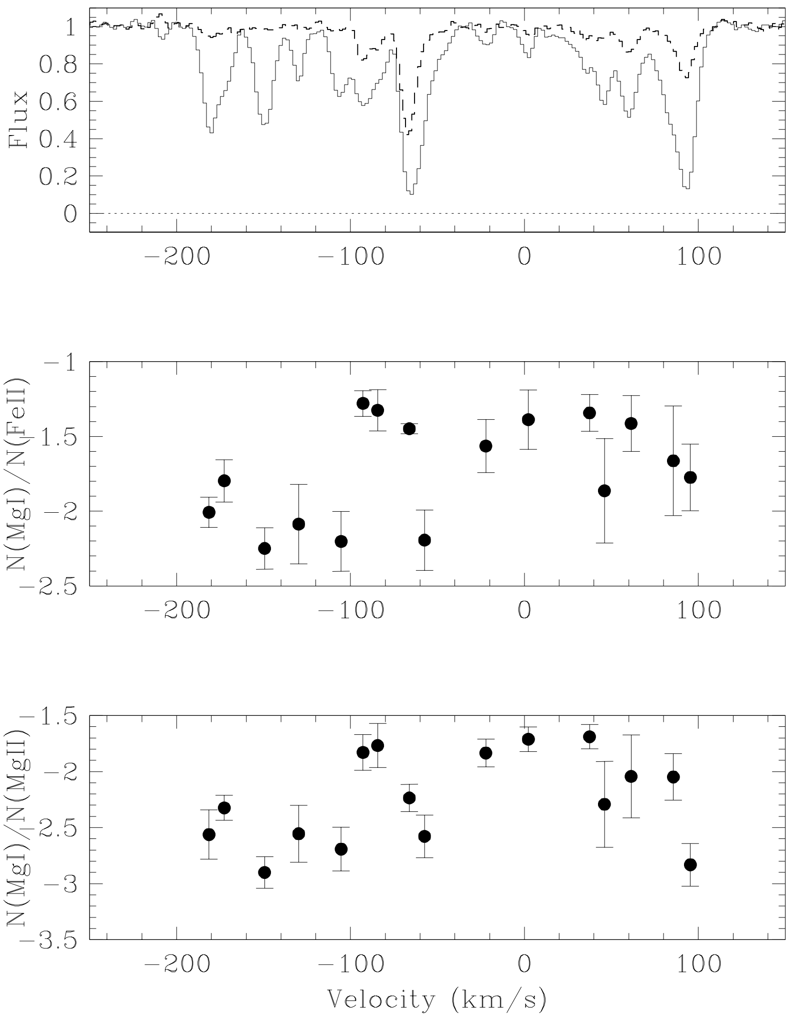


Fig. 1.3. Top panel: Fe II $\lambda2382$ (solid line) and MgI (dashed line) plotted on a common velocity scale. Middle panel: N(Mg I)/N(Fe II) on a component by component basis as determined by Voigt profile fitting. Bottom panel: N(Mg I)/N(Mg II) on a component by component basis. Note that since many of the Mg II components are mildly saturated, these ratios are upper limits. The error bars are those produced by VPFIT for individual components and are largest when components are severely blended.

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