Interstellar Mg II and C IV absorption by $1\frac{1}{2}$ galaxies along the sightline to Mrk 205

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We present the first results of our HST survey designed to search for Mg II and C IV absorption lines from the disks and haloes of low-redshift galaxies, using background QSOs and supernovae as probes. Our survey utilizes the high resolution of the *Goddard High Resolution Spectrograph* enabling us to calculate the column densities and doppler parameters of individual components within an absorption complex, and hence determine the physical conditions of the absorbing gas. Observing the complexity of the absorption line profiles i.e., the velocity distribution and total velocity extent of the constituent components, offers an important description of the kinematics of the absorbing gas, and hence an understanding of its origin.

We focus on one sightline in particular, that towards Mrk 205, which passes 3 – 5 kpc from the intervening galaxy NGC 4319. We detect Mg II and C IV absorption from both local Milky Way halo gas and from NGC 4319 (Fig. 1). The equivalent width (W) of the local C IV(λ1548) line is weak, $W(\lambda1548) = 159 \pm 29$ mÅ, but very similar to the extragalactic absorption, $W(\lambda1548) = 187 \pm 32$ mÅ. However, the disparity between the local Mg II absorption and that in NGC 4319 is severe: the lines arising in the Milky way gas are saturated [$W(\lambda2796) = 1.08 \pm 0.02$ Å], are composed of several components (≥ 5) covering a total velocity span of 100 km s^{-1}, and are flanked by weak high-velocity components at −215, −153. In contrast, the absorption by NGC 4319 is weak [$W(\lambda2796) = 234 \pm 17$ mÅ] and can be modelled with a single component.

Absorption by the local Milky Way

The line-of-sight towards Mrk 205 lies at Galactic co-ordinates $l = 125.4$, $b = 41.7$, passing through the outer spiral arm in the second quadrant and intercepting the edge of the HVC Complex C. Models which assume that a halo corotates with the disk demonstrate that the negative velocities of the Mg II components are entirely consistent with corotating gas. Only the two high velocity components (−215 & −153 km s^{-1}) show velocities which cannot be accounted for by corotation.

The 21 cm H I emission associated with the most negative velocity component is $N(\mathrm{H\ I}) = 1.93 \times 10^{19}$ cm^{-2} (Lockman & Savage 1992, in preparation), giving $N(\mathrm{Mg\ II})/N(\mathrm{H\ I}) = 3.1^{+2.0}_{-1.0} \times 10^{-7}$ for this HVC. However, the nearest 21 cm emission obviously associated with the second component at −153 km s^{-1} lies at −135 km s^{-1}. The feature is extremely weak, which may account for the discrepancy of 18 km s^{-1}, and is measured to have $N(\mathrm{H\ I}) = 1.4 \times 10^{18}$ cm^{-2}, with errors of a factor of 2. Whether of not this emission can be associated with the HVC, the number serves as a lower limit to N(H I), giving a ratio $N(\mathrm{Mg\ II})/N(\mathrm{H\ I})$ of $\lesssim 6.9 \pm 0.6 \times 10^{-5}$, over 200 times that in the higher velocity HVC!

For the C IV, the derived $N \sin b$ is little different from the values seen towards the stars furthest away from the Galactic plane, demonstrating that there is no extra gas beyond the few kiloparces probed by halo stars. This uniformity is even more surprising considering that none of the sightlines previously investigated (Savage and Massa 1987) lay at positive declinations in the second quadrant. Assuming that the density of the gas $n(Z)$ is related to the height above the plane Z by $n_{\mathrm{C\ IV}}(Z) = n_{\mathrm{C\ IV}}(0)\exp(-Z/h)$, where h is the scale height above the plane, a formal fit to the line-of-sight towards Mrk 205 gives $h = 2.0$ kpc for $n_{\mathrm{C\ IV}}(0) = 8.0 \times 10^{-9}$ cm^{-2}.

Absorption by NGC 4319

The Mg II absorption seen in NGC 4319 characterizes a quiescent cool-phase of the ISM. Observations by Womble *et al.* (1992, in preparation) of 21 cm emission towards NGC 4319 show that the galaxy is completely anemic; at the position of Mrk 205, $N(\mathrm{H\ I}) < 2.8 \times 10^{19}$ cm^{-2}. Further, the existence of a single component means that the gas resides in a much less 'active' ISM than our own, that corotation, for example, does not serve to spread many components out over a wide velocity range. This is not simply an effect of inclination.

Though NGC 4319 appears face-on, the inclination of the galaxy ranges from $38° - 62°$ (where zero represents face-on inclinations), similar to the sightlines $(90 - b)$ latitude through our own Galaxy.

Though the local and extragalactic Mg II absorption and H I column densities are very different, N(C IV) in NGC 4319 and our own halo are surprisingly similar. However, the *lower limit* to the log$N$(C IV)/N(H I) ratio is quite different, $\gtrsim -5.4$, some 15 times the local value along the same sightline (which is already high compared to lines of sight to halo stars).

If Mg II and C IV absorption arise in the same gas, then we conclude that the gas in the inter-arm region of NGC 4319 is much more highly ionized than local, spiral arm gas. Alternatively, it could be that the C IV we see in the Galactic halo is in no way associated with the H I along the same sightline (for example, if the high-ionization species occur in cloud interfaces), in which case the quantities of C IV would be ambivalent towards the H I/Mg II columns, and no 'unusual' ionization mechanisms need be invoked. If so, however, any models of galactic halo production and support must allow that highly ionized species be produced specifically without the presence of large H I column densities.

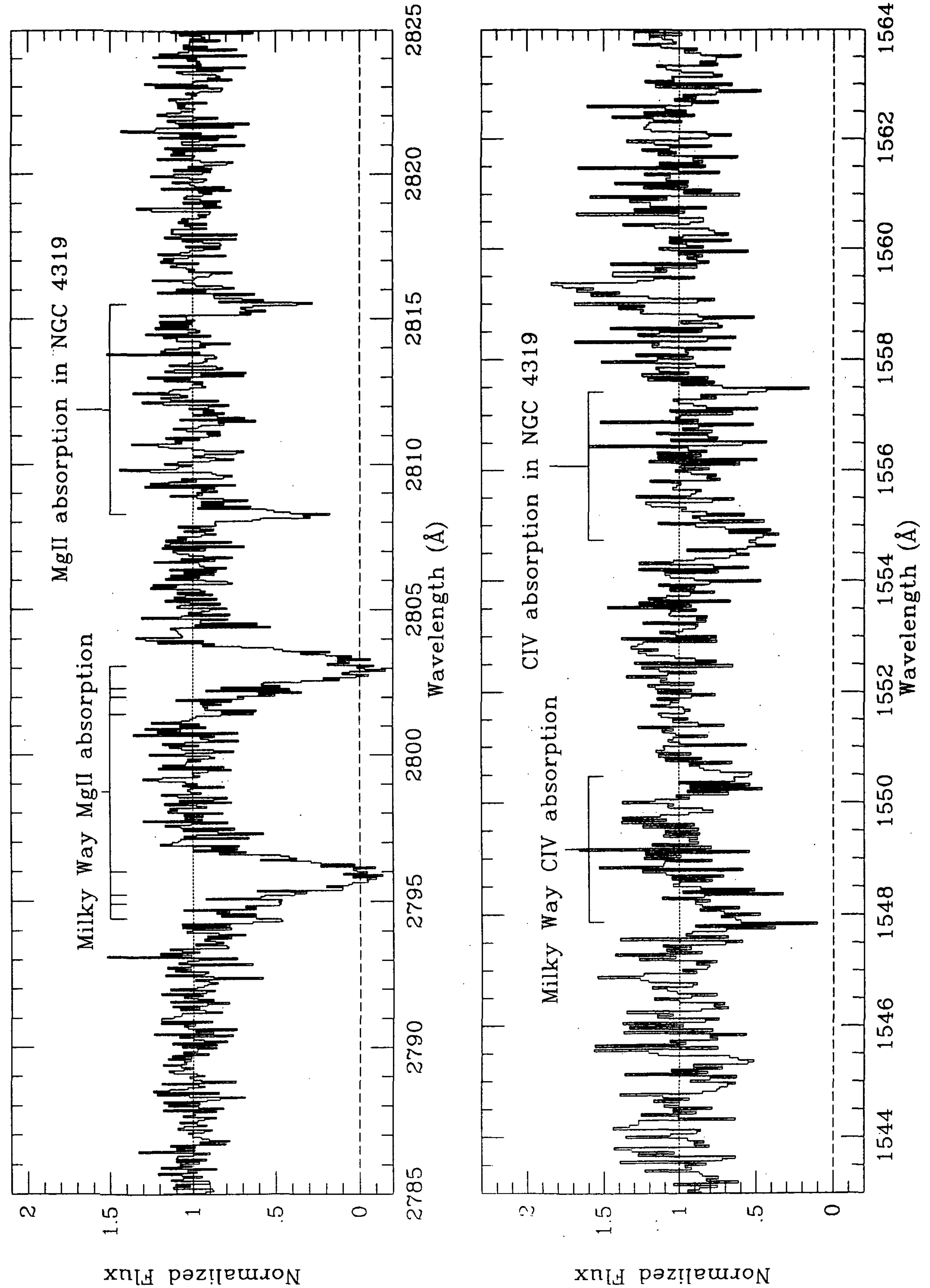
Comparisons to higher-z absorption lines

The sightline towards Mrk 205 samples one and a half galaxy disks and haloes—half our own and all of NGC 4319's. Both sightlines demonstrate that galaxies can indeed produce the UV absorption lines seen at higher redshift, and both are examples of low-ionization systems, ones in which both Mg II and C IV are detected. At a mean redshift of $< z_{\rm abs} > = 1 - 2$ these two absorbers would be representative of $\approx$ 1/3 of all absorption systems (Caulet 1989, Steidel & Sargent 1992, hereafter SS92). Further, the difference in the H I column densities between our galaxy and NGC 4319 means that we are observing the metal line properties of one damped, and one non-damped Lyα system at $z = 0$.

The equivalent width distribution of Mg II absorption lines at a mean redshift of $< z_{\rm abs} > = 1.12$ has been constructed by SS92. The observed absorption systems have equivalent widths which lie at the two extreme ends of this distribution. In NGC 4319, $W(\lambda2796) =$ 0.23 Å, which is less than the nominal 0.3 Å set by SS92 as the limit above which at least $\sim$ 80% of all Mg II absorbers are detected. In contrast, the total equivalent width observed through our own galaxy, including the HVC equivalent widths (but for only *half* a disk) is 1.40 ± 0.03 Å. Assuming, for example, that $n(W)dW \propto W^{-\delta}$, and that $\delta = 1.65$ (SS92), then only 18% of absorbers at $< z_{\rm abs} > = 1.12$ have $W(\lambda2796)$ greater than that seen locally. This equivalent width distribution, however, is known to vary with redshift, in the sense that there are less strong lines at lower redshift (Petitjean & Bergeron 1990, SS92). This means that the type of absorption seen in our own Galaxy is predicted to be a rarity at zero-redshift. The redshift distribution of absorbers is usually expressed as $N(z) = N(0)(1+z)^{\gamma}$; given the values of γ and $N(z)$ found by SS92, and calculating $N(0)$, we expect systems with $W(\lambda2796) \geq 0.3$ Å to be 14 times more common than systems with $W(\lambda2796) \geq 1.0$ Å.

By analogy, the observed Galactic absorption—by gas whose kinematic behaviour we crudely understand—demonstrates that the velocity spread of individual components is completely consistent with absorption by galactic disks with scale heights of a few kiloparsecs at higher z, at least for the strongest Mg II systems. A similar conclusion was reached by Lanzetta & Bowen (1992) for the $z_{\rm abs} = 0.524$ system towards 0235+164, and the $z_{\rm abs} = 0.359$ system towards 1229−021. High resolution observations showed asymmetric line profiles with clouds clumped at velocities consistent with a model of rotating gas clouds intercepted at high inclination angles. The similarity between their profiles and the observed Galactic absorption is intriguing: one possible explanation for the HVCs seen locally is that they are simply distant spiral arms differentially rotating with the Galaxy. Are the weak components seen at the edges of the $z \sim 0.5$ complexes manifestations of corotating disks as predicted, or could they be the HVCs of external galaxies?

These results provide evidence that galaxies with kinematically ordered 'thick disks' have existed from redshifts of zero to at least 0.5. However, the evolution of the strong systems mentioned above offers the tantalizing possibility that either the disks of this population have collapsed and are, on average, smaller then they were at $z \sim 0.5 - 1.0$, or there are now fewer galaxies with such disks!


Milky Way MgII absorption
MgII absorption in NGC 4319
Normalized Flux
Wavelength (Å)
2785
2790
2795
2800
2805
2810
2815
2820
2825
0
.5
1
1.5
2
Milky Way CIV absorption
CIV absorption in NGC 4319
Normalized Flux
Wavelength (Å)
1544
1546
1548
1550
1552
1554
1556
1558
1560
1562
1564
0
.5
1
1.5
2