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# THE GASEOUS GALACTIC HALO AS INFERRED FROM THE LINE SPECTRA OF THE GALAXIES MARKARIAN 509 AND FAIRALL 9

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## ABSTRACT

Narrow interstellar absorption lines of S II λ1259.52, Si II λ1260.42, and Fe II λ1608.46 due to gas in the disk and the halo of our Galaxy have been detected in the spectrum of the Seyfert galaxy Mrk 509 with the *International Ultraviolet Explorer*. This gas is also seen at higher resolution in the Ca II and Na I absorption lines in two components at LSR velocities of +6 and +62 km $s^{-1}$. In addition, narrow Lyα and C IV absorption near the Seyfert redshift seem to be present in the spectrum. Si II λ1260.42 absorption from the galactic disk and from the Magellanic Stream or the halo of the SMC have been detected with the *IUE* in the spectrum of Fairall 9. The observations of these two objects when combined with existing results are shown to be consistent with a corotating galactic halo having a height of less than 10 kpc at the Sun.


*Subject headings:* galaxies: individual — galaxies: Milky Way — galaxies: Seyfert — galaxies: structure — interstellar: matter — ultraviolet: spectra

## I. INTRODUCTION

The launching of the *International Ultraviolet Explorer* (*IUE*) (Boggess *et al.* 1978*a*, *b*) with a high resolution spectrograph and a sophisticated guidance system has provided the capability to search for gas clouds beyond our galactic disk but in the neighborhood of our own and other low redshift galaxies. The brightest extragalactic objects which may be observed are the O and B supergiants in the Magellanic Clouds, where Savage and de Boer (1979, 1981) have suggested that both absorption from our own galactic halo and that of the Clouds may be seen along the line of sight. However, Songaila (1981) has argued that this direction cannot be considered representative owing to the tidal interaction of the Galaxy with the Magellanic Clouds.

Other lines of sight are more difficult to observe since the next brightest extragalactic targets are close to the detection limit of the *IUE* in its high dispersion mode. For example, the strongest known extragalactic UV sources, excluding the Magellanic Clouds, are 3C 273 and NGC 4151 which have fluxes $\sim 2 \times 10^{-13}$ ergs $cm^{-2}$ $s^{-1}$ $Å^{-1}$ at 1300 Å, while a well-exposed spectrum in the maximum 14 hour exposure generally obtainable with the *IUE* requires a flux of $\sim 3 \times 10^{-12}$ ergs $cm^{-2}$ $s^{-1}$ $Å^{-1}$. However, the regions of the strongest emission lines contain substantially more flux. By concentrating on the 20–60 Å wavelength region covered by the Lyα and C IV emission lines, useful observations (S:N ~ 6:1 at a resolution of 0.1 Å) may be obtained with a few 14 hour exposures. This procedure extends the range of the *IUE* for extragalactic interstellar studies to about a dozen Seyfert galaxies and QSOs. The distribution in galactic coordinates of these objects is shown in Figure 1 which is discussed later; their Lyα fluxes are given by Wu, Boggess, and Gull (1980). In addition, occasional supernovae are bright enough for this purpose.

By combining the *IUE* observations with high dispersion observations of the optical species Ca II and Na I, a detailed picture of the gas distribution can be constructed. We have embarked on such a program, and in this paper we present our first results for two lines of sight, namely the Seyfert 1 galaxies Markarian 509 and Fairall 9. The coordinates and redshifts are given in Table 1. Gas in our Galaxy is seen toward both, as well as near the redshift of Mrk 509 and in the Magellanic Stream. We demonstrate how these data constrain the properties of the gaseous halo of our Galaxy.

## II. OBSERVATIONS

### *a*) *Ultraviolet Data*

The *IUE* observations of Mrk 509 and F9 were made at high dispersion using the short wavelength prime (SWP) camera. These exposures were started at the Villafranca Satellite Tracking Station and read down at the Goddard Space Flight Center (GSFC). In this way,

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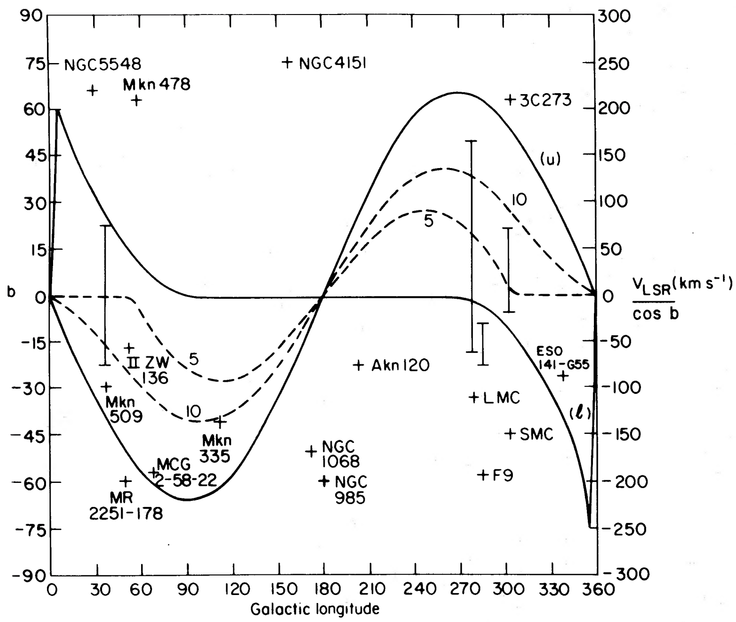


FIG. 1.—Plot of galactic latitude (left ordinate) vs. longitude showing the distribution of extragalactic sources suitable for high resolution interstellar studies with the *IUE*. The plot of LSR velocity/cos *b* (right ordinate) vs. longitude illustrates the extreme velocities predicted for a halo corotating with the disk, according to the rotation curve of Gunn, Knapp, and Tremaine (1979). The range is expected to extend from the solid curve *u* to curve *l* for a halo of infinite extent, and from the appropriate dashed curve to *l* for halos of 5 and 10 kpc. The vertical bars show the range of observed velocities for the directions to the Magellanic Clouds (Savage and de Boer 1981) and Mrk 509 (this paper).

advantage was taken of the low particle radiation encountered by the satellite during this part of its geosynchronous orbit. The journal of observations is given in Table 2.

These long exposures show evidence of camera fogging which is induced by background radiation and the delayed effects of flooding the camera face plate during preparation. The *IUE* data number values (DN) for the gross and background exposures for the Ly$\alpha$ and C IV emission regions are given in Table 2.

In high dispersion mode, the SWP camera is expected to have a resolving power of $R \sim 1.2 \times 10^4$. This agrees reasonably well with the FWHM of 0.085 Å or 22 km s$^{-1}$ measured for an emission line at 1150 Å from the Pt-Ne wavelength calibration lamp on board the satellite (Boggess *et al.* 1978*b*). The wavelength scale for exposures using the small aperture and the SWP can be determined to an accuracy of 5 km s$^{-1}$ in high dispersion (Leckrone 1980), although instrumental changes (temporal and thermal) can introduce spectral shifts, which are correctable, as large as 20 km s$^{-1}$ (Turnrose, Harvel, and Bohlin 1981). We took precautions to minimize such uncertainties by taking calibration Pt-Ne arc and flat field exposures between two of the Mrk 509 exposures, SWP 9358 and SWP 9359, and using these images to establish the wavelength scale. No calibration spectra were used for the third Mrk 509 image nor for SWP 13319 of F9. However, checks show that these data will not be in error by more than 10.5 km s$^{-1}$, which is smaller than the instrumental resolution.

TABLE 1

COORDINATES AND REDSHIFTS OF MRK 509 AND F9

| | Mrk 509 | F9 (ESO 113, IG 45) |
|---|---|---|
| $\alpha$(1950.0)............... | $20^h41^m26^s.25$ | $01^h21^m51^s.18$ |
| $\delta$(1950.0)............... | $-10°54'17''.4$ | $-59°03'58''.2$ |
| *l* ....................... | 35°.97 | 295°.07 |
| *b* ....................... | $-29°.86$ | $-57°.83$ |
| Heliocentric velocity ... | 10,150 km s$^{-1}$ | 13,850 km s$^{-1}$ |
| Correction to LSR...... | +11 km s$^{-1}$ | $-12$ km s$^{-1}$ |
| References ............ | Wilson and Meurs 1978<br>AAT measured H$\alpha$ velocity | Wilson and Meurs 1978<br>Martin *et al.* 1978 |

TABLE 2

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| Date (UT start) | Exposure (min) | *IUE* Image Number | *IUE* Exposure Level Lyα (DN) | *IUE* Exposure Level C IV (DN) | Aperture (arcsec) | Spectral Region (Å) |
|---|---|---|---|---|---|---|
| | | | Mrk 509 (*IUE* observations) | | | |
| 1980 Jun 23.93 .... | 820 | SWP 9357 | gross 135 | 155 | ... | ... |
| | | | bkgd 90 | 115 | | |
| 1980 Jun 24.93 .... | 820 | SWP 9362 | gross 125 | 140 | 22×9 | 1246–1270 |
| | | | bkgd 80 | 100 | | &1591–1621 |
| 1981 Apr 13.01 ... | 1200 | SWP 13708 | ... | ... | ... | ... |
| | | | Mrk 509 (AAT observations) | | | |
| 1980 Aug 01.45 ... | 100 | ... | ... | ... | 4.2×0.64 | 3920–4060 |
| 1980 Aug 01.57 ... | 107 | ... | ... | ... | 2.8×0.64 | 5855–6140 |
| | | | F9 (*IUE* observations) | | | |
| 1981 Feb 16.29 ... | 885 | SWP 13319 | gross 150 | 170 | 22×9 | 1264–1280 |
| | | | bkgd 85 | 115 | | &1611–1631 |

The *IUE* spectra were reduced with the standard point source extraction schemes by the GSFC observatory staff. The data were averaged into 0.2 Å intervals, and in the case of Mrk 509 the three images were added.

### *b*) *Optical Data*

High dispersion spectra of Na I and Ca II were obtained with the 3.9 m Anglo-Australian telescope (AAT) on 1980 August 1. These data were taken with the RGO spectrograph 82 cm camera and a 1200 lines $mm^{-1}$ grating, using the image photon counting system (IPCS) as detector (Boksenberg and Burgess 1973). The journal of these observations is also contained in Table 2. The observations were made at a dispersion of 5 Å $mm^{-1}$ (2d order) Ca II and 10 Å $mm^{-1}$ for Na I, using a spectrograph entrance slit that corresponded at 0.″64 on the sky and projected to 60 μm at the photocathode.

During the exposures, Mrk 509 was beam switched between two IPCS photocathode positions to allow for subsequent removal of the night-sky spectrum. The resulting net spectra have ~500 photon counts per IPCS channel in the continuum near Ca II and ~320 at Na I with sky signals of 10 and 17, respectively. Comparison arc spectra using a Cu-Ar hollow cathode lamp were taken at frequent intervals during the course of the Mrk 509 exposures. The narrowest Ar comparison lines have widths of about 0.28 Å for Ca II and 0.60 Å for Na I. The spectra were reduced using the scanner data reduction system largely developed at the Anglo-Australian Observatory by J. O. Straede.

Observations of interstellar Ca II and Na I in the F9 line of sight, already published by Songaila (1981), were obtained with the echelle spectrograph at the 4 m telescope of the Cerro Tololo Inter-American Observatory. These spectra are at a similar resolution as the AAT data.

## III. RESULTS

### *a*) *Markarian 509*

The wavelength regions about the Lyα and C IV emission lines are shown in Figure 2. In these spectra we detect absorption lines belonging to Fe II λ1608.46, Si II λ1260.42, and S II λ1259.52 near zero redshift, as well as Lyα λ1215.67 and probably C IV λ1548.20 at a redshift

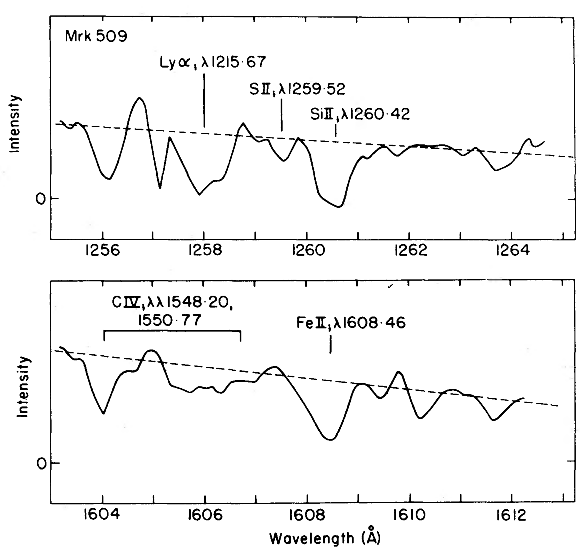


FIG. 2.—Spectra of the Lyα and C IV emission features in Mrk 509. Position of the adopted continuum is shown by the broken line.

TABLE 3

ULTRAVIOLET INTERSTELLAR LINES IN MRK 509 AND F9

| $\lambda_{obs}^{vac}$ (Å) | Ident. | $\lambda_{lab}^{vac}$ (Å) | EW[a] (Å) | $v_{LSR}$ range at FWHM[b,c] (km s$^{-1}$) |
|---|---|---|---|---|
| | | Mrk 509 | | |
| 1256.1 .... | ... | ... | 0.37 | ... |
| 1258.0 .... | Lyα | 1215.67 | 0.77 | +10,355–+10,560 |
| 1259.5 .... | S II | 1259.52 | 0.14 | −30–+40 |
| 1260.6[d] ... | Si II | 1260.42 | 0.91 | −55–+100 |
| 1604.0 .... | C IV | 1548.20 | 0.31 | +10,785–+10,850 |
| 1608.4 .... | Fe II | 1608.46 | 0.57 | −75–+55 |
| | | F9 | | |
| 1260.6, 1261.1 .... | Si II | 1260.42 | 1.41 | −45–+220 |

[a]Uncertainties ±0.05, 1 σ.

[b]Heliocentric, $v_{LSR}$ corrections are +11 km s$^{-1}$ for Mrk 509, −12 km s$^{-1}$ for F9.

[c]Each number could be in error by ±20 km s$^{-1}$, because of noise and errors in object centering, sampling, and wavelength calibration; $v_{LSR}$ is accurate to +20 km s$^{-1}$, since some error sources are systematic.

[d]Uncorrected for a likely contribution of <6% from a blended Fe II line (Morton 1978).

of 0.0354. After allowance is made for the instrumental broadening, the mean velocity width (FWHM) of the Si II and Fe II lines is from −65 to +75 km s$^{-1}$ (LSR). Equivalent widths of these lines are contained in Table 3. At 1260 Å in ζ Pup, Morton (1978) found Fe II to have about 6% the equivalent width of Si II, so we have ignored the Fe II contribution here.

In the weaker optical lines, we detect two components in both the Ca II λλ3933.66, 3968.47 and Na I λλ5889.95, 5895.92 doublets with weighted mean velocities (LSR) of +5.9 and +62.4 km s$^{-1}$. Velocities, equivalent widths, and column densities of all these components are given in Table 4. An upper limit of ±15 mÅ can be set on any other Ca II absorption up to ±500 km s$^{-1}$. The same limit applies to any intergalactic gas out to +9453 km s$^{-1}$. Ca II at 10,150 km s$^{-1}$, corresponding to the heliocentric velocity of Mrk 509, lies outside the range of the observation.

### *b*) *Fairall 9*

We have supplemented our data by adding in SWP 9615 (802 min exposure) obtained from the data archive. The resulting Si II λ1260.42 absorption feature

TABLE 4

OPTICAL INTERSTELLAR LINES IN MRK 509 AND F9

| Ident. | $v_{LSR}$ (km s$^{-1}$) | $W_\lambda$ (Å) | $b$ (km s$^{-1}$) | log $N$ (cm$^{-2}$) | $v_{LSR}$ (km s$^{-1}$) | $W_\lambda$ (Å) | $b$ (km s$^{-1}$) | log $N$ (cm$^{-2}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | Mrk 509 (AAT observations) | | | | |
| Na I D$_1$ ... | +9.9 | 0.088 | ≥ 8 | 11.98±0.04 | +59.4 | 0.023 | 1 | 11.41±0.08 |
| Na I D$_2$ ... | +9.7 | 0.157 | | | +66.4 | 0.036 | | |
| Ca II H ... | +1.0 | 0.102 | ≥15 | 12.38±0.04 | +51.7 | 0.073 | ≥15 | 12.24±0.04 |
| Ca II K ... | +2.5 | 0.201 | | | +65.2 | 0.146 | | |
| | | | | F9 (CTIO observations) | | | | |
| Na I D$_2$ ... | ... | <0.045 | ... | ... | ... | <0.045 | ... | ... |
| Ca II K ... | −12 | 0.135 | ... | ... | +193 | 0.187 | ... | ... |

NOTE.—Wavelengths and oscillator strengths are taken from Morton and Smith 1973. Column densities and $b$ values have been determined assuming a single cloud with a Gaussian velocity distribution.

shows two velocity components, with an overall FWHM extending from $-45$ to $+220$ km $s^{-1}$ (LSR) after allowance for the instrumental broadening. Measurements are contained in Table 3. We attribute the lower velocity component to gas in our Galaxy; the higher velocity component, which extends from $\approx +100$ km $s^{-1}$ to $+220$ km $s^{-1}$, may be associated with the Magellanic Stream or be an outer halo component of the SMC. On kinematic grounds, it is unlikely to be associated with our own galactic halo (cf. § IV).

The Ca II K profile in this direction (Songaila 1981) is similar to that of Si II. In particular, the K line extends out to $+235$ km $s^{-1}$. However, the sharp edge at $+180$ km $s^{-1}$ seen in the K line does not appear in Si II—there is almost continuous absorption in Si II extending down to the low velocity galactic component.

### *c*) *N*(Ca II)/*N*(Na I) *Ratios*

In low velocity H I clouds that originate in the galactic disk, the value of the Ca II/Na I ratio tends to be unity (Münch 1968). However, in high velocity clouds (Routly and Spitzer 1952; Siluk and Silk 1974) and in some gas along high latitude lines of sight ($z \leq 1$ kpc) (Cohen and Meloy 1975), this ratio is enhanced.

Enhancement of the Ca II/Na I ratio is present for the high velocity clouds in both Mrk 509 and F9 lines of sight. In the case of Mrk 509, the $+62.4$ km $s^{-1}$ component exhibits $N(\text{Ca II})/N(\text{Na I}) = 6.6$, while the other component has a value of 2.5.

In the line of sight to F9, the high velocity component at $v_{\text{LSR}} = +193$ km $s^{-1}$ has $W_\lambda(\text{K}) = 187$ mÅ, whereas Na I is not detected to the limit of $W_\lambda(\text{D}_2) < 45$ mÅ. In this second example of a high Ca II/Na I ratio, Songaila (1981) has shown from considerations of Ca and Na ionization equilibria that the cloud must be hot with $T_e \approx 10^4$ K and ascribes its origin to the Magellanic Stream (Mathewson, Cleary, and Murray 1974). In fact, this cloud could extend as far as the Small Magellanic Cloud, where numerous stars widely spaced over the face of the SMC exhibit a $+200$ km $s^{-1}$ component (Blades, unpublished). The low velocity Ca II cloud in F9 is attributed to local disk material.

### *d*) *Intergalactic Absorption*?

It is also of interest to note that an absorption line system may be seen at a redshift of $0.0354 \pm 0.0007$ in the Ly$\alpha$ and C IV absorption lines of Mrk 509. This is close to the redshift of 0.0344 of Mrk 509 found from optical emission lines (AAT measure of H$\alpha$). According to Table 3, the good agreement in the galactic S II and Fe II wavelengths make it unlikely that the proposed identifications of Ly$\alpha$ and C IV at $z \sim 0.0354$ have exactly the same redshift, and these identifications require confirmation. Sargent *et al.* (1979) suggest that there should be about 100 clouds showing mainly Ly$\alpha$ absorption to a QSO having a redshift of $z = 1$. Our observations sample $\Delta z \sim 0.01$ to the blueward of the Seyfert so that one such system should indeed be found, though in our case it may be associated with Mrk 509 rather than being truly intergalactic.

## IV. ANALYSIS

Weisheit (1978) discussed the possibility that halo gas corotated with the disk. Bregman (1980) has published hydrodynamic calculations for a "galactic-fountain" model (Shapiro and Field 1976) in which halo gas is disk gas that has risen and moved outward by virtue of its high temperature, then cooled at high latitudes, and fallen back to its point of origin in the disk. In addition, random motions may exist, owing to gas accelerated by recent supernovae explosions in the halo, for instance.

For the simplest case of a hydrostatic halo described by a barytropic equation of state, $P = f(\rho)$, where $P$ is the pressure and $\rho$ is the density, it may be trivially shown that the gas must have a rotation curve which is independent of $z$, the distance from the galactic plane. For, in this case, the hydrostatic equation ($v$ = rotation velocity, $\Phi$ = gravitational potential),

$$-\nabla P + \frac{\rho v^2}{r}\hat{r} = -\rho \nabla \Phi,$$

in cylindrical coordinates $(r, z, \phi)$ with origin at the galactic center, may be written as,

$$\frac{d}{dz}(G(\rho) - \Phi) = 0, \quad \frac{d}{dr}(G(\rho) - \Phi) = \frac{v^2}{r},$$

$$G(\rho) = \int \frac{1}{\rho}\frac{dP}{d\rho}\, d\rho.$$

Integration of the first equation shows that $G(\rho) - \Phi$ is $z$ independent, and substitution into the second shows that $v$ is a function of $r$ only.

This is the simplest plausible model for the galactic halo, and on this basis we have calculated the extreme velocities using the rotation curve of Gunn, Knapp, and Tremaine (1979). In Figure 1, the abscissa is galactic longitude while the ordinate is galactic latitude, $b$. Material in a halo of infinite extent would extend in velocity from the solid curve marked ($u$) to that marked ($l$). Random motions would widen the velocity range. We have also shown the range of absorption velocities which would be seen if the halo has a finite extent (dashed curve) $z/\sin b$ for two values of $z/\sin b$ (5 kpc and 10 kpc). In this case, gas would extend from the dashed curve to the solid curve marked ($l$).

Sources observable with the *IUE* high dispersion mode are also shown on Figure 1. In those cases where useful results are available, we have shown the range of observed velocities.

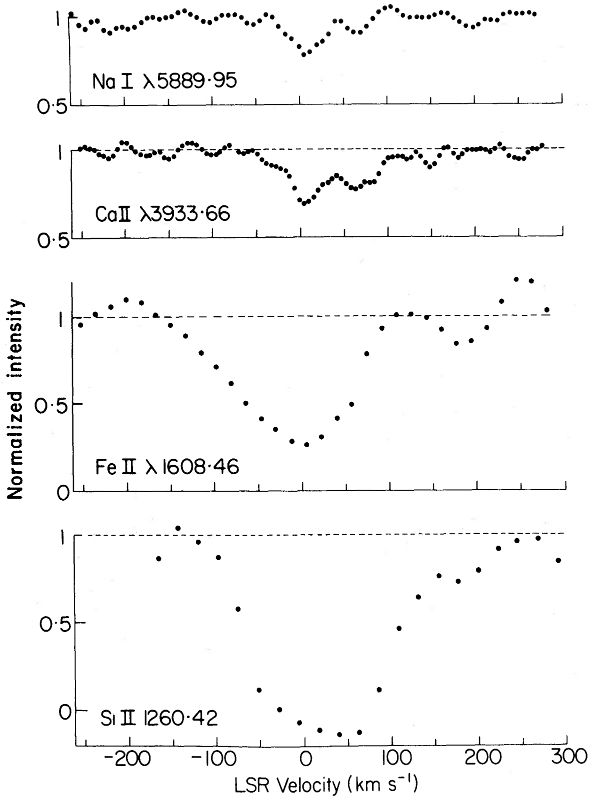


FIG. 3.—Velocity profiles (LSR) of the galactic absorption lines Na I $D_2$, Ca II K, Fe II λ1608.46, and Si II λ1260.42 in the direction of Mrk 509.

In Figure 3, we plot the velocity profile of the galactic absorption lines of Si II, Fe II, Ca II, and Na I for the lines of sight to Mrk 509. We have also calculated the velocity difference owing to rotation as a function of the height ($z$) of the observed gas. This calculation follows the procedure adopted by Savage and de Boer (1981) in the case of the Magellanic Clouds. The computed velocity difference as a function of height is shown in Figure 4, where we also indicate the velocity range covered by the UV absorption lines and show the position of the visual absorption lines.

The most important point to emphasize in these figures is that all the available data are consistent with a corotating halo. There are no indications of large systematic motions superposed on such a pattern. The absence of any negative velocity in the gas in the spectrum of F9, in particular, strongly suggests that random motions of much greater than 20 or 30 km $s^{-1}$ are not present in the halo gas seen in these observations. The absence of the most negative velocity gas in Mrk 509 and the most positive velocity material in the LMC/SMC and in F9 indicates that the height of the gas producing the UV absorption lines is less than 10 kpc. Pettini *et al.* (1981) found the same result for interstellar lines in the 1981 supernova in NGC 6946. This line of sight ($l=96°$, $b=+12°$) samples a quite different region of the Galaxy than the Mrk 509 and the F9/Magellanic Clouds sight lines.

Interestingly, in the case of Mrk 509 the optical absorption lines do not require material to extend more than a few kiloparsecs from the plane. This is well shown in Figure 4. Note the absence of negative velocity gas which should be present for material situated more than 7 kpc below the plane. This result is consistent with that found for galactic Ca II in the 1980 supernova in Fornax A (Blades 1981). In this context, we point out also that the absorption strength of Ca II in Mrk 509 and F9 is within the range of strengths seen toward other high latitude, extragalactic background sources such as supergiants in the Magellanic Clouds (Blades 1980, and in preparation), supernovae (Penston and Blades 1980; Blades 1981), and other Seyfert galaxies and QSOs (Blades and Morton, in preparation). High latitude galactic B stars observed at the same resolution with the same instrumentation on the AAT (Keenan *et al.* 1981) also show very similar Ca II strengths. The implication is that most of the low velocity absorption seen in high latitude background sources originates within local material (1–2 kpc of the solar neighborhood).

While the existing kinematic data are not compelling as yet, we think we are beginning to see the signs of an extended corotating gaseous halo possibly having a decreasing density as a function of height.

Si II is an ion typically found in QSO absorption-line spectra at redshift $z \leq z$ (QSO). Such lines are normally associated with halos of intervening galaxies, but the required spherical halo sizes are typically 100 kpc (Bahcall and Spitzer 1968). Our initial purpose was to determine whether or not our own halo has such an extent. The present results are not consistent with a halo with such a large extent in Si II perpendicular to the disk, except in the unlikely event that gas at such large distances has velocities similar to the LSR velocity of the solar position.

## V. SUMMARY

In this preliminary report, we have argued that available data on extragalactic lines of sight are consistent with a hydrostatic halo with an observable height of 10 kpc in the strong UV lines and 2 kpc in the Ca II absorption lines. It is very important to emphasize that this conclusion is entirely consistent with previous observations of high latitude stars. Clearly more information is required to reach a firm conclusion. According to Figure 3, it is particularly important to observe gas in Mrk 335 ($l=109°$, $b=41°$) and Akn 120 ($l=200°$,

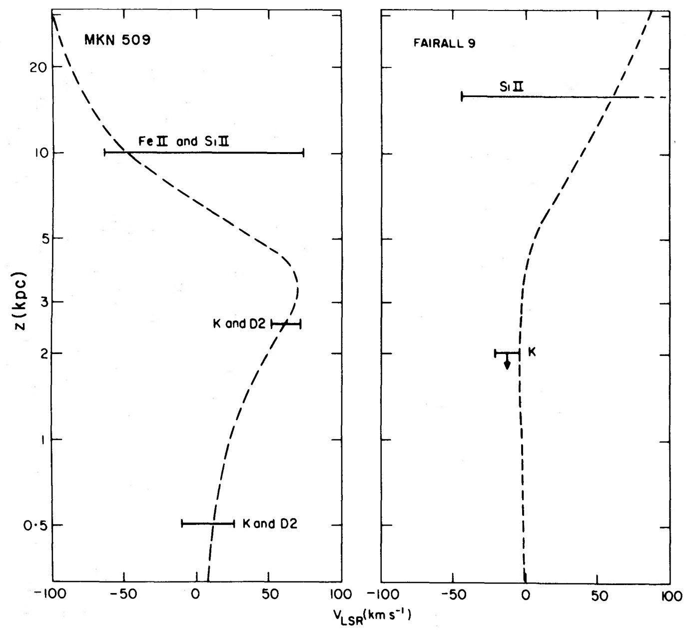


FIG. 4.—Plot of LSR velocity due to galactic rotation as a function of $z$ distance from the plane for Mrk 509 and F9. The horizontal bars show the velocity ranges of the interstellar absorption lines after allowance for instrumental broadening. Their vertical position shows the distance from the galactic plane where these lines could originate according to the corotating model, assuming the velocities are exact. The actual distance could be greater or lesser, depending on (a) the true gas velocity (ours is observationally uncertain) and (b) the random dispersion of gas clouds within the corotation picture. With these uncertainties, the low velocity cloud in the spectrum of Mrk 509 has $d < 2$ kpc, the other has 2 kpc$< d < 5$ kpc, allowing up to $\pm 20$ km s$^{-1}$ deviation from pure corotation.

$b = -20°$). Any galactic gas in these directions should have purely negative and purely positive velocity, respectively. These objects are presently being observed, and we will report on the results in a subsequent and more detailed paper.

Two extragalactic clouds were also detected, one associated in velocity with the SMC/Magellanic Stream complex and one with Seyfert galaxy, Mrk 509.

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## REFERENCES


Bahcall, J., and Spitzer, L. 1969, *Ap. J. (Letters)*, **156**, L63.
Blades, J. C. 1980, *M.N.R.A.S.*, **190**, 33.
______. 1981, *M.N.R.A.S.*, **196**, 65P.
Boggess, A., *et al.* 1978*a*, *Nature*, **275**, 372.
______. 1978*b*, *Nature*, **275**, 377.
Boksenberg, A., and Burgess, D. E. 1973, *Proc. Symposium on Astronomical Observations with Television-type Sensors*, ed. J. W. Glaspey and G. A. H. Walker (Vancouver: University of British Columbia Press), p. 21.
Bregman, J. N. 1980, *Ap. J.*, **236**, 577.
Cohen, J. G., and Meloy, D. A. 1975, *Ap. J.*, **198**, 545.
Gunn, J. E., Knapp, G. R., and Tremaine, S. D. 1979, *A.J.*, **84**, 1181.
Keenan, F. P., McKeith, C. D., Dufton, P. L., and Blades, J. C. 1981, *M.N.R.A.S.*, in press.
Leckrone, D. S. 1980, *IUE Newsletter*, No. 10, p. 25.
Martin, W. L., Penfold, J. E., and Glass, I. S. 1978, *M.N.R.A.S.*, **184**, 15P.
Mathewson, D. S., Cleary, M. N., and Murray, J. D. 1974, *Ap. J.*, **190**, 291.
Morton, D. C. 1978, *Ap. J.*, **222**, 863.
Morton, D. C., and Smith, W. H. 1973, *Ap. J. Suppl.*, **26**, 333.
Münch, G. 1968, *Stars and Stellar Systems*, Vol. **7**, *Nebulae and Interstellar Matter*, ed. B. M. Middlehurst and L. H. Aller (Chicago: University of Chicago Press), p. 365.
Penston, M. V., and Blades, J. C. 1980, *M.N.R.A.S.*, **190**, 51P.
Pettini, M., *et al.* 1981, *M.N.R.A.S*, submitted.
Routly, P. McR., and Spitzer, L., Jr. 1952, *Ap. J.*, **115**, 227.
Sargent, W. L. W., Young, P. J., Boksenberg, A., Carswell, R. F., and Whelan, J. A. J. 1979, *Ap. J.*, **230**, 49.
Savage, B. D., and de Boer, K. S. 1979, *Ap. J. (Letters)*, **230**, L77.
______. 1981, *Ap. J.*, **243**, 460.
Shapiro, P. R., and Field, G. B. 1976, *Ap. J.*, **205**, 762.
Siluk, R. S., and Silk, J. 1974, *Ap. J.*, **192**, 51.
Songaila, A. 1981, *Ap. J. (Letters)*, **243**, L19.

Turnrose, B. E., Harvel, C. A., and Bohlin, R. C. 1981, *The Universe at Ultraviolet Wavelengths: The First Two Years of IUE*, ed. R. D. Chapman (NASA CP-2671, Washington, DC: GPO), p. 792.
Weisheit, J. C. 1978, *Ap. J.*, **219**, 829.
Wilson, A. S., and Meurs, E. J. A. 1978, *Astr. Ap. Suppl.*, **33**, 407.
Wu, C.-C., Boggess, A., and Gull, T. R. 1980, *Ap. J.*, **242**, 14.

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