The Milky Way halo as QSO absorption-line system

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Summary

We use archival UV absorption-line data from HST/$STIS$ to statistically analyze the absorption characteristics of the high-velocity clouds (HVCs) in the Galactic halo towards more than 40 extragalactic background sources and compare them with the properties of (strong) intervening Mg II absorbers. Combining information for Si II and Mg II, and using the geomeotrical HVC model of Richter (2011) [1] we estimate that the mean projected covering fraction of strong Mg II absorption (with $W_{2796} > 0.3$ Å) in the Milky Way halo and disk from an exterior vantage point is $\langle f_{\rm c,sMgII}\rangle = 0.35$ for a halo radius of $R = 61$ kpc.

Results

These numbers, together with the observed number density of strong Mg II absorbers, imply that the Milky Way disk and halo have a cross section for strong Mg II absorption that is lower than the average cross section of Milky Way-size galaxies at $z = 0$. This finding are in line with the idea that galactic winds and outflows that arise the halos of more actively star-forming galaxies dominate the absorption-cross section of strong Mg II absorbers in the local Universe, while the contribution of infalling gas (i.e., HVC analogs) to the Mg II cross section is small.

HVC Complexes

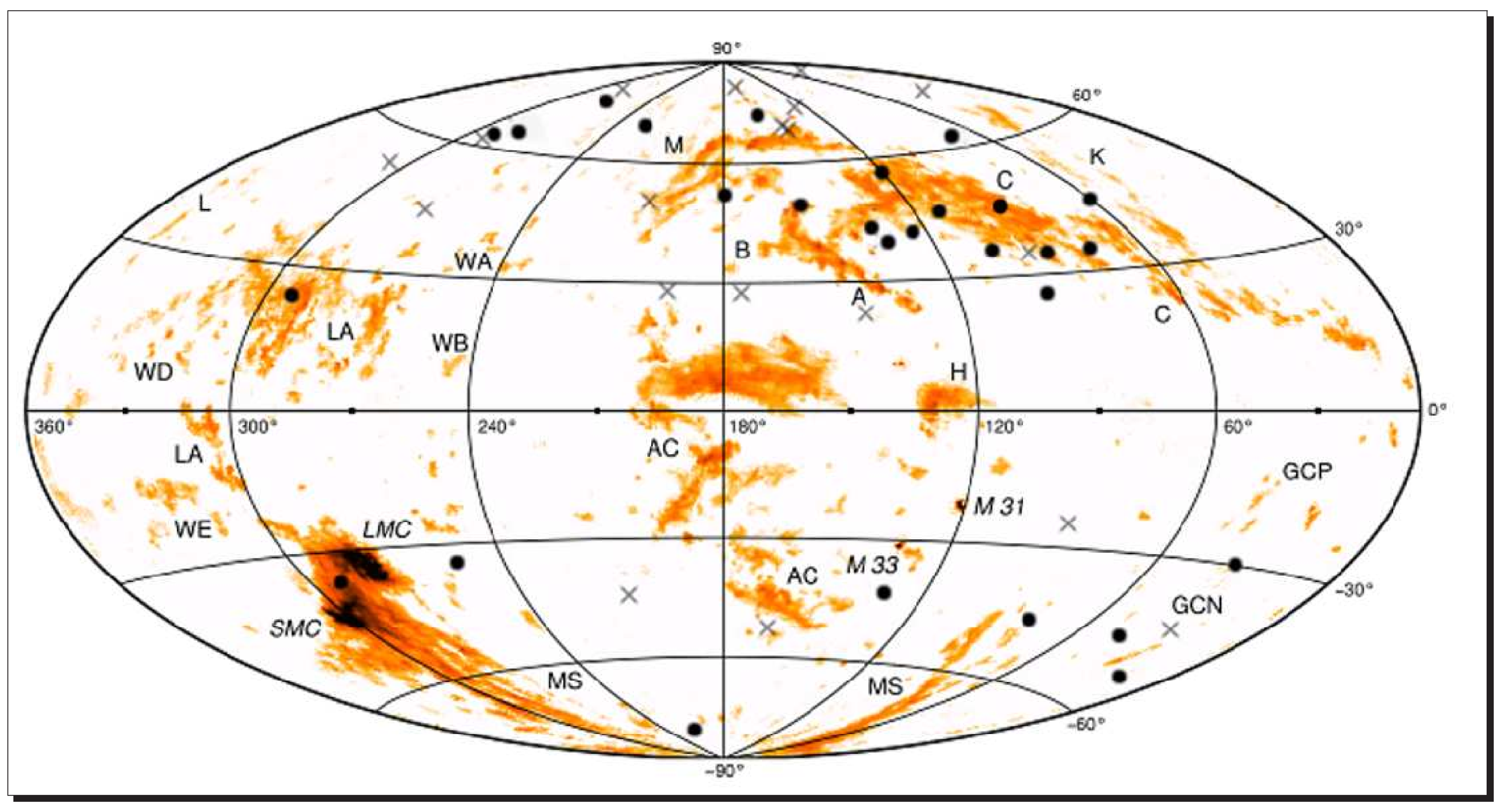
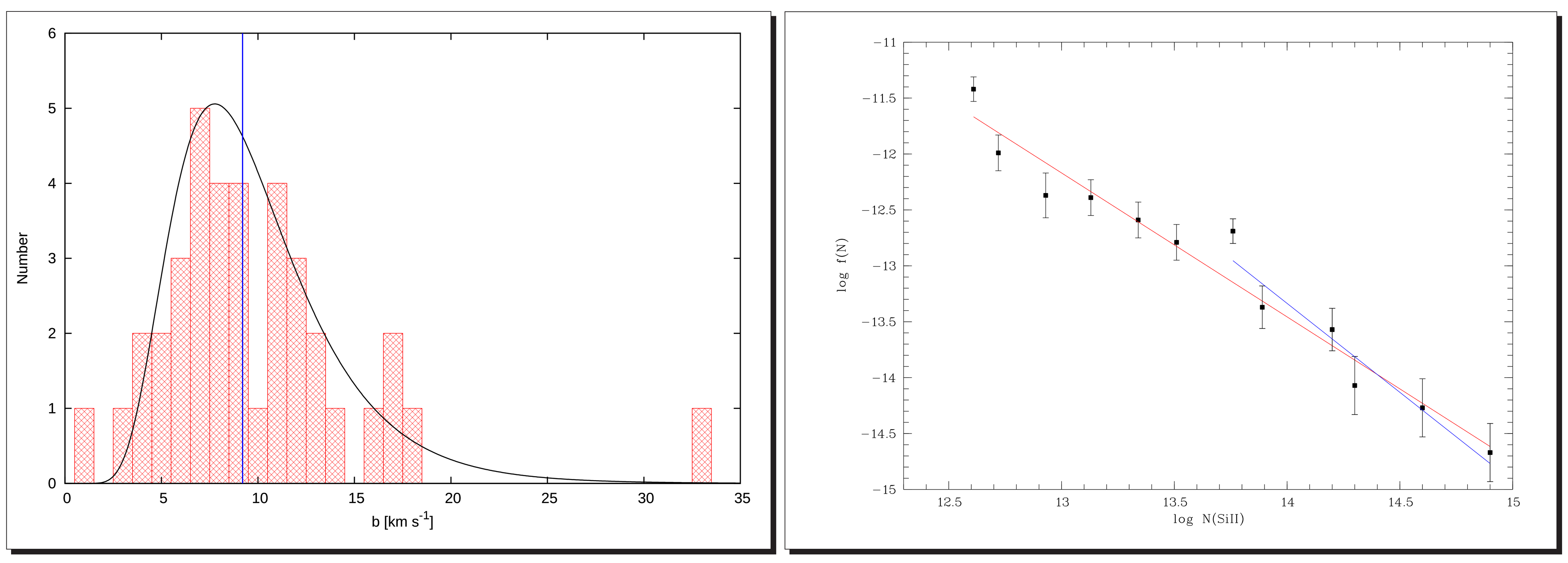


Figure 1: H I 21cm sky map of HVC complexes, based on the LAB survey [2]. The symbols mark the STIS sightlines inspected in this analysis. The filled circles indicates sightlines with HVC detections, whereas crosses indicate sightlines where no HVC absorption was found.

HVC Statistics

QSO Name	z_{em}	l (deg)	b (deg)	HVC status (yes/no)	HVC velocity range (km s^{-1})	HVC name (if known)	Relevant STIS grating	detected ions
PKS 2155−304	0.117	18	−52	yes	−138...−190	...	E140M	Si II, C II, Si III, Si IV, C IV
NGC 5548	0.020	32	+71	no	-	-	E140M, E230M	-
B 2121−1757	0.110	33	−42	no	-	-	E140M	-
Mrk 509	0.034	36	−30	yes	−295...−310	GCN	E140M, E230M	C II, Si III, Si IV, C IV
CSO 873	1.010	38	+84	no	-	-	E230M	-
PHL 1811	0.192	47	−45	yes	−130...−270	GCN	E140M	Si II, C II, O I, Al II, Si III, Si IV, C IV
PG 1630+377	1.480	60	+43	yes	−160...−60	-	E230M	Mg II, Fe II
PG 1444+407	0.270	70	+63	yes	−80...−90	-	E140M	Si II, C II, O I, C IV
PG 1718+481	1.083	74	+35	yes	−100...−215	C Extension	E230M	Fe II
NGC 7469	0.016	83	−45	yes	−190...−400	MS	E140M	Si II, C II, O I, Si III, Si IV, C IV
3c351	0.372	90	+36	yes	−130...−230	Complex C	E140M	Si II, C II, O I, Al II, Si III, Si IV, C IV
Mrk 290	0.030	91	+48	yes	−128	Complex C	E230M	Fe II
Akn 564	0.030	92	−25	no	-	-	E140M	-
H 1821+643	0.297	94	+27	yes	−130...−170	Outer Arm	E140M	Si II, C II, O I, Al II, Si III, Si IV, C IV
HS 1700+6416	2.740	94	+36	no	-	-	E140M	-
PG 1634+706	1.337	103	+37	yes	−100...−215	Complex C	E230M	Fe II
Mrk 279	0.031	115	+47	yes	−150...−200	Complex C south	E140M	Si II, C II, O I, Al II, Si III, Si IV
PG 1259+593	0.472	121	+58	yes	−120...−145	Complex C III	E140M	Si II, C II, O I, Al II, Si III, C IV
PG 1248+401	1.030	123	+77	no	-	-	E230M	-
Mrk 205	0.071	125	+42	yes	−110...−230	Complex C south	E140M	Si II, C II, O I, Al II
3c249.1	0.310	130	+39	yes	−135	-	E140M	Si II, C II, Si III
PG 0117+21	1.500	132	−41	yes	−134	-	E230M	Mg II, Fe II
NGC 3516	0.009	133	+42	yes	−160...−170	-	E140M, E230M	Si II, C II, Fe II, Mg II, Si III
PG 1206+459	1.160	145	+70	no	-	-	E230M	-
HS 0624+6907	0.370	146	+23	no	-	Outer Arm	E140M	-
NGC 4051	0.002	149	+70	no	-	-	E140M	-
NGC 4151	0.003	155	+75	yes	+120...+145	...	E140M	Si II, C II, Si III, C IV, Fe II, Mg II
Mrk 132	1.760	159	+49	yes	−140...+80	-	E230M	Mg II, Fe II
NGC 4395	0.001	162	+82	no	-	-	E140M, E 230M	-
PKS 0232-04	1.440	174	−56	no	-	-	E230M	-
HS 0747+4259	1.900	177	+29	no	-	-	E230M	-
PG 0953+415	0.239	180	+52	yes	−150	Complex M	E140M	Si II, C II, Si III, Al II
HS 0810+2554	1.510	197	+29	no	-	LLIV Arch	E230M	-
Ton 28	0.330	200	+53	no	-	-	E140M	-
PKS 0405−123	0.570	205	−42	no	-	-	E140M	-
PG 1116+215	0.177	223	+68	yes	+180...+190	EPn	E140M, E230M	Si II, C II, O I, Fe II, Mg II, Si III, Si IV, C IV
Ton S210	0.117	225	−83	yes	−150...−235	CHVC 224.0−83.4−197	E140M, E230M	Si II, C II, O I, Si III, Si IV, C IV
HE 0515−4414	1.713	250	−35	yes	+120...+230	-	E230M	Mg II, Fe II
PG 1211+143	0.081	268	+74	yes	+169...+184	...	E140M	Si II, C II, O I, Si III, C IV
PKS 1127−145	1.187	275	+44	no	-	-	E230M	-
PG 1216+069	0.330	281	+68	yes	+210...+270	...	E140M	Si II, Si III, C IV
NGC 3783	0.010	287	+23	yes	+180...+250	WW187	E140M, E230M	Si II, C II, O I, Al II, Fe II, Mg II, Si III
3c273	0.160	290	+64	no	-	EPn	E140M	-
RXJ 1230.8+0115	0.117	291	+63	yes	−216...−310	...	E140M	Si II, C II, O I, Si III, Si IV
PKS 0312−77	0.223	293	−38	yes	+160...+240	MB	E140M, E230M	Si II, C II, O I, Fe II, Mg II, Si III
PG 1241+176	1.280	293	+80	no	-	-	E230M	-
PKS 1302−102	0.290	309	+52	no	-	...	E140M	-

Table 1: Summary of QSO Sightlines and HVC Detections.



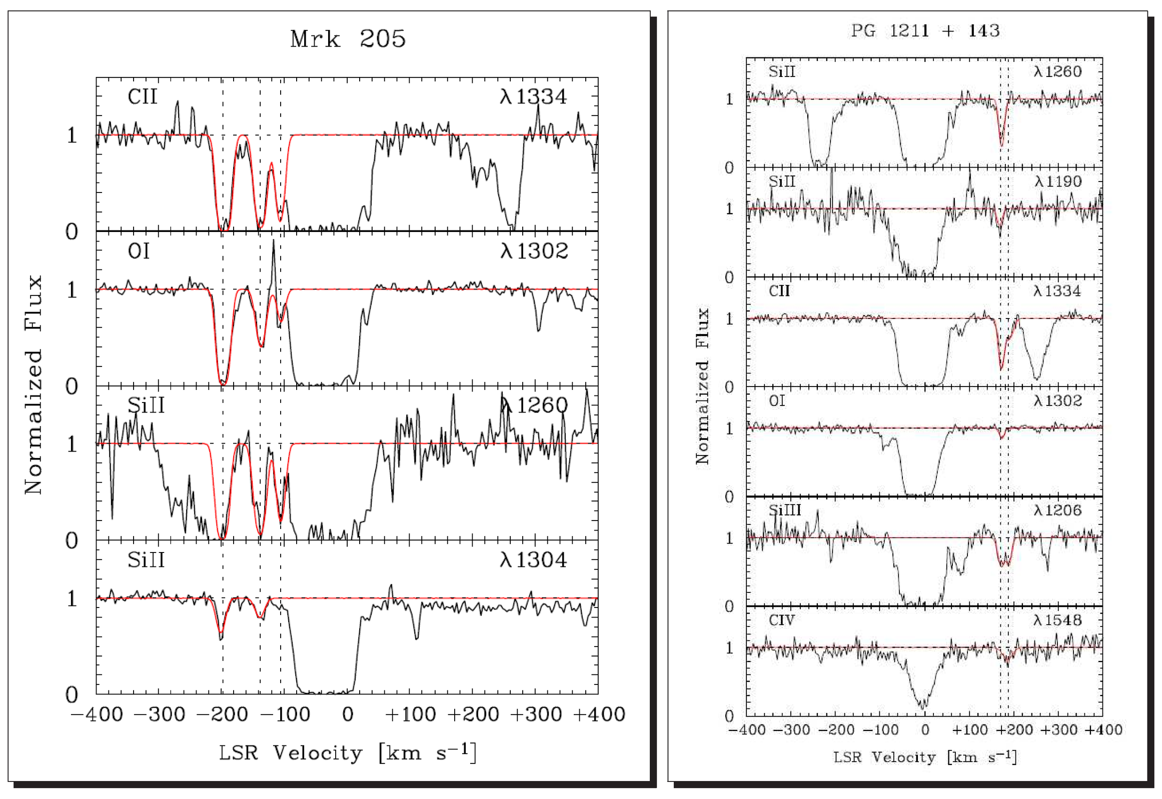
These two figure show an excerp of the statistic analysis. In the left panel the distribution of the Si II Doppler parameters based on Voigt-profile fitting is shown. The black solid line indicates a fit with a log-normal function. The blue line marks the median value at 9.2 km s^{-1}. In the right panel the column-density distribution function of Si II absorption components with parameters of log N(Si II) ≥ 12.5, $\beta = 1.29 \pm 0.09$ and log $C = 4.57 \pm 1.20$ for the red line is shown. It turns out that a simple power law doesn´t fit the distribution very well. If we apply a restriction of log N(Si II) ≥ 13.7 (blue line) we obtain parameters of $\beta = 1.59 \pm 0.23$ and log $C = 8.94 \pm 3.31$.

HVCs as intervening metal-line absorbers

The following table list the covering fraction and the limits for the column densities above which our sample is complete.

Ion	$\mathcal{N}/\mathcal{N}_{\rm tot}$ [a]	$f_{\rm c}$	log $N_{\rm min}$
C II	21/30	0.70	13.20
C IV	12/30	0.40	13.00
O I	14/29	0.48	13.65
Si II	20/30	0.67	12.25
Si III	21/30	0.70	12.15
Si IV	6/30	0.20	12.90
Mg II	10/19	0.53	12.70
Fe II	10/21	0.48	12.90

[a] Number of HVC detections above column-density threshold/total number of sightlines;



The upper figures show two representive sightlines with their individual ions and HVC fits.

Absorption-cross section of galaxies and their halos

The number density of gas in and around galaxies is directly related to the geometric cross section, so that for z = 0 [3]

$$\frac{dN}{dz} = \frac{n_g \langle f_c\rangle\, c\, \pi R_h^2}{H_0}. \quad (1)$$

Combining the data of Si II and Mg II and convolving it for a vantage point with $f_{HVC} = 2.1\, exp(-r/h)$ [4] we now can estimate the total absorption cross section and mean covering fraction of strong Mg II absorbers of Milky Way/M31 type galaxies. If we adopt a projected covering fraction of strong Mg II absorption in HVCs of $f_{c,s,MgII,halo}$ = 0.34 as derived from our STIS data we obtain a halo radius of r = 61 kpc and an avarage covering fraction (disk + halo) of $\langle f_{c,s,MgII}\rangle$ = 0.35.

References

[1] Richter, P., Krause, F., Fechner, C., Charlton, J. C.,& Murphy,M. T. 2011, A&A, 528, A12

[2] Kalberla, P. M. W. & Haud, U. 2006, A&A, 455, 481

[3] Kacprzak, G. G., Churchill, C. W., Steidel, C. C., & Murphy, M. T. 2008, AJ, 135, 922

[4] Richter, P. 2012, ApJ, 750, 165R