Probing Galaxies through Quasar Absorption Lines
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A search for organic molecules in intermediate redshift DLAs

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Abstract. There has been a renewed interest in searching for diffuse interstellar bands (DIBs) due to their probable connection to organic molecules and, thus, their possible link to life in the Universe. Our group is undertaking an extensive search for DIBs in DLAs via QSO absorption-line systems. Six of our DLA targets are presented here. Our equivalent width (EW) limits for the λ5780 DIB line strongly suggest that DIB abundance is below the Milky Way expected value or that metallicity plays a large role in DIB strengths.

1. Introduction

Diffuse interstellar bands (DIBs) are absorption features seen abundantly in the Galaxy towards highly reddened stars, implying that DIBs exist in dusty environments. The current belief is that the majority of the several hundred DIB lines discovered so far are due to organic molecules such as polycyclic aromatic hydrocarbons (PAHs). Due to the possible connection to the building blocks of life, DIBs have experienced an enhanced level of interest in the last several years. Because of the difficulty in detecting their relatively weak spectral features, extragalactic searches for DIBs using QSO absorption lines are more rare; however, there is one detection of the λ4428 DIB line in a DLA at $z = 0.5$ toward AO 0235+164 (Junkkarinen *et al.* 2004).

It would be desirable to put DIBs on the same statistical grounds as metal line systems typically seen in QSO absorption-line studies. In our search for extragalactic sources of DIBs, we are investigating the feasibility of using the redshift path density (dN/dz) to constrain the evolution of organic molecules through cosmic time and of using DIBs as a proxy for finding DLAs with $z < 1$. In this article we examine six DLAs for the five strongest DIB lines (λ4428, λ5780, λ5797, λ6284, and λ6613) and place upper-limits on their strengths relative to Galactic DIBs.

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Table 1. Equivalent width limits of DIBs in DLAs

QSO	z_{abs}	log N(H I)	Facility	DIB 3σ Rest–Frame EW Limits, mÅ λ4428	λ5780	λ5797	λ6284	λ6613
0738+313	0.091	21.2	**APO/DIS**	**<37**	**<22**[a]	**<21**	**<28**	**<28**
			MW Predicted	197	205	47	218	82
			Z=−1 Scaled	20	20	5	22	8
0738+313	0.221	20.9	**APO/DIS**	**<51**	**<22**	**<22**	**<30**	**...**
			MW Predicted	82	85	19	91	
			Z=−1 Scaled	8	9	2	9	
0827+243	0.518	20.3	**Keck/HIRES**	**<390**[b]	**<34**	**<34**	**...**	**...**
			MW Predicted	13	13	3		
			Z=−1 Scaled	1	1	<1		
0952+179	0.239	21.0	**WHT/ISIS**	**...**	**<146**	**<129**	**<211**	**...**
			MW Predicted		324	74	346	
			Z=−1 Scaled		35	7	34	
1127-145	0.313	21.7	**Gem/GMOS**	**...**	**<569**	**<759**	**<248**	**<427**
			VLT/UVES	**<63**	**...**	**...**	**...**	**...**
			MW Predicted	1,053	1,093	249	1,167	436
			Z=−1 Scaled	103	107	24	114	43
1229-020	0.395	20.7	**WHT/ISIS**	**...**	**<262**	**<185**	**<475**	**...**
			MW Predicted		53	12	57	
			Z=−0.47 Scaled[c]		42	4	19	

[a] Sky Line - not included in limit
[b] Large Blend - unblended limit is 7 mÅ
[c] Metallicity from Boissé *et al.* (1998)

2. Results and discussion

The results for our observations and predictions are presented in Table 1; the observations are in bold. To arrive at our "MW Predicted" limits for DIB strengths we use a known correlation where the λ5780 equivalent width (EW) is proportional to the neutral hydrogen column density, N(H I), in Milky Way clouds (Herbig 1993; York *et al.* 2005, in preparation). We use this relation to scale the Milky Way values to the observed N(H I) of the DLAs. Our results are plotted in the left panel of Fig. 1 for the λ5780 DIB line. Presented are observed limits on the DLA DIB strength versus expected Milky Way DIB strength for a cloud with the DLA N(H I). Those points below the 1:1 correlation line correspond to DLAs that are deficient in the λ5780 DIB based purely on Milky Way expectations. Four of our six DLAs have λ5780 DIB strengths at least 0.5 dex below Milky Way strengths. Points above the 1:1 correlation line are unconstrained and additional data are required to obtain meaningful limits on the DIB strengths. For our entries in Table 1, we applied a similar scaling to the other DIB lines using their relative strengths in the Milky Way (Jenniskens & Desert 1994). The λ4428 DIB line is scaled by an additional factor of 25% based on the DLA at $z = 0.5$ towards the QSO AO 0235+164 (Junkkarinen *et al.* 2004).

Including the DLA metallicity, we estimate the DIB strengths by

$$\log EW = \log EW_{DIB} + \Big(\log N(\mathrm{H\,I}) - 20.3 \Big) + [\mathrm{Zn/H}]\ \mathrm{m\AA}, \tag{2.1}$$

where EW_{DIB} is the EW of the particular DIB line in the Milky Way at log N(H I) =20.3, the second factor is due to the slope of the known Milky Way relation between the log EW of the λ5780 DIB line and the log N(H I) of the cloud, and a linear relationship with metallicity is assumed. A [Zn/H] of −1 is applied when metallicity is not known

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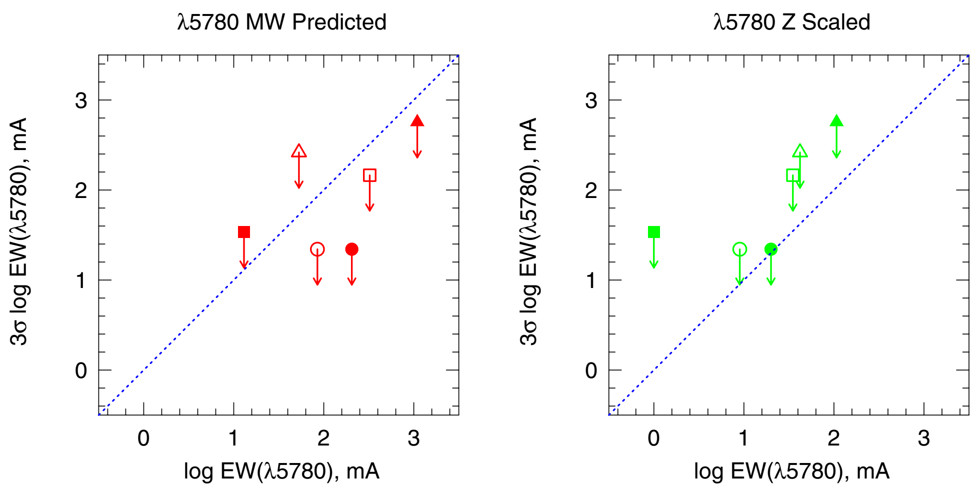

Figure 1. — (left) Measured 5780 DIB strength (upper limits) vs. "MW Predicted" 5780 DIB strength. — (right) Same as left except for "Z-Scaled". The filled circles are 0738+313 for $z = 0.091$, and the open circles are 0738+313 for $z = 0.221$. The filled squares are 0827+243, the open squares are 0952+197, the filled triangles 1127-145, and the open triangles are 1229-020.

(standard DLA metallicity). As done with the "Milky Way" predicted DIB strengths, all of the DIB lines are scaled by their relative strengths in the Milky Way, and the λ4428 DIB line is further scaled by a factor of 25%. These results are noted as "Z−Scaled" in Table 1. The right panel of Fig. 1 shows our predictions of the expected λ5780 DIB strength using Eq. 2.1. The data all lie above the 1:1 correlation line. To find if metallicity is responsible for the DIB deficiency we require additional data to adequately constrain our limits.

There are several potential scenarios that can inhibit DIB strength in DLAs. If DIB strength scales with metallicity, we would expect to detect them with higher S/N data. Perhaps the ionising radiation field in regions probed by QSO sight-lines destroy these molecules. Another possibility is that the covering factor of DIB absorbing gas is much smaller than the covering factor in DLA regions in which case the QSO "pencil-beam" technique is truly hit or miss. Also, it may be that our DLAs are not dusty enough to contain DIBs. In conclusion, placing DIB absorbers on a substantial statistical footing may be a difficult goal to realise, and using DIB strengths as a proxy for N(H I) to find intermediate redshift DLAs does not hold much promise.

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