Session II

Abundances of D, ^{3}He and ^{4}He: Observations

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Measurements of deuterium in the Milky Way

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Abstract. In this article I review measurements of deuterium in the Milky Way.

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1. Introduction

The abundance of deuterium in galactic environments depends upon both the primordial abundance created during Big Bang nucleosynthesis and the subsequent chemical evolution of the gas as a function of time. The primordial abundance is inferred from measurements of the angular power spectrum of the cosmic microwave background with the *Wilkinson Microwave Anisotropy Probe* (Spergel *et al.* 2007; Dunkley *et al.* 2009) and from ground-based measurements of D I absorption in a small number of quasar absorption systems at redshifts $z > 2$ (see Kirkman *et al.* 2003; O'Meara *et al.* 2006; Pettini *et al.* 2008; and references therein). A review of the extragalactic measurements and theory is given by Steigman (2007), who adopts $(\mathrm{D/H})_p = (2.68\pm^{0.27}_{0.25}) \times 10^{-5}$.

The deuterium nucleus has a binding energy of only ~ 2.2 MeV, and thus is easily destroyed in the following step of the proton-proton chain reaction occurring in the interiors of stars:

$$^{2}_{1}\mathrm{D} + \mathrm{p} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma + 5.49 \text{ MeV}$$

This astration of deuterium leads to a net decrease in its abundance with time. Galactic chemical evolution models typically predict astration factors $f_D \sim 1.4 - 1.8$, leading to expected present-day values of $\mathrm{D/H} \sim (1.4 - 1.9) \times 10^{-5}$ (see Tosi *et al.* 1998; Steigman, Romano, & Tosi 2007; and references therein). These models incorporate estimates of the production of heavier elements (C, N, O, Fe, etc.), as well as varying degrees of interstellar mixing and infall of unprocessed material from outside the Galaxy. Most models assume the interstellar material is chemically homogeneous, a reasonable assumption for regions of 100-200 parsecs in size but perhaps less certain for larger volumes (see the discussion in Moos *et al.* 2002). In conjunction with such models, measurements of deuterium in the Milky Way can provide valuable insights into the efficiency of mixing and the role of infalling gas in the evolving interstellar medium. They can also provide some guidance on the possible explanations for the large scatter in D/H values observed at higher redshifts.

There are two primary means by which the deuterium abundance in the neutral interstellar medium can be estimated. The most common is measurement of the D I Lyman series absorption in the ultraviolet spectra of stars, which began with pioneering observations by the *Copernicus* satellite in the 1970s (Rogerson & York 1973; York & Rogerson 1976; Vidal-Madjar *et al.* 1977), followed by extensive work with the *Hubble Space Telescope (HST)* and the *Far Ultraviolet Spectroscopic Explorer (FUSE)* (see Linsky *et al.* 2006 for a relatively recent review). Observations with these latter facilities have been particularly important in making precise measurements for nearby gas, increasing the number of sight lines examined, and extending the path length over which the absorption is probed. D I Lyman series observations were a key science driver for the design and operation of the *FUSE* mission (Moos *et al.* 2002). Although limited in number, important observations have also been made with experiments on the Shuttle-based *ASTRO-SPAS* platform; these include high resolution measurements with the Princeton *IMAPS* experiment (Jenkins *et al.* 1999; Sonneborn *et al.* 2000) and echelle spectroscopy with the *ORFEUS* telescope (Bluhm *et al.* 1999).

The other primary means for estimating the deuterium abundance is measuring the emission of the D I hyperfine transition at 91.6 cm (327 MHz). Work to detect this radio line began with Weinreb (1962) and has continued sporadically to the present day (Anantharamaiah & Radhakrishnan 1979; Blitz & Heiles 1987; Lubowich, Anantharamaiah, & Pasachoff 1989; Heiles, McCullough, & Glassgold 1993; Chengalur, Braun, & Burton 1997), albeit with limited success until recently (Rogers *et al.* 2005, 2007). The main limitation here is one of sensitivity, and as these latter two studies have shown this can be overcome with appropriate instrumentation tailored to detect the weak D I signal. Sadly, Tom Bania reported at this conference that the antenna array used for these observations at Haystack Observatory has been moth-balled and is unlikely to be resurrected anytime soon.

A secondary means for estimating the deuterium abundance is radio emission observations of deuterated molecules in the molecular component of the interstellar medium. However, even simple deuterium chemistry networks in molecular clouds become complicated quickly (Watson 1976; Dalgarno & Lepp 1984). Chemical fractionation makes it very difficult to determine D/H from molecular observations in most dark cloud environments because of the large number of molecular species and transitions that must be observed to account for each element (see, for example, Parise *et al.* 2009). This is a topic worthy of review, but too extensive to do so here.

Work on determining D/H in the Milky Way has slowed in the past few years since *FUSE* is no longer operating, but the debate over what the results mean continues. Figure 1 shows the value of D/H measured for sight lines in the local interstellar medium, the solar neighborhood, and the Galactic disk. These regions are delineated with dashed vertical lines. As can be seen in this figure, there is considerable variation in the D/H ratio from sight line to sight line, particularly at higher column densities. The measurements shown are estimates of the D/H ratio in the gas and do not account for any deuterium that may be locked into dust grains, a topic to which I will return briefly later. In the sections that follow, I summarize the measurements of atomic deuterium in the Milky Way that have been made to date and discuss some of their implications. I refer the reader to other articles in this proceedings by Linsky, Hébrard, Pradanović, and others for specific details on some of the topics discussed below.

2. The Local Bubble [$d \lesssim 100$ pc]

The local interstellar medium within about 100 pc of the Sun is often referred to as the Local Bubble. Within this cavity the properties of the interstellar medium are relatively homogeneous. The boundary of the Local Bubble appears to occur at hydrogen column densities of log N(H) $\sim 19.2 - 19.3$ (Sfeir *et al.* 1999). Within the Local Bubble D/H $\approx (1.5 - 1.6) \times 10^{-5}$ (Wood *et al.* 2004; Linsky *et al.* 2006), with some variation seen. Most of the Local Bubble measurements shown in Figure 1 are for sight lines to nearby, hot white dwarf stars with strong UV continua (e.g., Hébrard *et al.* 2002; Kruk *et al.* 2002; Lehner *et al.* 2002) or for later-type stars for which it is possible to measure

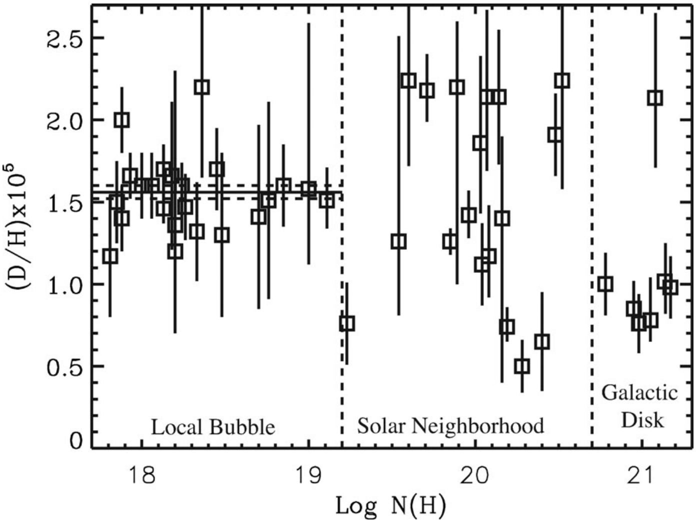

Figure 1. D/H as a function of hydrogen column density for sight lines observed with *Copernicus*, *IMAPS*, *HST*, and *FUSE* (adapted from Linsky *et al.* 2006 and Oliveira & Hébrard 2006). The vertical dashed lines denote the approximate column densities [N(H) = N(H I)+2N(H_2)] distinguishing the Local Bubble and Solar Neighborhood from more distant gas.

the H I and D I absorption against chromospheric emission lines (see, e.g., Linsky *et al.* 1995).

Vidal-Madjar *et al.* (1998) first suggested the possible detection of spatial variations in the D/H ratio within the Local Bubble. For many years debate raged over whether such variations were real or simply due to measurement error. Today, it seems reasonable to conclude that there are sight line to sight line variations of D/H in the Local Bubble, but for the most part such variations are small, especially when compared to those of more extended sight lines (see Figure 1). At this conference, Hébrard raised the interesting point that both the D/O and O/H ratios for Local Bubble sight lines tend to show less scatter than D/H, suggesting that there may be some systematic effects that could give rise to the (albeit small) variations seen in D/H.

3. The solar neighborhood [$100 \lesssim d(pc) \lesssim 500$]

There are now approximately 20 estimates of D/H for sight lines extending beyond the Local Bubble out to a few hundred parsecs. Most of the background sources are either white dwarf stars near the edge of the Local Bubble (e.g., Sonneborn *et al.* 2002), sub dwarfs (Friedman *et al.* 2002), or more distant OB stars (e.g., Jenkins *et al.* 1999; Sonneborn *et al.* 2000). These sight lines show a much stronger variation in D/H than the nearby stars, with roughly half showing larger values and half showing lower values than the Local Bubble average. There are no obvious correlations of D/H with Galactic longitude or latitude, nor with any known large interstellar structures. It is interesting that the mean value of D/H $= 1.5 \times 10^{-5}$ is indistinguishable from that of the Local Bubble.

On these scales, one would expect some variations around the Local Bubble value as a result of different gas mixing histories and deuterium astration. Several of these sight lines pass into known star-forming regions for which the chemical history of the gas is likely to be different than for the intervening interstellar medium along the sight lines. However, the magnitude of the variations seen, a factor of 2.5–3 for some sight line combinations, has led several authors to suggest that they might be due to deuteration of polycyclic aromatic hydrocarbons (PAHs → PADs; see Draine 2006; Linsky *et al.* 2006). Since astration and differential depletion into grains both serve to lower the gas-phase abundance of deuterium, this suggestion raises the obvious question: Why are some values of D/H so much higher than the Local Bubble values?

4. The Galactic disk [$d \gtrsim 500$ pc]

Deuterium absorption has been measured in the Galactic disk beyond the solar neighborhood along only seven sight lines for which the hydrogen column density exceeds log N = 20.7. Of these, only four (HD 41161, HD 53975, HD 90087, HD 191877) extend beyond 1 kpc (Hoopes *et al.* 2003; Hébrard *et al.* 2005; Oliveira & Hébrard 2006), and all lie within 3 kpc of the Sun. Several hundred extended sight lines have been observed with *FUSE* for a variety of purposes (see, e.g., Bowen *et al.* 2008), but few have proven useful for studies of D/H. The complex velocity structure arising from the superposition of gas clouds makes it difficult to disentangle the D I absorption from the very strong H I Lyman series absorption. Contamination of the D I lines by molecular hydrogen absorption is also problematic in many cases. We are fortunate to have seven cases for which N(D I) can be measured, but it is important to note that both the D I and H I measures are averages integrated over each sight line. The modest spectral resolution of *FUSE* and the great breadth of the H I absorption do not allow component by component analyses.

The D/H ratios for 6 of the 7 sight lines in this region of Figure 1 lie well below the Local Bubble average and are quite consistent with the average of the low D/H subset for the solar neighborhood. The single high D/H value (HD 41161) is similarly offset from the Local Bubble average and is consistent with the average of the high D/H subset for the solar neighborhood. This suggests that whatever processes serve to introduce variations in the solar neighborhood sample likely operate at larger distances as well. To first order, the variation in absorption beyond ~ 1 kpc does not seem dramatically larger (or smaller) than in the $100 \lesssim d(pc) \lesssim 500$ gas. Unfortunately, it isn't possible with the present data to separate out the foreground solar neighborhood contributions from the more distant cloud contributions for these sight lines.

A separate estimate for the D/H ratio in the Galactic plane has been made by Rogers *et al.* (2005, 2007), who report measurements of the 92 cm line emission in the Galactic plane at longitudes $l = 171°$, 183°, and 195°. Using an array of 24 small radio telescopes equipped with low-noise amplifiers to conduct these observations, they found values of D/H $= (2.4 \pm 0.3, 1.9 \pm 0.2,$ and $1.8 \pm 0.5) \times 10^{-5}$ in the three directions, with a final estimate of $(2.1 \pm 0.7) \times 10^{-5}$ (3σ) after accounting for uncertainties in the spin temperature of the gas. This value is very similar to that for the average of the high solar neighborhood and Galactic disk values inferred from the absorption-line measurements.

Rodgers *et al.* estimate that the deuterium emission is spread over approximately 5 kpc, which would make this the longest integrated path for which deuterium has been measured in the Galaxy. It may also well be the best average value for any region beyond the Local Bubble since the beam width of 14^o samples a much larger volume of gas than the absorption-line observations. The fact that the value of D/H found is high does not rule out the possibility that some of the gas has low D/H, but it does suggest that the average value for the Galactic disk and low halo in the Galactic anti-center is higher than the local value and has a relatively low astration factor, $f_D \lesssim 1.3$. Similar measures for other directions, particularly those for extended directions observed by *FUSE* would be highly desirable but do not appear to be feasible at this time.

5. The Galactic halo [$|z| \gtrsim 200$ *pc*]

High latitude sight lines with measurable D I absorption have been observed, but most of these are very nearby and do not extend far enough to probe the warm neutral medium of the Galactic halo, which has a different history than warm gas in the Galactic disk. In particular, the neutral Galactic halo gas has higher gas-phase abundances of refractory elements, due in large part to grain destruction caused by the passage of shocks that transport material from the disk into the halo (Sembach & Savage 1996).

Savage *et al.* (2007) report the detection of D I in the Galactic halo gas toward the high latitude QSO HE 0226-4110 observed with *FUSE*. Absorption is present in several lines of the Lyman series. They find D/H = $(2.1 \pm^{0.8}_{0.6}) \times 10^{-5}$ for the warm neutral medium of the Galactic halo, after correcting for absorption by foreground gas in the Local Bubble. The quoted value for the halo clouds is a weighted average over all clouds more distant than the Local Bubble. In these clouds, the gas-phase oxygen abundance is approximately solar and the gas-phase iron abundance is 1/10 solar; these differential depletion results are typical of halo clouds and are less severe than the depletions seen for the average warm neutral medium in the Galactic disk (Savage & Sembach 1996).

The value of D/H toward HE 0226-4110 is consistent with the higher values of D/H found in the Galactic disk, again suggesting a low astration factor that pushes up against the limits of predictions of galactic chemical evolution models. The past dynamical history of the gas does not help alleviate this problem since the transport time for disk gas into the low halo ($|z| \lesssim 3$ kpc) is on the order of a few hundred Myr. The high value of D/H also leaves little, if any, room for depletion of deuterium into dust grains, which is consistent with the expectation that the grain mantles in such clouds should be highly processed. An extremely low abundance of molecular hydrogen along the sight line also implies that there is little molecular material in which to incorporate deuterium.

6. The high velocity cloud Complex C [$d = 10 \pm 2$ *kpc*]

Sembach *et al.* (2004) report the detection of D I absorption in high velocity cloud Complex C, a large parcel of gas in the northern Galactic sky at a distance of 10 ± 2 kpc and an altitude of ~ 8 kpc (Thom *et al.* 2008). Complex C has a metallicity of 0.1-0.25 solar, exhibits no evidence of dust, and has a low nitrogen abundance thereby implying that it is chemically young. It is composed of gas falling onto the Milky Way and is unlikely to be Galactic disk or halo gas ejected to large distances. The mass of Complex C is on the order of 10^7 M_o.

The velocity separation between Complex C and the Galaxy in the *FUSE* spectrum of QSO PG 1259+593 allows for an analysis of D/H in the high velocity gas. Sembach *et al.* (2004) find a value of D/H = $(2.2 \pm 0.7) \times 10^{-5}$, similar to that obtained for the warm halo clouds toward HE 0226-4110. Complex C contains metals and has therefore undergone some chemical evolution. Therefore, the similarity of its D/H value to some of the values found for the disk and halo of the Milky Way is somewhat perplexing since the oxygen abundances in Complex C and these other regions differ by roughly a factor of 5-10.

7. The outer planets

Several estimates of D/H have been made for Jupiter and Saturn, with the most reliable being those for Jupiter. There have been three different techniques used to measure D/H on Jupiter: weak optical H_2 and HD absorption lines (Trauger *et al.* 1973), in-situ *Galileo*

Table 1. D/H Summary

Site	D/H [ppm]	Possible Importance of Dust Depletion	No. of Meas.	Reference or Compilation
Primordial gas	$26.8 \pm^{2.7}_{2.5}$	Not important	...	Steigman 2007
IGM	28.5 ± 7.6 (SD)	Not important	7	Pettini *et al.* 2008
Complex C	22 ± 7 (1σ)	Not important	1	Sembach *et al.* 2004
Galactic halo	$22 \pm^{8}_{6}$ (1σ)	Not important	1	Savage *et al.* 2007
Galactic disk (92cm)	21.0 ± 2.3 (1σ)	Probably not important	3	Rodgers *et al.* 2007
Galactic disk (high)	$21.4 \pm^{5.1}_{4.3}$ (1σ)	Probably not important	1	Oliveira & Hébrard 2006
Galactic disk (low)	9.0 ± 1.2 (SD)	Perhaps important	6	Oliveira & Hébrard (2006)
Solar neighborhood (high)	21.1 ± 1.5 (SD)	Probably not important	8	Oliveira *et al.* 2006 Oliveira & Hébrard 2006
Solar neighborhood (low)	10.3 ± 3.3 (SD)	Perhaps important	10	Oliveira *et al.* 2006 Oliveira & Hébrard 2006
Local Bubble	15.8 ± 2.1 (SD)	Perhaps important	22	Linsky *et al.* 2006
Jupiter	23.0 ± 2.6 (1σ)	Unknown	3	see Section 7

Note: This table is an update of a similar table that first appeared in Savage *et al.* (2007). "SD" indicates that the simple standard deviation of the mean was adopted in computing the error.

mass spectrometer measurements (Mahaffy *et al.* 1998), and *Infrared Space Observatory* observations of H_2 and HD emission (Lellouch *et al.* 2001). Following Savage *et al.* (2007), I adopt here an error-weighted average of these values: $D/H = (2.30 \pm 0.26) \times 10^{-5}$.

8. D/H summary

Table 1 and Figure 2 summarize the results for D/H in various Galactic environments, together with the values available for QSO absorption-line systems at high redshift. Data for each of these points comes from the references cited in Table 1 and references therein. For regions for which multiple measurements exist, the values shown are straight averages of the measurements, and the error quoted is the standard deviation about the mean value. Otherwise, the 1σ error on the mean value is quoted from the original source.

9. Variations in D/H and the role of dust

Variations in D/H and D/O have been discussed extensively elsewhere (see Linsky *et al.* 2006; Oliveira & Hébrard 2006; Oliveira *et al.* 2006), so I will not delve into the details here. Suffice it to say that variations in D/H, O/H, and D/O exist to differing degrees for the sight lines measured, and that one possible explanation for some of these variations is extreme deuteration of hydrocarbon molecule chains (Draine 2006). It is tempting to jump on the "dust bandwagon" to explain all of these variations, but it seems equally plausible that differing levels of astration and incomplete mixing play important roles as well. It is probably fair to say that what we presently (don't) know about these sight lines leaves room for all of these possibilities. Indeed, in the one region we expect to have a reasonably uniform chemical history and be well mixed, the Local Bubble, the variations in D/H and D/O are small.

Table 1 contains a subjective assessment of whether or not depletion of deuterium onto dust is likely to be important for the regions represented. Some regions with high D/H values, such as the QSO absorbers and Complex C, should contain very little dust and are unlikely to harbor PAHs or PADs. But what about the regions with lower D/H

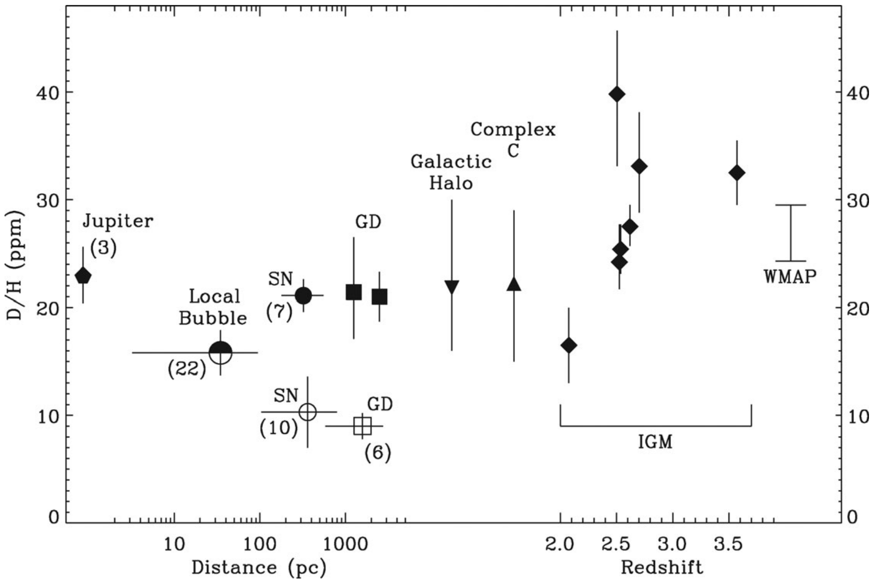

Figure 2. D/H measurements for a variety of environments. Values for the data points shown are given in Table 1, with symbol coding corresponding to the types of regions considered ("SN" = solar neighborhood. "GD" = Galactic disk). Numbers in parentheses indicate the number of measurements included for each data point if greater than one. Filled symbols indicate those measurements for which depletion of deuterium into dust is unlikely to be important.

values? Oliveira *et al.* (2006) find an anti-correlation between D/H and n(H), the sight line averaged density of H, as one typically sees for elements incorporated into dust (see Jenkins, Savage, & Spitzer 1986), but this result depends strongly on the measurements for a few sight lines.

It has been proposed that a positive correlation of D/H with the gas-phase abundances of highly refractory elements would indicate that deuterium is subject to inclusion in dust grains, as the gas-phase abundance of the refractories is highly dependent on the presence and processing of dust. Higher observed abundances of elements such as Si, Fe, and Ti would imply less dust and should be associated with higher values of D/H. Similarly, the more refractory elements are depleted from the gas phase, the better the chance that deuterium is also depleted. Linsky *et al.* (2006) checked this hypothesis using measures of Fe II and Si II along 38 of the Galactic disk sight lines with D/H measures (see their Figures 3 and 4) and found a positive correlation, as expected, with considerable scatter. The correlation between $(\mathrm{Si/H})_{gas}$ and D/H is strongly dependent on a few data points, but the correlation with $(\mathrm{Fe/H})_{gas}$ appears to be more secure.

Follow-up observations of the abundance of Ti from the ground have provided preliminary evidence for a correlation with D/H. Early results for 7 sight lines by Prochaska, Tripp, & Howk (2005) showed a strong correlation between $(\mathrm{Ti/H})_{gas}$ and D/H, providing further support to the idea that the scatter in D/H is linked to differential depletion. More extensive studies (Ellison, Prochaska, & Lopez 2007; Lallement, Hébrard, & Welsh 2008) confirm a correlation, but indicate that it is weaker than originally found and that the gradient observed for Ti/D is less than for Fe/D, contrary to expectations. It is possible that the results are subject to sight line selection effects (see below).

10. Some things to consider

It is tempting to take the existing deuterium results and generalize them to the Galaxy as a whole. However, that would surely be a dangerous thing to do, as the existing samples are subject to a variety of selection effects. The majority of deuterium measurements are obtained through observations of D I Ly-series absorption at far-ultraviolet wavelengths. Some possible caveats and concerns to keep in mind when considering the broader applicability of these results include:

(*a*) *Volume probed*: The volume of the Galaxy probed by the absorption-line measurements is very small, even with *FUSE*. Most of the sight lines are confined to within a few hundred parsecs of the Sun, a region which is not necessarily typical of the rest of the Galaxy. Only a few sight lines extend outside the local spiral arm, and only 1 or two sight lines extend as far as the nearest (Sagittarius) spiral arm.

(*b*) *Sight line conditions*: The types of regions probed are *not* conducive to the formation of molecules or dust grains. The sight lines observed have average densities typical of very diffuse clouds and were chosen for their simple velocity structure. The molecular content of the sight lines is orders of magnitude smaller than the atomic content. As a result, there is a strong selection against dark cloud environments where grain growth and molecular chemistry occurs.

(*c*) *Biased line strength*: There is probably a bias to report results for which the D I absorption is strong enough to detect, but not so strong as to be overwhelmed by H I absorption in close spectral proximity. This may limit the range of D/H probed, and sight line to sight line variations larger than those reported may exist. I am unaware of any systematic search through the existing archives for sight lines for which D I absorption should have, and could have, been seen but isn't.

(*d*) *Line saturation and unresolved velocity structure*: At the velocity resolution of *FUSE*, about 20 km s^{-1}, it is not possible to distinguish one absorbing region from another along most sight lines. Therefore, the values of N(D I) and N(O I) are necessarily averages for the sight line, weighted by the gas content of the individual clouds encountered. Similarly, only the total sight line column density of H I can be measured from the Ly-series lines. Narrow velocity structure resulting in line saturation could depress the values of N(D I) and N(O I) below their true values, even for cases for which multiple transitions can be observed. This effect can be quantified but depends strongly on the actual velocity structure encountered.

(*e*) *Not all grains are the same*: PADs and "normal" silicate or carbonaceous grains may have very different histories. Comparisons of D/H or D/O to the gas-phase abundances of refractory elements to infer the depletion of D are most meaningful if the deuterium and refractories are incorporated into the same grains. The relatively small variation in refractory element abundance with changes in D/H is somewhat surprising. Take Ti as an example. For diffuse clouds like those observed toward ζ Oph, this element has 999 of 1000 atoms locked into dust grains, with only 0.1% of the atoms in the gas phase (see Savage & Sembach 1996). To change the gas-phase depletion of Ti by two requires only 1 more of those 1000 atoms to be liberated into the gas, whereas for deuterium which has a depletion no more than a factor of a few, roughly half of the D atoms would have to be liberated to change the gas-phase abundance of D by a factor of two. Why isn't there more variation in the abundances of the refractory elements along these sight lines if dust content and the processing of dust are responsible for the variations in D/H? I suspect it is because the grains are already highly processed, and I remain somewhat skeptical that the observed variations are due mainly to differential depletion.

(*f*) *Local sources of deuterium*: All methods of deuterium production require either extreme environments or special conditions, with Big Bang nucleosynthesis being the only viable source for cosmological quantities (see Epstein, Lattimer, & Schramm 1976; Jedamzik 2002). However, localized sources could potentially account for some variability of D/H within the Galaxy. Possible sites of production include stellar flares (Mullan & Linsky 1999; Prodanović & Fields 2003) or supernova shock waves (see above references). Unfortunately, independent confirmation of deuterium production in such sources is notoriously difficult to come by, so for now it is difficult to quantify their importance.

(*g*) *Unknown unknowns*: There may be unknown systematic measurement effects leading to the apparent bifurcation of D/H into high and low branches beyond the Local Bubble. The absence of many points near the mean value for the Local Bubble, which is also the mean for all of the solar neighborhood points, is surely telling us something important about either the nature of the absorption or our ability to measure it.

11. Concluding remarks

Over the years, the focus of D/H determinations has evolved from trying to determine the primordial abundance of deuterium to trying to understand chemical evolution and the detailed physics of the sight lines along which deuterium can be measured. Despite their limitations, observations of deuterium in the Galaxy have proven to be extremely interesting and thought provoking. The lively discussion at this conference was direct proof of that!

The prospects for obtaining further D I absorption-line measurements within the Milky Way in the near future are not very bright. However, with the installation of the Cosmic Origins Spectrograph in *HST* in May 2009, there is again a chance that it will be possible to measure D/H in the low-redshift intergalactic medium along one or more of the many QSO sight lines that will be observed in the coming years. The key to doing this will be to find a strong enough Lyman-limit system at $z \lesssim 0.5$ in which to measure the D I Lyα absorption. The COS Team is also investigating whether it might be possible to use COS to observe at wavelengths below 1100 Å. Initial results using the low resolution grating (G140L) demonstrate that the *HST* optics transmit light at these wavelengths (McCandliss *et al.* 2010). Further tests using the G130M medium resolution grating, which could potentially reopen the possibility of measuring deuterium absorption in the Galaxy, may be undertaken.

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