GALILEO PROBE MEASUREMENTS OF D/H AND ^{3}HE/^{4}HE IN JUPITER’S ATMOSPHERE

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Abstract. The Galileo Probe Mass Spectrometer measurements in the atmosphere of Jupiter give

$$\mathrm{D/H} = (2.6 \pm 0.7) \times 10^{-5}$$

$$^3\mathrm{He}/\,^4\mathrm{He} = (1.66 \pm 0.05) \times 10^{-4}$$

These ratios supercede earlier results by Niemann *et al.* (1996) and are based on a reevaluation of the instrument response at high count rates and a more detailed study of the contributions of different species to the mass peak at 3 amu. The D/H ratio is consistent with Voyager and ground based data and recent spectroscopic and solar wind (SW) values obtained from the Infrared Spectroscopic Observatory (lSO) and Ulysses. The ^{3}He/^{4}He ratio is higher than that found in meteoritic gases $(1.5 \pm 0.3) \times 10^{-4}$. The Galileo result for D/H when compared with that for hydrogen in the local interstellar medium $(1.6 \pm 0.12) \times 10^{-5}$ implies a small decrease in D/H in this part of the universe during the past 4.55 billion years. Thus, it tends to support small values of primordial D/H – in the range of several times 10^{-5} rather than several times 10^{-4}. These results are also quite consistent with no change in (D+^{3}He)/H during the past 4.55 billion years in this part of our galaxy.

1. Introduction

Measurements of the relative abundances of primordial light nuclei can provide fundamental insights into conditions prevailing in the early universe. They have implications in particular for the baryon-to-photon density ratio at that time and thus for the fraction of dark matter that can be ordinary matter. Following the Big Bang, the ratio of deuterium to hydrogen (D/H) in the universe should have decreased monotonically, since destruction of D in stars far outstrips any known processes that create it. The situation with ^{3}He is less simple, since it can be destroyed as well as created in stars. To constrain models of galactic evolution of deuterium and ^{3}He it is necessary to know the primordial ratio of D to H and how it and the ^{3}He to H ratio have evolved. Unfortunately, measurements of D/H in extragalactic, very highly red-shifted hydrogen clouds that would give us the primordial ratio have ranged over a full order of magnitude (Songaila, *et al.*, 1997; Tytler *et al.*, 1996; Webb *et al.*, 1997). Consequently we are far from realizing this objective. On the

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other hand rather precise measurements of ^{3}He/H and D/H in the local interstellar medium are now available.

The values of these ratios 4.55 billion years ago in the region of the interstellar medium where the solar system was formed can be determined if they can be measured at suitably chosen places in solar system objects today. One such measurement involves determining the ratio of ^{3}He to ^{4}He in the solar wind and subtracting the contribution of protosolar ^{3}He to obtain the protosolar D to He ratio (Geiss and Gloeckler, 1998). All of the sun's deuterium was converted to ^{3}He during its pre-main sequence phase. To derive the D/H ratio in the primitive solar nebula itself (the protosolar value) from these measurements it is necessary to correct the solar wind value. These corrections account for changes in isotopic composition that occur in the chromosphere and corona and then for changes of ^{3}He/H and ^{4}He/H in the outer convective zone that have occurred because of transport processes and incomplete H burning. Until the measurements reported here were made, meteorites have been the sole sources of helium that might yield the protosolar nebular ^{3}He/^{4}He ratio. They can do so only if the unknown process by which helium was incorporated in the bodies from which the meteorites formed did not fractionate the isotopes.

Another method of determining the values of D/H and ^{3}He/^{4}He in the primitive solar nebula is to measure these quantities in the atmosphere of Jupiter. This procedure is valid if all but a negligible portion of the isotopes of the light gases found in the Jovian atmosphere today came directly from the gaseous nebula with no important contributions from sources of fractionated hydrogen or helium, such as icy planetesimals. This assumption is supported by the fact that the D/H in comet Halley (Balsiger *et al.*, 1995; Eberhardt *et al.*, 1995), Hyakutake (Bocklee-Morvan *et al.*, 1998) and Hale-Bopp (Meier *et al.*, 1998) is at least an order of magnitude greater than the Jovian value derived in this paper. It also supposes that the process that depletes He in the atmosphere of Jupiter is not mass dependent; that no significant fractionation of hydrogen isotopes had occurred in the solar nebula by the time and in the place where Jupiter formed; and that the appropriate He to H ratio is known.

It is the purpose of this paper to report measurements of D/H and ^{3}He/^{4}He in the Jovian atmosphere by the Galileo Probe Mass Spectrometer (GPMS) and to discuss their implications. The new analysis presented here is based on extensive laboratory calibration and replaces our earlier result (Niemann *et al.*, 1996). These results are compared with remote sensing observations of Jupiter, which give a D/H measurement, and meteoritic measurements of ^{3}He/^{4}He, which give an estimate of the protosolar value of this ratio.

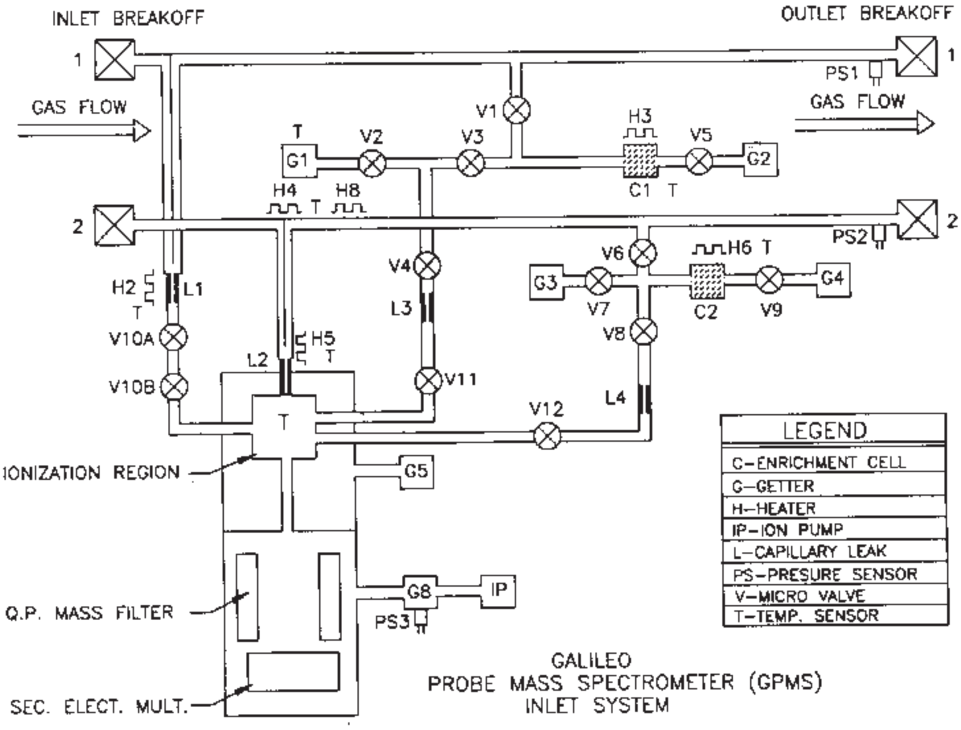

Figure 1. Schematic diagram of the Galileo Probe Neutral Mass Spectrometer

2. Galileo Probe Mass Spectrometer Measurements

2.1. THE INSTRUMENT AND ITS OPERATION

The GPMS has been described in detail by Niemann *et al.* (1992), and a report shortly after the Probe encounter of results obtained during its descent through the Jovian atmosphere has been published (Niemann *et al.*, 1996). A schematic diagram is shown in Figure 1. The mass analyzer was a quadrupole mass filter with a secondary electron multiplier detector. The instrument scanned in integral steps from 2 to 150 amu, devoting 0.5 sec to integrate the detector response at each step. The dynamic range was 10^8. Chemical getter pumps pumped the ionization and detector chambers of the GPMS, and a sputter ion pump backed the chamber getter pump. Atmospheric gases were admitted to the ionization chamber through a system of capillary leaks. On their high-pressure sides these leaks were exposed to gas flowing through tubing open to the atmosphere or to enrichment chambers in which these gases had been processed. At pressures between 0.5 and 4 bar a relatively high conductance leak (L1), sampled the atmosphere. During a portion of this time, gas was also circulated through an enrichment cell (EC1) to collect a portion of the heavier species. After L1 had been sealed, the contents of a volume next to the enrichment cell from which hydrogen and other chemically active species had been eliminated by getter pumps was admitted to the ionization chamber through leak L3. Methane and the noble gases were sampled in this experiment designated the noble gas (NG) sequence. Gas released from EC1 by heating this cell was then introduced through L3 to the ionization chamber. After an instrument background measurement, which extended to an atmospheric pressure of 8.6 bar, the direct atmospheric sampling resumed with a lower conductance leak (L2). A second enrichment cell sequence (EC2) took place between 12.1 and 15.6 bar and the cell contents introduced to the source through leak L4. Direct atmospheric sampling then continued until the end of the mission at approximately 22 bar. The portions of the L2 measurement sequence before and after the EC2 sequence are designated L2a and L2b respectively.

2.2. D/H AND ^{3}HE/ ^{4}HE FROM GPMS

The D/H ratio has to be derived from measurements of the ratio of HD to H_2, which is twice the D/H ratio. This requires separating the contributions of other ions appearing at 3 amu (^{3}He and H_3^+) from HD. The H_3^+ is manufactured in the ion source in two ways, one by ion-molecule reactions involving H_2 and the other by dissociative ionization of methane:

$$\mathrm{e} + \mathrm{CH_4} \rightarrow \mathrm{CH} + \mathrm{H_3^+} + \mathrm{e} \tag{1}$$

Thus, if [3], [2], and [16] denote the number of counts per step at 3, 4 and 16 amu respectively,

$$[3] = a(\mathrm{HD}/\mathrm{H_2})[2] + b(^3\mathrm{He}/^4\mathrm{He})[4] + k[16] + c(\mathrm{H_3^+}) \tag{2}$$

where HD/H2 is the relative abundance of HD and H2 in the atmosphere, ^{3}He/^{4}He the relative abundance of ^{3}He and ^{4}He, and a and b are factors that relate relative counting rates to relative atmospheric densities The ion source density depends on the flow characteristics through the capillary inlet into the source and the pumping speeds with which species are removed from the ionization chamber. The factor k is the rate constant for creation of H_3^+ from CH_4 by dissociative ionization multiplied by an instrument efficiency factor, and c (H_3^+) is the contribution of the other sources of H_3^+ to [3]. The values of these factors in the pressure regions of interest are obtained from the descent data, from calibration data obtained from the GPMS Flight Unit (FU) in 1985 prior to launch, and from dedicated experiments carried out after the Galileo Probe encounter using a refurbished Engineering Unit (EU) that duplicates the performance of the FU.

The sequence of measurements at 3 amu and at 2 and 4 amu before these species saturate, is illustrated in Figure 2 where the 3 amu counts per integration period are plotted from step 92 at 0.523 bar to step 6538, 54 minutes later at the 20.8 bar level. Between steps 1810 and 2160 and between steps 3100 and 3485 the mass spectrometer was isolated and background count rates were measured. It should be

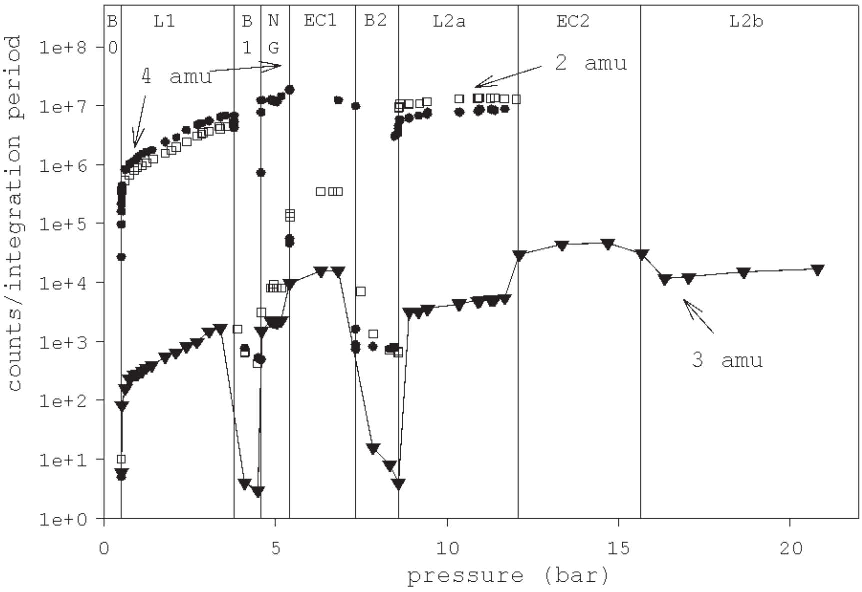

Figure 2. Log of counts per step at 3 amu versus pressure.

noted that, since the gas emerging from capillary leak L2 beams directly into the ionization region, the relative responses of L1 and L2 to different species is not the same. This is evident from the difference in the [4]/[2] ratios in the two leaks.

The relative contributions of CH_4 and ^{3}He to [3] can be determined from the measurement sequence involving EC1. In this sequence the chemical getters have largely removed the hydrogen and the ratio of CH_4 to He changes in different parts of this sequence as the enrichment cell is heated. The contribution of CH_4 to [3] has also been independently verified by recently obtained EU data. After the contributions of CH_4 and He to [3] have been subtracted from the signal in the L1 and L2 regions, the remaining 3 amu counts contain contributions from H_3^+ and from HD. The H_3^+ contribution can be quantified using 1985 FU calibration experiments where a descent sequence was carried out over the full range of pressures that were encountered during the Probe experiment. Following subtraction of the H_3^+ signal the residual [3]/[2] ratio together with instrument efficiency for detection of the HD and H_2 gave the HD/H_2 ratio from which the Jovian D/H ratio was derived.

2.2.1. *Contribution of CH_4 to [3]*

The change in the mixing ratio of helium and methane in EC1 on heating this cell can be used to determine the relative contributions of methane and helium to the 3 amu counts. The GPMS mass spectrum derived from measurements during the noble gas experiment is shown in Figure 3. The getter pump has removed much of the hydrogen and other active gases leaving methane and the noble gases as the primary constituents of the volume sampled by the mass spectrometer. The

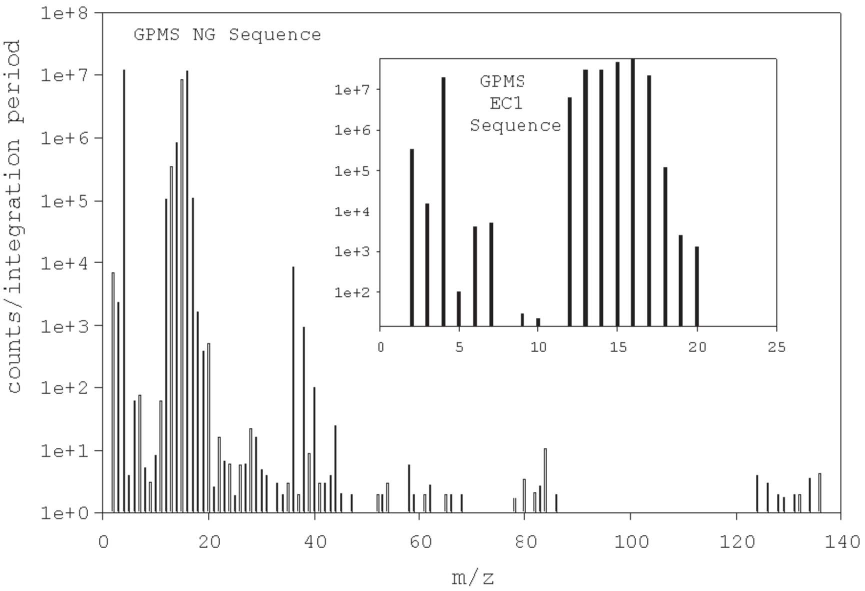

Figure 3. GPMS spectra in the NG portion of the descent sequence show counts per step *vs.* the m/z value. The full spectrum is derived from the signal expected near the center of this sequence based on a polynomial fit extrapolation of the signal at each m/z value to step 2400 in the NG sequence. The inset shows a portion of a similar spectrum extracted from the EC1 sequence. During this period, EC1 is heated to release gas trapped on the enrichment cell. At the mass values of interest for this study, there is a negligible cross talk between adjacent mass channels.

H_2-derived H_3^+ will not contribute substantially in this case to [3] and the terms associated with factors a and c in equation (2) are zero. The inset in this plot shows a portion of the EC1 sequence spectrum resulting from heating the enrichment cell to release its trapped gas. The signal at 16 amu and several methane fragment peaks saturate the detector sufficiently in the EC1 spectrum that it is difficult to derive accurate corrected count rates at these masses. The 12 amu signal, however, is not saturated and can be used to retrieve the relative increase in the methane mixing ratio from the noble gas sequence. The counts at 12 amu come almost entirely from methane in this spectrum since the relative abundances of other carbon containing species are very low.

Polynomial fits to [3], [4], and [16] in the NG region give values of $2.266 \times 10^3, 1.239 \times 10^7$, and 1.027×10^7 respectively for the counts per period at these masses at step 2400. A similar exercise in EC1 gives $[3] = 1.583 \times 10^4, [4] = 1.856 \times 10^7$, and $[16] = 6.877 \times 10^8$ where the latter value is derived from the ratio to [12]. Solution of the simultaneous equations for the contributions to [3] give the ^{3}He/^{4}He ratio and the contribution of CH_4 to [3] of $[3]/[16] = 1.85 \times 10^{-5}$. A recent exercise on the EU with pure CH_4 agrees quite closely with the latter result giving directly $[3]/[16] = 2.2 \times 10^{-5}$. The EU exercise furthermore demonstrated that there are no large variations in this ratio over the pressure range of interest for the FU NG and EC1 sequences.

2.2.2. *The ^{3}He/^{4}He Ratio*

The [3]/[4] ratio derived from the FU NG and EC1 [3], [4], and [16] data as described above is 1.67×10^{-4}. Additional EU experiments show that the instrument response to the two helium isotopes introduced to the ion source in the molecular flow regime is flat for ^{3}He and ^{4}He so this count ratio represents a measure of the Jovian ^{3}He/^{4}He ratio. Using the EU derived [3]/[16] ratio gives a Jovian ^{3}He/^{4}He ratio of 1.65×10^{-4}. The adopted ^{3}He/^{4}He is an average of these two giving

$$^3\mathrm{He}/^4\mathrm{He} = (1.66 \pm 0.04) \times 10^{-4}.$$

2.2.3. *The D/H Ratio*

The EC1 data allow the contributions of helium and methane to be subtracted in the direct leaks using ratios to [4] and [16]. Figure 4 shows the result of this subtraction together with the subsequent subtraction of other contributions to [3] on the [3]/[2] ratio in the L1 and L2a portions of the descent sequence. The counts from ^{3}He in the L1 sequence region are designated $[3]_{\mathrm{He}}$ and have a value of $1.66 \times 10^{-4}[4]$. The residual 3 amu counts due to H_3^+ and HD are labeled "$([3] - [3]_{\mathrm{He}})/[4]$" in Figure 4. In both this and the EC1 sequence, the transport both into and out of the ionization region is in the molecular flow regime and no pumping speed corrections are required. In the higher pressures of the L2a region the flow into the ionization region is nearly viscous and the ^{3}He contribution takes the form $\{(3/4)^{0.5} 1.66 \times 10^{-4}[4]\}$ where the additional factor accounts for the faster pumping speed for ^{3}He out of the ionization region.

In L1 and L2a the H_3^+ correction is primarily from H2 with an additional small contribution from CH_4. The magnitude of the correction for this contribution shown in Figure 4 is established through analysis of a calibration run carried out on the FU in 1985 where a hydrogen and helium mixture was introduced to the mass spectrometer over the full range of pressures expected during the descent. In this run the ^{3}He contribution to [3] was negligible and a correction to [3] of the form $[3]H_3^+ = ([3] - 1.05 \times 10^{11}[2]^2)$ gave a constant $[3]H_3^+/[2]$ ratio over much of the low pressure side of the L2a region. A correction of this form applied to the FU [3] counts from which the ^{3}He contribution has been subtracted gives the ratio in Figure 4 labeled H_3^+ corrections.

Final corrections to the [3]/[2] ratio to reflect the HD/H_2 abundance arise from instrumental discrimination between HD and H_2. This effect is approximately 10 in L1 as determined from introduction of a known mixture of HD and H_2 into the EU L1. It is even higher in L2 as illustrated in Figure 2 where the gas mixture is beaming directly into the ionization region. Our present best estimate of the D/H ratio is derived from an average of points near the minimum of these two curves. Points above the minimum for each leak are thought to arise from additional contributions

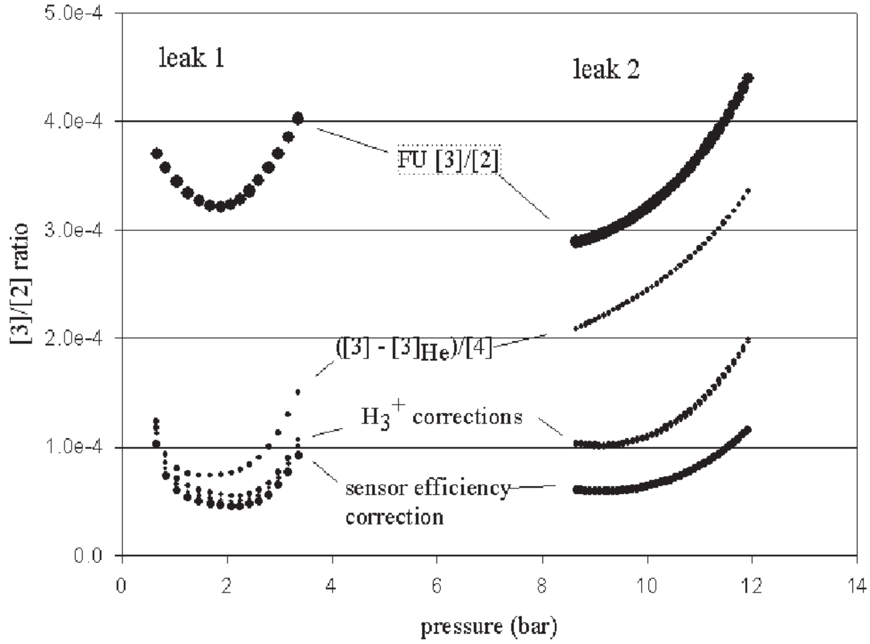

Figure 4. The effect of sequential removal of contributions to the 3 amu signal on the [3]/[2] ratio. The minimum in the bottom curves gives the HD/H_2 ratio derived from each of the two direct leak experiments. This value is twice the D/H ratio. The points shown represent values selected at regular intervals along polynomial fits to the [3] and the [2] data.

to H_3^+. The ratio derived from this analysis is

$$\mathrm{D/H} = (2.6 \pm 0.7) \times 10^{-5}.$$

The errors for both this ratio and the ^{3}He/^{4}He ratio are 1σ limits derived from GPMS count variations and then increased to reflect additional systematic and instrumental uncertainties. Investigations of the dependence of [3] on pressure are continuing with the EU with the goal of increasing the precision of the analysis.

3. Comparison with Other Determinations of D/H

A summary of several Jovian D/H determinations by remote sensing is given in Table I. This table also gives protosolar D/H inferred from a comparison of (^{3}He/^{4}He) in the solar wind (SW) and in meteorites. The latter value of D/H must be identical to the Jovian value if the assumptions described above concerning Jupiter's formation are valid.

Table I

type	D/H value	authors (label in Fig. 5)	measurement
CH_3D	$(2.1 \pm 0.6) \times 10^{-5}$	Gautier and Owen (1989) (GO)	Voyager 7.7 μm, Bjoraker *et al.* (1986) CH_3D (5 μm)
CH_3D	$(1.2 \pm 0.5) \times 10^{-5}$	Bjoraker *et al.* (1986) (B)	5μm airborne
CH_3D	$(3.6 \pm 0.5) \times 10^{-5}$	Carlson *et al.* (1993) (C)	Voyager 7.7μm (reanalysis)
HD	$(1.0 \pm 2.9) \times 10^{-5}$	Smith *et al.* (1989) (S)	ground based visible
HD	$(1.8^{+1.1}_{-0.5}) \times 10^{-5}$	Lellouch *et al.* (1996) Encrenaz (1998) (LE)	ISO 37.7 μm
SW	$(2.6 \pm 1.0) \times 10^{-5}$	Geiss (1993)	Apollo, ISSE-3 solar wind measurements
SW	$(3.01 \pm 0.17) \times 10^{-5}$	Gautier and Morel (1997) (GM)	Apollo, ISSEE-3, Ulysses, solar wind measurements, earlier GPMS $^3He/^4He$
SW	$(2.1 \pm 0.5) \times 10^{-5}$	Geiss and Gloeckler (1998) (GG)	Apollo, ISSEE-3, Ulysses, solar wind measurements
in situ	$(2.6 \pm 0.7) \times 10^{-5}$	this work	GPMS value [superceding previous GPMS report of $(5 \pm 2) \times 10^{-5}$ of Niemann *et al.* (1996)]

3.1. SPECTROSCOPIC MEASUREMENT OF D/H

One method to measure D/H in Jupiter's atmosphere is by optical spectroscopy. For example, a determination of the CH_3D/CH_4 ratio and an analysis which then takes into account the fractionation that occurs in the production of methane gives an inferred D/H as it would be measured in H_2 (Lecluse *et al.* 1996). Three such determinations giving the values labeled "CH_3D" are shown in Table I.

The first, by Gautier and Owen (1989), represents the result of an analysis of Voyager 1 data at 7.7μm combined with Bjoraker 5μm observations to get CH_3D/H_2. The second, by Bjoraker *et al.* (1986), is from airborne spectra at 5μm. The third is the result of a reanalysis of Voyager IR data (Carlson *et al.* 1993). Each of these values changes when adjusted for a C/H ratio 2.9 times solar (solar $C/H = 3.62 \times 10^{-4}$, Anders and Grevesse, 1989) and a $^4He/H_2$ ratio of 0.157 (Niemann *et al.*, 1996; von Zahn and Hunten, 1996). In particular, the Bjoraker *et al.* (1986) value increases to greater than 2×10^{-5} and the Carlson *et al.* (1993) value increases to greater than 4×10^{-5}.

The measurements labeled "HD" in Table I give a preliminary value of HD/H_2 as determined from recent IR observations of the HD R(2) line at 37.7μm by the short wavelength IR spectrometer on ISO (Encrenaz *et al.*, 1996 and reanalyzed by Lellouch *et al.*, 1996; Encrenaz, 1998). The ISO result is provisional, as analysis is still continuing. Ground based measurements of HD/H_2 in the visible spectrum have also been carried out by Smith *et al.* (1989).

On normalization to the GPMS derived CH_4/H_2 and He/H_2 ratios, the original Voyager measurements, the ISO observations, the airborne IR observations, the ground based visible observations, and the GPMS results are all consistent within the measurement errors. The analysis of the Voyager 1 CH_3D measurements by Carlson *et al.* (1993) gives a somewhat higher value.

3.2. D/H DERIVED FROM SOLAR WIND MEASUREMENTS OF ^{3}HE/^{4}HE

$(D/H)_{ps}$ for the protosun can also be determined by measuring $(^3He/^4He)_{sw}$ in the solar wind. Deuterium in the young sun was converted very efficiently to ^{3}He. The helium has subsequently remained virtually unprocessed, as is implied by the continuing presence in the Sun of the more reactive ^{9}Be (Geiss and Reeves, 1972). Thus

$$(D/H)_{ps} = (^4He/H)_{ps}\{(^3He/^4He)_s - (^3He/^4He)_{ps}\} \tag{3}$$

(Geiss and Reeves, 1972) where $(^3He/^4He)_{ps}$ is the $^3He/^4He$ ratio in the protosolar cloud and $(^3He/^4He)_{sw}$ in the solar wind today is corrected for modifications occurring in the corona and chromosphere as well as for changes that have occurred over time in the solar interior (Gautier and Morel, 1977; Geiss and Gloeckler, 1998). For $(^3He/^4He)_{ps}$ either the meteoritic value

$$(^3He/^4He)_{ps} \equiv (^3He/^4He)_m = (1.5 \pm 0.3) \times 10^{-4} \tag{4}$$

(Black, 1972; Eberhardt, 1974; Geiss and Reeves, 1972; Geiss, 1993) or the GPMS value $(1.66 \pm 0.05) \times 10^{-4}$, which agrees with it may be used. The result as given by Geiss and Gloeckler (1998) is $(D/H)_{ps} = (2.1 \pm 0.5) \times 10^{-5}$. Gautier and Morel (1997) obtained $(D/H)_{ps} = (3.01 \pm 0.17) \times 10^{-5}$. This was in part the consequence of their using the earlier smaller GPMS value for $^3He/^4He$ (1.1×10^{-4}) given by Niemann *et al.* (1996) and in part from use of a higher $(^3He/^4He)_{sw}$ than that of Geiss and Gloeckler (1998). These results for $(D/H)_{ps}$ agree with the in situ GPMS measurement as well as most of the spectroscopic measurements.

The cited values for Jovian D/H or $(DH)_{ps}$ are shown in Figure 5. We note in passing that simply substituting the GPMS value for $(^3He/^4He)_{ps}$ of Equation (3) together with the initial Ulysses value of $(^3He/^4He)_{sw}$ (Bodmer *et al.*, 1995) gives $(D/H)_{ps} = (2.7 \pm 0.3) \times 10^{-5}$, in excellent agreement with the GPMS result

4. Solar System and Local Interstellar Medium D/H and ^{3}He/H

In the nearby Local Interstellar Medium (LISM) Linsky *et al.* (1996) have measured an isotopic ratio $D/H = (1.6 \pm 0.12) \times 10^{-5}$. This is the present day value of D/H, in this region of the galaxy (which is not where the solar nebula was formed). The GPMS and the other three low values of D/H measured in the Jovian atmosphere indicate a modest 45% consumption of deuterium in the galactic neighborhood

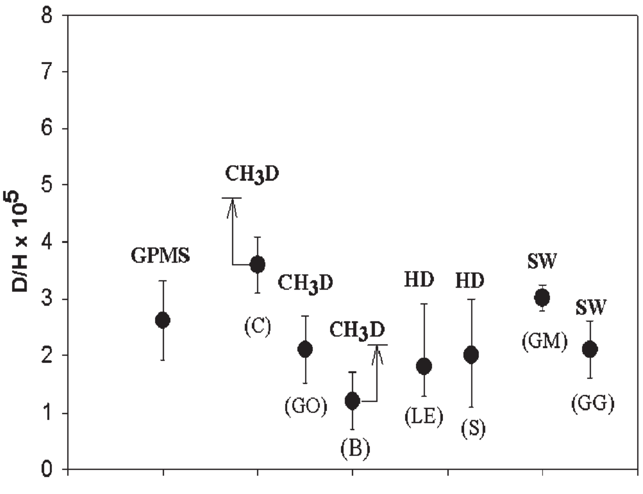

Figure 5. The D/H ratios derived through the measurements summarized in Table I. The arrow from the (C) value points to a value obtained by Lecluse *et al.* (1996) following a normalization to a methane mole fraction of 1.8×10^{-3} and using an isotopic enrichment factor of 1.25. The (B) value would similarly be increased with use of a more recent methane mole fraction. In the case of (GM) their value of 3.01×10^{-5} would be reduced with use of our new ^{3}He/^{4}He result.

during the past 4.55 Gy. In this regard it is interesting to examine the behavior of (^{3}He + D)/H. An isotopic analysis of helium ions entering the solar system from the surrounding interstellar cloud has been performed from measurements of pickup ions by the ion composition spectrometer on Ulysses (Gloeckler and Geiss, 1998). This measurement gives $^3\mathrm{He/H} = (2.48^{+0.85}_{-0.79}) \times 10^{-5}$ assuming ^{4}He/H to be 0.1. Thus in the LISM $(^3\mathrm{He} + \mathrm{D})/\mathrm{H} = (4.08 \pm 0.97) \times 10^{-5}$. The protosolar value of (D + ^{3}He)/H would be $(4.3 \pm 0.7) \times 10^{-5}$ if $^4\mathrm{He/H} = 0.1$ and the GPMS measurement of D/H and ^{3}He/^{4}He in the Jovian atmosphere represent conditions in the protosolar cloud. This, as well as those obtained by combining most other Jovian D/H measurements with either the meteoritic or GPMS values for ^{3}He/^{4}He, are indistinguishable from the LISM value. Thus they are consistent with no change in the ratio during the past 4.55 Gy and thus no significant consumption of ^{3}He.

5. Discussion and Conclusions

The ^{3}He/^{4}He ratio measured by the GPMS in Jupiter’s atmosphere is within the error bars of the ratio in the “planetary" component of meteorites. The higher meteoritic value may reflect fractionation of the solar nebular gas in favor of the heavier isotope. The value of D/H that we have derived in Jupiter’s hydrogen is consistent with several previous remote sensing determinations but excludes others. Further calibration work with the EU may allow us to reduce the error bars on D/H somewhat. We have established the anticipated result that Jupiter indeed represents a repository of solar nebula material unmodified by nuclear reactions for the last 4.55 Gy. The small change in the 'local' value of D/H that occurred during the last 4.55 Gy according to the GPMS, SW, ISO, and LISM measurements is consistent with values of D/H in the range $2 - 5 \times 10^{-5}$ for intergalactic clouds adsorbing Lyman (from quasars at very large redshifts (Tytler *et al.*, 1997, Burles and Tytler, 1998). The GPMS measurements are more difficult to reconcile with primordial values of D/H as high as 10^{-4} (Rugers and Hogan 1996; Songaila *et al.*, 1997; Webb *et al.*, 1997). In principle, one can test models for galactic evolution by comparing values of D/H and ^{3}He/^{4}He measured at different times. If there is no major consumption of ^{3}He, the ratio (D+^{3}He)/H should remain constant in time. However, present uncertainties on the LISM value for ^{3}He/^{4}He prevent this test from being rigorous. The lowest value of LISM ^{3}He/^{4}He$= 1.69 \times 10^{-4}$, overlaps the high end of the GPMS determination: 1.7×10^{-4}. This alone suggests negligible consumption of ^{3}He during the last 4.55 Gy, and is consistent with the results for (D+^{3}He)/H. Future higher precision studies of the Interstellar ^{3}He/^{4}He would make this approach more useful.

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