The Ratio of D to H in the Milky Way

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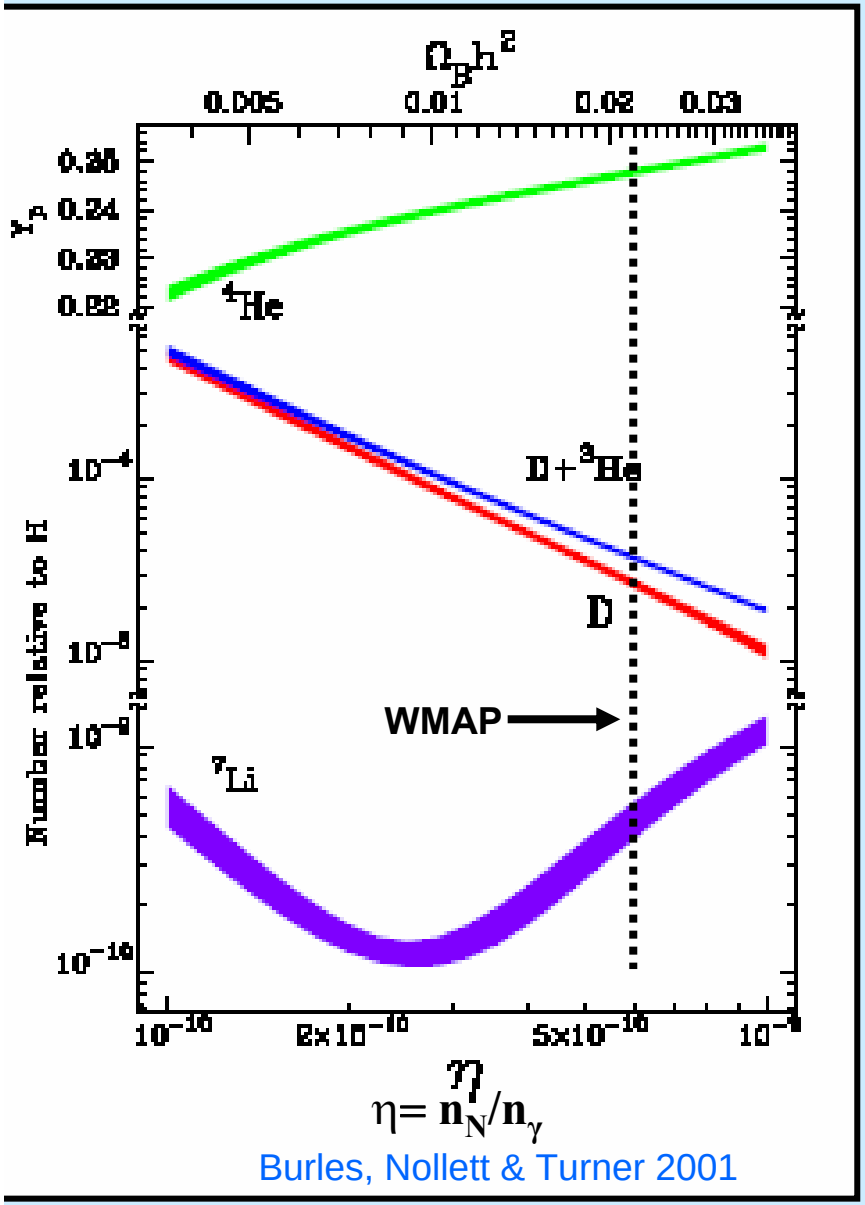
What Do We Know About D/H?

- D/H within ~1kpc of sun highly variable.
- Depletion on interstellar carbonaceous grains likely the cause.
- Highest D/H ratios may provide a lower limit to the total D in the Galaxy.

Introduction



Burles, Nollett & Turner 2001

D is a sensitive indicator of Ω_B. More baryons<=>less D.

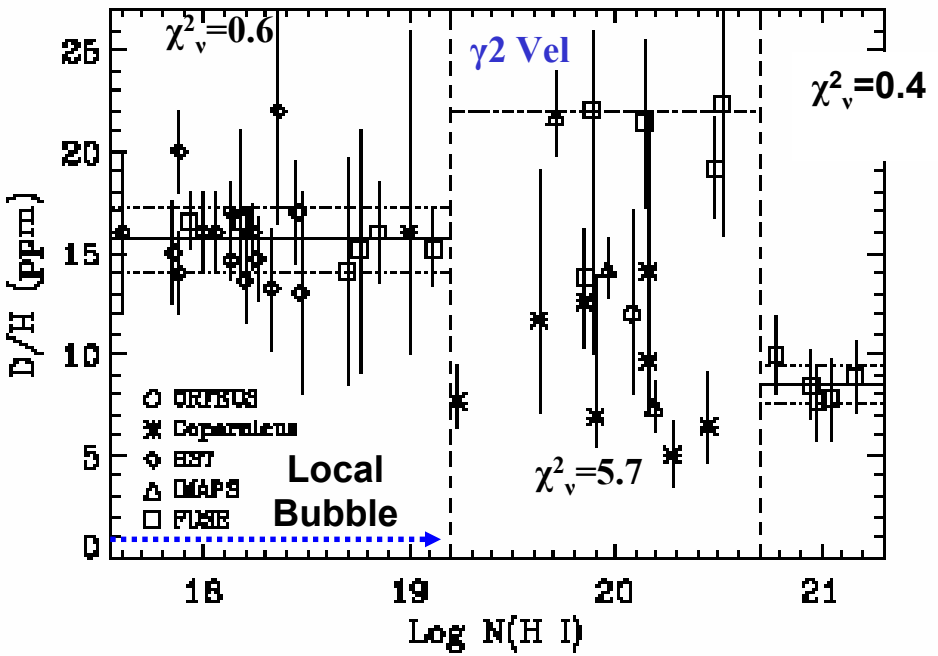
In IGM, D/H=27.8+4.4/-3.8 ppm (Kirkman et al. 2003). WMAP: $\Omega_b h^2$ = 0.0224±0.0009 (Bennett et al. 2003) => D/H=26 to 27.5 ppm (nuclear reaction rate dependent).

D is destroyed inside stars. No sources other than the BB. D/H in the Milky Way provides a lower limit to the primordial value

What is the Milky Way Value?

Summary of Milky Way Values of D/H

- Variability large beyond LB.
- Weighted mean of four high values = 21.9 ±2.7 ppm. Total D/H? (Linsky et al. 2006)



1 σ uncertainties

Linsky et al. 2006

- Five low sightlines for N(H I)>$10^{20.7}$. Wt. Mean=8.6 ppm.
- If the high mean is the true Milky Way value, astration is low, f_d~1.25. For the low mean, astration is high, f_d~3.
- Rogers et al. 2005, 327 MHz hyperfine transition, report D/H=23+15/-13 ppm (3σ) in the l=183°, b=0° direction.

O Does not Vary as much as D

- $(O/H)_{LB}=345\pm19$ ppm. $(O/H)_{ISM}=347\pm16$ ppm for R<800pc and <n>≡N(HI)/R<1 (Oliveira et al. 2004, Cartledge et al. 2005).
  - $(O/H)_{ISM}$ changes by less than 30% for even larger distances and higher volume densities.
- Why does D vary much more than O?

Variable Infall and/or Astration as a Cause?

- Infall => increases D/H but decreases O/H; Astration => decreases D/H but increases O/H. However O/H largely constant even in LB. Also D/H or D/O vs O/H => Scatter plots.
  - Goldilocks solutions may be possible

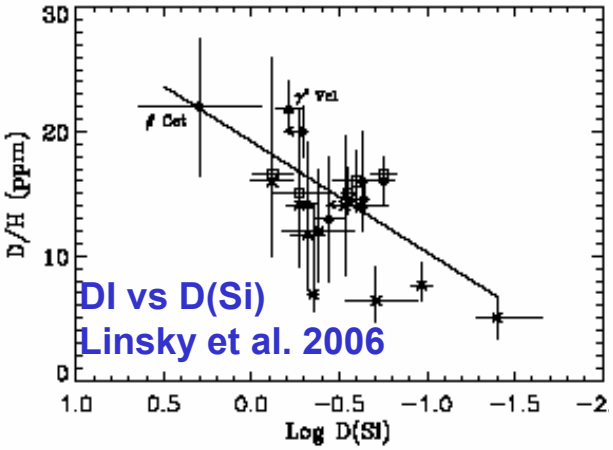
What about Chemical Effects?

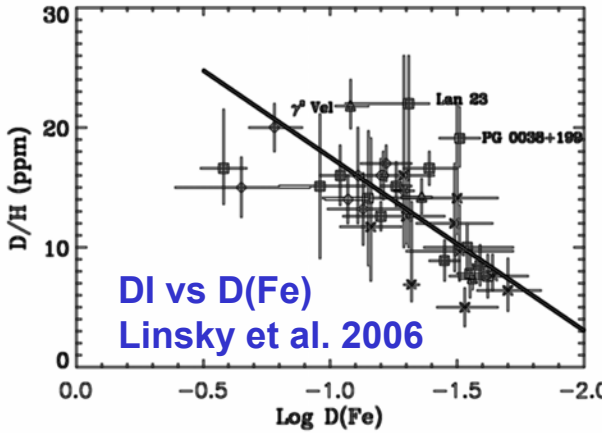
- H (and D) are highly reactive. D/H is 156 ppm in the earth's oceans, 10 times that of the LB. The stratosphere is 44% higher.
- Interstellar medium chemistry may be important => *Depletion*

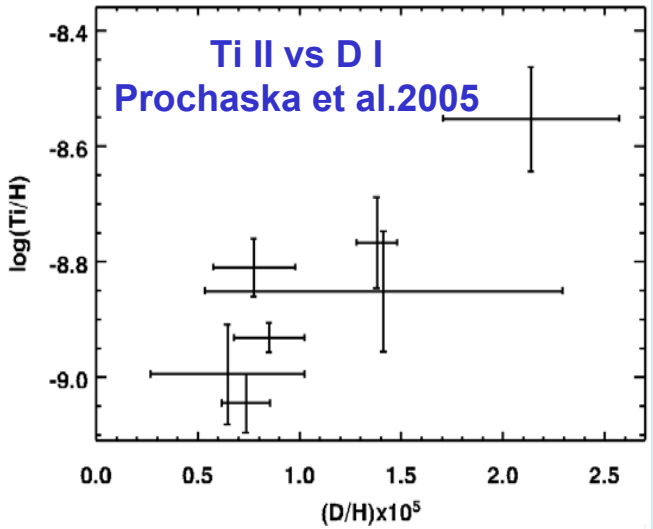

Hindenburg Airship
May 6, 1937

- Jura 1982 => dust depletion.
- Draine (2005, 2006) $\Delta E=0.083$ eV => carbonaceous interstellar grains, polycyclic aromatic hydrocarbons (PAHs), as a possible repository for D.

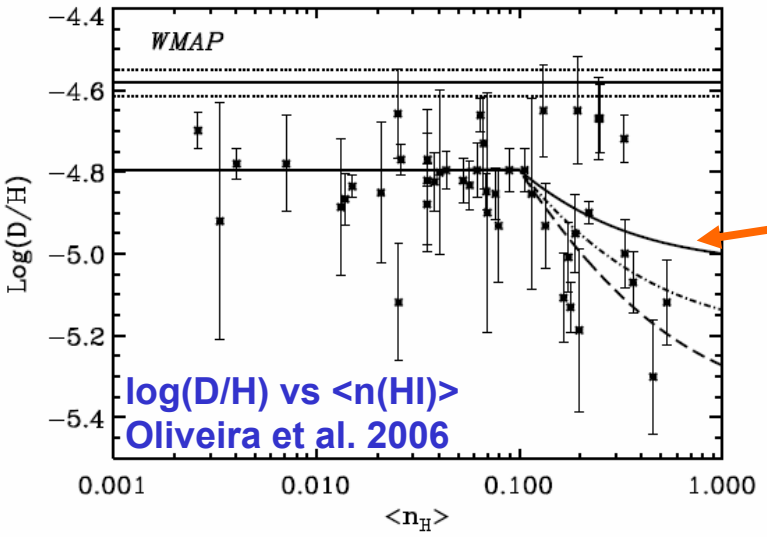
If D is depleted onto dust grains, D and metals will be correlated. Grain destruction in shocks should release both D and depleted metals.







- **D will be more depleted in cooler, denser gas.**



Depletion models similar to Jenkins, Spitzer & Savage 1986

SUMMARY

- D/H has been measured in the Milky Way Disk over a wide range of sightlines from Sirius to HD90087: 2.6 pc to 2700 pc and log(HI)=17.60 to log(HI)=21.22.
  D/H varies much more than O I/H I
  - Did not review D/O (e.g. Hebrard 2006, Oliveira 2006). Similar, but fewer high points.
- Discussed potential mechanisms: variable astration, infall and depletion.
- Correlations of D/H with Fe II, Si II, Ti II and <n> are evidence for depletion.
- The high values of D/H can be interpreted as a lower limit for total Milky Way D/H$\geq$22 ppm. Interesting lower limit to WMAP and extragalactic values: 26-28 ppm.

Deuterium Poster Papers: Session 175.
Recent Discoveries in the FAR UV

- 175.03 **What is the Total Deuterium Abundance in the Local Galactic Disk?**
  - *J.L. Linsky (JILA/Univ. Colorado), B.T. Draine (Princeton Univ.), H.W. Moos (JHU), E.B. Jenkins (Princeton Univ. Obs.), B.E. Wood (JILA/Univ. Colorado), C. Oliveira, W.P. Blair (JHU), S.D. Friedman (STScI), C. Gry (Lab. d'Astro. Marseille), D. Knauth (Northwestern Univ.), J.W. Kruk (JHU), S. Lacour (Obs. Paris-Meudon), N. Lehner (Univ. Wisconsin), S. Redfield (Univ. Texas), J.M. Shull (CASA/Univ. Colorado), G. Sonneborn (Lab. Obs. Cosmology/GSFC), G.M. Williger (JHU)*
- 175.04 **Deuterium, Oxygen and Nitrogen Abundance towards LSE 44**
  - *S.D. Friedman (STScI), G. Hebrard (IAP), T.M. Tripp (UMASS), P. Chayer (JHU), K.R. Sembach (STScI)*
- 175.07 Deuterium abundances along three extended sightlines from FUSE observations: Preliminary Results
  - *C. M. Oliveira, H. W. Moos (Johns Hopkins University), G. Hebrard (Institut d'Astrophysique de Paris), D. C. Knauth (Northwestern University)*
- 175.10 **Deuterium abundance in the interstellar medium: six new trgets observed with FUSE**
  - *G. Hebrard (Institut d'Astrophysique de Paris), S. D. Friedman (Space Telescope Science Institute), T. M. Tripp (University of Massachusetts), P. Chayer (JHU/UVIC), A. Lecavelier des Etangs (Institut d'Astrophysique de Paris), C. M. Oliveira, H. W. Moos (Johns Hopkins University), A. Vidal-Madjar (Institut d'Astrophysique de Paris)*
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- 175.18 **D/H, N/H, O/H and D/O along the sightline to the hot White Dwarf REJ178+665**
  - *J. Dupuis (CSA), C.M. Oliveira (JHU), G. Hebrard (IAP), H.W. Moos, P. Sonnentrucker (JHU)*
- 175.20 **D/H and D/O in the Galactic disk towars the CSPN RX J2117+3412**
  - *J.W. Kruk, C. Oliveira (JHU)*