Martian Isotopic D/H Ratio

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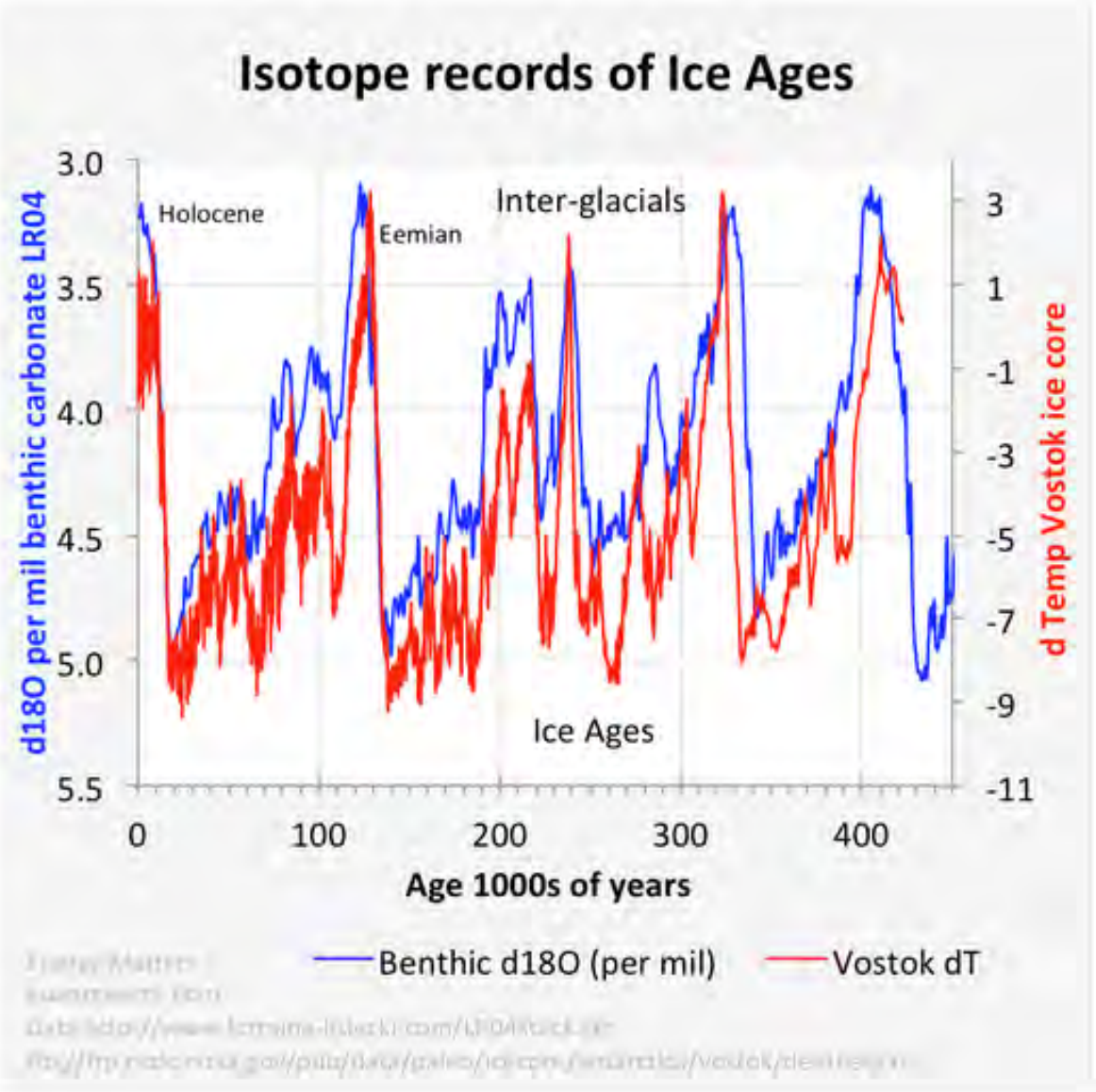
Climate Study Using Isotopologues

- Isotopologues of common molecules (such as water) are often used on earth as a probe of climatic variations (geographically and with time).
- Oxygen isotopes ($^{16}O/^{18}O$) and deuterium/hydrogen (D/H) ratios are used to track the terrestrial paleoclimate (e.g. ice cores)
- On Earth, changes we observe are measured relative to the ocean water.
- We want to determine a Martian standard for the ratio of hydrogen isotope abundances.



Earth temperatures derived from benthic 16O/18O ratio and Vostok ice core D/H ratio line up

What Can D/H Tell Us?

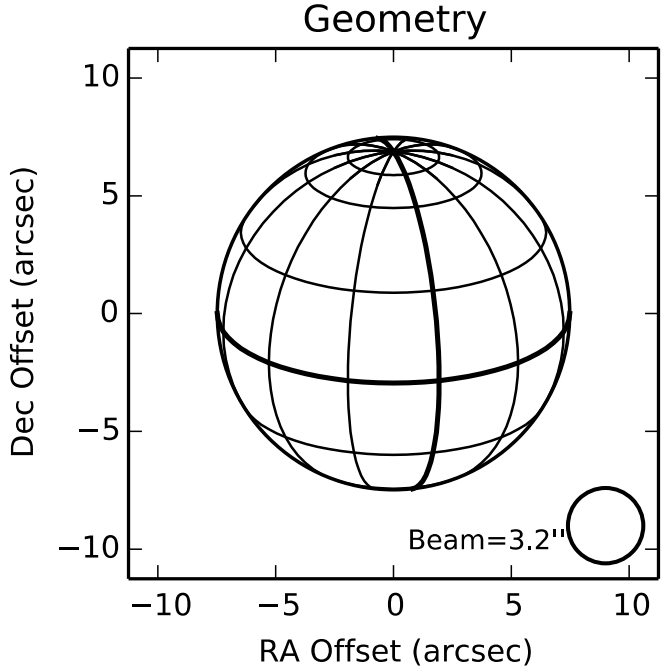
- Understand relationship between water in the atmosphere and ground reservoirs
- Determine current D/H values at various locations
- Track geographic and seasonal variations, and compare to paleoclimatic measurements
- Understand 'long history' of Mars's water
- 'Fingerprint' and track air masses

Martian Atmospheric D/H

- Generally measured relative to SMOW (Standard Mean Ocean Water) D/H
- Past measurements have been between 2 and 10 times SMOW
- Only recently has it been suggested that the D/H ratio might vary geographically

Observations

- Data collected using the SMA (an interferometric array covering the short millimeter and sub-millimeter wavelengths) on April 26, 2014 (Ls = 122.8)
- Two spectral lines: HDO (225.9 GHz transition) and $H_2{}^{18}O$ (203.4 GHz)

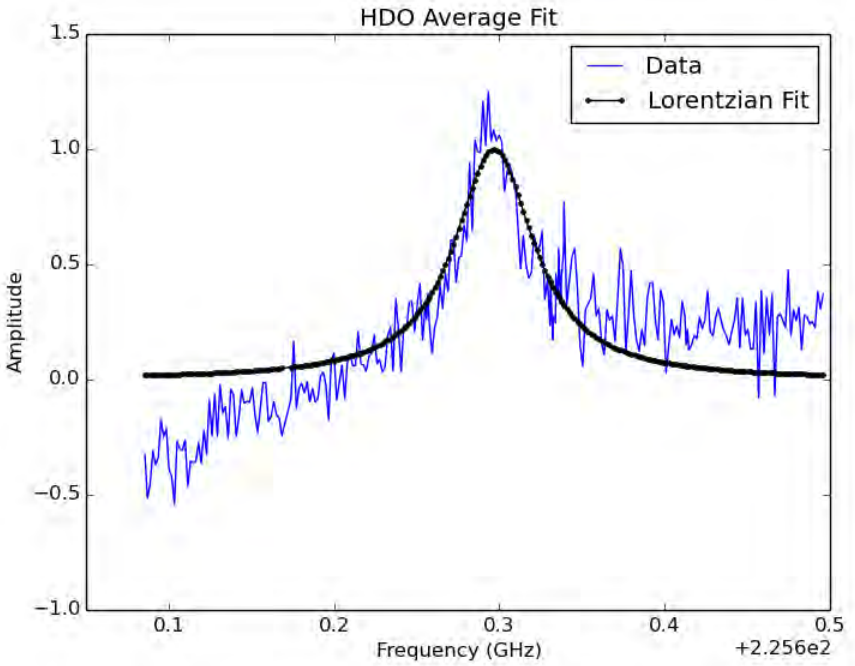


- At time of observations, Mars had a sub-Earth latitude of 23.2 degrees
- Data are averaged in longitude, but not in local time

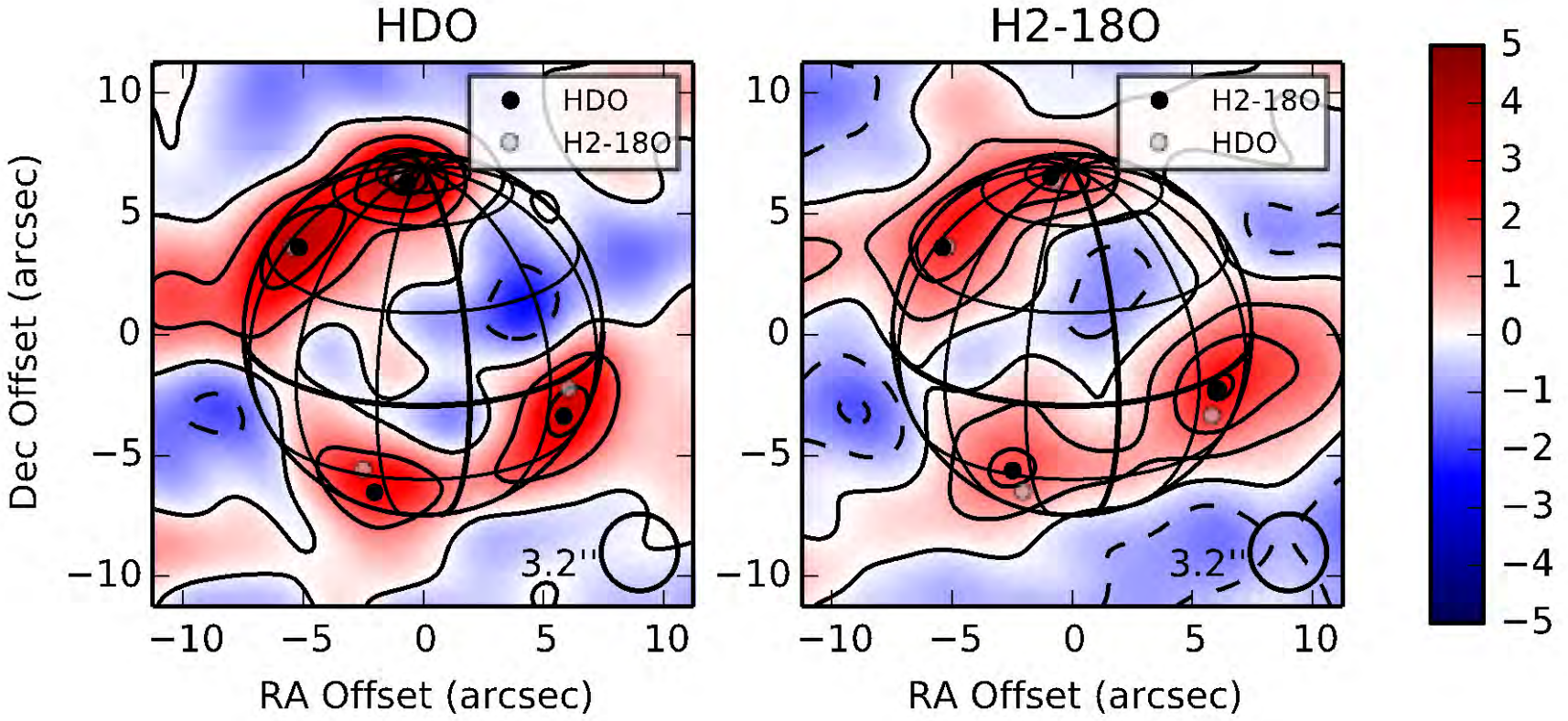
Lineshape Fitting

- After initial calibration (performed by Dr. Mark Gurwell at the CfA), spectral cubes were produced
- The spectra at each pixel were averaged around the limb and fit with a Lorentzian lineshape (due to collisional broadening)
- Then, each pixel was fit for a scale height, relative to the overall lineshape, producing maps of the relative line emission across the field of view.

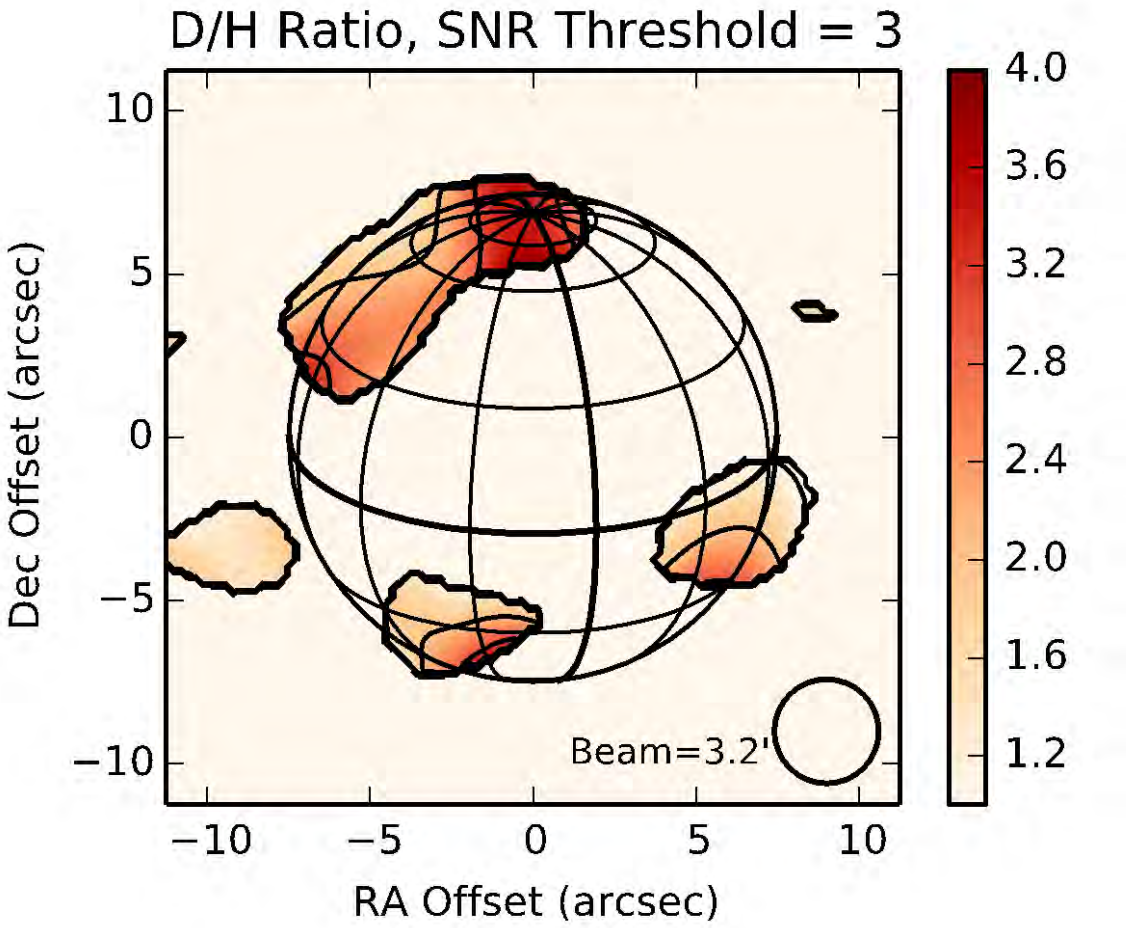
$$f(\nu) = a * \frac{b}{(\nu - \nu_0)^2 + b^2} + c,$$



HDO and H2-18O Intensity



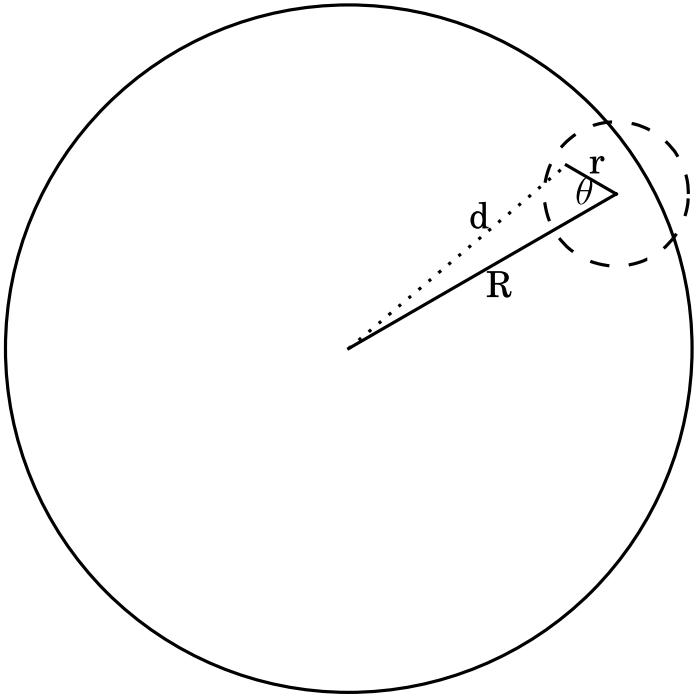
D/H Ratio

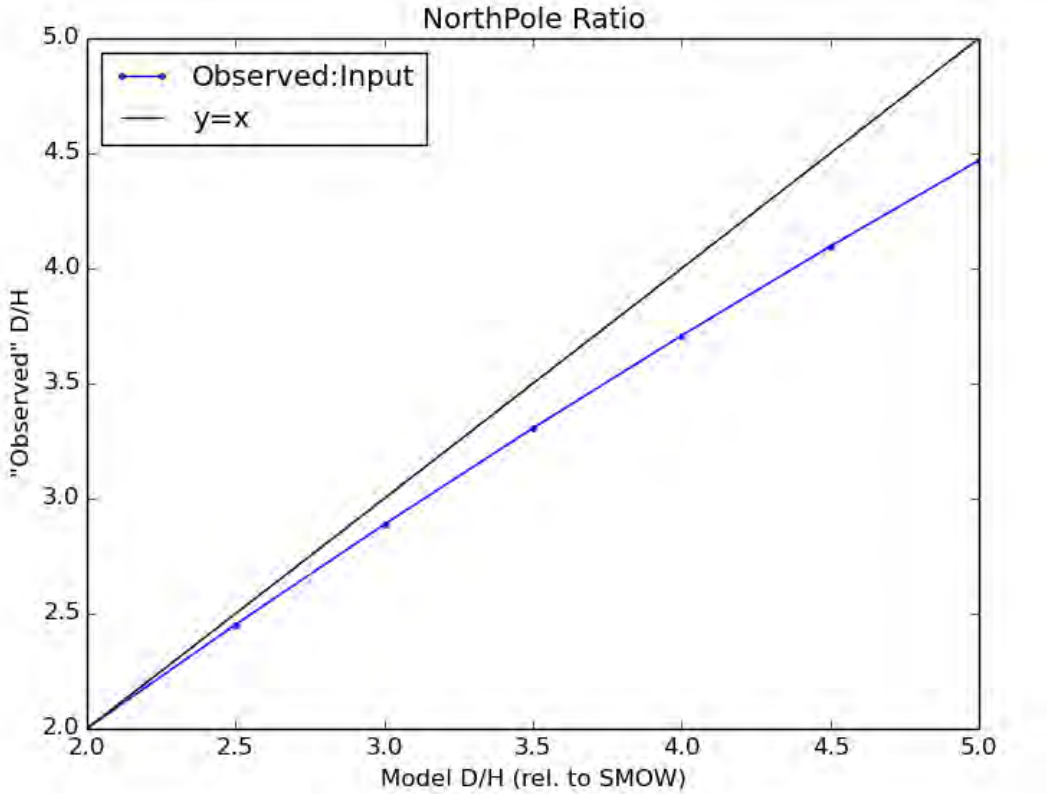

D/H Ratio, SNR Threshold = 3
Dec Offset (arcsec)
RA Offset (arcsec)
10
5
0
−5
−10
−10
−5
0
5
10
Beam=3.2'
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2

Temperature Profiles

- The observed intensity at a particular point depends on abundance AND temperature contrast.
- If the surface is cold relative to the atmosphere, the observed emission will be stronger.
- To account for this, temperature models were used to correct the ratios.
- Model temperature and pressure profiles were input into a radiative transfer code (written by Dr. Gurwell) to obtain radius-dependent spectra.

Beam Weighting



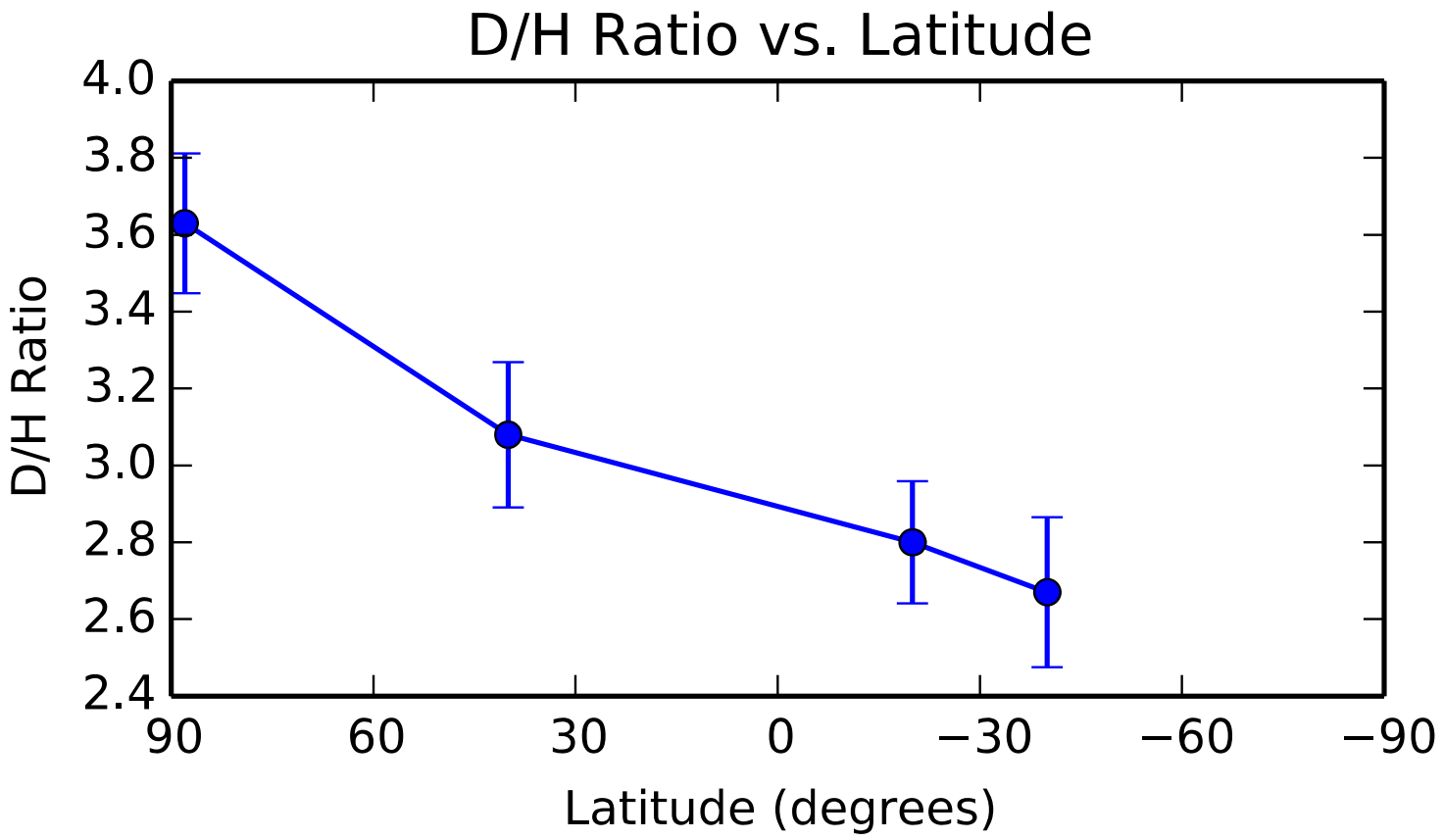


Results

Table 1: D/H for each location, before and after corrections from temperature profile models.

Location	D/H (Uncorrected)	D/H (Corrected)	Errors
North Pole	3.42	3.63	0.159
North Mid-Latitude	2.91	3.08	0.195
South Mid-Latitude	2.67	2.80	0.182
Deep South	2.64	2.67	0.189

- The temperature profile corrections have little effect on the results.


D/H Ratio vs. Latitude
D/H Ratio
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
90
60
30
0
−30
−60
−90
Latitude (degrees)

Conclusions

- D/H decreases from north to south
- D/H ratios are somewhat lower than past literature (~3 vs. ~5.5)
- If there are no systematic errors in our measurements, and the past globally averaged value of 5.5 is correct, our data support the hypothesis that there are geographic variations in D/H
- This is a probe of the D/H ratios in the various martian water reservoirs

Acknowledgements

- Michael Hecht and Mark Gurwell
- Phil Erikson and Vincent Fish
- and everyone at Haystack!

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Questions?