Median Statistics Analysis of Deuterium Abundance and Spatial Curvature Constraints

By: Jarred Penton

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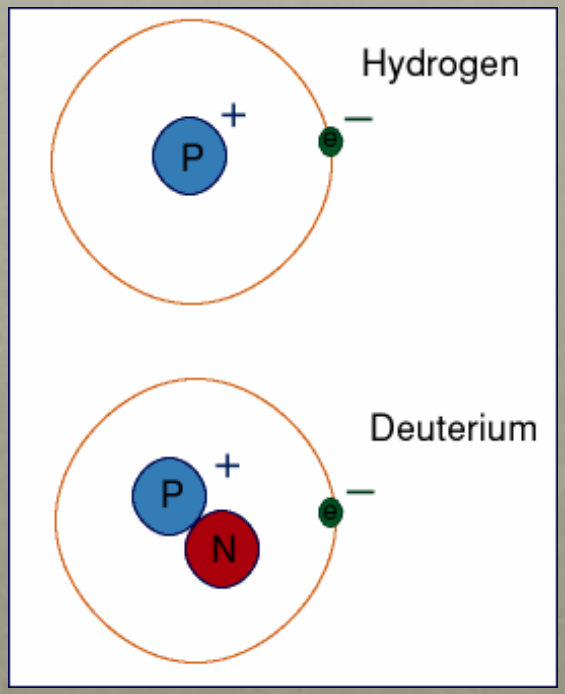
OUTLINE

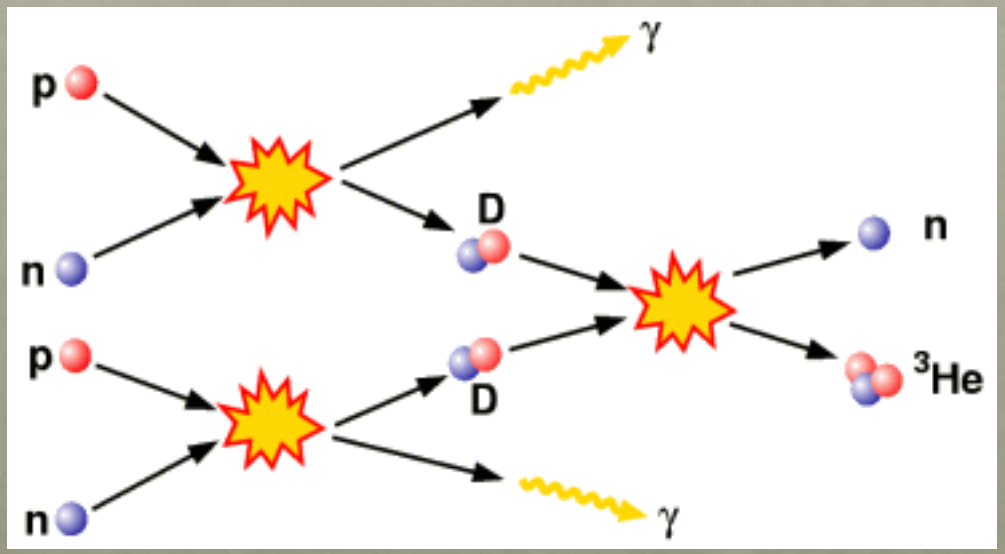
- Deuterium Abundance
- Median Statistics
- Baryonic Density
- Results

WHAT IS DEUTERIUM?

- "Heavy Hydrogen"
- Big Bang Nucleosynthesis



https://archive.stsci.edu/fuse/scisumm/sci_d2h.html



http://www.einstein-online.info/spotlights/BBN.html

RESEARCH

Quasar	D/H($\times 10^5$)	References
HS 0105+1619	$2.58^{+0.16}_{-0.15}$	Cooke et al. (2014)
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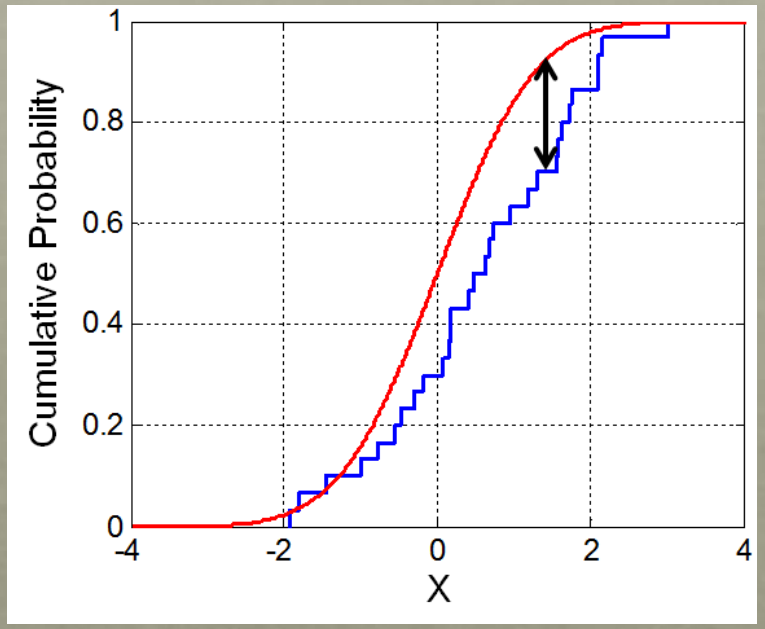
PKS1937-1009	$2.45^{+0.30}_{-0.27}$	Riemer-Sørenson et al. (2015)
PKS1937-101	2.62 ± 0.05	Riemer-Sørenson et al. (2017)
Q2206-199	1.65 ± 0.35	Pettini et al. (2001)

- Calculate central estimates
- Test error distributions of central estimates
- Compare to current theoretical model

Zavarygin, E. O., Webb, J. K., Dumont, V., & Riemer-Sørensen, S. 2018, MNRAS, 477, 5536 [arXiv:1706.09512]

STATISTICAL ANALYSIS

- Kolmogorov-Smirnov "Goodness of Fit" Test
- Kolmogorov-Smirnov Distribution



$$p = 2\sum_{i=1}^{\infty}(-1)^{i-1}e^{(-i^2z^2)}$$

$$z = \left(\sqrt{N} + 0.12 + \frac{0.11}{\sqrt{N}}\right)D$$

KS TEST RESULTS

	Truncated 13	All 15
Dist.	p	p
Median		
Gaussian	0.999	0.809
Cauchy	0.385	0.921
Weighted Mean +		
Gaussian	0.999	0.885
Cauchy	0.517	0.948
Weighted Mean -		
Gaussian	0.997	0.613
Cauchy	0.604	0.950
Arithmetic Mean		
Gaussian	0.999	0.238
Cauchy	0.612	0.722

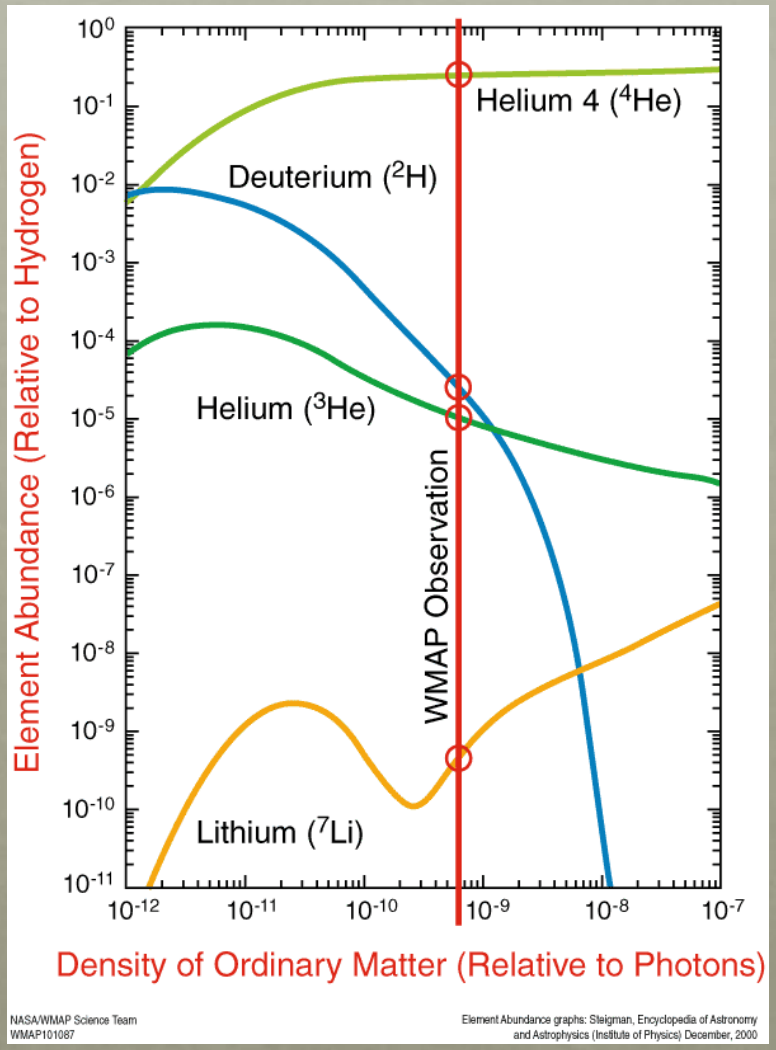
- Truncated 13 is gaussian
- All 15 is non-gaussian
- Median Statistics does not assume gaussianity

CENTRAL ESTIMATES

$$\text{CMB Prediction} = 2.45 \pm 0.05$$

Truncated 13	All 15
$\text{Weighted Mean} = 2.54 \pm 0.03$	~~$\text{Weighted Mean} = 2.53 \pm 0.03$~~
~~$\text{Arithmetic Mean} = 2.46 \pm 0.06$~~	~~$\text{Arithmetic Mean} = 2.32 \pm 0.11$~~
~~$\text{Median} = 2.51^{+0.07}_{-0.06}$~~	$\text{Median} = 2.48^{+0.05}_{-0.08}$

BARYONIC DENSITY



https://wmap.gsfc.nasa.gov/universe/bb_tests_ele.html

- D/H is correlated to $\Omega_b h^2$, the density of ordinary matter in the universe

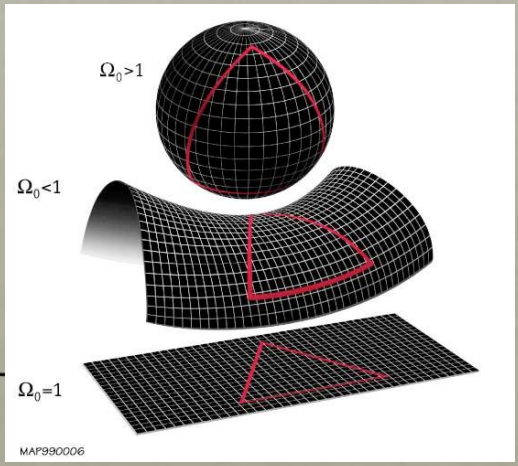
$$(D/H)_p = (2.45 \pm 0.04) \times 10^{-5} \left(\frac{\Omega_b h^2}{0.02225} \right)^{-1.657}$$

- Compare our values to current CMB predictions of $\Omega_b h^2$

RESULTS

$$\Omega_b h^2_{\rm wm} = 0.02175 \pm 0.00025$$

$$\Omega_b h^2_{\rm med} = 0.02209 \pm 0.00041$$



https://wmap.gsfc.nasa.gov/universe/bb_concepts.html

	CMB data alone			CMB and other data		
Cosmogony	$\Omega_b h^2$	WM σ	Median σ	$\Omega_b h^2$	WM σ	Median σ
Flat ΛCDM	0.02225 $\pm$0.00023	1.5	0.34	0.02232 $\pm$0.00019	1.8	0.51
Nonflat ΛCDM	0.02305 $\pm$0.0002	4.1	2.1	0.02305 $\pm$0.00019	4.1	2.1
Flat XCDM	0.02229 $\pm$0.00023	1.6	0.43	0.02233 $\pm$0.00021	1.8	0.52
Nonflat XCDM	0.02305 $\pm$0.0002	4.1	2.1	0.02305 $\pm$0.0002	4.1	2.1
Flat ϕCDM	0.02221 $\pm$0.00023	1.4	0.26	0.02238 $\pm$0.0002	2.0	0.64
Nonflat ϕCDM	0.02303 $\pm$0.0002	4.0	2.1	0.02304 $\pm$0.0002	4.0	2.1

CONCLUSION

- Using median statistics allows us to take all data points
- The All 15 dataset is clearly non-gaussian
- The weighted mean central estimate not only omits data points, but is also less-consistent with CMB predictions
- The median central estimate we measure is, in all cases, more consistent with CMB predictions
- Measurements of $(D/H)_p$ provide $\Omega_b h^2$ values that favor flat universe predictions

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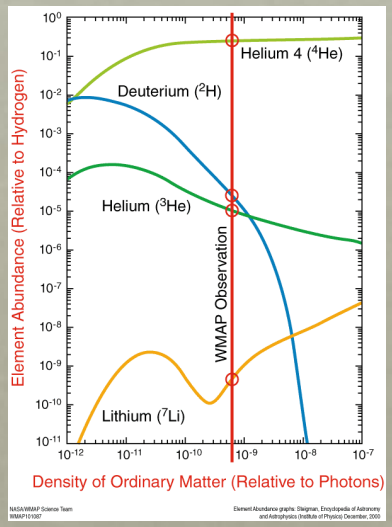
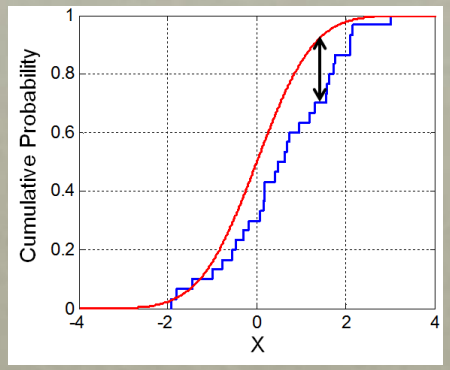
- Aasim Zahoor
- Aman Singal

QUESTIONS?





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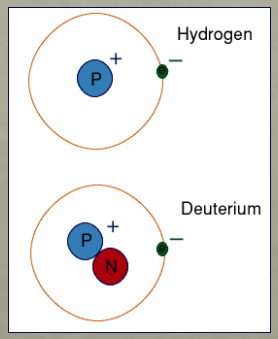

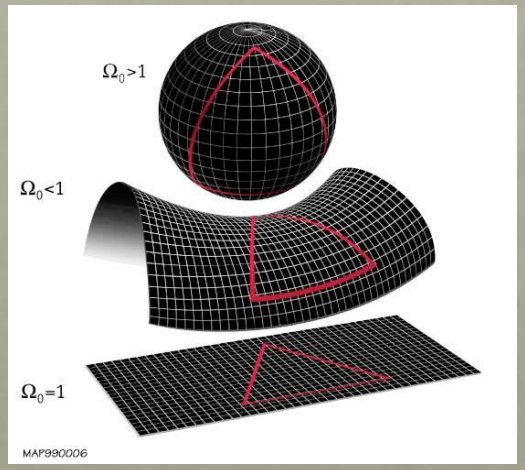

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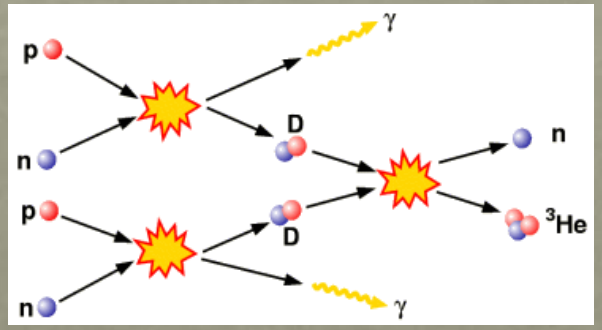

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