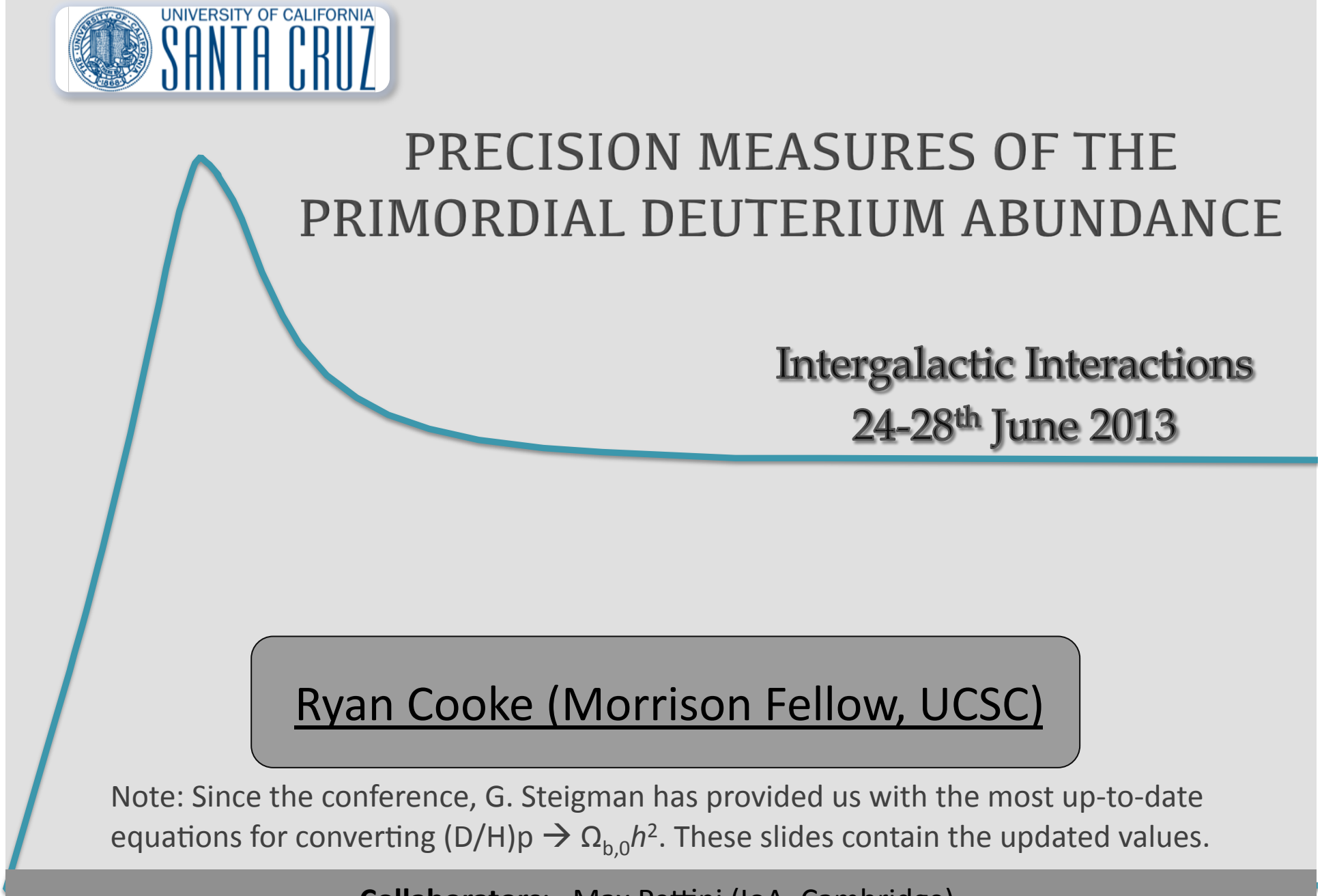


PRECISION MEASURES OF THE PRIMORDIAL DEUTERIUM ABUNDANCE

Intergalactic Interactions
24-28th June 2013

Ryan Cooke (Morrison Fellow, UCSC)

Note: Since the conference, G. Steigman has provided us with the most up-to-date equations for converting (D/H)p → $\Omega_{b,0}h^2$. These slides contain the updated values.

Collaborators: Max Pettini (IoA, Cambridge),
Regina Jorgenson (IfA, Hawaii), Michael Murphy (Swinburne)

Big Bang Nucleosynthesis (BBN) Ingredients

Input parameters

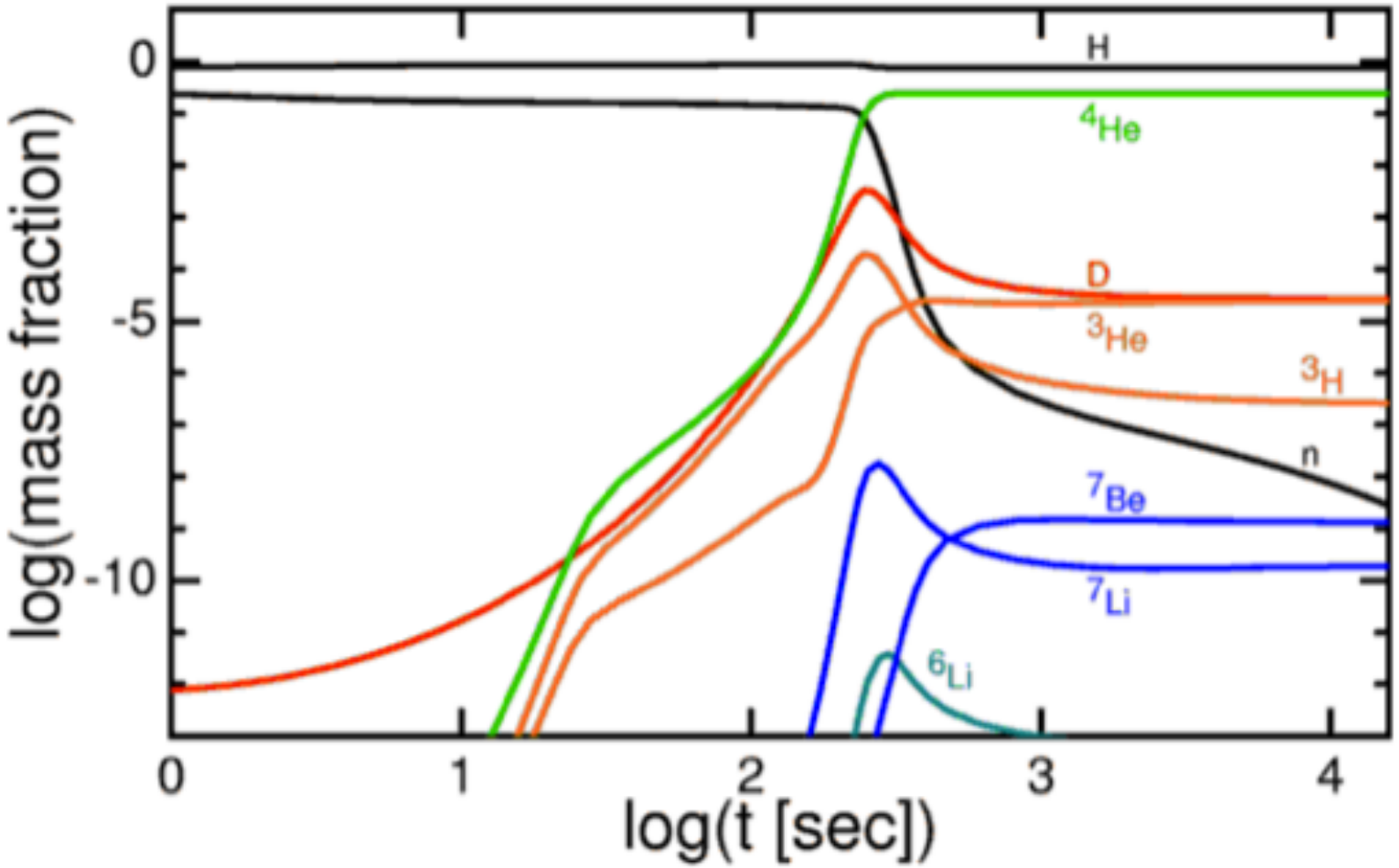
- The expansion rate of the Universe
- Baryon density parameter
- Neutrino Degeneracy (i.e. lepton asymmetry)

Standard Model Assumptions

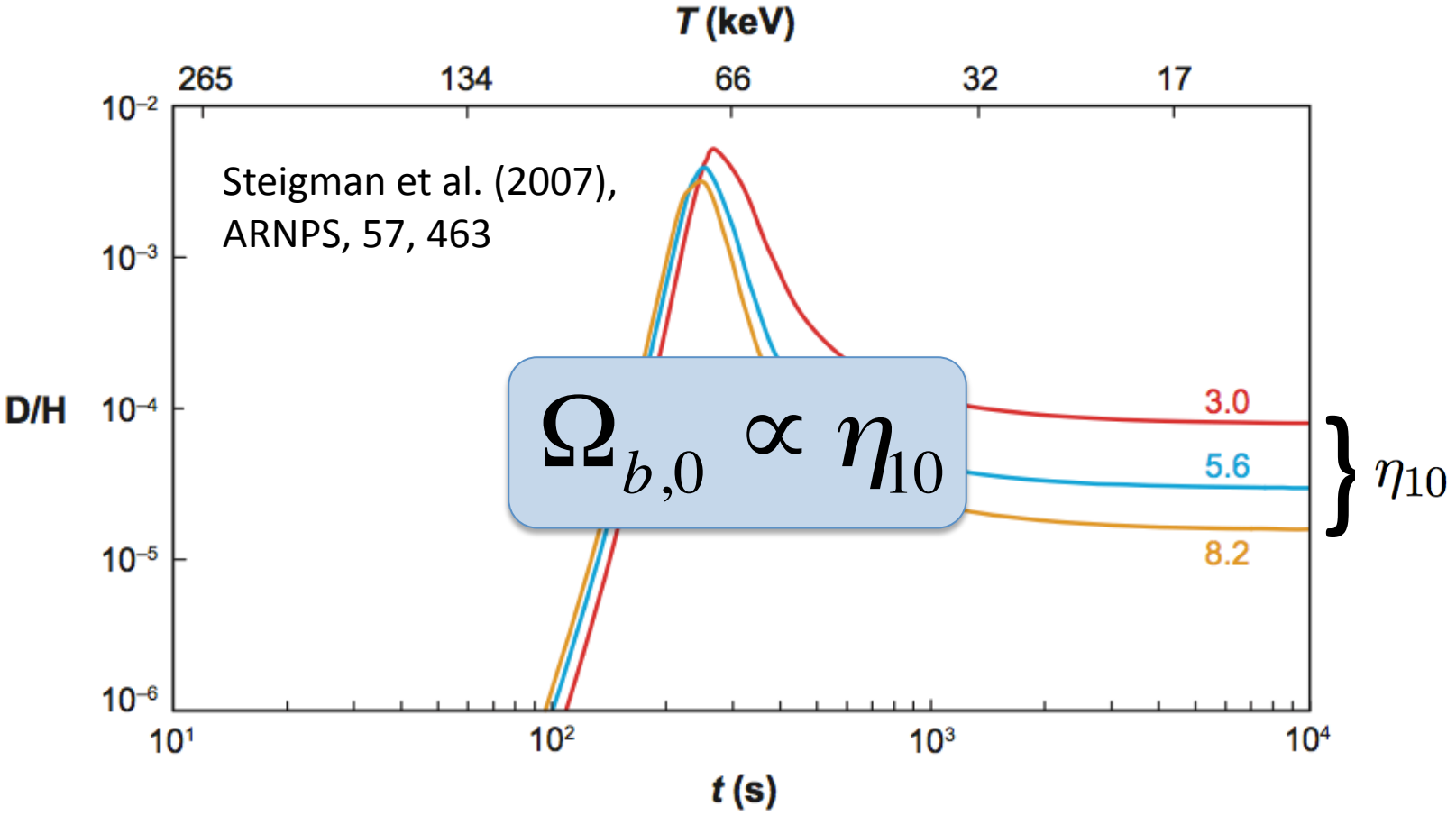
- Laboratory measured reaction cross-sections
- General Relativity (i.e. the Friedman Equation)
- 3 families of neutrinos
- No lepton Asymmetry

Big Bang Nucleosynthesis

A story of success! --- Just one parameter



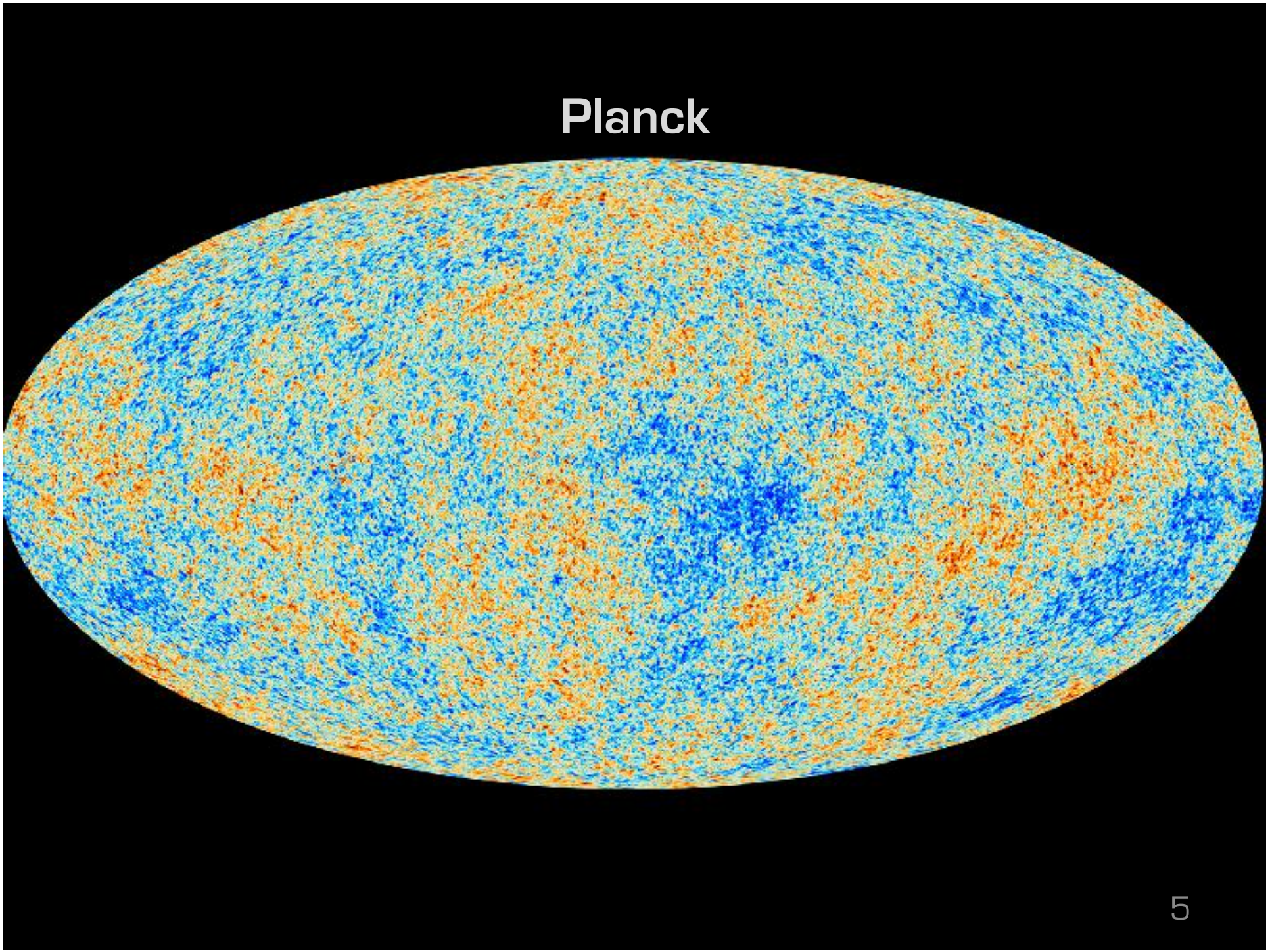
How to predict D/H



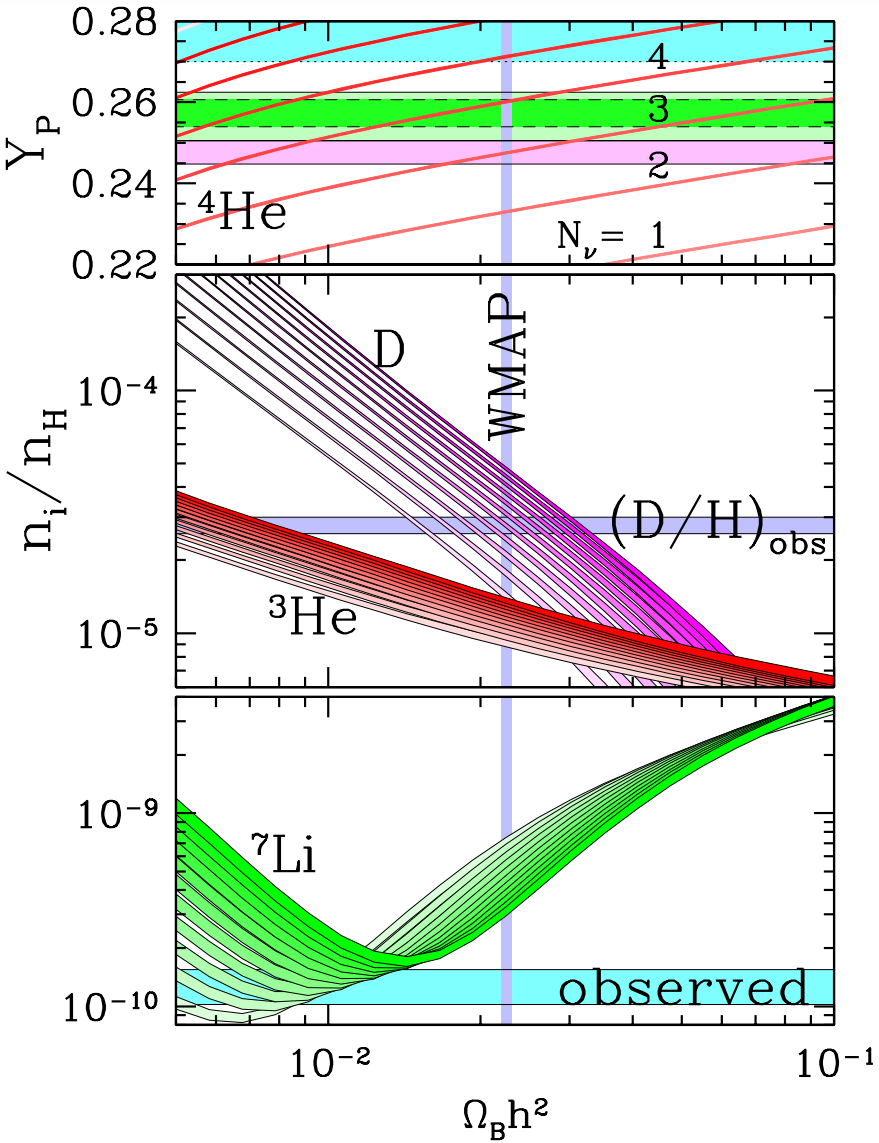
$$\Omega_{b,0} \propto \eta_{10}$$

$$(\mathrm{D/H})_{\mathrm{P}} \propto \eta_{\mathrm{D}}^{-1.6}$$

$$\eta_{\mathrm{D}} \propto \eta_{10} + \text{non-standard BBN parameters}$$


Planck

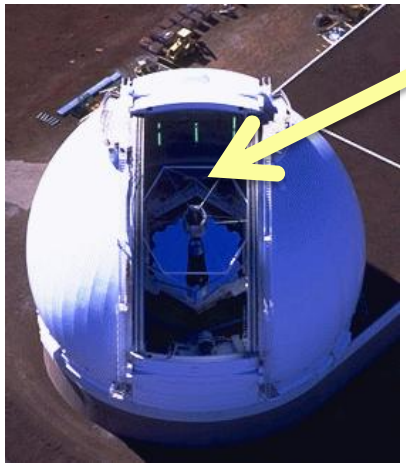
Big Bang Nucleosynthesis

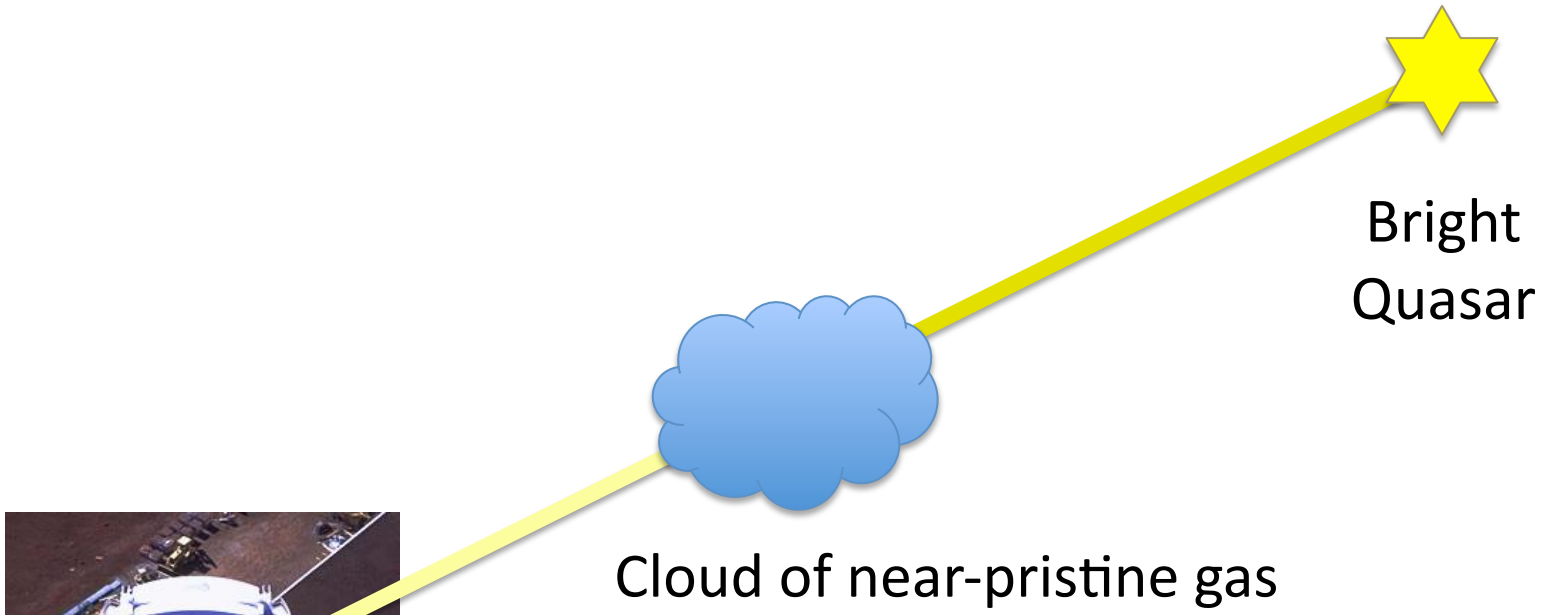


Nollett & Holder (2011), Phys. Rev. D (submitted), arXiv: 1112.2683

- Some disagreement between Standard BBN Calculations and observed data
- D/H offers tightest constraint on Ω_b
- ^{4}He offers tightest constraint on N_ν at present

Near-pristine clouds of gas

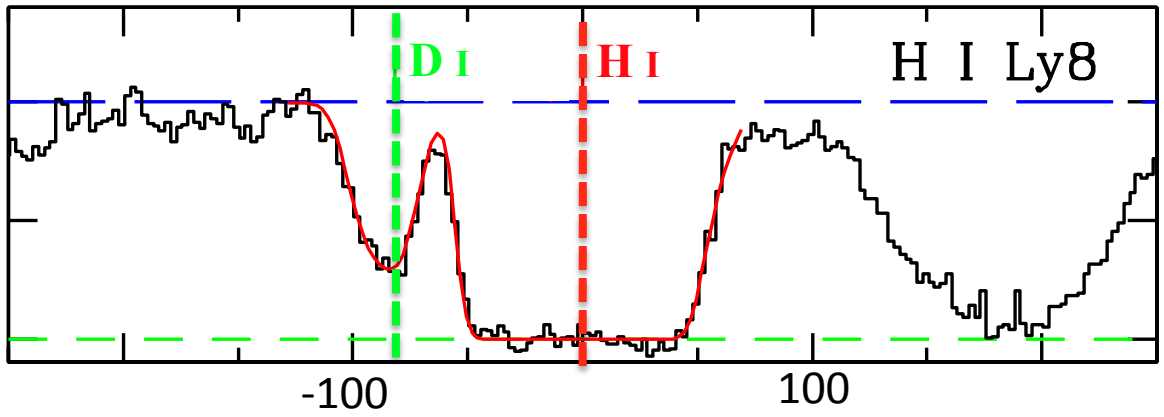




How to *precisely* measure D/H

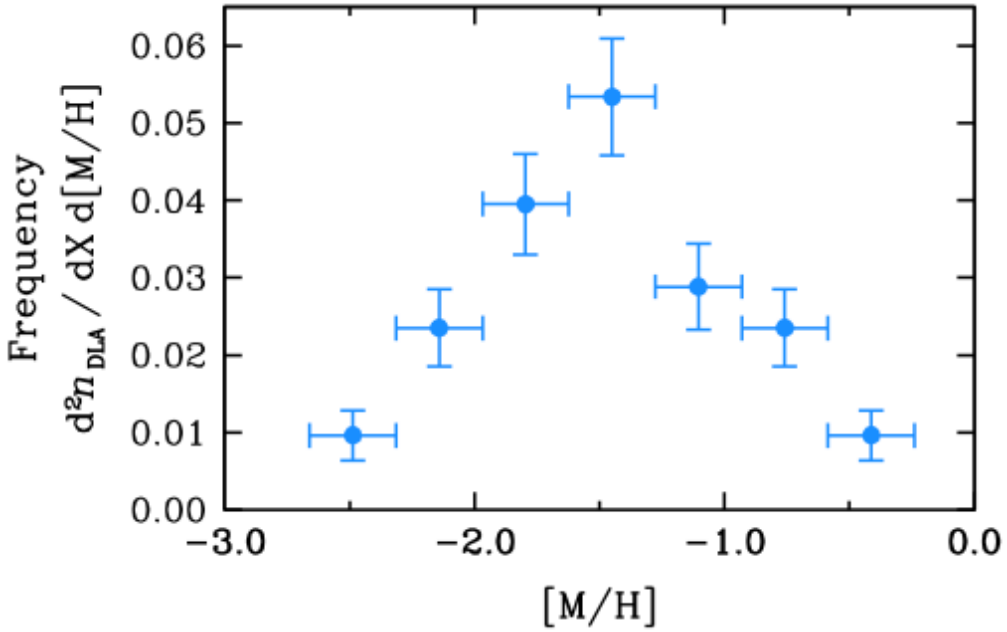
Potentially the best systems are the most metal-poor DLAs

- Ease of measuring the H I column density from the wings of the damped Lyman-α line.
- Many transitions available for the D I Lyman series to measure deuterium column density
- Low metallicity implies negligible D astration
- Quiescent kinematics help to resolve the 82 km/s isotope shift

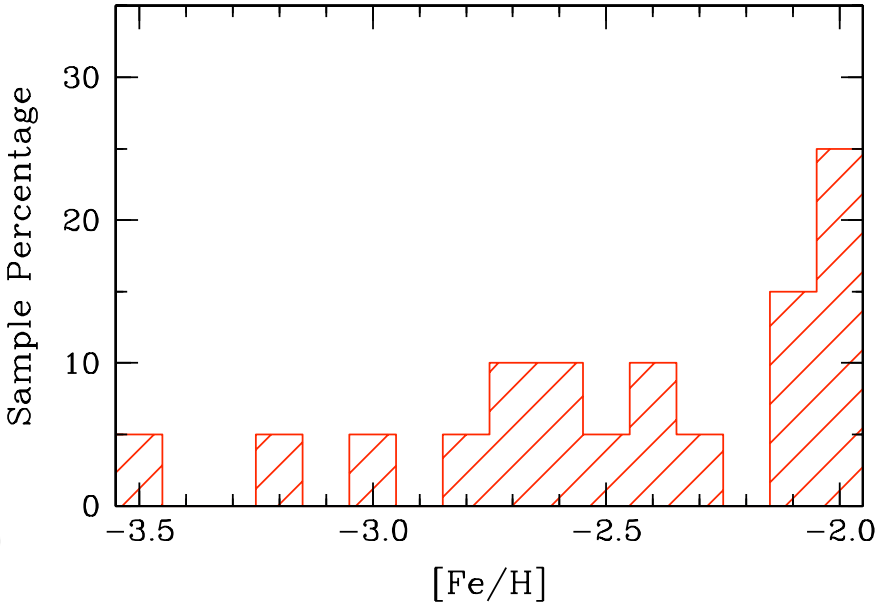


The Metal-poor DLAs Survey

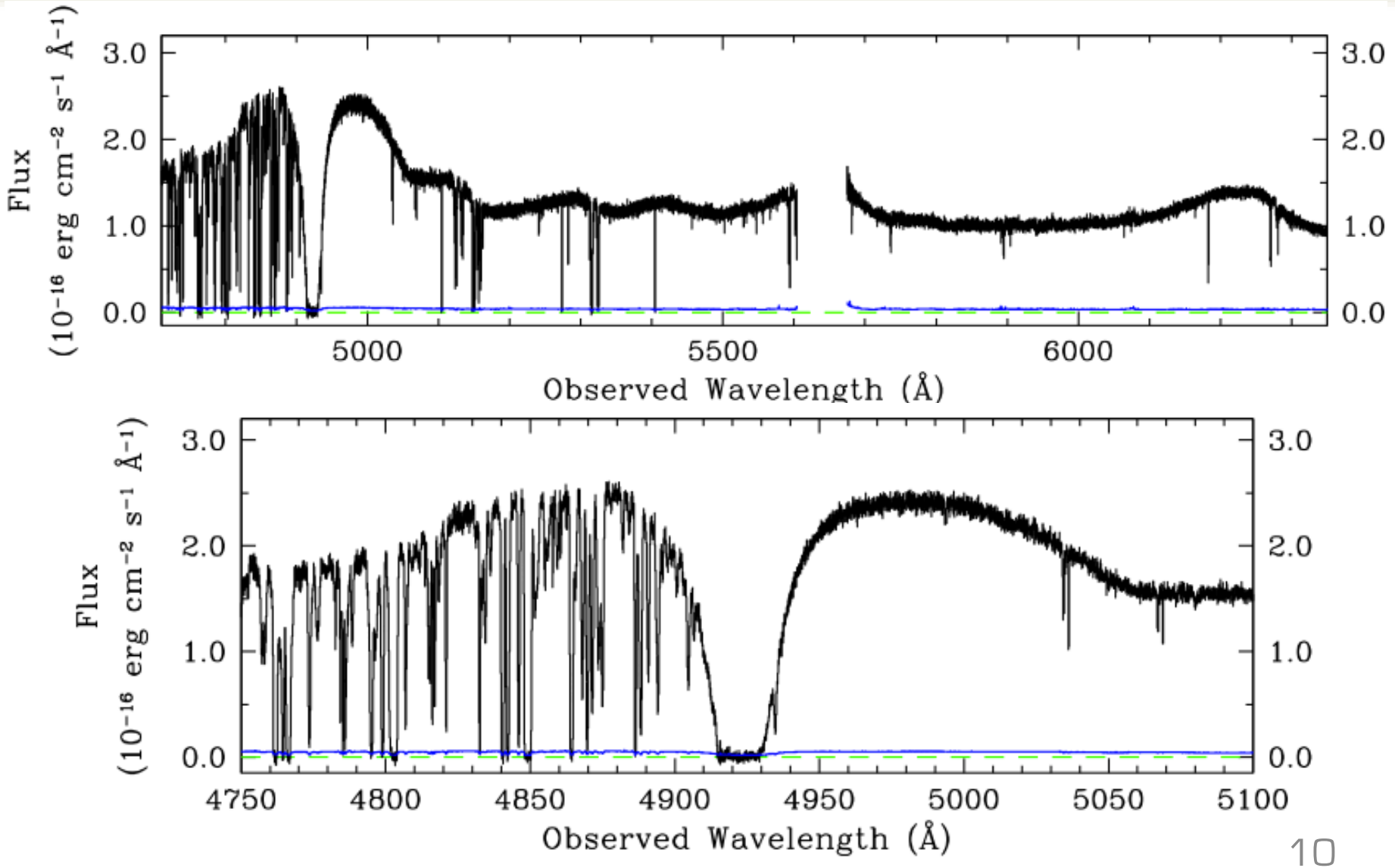
Data from:
Rafelski et al. (2012), ApJ, 755, 89



Cooke et al. (2011b) MNRAS, 417, 1534



What a system!

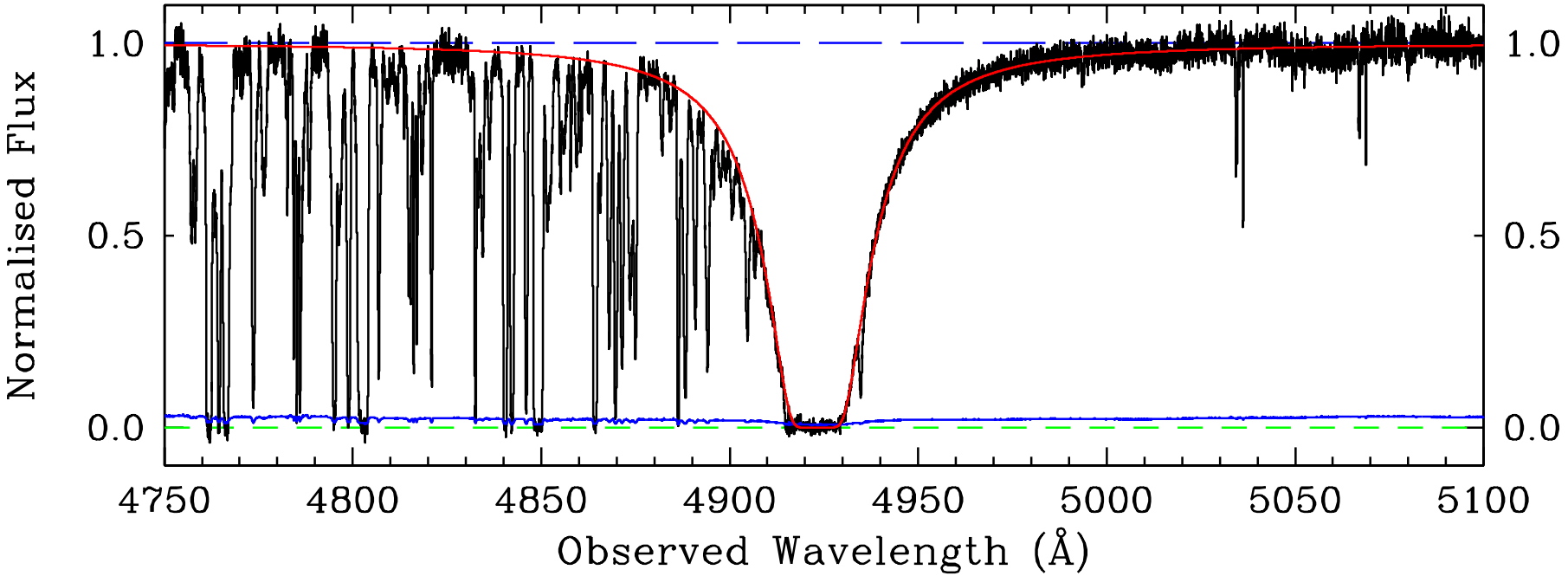


ALIS — Absorption LIne Software

- Simultaneously fit emission and absorption lines
- Fits to D/H directly
- Chi-squared minimization
- Calculates the systematic uncertainties in zero-level and continuum choice
- Multi-processed

What a system!

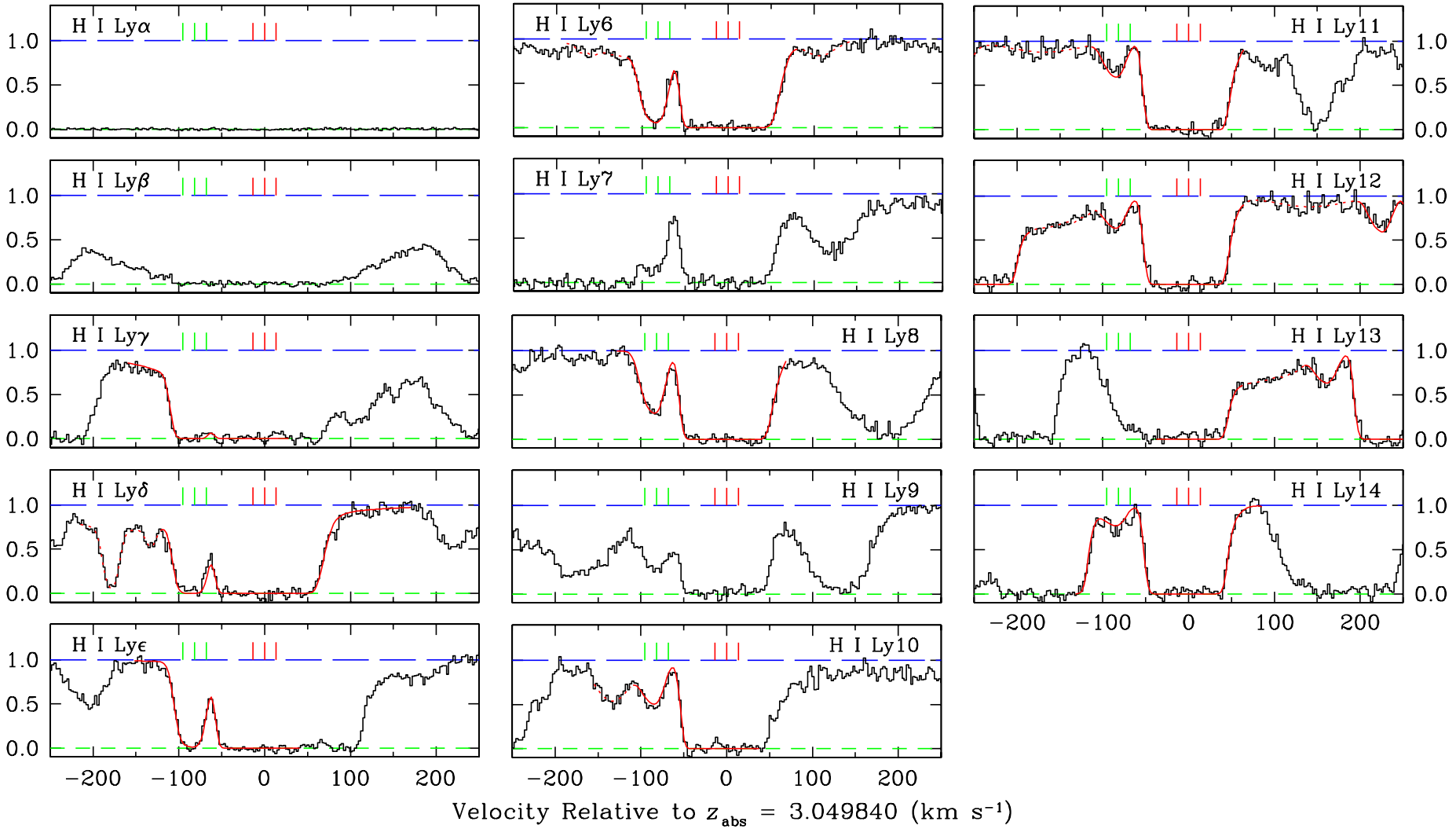
J1419+0829 z = 3.050 Fe/H = 1/200 of solar



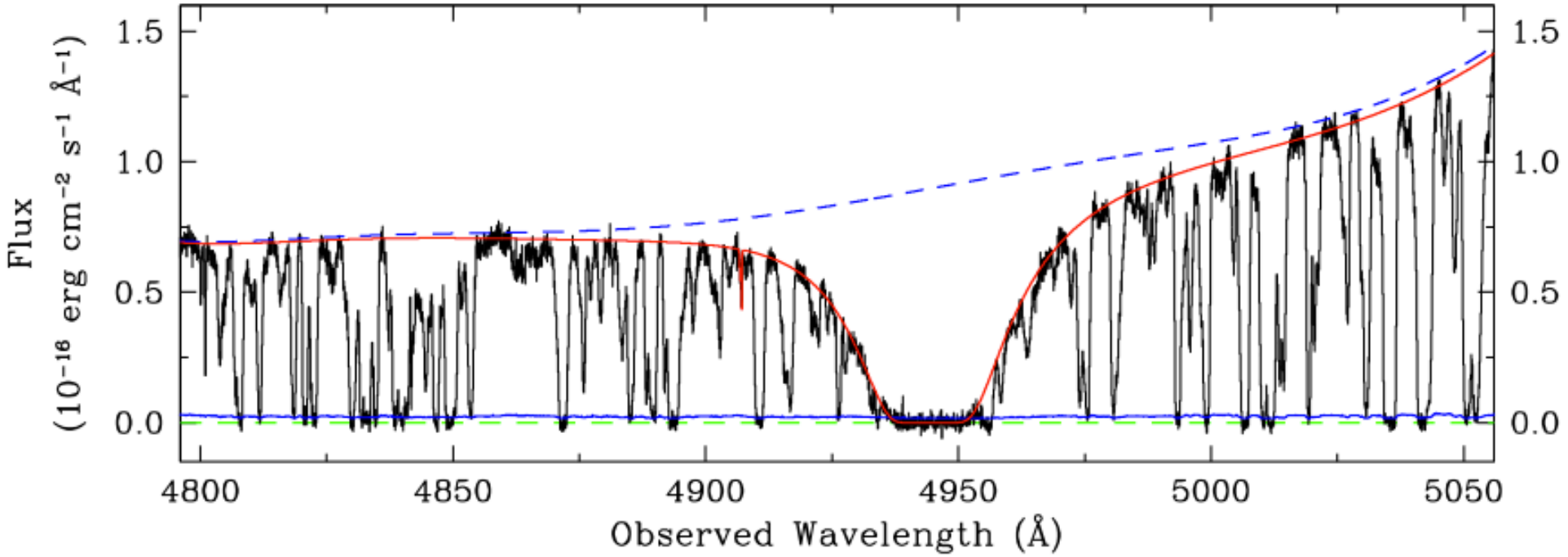
log N(H I)/cm^{-2} = 20.391 ± 0.008

The Lyman series

Pettini & Cooke (2012) MNRAS, 425, 2477

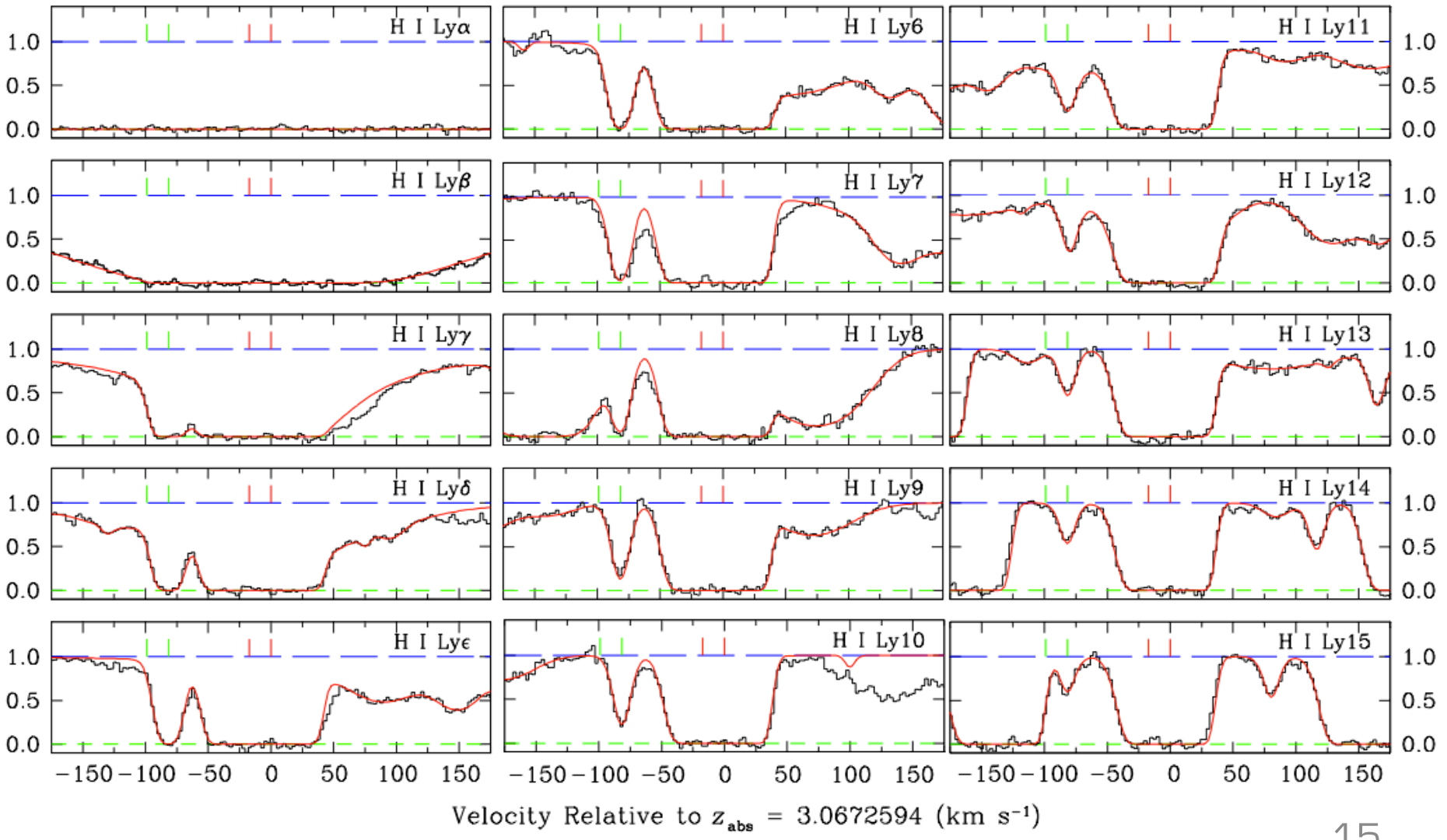


A new system with D/H



log N(H I)/cm^{-2} = 20.49 ± 0.01

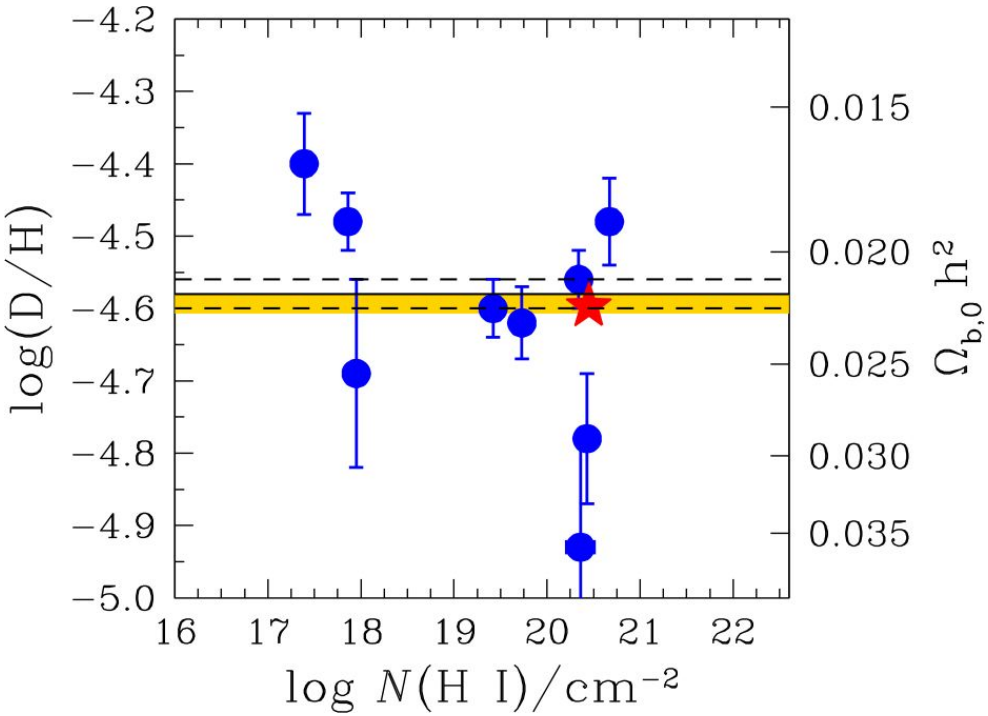
A new system with D/H



Precision Estimates of D/H

Why is there an excess dispersion in D/H measures?

- Careful modeling of the QSO continuum+emission lines
- Blind analysis technique
- Full accounting of the dominant systematics
- Simultaneous fit all of the important parameters



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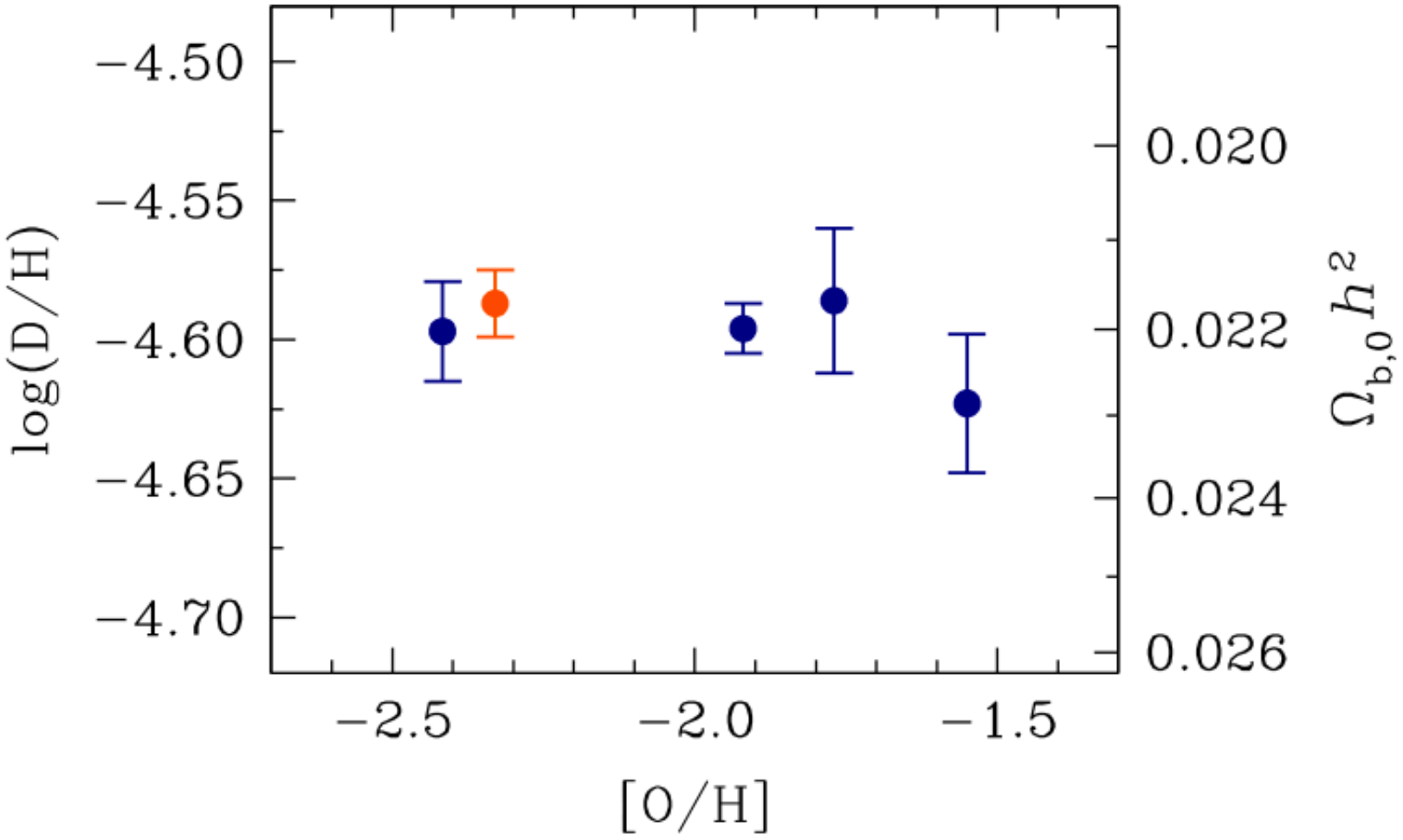

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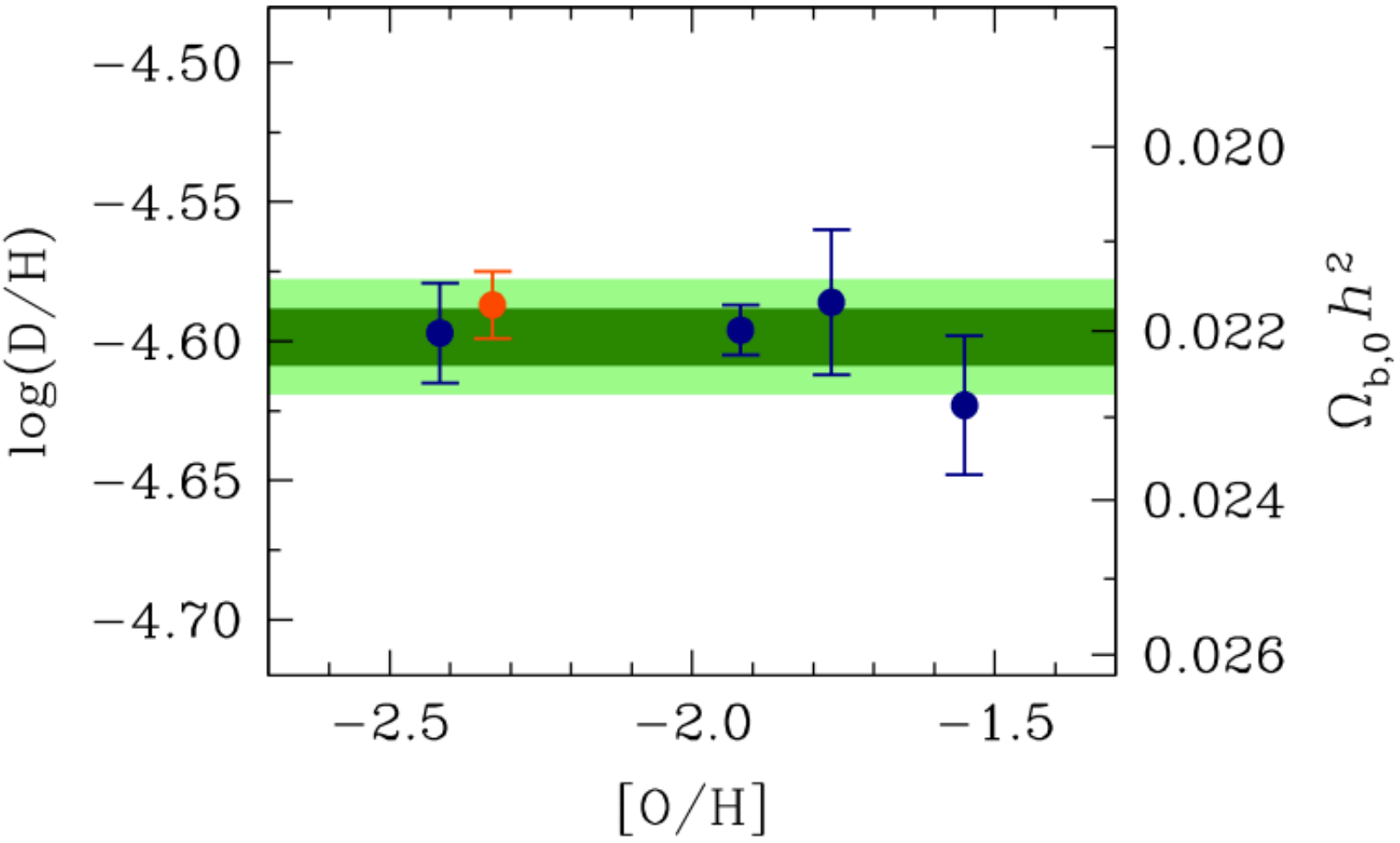
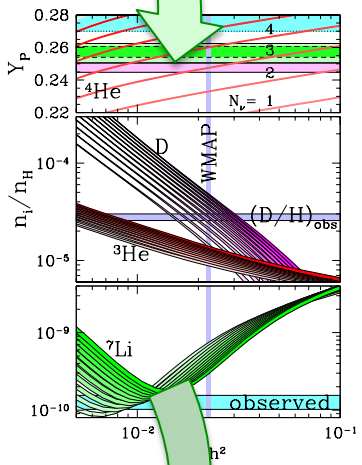


The baryon density

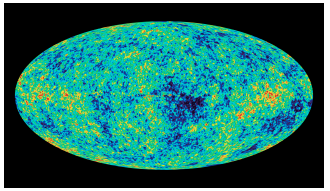
$$\log(D/H) = -4.595 \pm 0.004$$

ASSUMING STANDAND BIG BANG NUCLEOSYNTHESIS

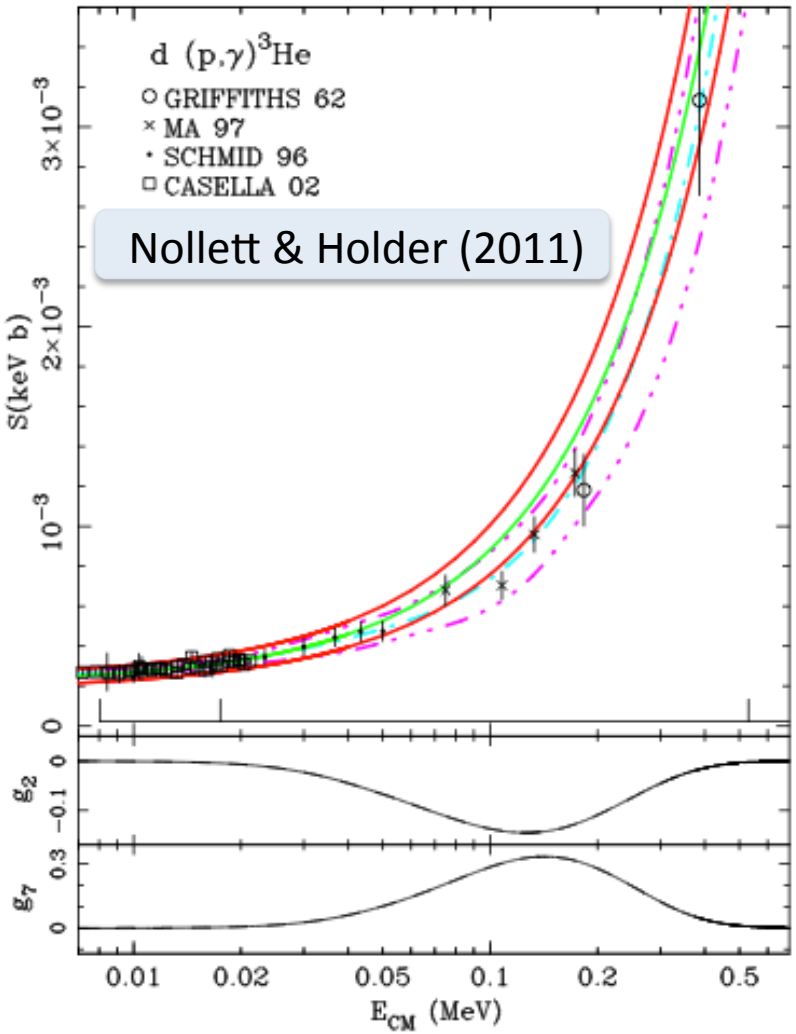
$$100\ \Omega_{b,0}\ h^2(\mathrm{BBN}) = 2.20 \pm 0.04$$

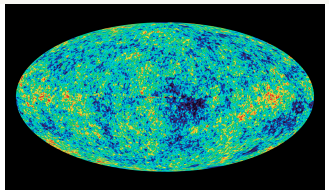


$$100\ \Omega_{b,0}\ h^2(\mathrm{CMB}) = 2.205 \pm 0.028$$



The current limitation





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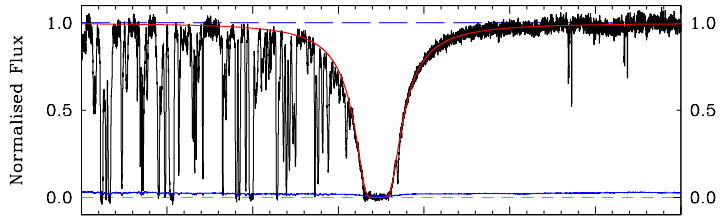
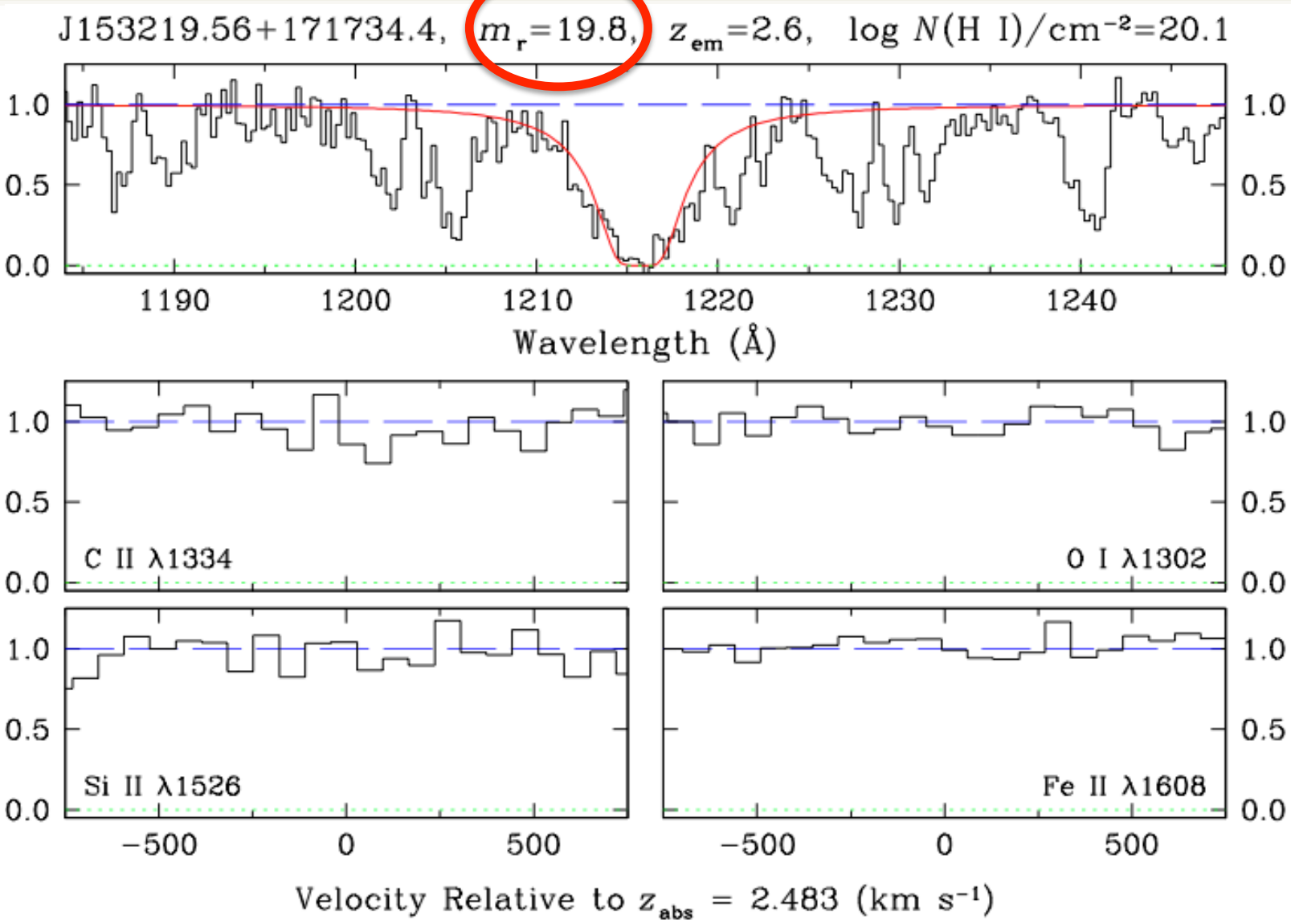


$100\ \Omega_{b,0}\ h^2(\mathrm{BBN}) = 2.20 \pm 0.04$

$100\ \Omega_{b,0}\ h^2(\mathrm{BBN}) = \#.\#\# \pm 0.01$

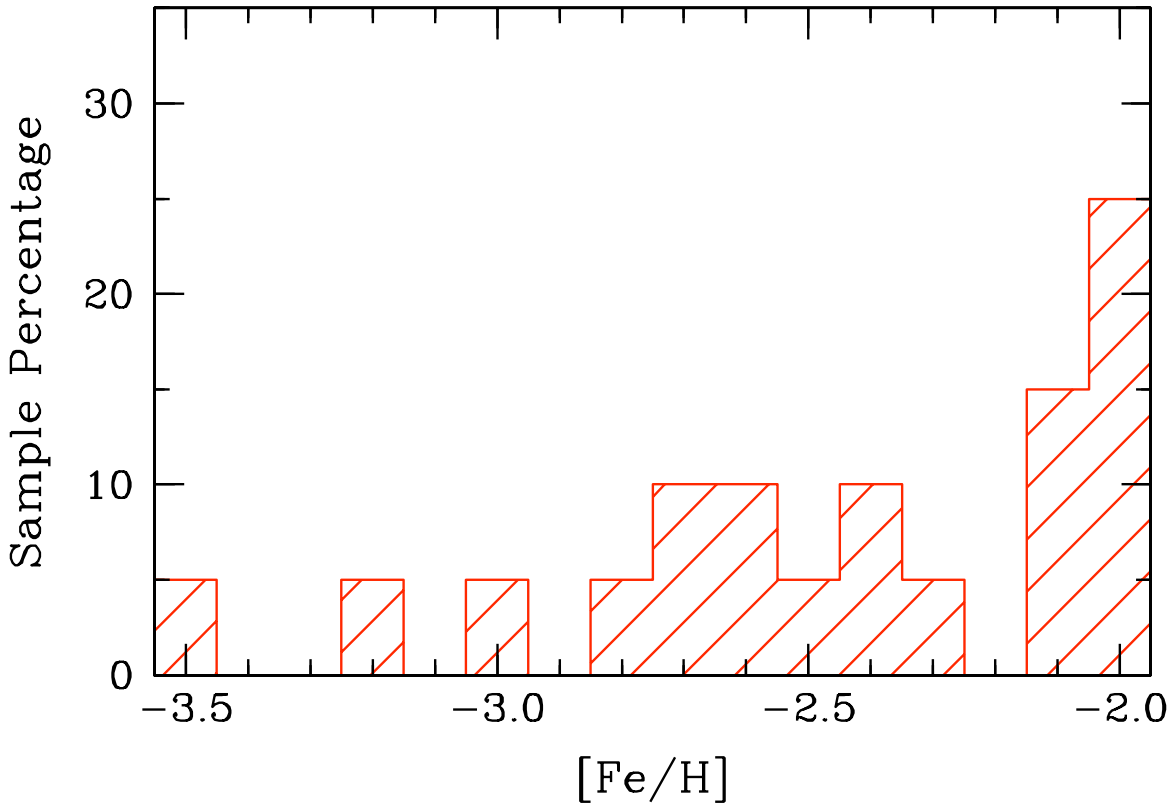
(projected)

The future — 30 m class telescopes...



Summary and Conclusions

- Conducted a survey to study the most metal-poor DLAs as probes of early stellar nucleosynthesis



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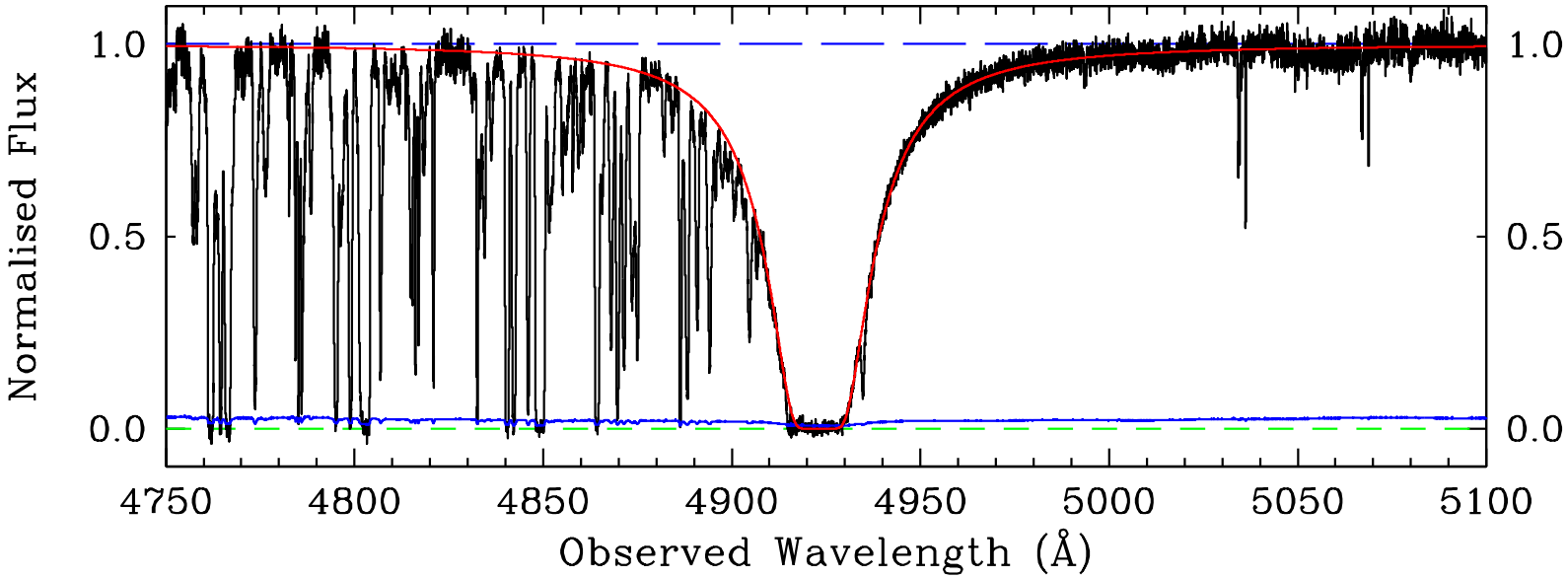

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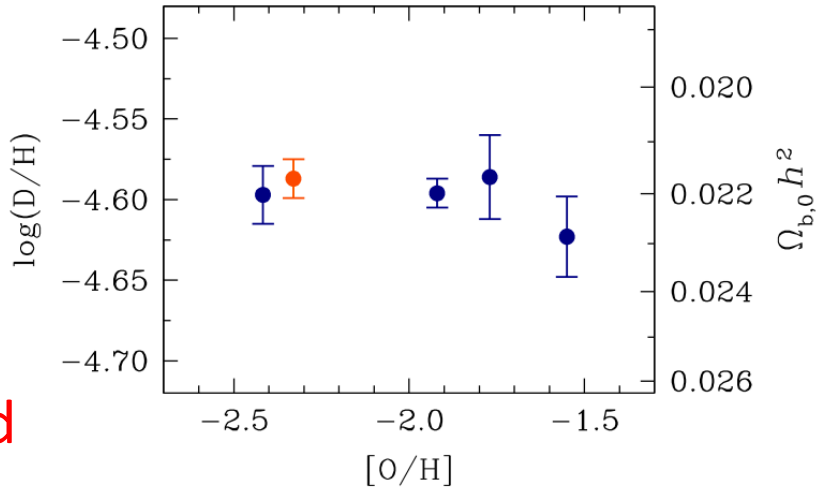

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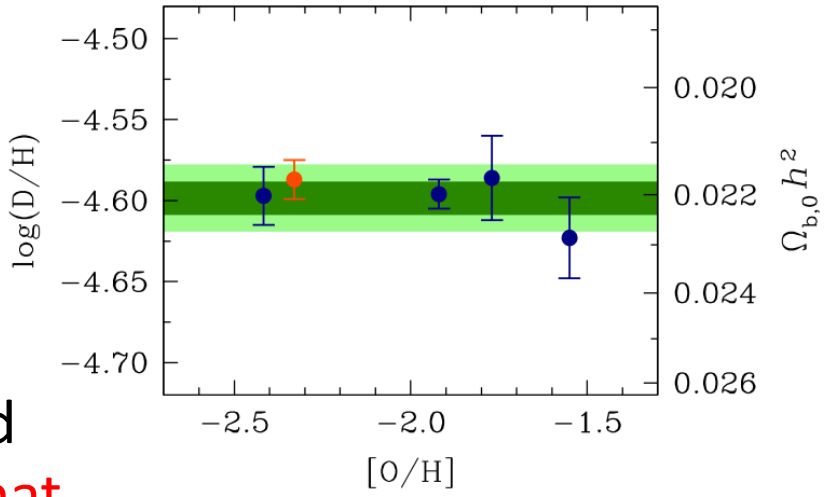

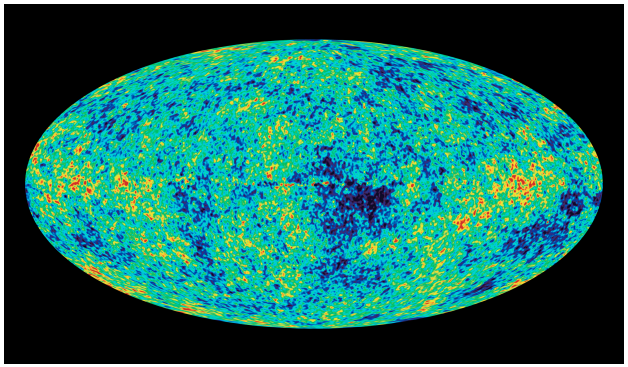

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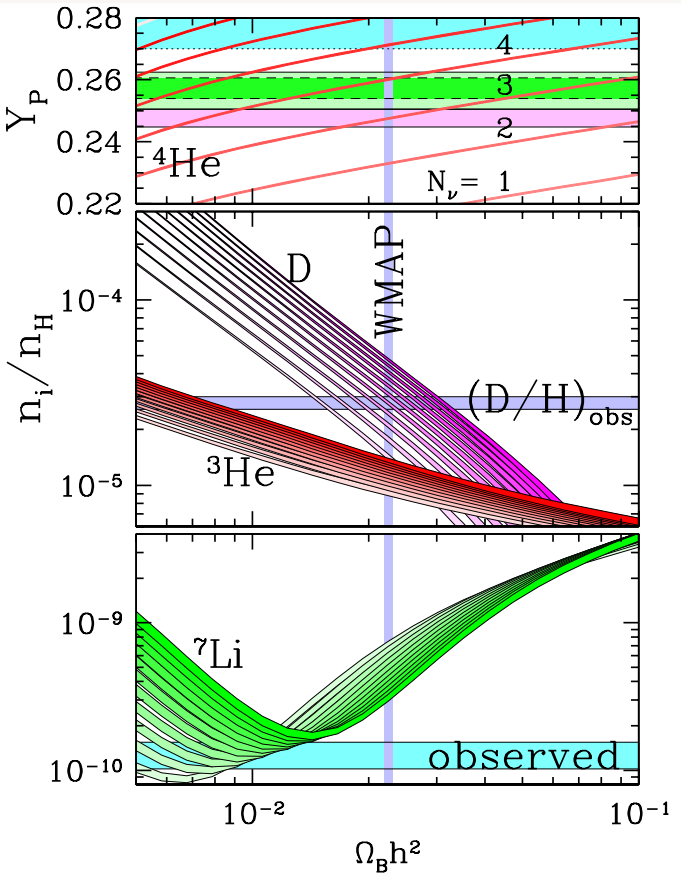

$$N_{eff} = 3 =$$

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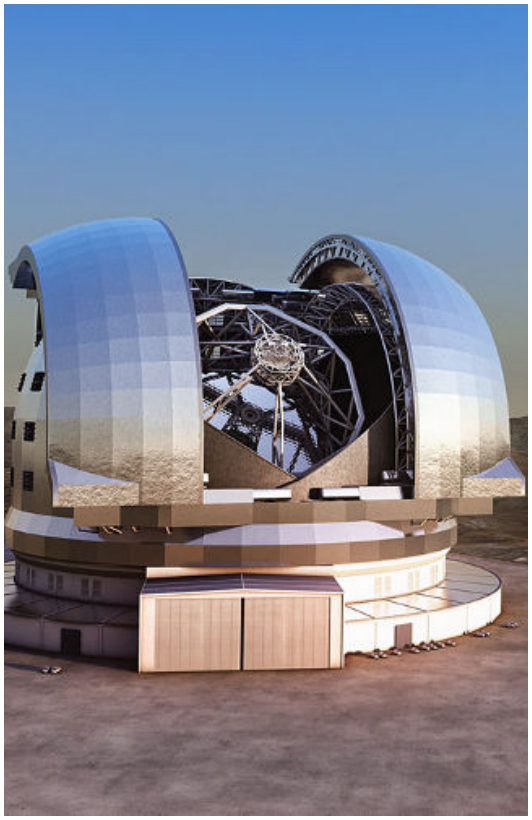

- The most metal-poor DLAs are ideal environments to probe early nucleosynthesis at the lowest metallicities