Title: Review of SBBN with WMAP input

Date: May 30, 2008 09:30 AM

URL: http://pirsa.org/08050046

Abstract:

Review of SBBN with WMAP input:
Experimental and Observational Input for BBN Concordance

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Outline

- Overview of BBN physics
- Nuclear input & uncertainties
- BBN predictions
- Abundance Observations
- WMAP
- Concordance
- Some Workshop Goals

Assumptions in Cosmology

- SM of particle physics (at least)
- GR valid (all places/all times)
- Cosmological Principle
- Dark Matter/Dark Energy
- Universal Expansion

Earliest Epochs

- T>1 MeV, t<1 sec
- γ, ν, $e^{\pm}$, p, n
- All reactions fast
  - $\Gamma >> H$
- Chem/therm EQ
- n/p=exp[-Δm/T]

- T<1 MeV, $\Gamma_w << H$
- ν's decouple
- n/p freeze-out
- $e^{\pm}$ NR/annih ($T\gamma > T\nu$)
- D bottleneck d(γ,n)p
- n-decays

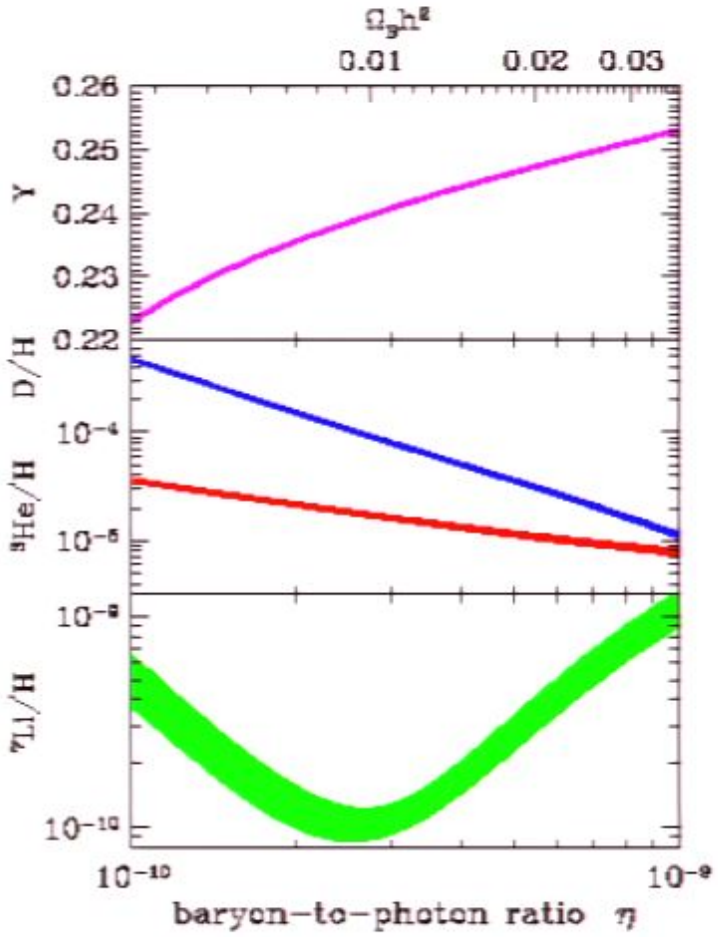
Primordial Nucleosynthesis

- T~70 keV D bottleneck ends
- D, ^{3}He, ^{4}He, ^{7}Li
- T~40 keV Coulomb halts nucl.
- Universe of p, ^{4}He w/trace D, ^{3}He, ^{7}Li
- Errors from nucl. rxn uncertainties

Important Reactions

N-lifetime	~0.1% (new discrepancy)
p(n,g)d	~1%
d(p,g)3He	~6%
d(d,n)3He	~5%
d(d,p)t	~7%
3He(d,p)4He	~7%
t(d,n)4He	~4%
3He(n,p)t	~5%
3He(a,g)7Be	~17% (2004) new data!
t(a,g)7Li	~23%
7Li(p,a)4He	~8%
7Be(n,p)7Li	~5%

BBN Predictions



- Y ~0.1%
- D ~5.0%
- ^{3}He ~7.0%
- ^{7}Li ~20%

Cyburt 2004

^{4}He Observations

- Emission from extra-galactic HII regions
- Y=0.228-0.250 w/ σ~0.002
- Diff analysis, diff number (unknown systematics)
  - Largely due to stellar absorption
  - Olive & Skillman (2001) σ>0.005

Y=0.2495$\pm$0.0092
Olive & Skillman (2004)

D observations

- Absorption of Quasar light
- Most systems have single D feature
- Few have multiple absorption features
  D/H=(2.78+0.44-0.38)e-5 (world avg)
  D/H=(2.49+0.20-0.18)e-5 (mult abs avg)
  Kirkman et al. 2003
- New Pettini (2008) result ~2.75e-5
- Possible unknown systematics

^{3}He Observations

- Emission from Galactic HII regions
- Primordial value VERY model dep.

  Bania et al (2002) Vangioni-Flam (2003)
- Since ^{3}He is slowly varying
- And D only decreases with time

$$^3\mathrm{He/D} < 1$$

Sigl et al. (1995)

^{7}Li Observations

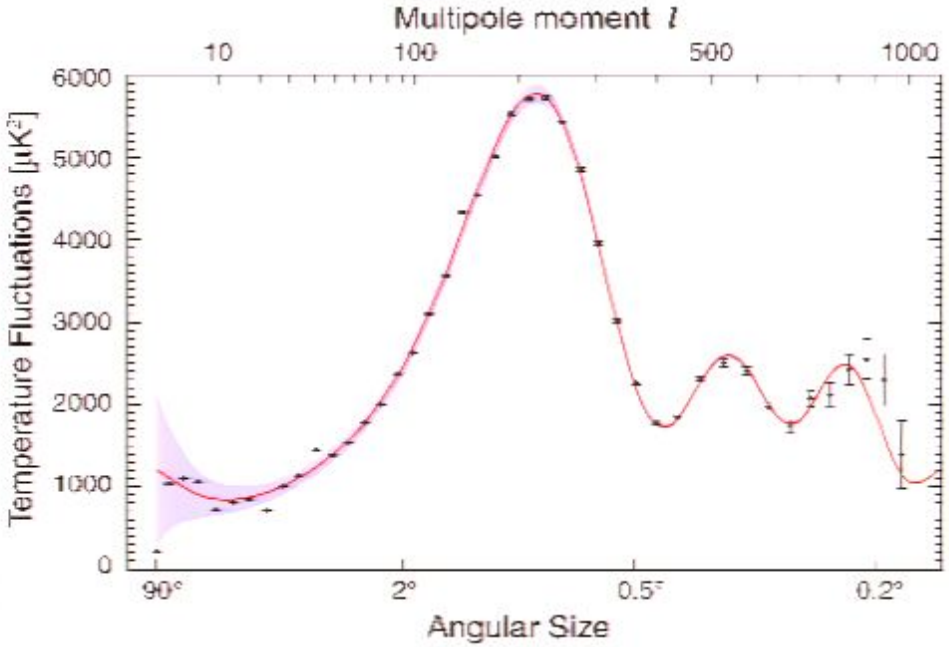
- Atmospheres of metal-poor Halo stars
- Very sensitive to atomic data used

^{7}Li/H = (1.23$\pm$0.06+0.68-0.32)e-10 (Ryan et al. 95%)

^{7}Li/H = (2.19+0.46-0.38)e-10 (Bonifacio et al.)

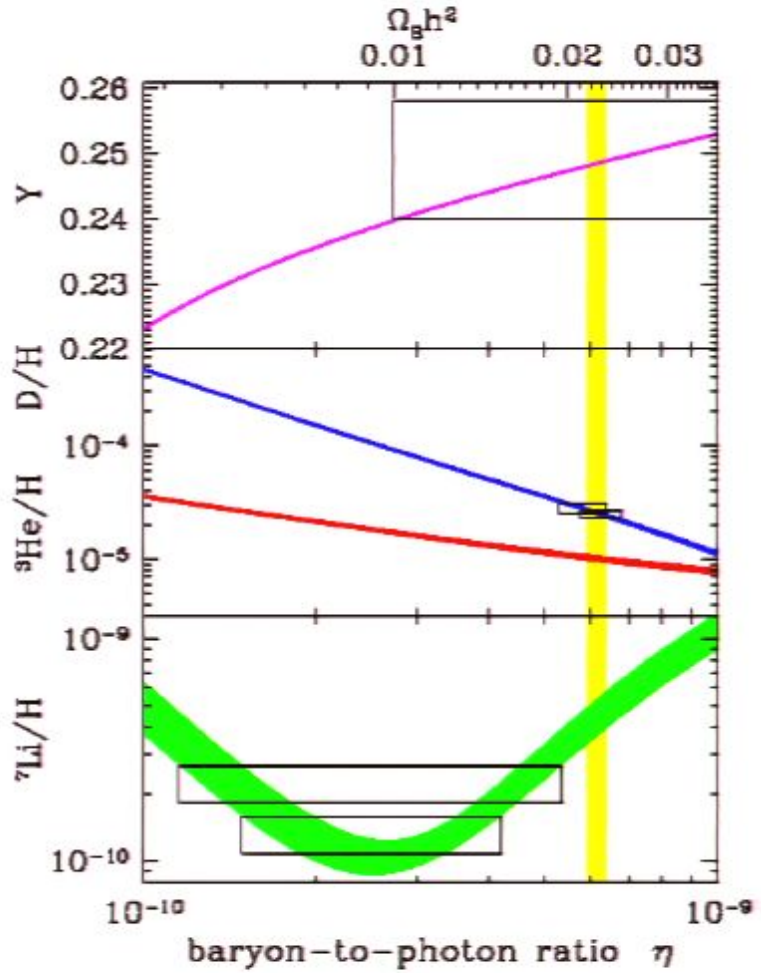
- Large systematic errors

WMAP 5year results



- $\eta_{10}=6.21\pm0.16$
- $\Omega_c h^2=0.1143\pm0.0034$
- $\Sigma m_\nu < 0.61$ (95%)
- $\Omega_{tot}=1.0052\pm0.0064$

Concordance



- ^{4}He agrees
- D agrees
- ^{3}He agrees
- ^{7}Li off by 2-3

JINA efforts (www.jinaweb.org)

- Thermo-nuke rxn rate database
  www.nscl.msu.edu/~nero/db
- NNDC data repository & online tools
  www.nndc.bnl.gov
- ORNL nucl. Astro. Tools & forum
  www.nucastrodata.org

Workshop Goals

- Repository of constraints
  - Agreed-upon abundance limits
  - Other Cosmological constraints
  - User-supplied data tables
- BBN Particle Physics Forum
  - Discuss new observations
  - Discuss new papers