Generating the Observed Baryon Asymmetry from the Inflaton Field

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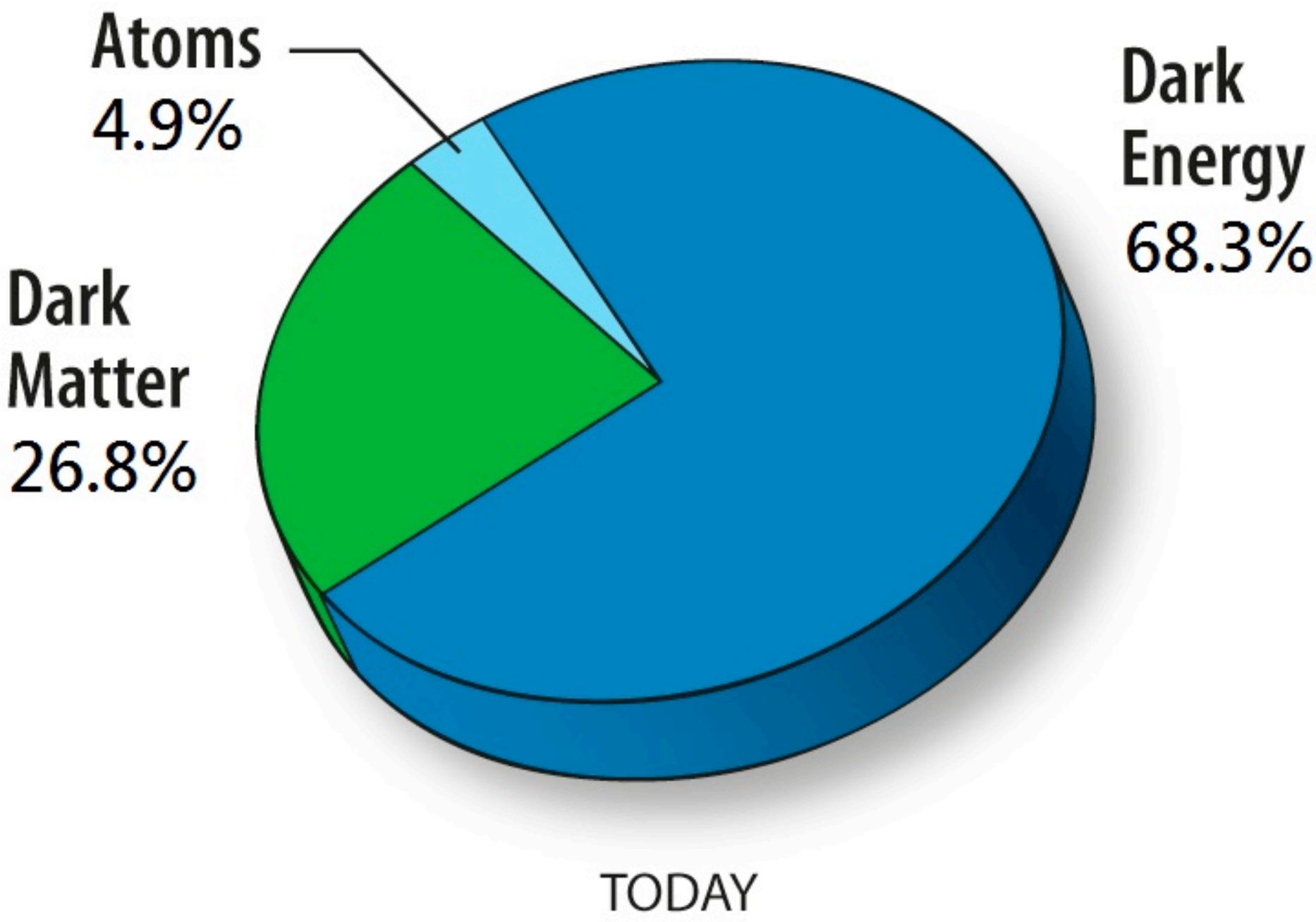
PHENO2014 May 5 2014

Contents of Universe in Modern Cosmology



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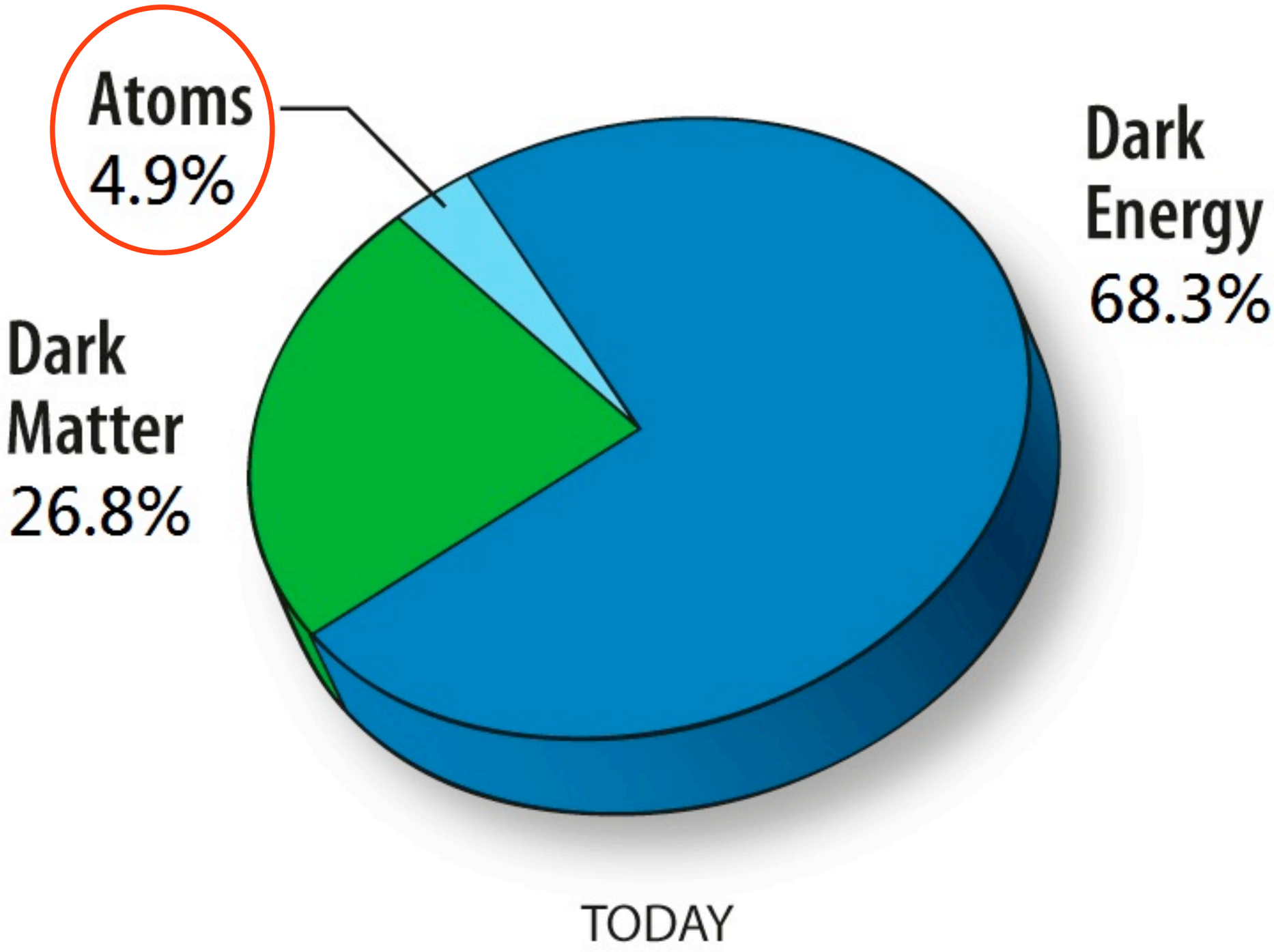
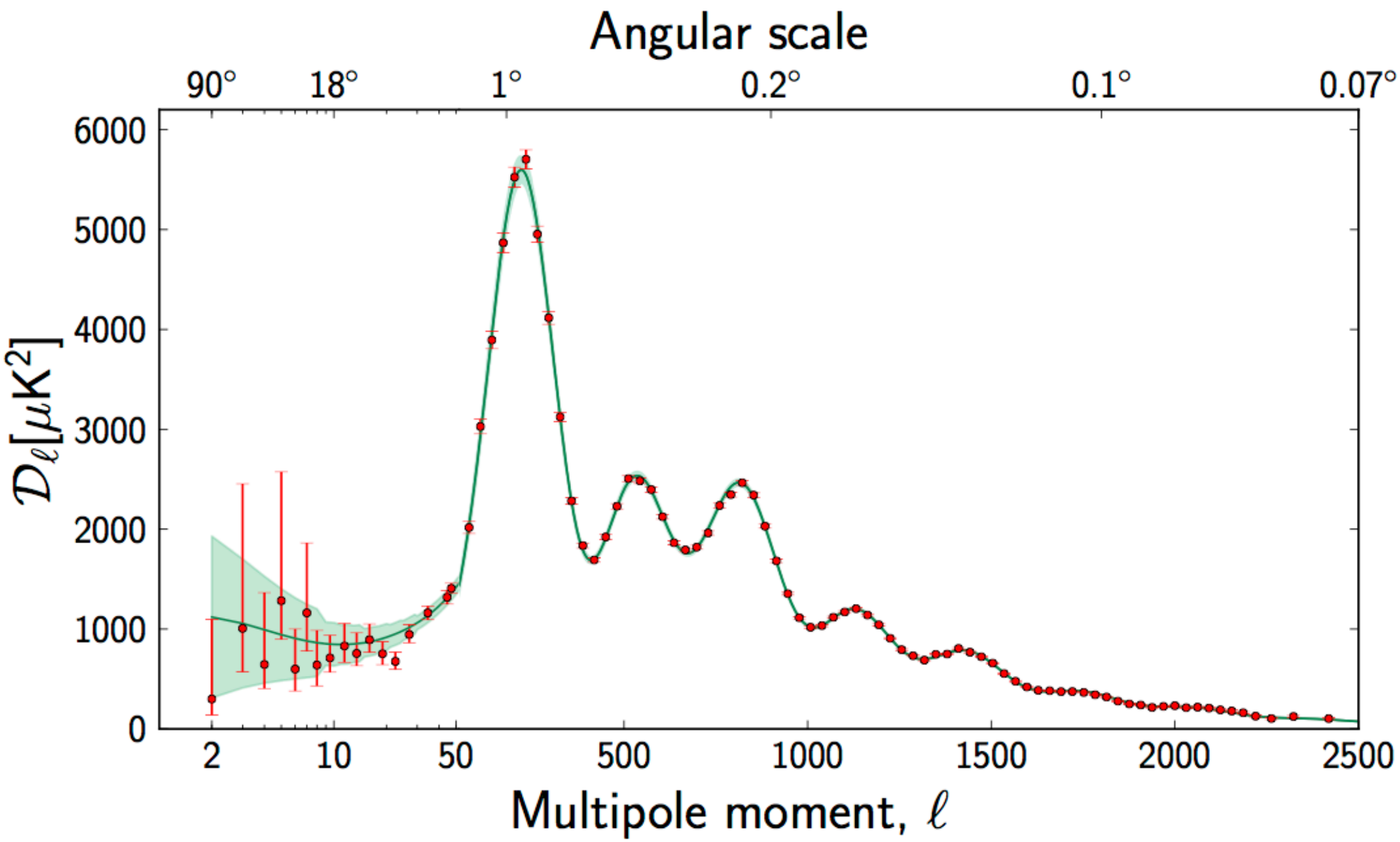
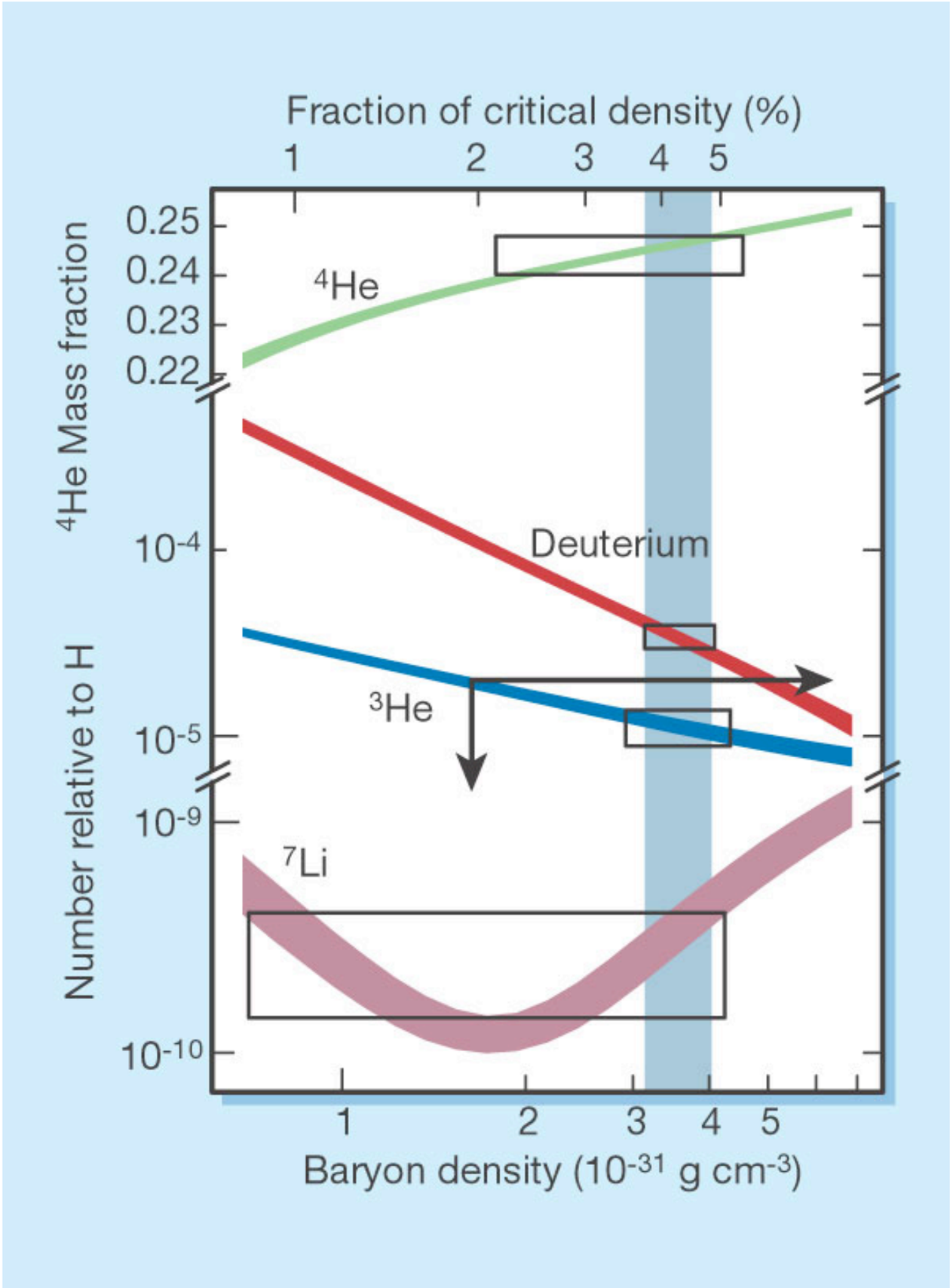


Acoustic Oscillations in CMB



(Planck Collaboration)

Big Bang Nucleosynthesis



$$\eta \equiv \frac{n_B - \bar{n}_B}{n_\gamma}$$

$$\eta_{obs} \approx 6 \times 10^{-10}$$

(Atoms: 4.9%)

What is the origin of the baryon asymmetry?

The following work appears in:

M.H, Johanna Karouby, Phys. Rev. D 89, 063523 (2014)
M.H, Johanna Karouby, 1309.0007

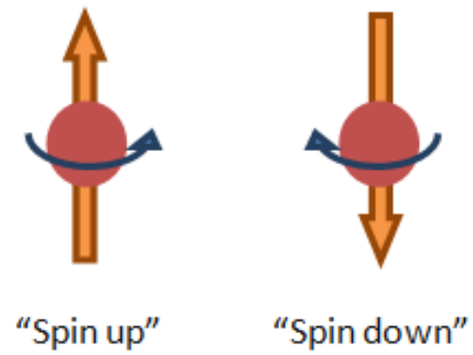
Important earlier work, with emphasis on the TeV scale,
was performed by Affleck-Dine 1986, and other followup papers

To investigate the origin of baryon asymmetry, forces us to consider the initial conditions/state of the universe

Our best guess at initial state comes from asking how a transition from a microscopic to a macroscopic universe could've occurred

Relativity and Quantum Mechanics

Elementary particles are organized by spin



Spin: 0 1/2 1 3/2 2

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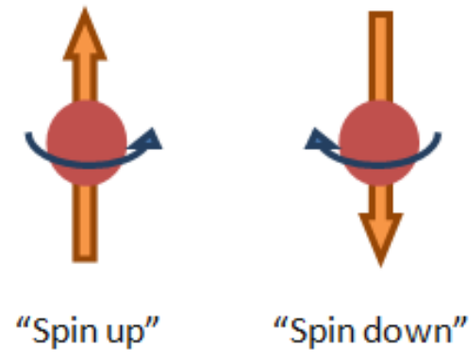

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Gravity

Other forces,
EM, QCD, Weak

Susy?

Matter particles,
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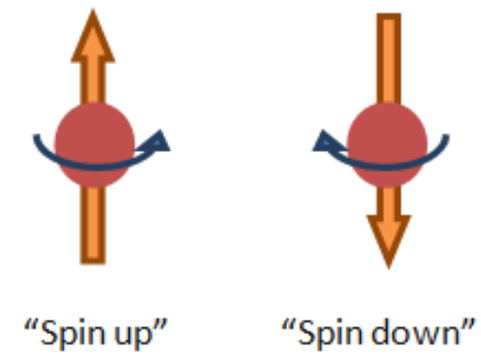

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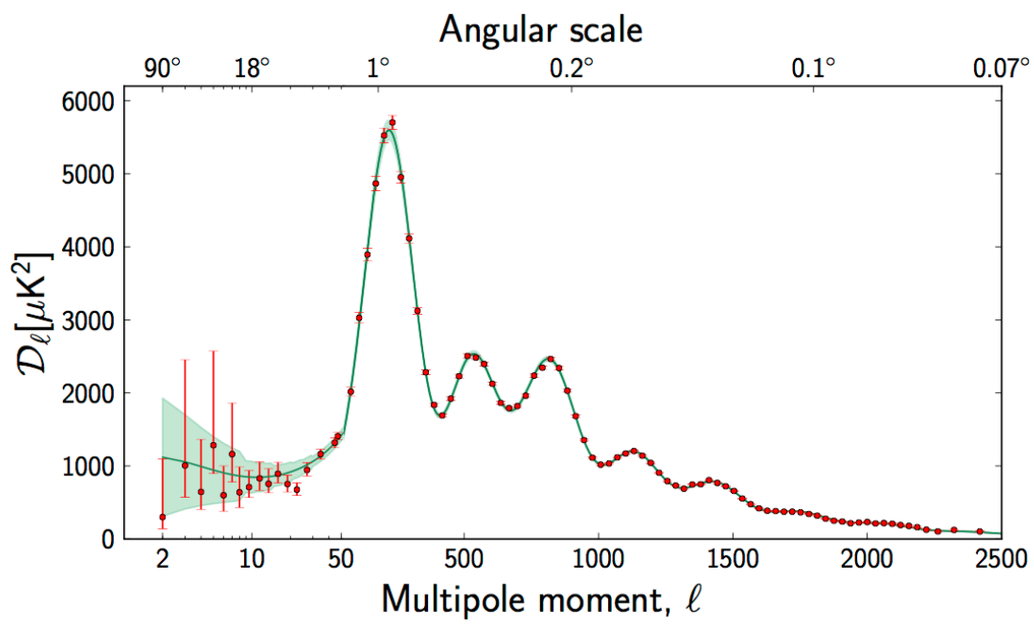
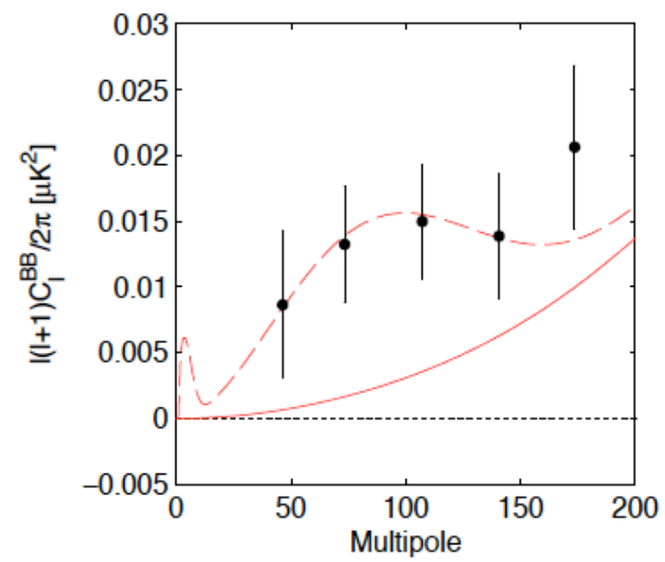
Inflation





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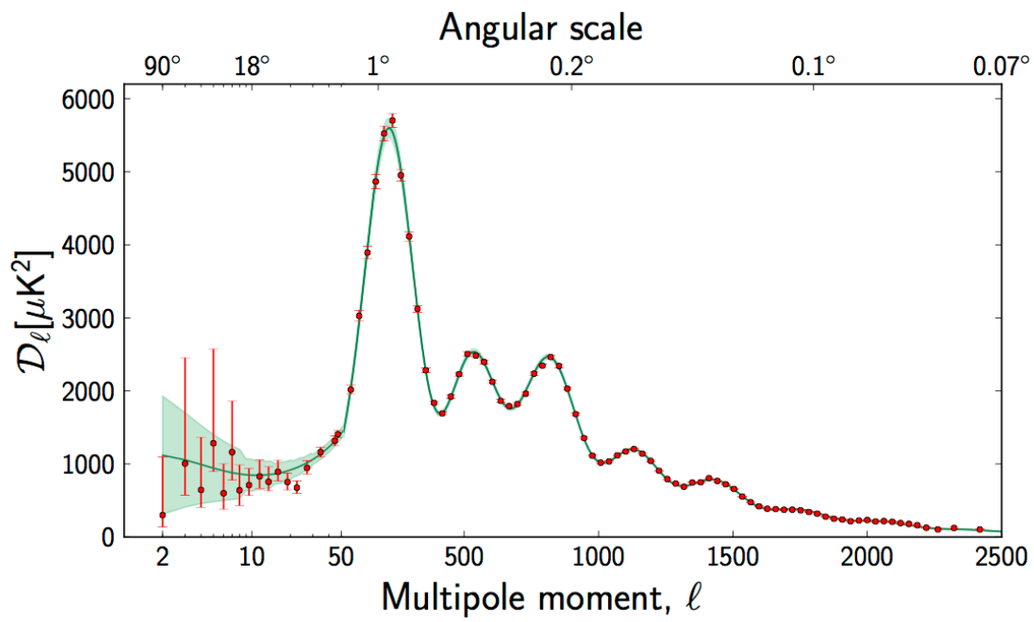
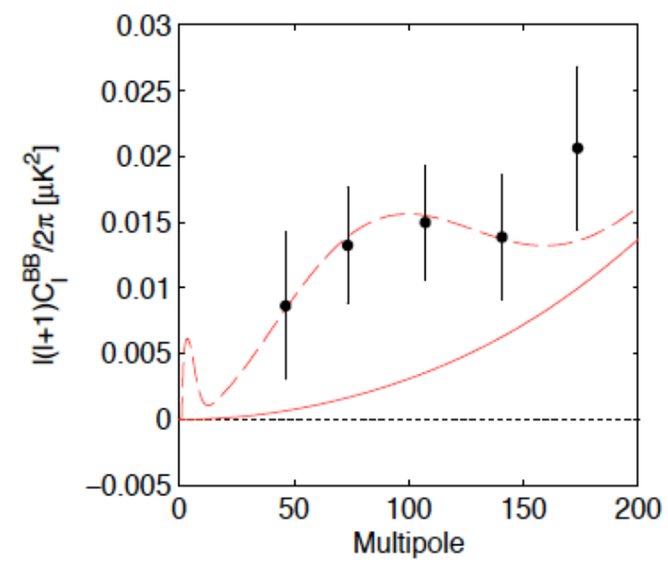
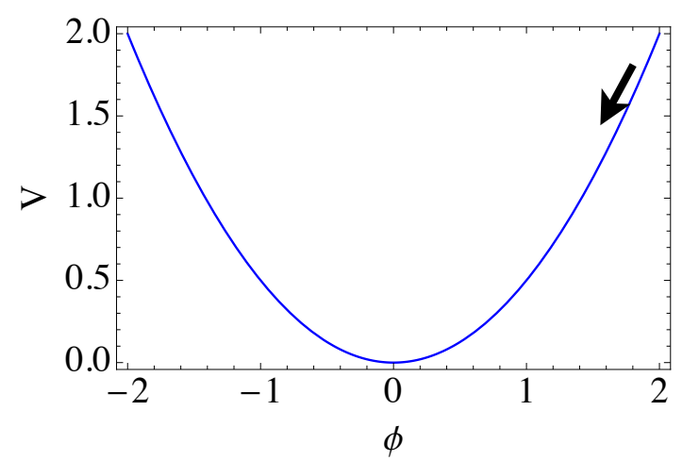




- The inflationary condensate is so non-intuitive in terms of quantum particles, it is best to switch to the language of fields

Scalar: $\phi(x,t)$



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$$S = \int d^4x\sqrt{-g}\left[\frac{1}{16\pi G}\mathcal{R} + |\partial\phi|^2 - V_s(|\phi|) + \lambda(\phi^n + \phi^{*n}) + \ldots\right]$$

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Standard inflationary action

$(e.g.,\ V_s(|\phi|) = m^2|\phi|^2)$

Weakly broken symmetry

Tower of small corrections

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Colored

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$(\text{colored} \sim \epsilon_{ijk}\phi^i\phi^j\phi^k)$

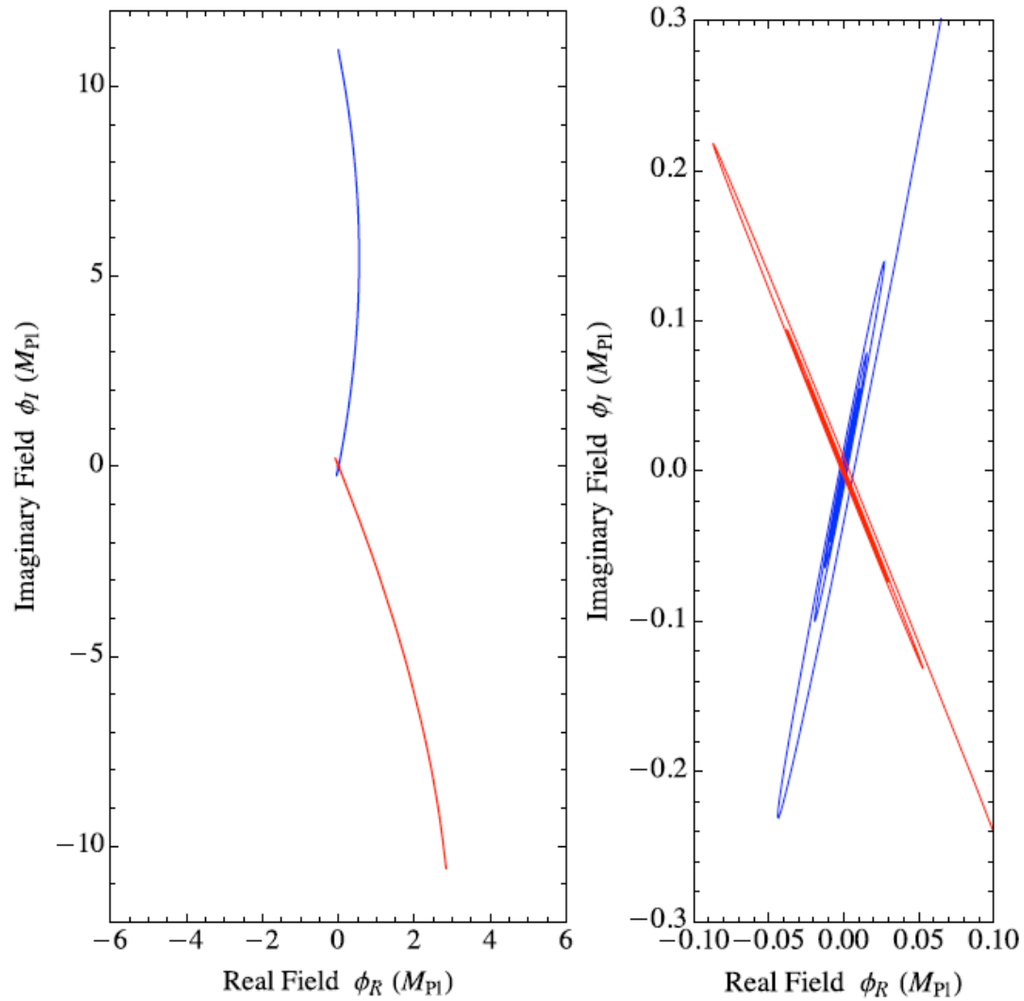
Weakly broken symmetry

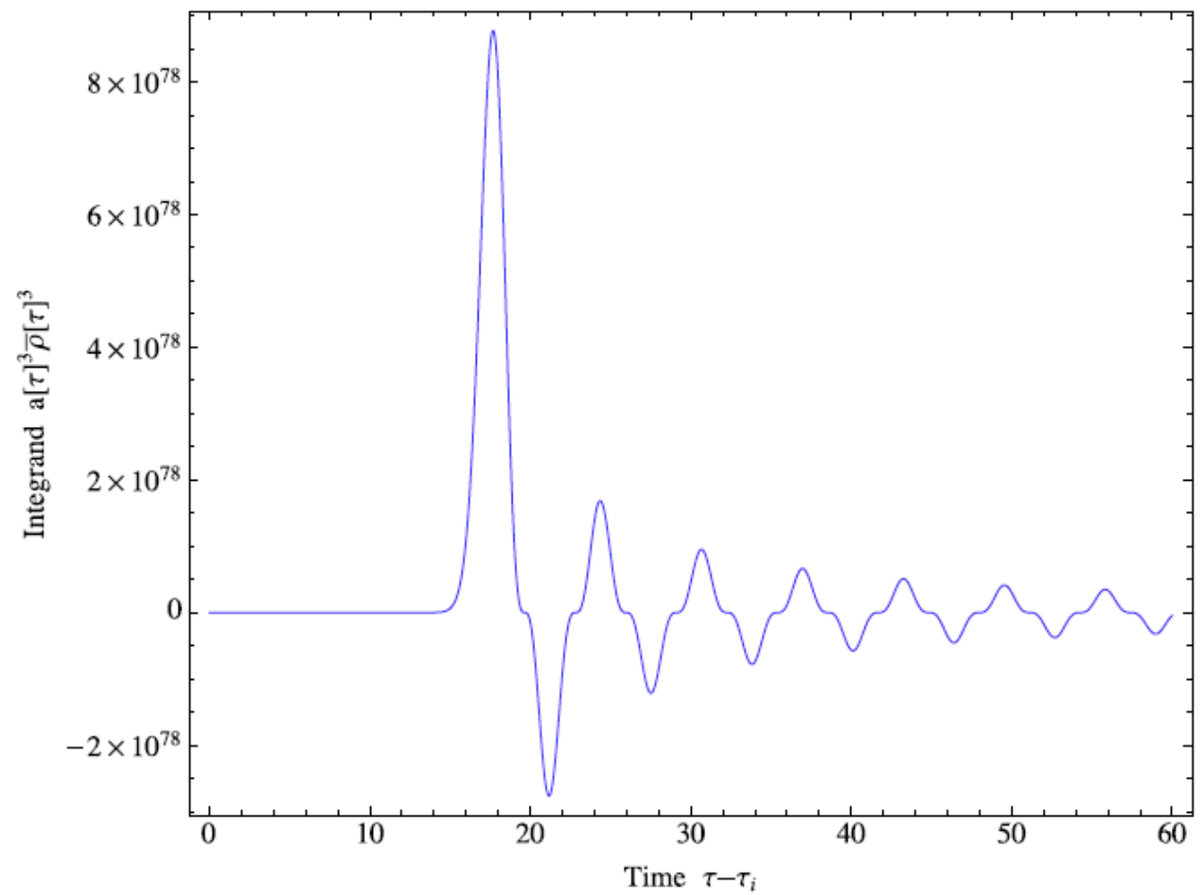
$U(1)$ Symmetry implies conserved particle number (Noether)

Tower of small corrections

Particle Number Stored in the Inflaton

$$\Delta N_\phi(t_f) = \Delta N_\phi(t_i) - \lambda \frac{V_{\rm com} n}{2^{\frac{n}{2}-1}} \int_{t_i}^{t_f} dt a(t)^3 \rho(t)^n \sin(n\theta(t))$$





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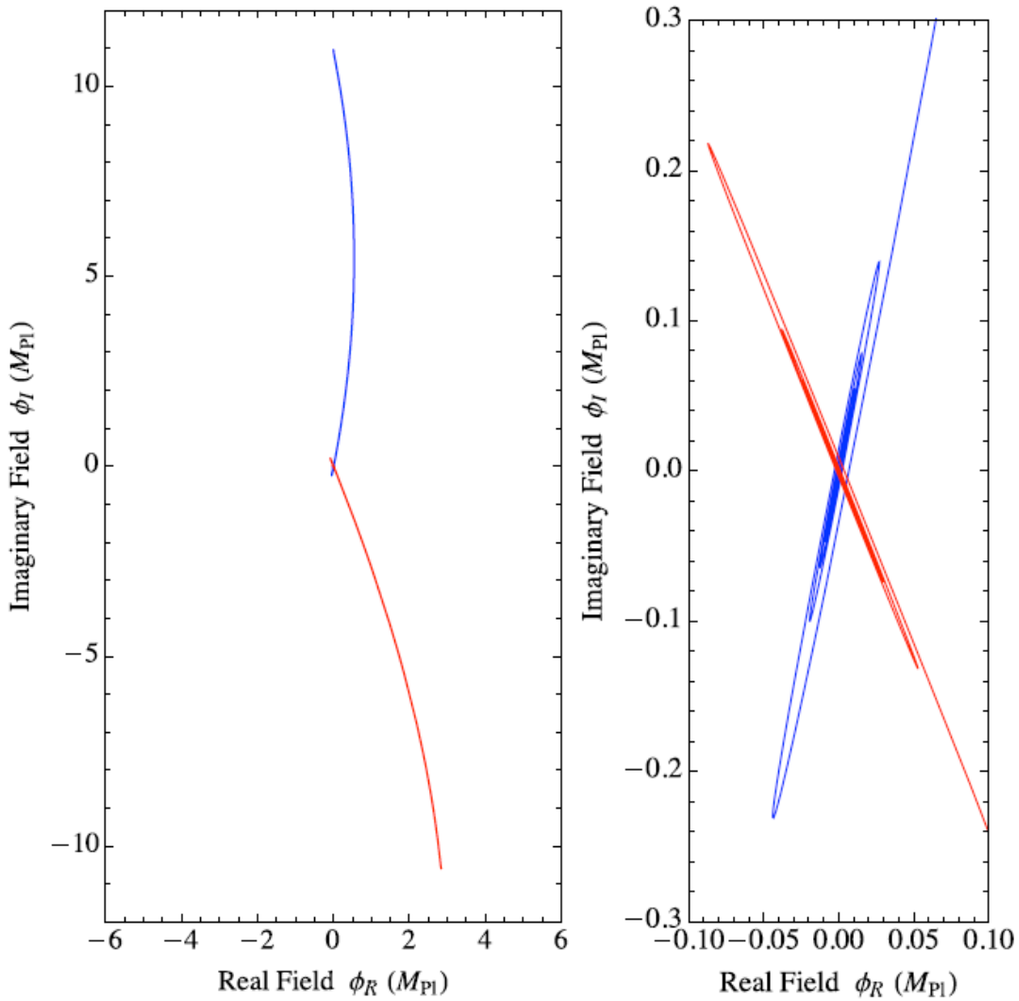

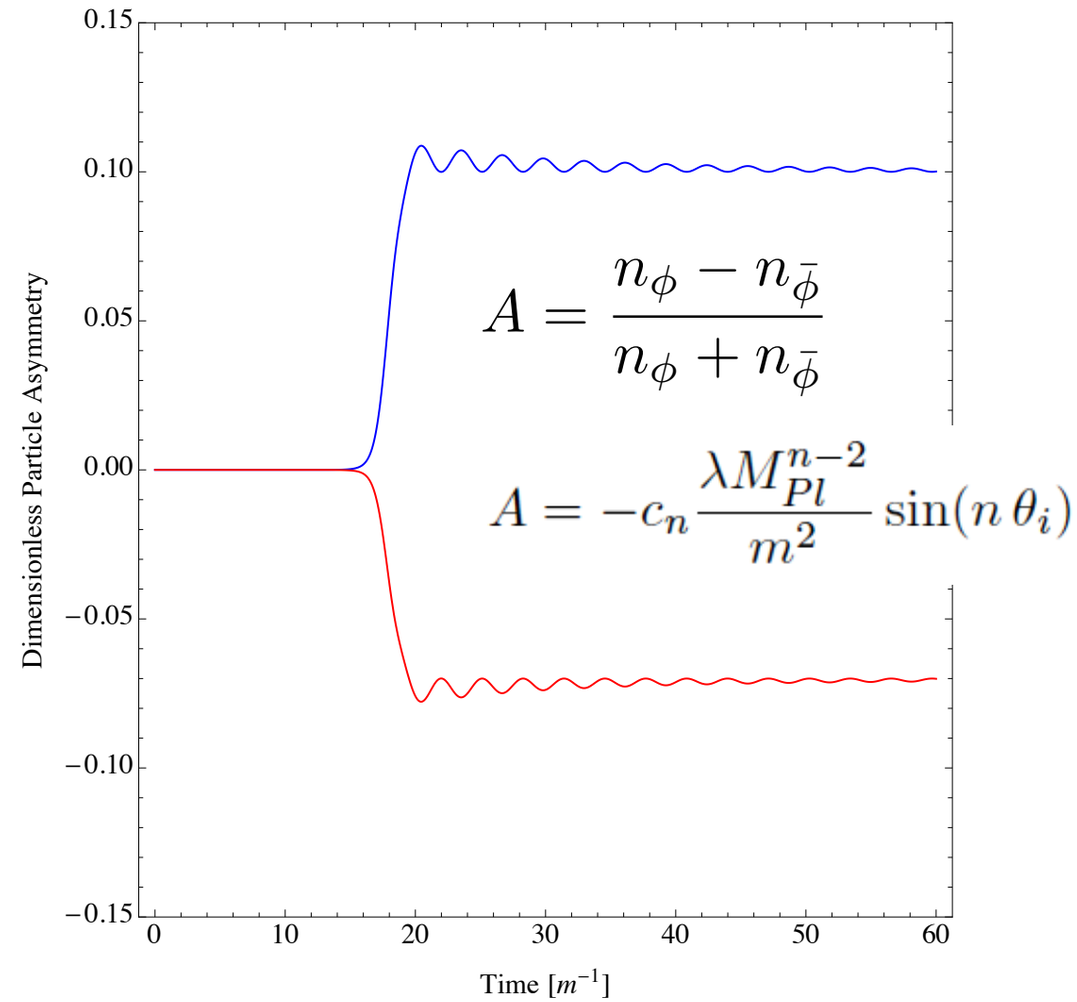

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- Another possibility for colored inflaton, leading effective operator

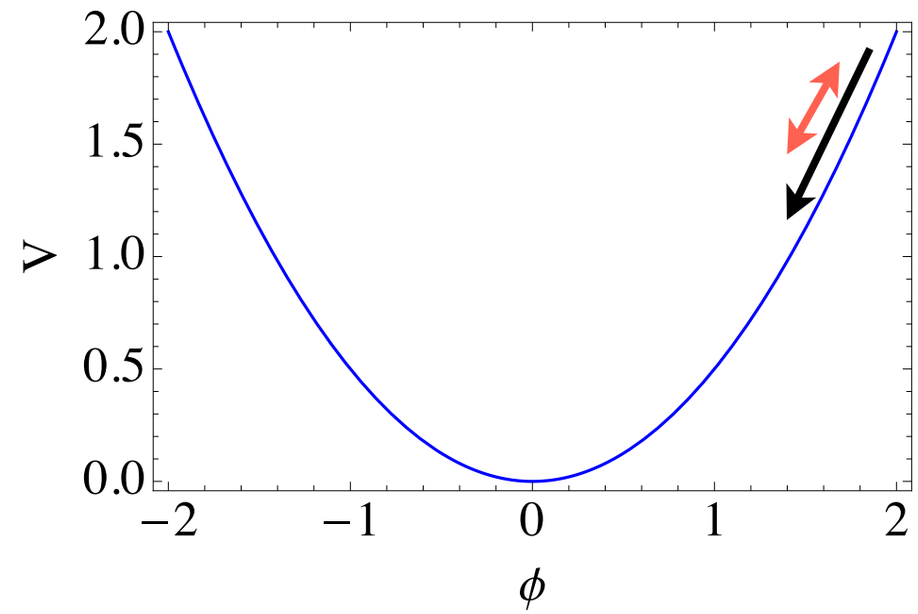
$$\Delta\mathcal{L} \sim y\phi^{i*} q^i \bar{f} + h.c$$

- Requires small coupling, which may be justified by approximate shift symmetry for inflaton

Observational Consequences Results

- Quantum fluctuations in the inflaton field is the leading candidate for the origin of primordial fluctuations

- These lead to the observed adiabatic fluctuations



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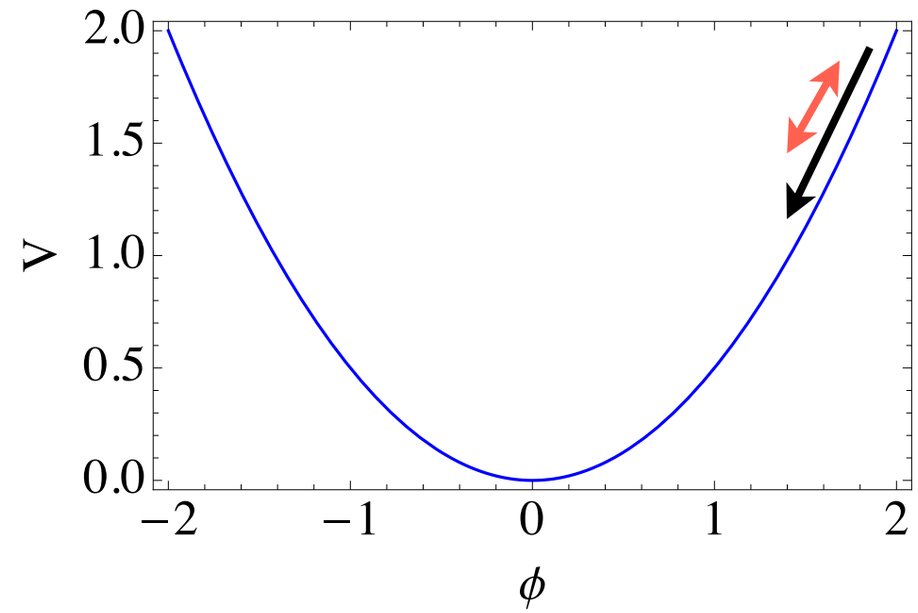

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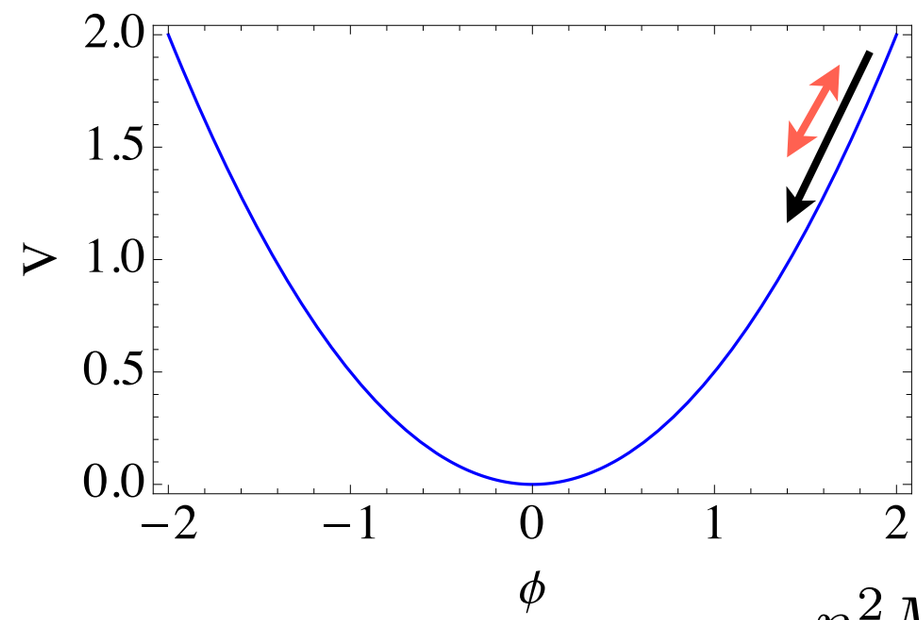

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- Computation:

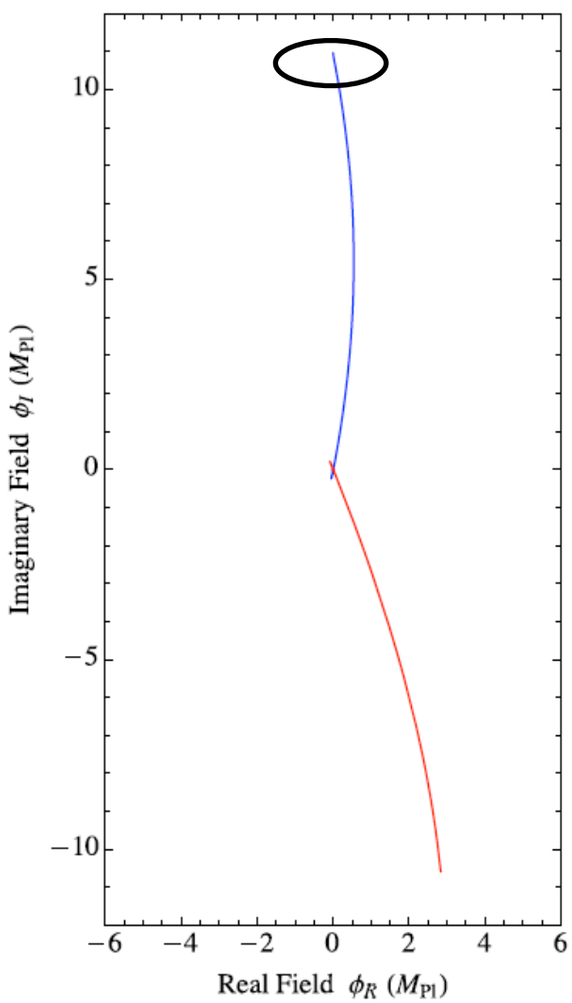
$$\alpha_{II} \approx \frac{n^2 M_{Pl}^2 r}{10 |\phi_i|^2}$$

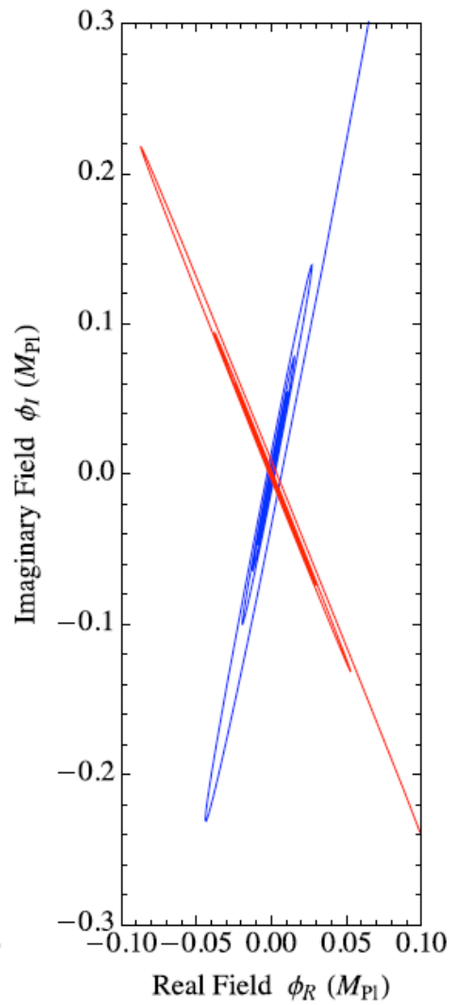
- For BICEP2 value: the amplitude of baryon isocurvature fluctuations ~ 1 order of magnitude below current Planck bounds; may be detectable in future

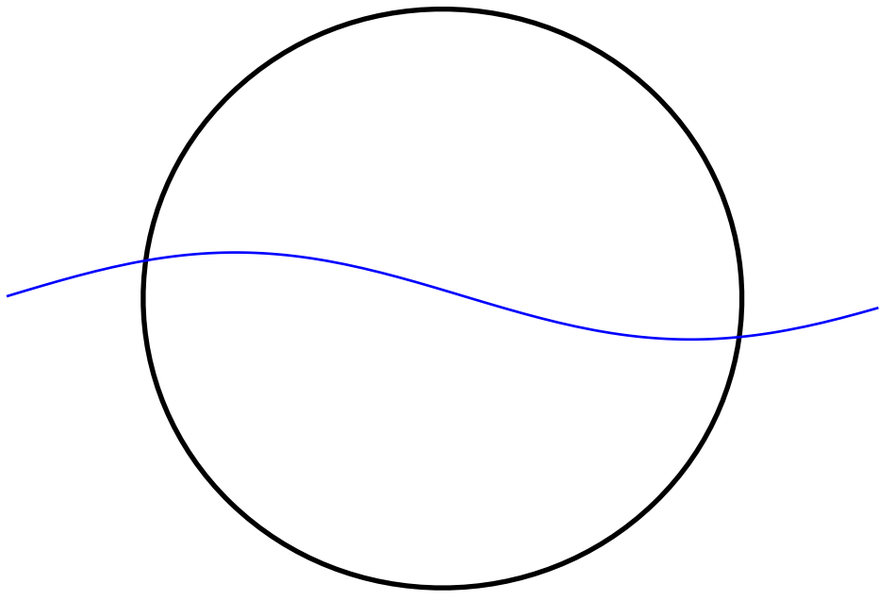
- If scalar is not inflaton (Affleck Dine), and has sub-Planckian VEV, then such models are typically ruled out

Observational Consequences Results

- If only the minimum amount of inflation occurred, there will be a related baryon (isocurvature) dipole







Conclusions

- A range of recent cosmological observations have led to increased confidence that inflation occurred; so it is natural to investigate if it can directly produce the origin of matter

- We see promising and falsifiable predictions of a surprisingly simple model that unifies a complex inflaton and baryogenesis

- The model predicts an isocurvature fluctuation just below current bounds, while many low energy Affleck-Dine models are ruled out from exceeding the isocurvature bounds