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Chalonge School
July 19, 2008

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Cosmology Confronts Fundamental Questions:

From Dark Energy and Inflation to Eternity..

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or.. The Good, the Bad, and the Ugly

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A Fundamental Question

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Are Fundamental Cosmological Questions Falsifiable?

1. The Good:

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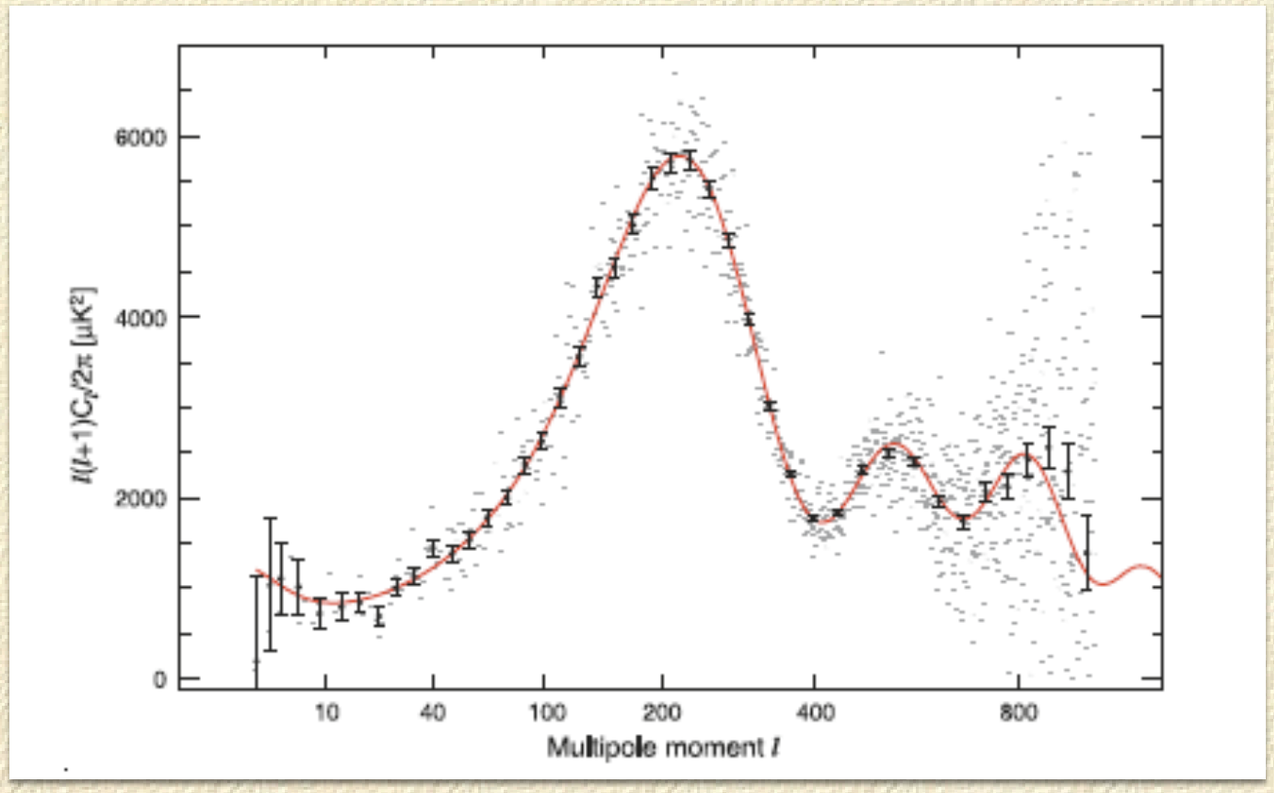

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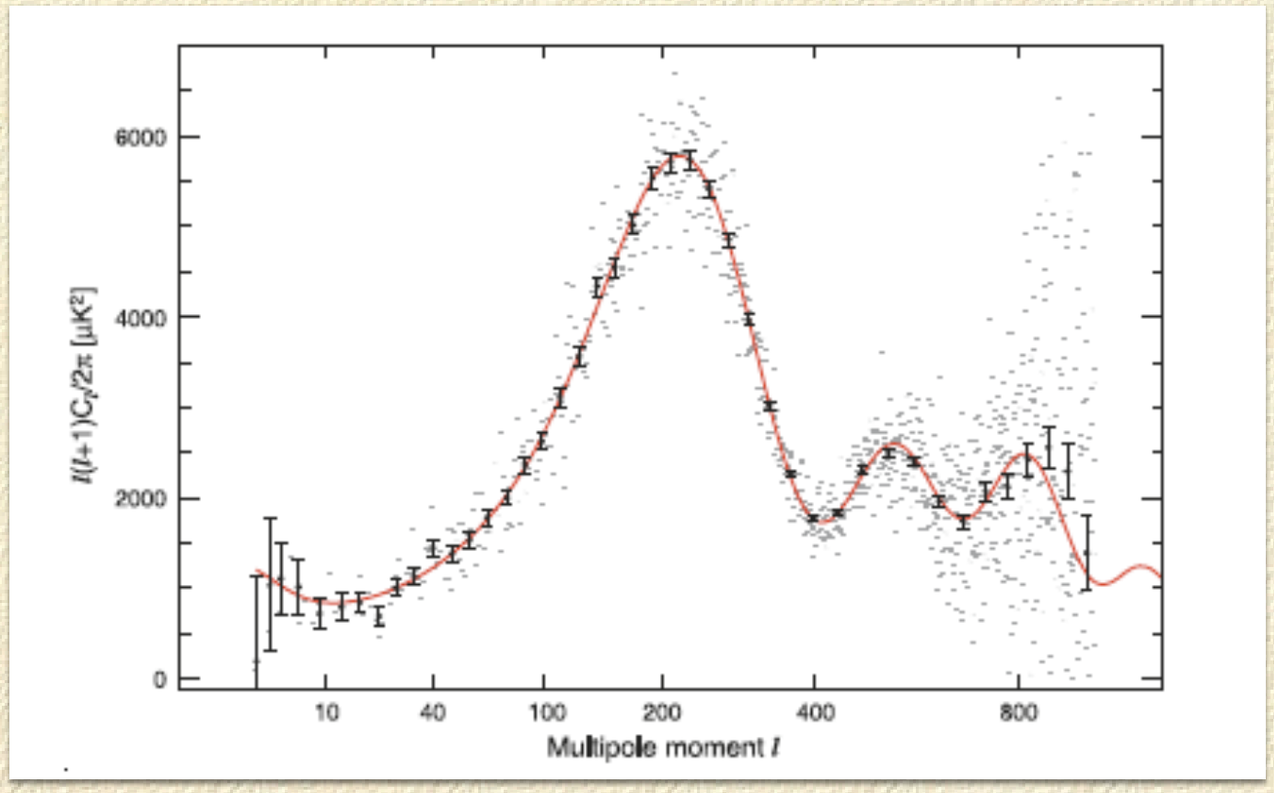

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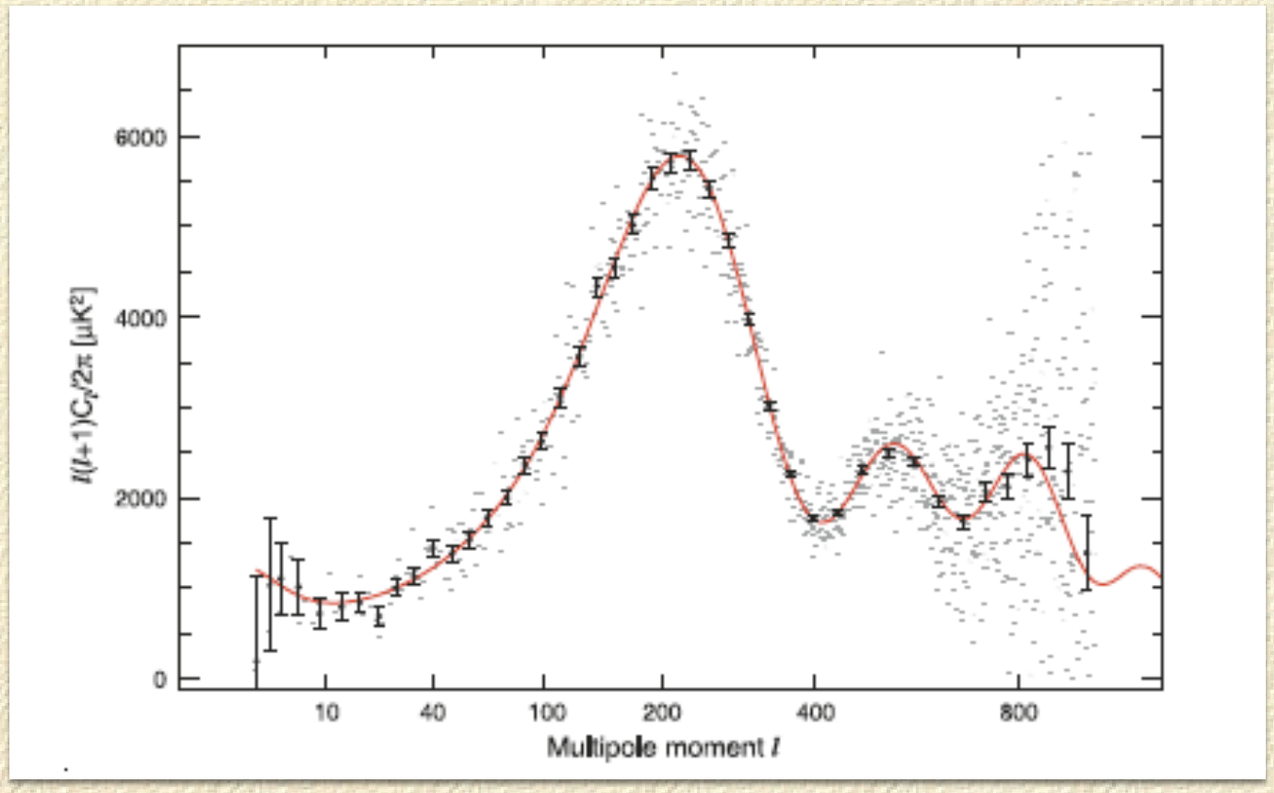

- Is Consistency Enough?
- Unique, Falsifiable Predictions?

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Quantum Fluctuations in De Sitter Space:

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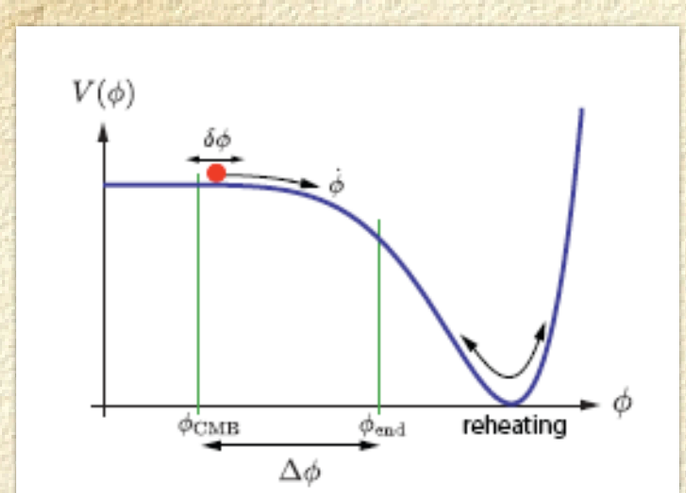

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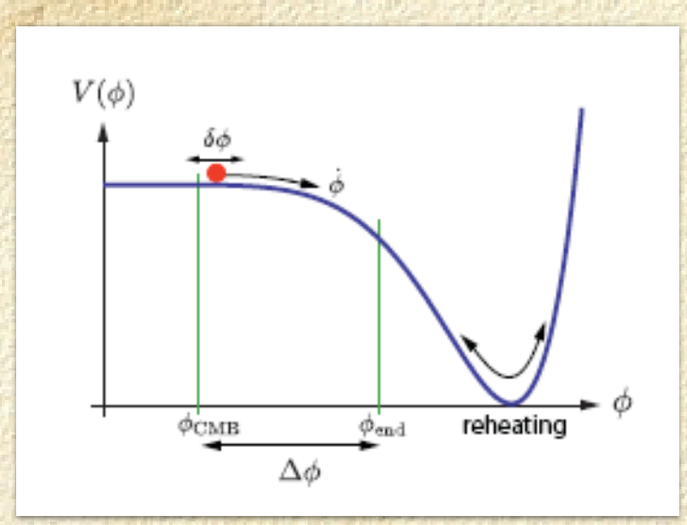

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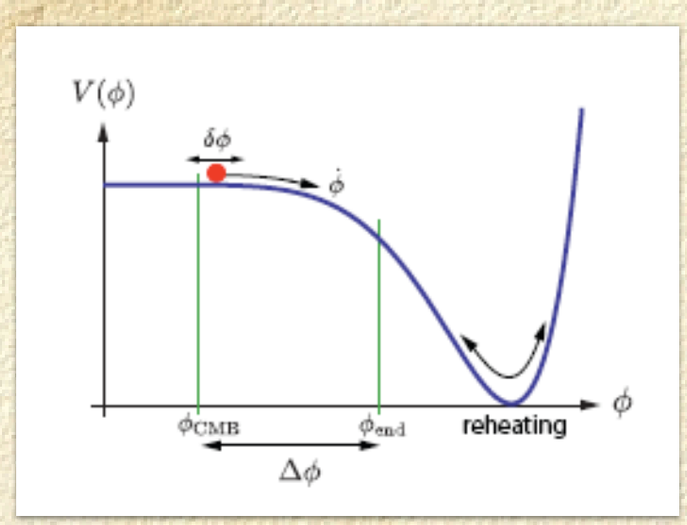

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Note: Scalar density perturbations depend upon shape of potential. Tensor perturbations just depend upon scale!

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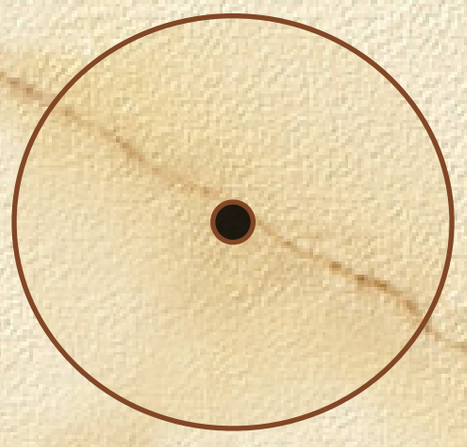

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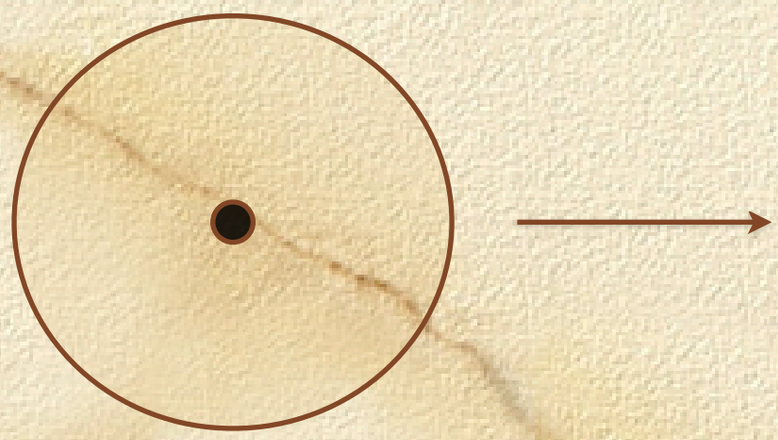

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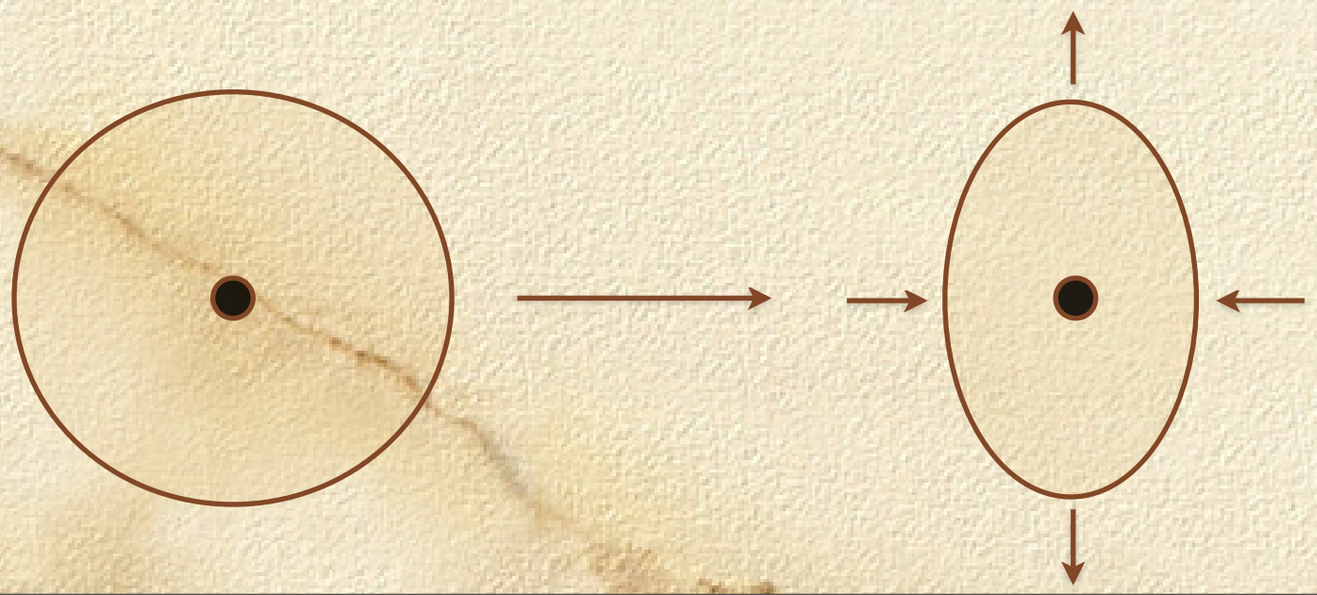

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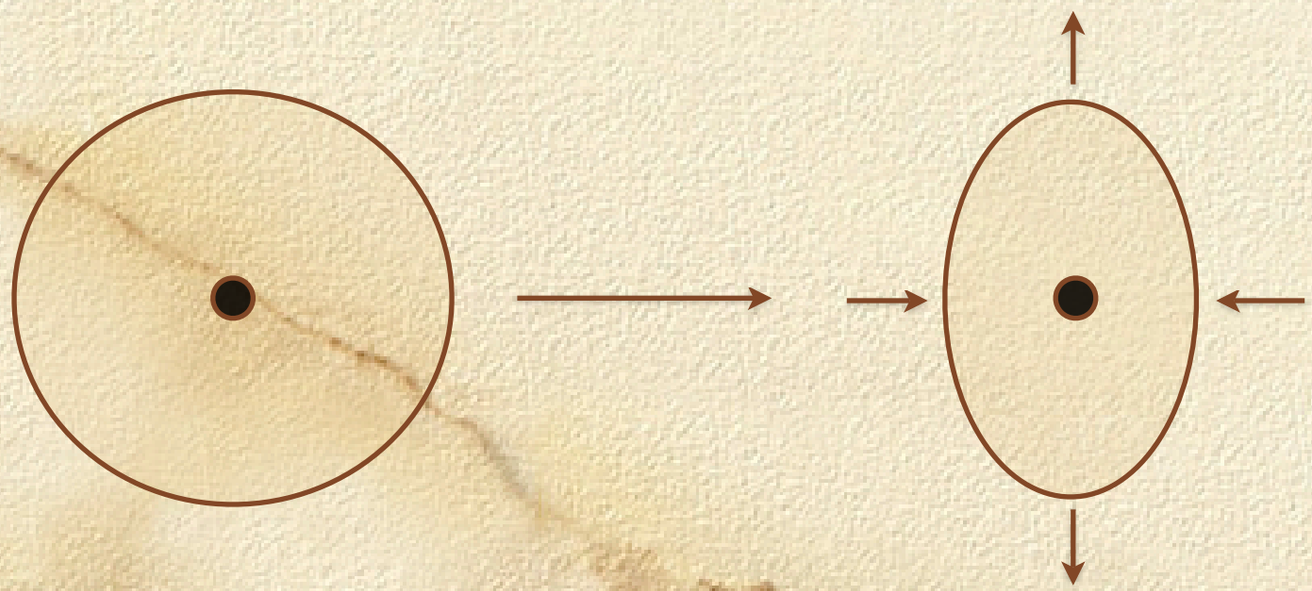
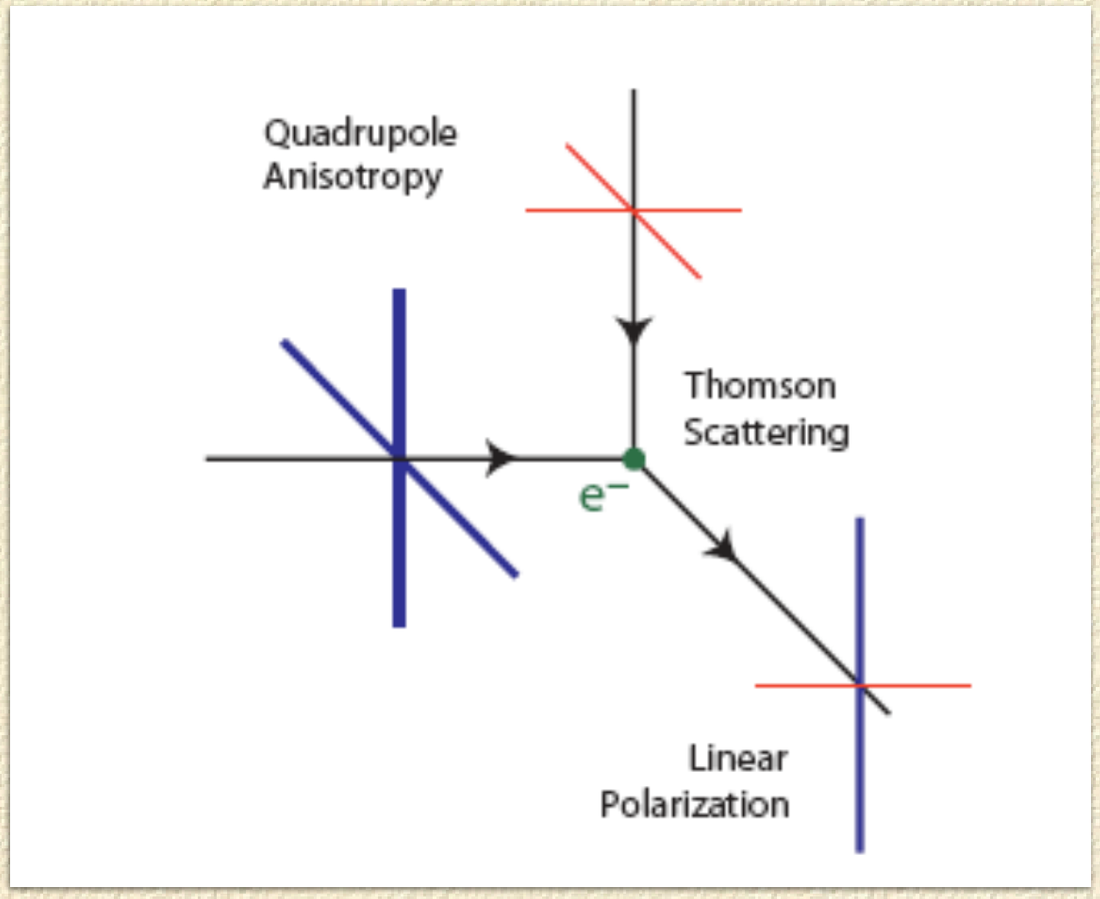


Quadrupole Moment of Radiation: Anisotropic scattering..

Polarization from Quadrupole



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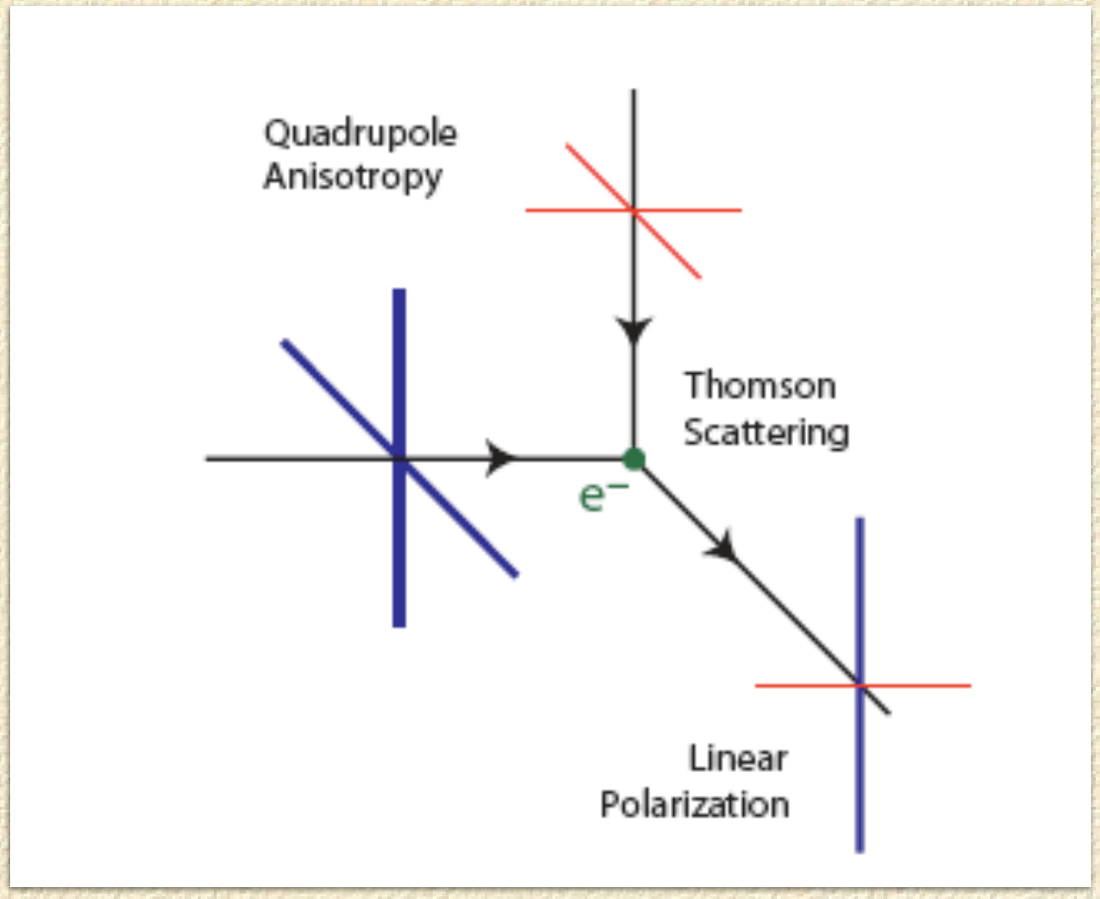

cf:
Dodelson

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NOTE: This actually makes it appear that r is insensitive to M, but this is not true... i.e. $r \approx 0$ for flat potential because $S = \infty$

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MEASURING POLARIZATION *AND* SPECTRUM CONSTRAIN r and PROBE INFLATION!

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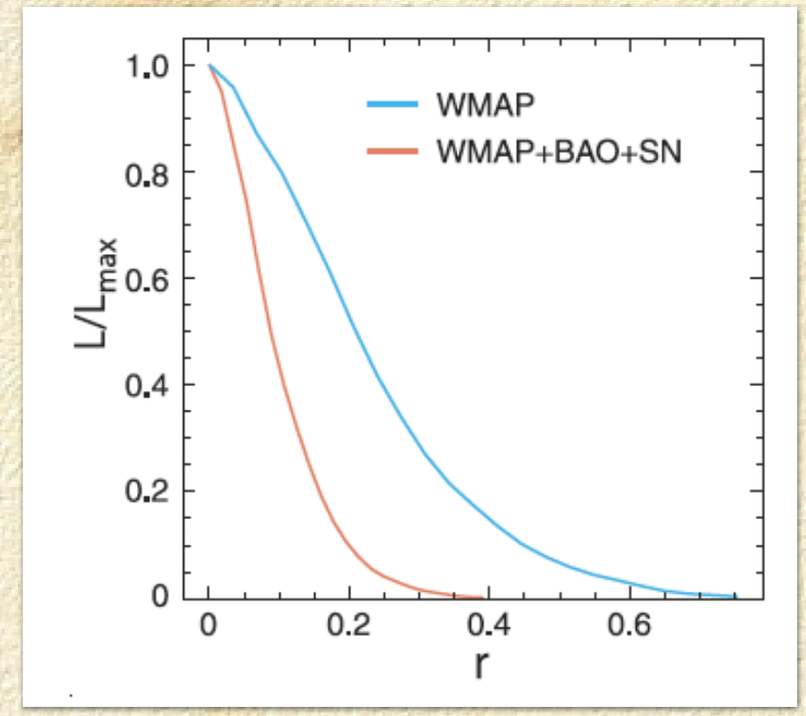

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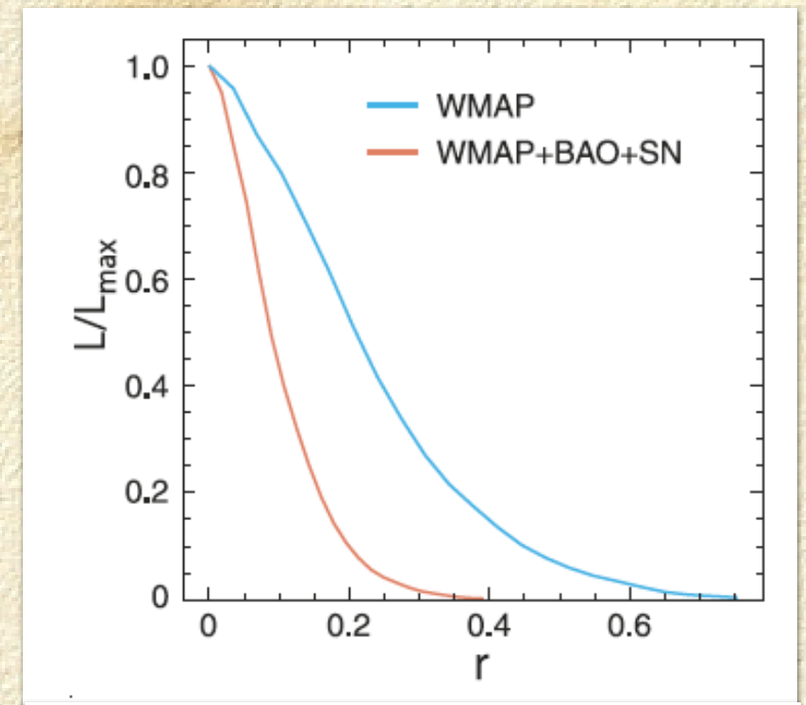

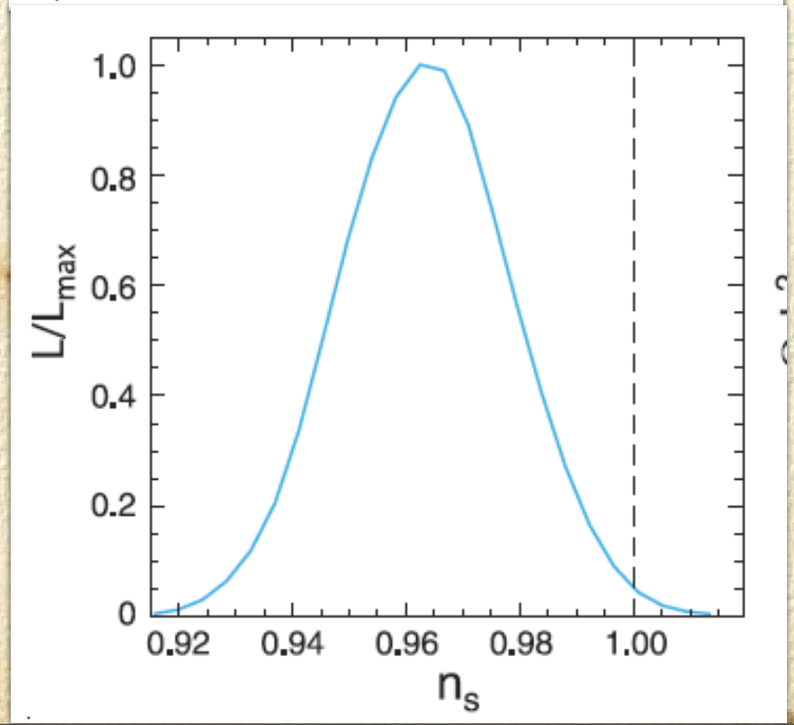

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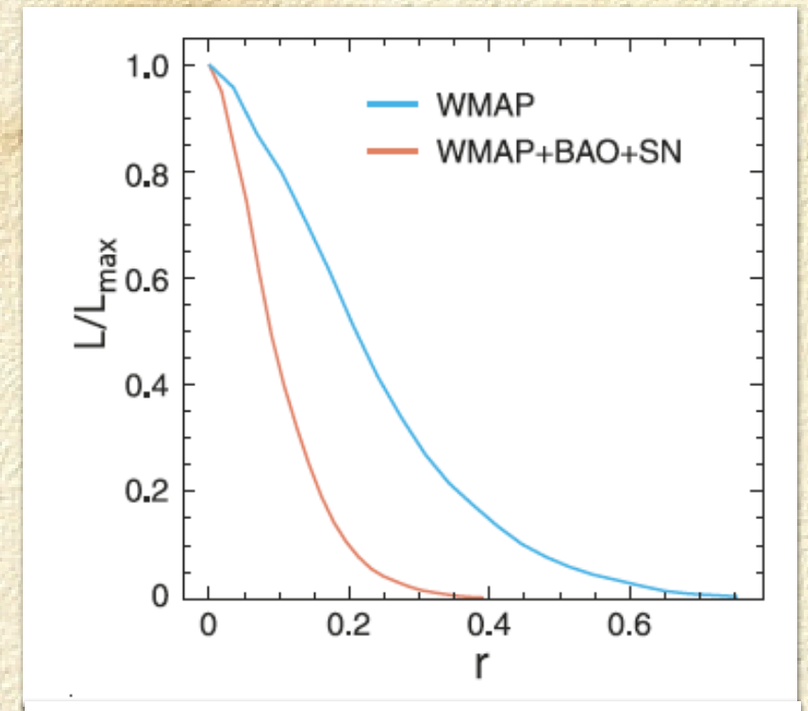

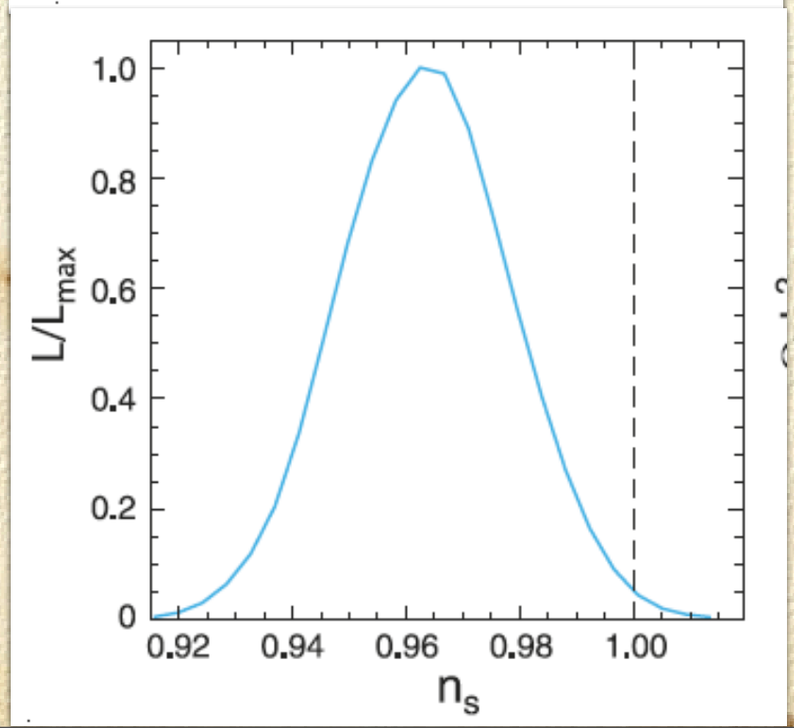

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(LB)

see

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NS,

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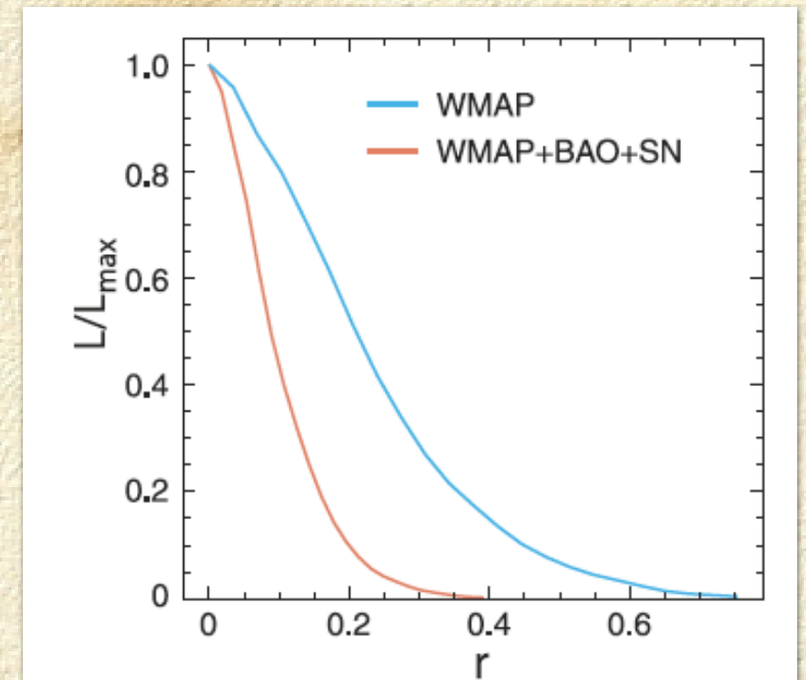

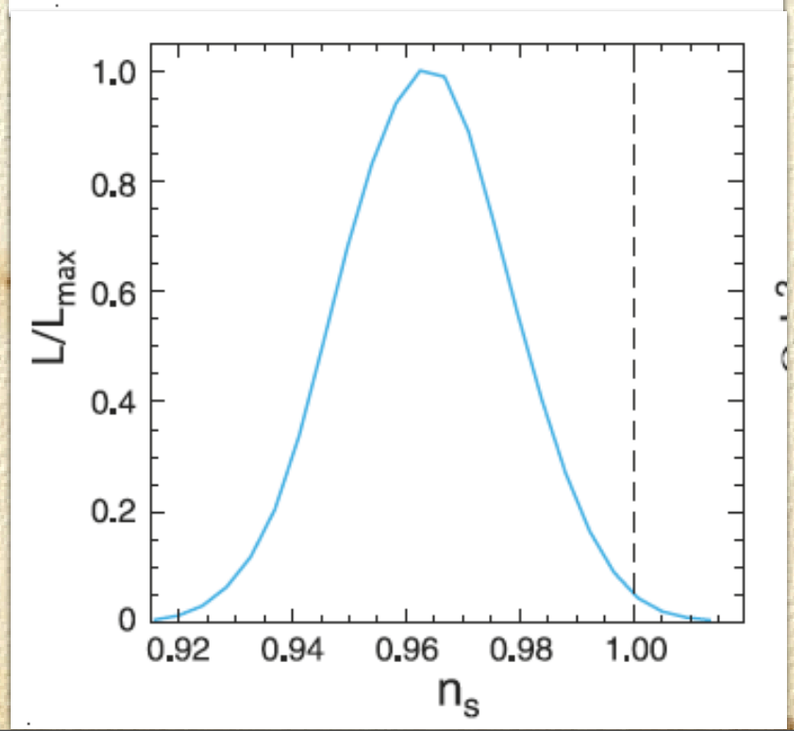

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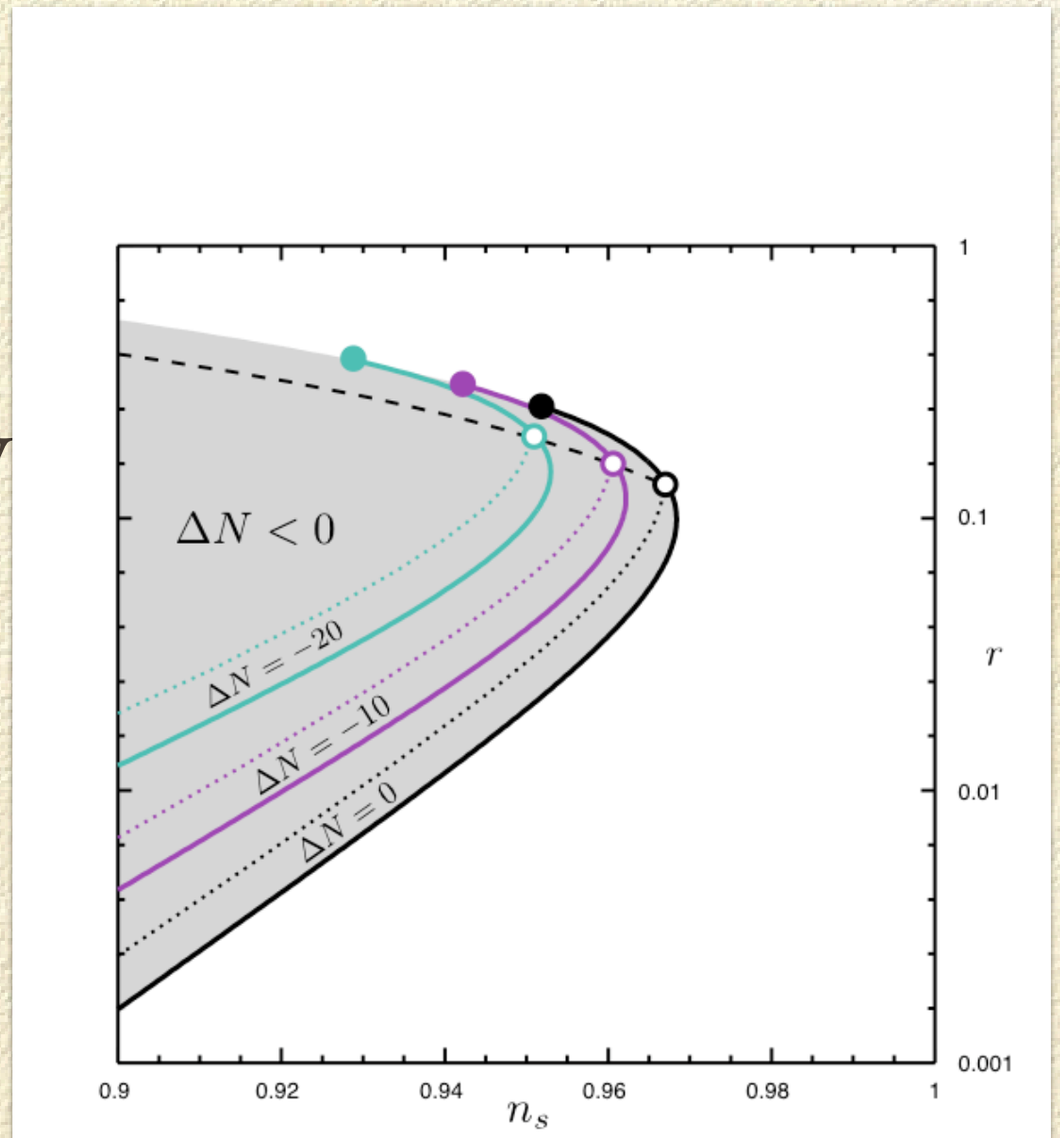

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(ii) Super-planck excursions: NOT ALLOWED? (String Theory!) Hence r << .01 ?

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(WV,LMK,JH, '08)

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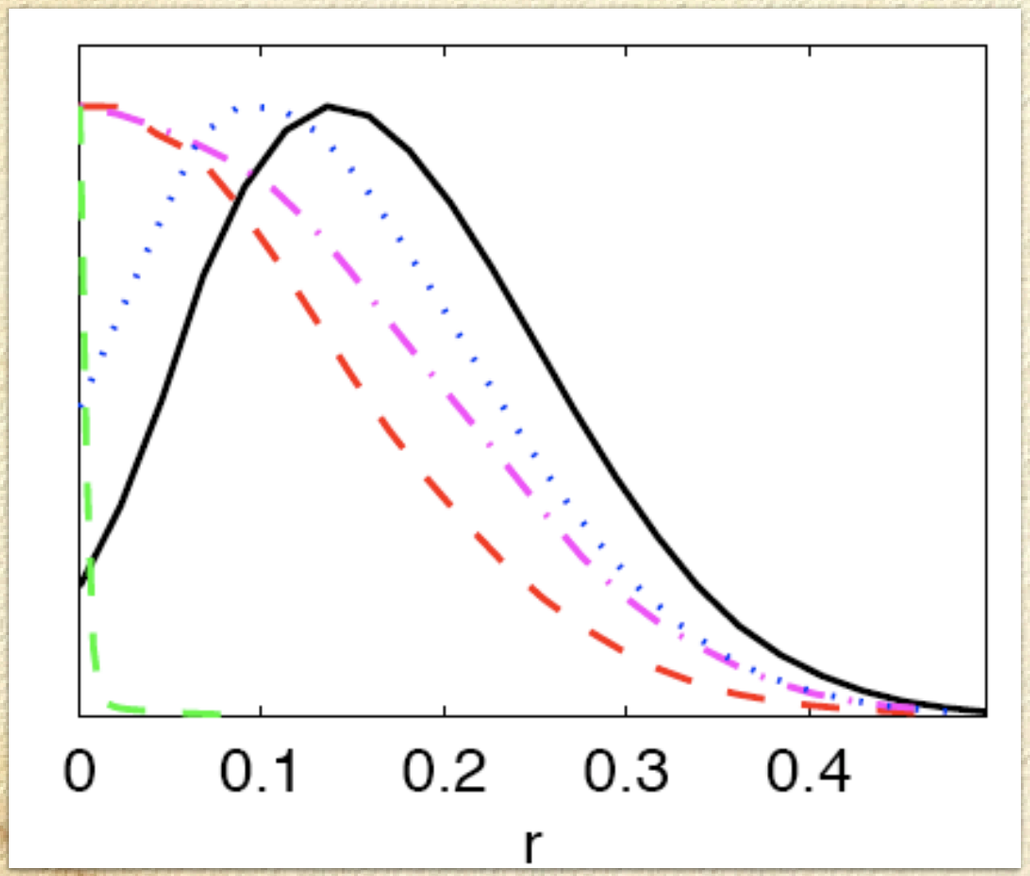

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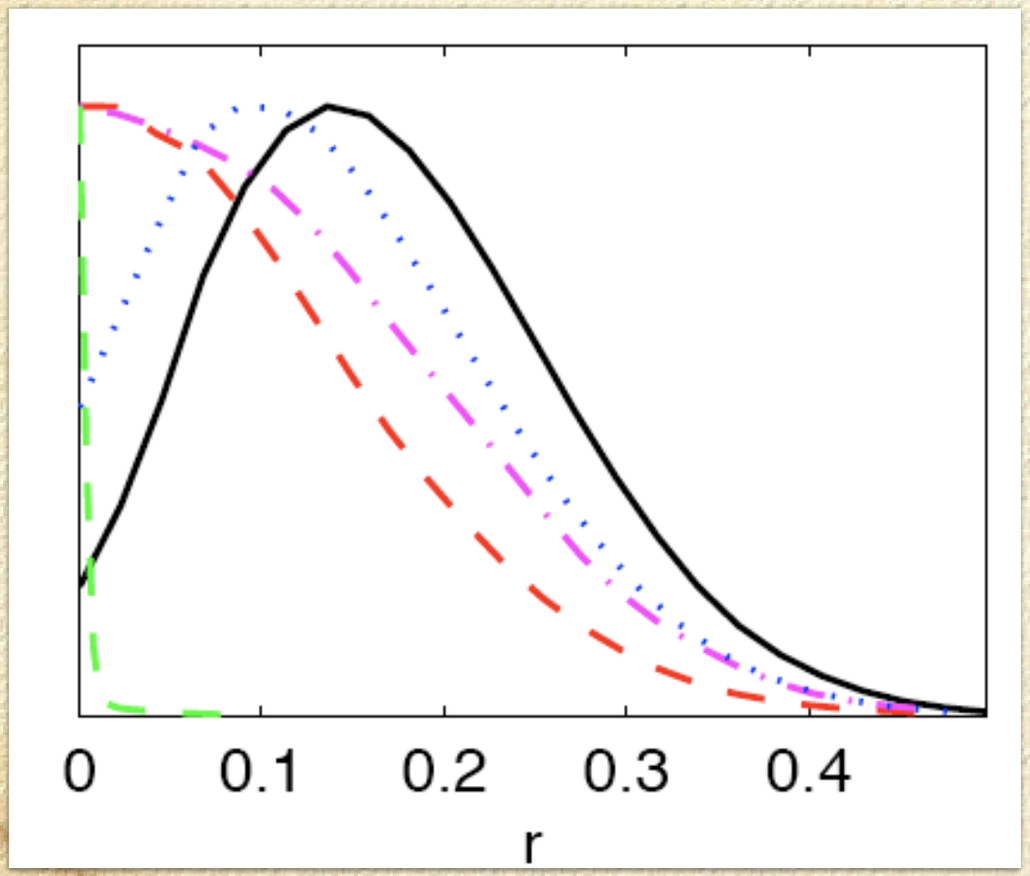

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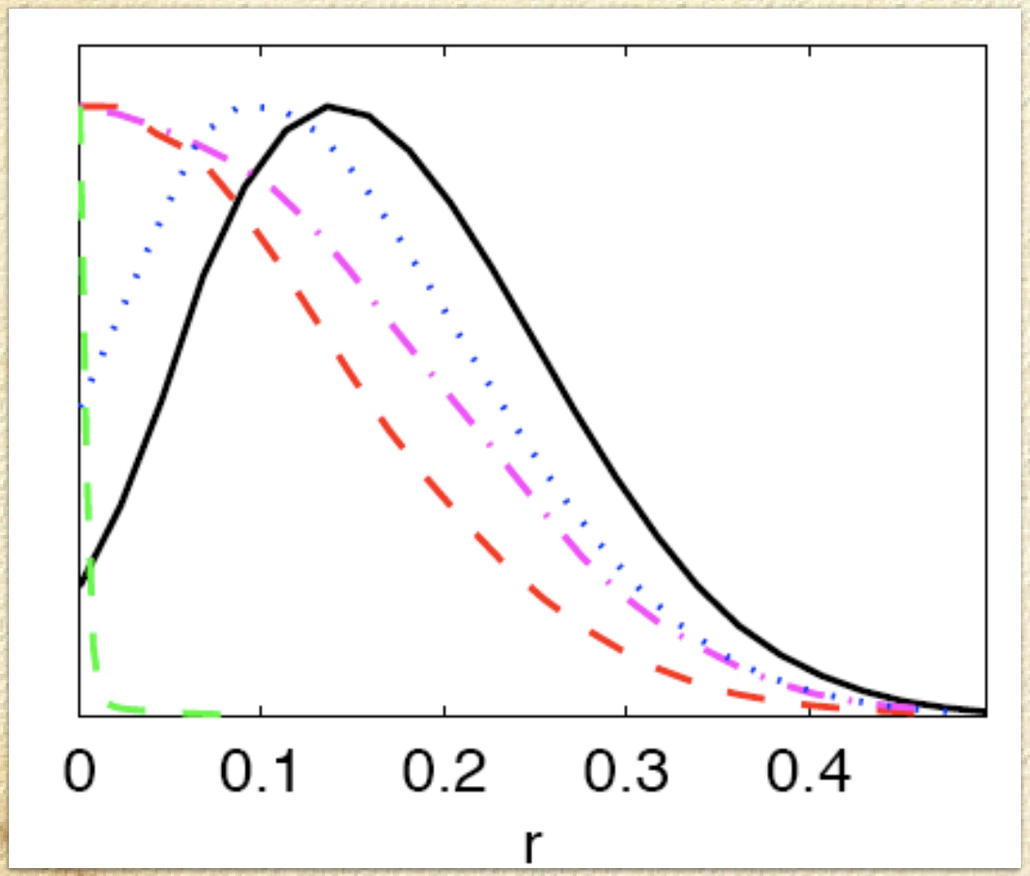

Bayesian Complexity < 8

Good News?

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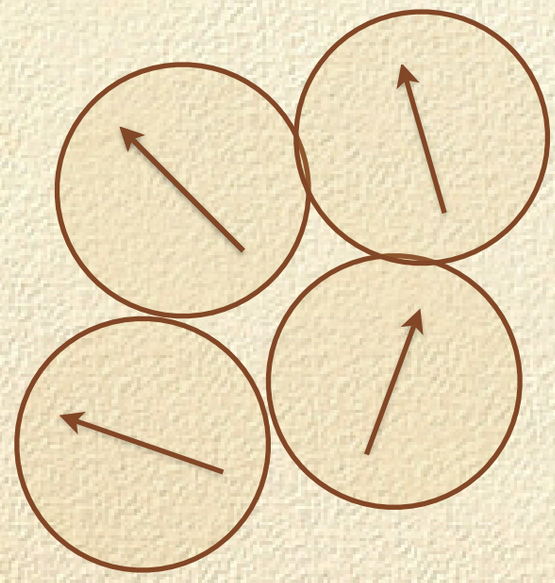

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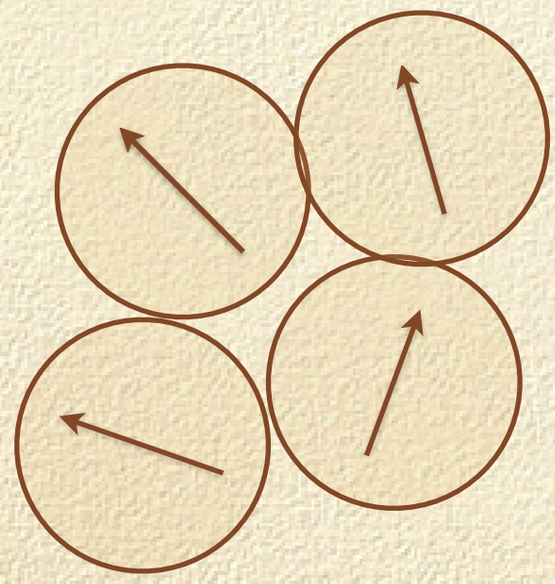

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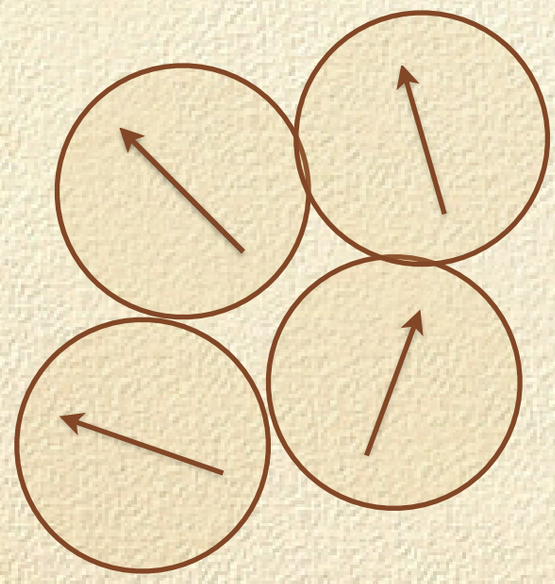

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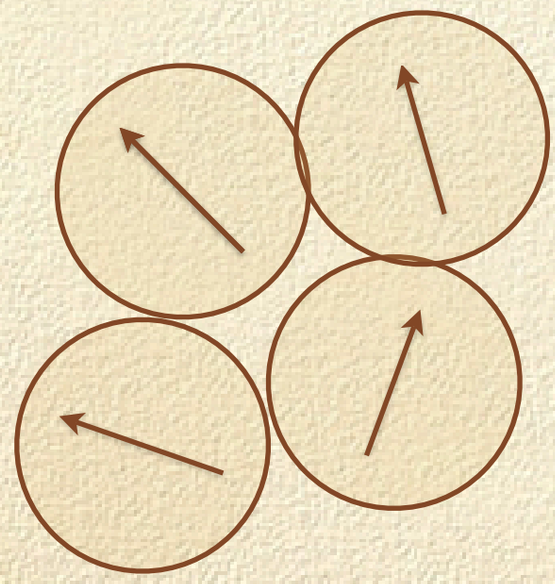

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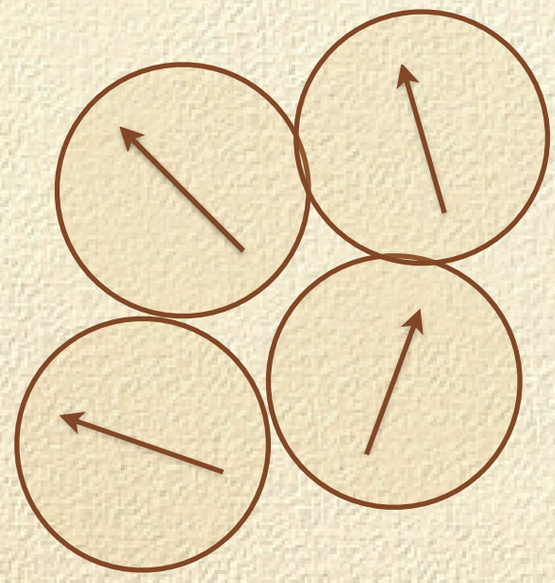

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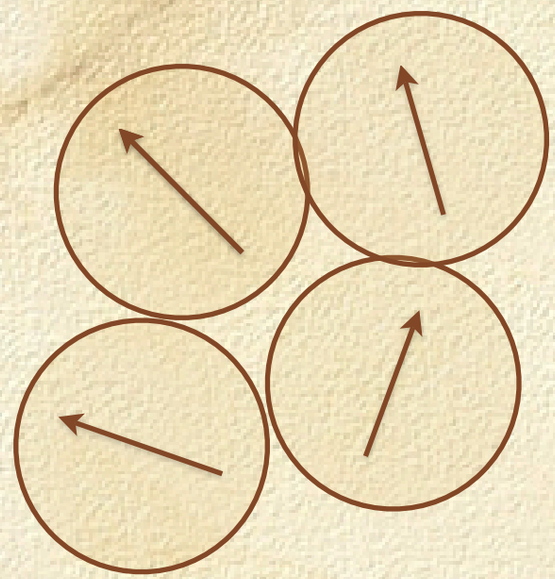
When horizon grows, gradients relax. Use quadrupole approx to calculate generation of gravitational waves ON THE HORIZON.

Smoking Gun??



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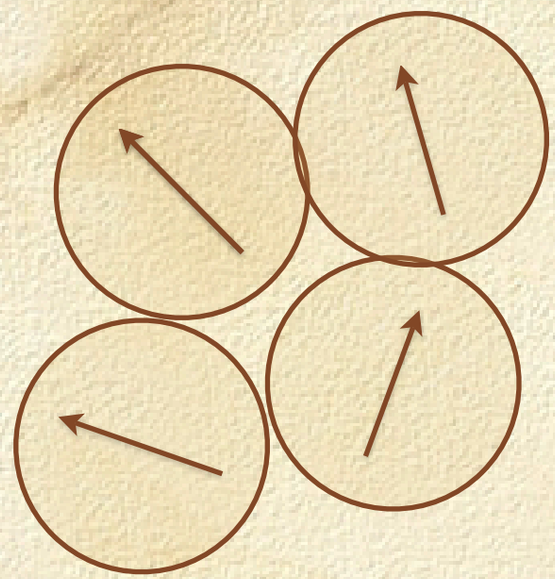

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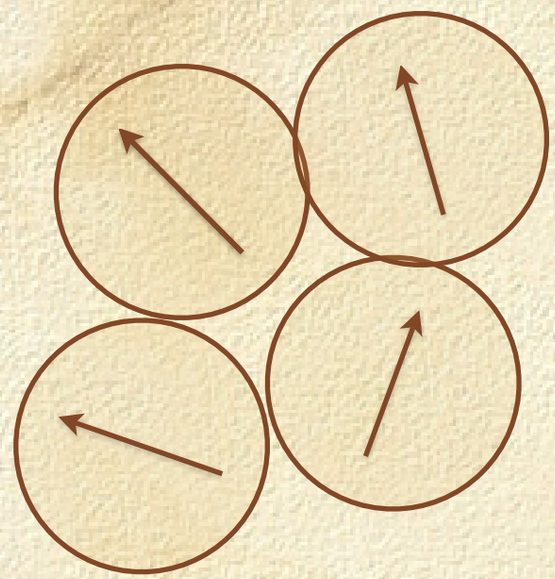

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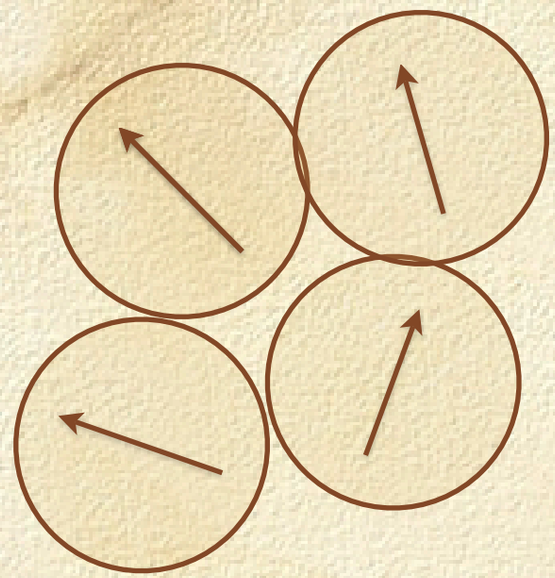

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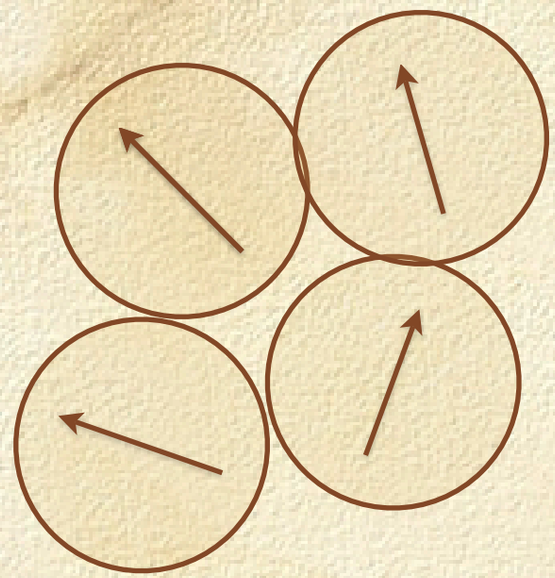

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RMS Strain:

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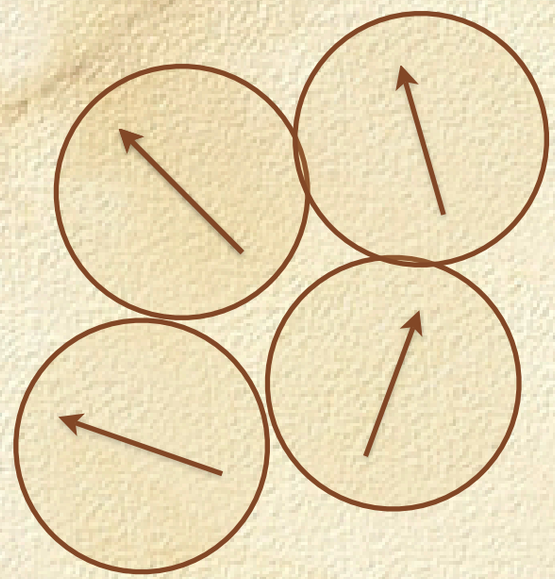

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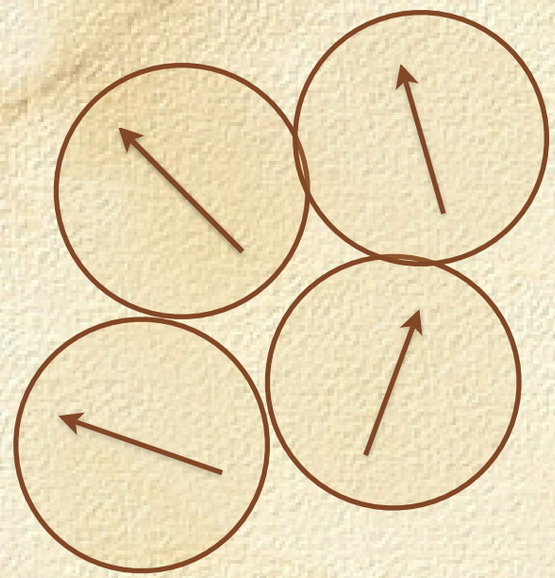

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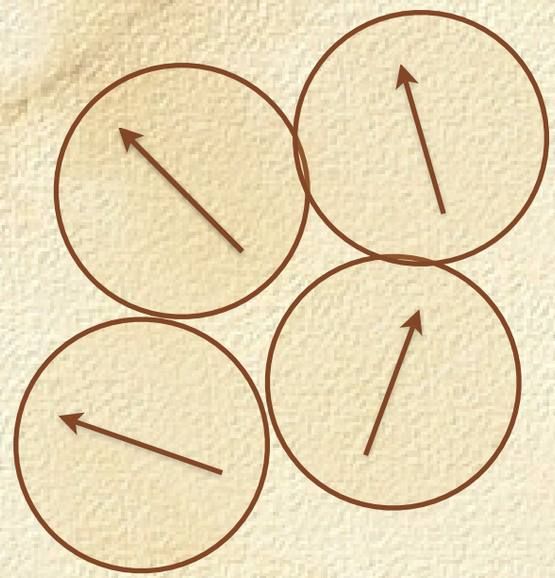

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RMS Strain: $h \approx H^{-1} (G^2 f^2 v^4 H^2)^{1/2} = G f v^2 \approx f \left(\frac{v}{M_{\mathrm{Pl}}}\right)^2$

Identical to Inflation.. Flat Spectrum..continued relaxation on H scale.. up to factor of f.. Q: What is f?

Smoking Gun??

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Trick: find analytical model where calc. can be done exactly:

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BUT!!!! for pτ ≈ 1 C ≈ 2000 ! FOUR ORDERS of MAG!

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→ Ratio of strengths:

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Ratio of strengths: $10^4\left[\frac{\eta}{N^{1/4}v}\right]^4$

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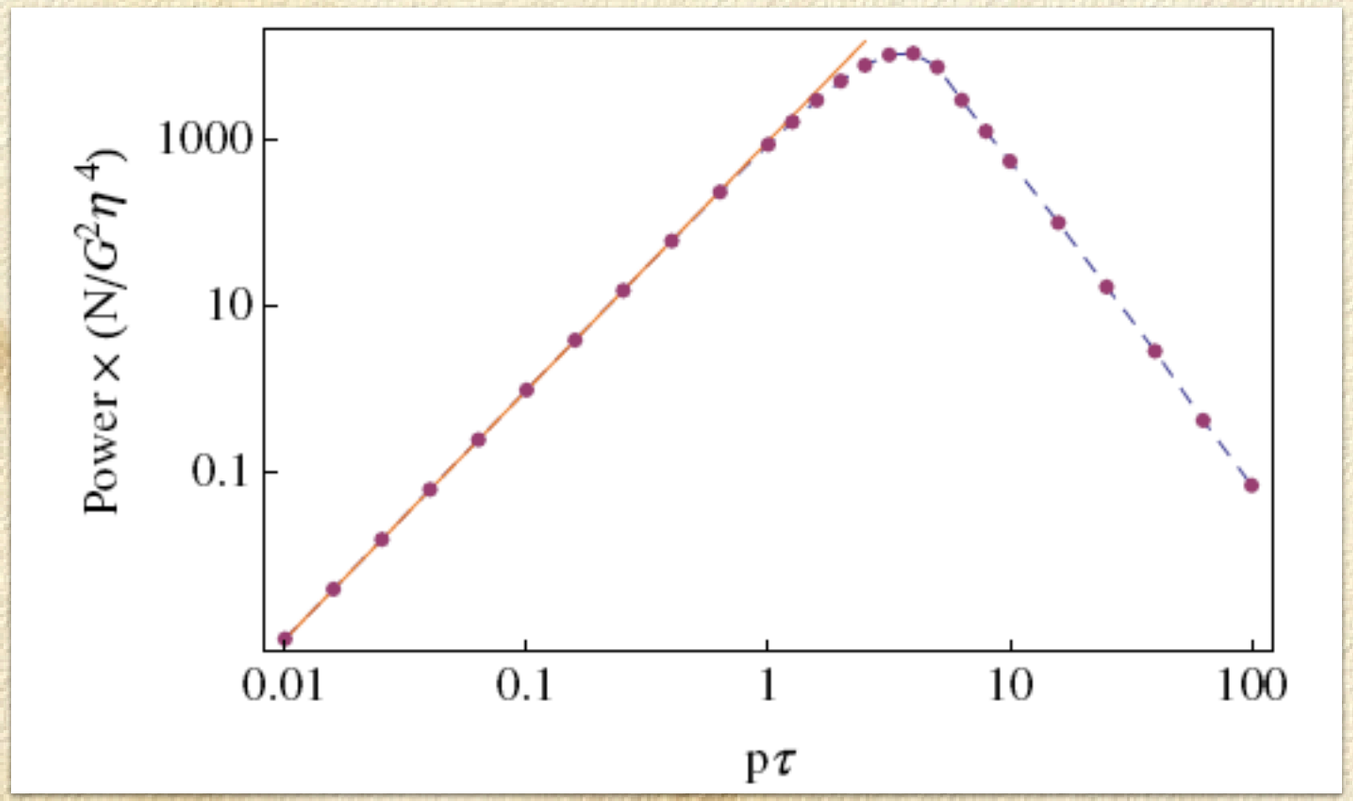

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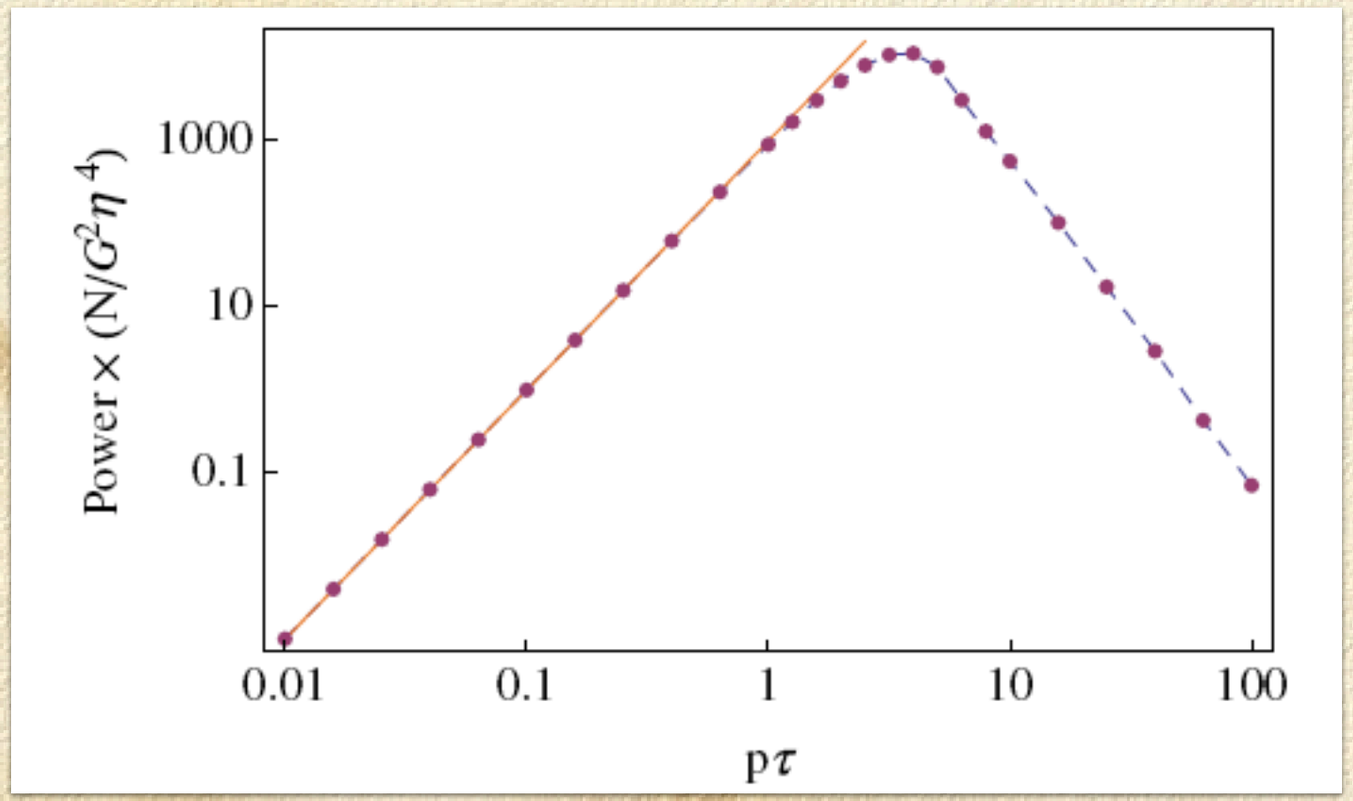

Q: Spectrum is flat on horizon scale, but differs on superhorizon at any time. Does this produce difference in polarization???

“Proving” Inflation with Gravity Waves

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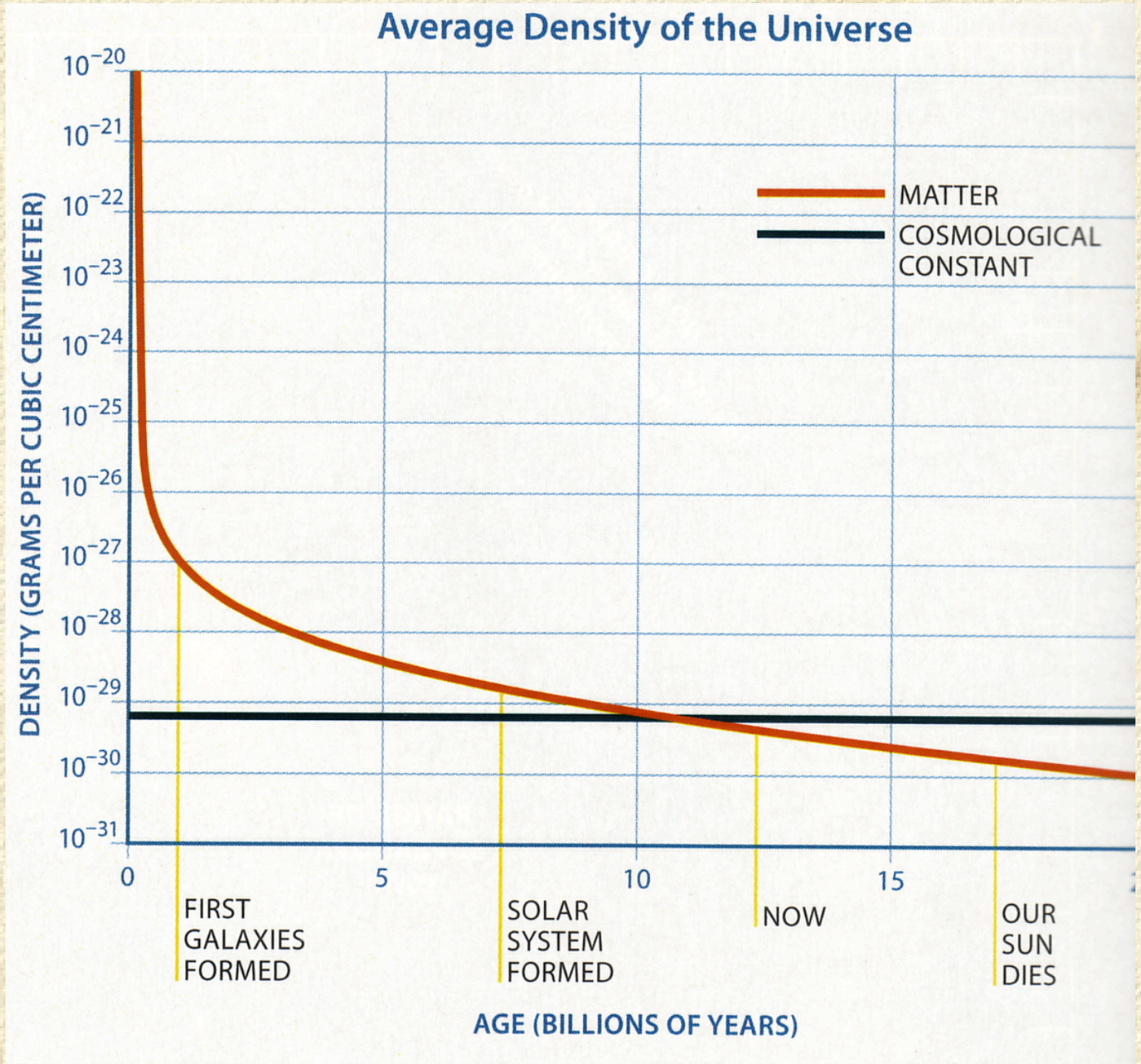

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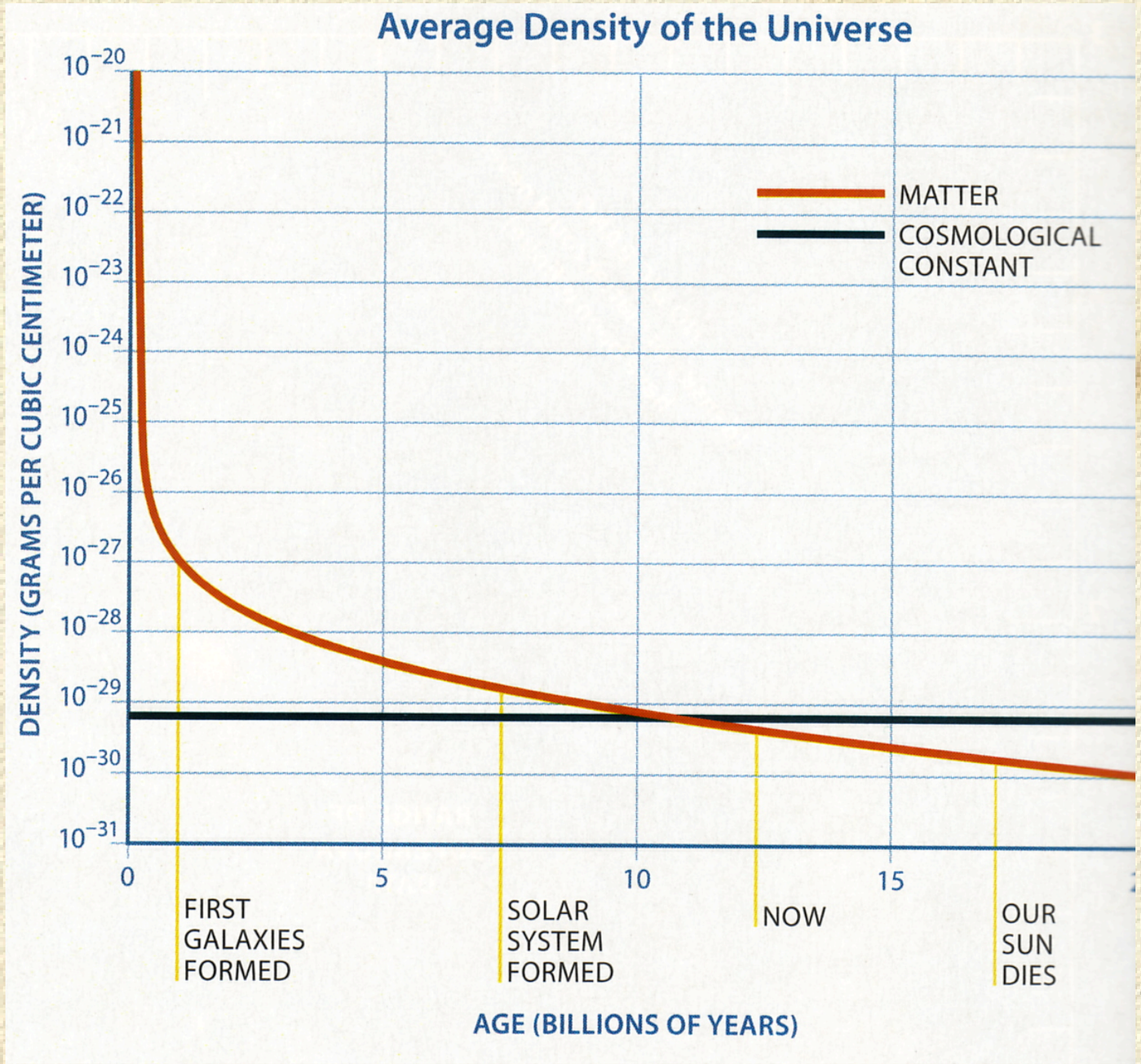

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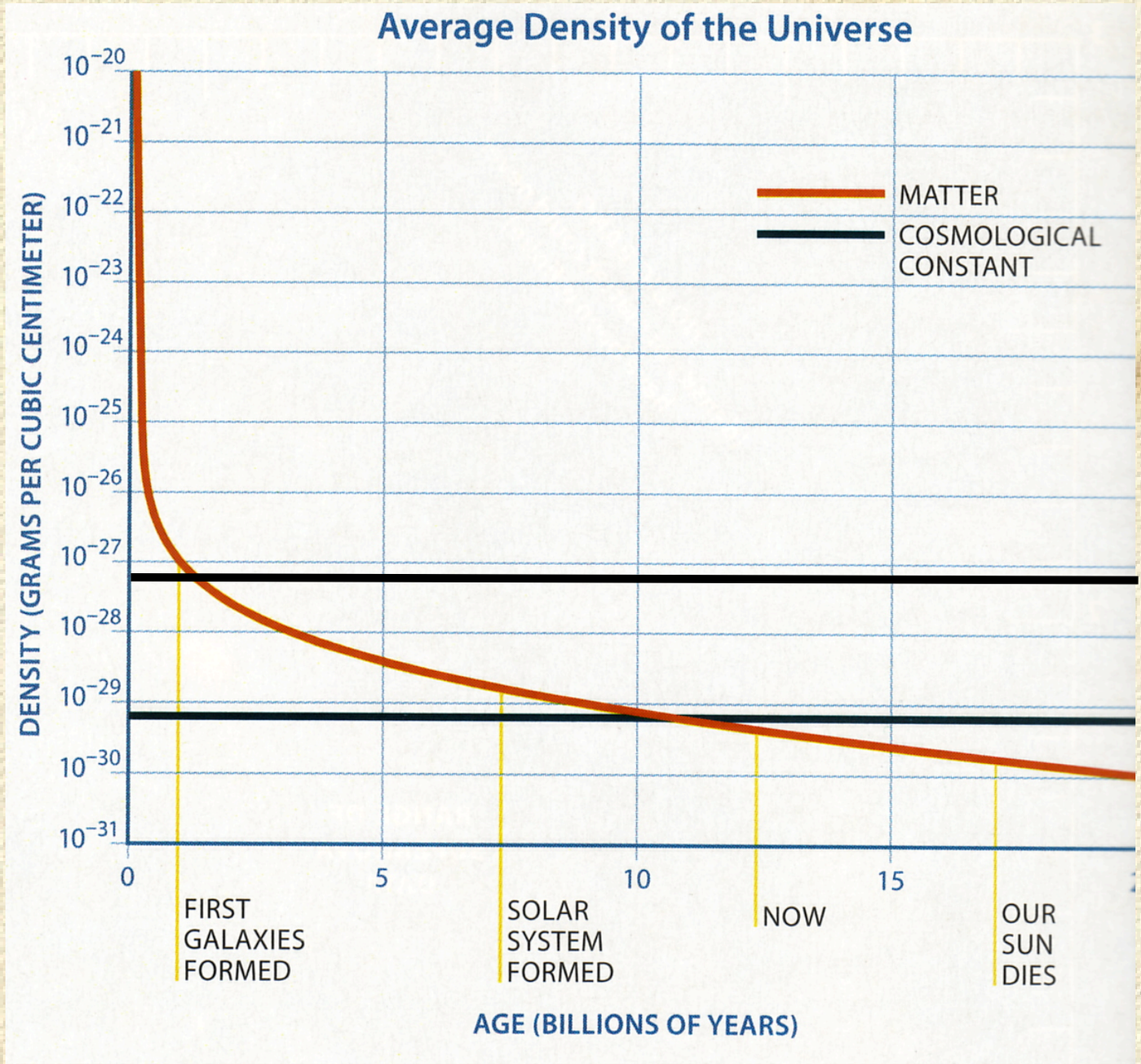

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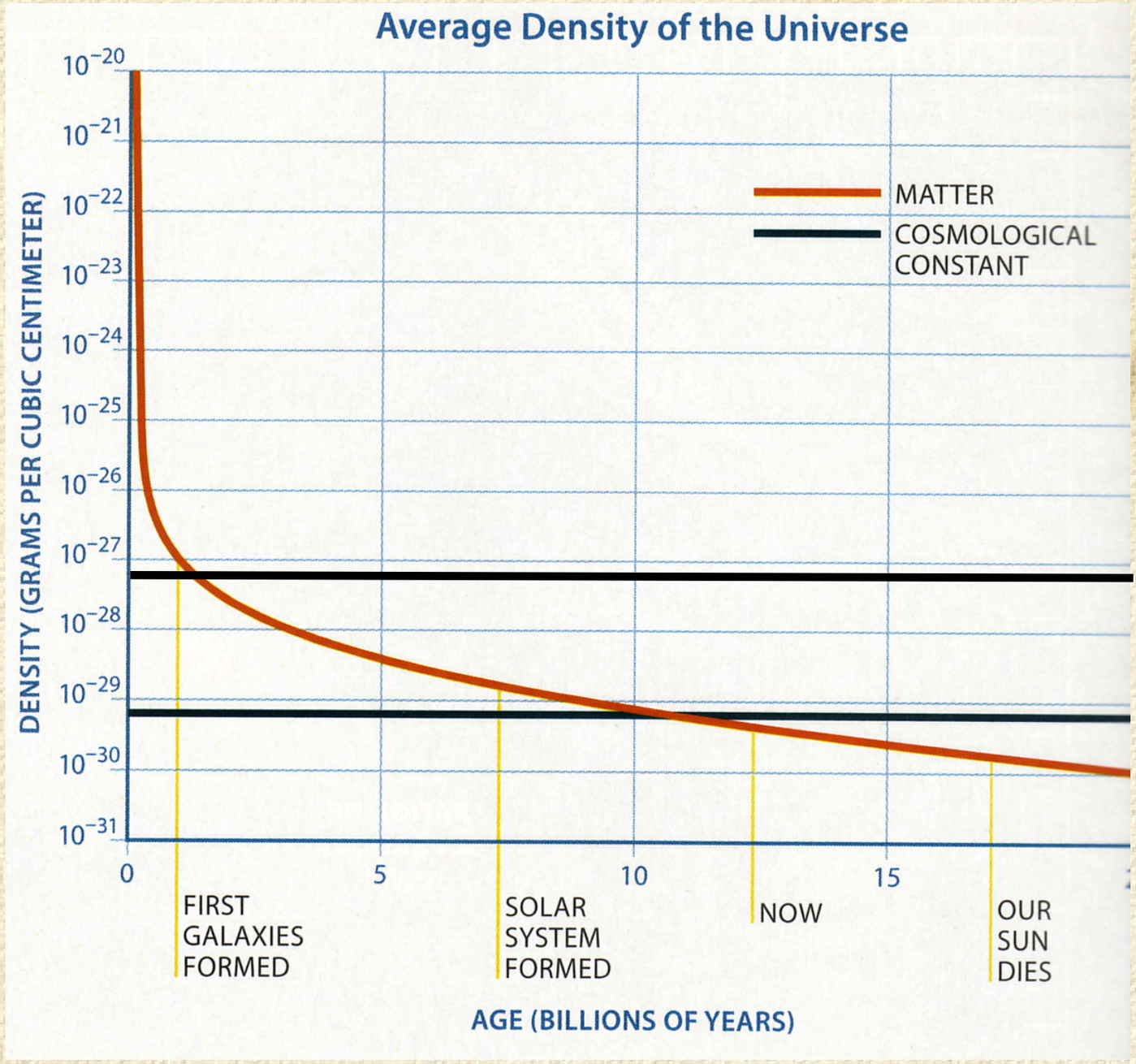

Maybe this is telling us something?

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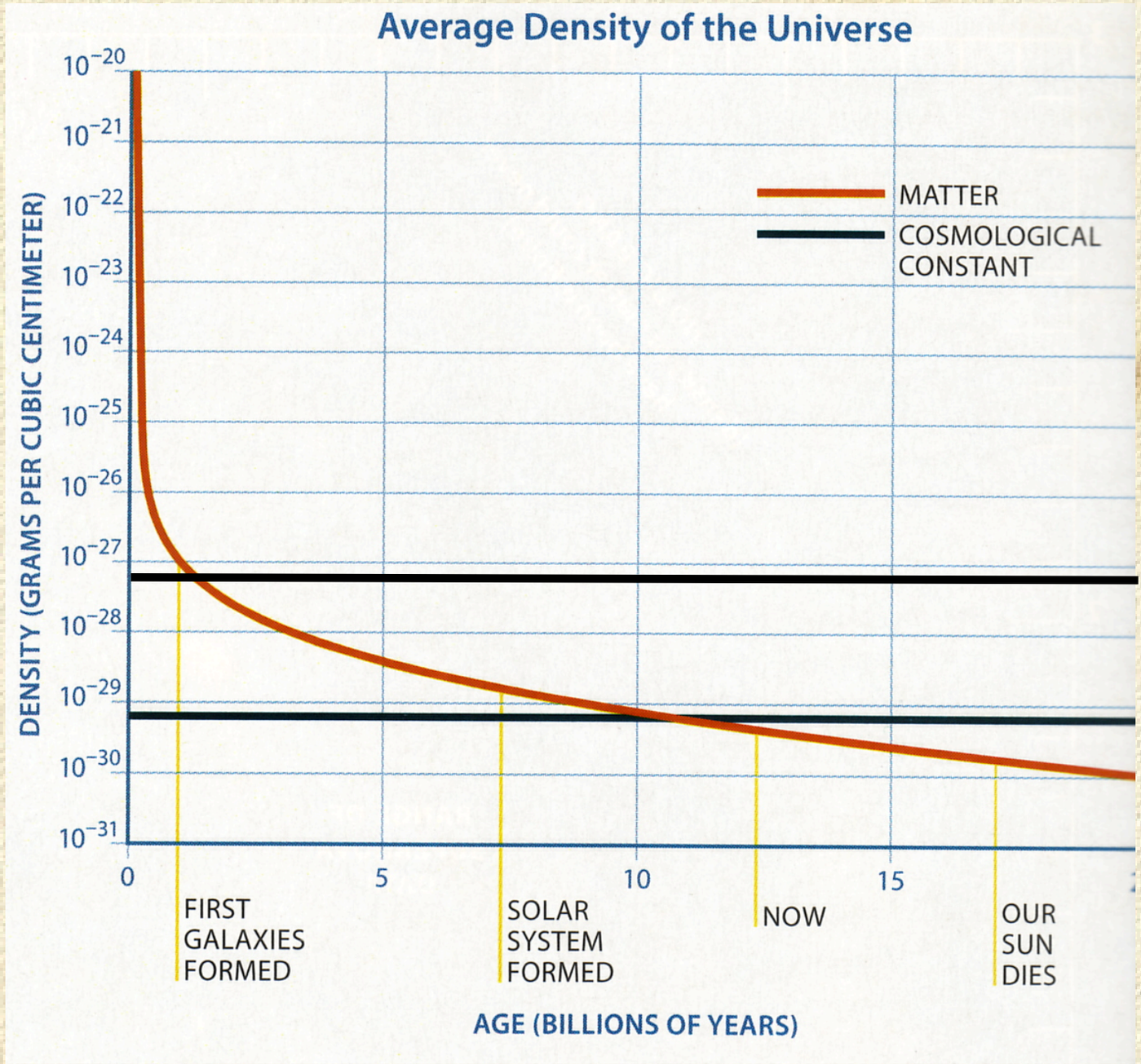
Galaxies Never Form?



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Anthropic Mania

IF there are many different universes, and the energy of empty space can vary in each one, then only those in which it is not much greater than what we measure will galaxies form... and only then will stars and planets form, and only then astronomers....

Why Stop There?

The Constants of Nature and the Puzzles of Modern Physics

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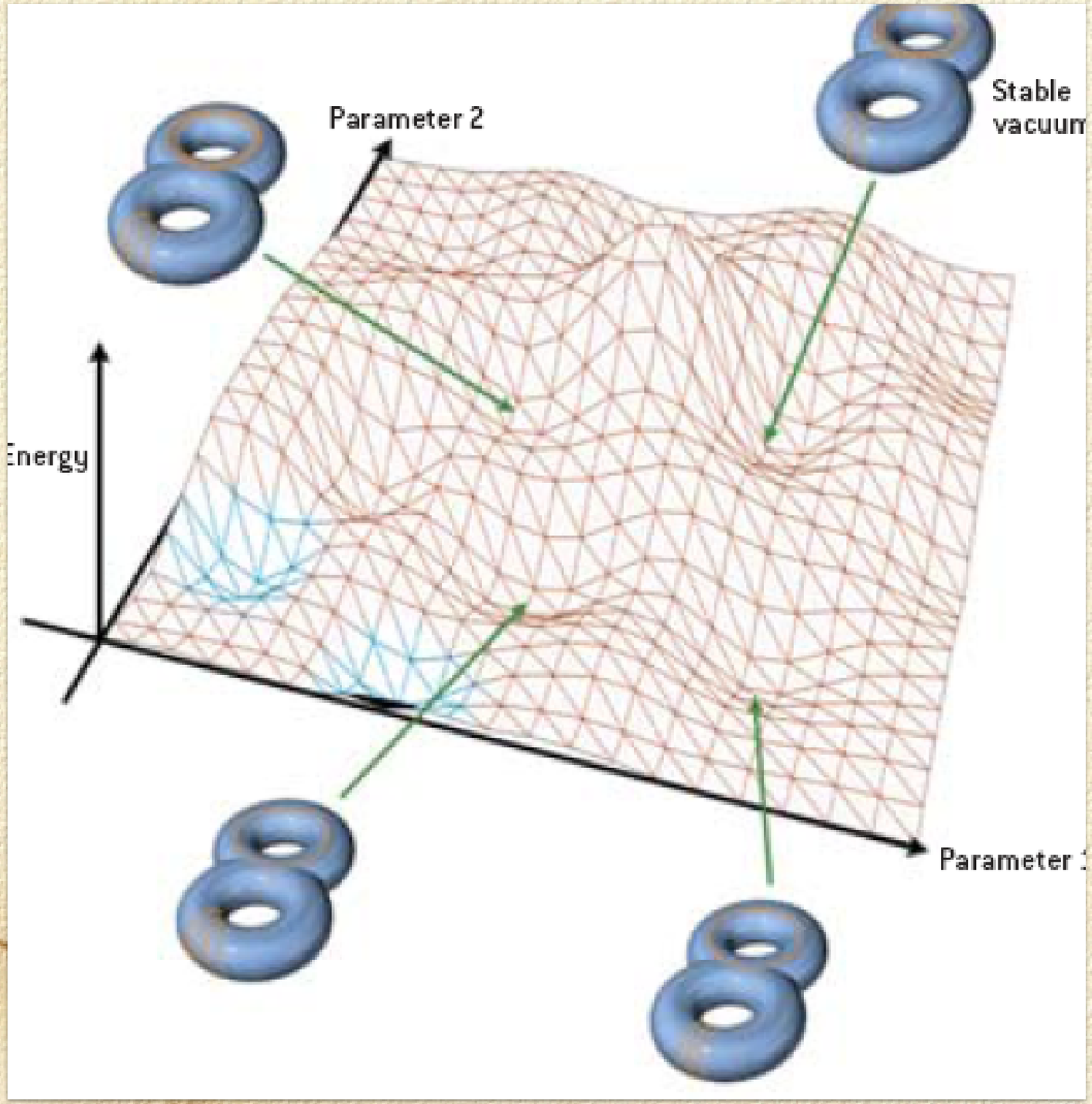
The Landscape of Nothingness



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- It has been wrong before!

Which is the best Anthropic Measure?

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VASTLY DIFFERENT RESULTS DEPENDING UPON CHOICE!

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$$P = \delta\,(x - \text{  }\,)$$

Limits to Growth?

LMK, GDS 04

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We Can Calculate the Total Recoverable Energy with the Horizon:

Limits to Growth?

LMK, GDS 04

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$$E_{\max}(R^*) = \int_0^{R^*} 4\pi R^2 dR \rho_M(R) \frac{E_a(R)}{E_e(R)} = \frac{4\pi}{3} R^{*3} (\Omega_m \rho_c) \left[1 - (HR^*)\right]^3$$

Limits to Growth?

LMK, GDS 04

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Total Energy $\approx 3 \times 10^{67}$ Joules

$\approx$ total baryonic rest mass within today's horizon.

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Moore's Law < 400 Years!

High Tech Civilizations don't last long?

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- Favors a cosmological constant < 10^{-4} present value...

Can Anthropic Principle "Explain" Lambda?

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As currently framed: just demonstrates correlations..

Typicality is Everything!!

IM, LMK, GDS 07

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IM, LMK, GDS 07

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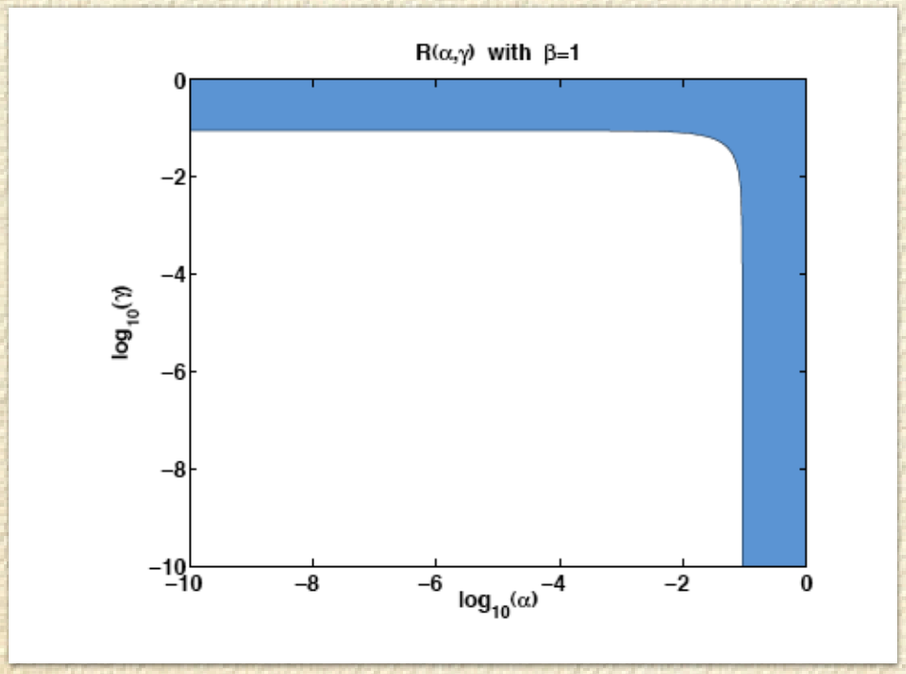

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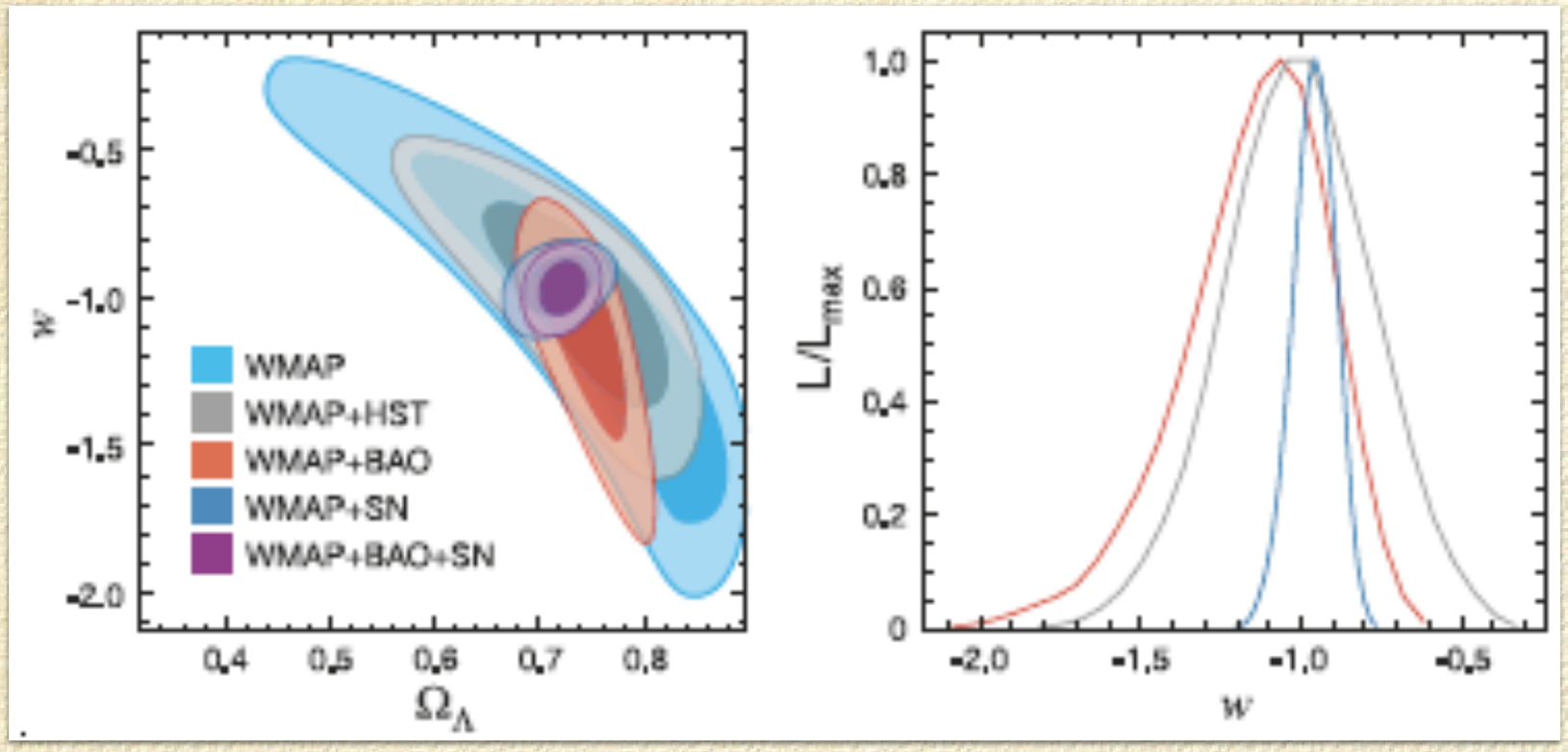
- Measuring $w \approx -1$ therefore tells us nothing.

The End of an Era?


-0.5
-1.0
-1.5
-2.0
w
WMAP
WMAP+HST
WMAP+BAO
WMAP+SN
WMAP+BAO+SN
0.4
0.5
0.6
0.7
0.8
Ω_Λ
1.0
0.8
0.6
0.4
0.2
0
L/L_{max}
-2.0
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w

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- The PROBLEM: We DON'T HAVE ANY IDEA of w(z). Hence limits on w=constant are not appropriate.

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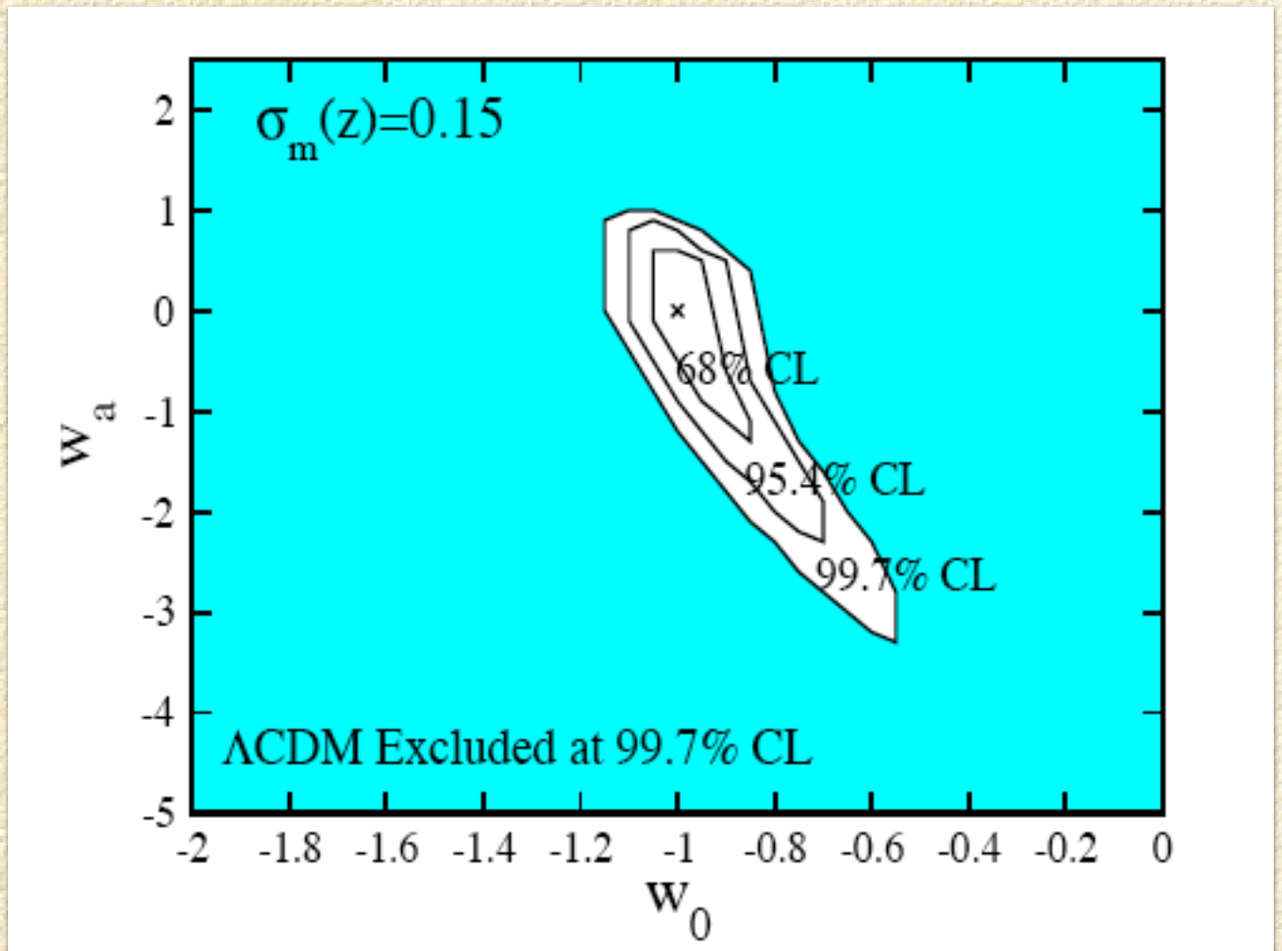

Pure theory required?

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Betting on the future!

Is Falsifiable Science False? (LMK RS 07)

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What will the future bring?:

Our Island Universe....

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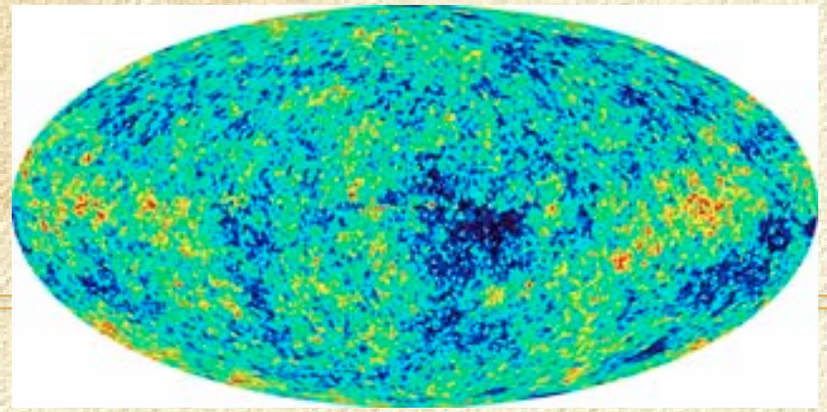
$\rho_\Lambda \ll \rho_M$, but also when $\rho_\Lambda \gg \rho_M$.



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- achieved when universe less than 50 times its present age..

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7. What about finite past?

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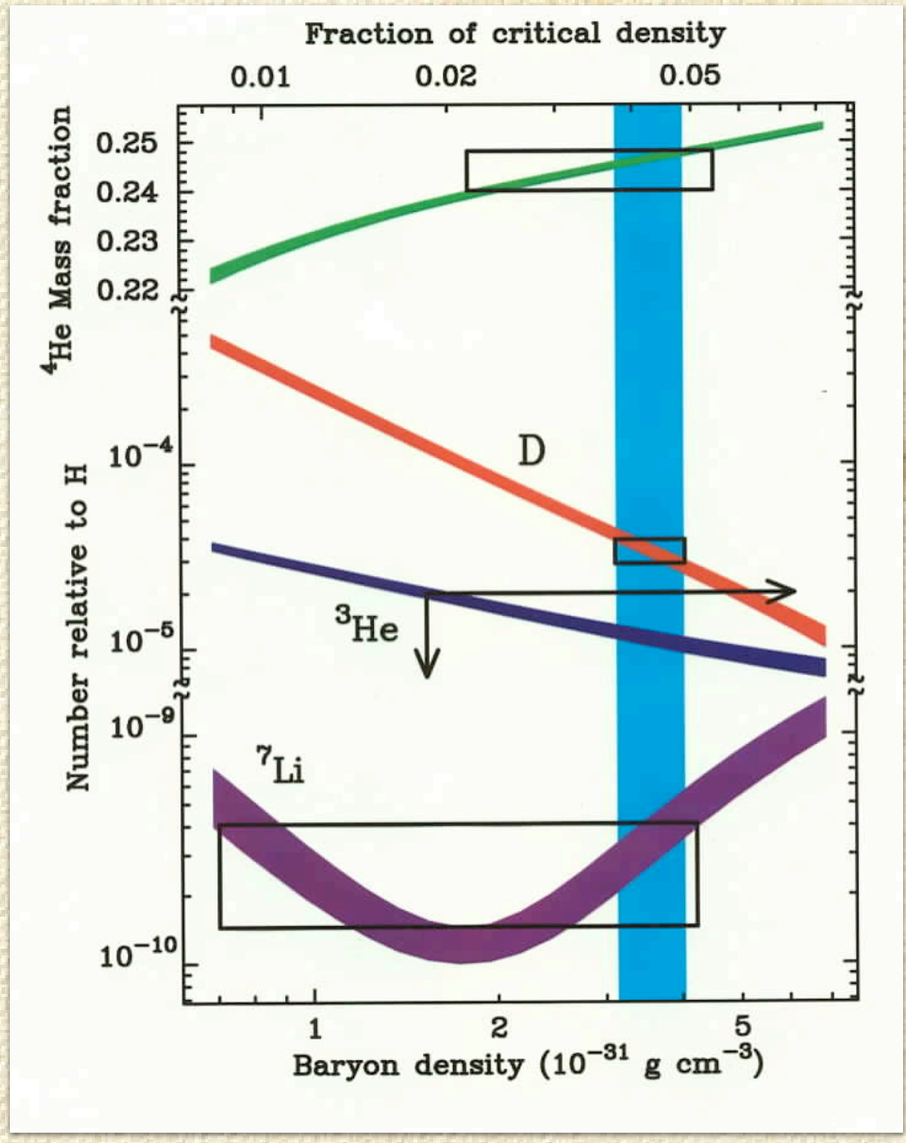

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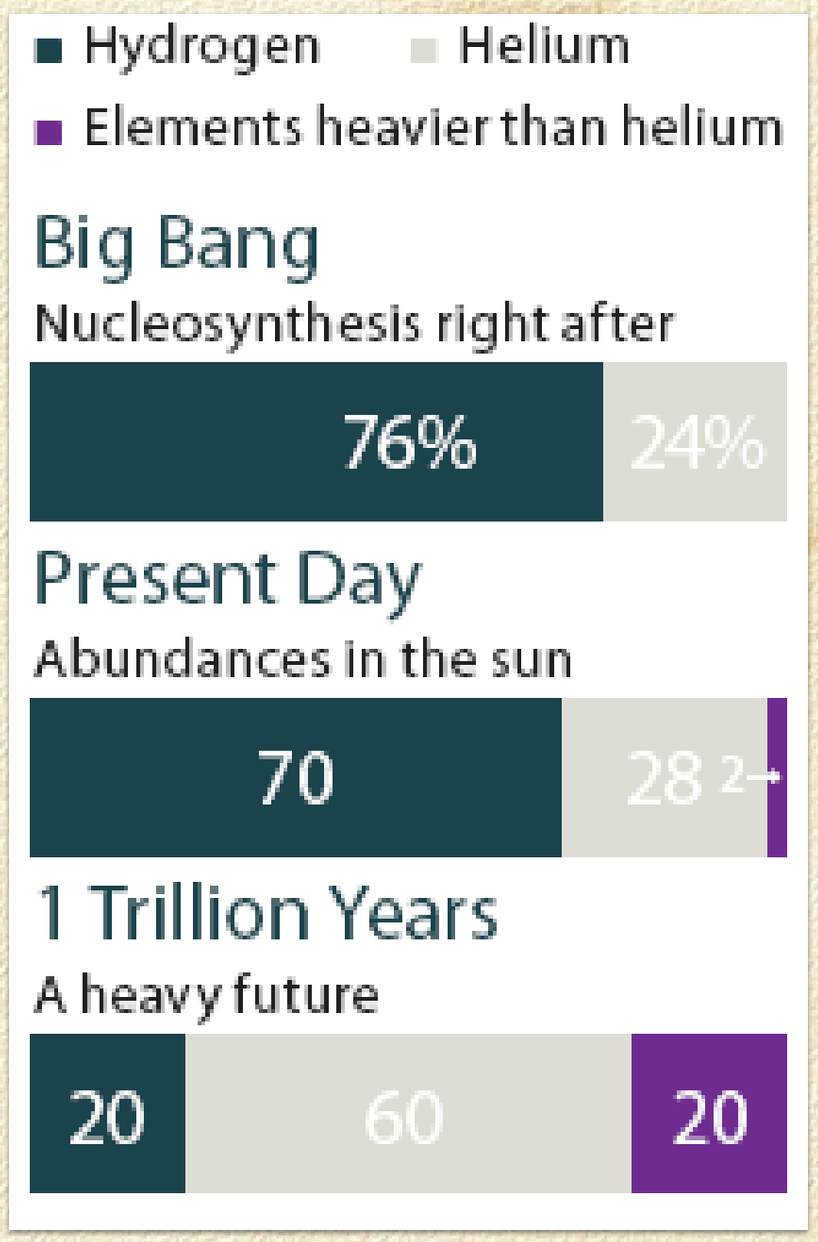

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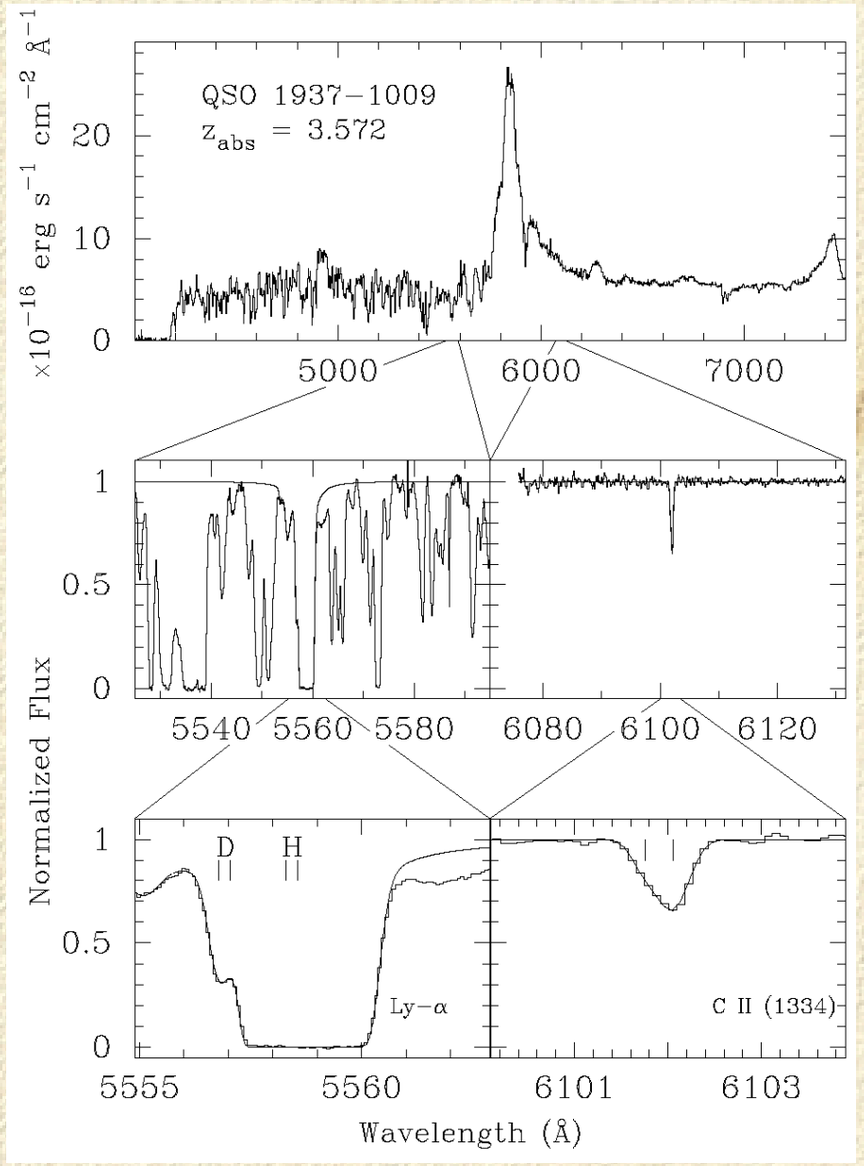

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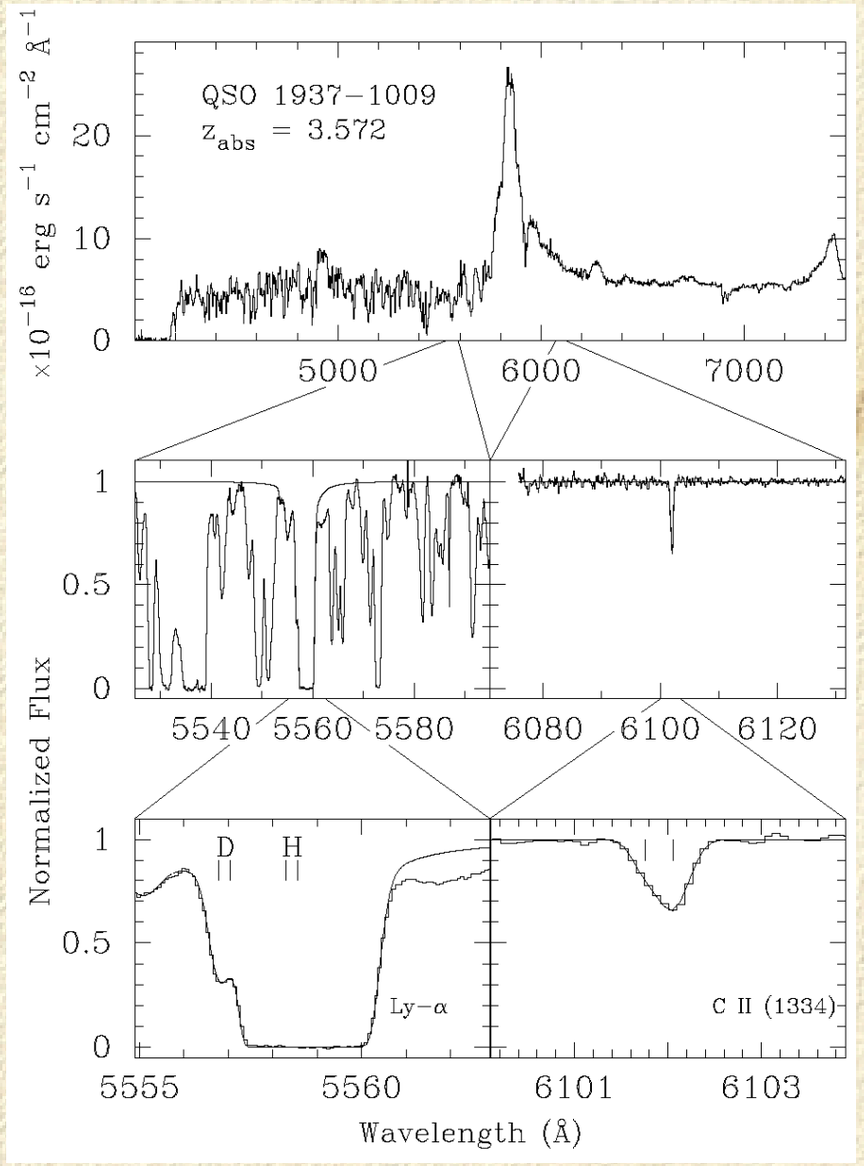

FALSIFIABLE SCIENCE:
Return of Static Universe!

The Good News

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We live in a very special time: the only time when we can observationally verify that we live at a very special time!

More important, although we are certainly fortunate to live at a time when the observational pillars of the big bang are all detectable, we can easily envisage that other fundamental aspects of the universe are unobservable today. What have we already lost? Rather than being self-satisfied, we should feel humble. Perhaps someday we will find that our current careful and apparently complete understanding of the universe is seriously wanting. ■

THE GOOD:

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Golden Era of Observational Cosmology has changed everything. New observations have a realistic chance of probing nature on heretofore unimaginable scales.

THE BAD:

THE BAD:

Fundamental Limits on science may be looming

THE UGLY?:

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The nature of fundamental science may change

THE UGLY?:

The nature of fundamental science may change

or end

We will be lonely and ignorant, but dominant.....