What r to target?

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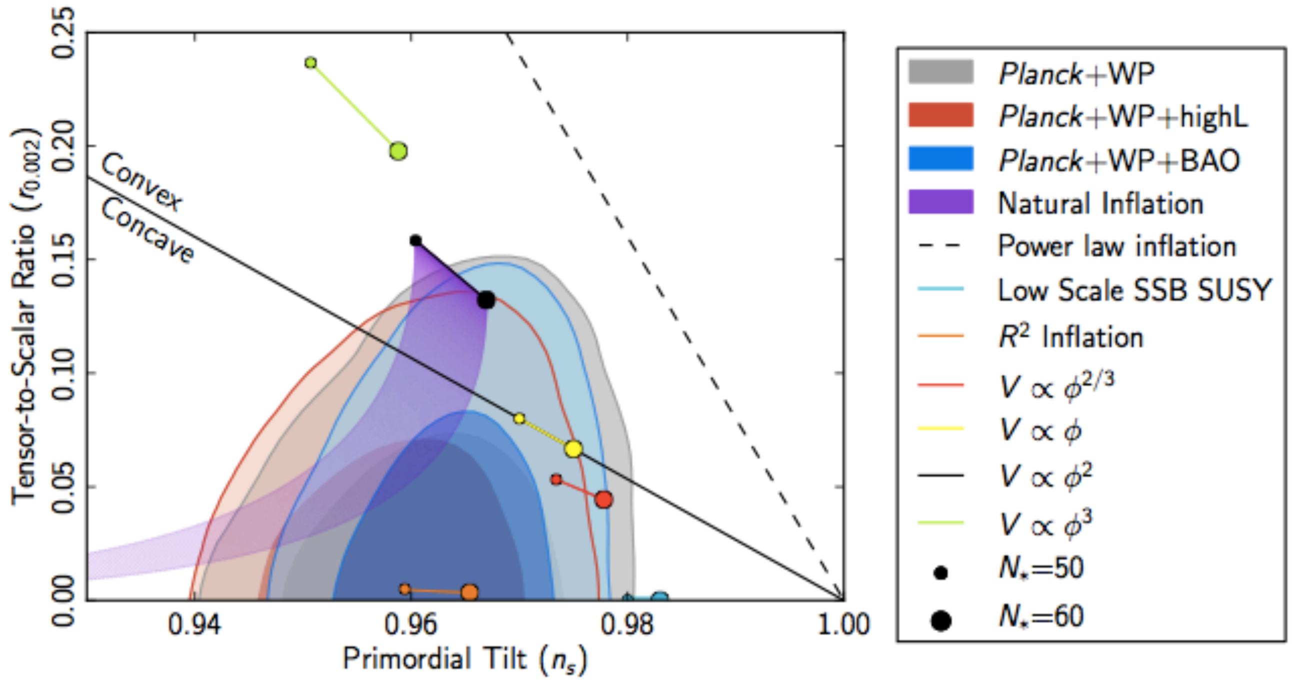
Easy answer

- The smaller the better

Easy but useless…

Elaborate:

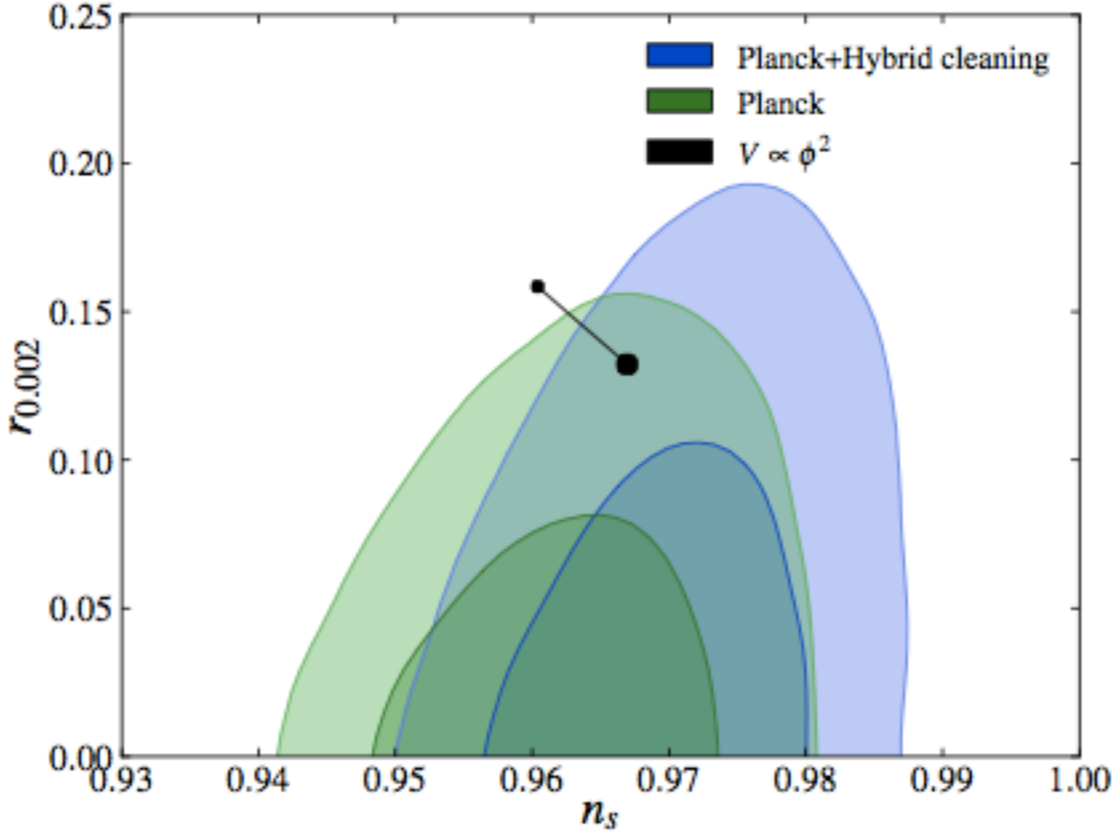
Where are we…



Planck 2013, but constraint comes from T not from B

Elaborate:

Where are we…



Re-analysis: Spergel et al. '13

Elaborate:

- I Really! think we should make "model-independent" statements as far as possible
- Inflation is a phenomenological paradigm for the early universe.
- There are many models out there (and many still to be invented/proposed)
- Should focus on generic and "model-independent" connection between inflationary gravitational waves and fundamental questions about the high energy origin of inflation.

There is no clear theoretical target

r can be as small as he(or she) wants

BAD: potentially (likely) a null result

GOOD: if r is "large" then a measurement/detection would be a direct probe of physics at ~GUT scales. Energy scale a trillion times greater than LHC. A direct probe of low energy quantum field theory and UV completion of gravity.

THE ETERNAL OPTIMIST:
How can we turn a null result into a useful result?
What could be learned by a (unlikely) detection?

Elaborate:

$$V^{1/4} = 1.06 \times 10^{16}\,\mathrm{GeV}\left(\frac{r_\star}{0.01}\right)^{1/4}$$

Energy scale of inflation

relation fixed by the measurement
of amplitude of primordial perturbations

$$\frac{\Delta\phi}{M_{\mathrm{pl}}} \gtrsim \text{few} \times \left(\frac{r_\star}{0.01}\right)^{1/2}$$

Field excursion during inflation

Here we are being quasi-model independent in the sense that we are in a regime close (but not identical) to slow roll.

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Motivations:

ns is very close to 1 (not quite but close)
No evidence for running (i.e. if there is running it is small)
No evidence for primordial non-gaussianity
No evidence for large non-adiabatic contribution to perturbations

We could be surprised, of course, but do not plan (a space mission) on it

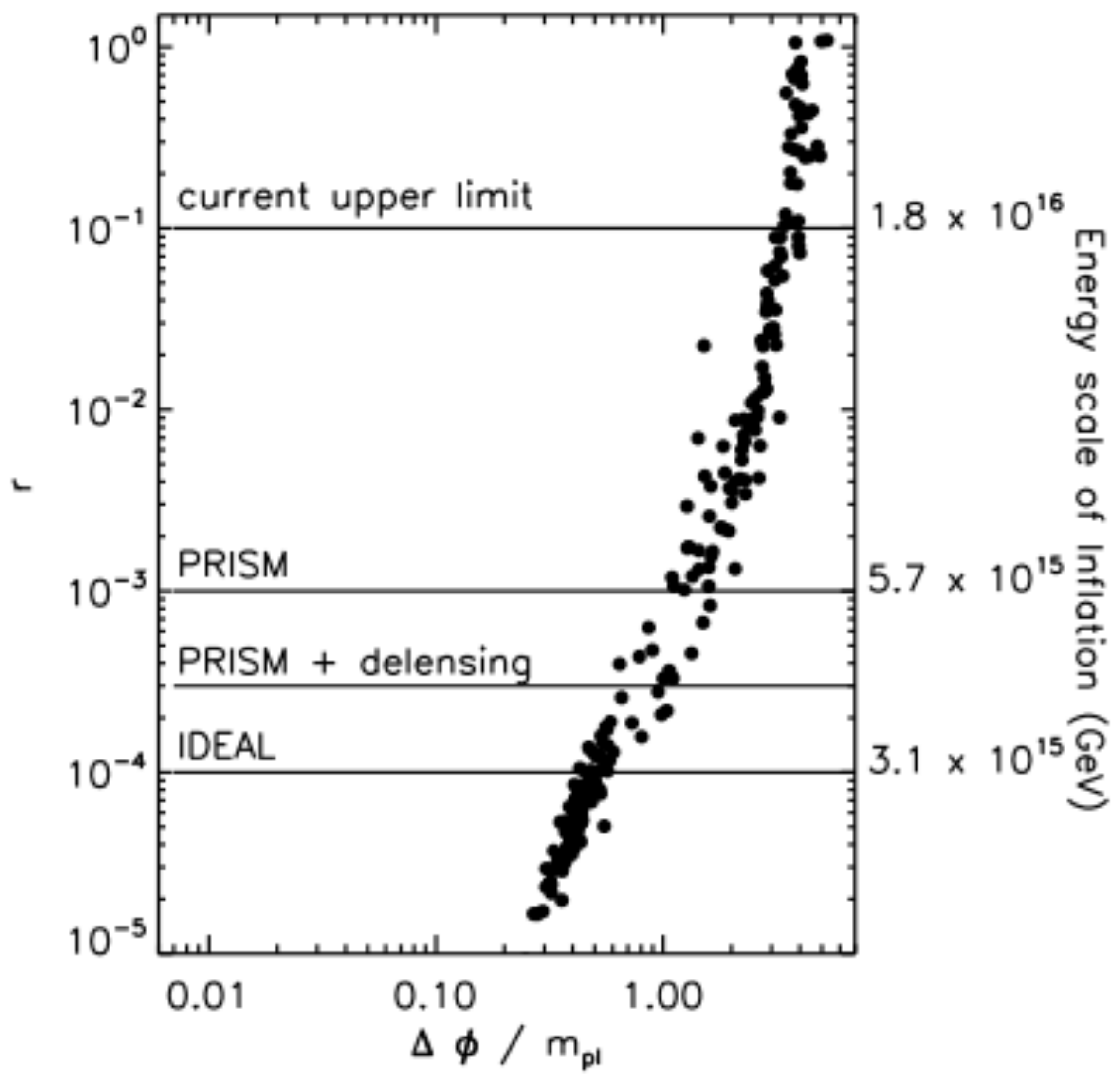
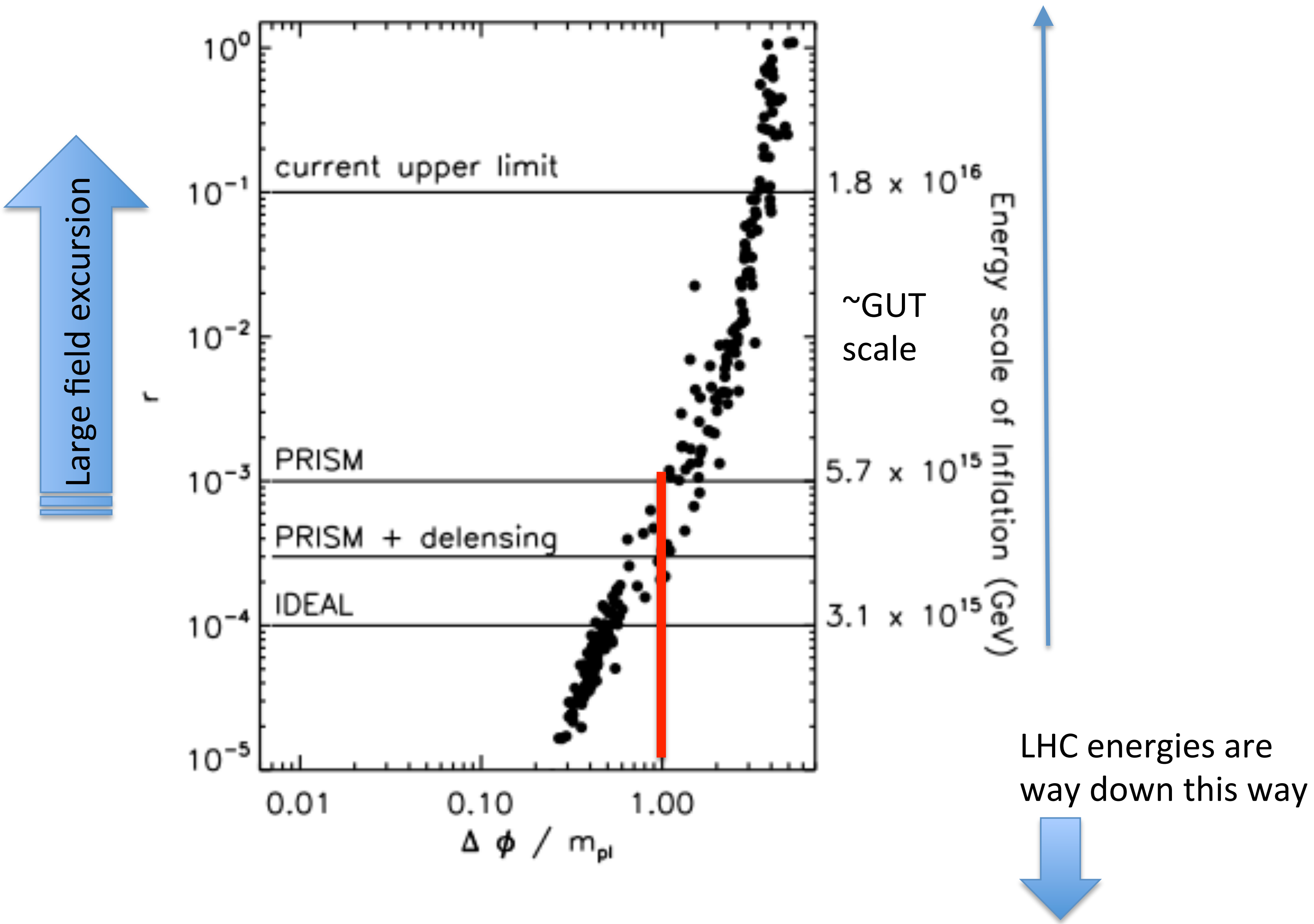


Fig from the PRISM white paper, analysis of LV, Peiris, Jimenez 2006 (mutatis mutandis)

The target



Large field excursion
current upper limit
PRISM
PRISM + delensing
IDEAL
r
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.01
0.10
1.00
$\Delta\phi / m_{pl}$
1.8×10^{16}
5.7×10^{15}
3.1×10^{15}
Energy scale of Inflation (GeV)
~GUT scale
LHC energies are way down this way

Single field consistency relation

If single field and slow roll

$$r = -8n_t$$

It would be very nice, but **forget it**!

$r<0.15 \rightarrow |n_t|< 0.02$

Fisher forecast error on nt, idealized case (more and less ideal)

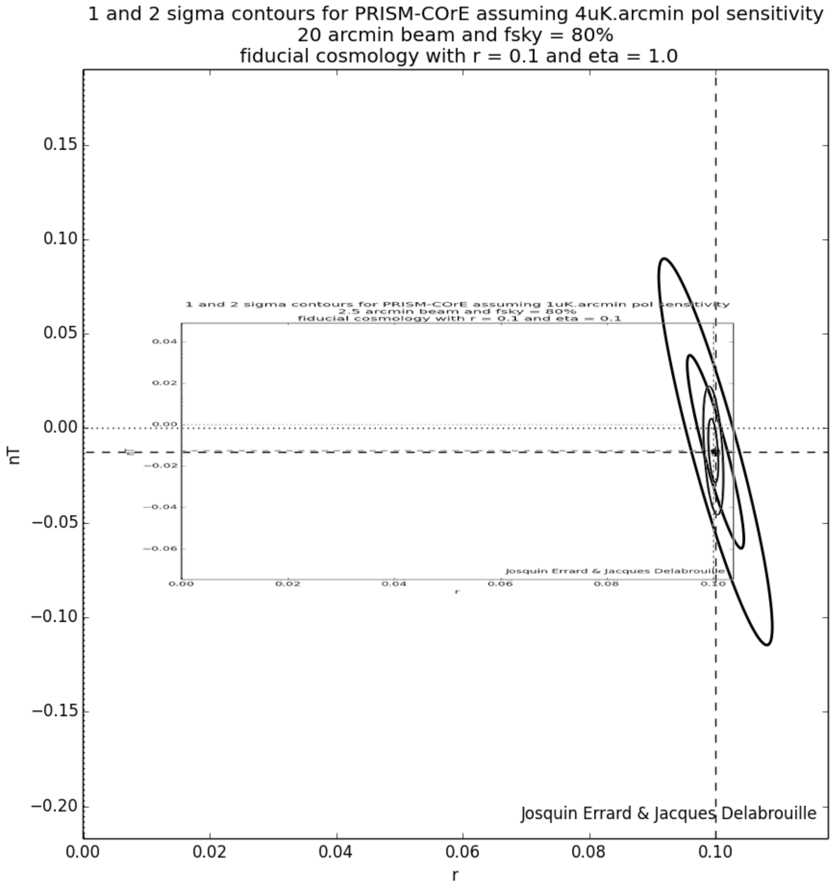
Fiducial r	Error on n_t	
0.1	0.035	0.05
0.01	0.056	0.096

Josquin Errard & Jacques Delabrouille

Expect nt=-r/8 !!!!!

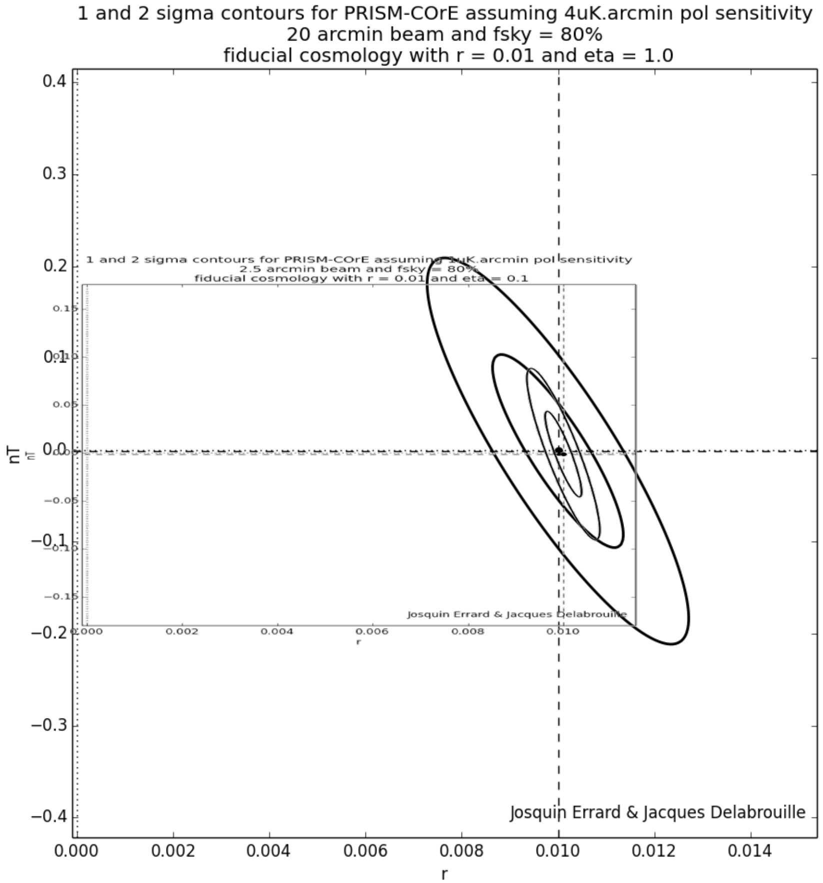
r=0.1

No delensing/90% delensing



r=0.01

No delensing/90% delensing



Modifications/extensions

$r = -8n_t \sin^2 \Delta$ Multi fields

$\cos \Delta$ Correlation between adiabatic and isocurvature

$r = -8n_t \, c_s$ Kinetic effects

But: $f_{\rm NL} \sim 1/c_s^2$

If violation of consistency relation:

Large negative tilt : e.g., multi-field inflation or a non-trivial speed of sound (non-canonical kinetic term).

Large positive tilt is only possible if the theory violates the null energy condition, $\dot{H} > 0.$

Attractors

``Universal" attractors in the ns r plane (wide range of models, but lacking UV completion)

n_s=1-2/N $\quad$ r=12/N^2

N is number of efoldings

→ r ~ 0.003

Read: of the order of, do not take too litterally

And extension/generalization

r= α 12/N^2

$\alpha < 1$ works

$\alpha > 1$ some cases
But currnet constraints α<10

String theory motivated models (with UV completion) have r orders of magnitude smaller

summary

- Get at least to r=0.001
- a null results will tell something
- And positive result would be revolutionary
- Forget about slow roll single field consistency relation
- Attractors (fad or fashion?) push you to r<~0.003

For more (quick) info (beyond PRISM paper)

- http://arxiv.org/pdf/0811.3919.pdf

(CMBPol Mission Concept Study Probing Inflation with CMB Polarization)

- http://arxiv.org/pdf/1402.0526v1.pdf

(A. Linde, Inflationary Cosmology after Planck 2013)

- http://arxiv.org/pdf/1309.5381.pdf

Inflation Physics from the Cosmic Microwave Background and Large Scale Structure (white paper)

Discussion

- What if from the ground r<0.01?
- What if from the ground r<0.001??
- What if detection from the ground r=0.03?

  (NB detection vs measurement!)
- What would you (and the rms physicist) believe?

- What if a small quick space mission sets upper limits?
- What if a small quick space mission detects r?