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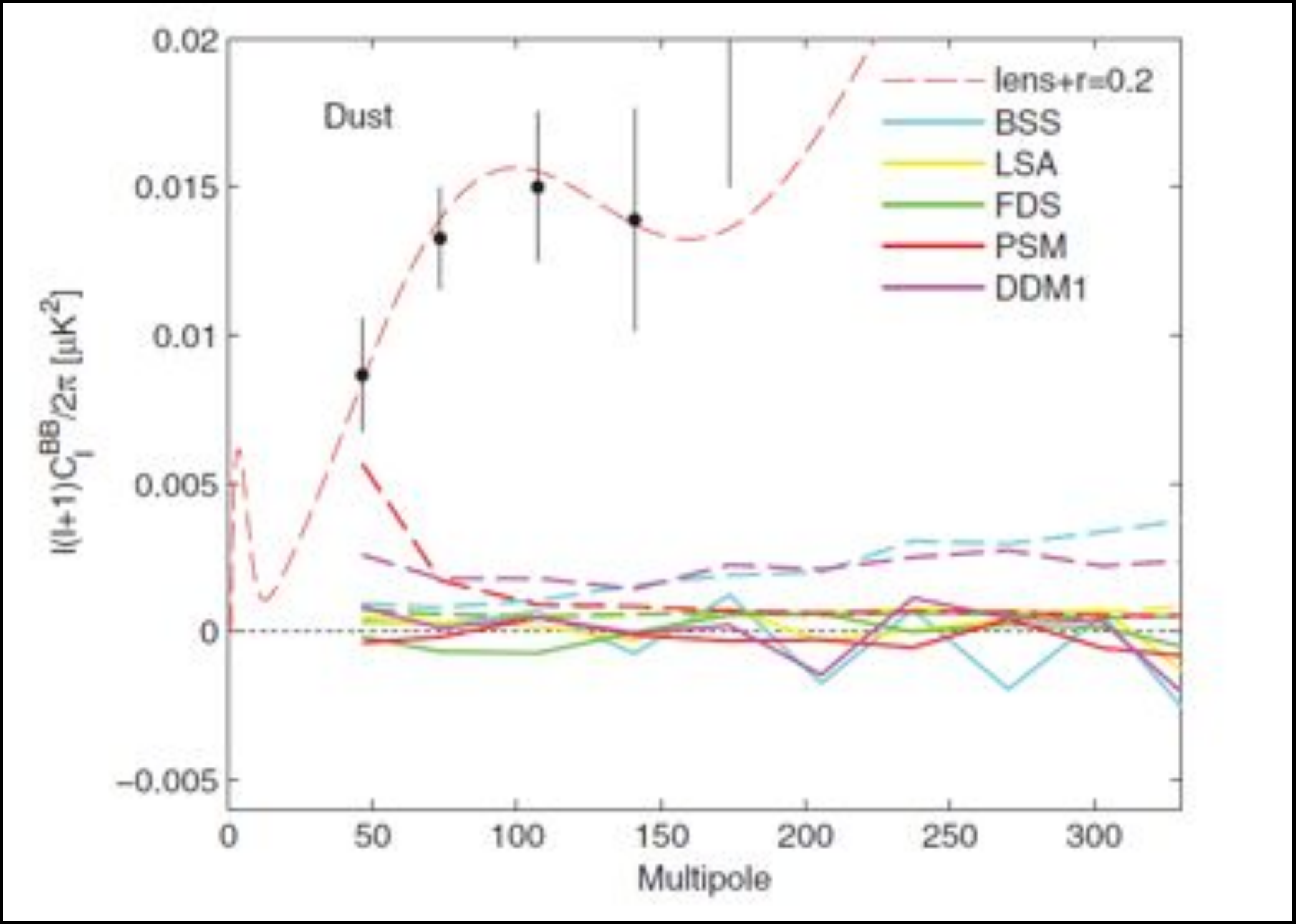
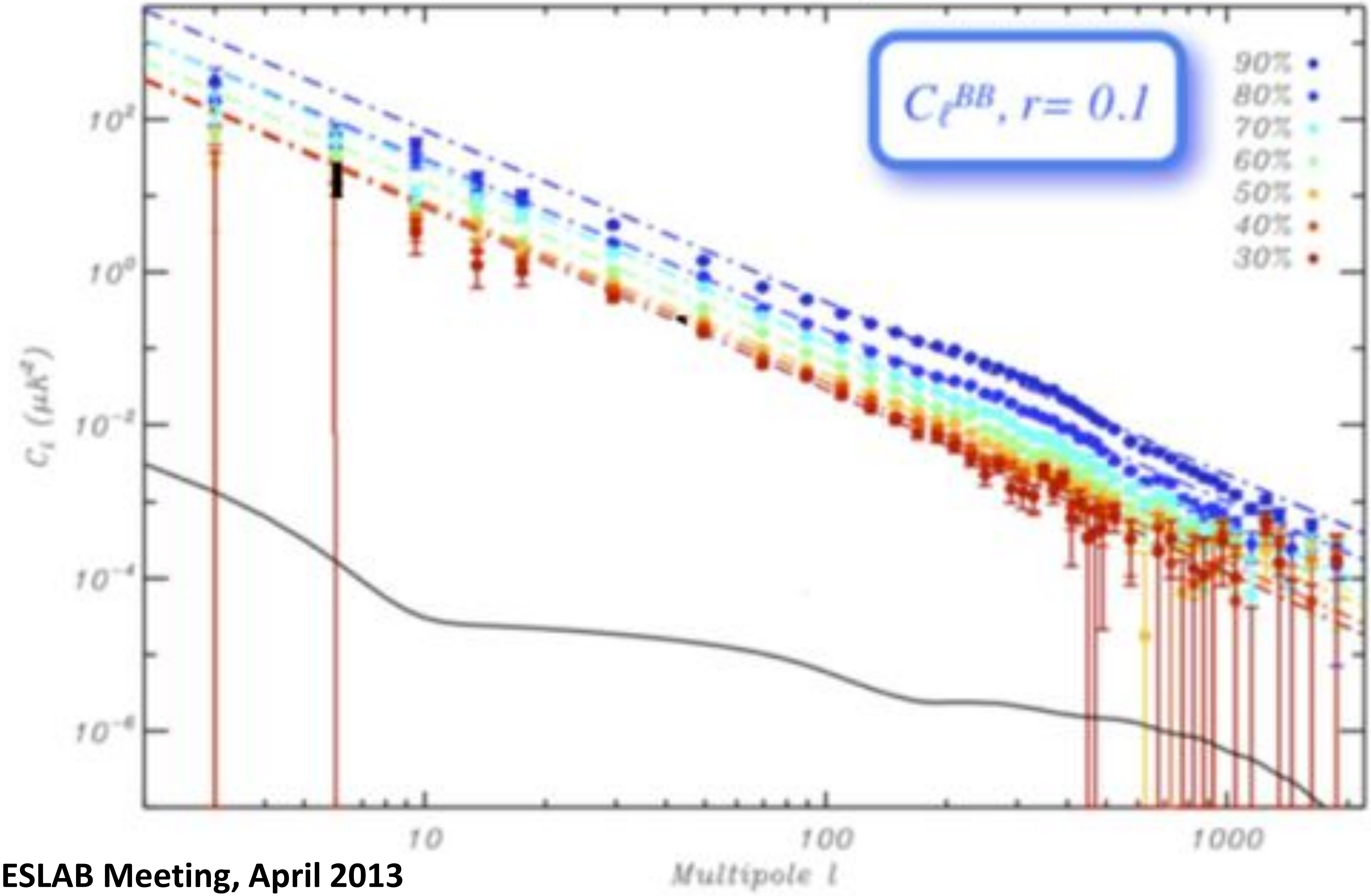
The signal detected by BICEP2 is due to lensing + foreground + instrumental noise

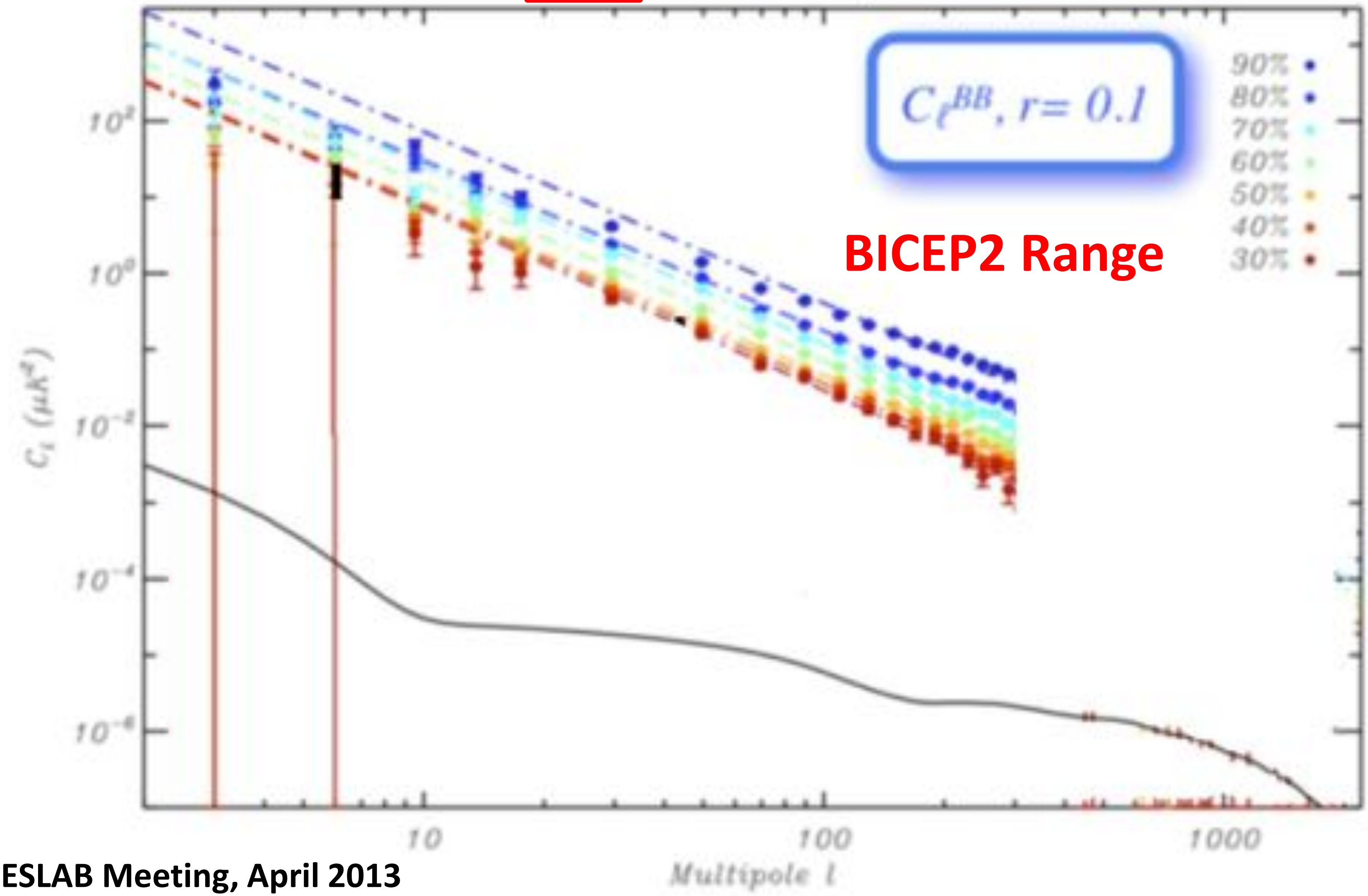

Dust
lens+r=0.2
BSS
LSA
FDS
PSM
DDM1
0.02
0.015
0.01
0.005
0
−0.005
$l(l+1)C_l^{BB}/2\pi$ [$\mu K^2$]
0
50
100
150
200
250
300
Multipole

# 353 GHz BB spectrum



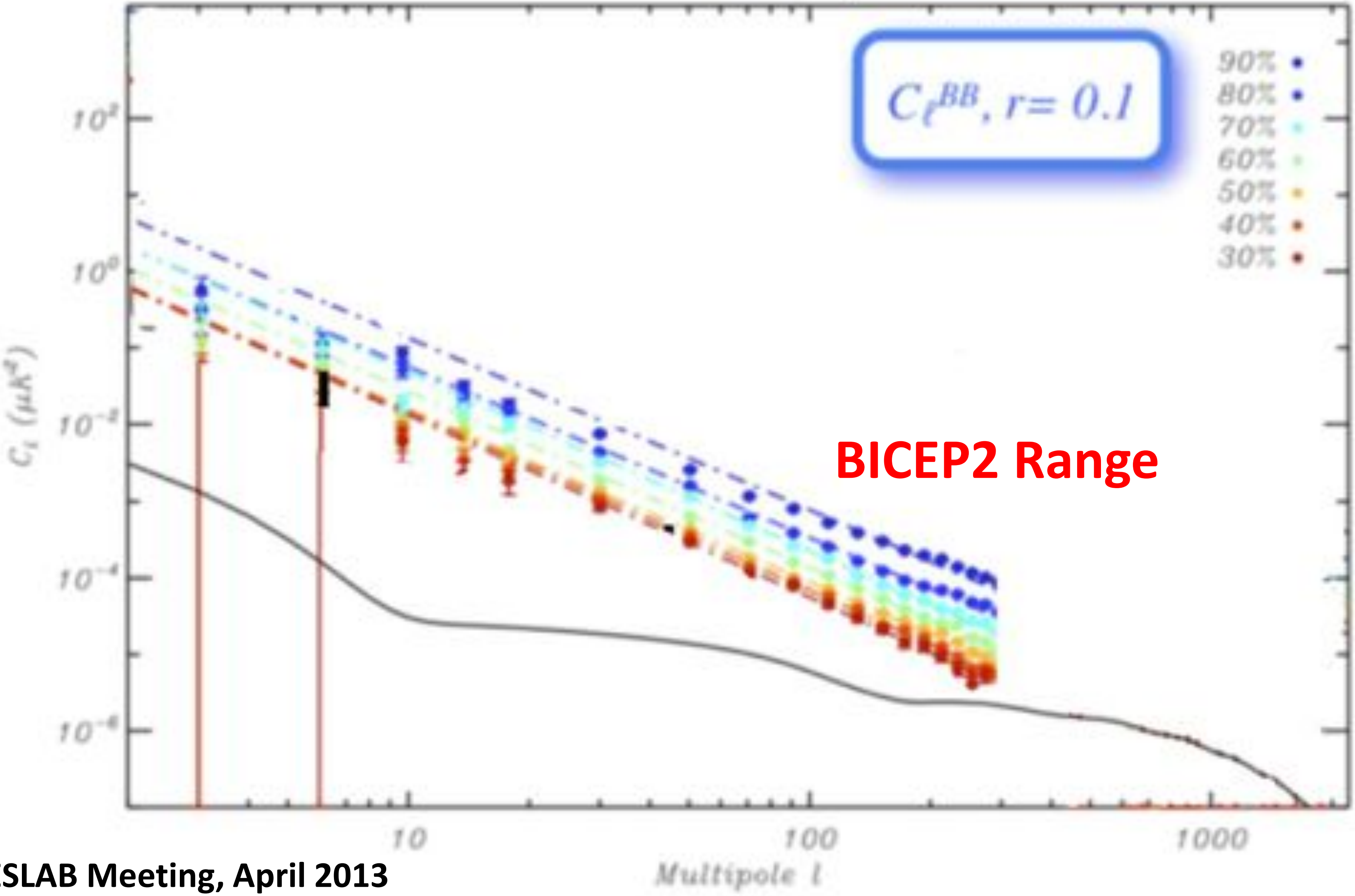

**ESLAB Meeting, April 2013**

# 353 GHz BB spectrum

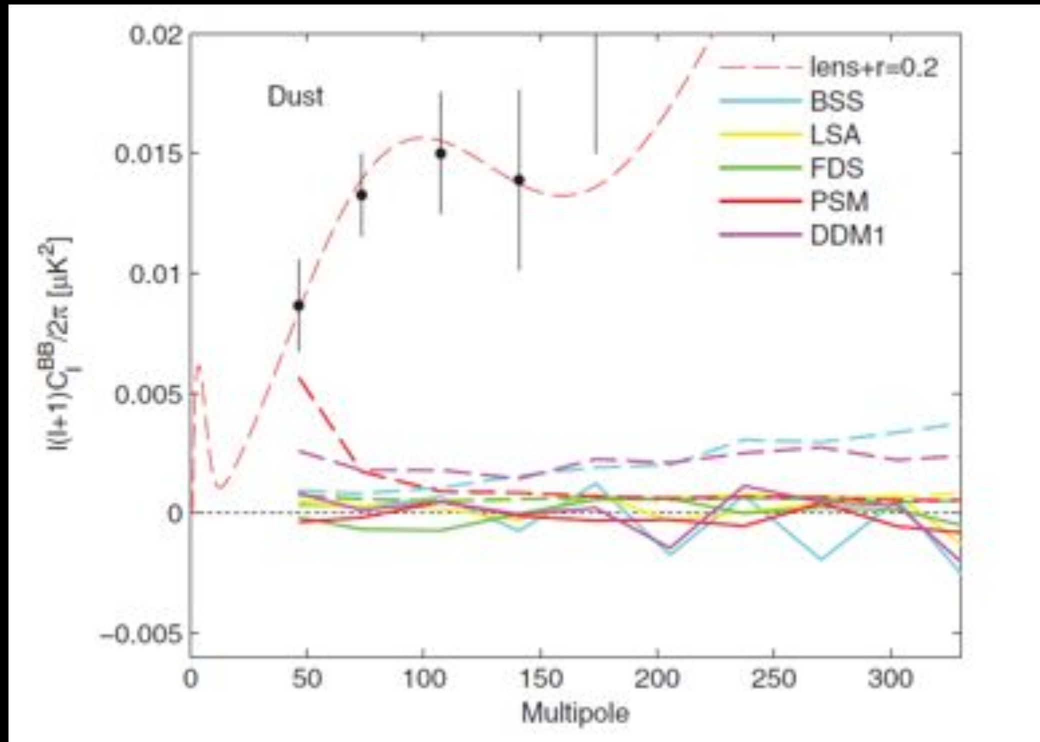


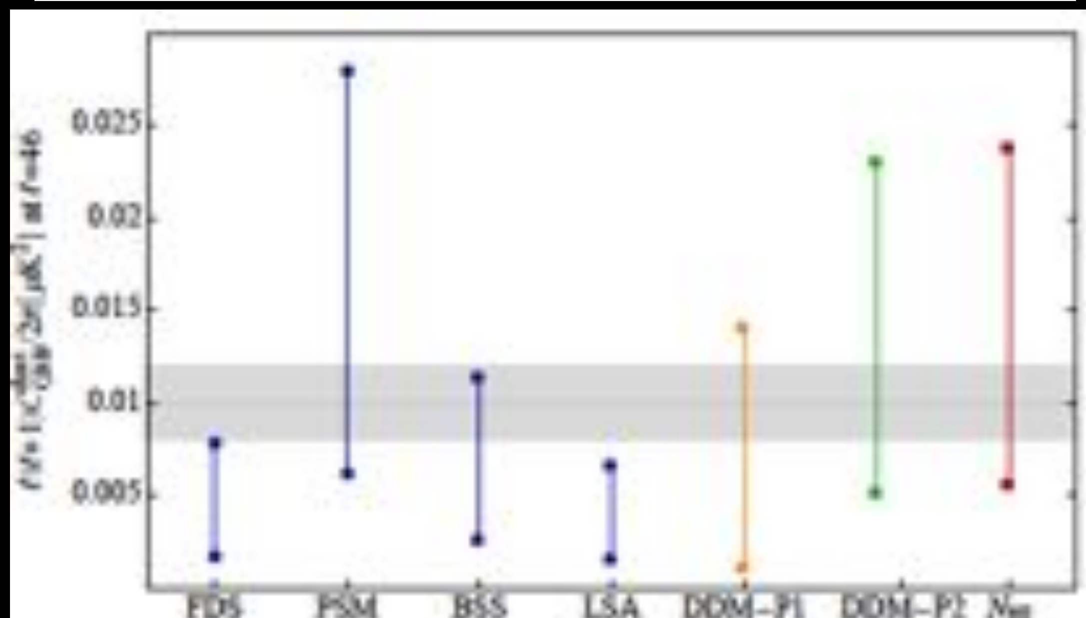

ESLAB Meeting, April 2013

# 143 GHz BB spectrum

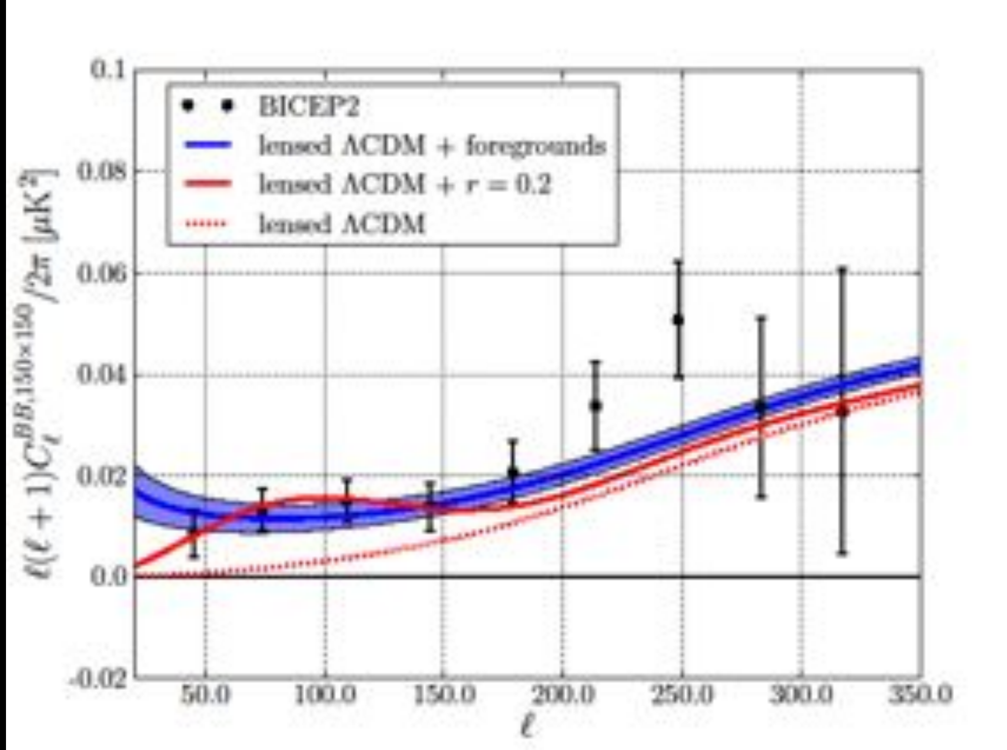


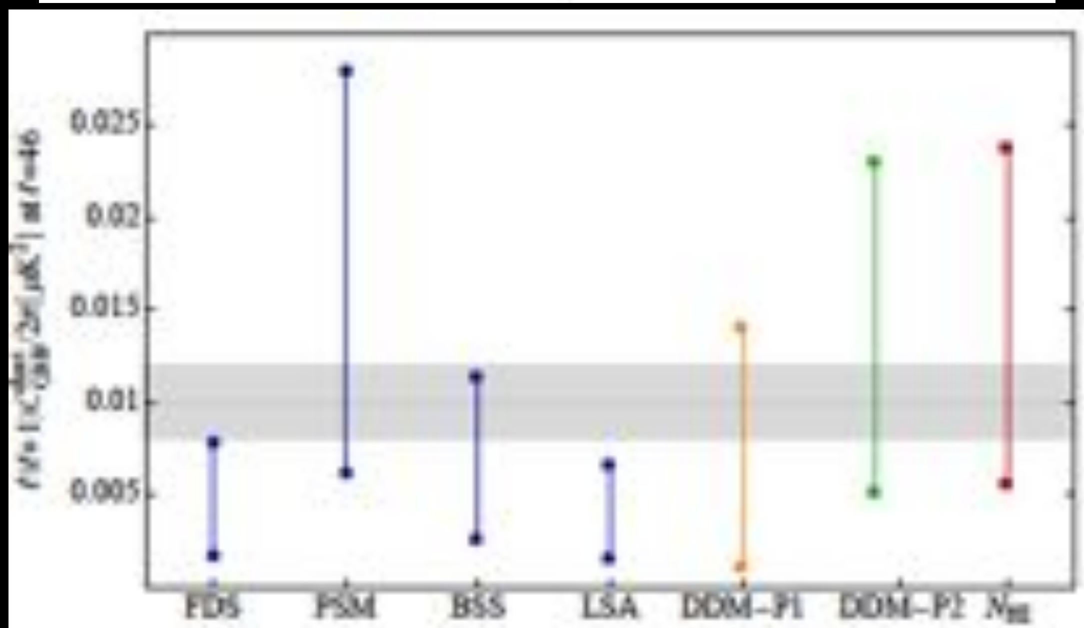

ESLAB Meeting, April 2013




**Flauger, Hill and Spergel, arXiv:1405.7351**

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Conclusion:

Based on the best available data at the time (and now), the null hypothesis could not be rejected

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Step 2. If null hypothesis is not rejected, do not proceed to step 3.

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Do not consider the ALTERNATIVE hypothesis (that the signal is due to gravitational waves)

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$r = 0.2^{+0.07}_{-0.05}$ ruling out r=0 at $7\sigma$ ??

# What has been learned from BICEP2?

The inflationary paradigm is so flexible
that *no test or combination of tests can disprove it*

*Note: It makes no difference if individual versions of a paradigm are testable.*

*If the paradigm includes a spectrum of versions that produce every conceivable outcome, then the paradigm is untestable.*

# Feynman (Cornell, 1964): The Scientific Method
(see also Feynman's lecture entitled "Cargo Cult Science")

*The vagueness of the inflationary paradigm is not disputed by proponents – rather, it is embraced*

## Harvard CMB Symposium (2014)

*Q*: Is inflation falsifiable?

*Alan Guth*: “I think that is kind of a silly question.

… I think inflation is too flexible of an idea for that to make sense.”

## *Andrei Linde, March 17 press release, Stanford U*

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*Andrei Linde, June 19 interview, New Scientist*

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# What has been learned from BICEP2?

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can disprove it

- *outcome sensitive to initial conditions*
- *outcome sensitive to parameters*
- *outcome varies across the multiverse*

# Must Rethink

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solve the initial conditions
& multiverse problems of inflation

find an alternative paradigm

# why consider a bounce?

**simple solution to flatness & homogeneity problems**

$$H^2 = \frac{8\pi G}{3}\frac{\rho_m^0}{a^3} + \frac{8\pi G}{3}\frac{\rho_r^0}{a^4} + \frac{\sigma^2}{a^6} + \ldots - \frac{k}{a^2}$$

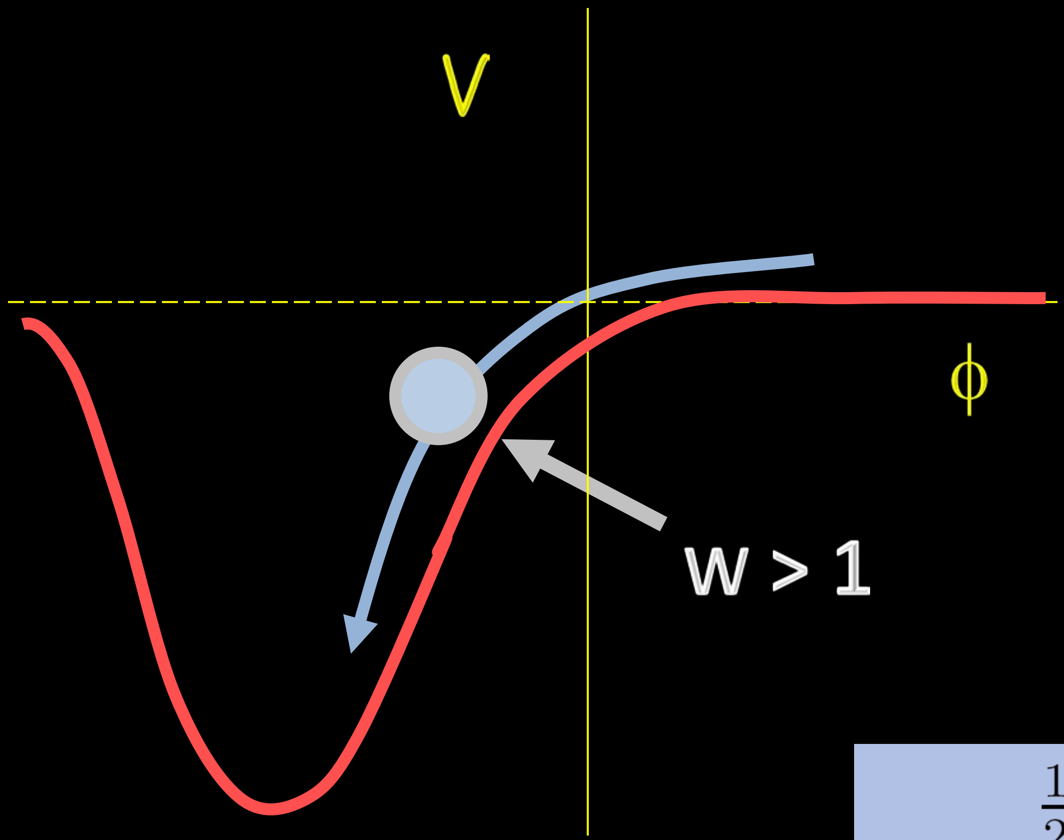
$$+ \frac{8\pi G}{3}\frac{\rho_\varphi^0}{a^{3(1+w)}}$$

$w = p/\rho \geq 1$

"EKPYROTIC"

ultra-high pressure, ultra-slow contraction

Khoury, Ovrut, PJS, Turok
Wesley, Erickson, PJS, Turok




$$w = \frac{\frac{1}{2}\dot{\phi}^2 - V(\phi)}{\frac{1}{2}\dot{\phi}^2 + V(\phi)}$$

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evades the multiverse/unpredictability problem

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cyclic

classically geodesically complete

current vacuum metastable or unstable

What happened at the bang?

⬇

What happened at the bounce?

Bars, Chen, PJS, Turok (2011); Bars, PJS, Turok (2012,2013, 2014)

# a proposal

Note that, near the bounce, the effective action simplifies:

$$S = \int d^4x \sqrt{-g}[\frac{1}{2\kappa^2} R(g) - \frac{1}{2}(\partial\sigma)^2 \text{ + radiation}]$$

. . . so can reformulate in Weyl-invariant form:

$$S = \int d^4x \sqrt{-g} \left[ \frac{(\partial\phi)^2 - (\partial s)^2}{2} + \frac{\phi^2 - s^2}{12} R \text{ + radiation} \right]$$

. . . now classical solutions for ϕ and s can be found that continue through the bounce, from big crunch to big bang, and cyclic cosmology can be made geodesically complete!

Bars, Chen, PJS, Turok (2011); Bars, PJS, Turok (2012,2013, 2014)

# *Weyl invariance can be extended* to all currently known physics

$$\mathcal{L}(x) = \begin{array}{c} \frac{1}{12}\left(\phi^2 - 2H^\dagger H\right) R(g) \\ +g^{\mu\nu}\left(\frac{1}{2}\partial_\mu\phi\partial_\nu\phi - D_\mu H^\dagger D_\nu H\right) \\ -\left(b\phi^4 + \frac{\lambda}{4}\left(H^\dagger H - \xi^2\phi^2\right)^2\right) \\ +L_{\text{SM}}\left(\begin{array}{c}\text{quarks, leptons , gauge bosons,} \\ \text{Yukawa couplings to } H\end{array}\right) \end{array}$$

$$g_{\mu\nu} \to \Omega^{-2} g_{\mu\nu},\ \phi \to \Omega\phi,\ H \to \Omega H,$$
$$\psi_{q,l} \to \Omega^{3/2}\psi_{q,l},\ A_\mu^{\gamma,W,Z,g} \to \Omega^0 A_\mu^{\gamma,W,Z,g}$$

$$H(x) = \left(\begin{array}{c} 0 \\ \frac{1}{\sqrt{2}}\left|s(x)\right| \end{array}\right)$$

can also add dark matter and r-handed ν's

Bars, PJS, Turok (to appear)

can reformulate string theory with a local scale symmetry in target space without any fundamental lengths such that the fundamental length in string theory

– the string tension –

emerges from gauge fixing a field.

What happened at the bang?

↕

What happened at the bounce?