QUIET II @ FNAL

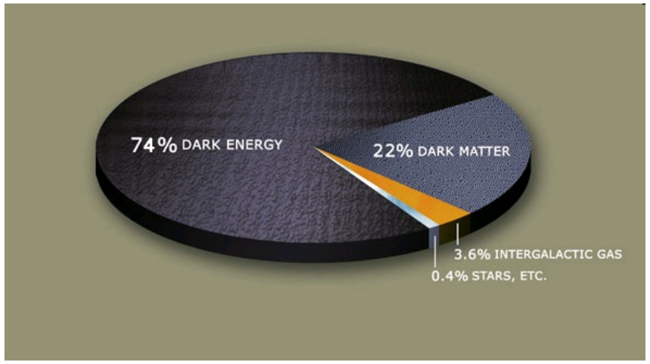
A Theoretical Perspective

Albert Stebbins
FNAL
August 11, 2009

Cosmology @ FNAL

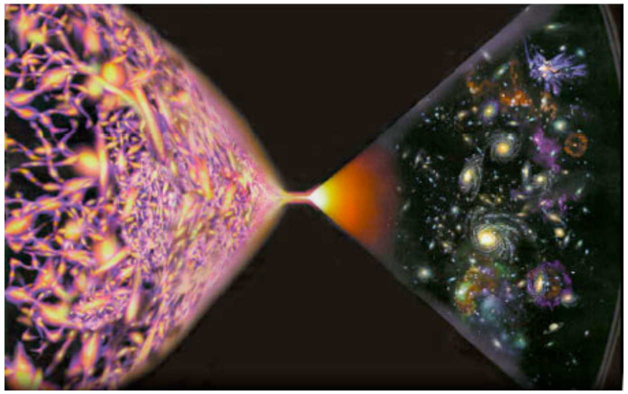
Fundamental Physics From Cosmology

Dark Sector



DM: SDSS/CDMS/COUPP/Indirect (theory)
DE: DES/CRT/JDEM

Early Universe / Inflation



Theory,
LSS: SDSS/DES/CRT/JDEM

Cosmology By Cartography

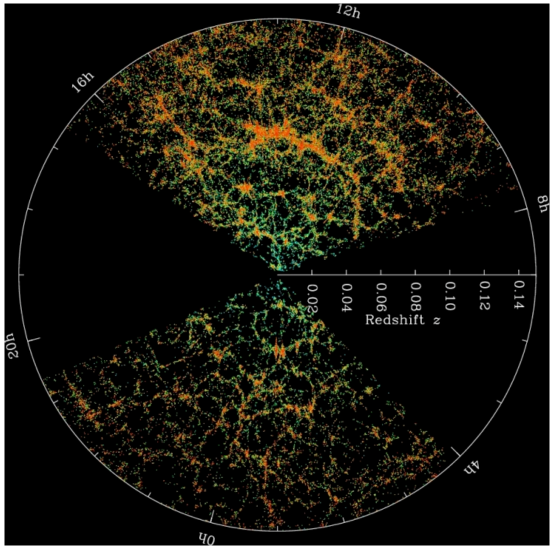
To study cosmology we need to study the things in the universe: e.g. galaxies, clouds, *etc.*

These things are generated as random noise!

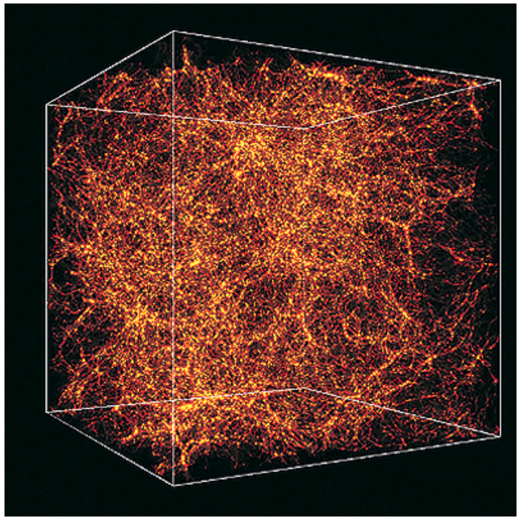
To characterize this random noise we need good statistics - *i.e.* large volumes, solid angle, *etc.*

Cosmology By Cartography

Large Scale Structure



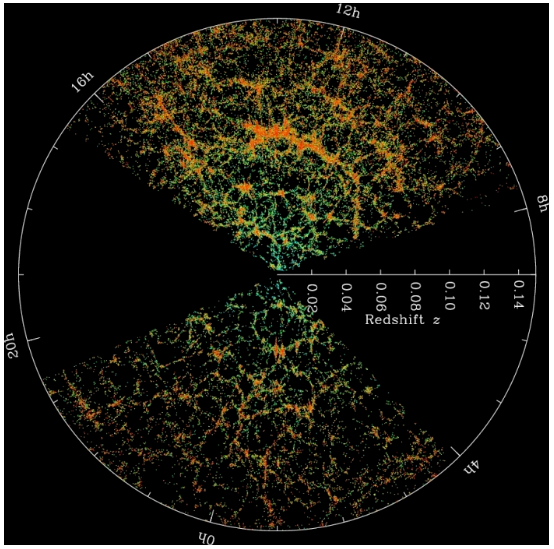
SDSS/DES/CRT/JDEM



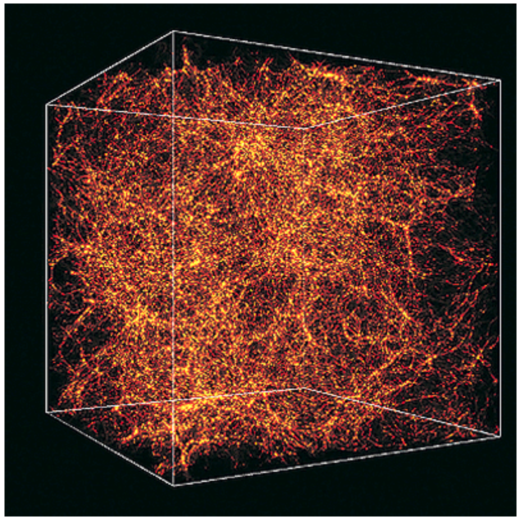
Cosmological Computing

Cosmology By Cartography

Large Scale Structure



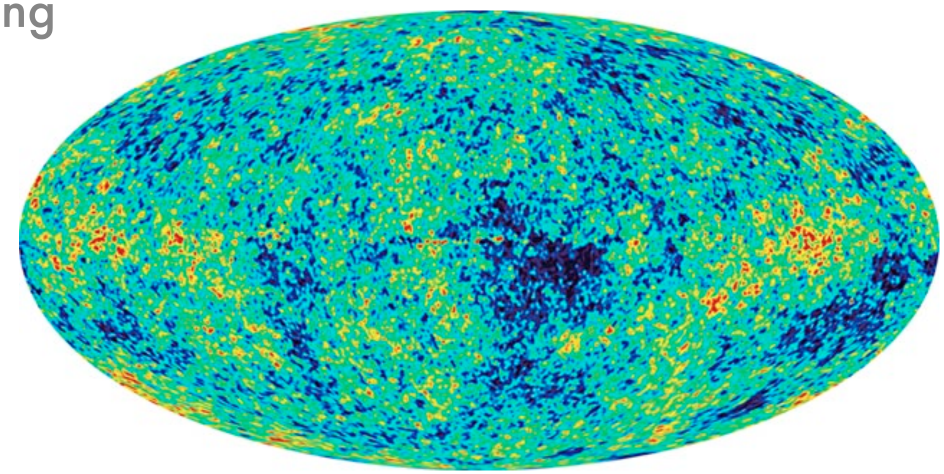
SDSS/DES/CRT/JDEM



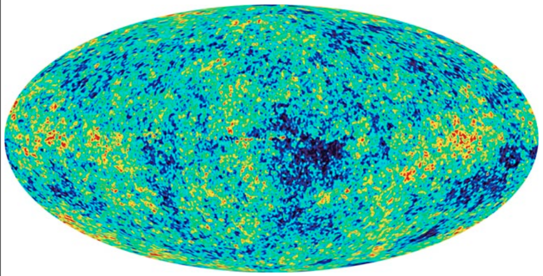
Cosmological Computing

CMBR

No FNAL involvement save theory!!



CMBR put the "precision" in Precision Cosmology



"LSS! We don't need no stinkin LSS!"

Parameter	*WMAP* 5 Year Mean[b]	*WMAP*+BAO+SN Mean
$100\Omega_b h^2$	2.273 ± 0.062	$2.267^{+0.058}_{-0.059}$
$\Omega_c h^2$	0.1099 ± 0.0062	0.1131 ± 0.0034
Ω_Λ	0.742 ± 0.030	0.726 ± 0.015
n_s	$0.963^{+0.014}_{-0.015}$	0.960 ± 0.013
τ	0.087 ± 0.017	0.084 ± 0.016
$\Delta^2_{\mathcal{R}}(k_0^{c})$	$(2.41 \pm 0.11) \times 10^{-9}$	$(2.445 \pm 0.096) \times 10^{-9}$
σ_8	0.796 ± 0.036	0.812 ± 0.026
H_0	$71.9^{+2.6}_{-2.7}$ km s^{-1} Mpc^{-1}	70.5 ± 1.3 km s^{-} Mpc^{-}
Ω_b	0.0441 ± 0.0030	0.0456 ± 0.0015
Ω_c	0.214 ± 0.027	0.228 ± 0.013
$\Omega_m h^2$	0.1326 ± 0.0063	$0.1358^{+0.0037}_{-0.0036}$
$z^{d}_{\rm reion}$	11.0 ± 1.4	10.9 ± 1.4
t_0^{e}	13.69 ± 0.13 Gyr	13.72 ± 0.12 Gyr

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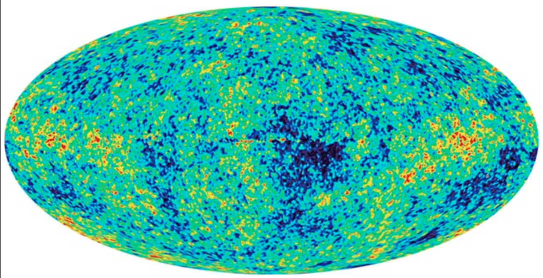

"LSS! We don't need no stinkin LSS!"

N.B. for some things you do, e.g. Dark Energy.

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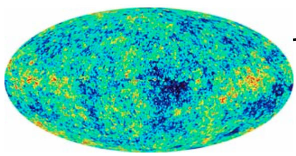
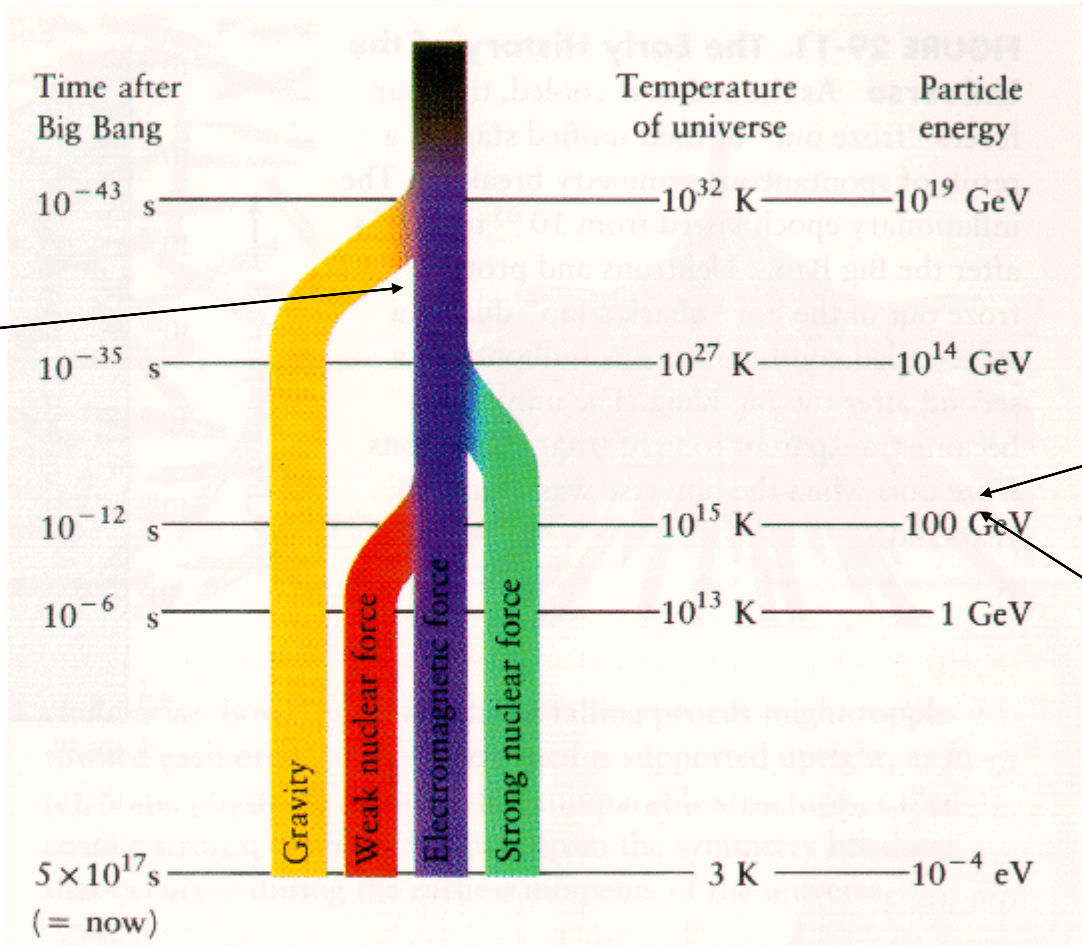
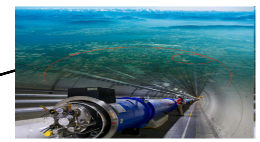
The Energy Frontier





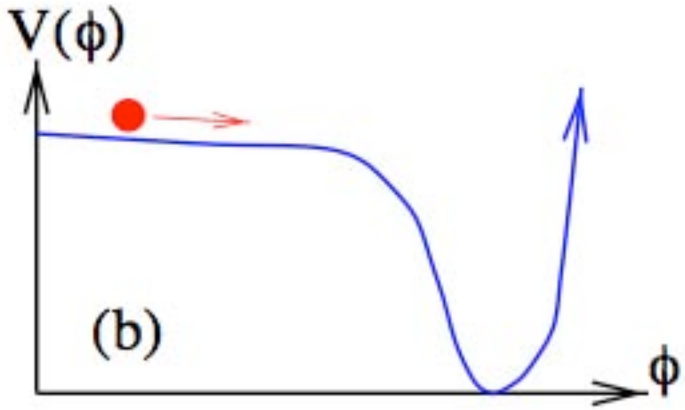
LHC



Tevatron

Inflation: E ~ M_{GUT}, M_{Planck}

Scalar Field Dynamics

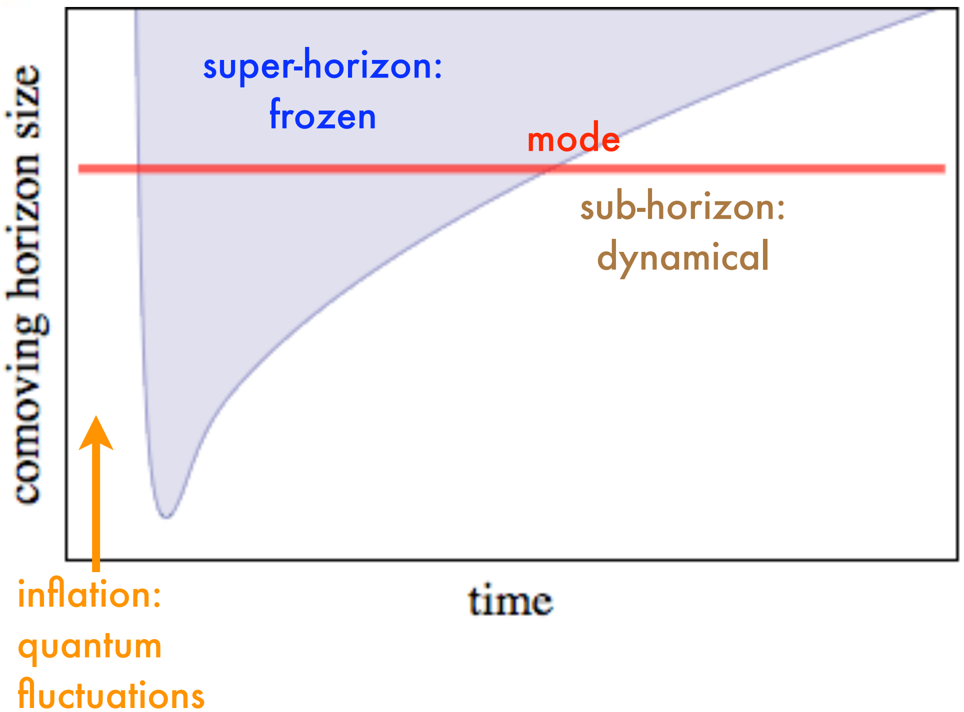


Dynamics:

ϕ inflaton field

h_t - grav. radiation

… any other dynamical field



Amplifier of Quantum Noise

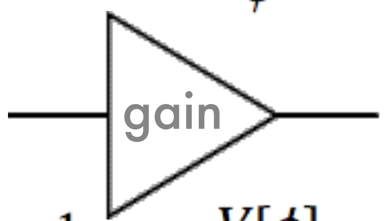
tensor modes / gravitational waves

$$\delta h_t \sim \frac{T_{\text{Hawking}}}{M_{\text{Planck}}} \sim \frac{H}{M_{\text{Planck}}} \sim \frac{\sqrt{V[\phi]}}{{M_{\text{Planck}}}^2}$$

scalar inflaton field → (scalar) gravitational potential

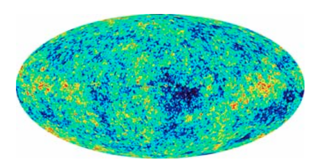
$$M_{\text{Planck}} \frac{H}{\dot\phi}$$

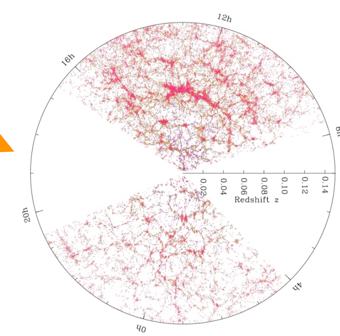
$$\frac{\delta\phi}{M_{\text{Planck}}} \sim \frac{T_{\text{Hawking}}}{M_{\text{Planck}}} \sim \frac{H}{M_{\text{Planck}}} \sim \frac{\sqrt{V[\phi]}}{{M_{\text{Planck}}}^2}$$



δh_s

$$\frac{1}{M_{\text{Planck}}} \frac{V[\phi]}{V'[\phi]}$$





10^{-5}

The Energy Frontier

CMBR / Large Scale Structure already tell us

$$E \sim \sqrt[4]{V[\phi]} = \frac{10^{-2.5} M_{\text{Planck}}}{\sqrt{\text{gain}}} \sim 10 \frac{M_{\text{GUT}}}{\sqrt{\text{gain}}}$$

The Energy Frontier

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We are <u>already</u> measuring physics at very large energy scales!

The Energy Frontier

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We are <u>already</u> measuring physics at very large energy scales!

If we could detect the gravity waves we could nail down the energy scales.

The Energy Frontier

CMBR / Large Scale Structure already tell us

$$E \sim \sqrt[4]{V[\phi]} = \frac{10^{-2.5} M_{\rm Planck}}{\sqrt{\rm gain}} \sim 10\, \frac{M_{\rm GUT}}{\sqrt{\rm gain}}$$

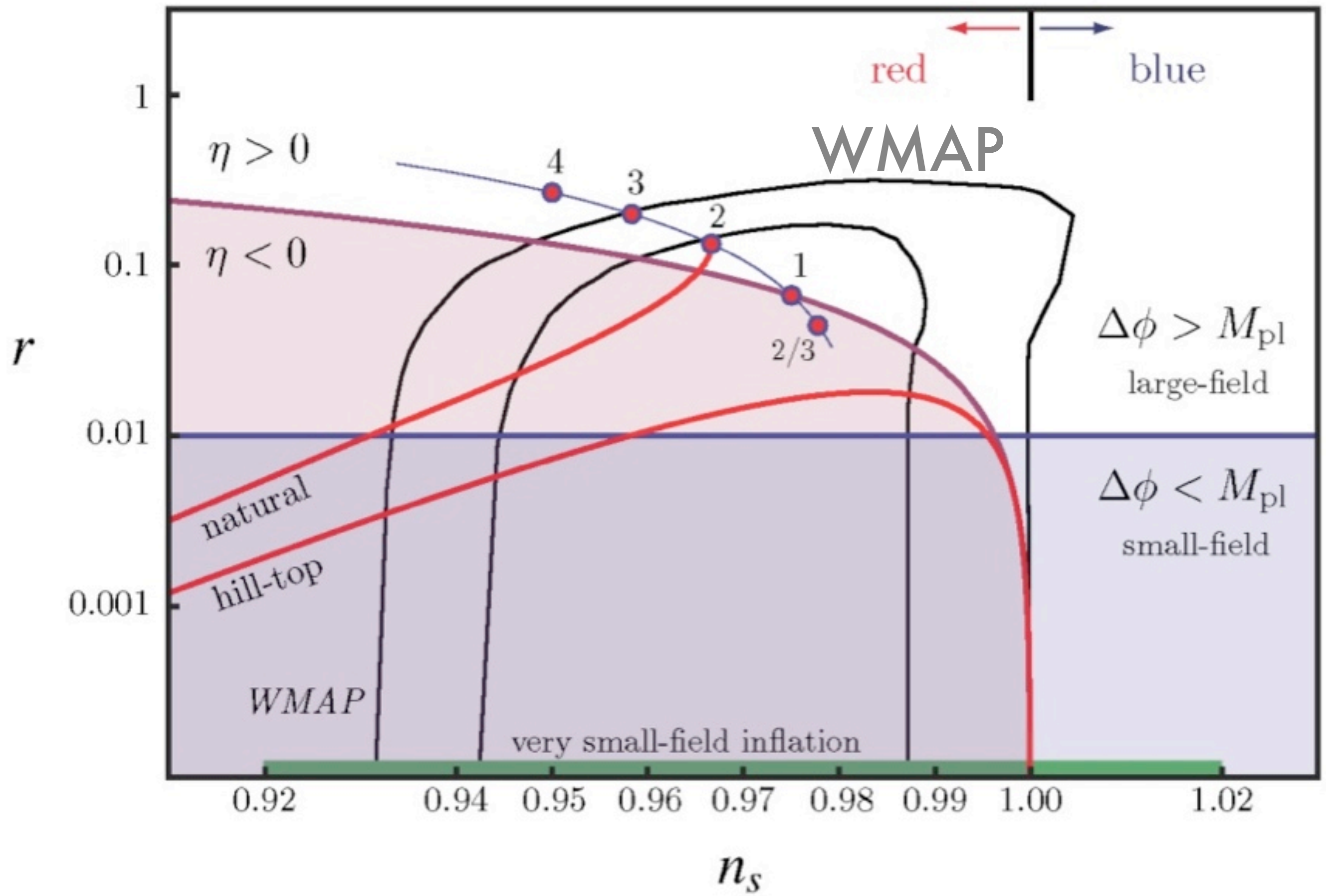
We are already measuring physics at very large energy scales!

If we could detect the gravity waves we could nail down the energy scales.

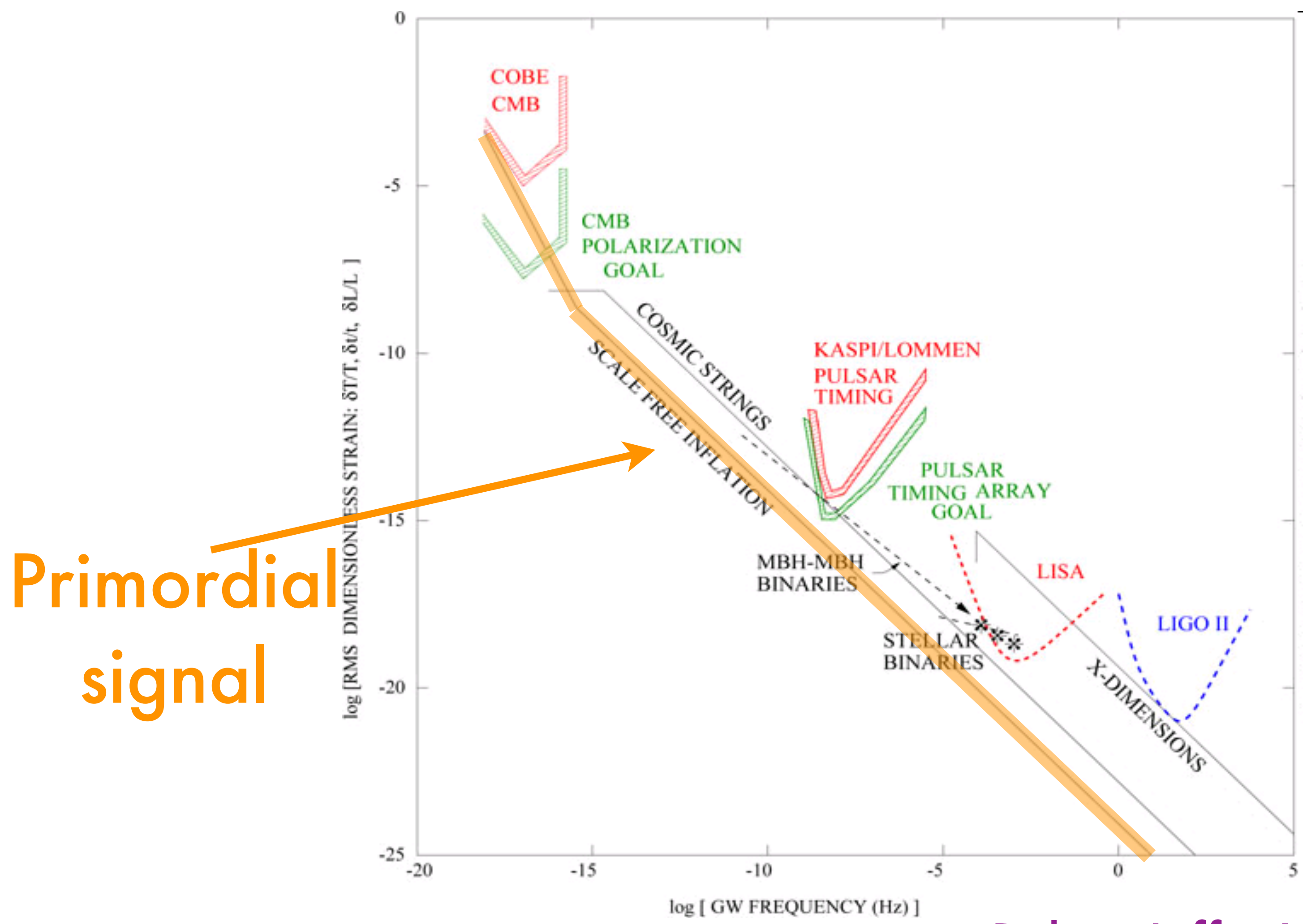
This clearly fits into FNALs mission of fundamental physics at very high energies!

Tensor / Scalar Ratio

$$r \sim \left(\frac{\delta h_t}{\delta h_s}\right)^2 \sim \frac{1}{\text{gain}}$$

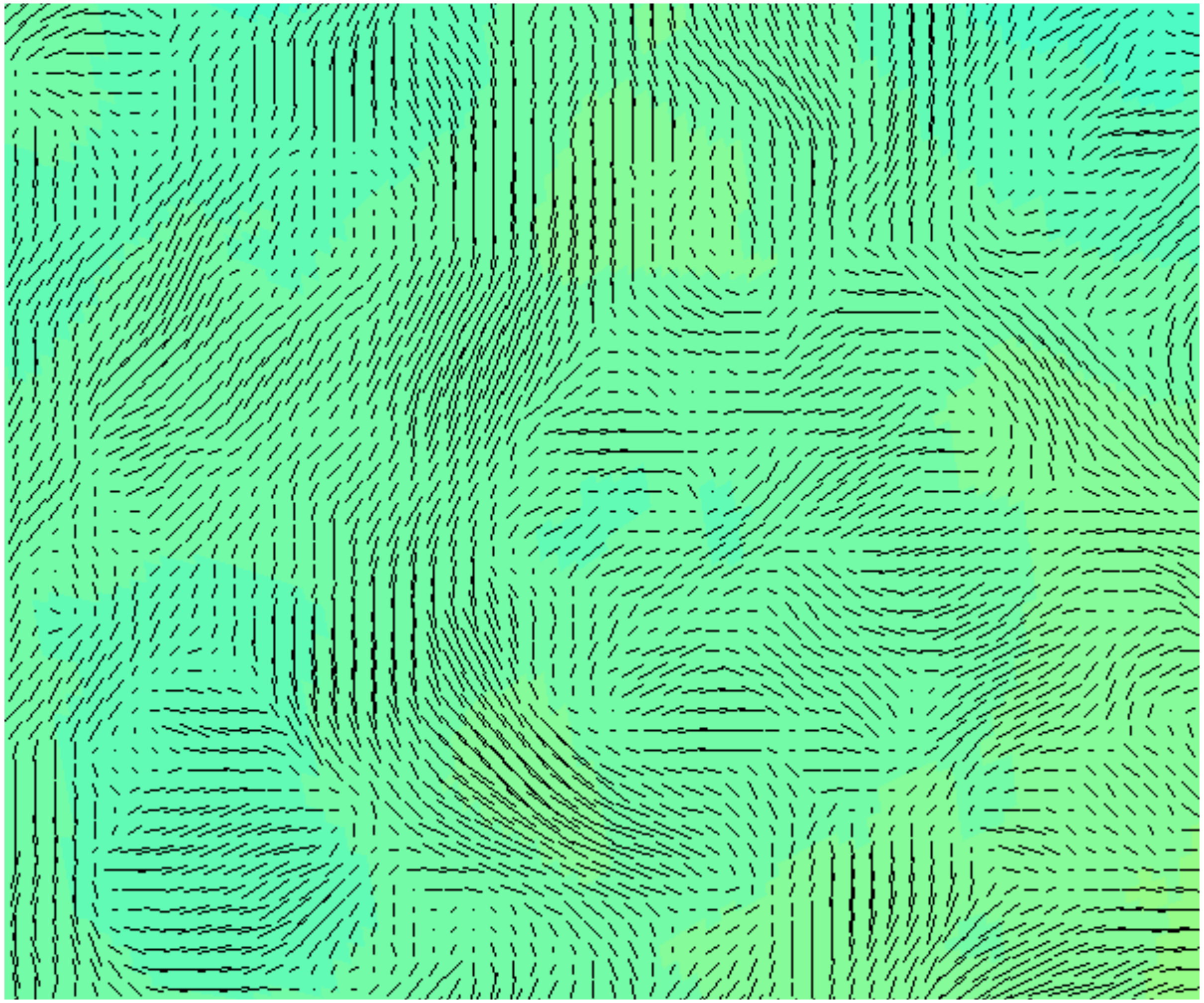


How To Detect Tensor Modes? (gravitational radiation)



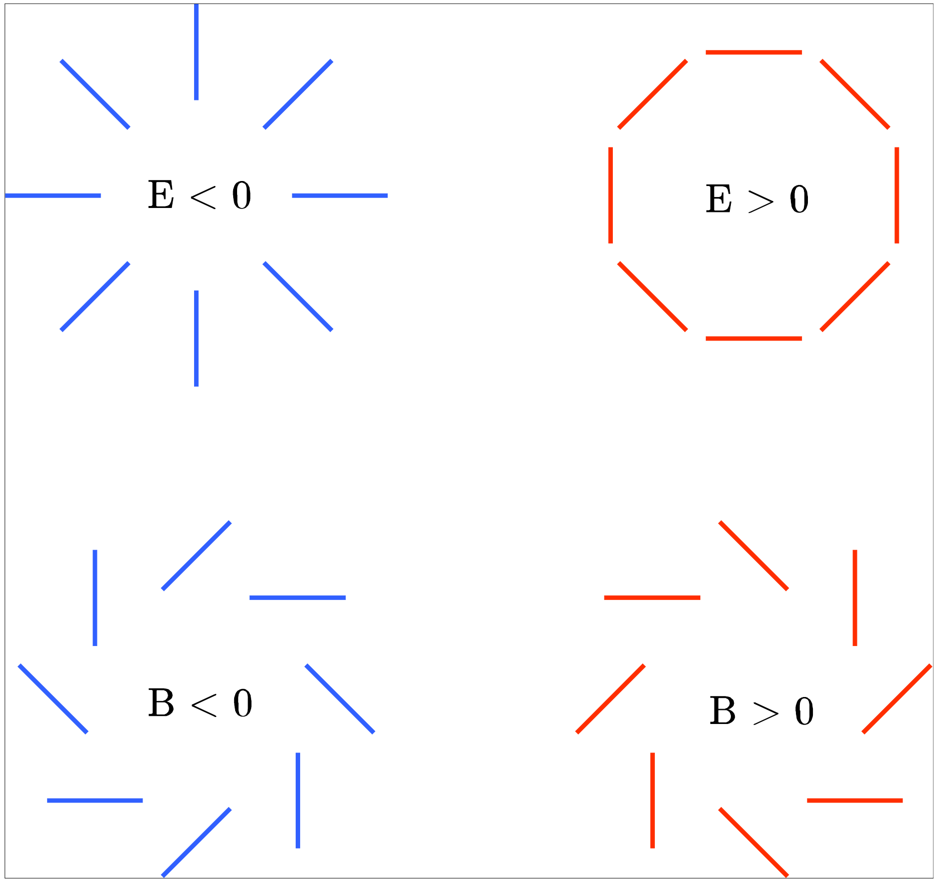
Baker, Jaffe, Lommen 2003

E & B Polarization



E & B Polarization

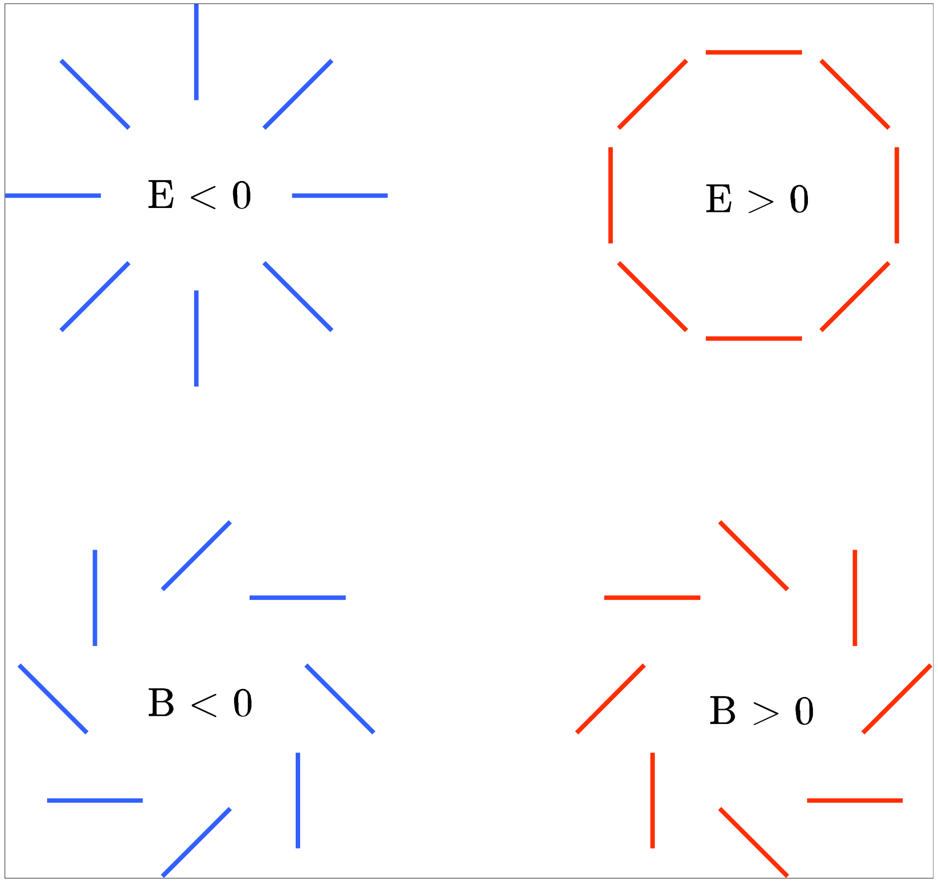
E / B decomposition developed at FNAL in 1996.



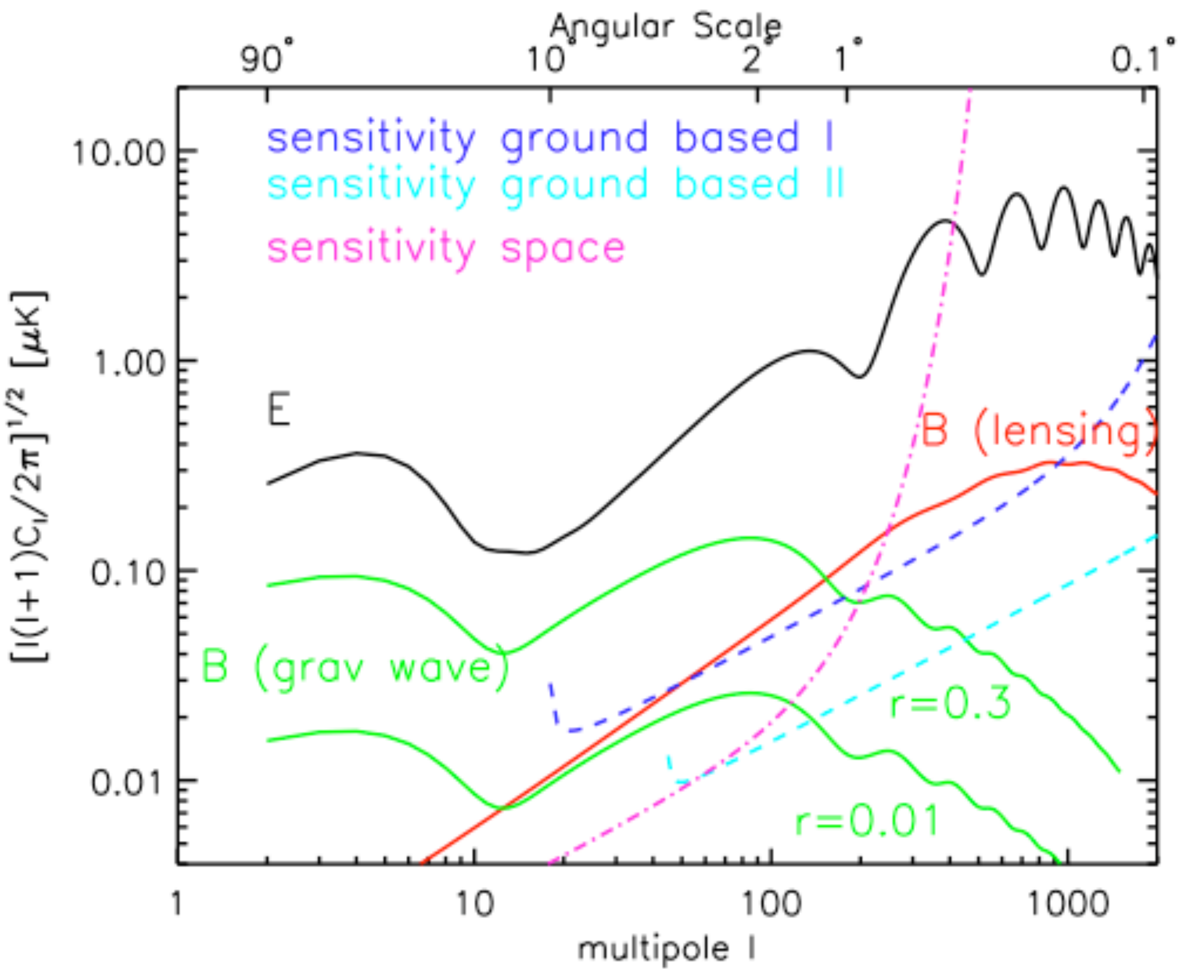
E & B Polarization

E / B decomposition developed at FNAL in 1996.

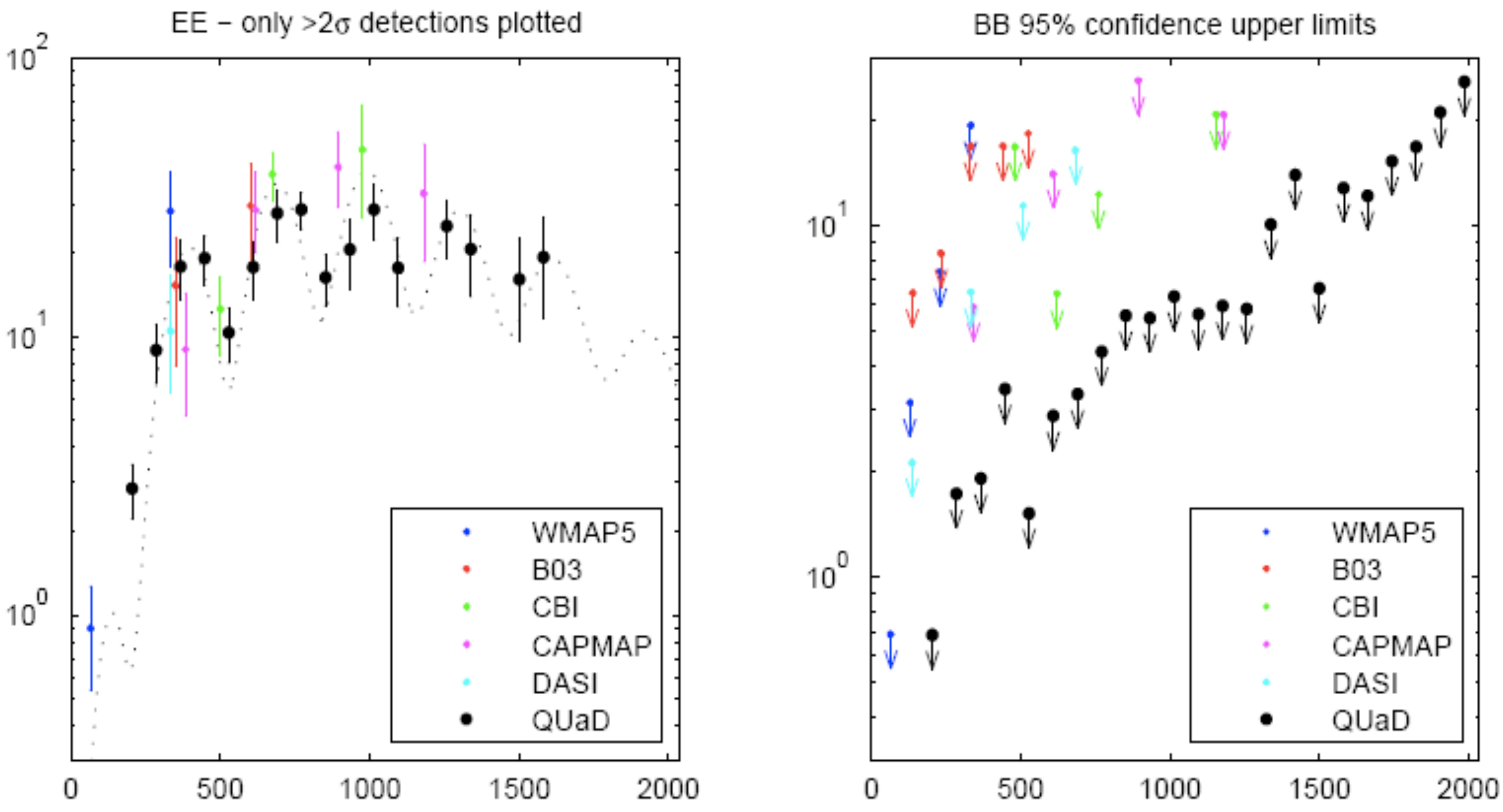
Because scalar modes have no parity they cannot (to linear order in δh) produce B-modes. B-modes make excellent probe for gravity waves on large scales.



Angular Spectrum of CMBR Polarization



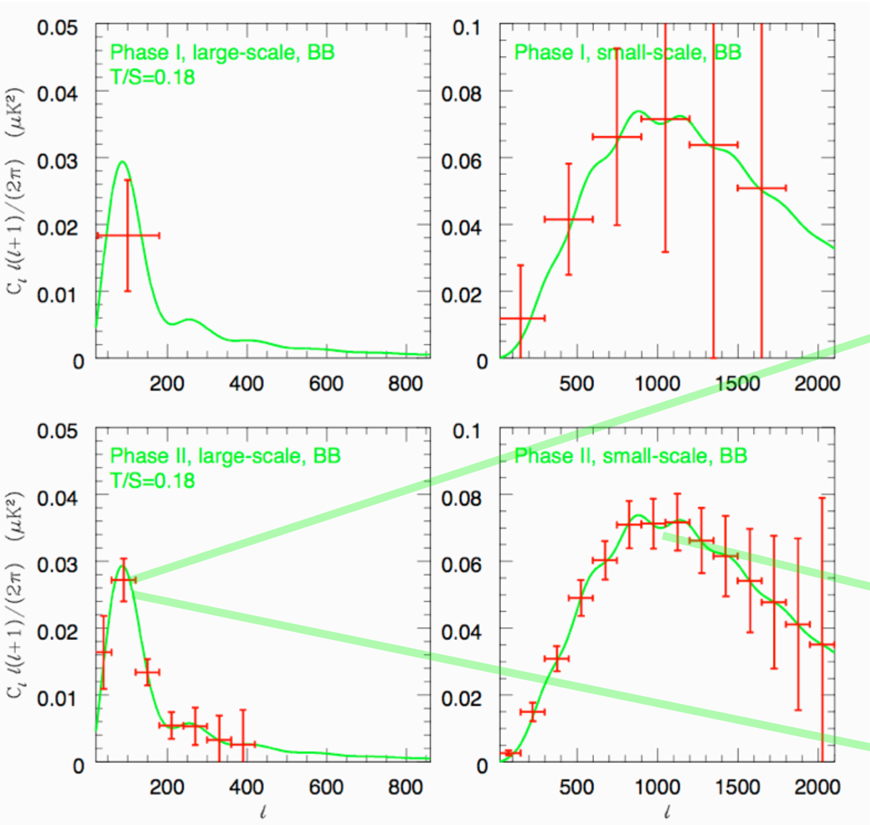
CMBR Polarization Status

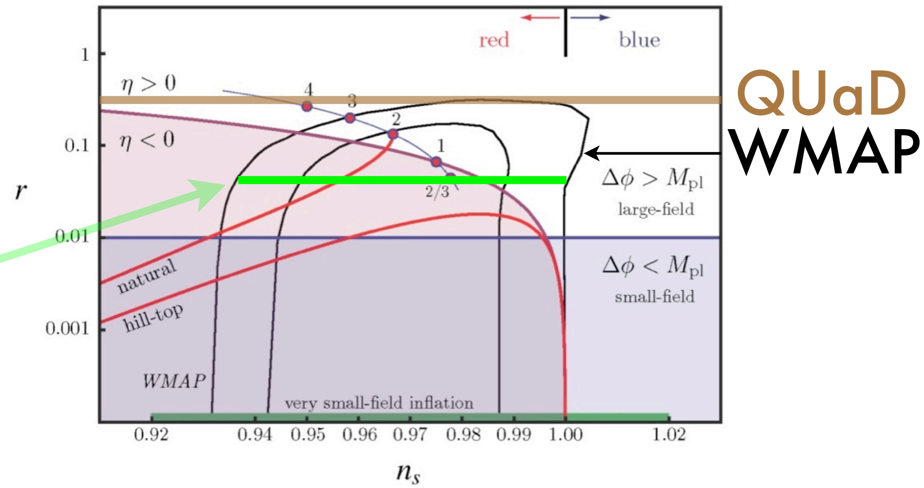


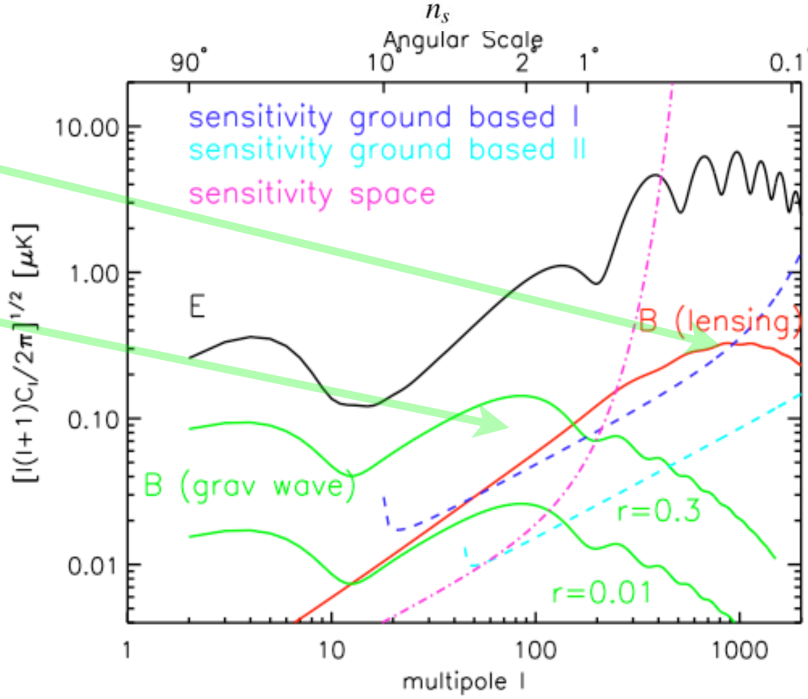
QUAD: Pryke et al. 2008

QUaD: r<0.33 Brown et. al 2009

How Does QUIET-II fit in?







Excellent chance of GW detection at design sensitivity!

Role of Astro-Theory Group

- Science analysis
  - Dodelson / Stebbins / postdocs
- Dodelson has experience w CMBR data
- We are currently studying cosmic shear
  - this is mathematically the same as polarization.

Summary

- QUIET-II clearly fits within FNAL mission.
- QUIET-II has good chance of detecting primordial gravity waves.
- FNAL team will play leading role in science analysis.

Foregrounds