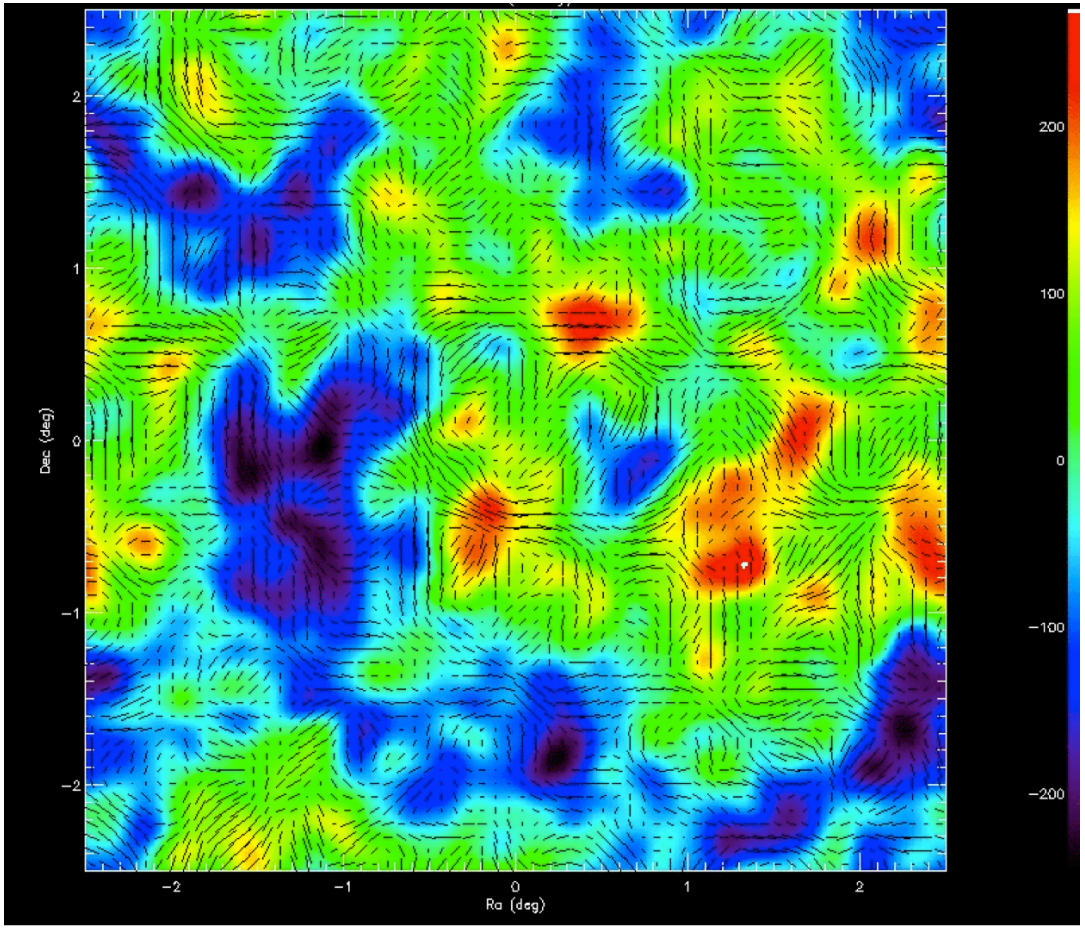
PhysPAG-Fest, August 2012
Report from the
Inflation Probe SAG

Shaul Hanany
University of Minnesota

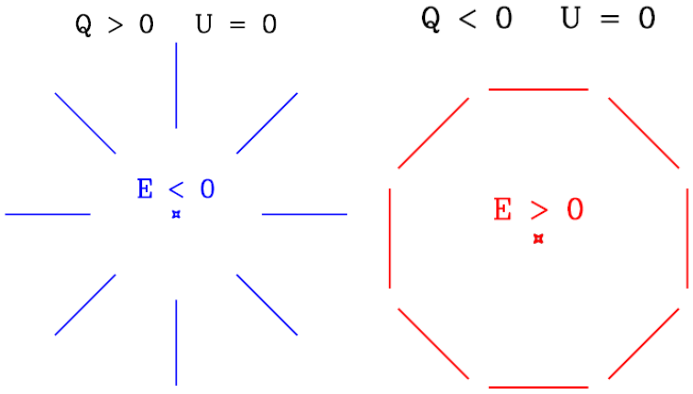
CMB Polarization: E and B Modes

Simulated Map of Temperature Anisotropy and Polarization

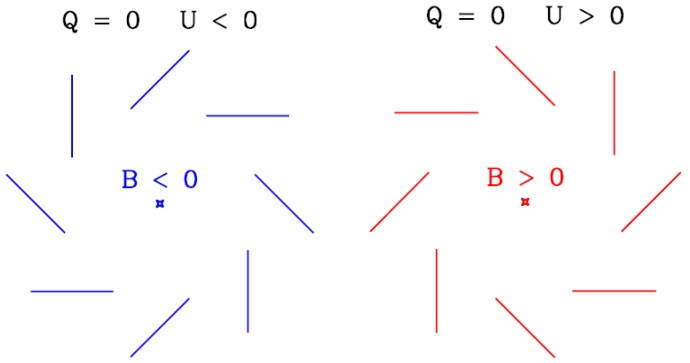


Bars indicate polarized intensity and orientation

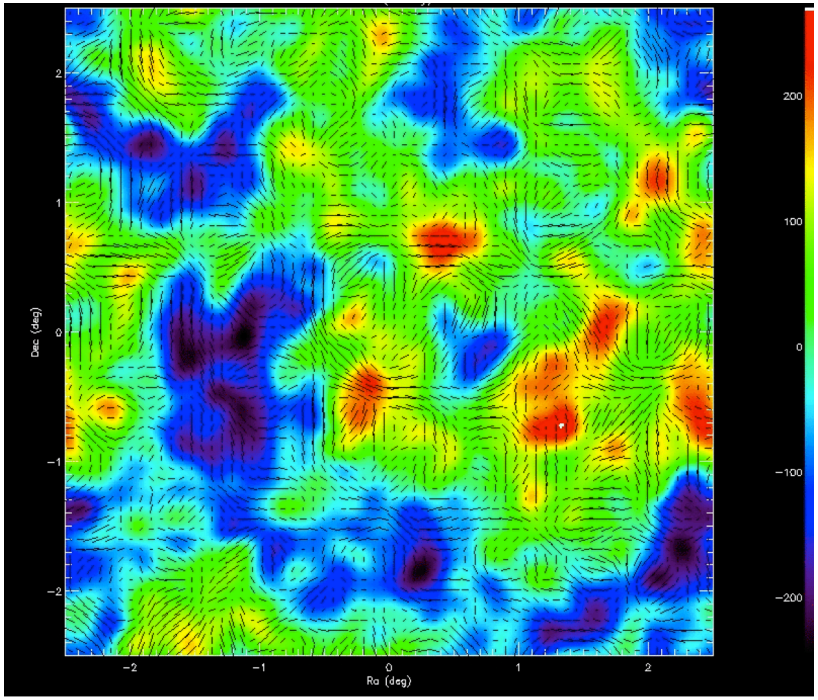
Curl Free E-Mode

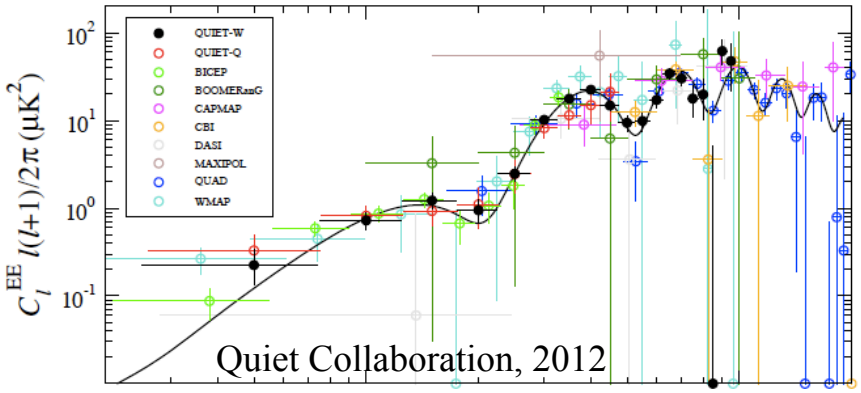


Divergence Free B mode



E Modes

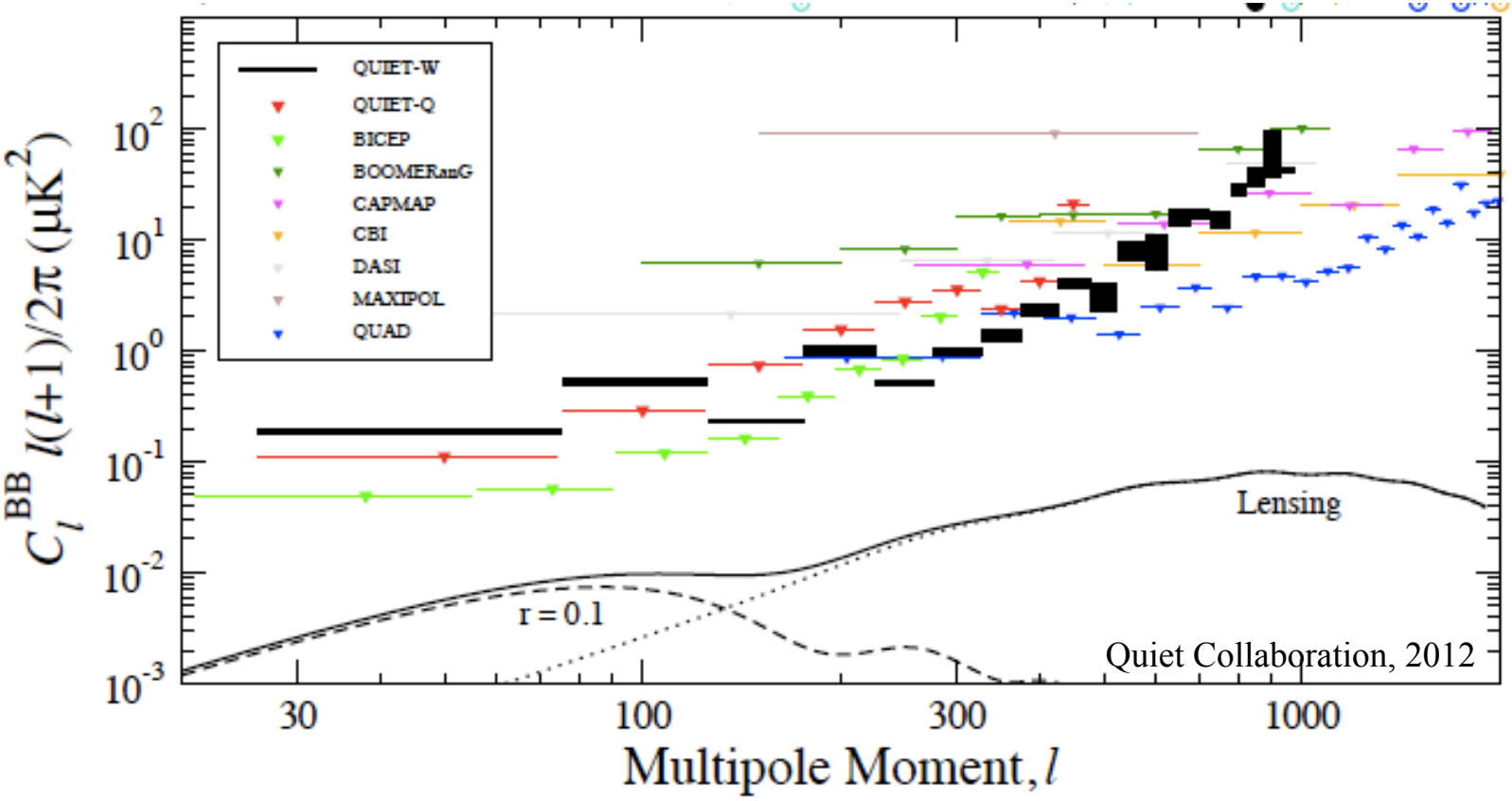




- Density perturbations in the early Universe produce only E mode polarization
- Given temperature data, the E mode level and shape can be calculated, and has been detected where expected

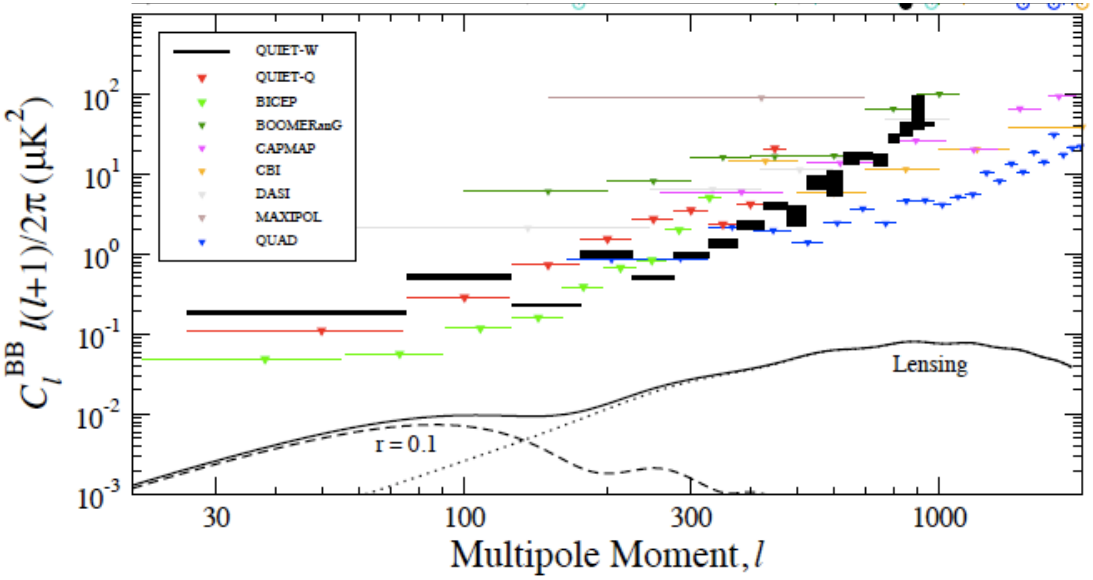
B Modes

- ***Gravity waves*** produce both E, and B polarization patterns
- Only gravity waves produce B-mode
- B modes: gravity waves from Inflation, from lensing by LSS



Significance of B Modes

- Low \ell detection of B-polarization is a direct signature of Inflation
- It constrains Big Bang physics
- It probes fundamental physics at GUT energy scales
- Simplest Inflation models predict a **detectable level** of r>=0.01

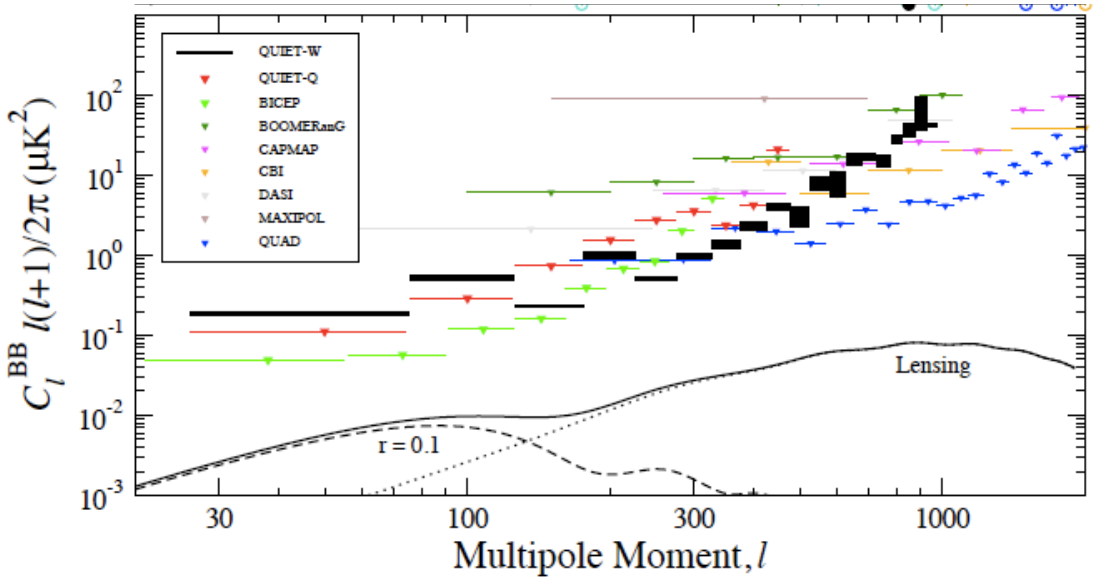


Significance of B Modes

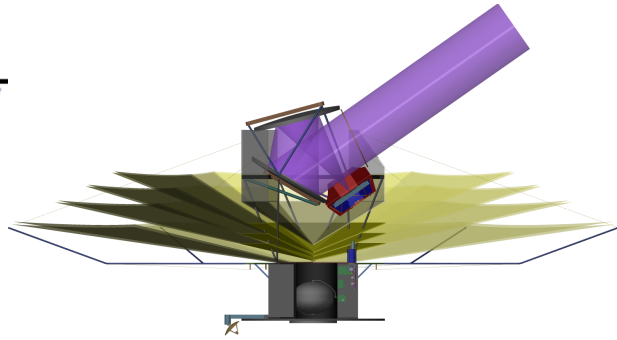
- Low \ell detection of B-polarization is direct signature of Inflation
- It constrains Big Bang physics
- It probes fundamental physics at GUT energy scales
- Simplest Inflation models predict a **detectable level** of r>=0.01

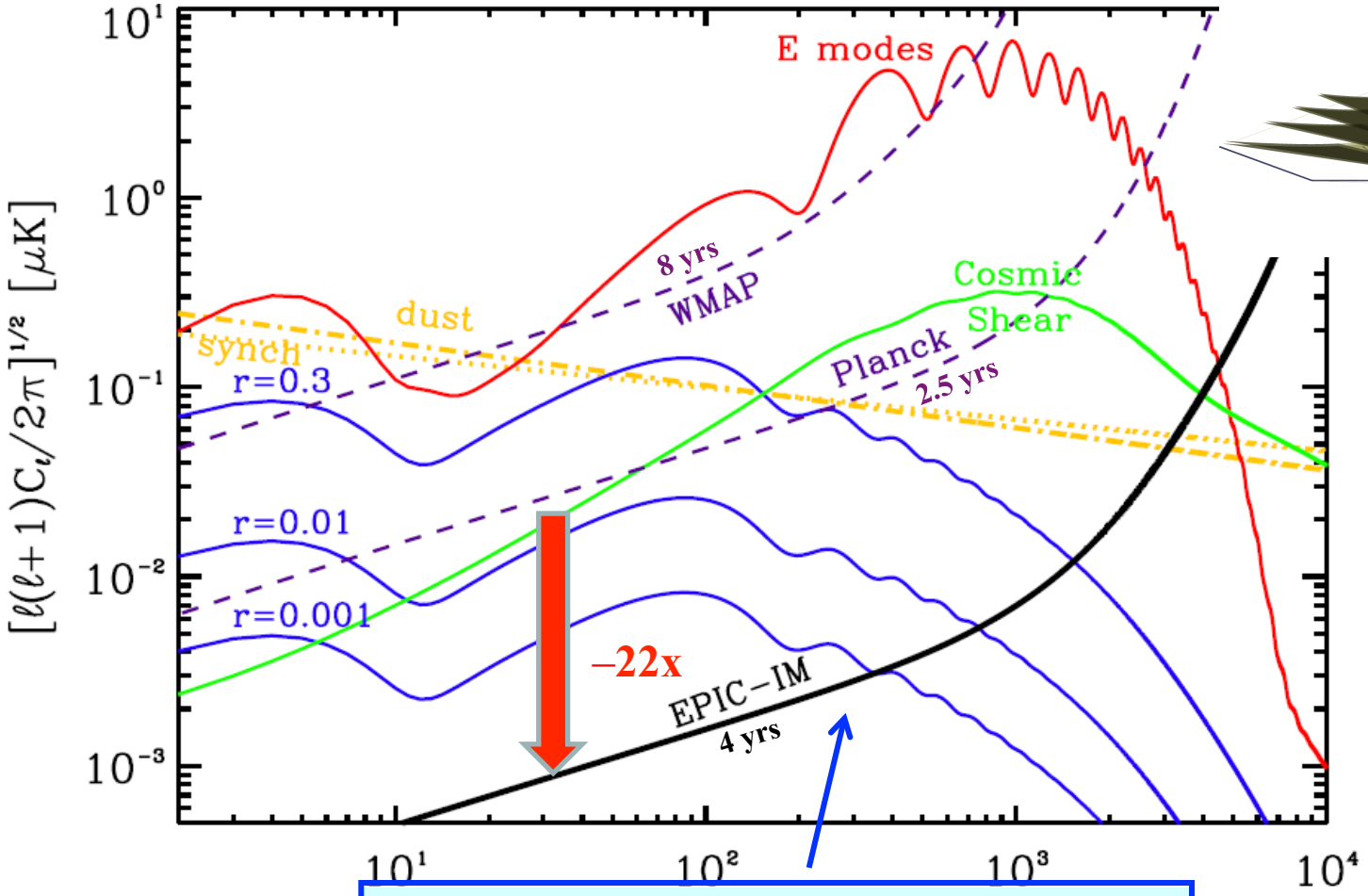
"The convincing detection of B-mode polarization in the CMB polarization … would represent a watershed discovery."

(from New Worlds, New Horizons)



Capabilities of Probe Class EPIC-IM Mission

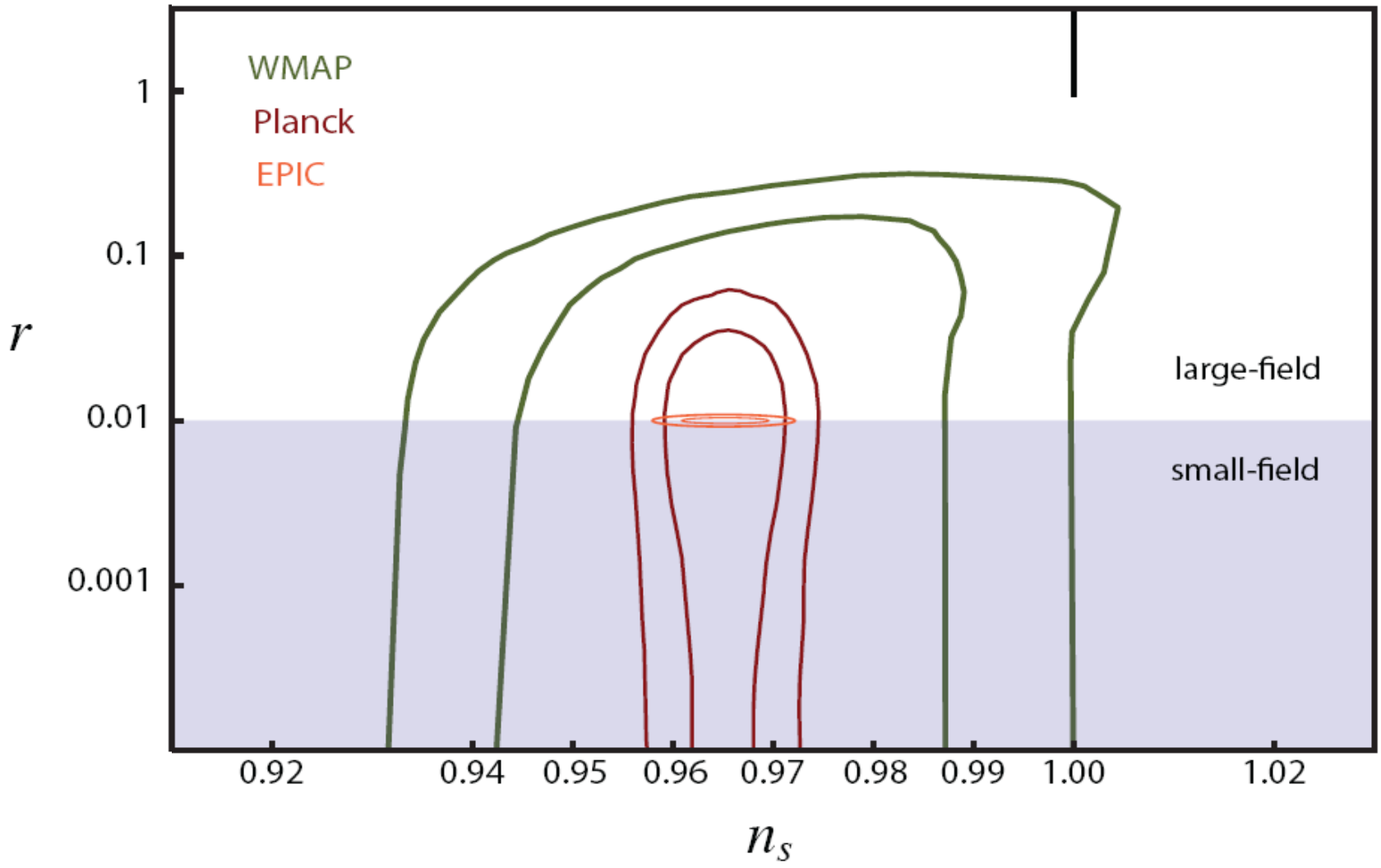




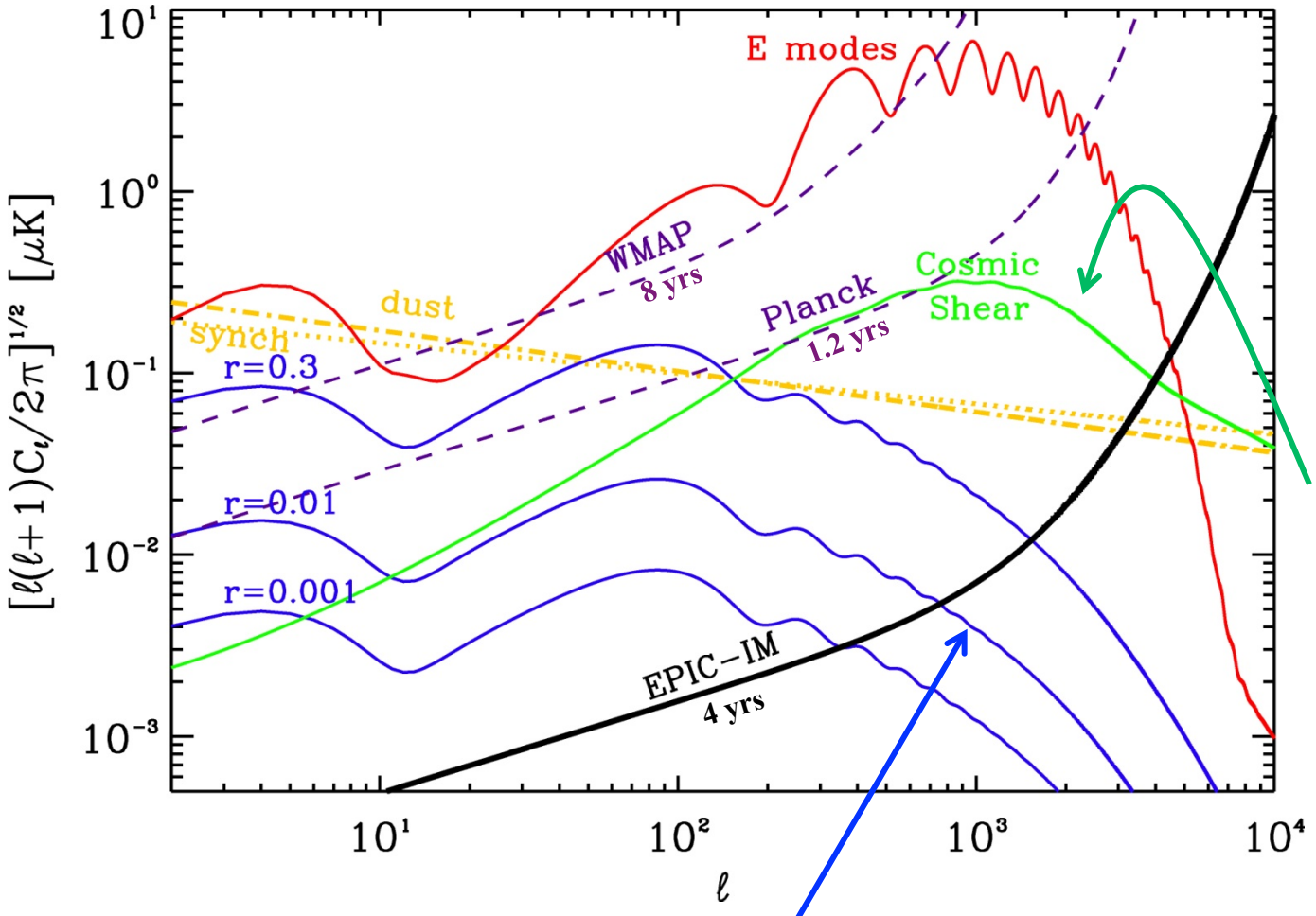
Measure Inflationary B-mode spectrum at r = 0.01 to astrophysical limits

- **GUT energy scale**
- **Large field inflation**

Confirm or Reject Large Field Inflation



Richness of the CMB Polarization Landscape



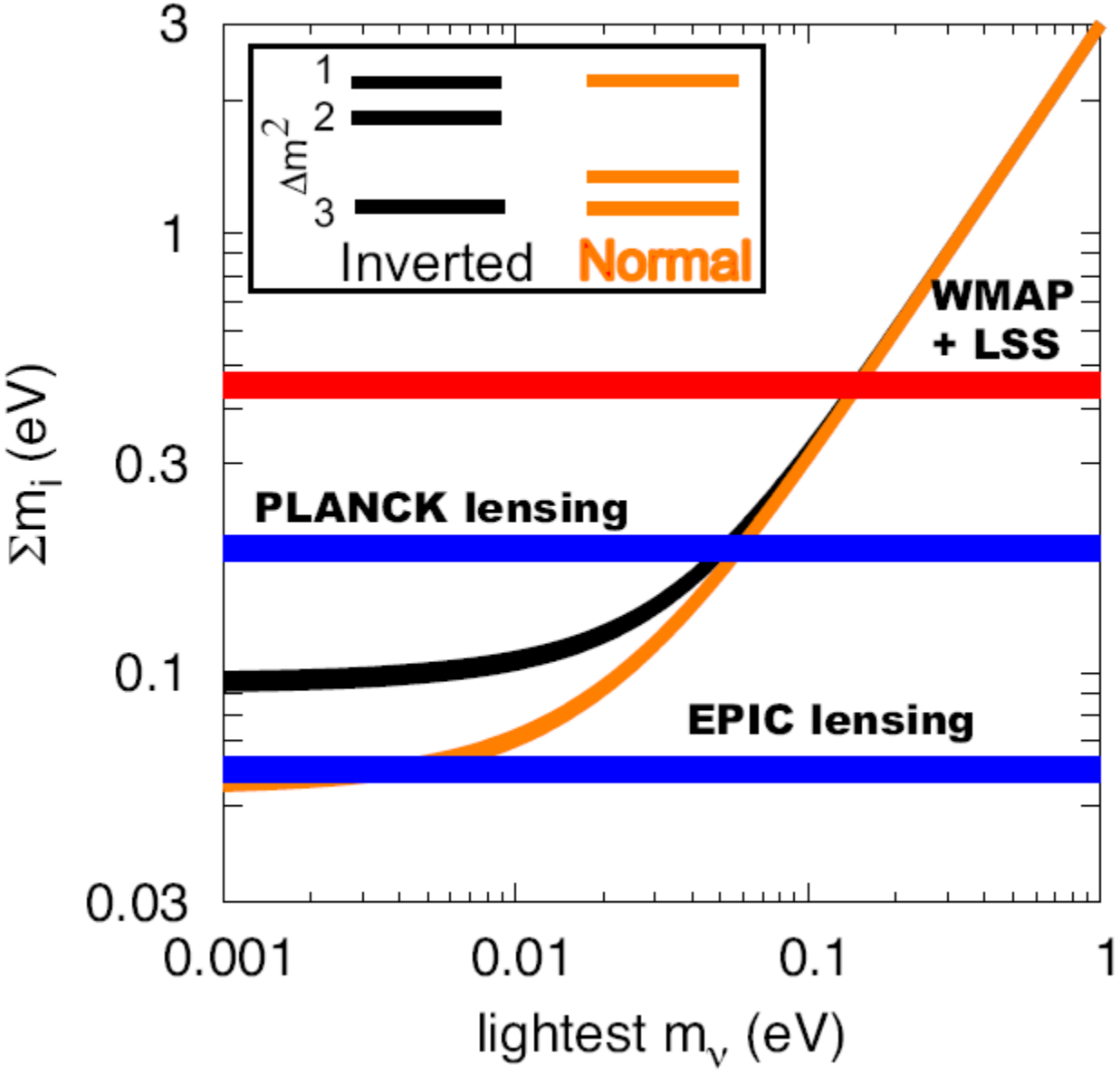
Measure B-mode cosmic shear spectrum to cosmic limits

- Neutrino mass hierarchy
- Dark energy at z > 2

Measure Inflationary B-mode spectrum at r = 0.01 to astrophysical limits

- GUT energy scale
- Large field inflation

Neutrino Masses



Decadal Panel Recommendations

- Combination of risk of null signal and potentially high return - we suggested:
  - Wait for hints of signal from sub-orbital experiments
  - Review science and mission technology case mid-decade
  - Provide interim technology development funding to support sub-orbital measurements and future space mission.

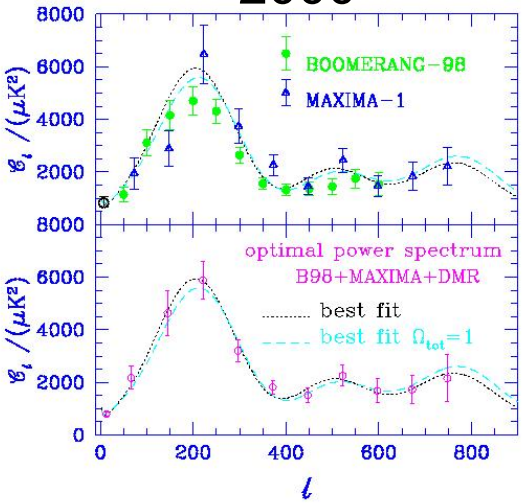
- Decadal agreed:

  "If these fingerprints of inflation are detected an independent advice committee could determine whether a technology development program could be initiated with a view to flying a space mission during the following decade"

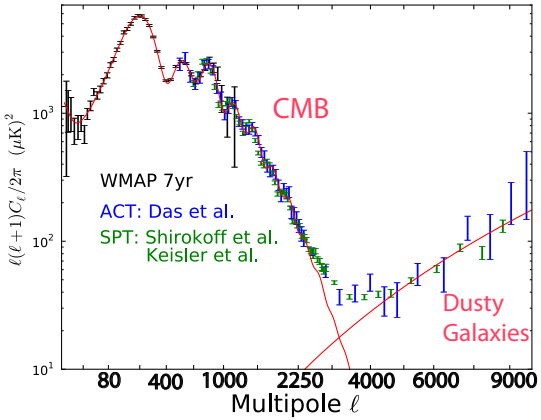
  $60 - $200M/10 years. Lower figure 'interim'. Higher figure includes 'accelerated development for a space mission'.

The Impact of Technology Development

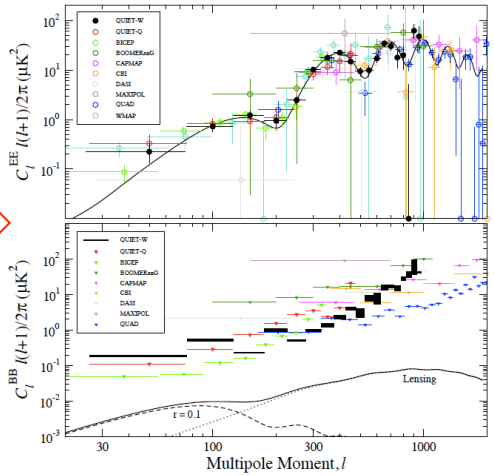
2000



2012



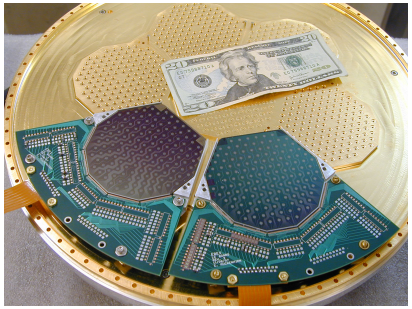
2012



EBEX

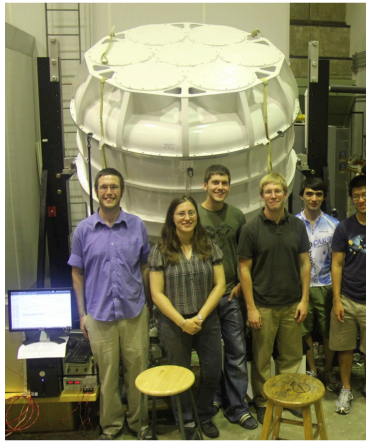
1564 element arrray

2 of 7x140 detectors

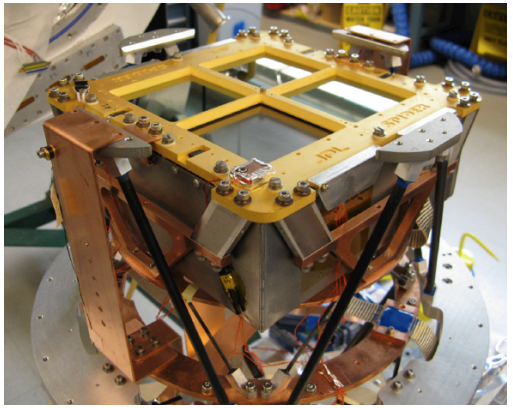


Spider

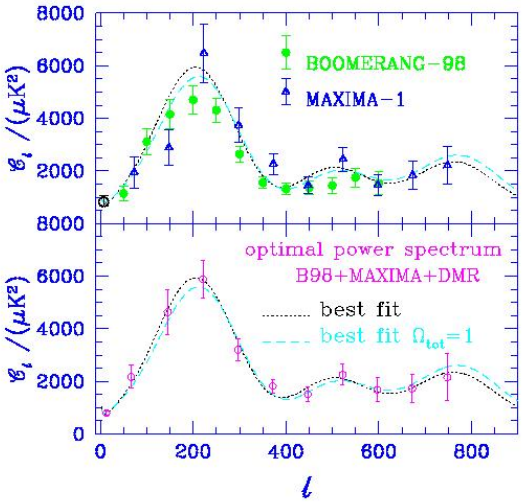
6x 256 element receiver

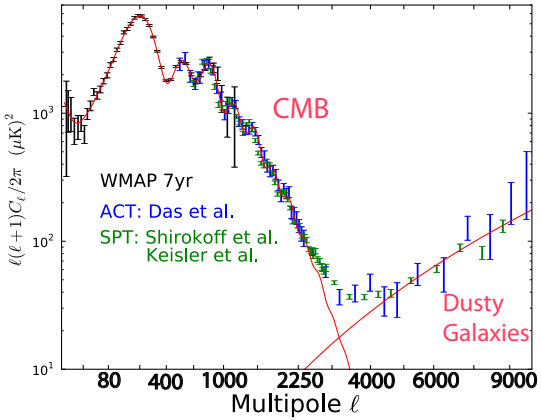


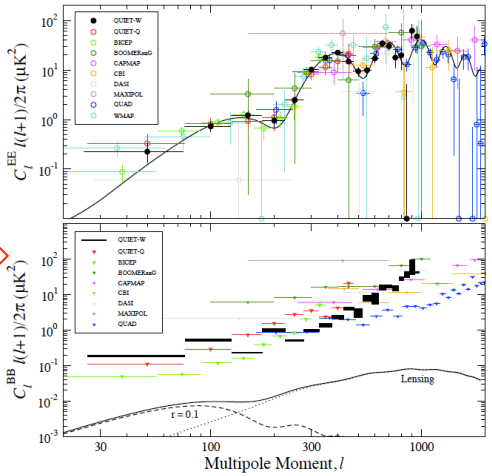
256 element array



The Impact of Technology Development







Planck – 54 polarization sensitive detectors

Now ~ 1,000 element arrays,
two wires reading ~10 detectors

Next Generation (few years) ~ 10,000 element arrays
two wires reading ~100 detectors

Current Status + Actionable Items

- Technology development funding has lagged *very significantly* behind the decadal's recommendations

- We have heard of specific identified technologies that will simplify a future probe mission and are likely to make it cheaper. These same technologies will make next generation experiments even more powerful.

- Many of the technologies have synergies with x-ray and Cosmic Origins science (TES arrays, squid muxing)

- *We strongly advocate augmentation of technology development funding across all PCOS areas*

Current Status + Actionable Items

- Currently: three funded balloon-missions and a host of ground-based experiments.

- Results (B-modes, foregrounds, systematics) - within the next few years.

- Planck will release temperature results in early 2013 and polarization results in early 2014

- *We advocate that a new IP mission concept study will begin in the 2014 time frame, sufficiently in advance to feed into the decision about the next mission*
  - *Revisit probe class design*
  - *Assess descopes to an explorer box*

Current Status + Actionable Items

- We have heard of US and international efforts to mount B-mode satellites.

- Japan is seriously considering a (null signal!) inflationary B-mode mission; funding decision may materialize in 2013

- European collaborators submitted a proposal for M-class in 2011; are planning to propose again in 2014.

- *The Europeans see valuable US contributions in focal plane technologies and coolers. If a US mission is funded, they can provide filters and other quasi-optical components.*

Current Status + Actionable Items

- As a result of the combination of promise and risk, the decadal panel has recommended an independent review of the IP around mid-decade

- This review was potentially a trigger for an accelerated technology development funding, leading to a potential mission the following decade

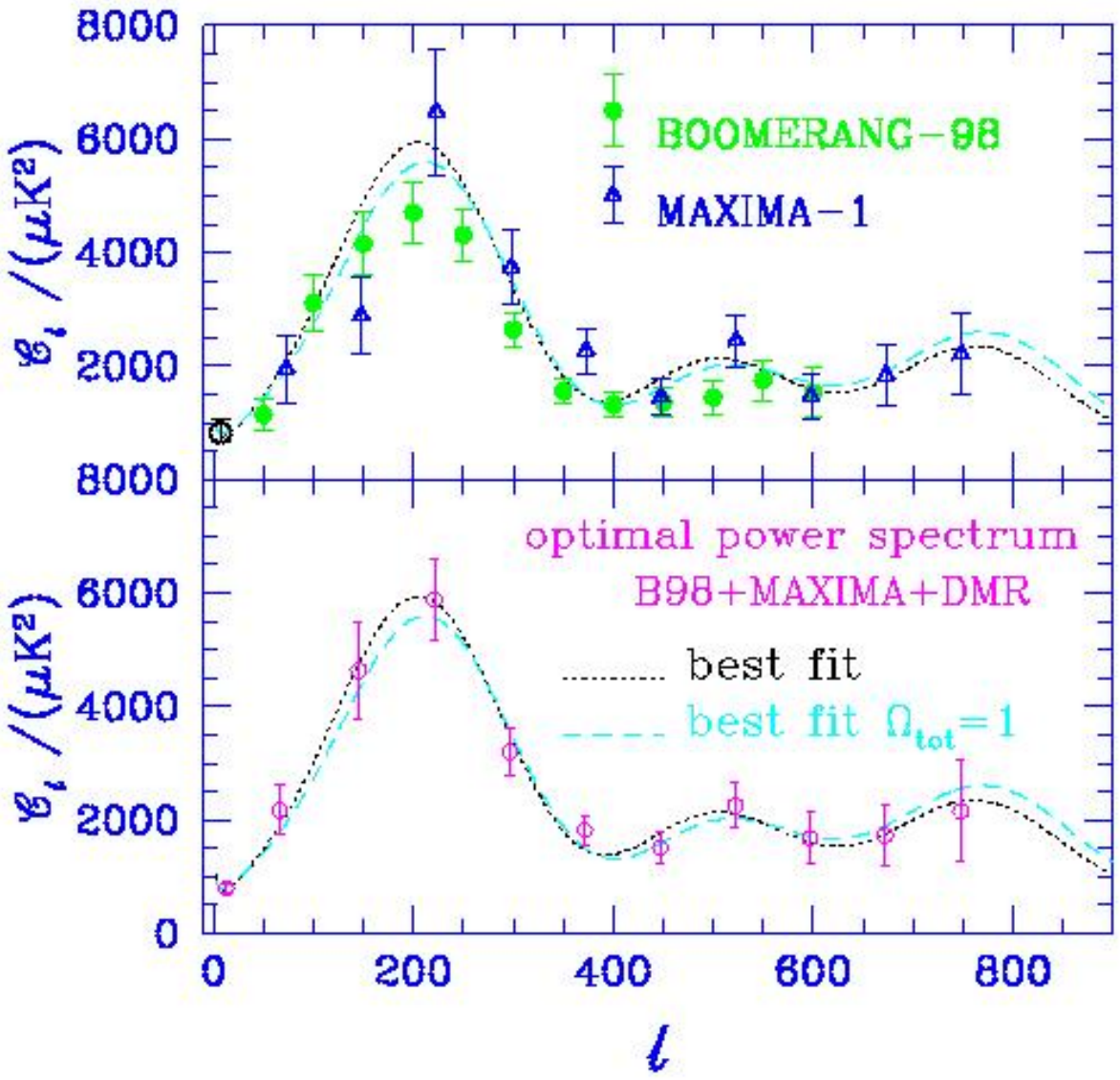
- *Given current evolving thinking about DSIAC/CAA - what is NASA planning to do with this recommendation?*

Current Status + Actionable Items

- Balloon payloads
  - Provide excellent science/$$
  - Are indispensable proving grounds for new technologies
  - Arguably the best training ground for the space-workforce of the future

- *We support strengthening the balloon program.*

CMB Temperature Power Spectrum in 2000

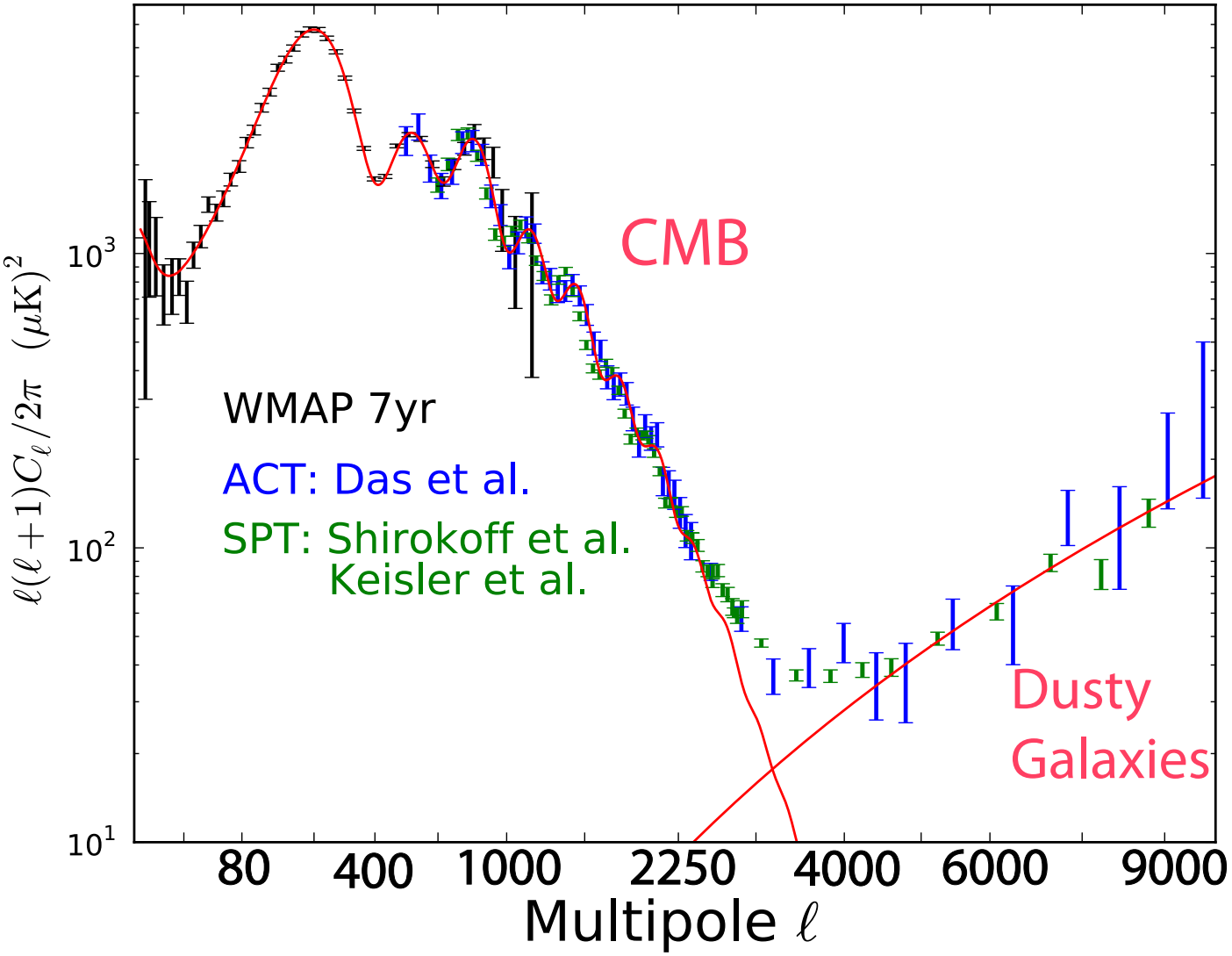


"One of the ten most important breakthroughs in science for 2000"

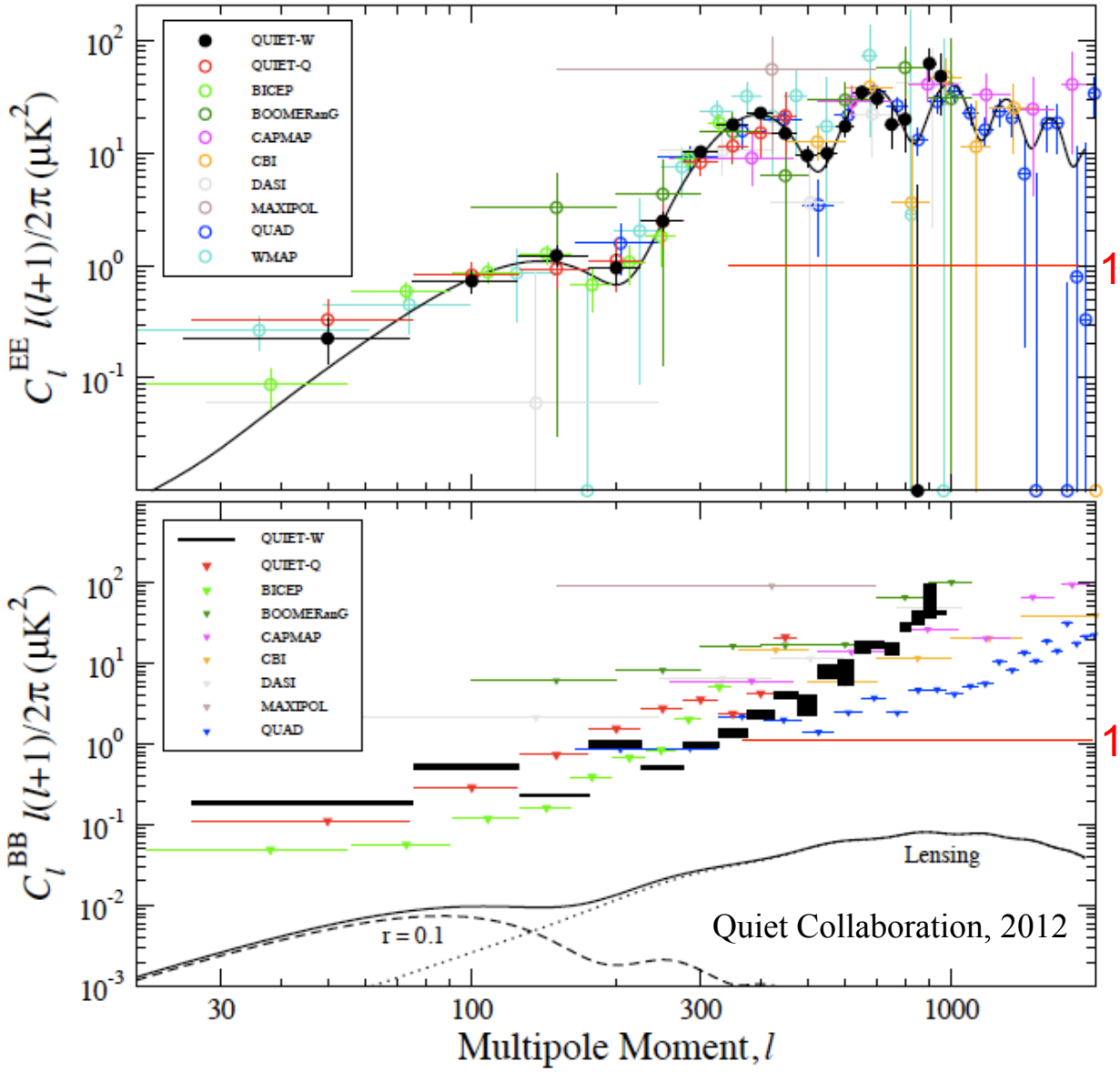
Science

Jaffe et al, 2000

CMB Temperature Power Spectrum in 2012



CMB Polarization Power Spectrum in 2012



E Mode

B Mode