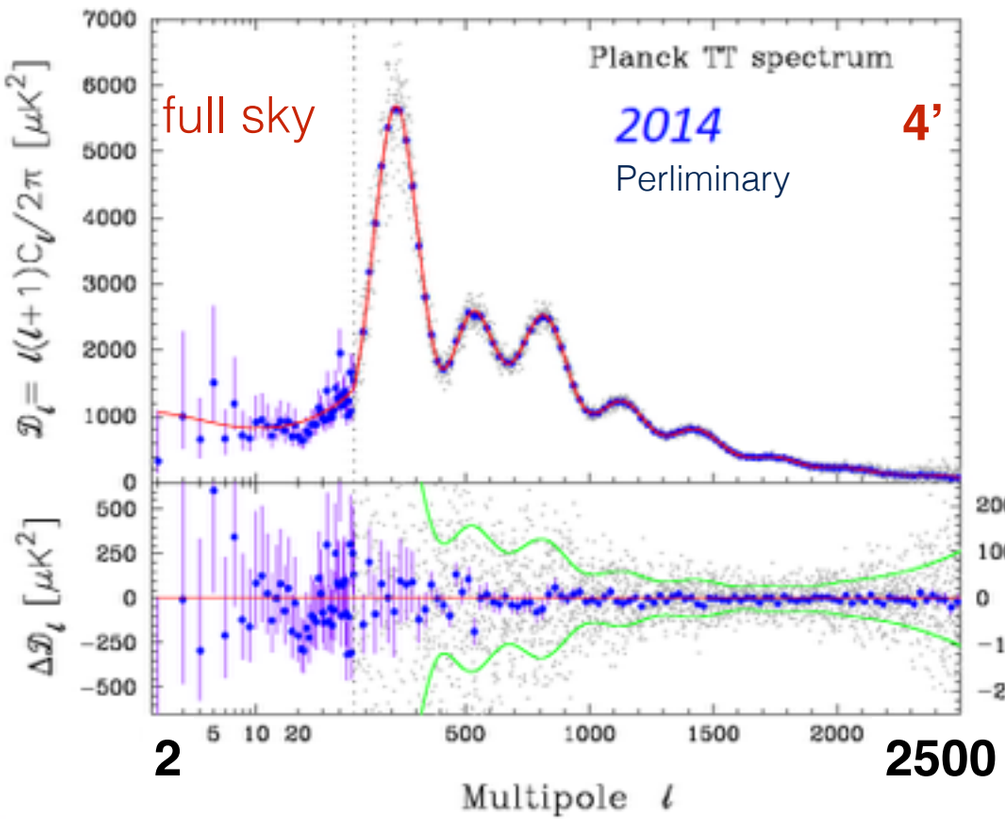
Inflation Probe SIG PhysPAG Update

Shaul Hanany
January 2015

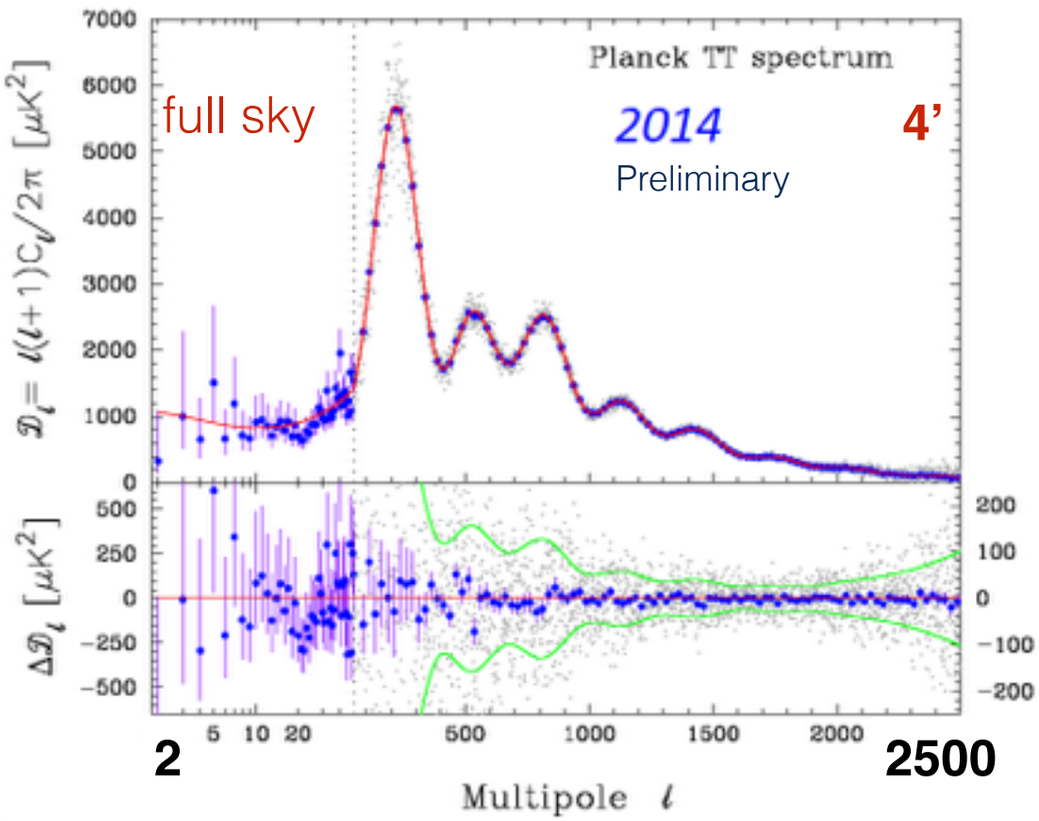
CMB: What's Happening Now - Temperature

- Planck temperature results: 2013 + 2014 (prelim.)
  - Rich cosmological and galactic data set
  - 33 papers covering: Cosmological parameters, topology of the Universe, cosmic strings, Inflation, Variation of the fundamental constants, Gravitational lensing, Properties of clusters, Cosmic Infrared Background, Zodiacal emission, Galactic CO emission, Galactic magnetic fields, Galactic synchrotron and free-free emission, Galactic dust, …

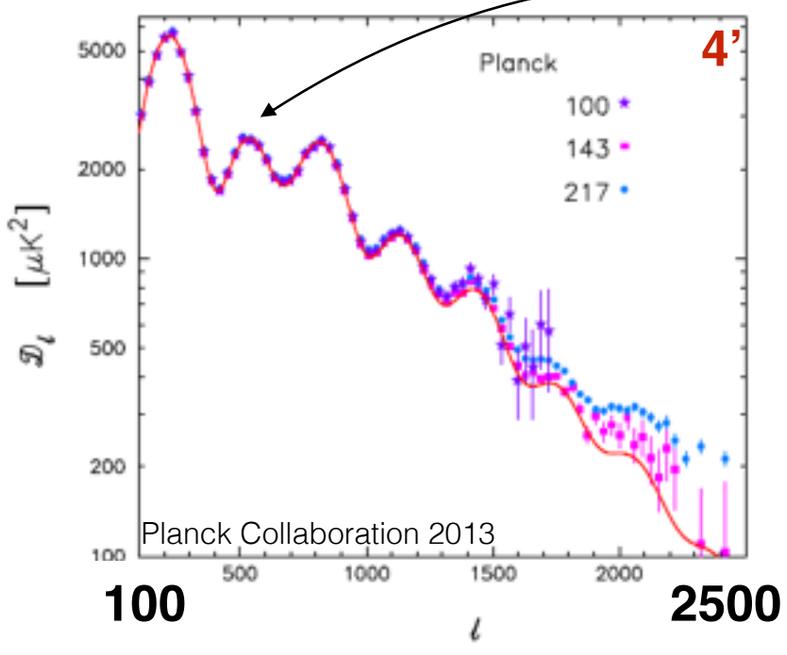


CMB: What's Happening Now - Temperature

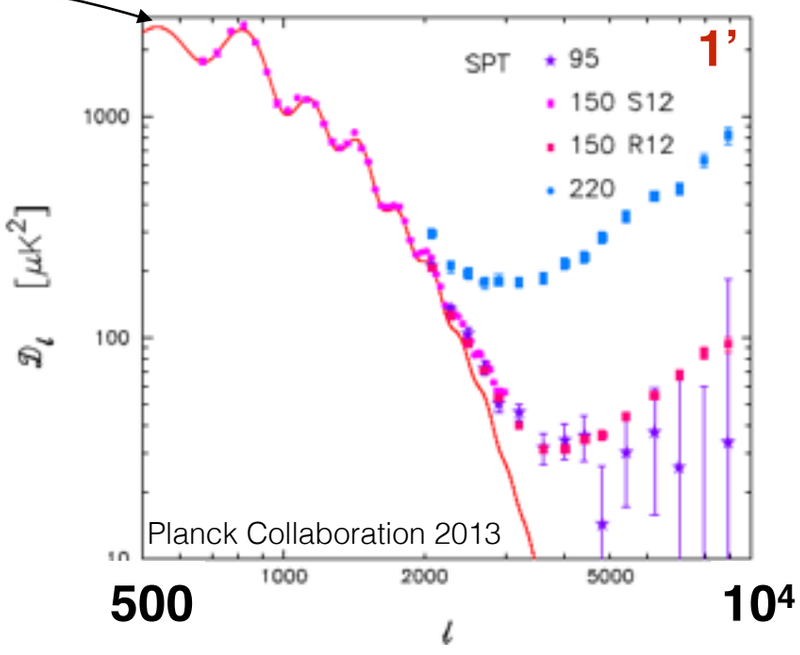
- Planck temperature results: 2013 + 2014 (prelim.)
  - Rich cosmological and galactic data set
  - Consistency with 6 parameter cosmological model
  - Consistency among different experiments
  - Session #220 on Tuesday (2 - 3:30 pm, 6B)



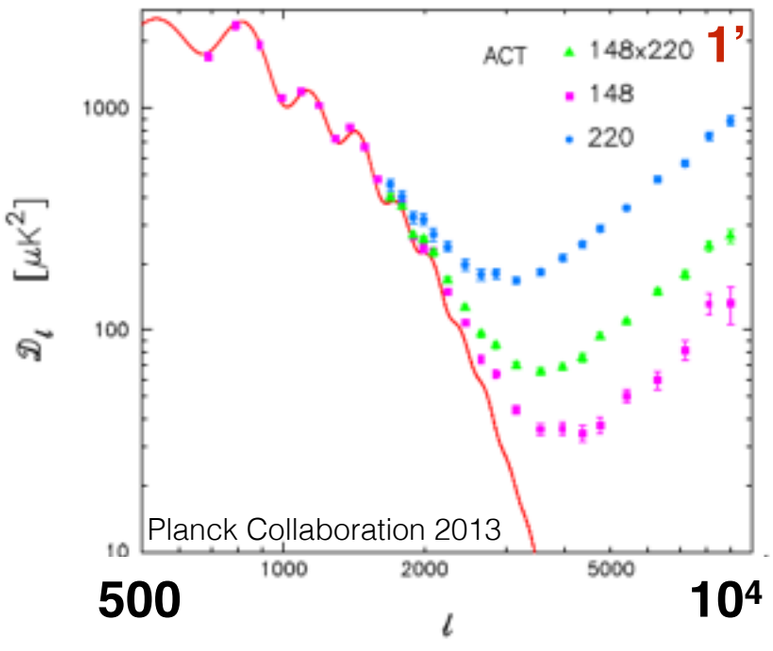
Planck



Planck Model + SPT

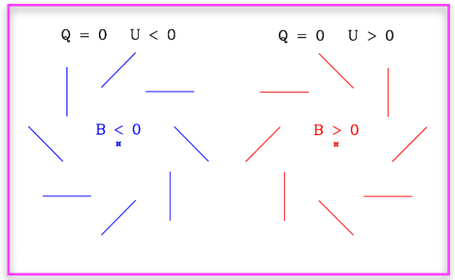


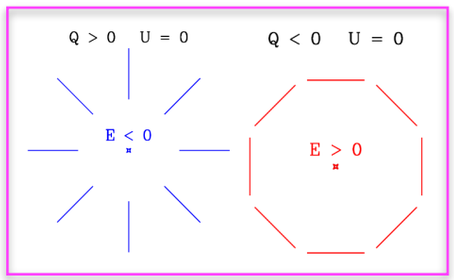
Planck Model + ACT

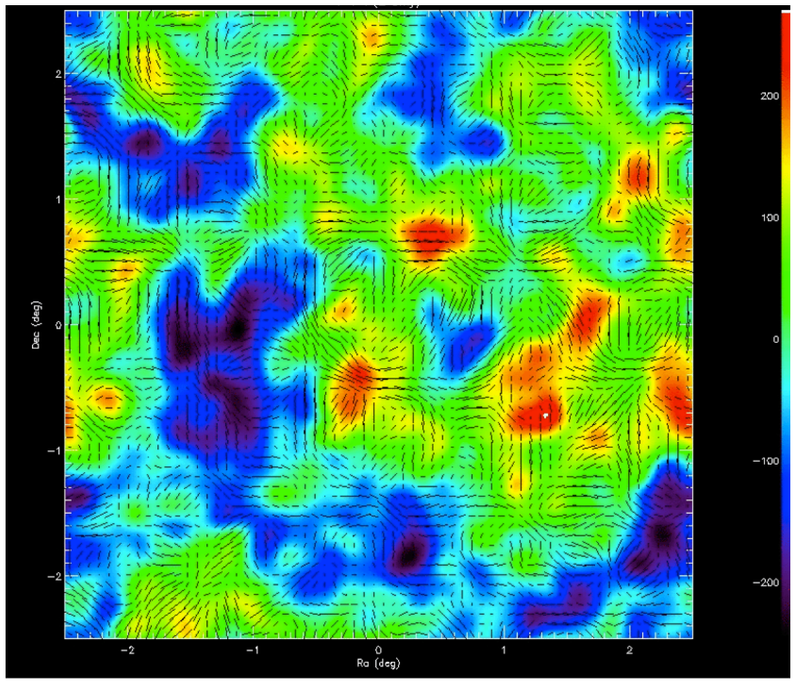


CMB: What's Happening Now - Polarization

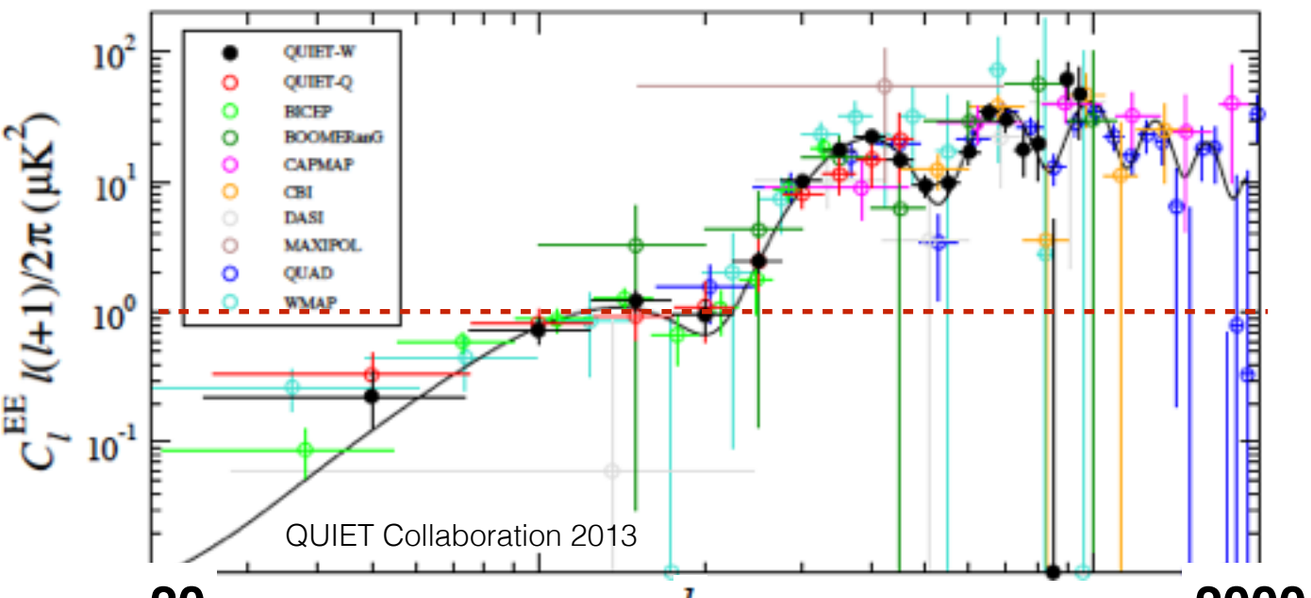
- The CMB is polarized with E and B modes
- E-mode: directly calculable from the T spectrum
- B-mode:
  - partly (high \ell) lensing
  - partly (low \ell) Inflation



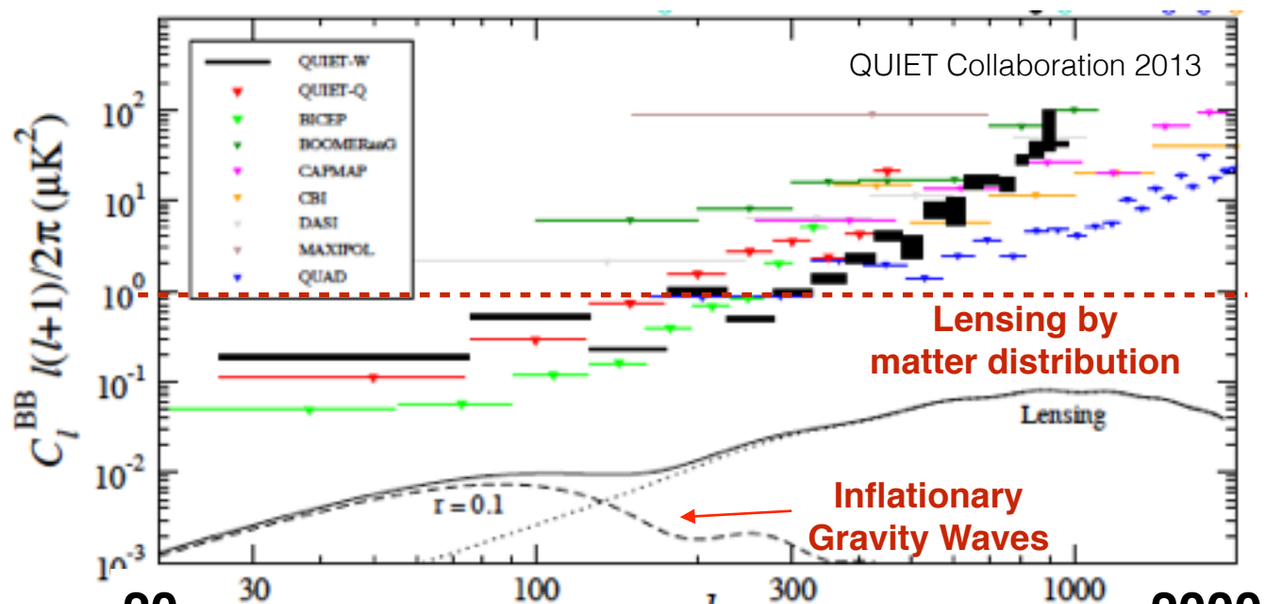




EE Power Spectrum



BB Power Spectrum



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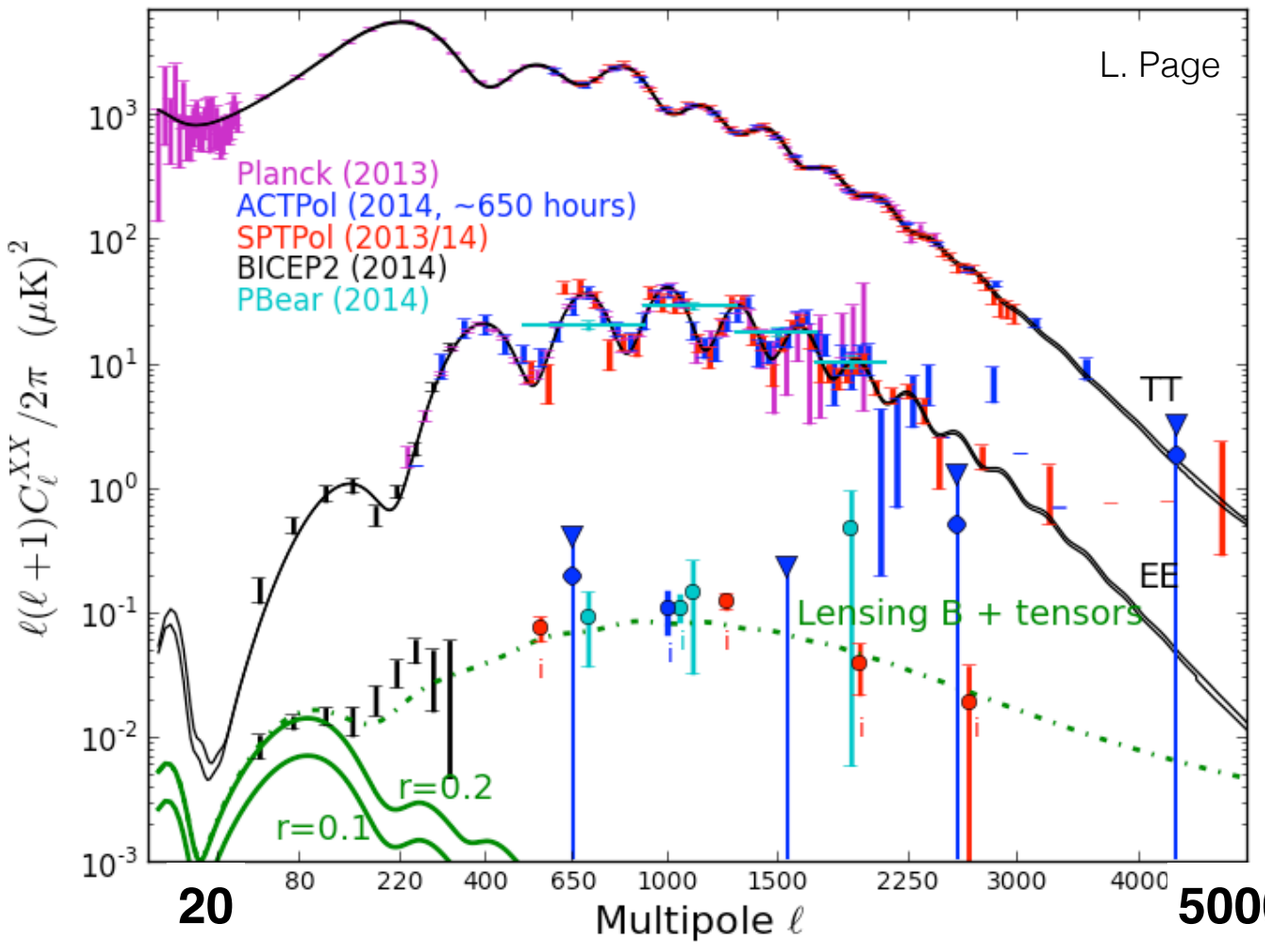
- The CMB is polarized with E and B modes
- No surprises with E-mode
- Detection of B-modes!

CMB Temp and Pol - Nov. 2014



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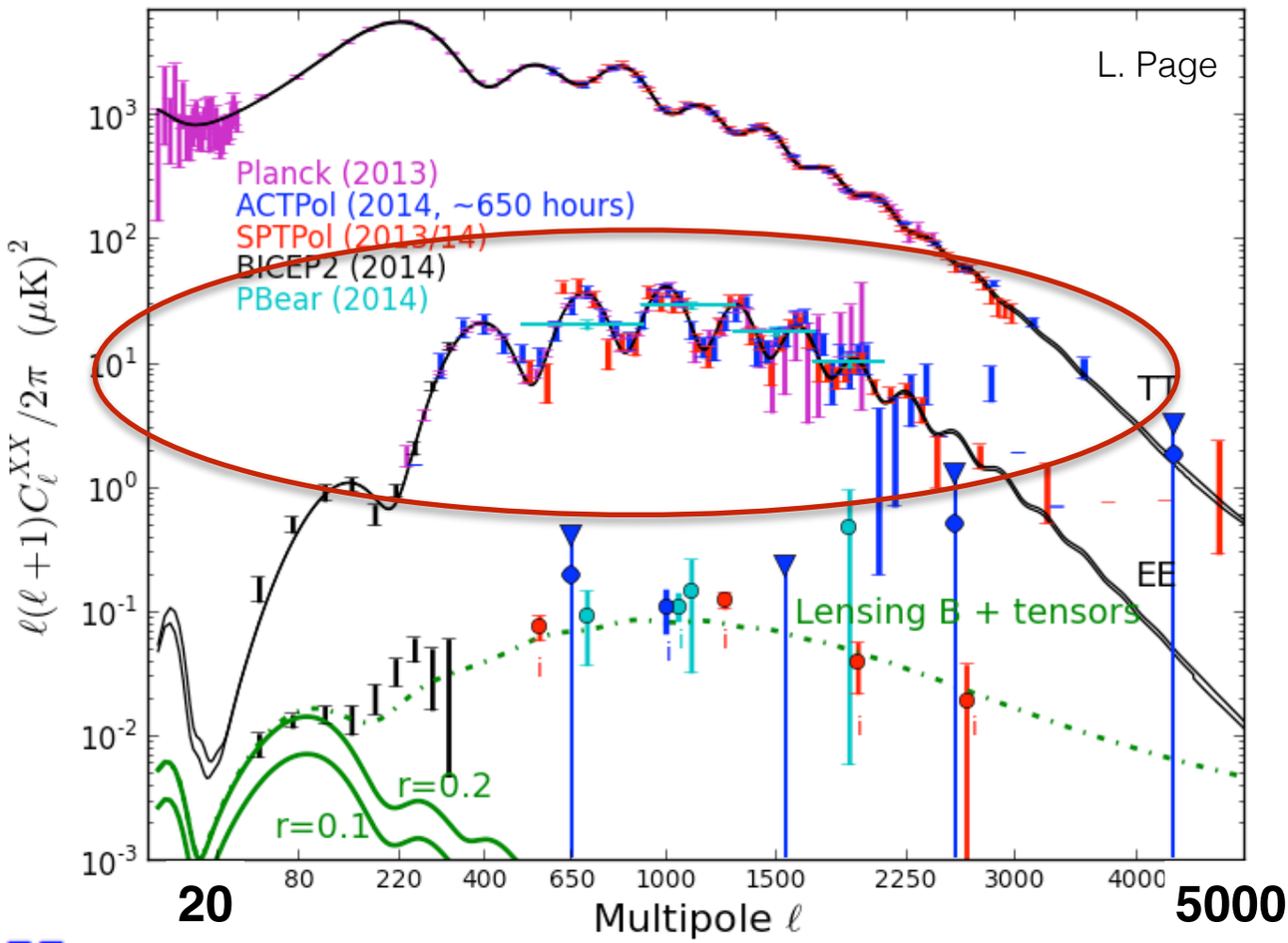
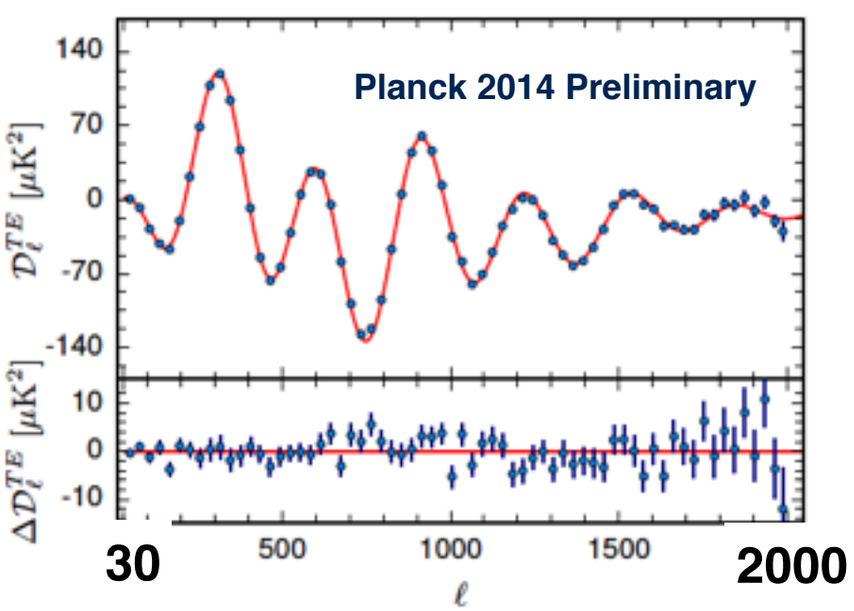


TE



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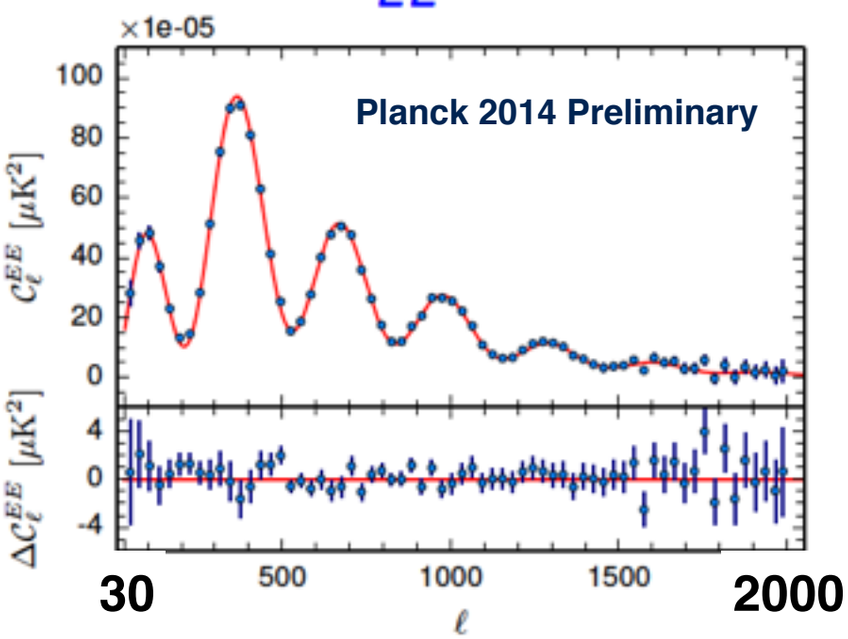

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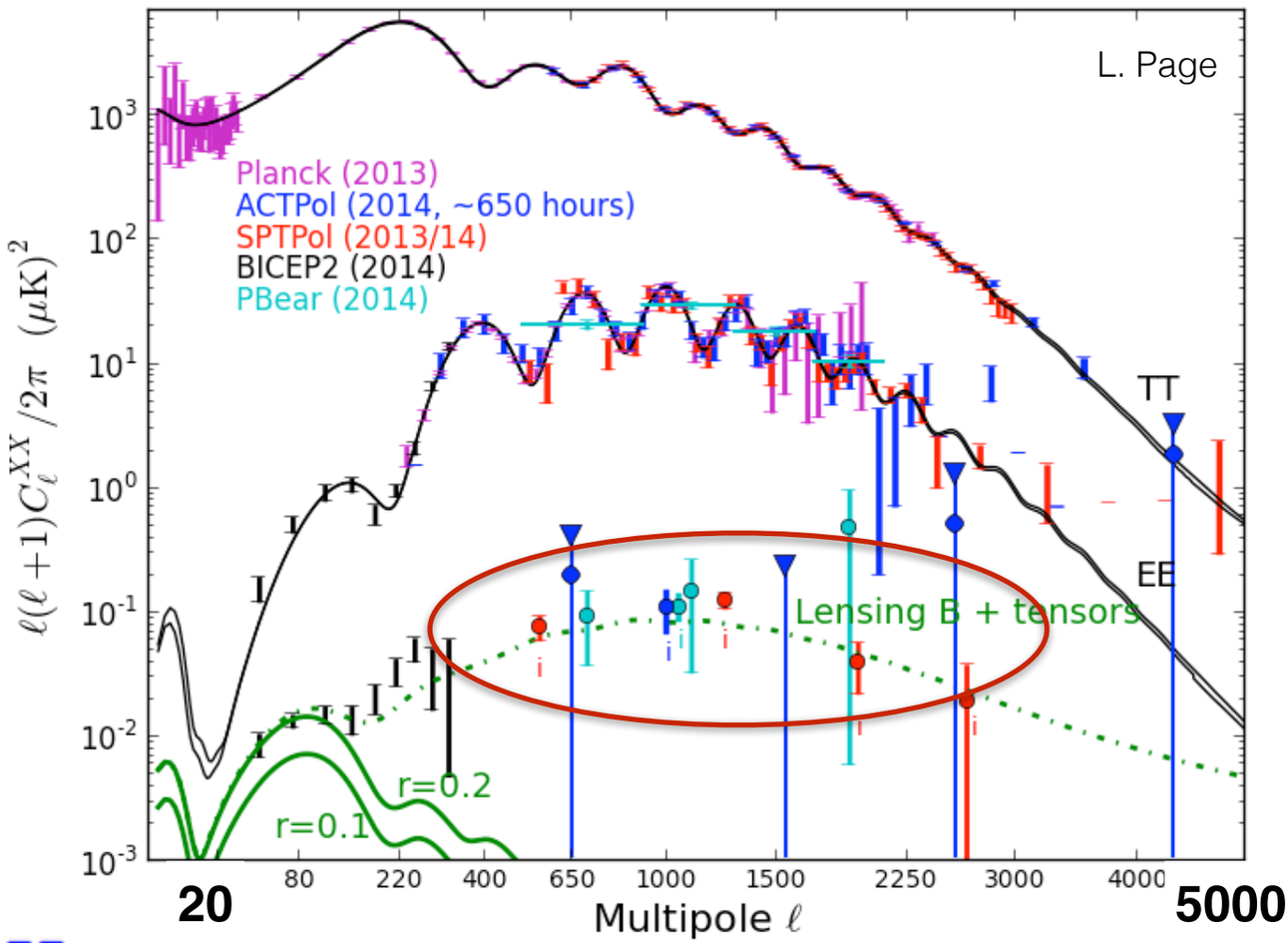

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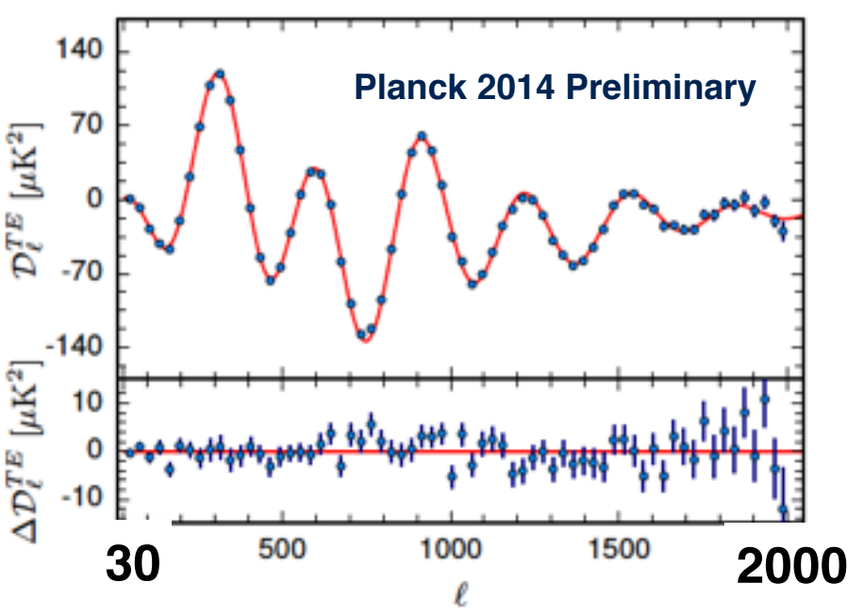

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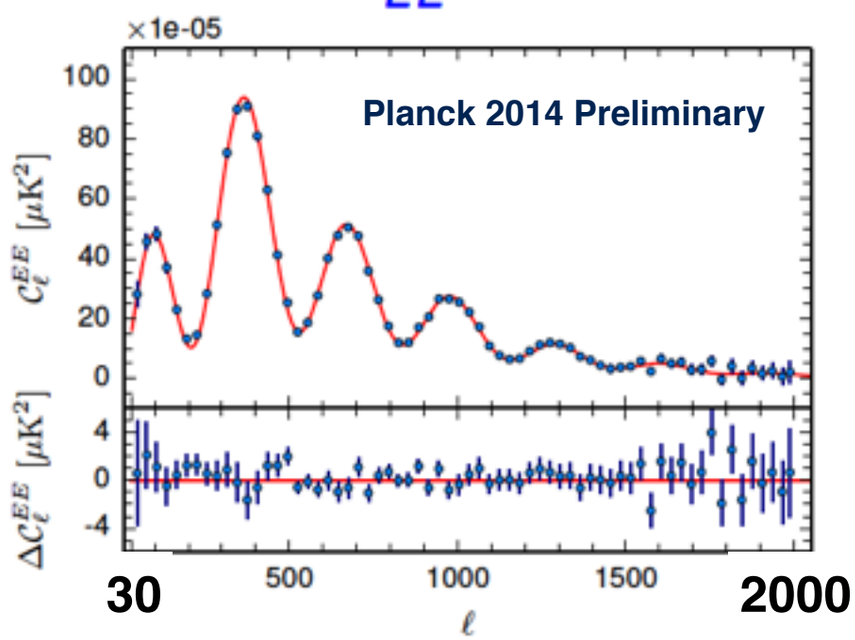

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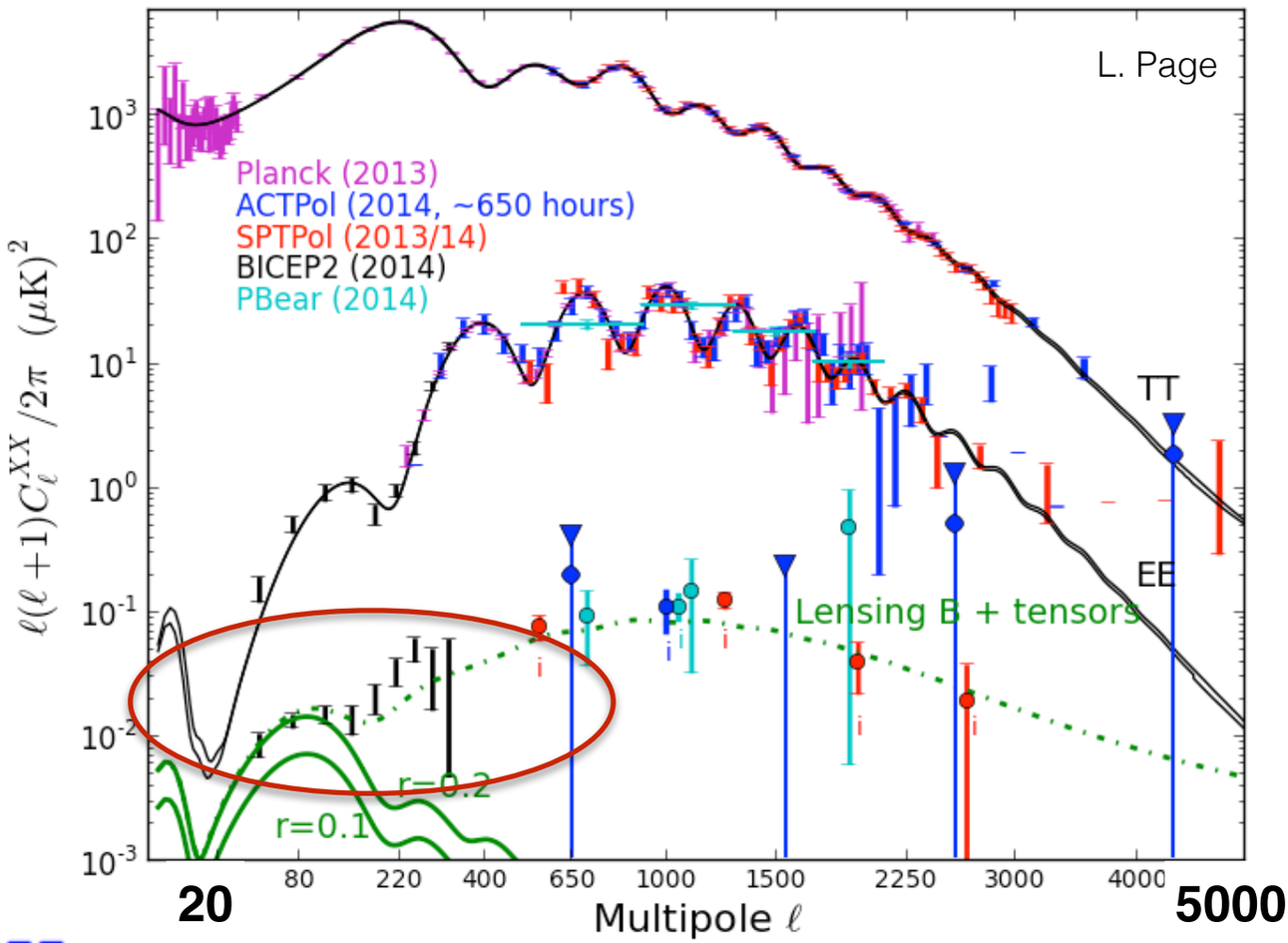

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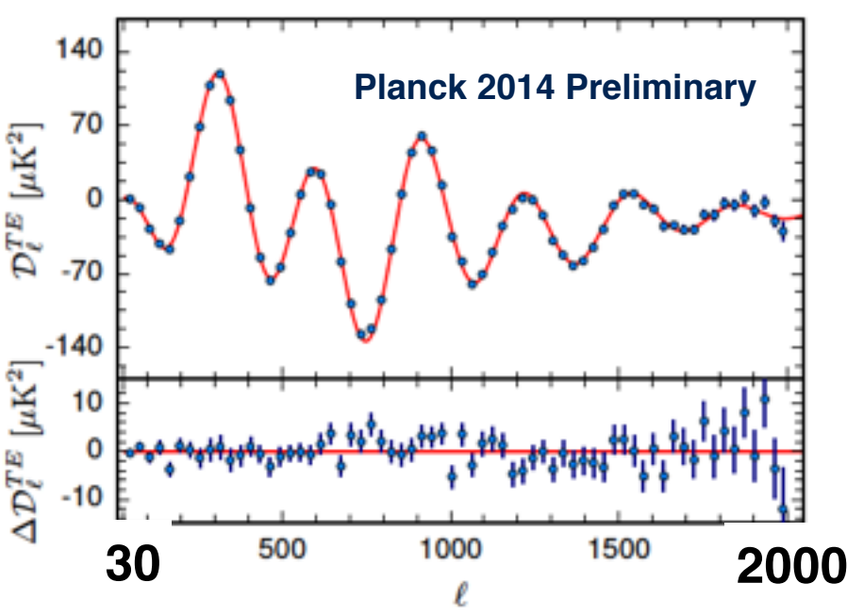

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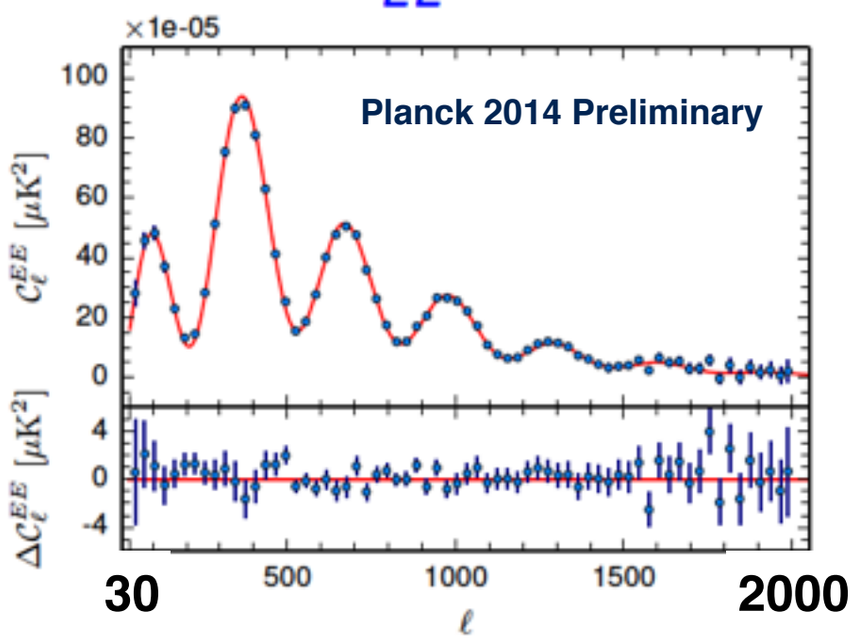
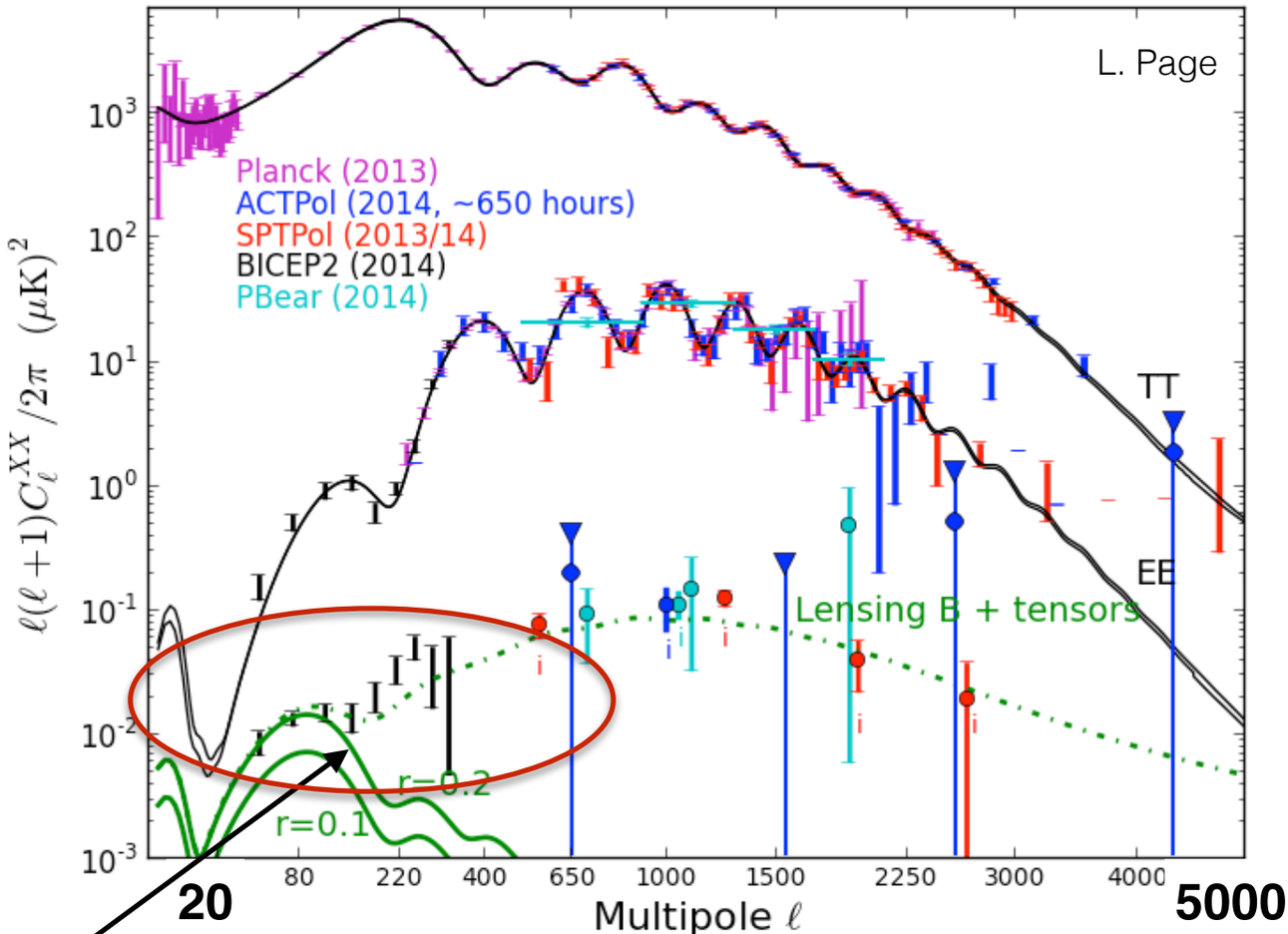
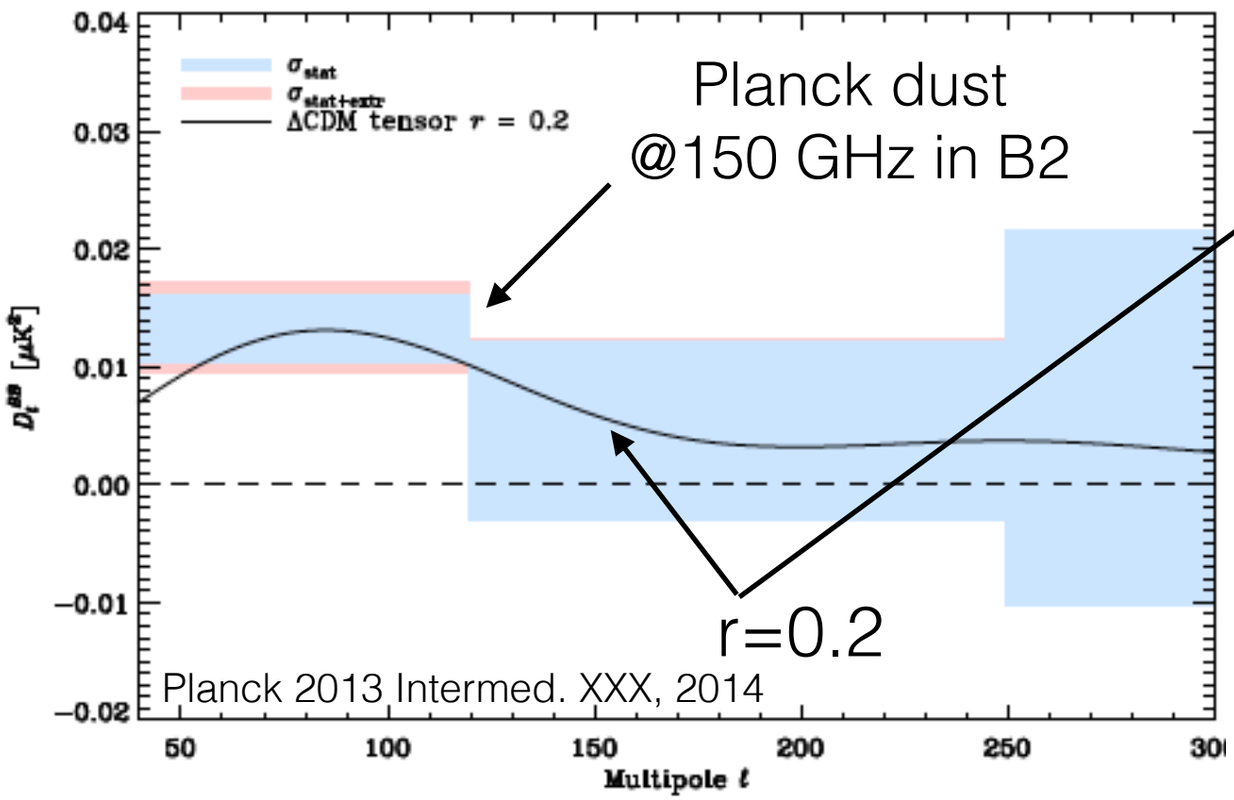


CMB: What's Happening Now - Polarization

- The CMB is polarized with E and B modes
- No surprises with E-mode
- Detection of B-modes!
- Planck finds significant levels of dust in the B2 region
- Planck 2014 (prelim) limit: r<=0.09

CMB Temp and Pol - Dec. 2014





CMB: Coming Soon

- Planck polarization results: January 2014
  - M. White Plenary (#334, Wed. 4:30 pm, 6E)

- Keck Array (ground, low ell)
- SPTPol (ground, high ell)
- ACTPol (ground, high ell)
- POLARBEAR (ground, high ell)
- EBEX (balloon, intermediate ell)

All Analyzing Available Polarization Data

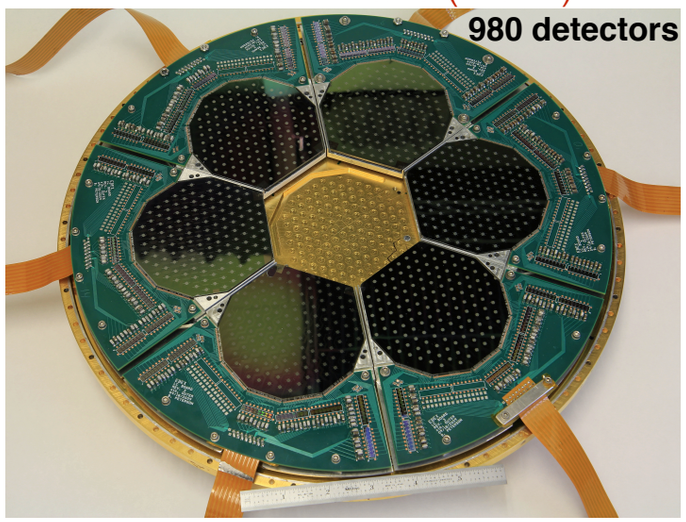
- SPIDER (balloon, low ell)
- PIPER (balloon, low ell)

Launch in 2015

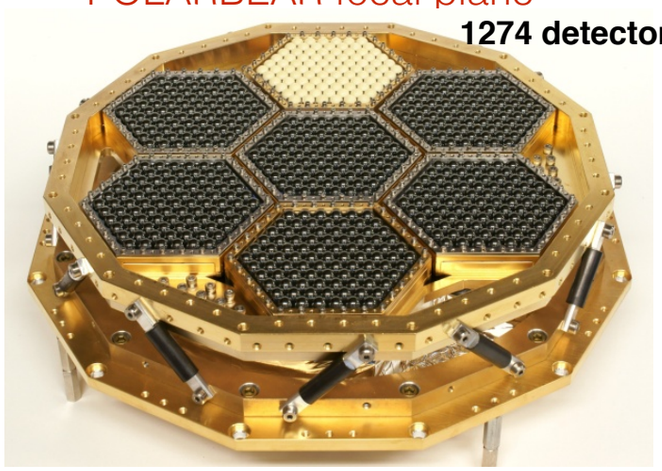
- SPT3G
- Advanced ACTPol
- POLARBEAR/Simons Array

Funded extensions to ~20,000 detectors

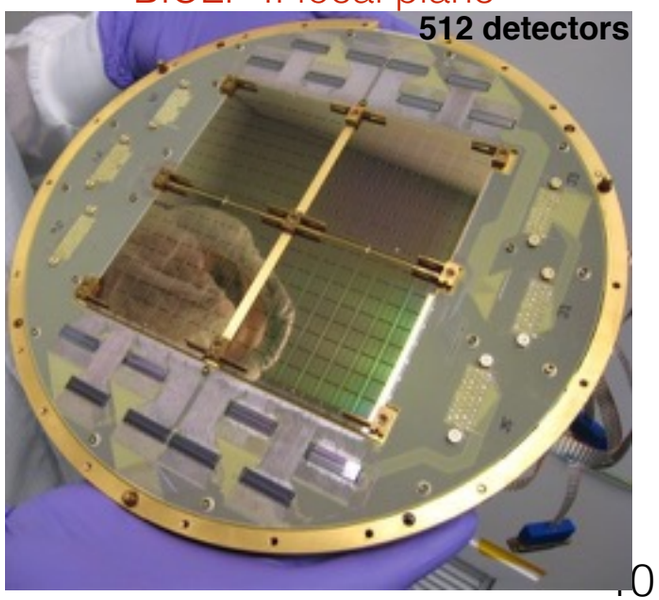
EBEX Focal Plane (1 of 2)



POLARBEAR focal plane



BICEP-II focal plane



IPSIG - Active Year: B2

- White Paper (April - August)
  - Wake of B2 results
  - What are the next steps? Are we done?
    - Step 1: verification
    - Step 2: implement NWNHs plan of considering a space mission
      - Need: high sensitivity; over entire sky; multiple frequencies
  - In parallel: Facilitate participation in International missions

- Community-wide (including international) contributions + telecons + several iterations

CMB Polarization Measurements: 2015 and Onward

A White Paper submitted by the IPSIG to
NASA's Astrophysics Subcommittee
Aug. 2014

The Theoretical Landscape

The BICEP2 experiment recently announced a detection of B-mode polarization at millimeter wavelength and at angular scale of about 1 degree. The results generated great interest because this is the angular scale in which gravitational waves from the epoch of inflation are expected to imprint a characteristic signature. But uncertainties about the cosmological origin of the signal remain because of uncertainties with the magnitude of emission of galactic dust. The response to the BICEP2 announcement highlights both the scientific importance of, and popular interest in, observational constraints on cosmic genesis. If the BICEP2 measurement contains an inflationary component then it sets the energy scale responsible for the inflationary epoch near $2 \cdot 10^{16}$ GeV, some 13 orders of magnitude above energy scales probed in the largest Earth-based colliders. This in itself would be a stunning discovery, but it would only be the beginning.

A measurement of the energy scale of inflation opens the observational door to a number of problems of fundamental physics:

IPSIG - Active Year: Planck Funding

- $4.7M cut to US Planck team request for FY15/16
  - Wake of 2014 Senior Review
  - Impact: incomplete calibration and characterization of systematic effects (with permanent effects on the legacy of Planck).
- IPSIG provided a letter with technical perspectives about the process of CMB data analysis and specifically in Planck's case.
- NASA reviews decision, consults Planck team and members of the community - restores the most critical $3.1M

Letter to NASA in Regard to Planck Data Analysis Activities
Submitted by the IPSIG

NASA's investments in the Planck mission have been enormously successful. Results published to date have already had a significant impact in cosmology and other areas of astrophysics. The scientific community eagerly awaits the second data release planned for November 2014, which may shed light on the physics of the big bang. The third and final data release is planned for December 2015; it is scheduled to include the final processing of the data by the Planck team. The data from Planck are critically important to the CMB community, and will set the foundation for scientific work for the next decade, including the basis for planning a future polarization mission, the Inflation Probe. The full and complete processing of the Planck data is thus vital.

We are writing to highlight aspects of the data analysis work that may be relevant for near term decisions about the final products forthcoming from the mission.

IPSIG - Active Year: CMB-S4

- Coordinating with CMB-S4
- P5 recommended project for DOE
- Using 250,000 detectors

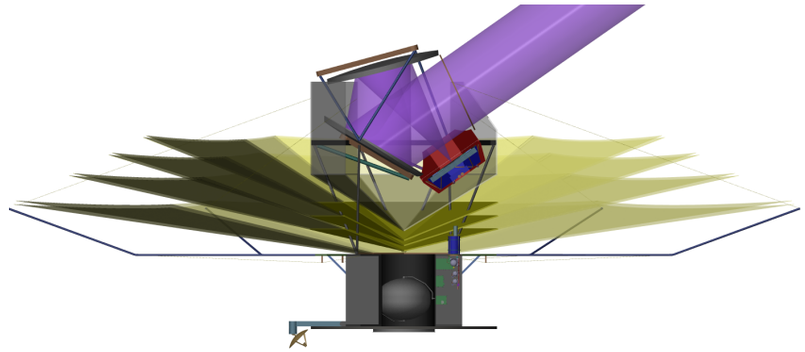
Funding Scenarios

Project/Activity	Scenario A	Scenario B	Senario C	Higgs	Neutri	Dark M	Cosm.	The Ur	Techni
Large Projects									
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y					✓	I
HL-LHC	Y	Y	Y	✓		✓		✓	E
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced		✓			✓	I,C
ILC	R&D only	R&D, possibly small hardware contributions. See text.	Y	✓		✓		✓	E
NuSTORM	N	N	N		✓				I
RADAR	N	N	N		✓				I
Medium Projects									
LSST	Y	Y	Y		✓		✓		C
DM G2	Y	Y	Y			✓			C
Small Projects Portfolio	Y	Y	Y		✓	✓	✓	✓	All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced	✓	✓	✓		✓	E,I
CMB-S4	Y	Y	Y		✓		✓		C

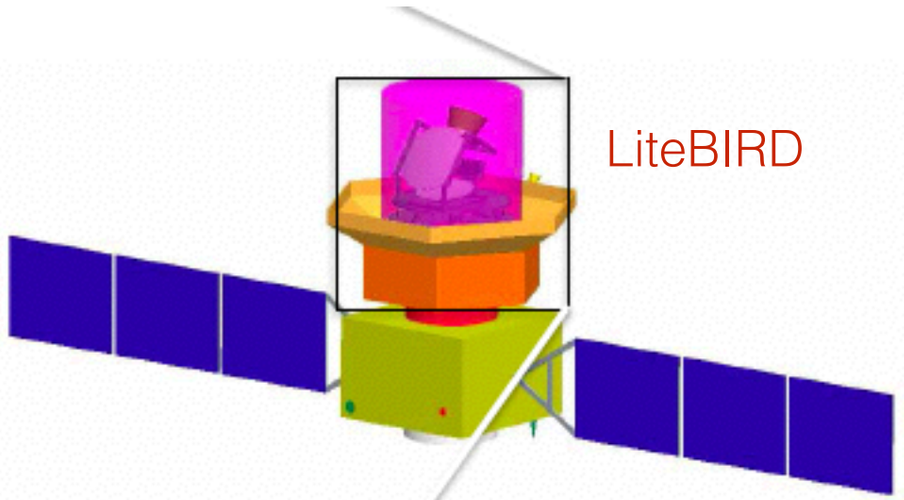
Response to NASA's PhysPAG Charge: Landscape of Inflation Probe Space Projects

- US
  - Decadal Panel: review case for Inflation Probe mission by a mid-decade review panel.
  - BEPAC cost (~2008): $1.2B - $1.33B
  - PIXIE - submitted as Explorer class mission (2011)
    - low resolution (1.6 deg), spectrometer, LEO
- ESA M4 (Jan. 15, 2015; ~E600M cost cap)
  - COrE+Light: $720M; COrE+Extended: $850M
    - medium resolution (5 arcmin), L2
  - Strong US community backing
- JAXA - ongoing discussions
  - LiteBIRD (includes US contribution)
    - low resolution, LEO
  - Less than $500M

EPIC-IM

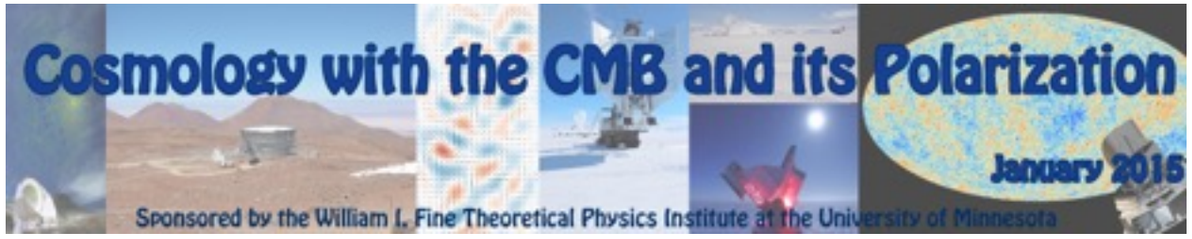


COrE+



Response to NASA's PhysPAG Charge: Landscape of Inflation Probe Space Projects

- Minneapolis CMB Workshop (Jan. 12 - 14)
- Satellite Session + IPSIG Discussion on Jan. 14
  - Large Mission: to be or not to be?
  - What input to provide for the Mid-Decade Review?
  - How should NASA respond to international opportunities?



Final Comments

- The response to BICEP2 demonstrated the intense interest in Inflation and CMB polarization science, both among scientists and among the general public

- With NASA's support the US has been leading CMB discoveries for most of its 50 years of history

- The US is currently leading the field of CMB Polarization in both science and focal plane technologies

- New PhysPAG EC members: Olivier Dore, Amber Miller, Ed Wollack

Extra Slides

To Do