



COSMIC MICROWAVE BACKGROUND POLARIZATION: STATUS AND EXPERIMENTAL PROSPECTS

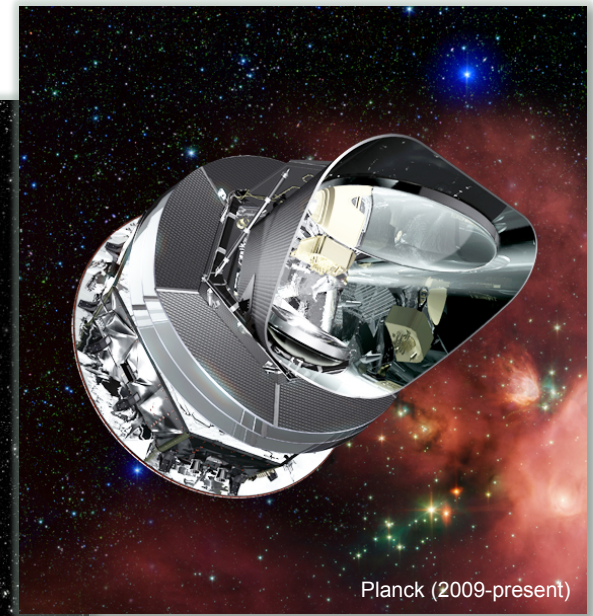
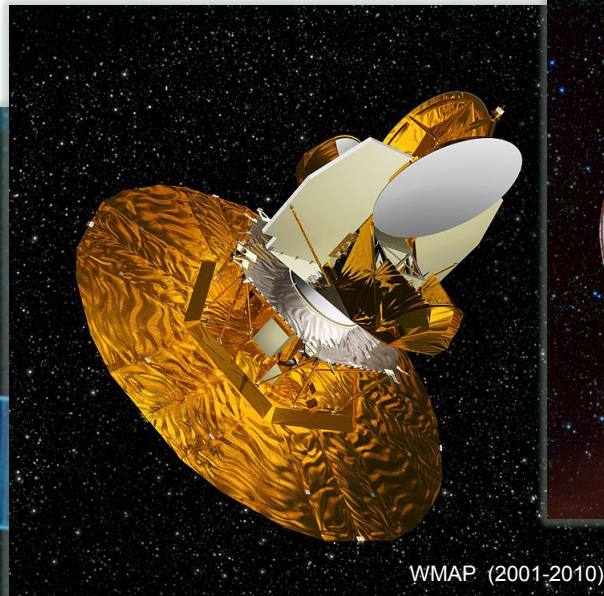
Edward J. Wollack

Inflation Probe Science Interest Group (IPSIG)

NASA Goddard Space Flight Center

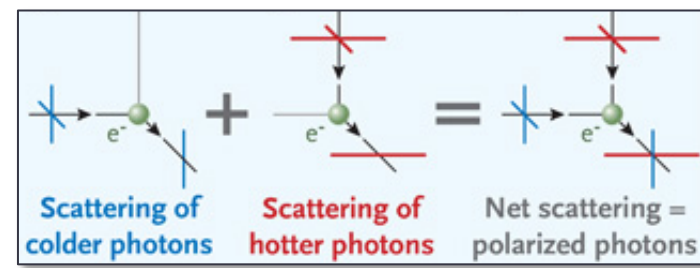
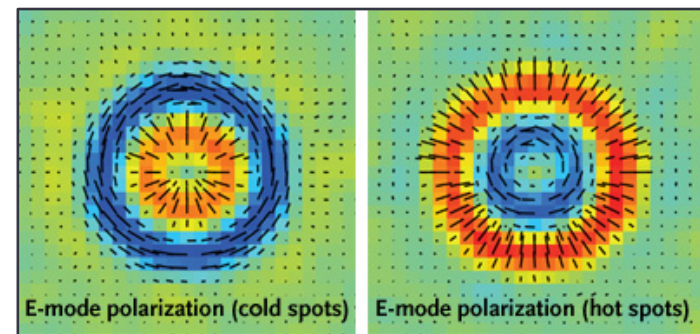
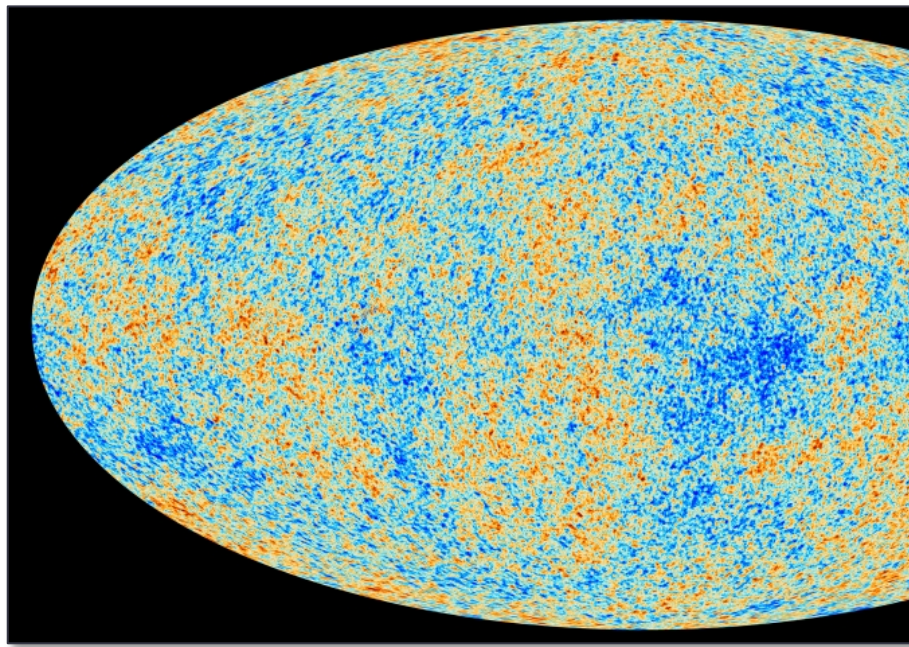
March 12, 2015

CMB: Past and Present...



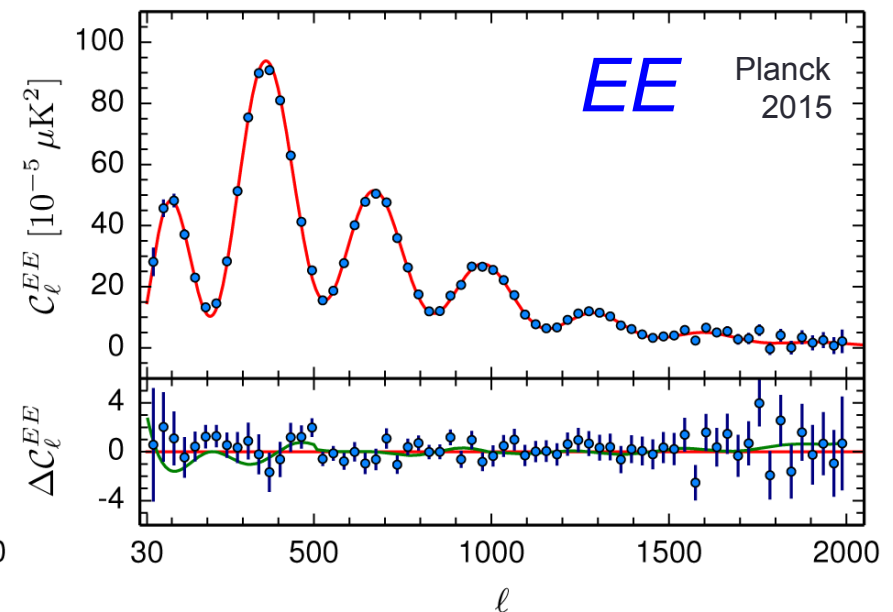
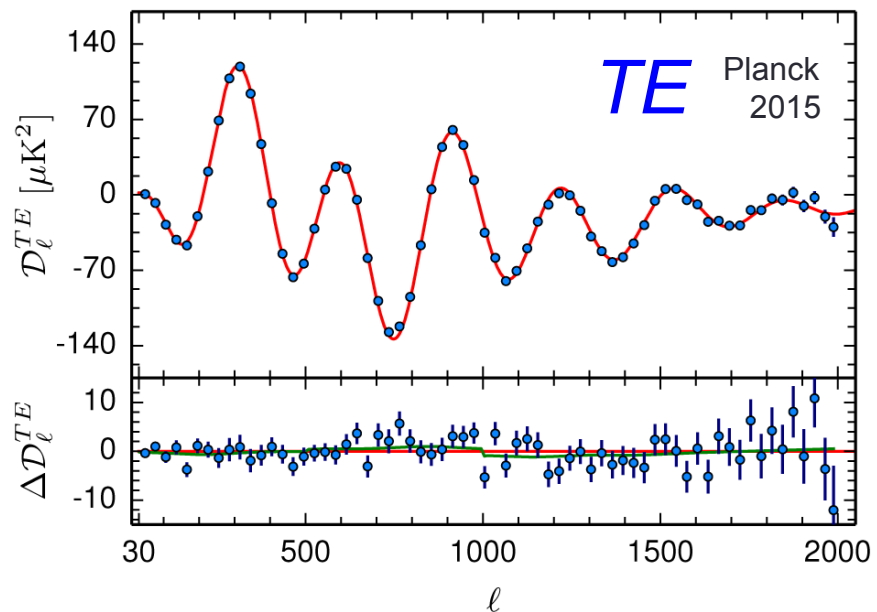
CMB Physics: Temperature & Polarization

- CMB blackbody radiation is anisotropic and polarized...
- Temperature anisotropy \rightarrow polarization via scattering
- Powerful constraints on physics of the early Universe

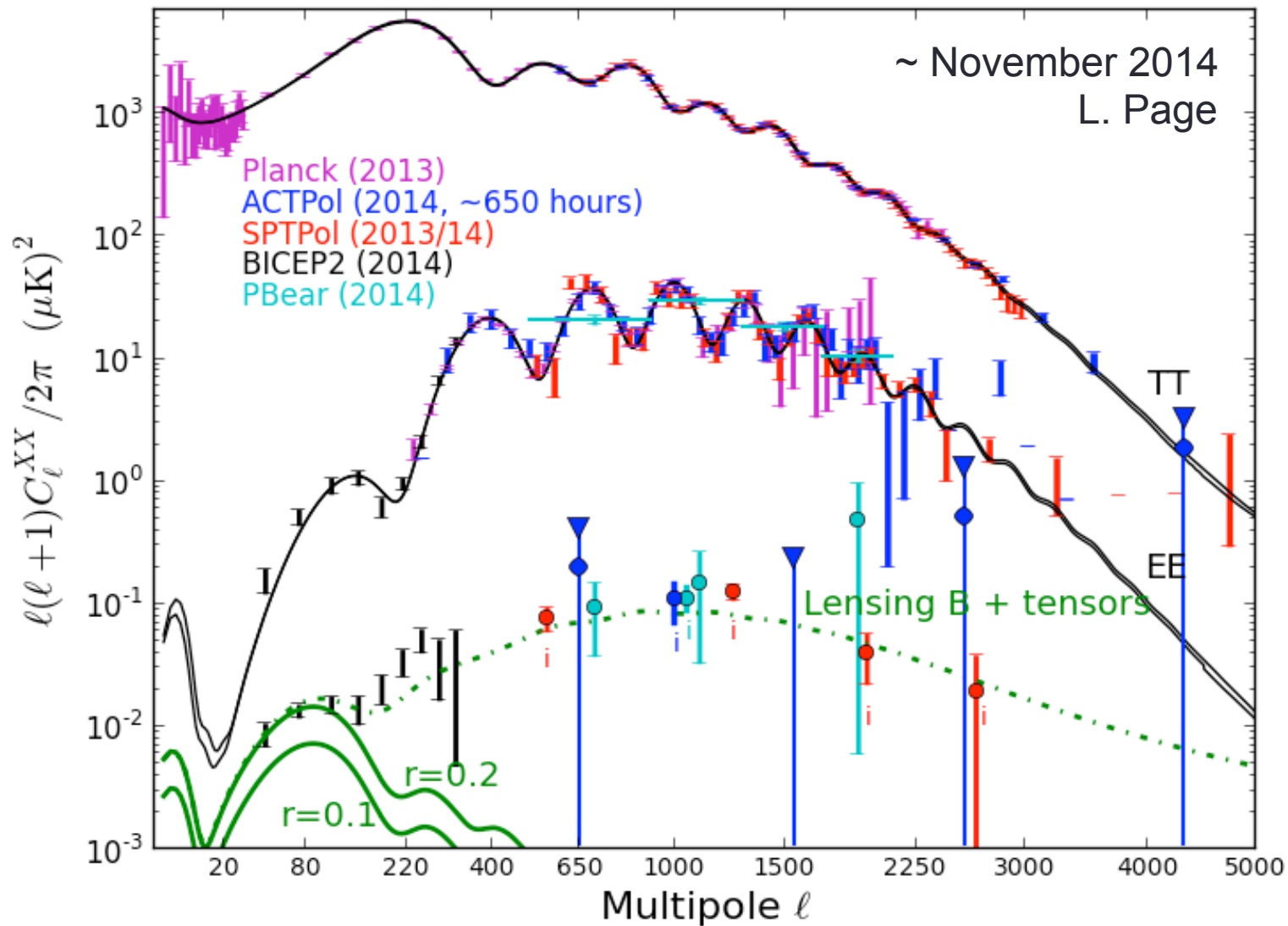


CMB Status: Temperature & Polarization

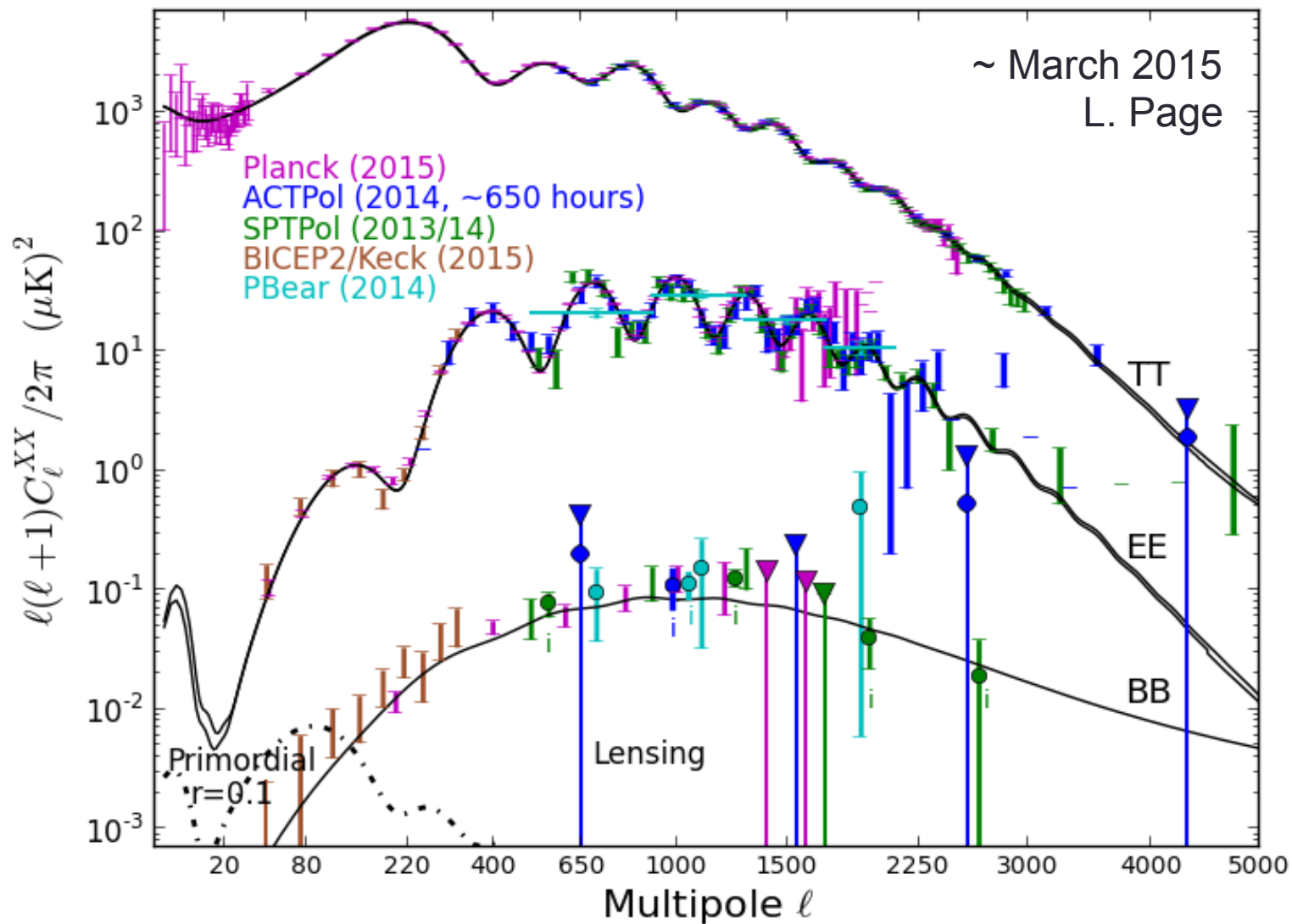
- Planck – full sky maps with 4' resolution available...
- Rich cosmological and galactic data sets...
- Consistency with 6 parameter cosmological model...
- Consistency among numerous experiments...



CMB Status: Temperature & Polarization



CMB Status: Temperature & Polarization



CMB Status: Temperature & Polarization

- Temperature power spectra characterized over \sim four decades by a variety of experiments...
- No surprises with E -mode power spectra...
- Indirect detections of B -mode via lensing...
- Joint BICEP2/Keck/Planck analysis limit on scalar to tensor ratio, $r < 0.12$, at 95% confidence. Marginalizing over dust and r , lensing B -modes are detected at 7σ significance. Dust a significant foreground at 150GHz...

P.A.R. Ade et al., "Joint Analysis of BICEP2/Keck Array and Planck Data" PRL (2015) 114, 101301.

CMB Coming Soon...

Analyzing available Polarization Data:

- Planck (space, intermediate ell)
- BICEP2/Keck (ground, low ell)
- SPTPol (ground, high ell)
- ACTPol (ground, high ell)
- POLARBEAR (ground, high ell)
- EBEX (balloon, intermediate ell)
- ABS (ground, low ell)

Launch/Deploy in 2015

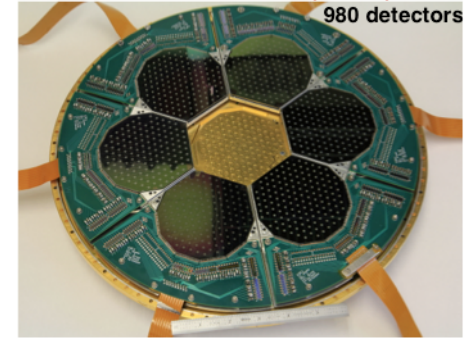
- SPIDER (balloon, low ell)
- PIPER (balloon, low ell)

Funded extension ~20,000 detectors

- SPT3G
- Advanced ACTPol
- POLARBER/Simons Array

EBEX Focal Plane (1 of 2)

980 detectors



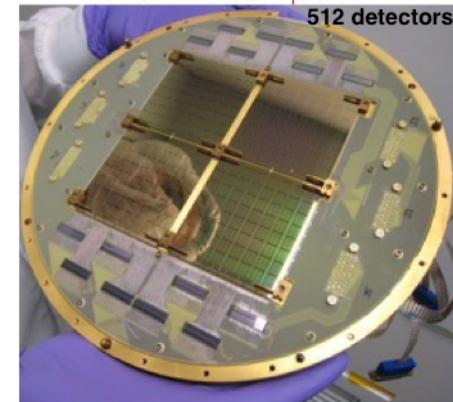
POLARBEAR focal plane

1274 detectors



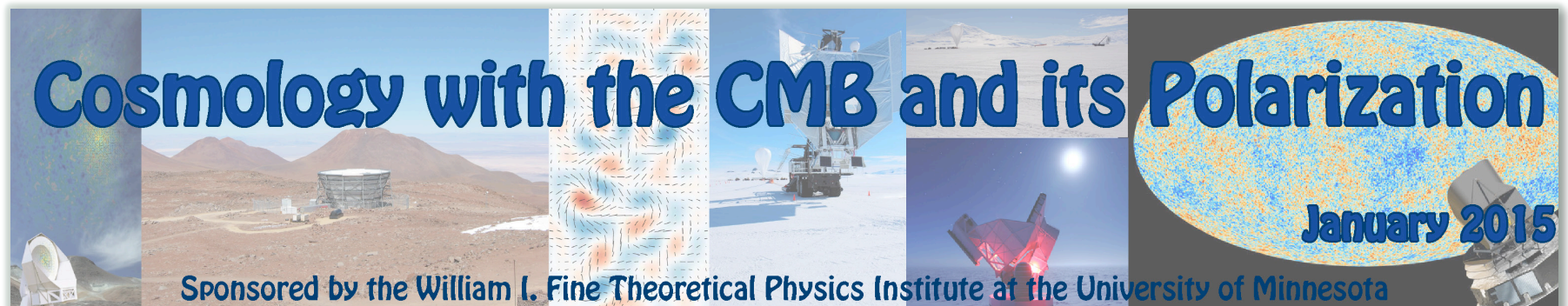
BICEP-II focal plane

512 detectors



CMB Community Meeting and Inputs

- Response to NASA's PhysPAG Charge – Provide input Inflation Probe and relation to other flag ship missions...
- Minneapolis CMB Workshop held January 12-14, 2015
 - IPSIG Satellite Discussion – Large Mission: to be or not to be?
 - What input to provide for the Mid-Decade Review process?
 - How should NASA respond to international opportunities?
 - Relation to CMB-S4 recommended as DOE project also discussed.
- Community Town Hall Telecon held March 4, 2015



Inflation Probe Mission Landscape

United States: NASA

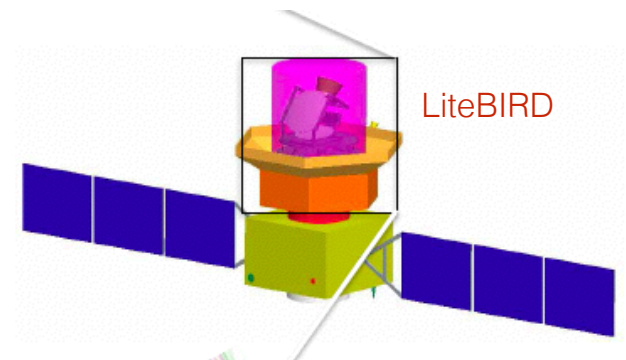
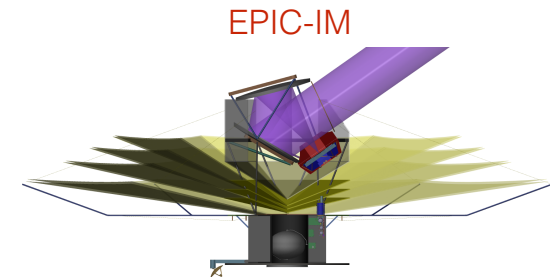
- Case for Inflation Probe mission case to be reviewed by a Mid-Decadal Panel
- BEPAC cost (~2008): ~\$1.2B - \$1.33B
- PIXIE - submitted as Explorer class mission (2011)
 - Low Resolution (1.6 deg), LEO, FTS Spectrometer

Europe: ESA M4 (~E600M cost cap)

- CORe+Light: \$720M; CORe+Extended: \$850M
 - medium resolution (5 arcmin), L2
 - Strong Community Backing
 - *...not selected to go forward...*

Japan: JAXA – ongoing discussions

- LiteBIRD (includes US contribution)
 - Low Angular Resolution, LEO
 - Less than \$500M



Inflation Probe Science Interest Group:

- Goal is to develop a US community response which articulates a consensus for a Inflation Probe mission priorities. Inputs from all members of the community are welcomed.
- Inflation Probe SIG website and mailing list:
<http://pcos.gsfc.nasa.gov/sigs/ipsig.php>
<http://pcos.gsfc.nasa.gov/sags/ipsag/ipsag-maillist.php>
- Physics of the Cosmos Program Analysis Group (PhysPAG) Inflation Probe Science Interest Group (IPSIG)
Community Representatives: Amber Miller & Ed Wollack



Backup...

CMB Polarization Stage-IV

- CMB-S4 recommended for DOE project
- Large scale instruments using ~250,000 detectors

Project/Activity	Funding Scenarios			Higgs	Neutri	Dark M	Cosm.	The Ur	Techni
	Scenario A	Scenario B	Senario C						
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									
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

...proposed experimental configuration will achieve $\sigma(m_\nu) = 16 \text{ meV}$ and $\sigma(N_{\text{eff}}) = 0.020$. Present lower bound derived from atmospheric and solar neutrino oscillation data is ~58 meV...

K.N. Abazajian, et al., "Neutrino physics from the cosmic microwave background and large scale structure," *Astropartical Phys.* (2015) 63, 66-80.