THE COSMIC MICROWAVE BACKGROUND RADIATION AND ITS POLARIZATION

Edward J. Wollack
Inflation Probe Science Interest Group (IPSIG)
NASA / Goddard Space Flight Center
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CMB: Past and Present...
Cosmic Microwave Background: Polarization Anisotropies

**Inflation Paradigm:**
Quantum fluctuations in the metric and inflaton expand to astronomical scales.

*Scalar perturbations* create density perturbations.

*Tensor perturbations* create gravity waves that propagate from early to late times.

**Cosmic Microwave Background:**
Thomson scattering → CMB Polarization

- Density perturbations (scalar) – *E mode only*
- Gravity waves (tensor) – *E and B modes*
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

~ November 2014
L. Page
CMB Status: Temperature & Polarization

~ March 2016
L. Page
CMB Status: Temperature & Polarization

• Temperature power spectra characterized over ~ four decades by a variety of experiments…

• No surprises with $E$-mode power spectra…

• Indirect detections of $B$-mode via lensing…

• BICEP2/Keck analysis yields $r = 0.028 \pm 0.026$ and $r < 0.09$ at 95% confidence


CMB Coming Soon...

Analyzing available Polarization Data:
- Planck (space, intermediate ell)
- BICEP2/BICEP3/Keck (ground, low ell)
- SPTPol (ground, high ell)
- ACTPol (ground, high ell)
- POLARBEAR (ground, high ell)
- EBEX (balloon, intermediate ell)
- ABS (ground, low ell)
- SPIDER (balloon, low ell)

Launch/Deploy in 2015/2016
- PIPER (balloon, low ell)
- CLASS (ground, low ell)

Funded extensions to ~20,000 detectors
- SPT3G
- Advanced ACTPol
- POLARBER/Simons Array
CMB Polarization Mission Planning

• NASA Inflation Probe to provide high-sensitivity measurements over entire sky enabling extraction of all cosmological information from CMB in polarization.
• B-mode polarization tests the physics behind the process of inflation plus tests of neutrino mass, mapping large-scale structure with gravitational lensing, and epoch of reionization science.
• Space provides access to the \textit{largest spatial scales} and \textit{entire spectral range} of interest – naturally complementing ground- and balloon-based capabilities...
Inflation Probe Mission Landscape

**NASA**
- NWNH: Case for Inflation Probe mission under review by Mid-Decadal Panel
  - Cost (BEPAC, ~2008): $1.2 - 1.3B$
  - **Science** *Inflation, Lensing, Clusters, Neutrinos, Galactic*
- PIXIE - submitted as Explorer class mission (2011)
  - Low Resolution (~1.6 deg@150GHz), LEO, FTS
  - **Science**: *Inflation, Spectral Distortions, Galactic*
  - Resubmission in late 2016

**ESA M5, CORe+**
- E550M ESA + E150M Members = E700M
- Submission expected in Spring 2016; Launch = 2028
- Medium resolution (5.5 arcmin @150 GHz), L2
  - **Science**: *Inflation, Lensing/Clusters, Neutrinos, Galactic*
- Intense interest in Europe for US contribution
- Strong European/US community backing
Inflation Probe Mission Landscape

**JAXA, LiteBIRD**
- Low Angular Resolution, Wide Spectral Coverage
  - **Science:** Inflation, Galactic
- Includes US contribution (Focal Plane)
- Phase A studies funded in Japan (to be concluded in 2017) and in the US (part of MO2014, to be concluded in summer 2016)
- Launch (if approved): 2025

**ESA/JAXA Collaboration**
Discussions ongoing between ESA/JAXA and science teams regarding possible collaboration as part of M5: Main discussion point is targeted angular resolution
CMB Community Meetings and Inputs

• Responses to NASA’s PhysPAG Charges:
  • Flagship Mission Concepts Study for the 2020 Decadal Survey
  • Whitepaper: “The Inflation Probe: A Probe-Class Astrophysics Mission”

• Meeting, “Towards the European Coordination of the CMB Programme”, held August 31-1 September 2015, Villa Finaly.


• AAS Special Session, "The Polarization of the Cosmic Microwave Background”, San Diego, June 15, 2016.

• Workshop Series, “Cosmology with CMB-S4”:
  • University of Michigan, September 21-22, 2015
  • Lawrence Berkeley National Laboratory, March 7-8, 2016
  • University of Chicago, September 19-20, 2016  ➔ save the date!
Inflation Probe Science Interest Group:

• Goal: 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

• Physics of the Cosmos Program Analysis Group (PhysPAG) Inflation Probe Science Interest Group (IPSIG) Community Representatives: Amber Miller & Ed Wollack