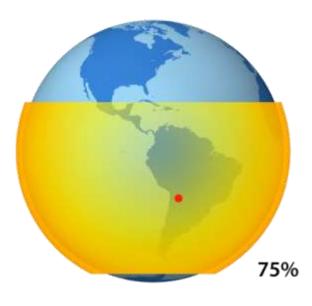
The Cosmology Large Angular Scale Surveyor (CLASS)

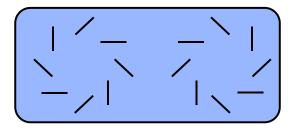
Tom Essinger-Hileman

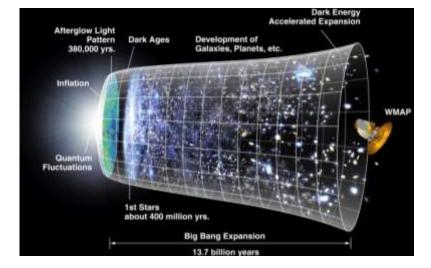
Quarknet 2014 Johns Hopkins University



HF W2 W1

The Search for B-Modes

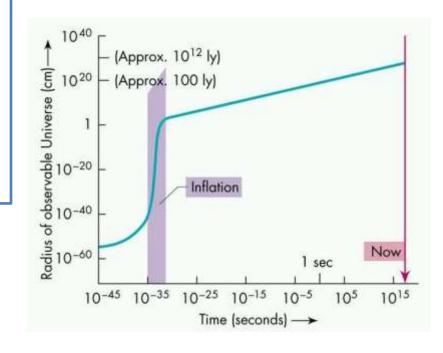


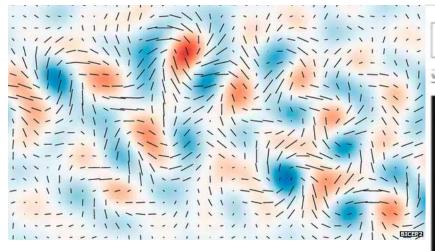


Measurement of primordial B-modes would be:

- Confirmation of Inflation.
- Measurement of energy scale of inflation.
- Evidence of quantum-gravitational effects.

Probing physics at energies around 10¹⁶ GeV, 13 orders of magnitude above those achievable by the Large Hadron Collider (LHC).





BICEP2 Announcement

Made headlines with measurement of celestial B-modes.

Open question whether they are seeing B-modes in the CMB or from our galaxy.

CLASS (among other experiments) is critical in verifying result.

'All the News That's Fit to Print"

VOL (LXIII No. 56,444 1000 10-00-

The New Hork Times



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CAMBRIDGE, Mass. -- One

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Lost Jet's Path Space Ripples Reveal Big Bang's Smoking Gun Seen as Altered Via Computer

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A Campaign Inquiry in Utah

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PUTIN RECOGNIZES CRIMEA SECESSION, DEFYING THE WEST

Decree Increases Fears of Annexation by Russia, Despite More Sanctions

> Reports a deput

rung future action

BUSTEVEN LAS INVERS and PETER BAKER

MUSICW - Proglest Visit-Romber and Ulerainian Spory sur V. Putits of Recoil signed a including. leaves on Monday Serminary rekeeping adviser to Mr. Putter Degni G. agniting Cristen as a "somernige. and independent state," last press manufer of Russia, and the grandwick for assertation Odeeting J. Manusceller, a Patie dofting the Canod States sity and the chairwassan of the ederation Council, the sport and Lisrope had heart after they es of Romita's Parts etr fint financial was term against Monovy smore the The European Ublan follows in in Likrain began with superfaces against 2 Revolu-

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> 3 Years of Strife And Cruelty Put Syria in Free Fall

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The Cosmology Large Angular Scale Surveyor (CLASS) experiment

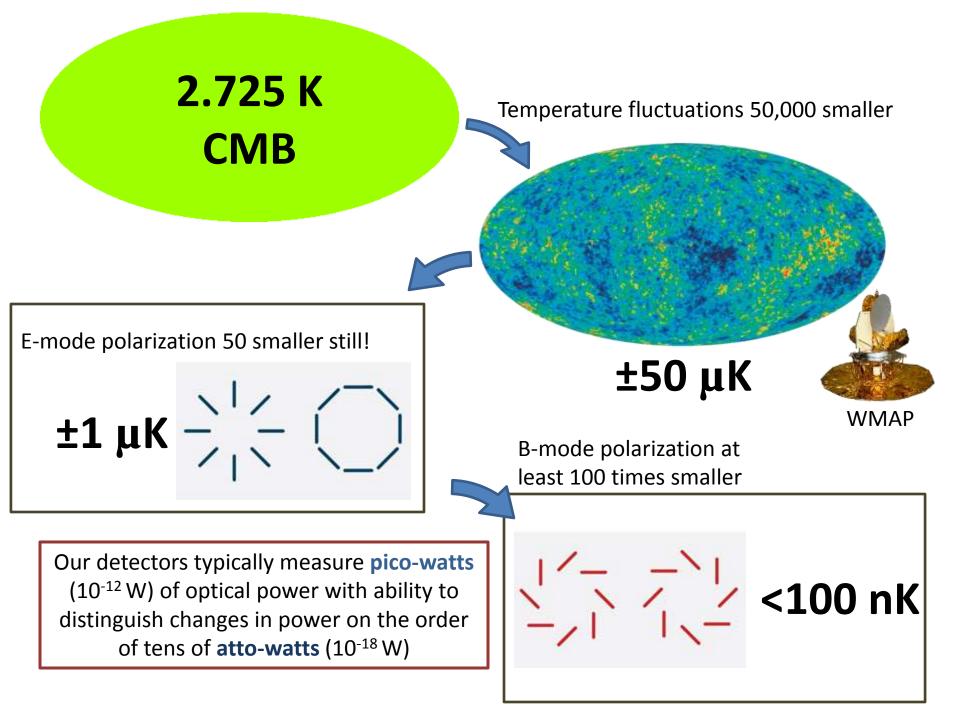
- Searching for gravitational-wave background from the birth of the universe, during a period of inflationary expansion.
- Observing at millimeter wavelengths in four observing bands.
 - Allows separation of Milky-Way signal from CMB.
- High-altitude site (17,000 ft above sea level!) in the Atacama Desert of Chile to reduce loading from the atmosphere.

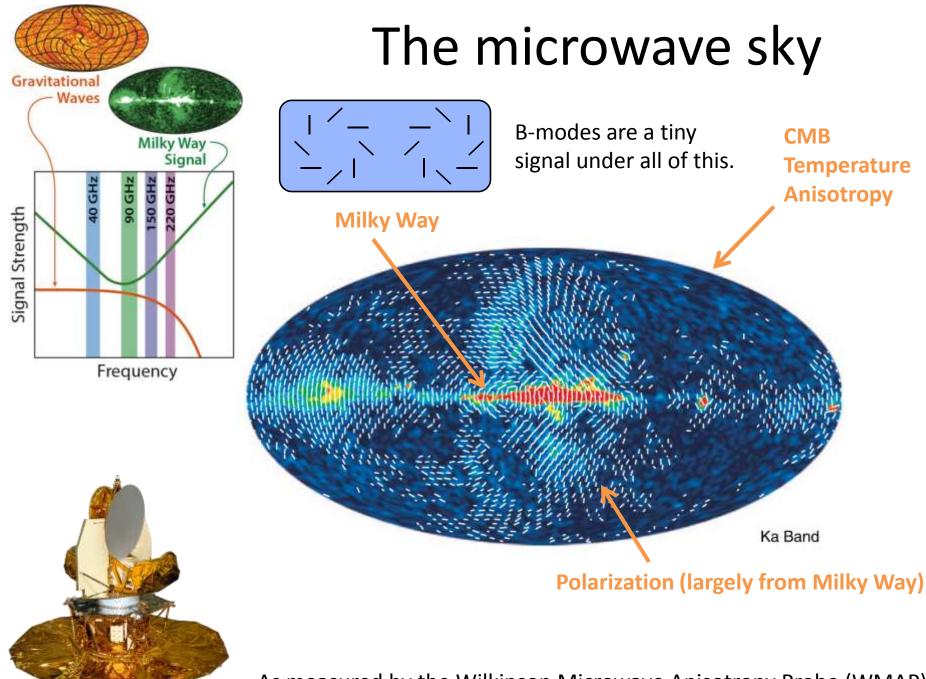


CLASS coming soon!

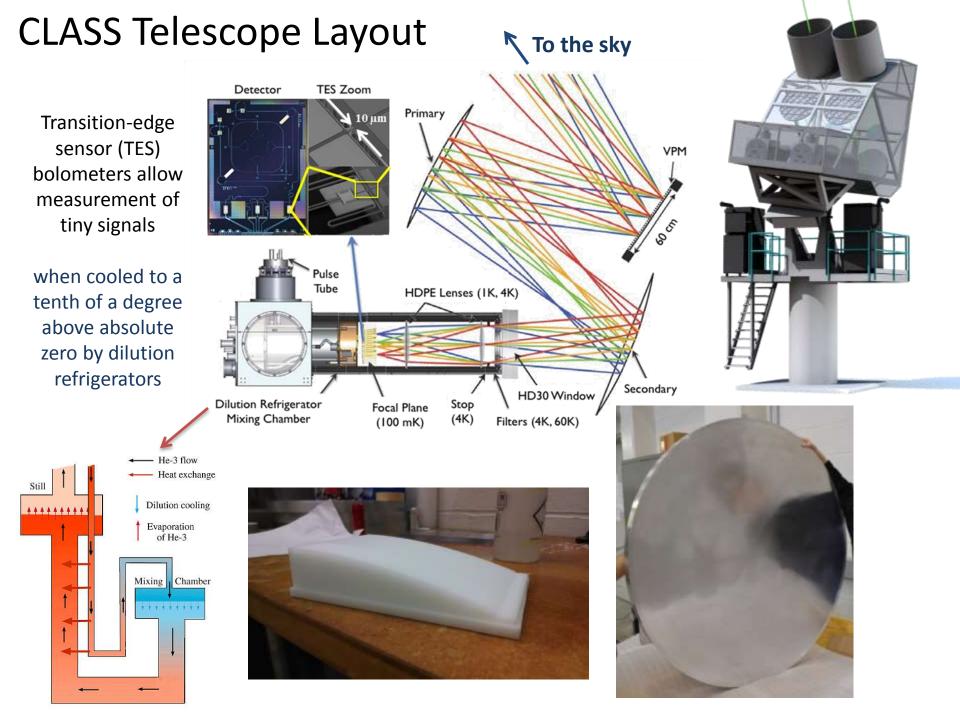


The Atacama Desert is one of the premier sites for microwave astronomy.





As measured by the Wilkinson Microwave Anisotropy Probe (WMAP)

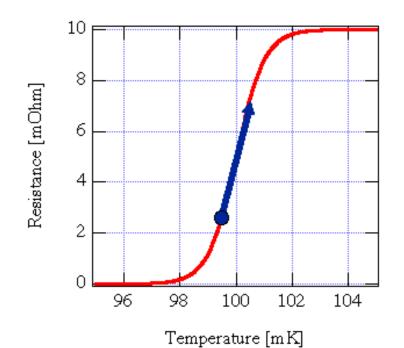


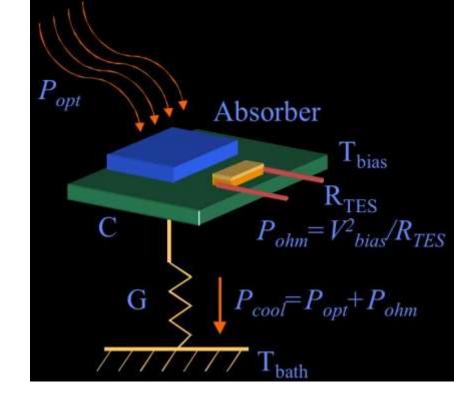
Transition-edge sensor (TES) bolometers

Cooled to below 100 mK to reduce thermal noise in the detector.

Allows detectors to be "background-noise limited" – the dominant noise seen by the detectors is from *quantum fluctuations of the incoming light*.

This arises from different numbers of photons arriving at different times.





A TES is a superconducting film operated at its transition between superconducting and normal-metal states.

Negative electrothermal feedback keeps detectors at a stable point on the transition.

The TES acts a thermometer. Optical power changes the temperature of an absorber, and we measure this change in temperature.

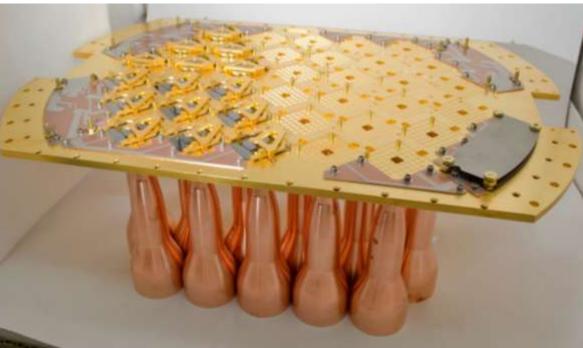
CLASS detectors

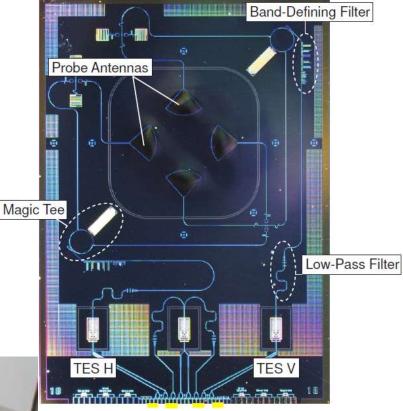
Two perpendicular linear (horizontal H and vertical V) polarizations are separated by metal probe antennas.

Microwave circuitry on a silicon detector chip carries signals from H and V probes to separate TES bolometers.

Example shown is for lowest frequency (40 GHz) channel of CLASS.

Detectors are made at NASA Goddard Space Flight Center







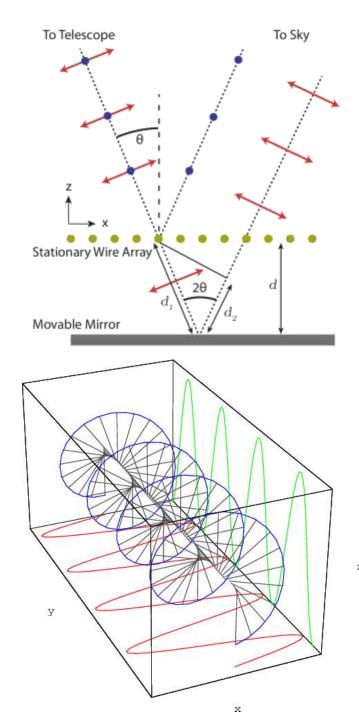
Variable-delay polarization modulators (a.k.a. VPMs)

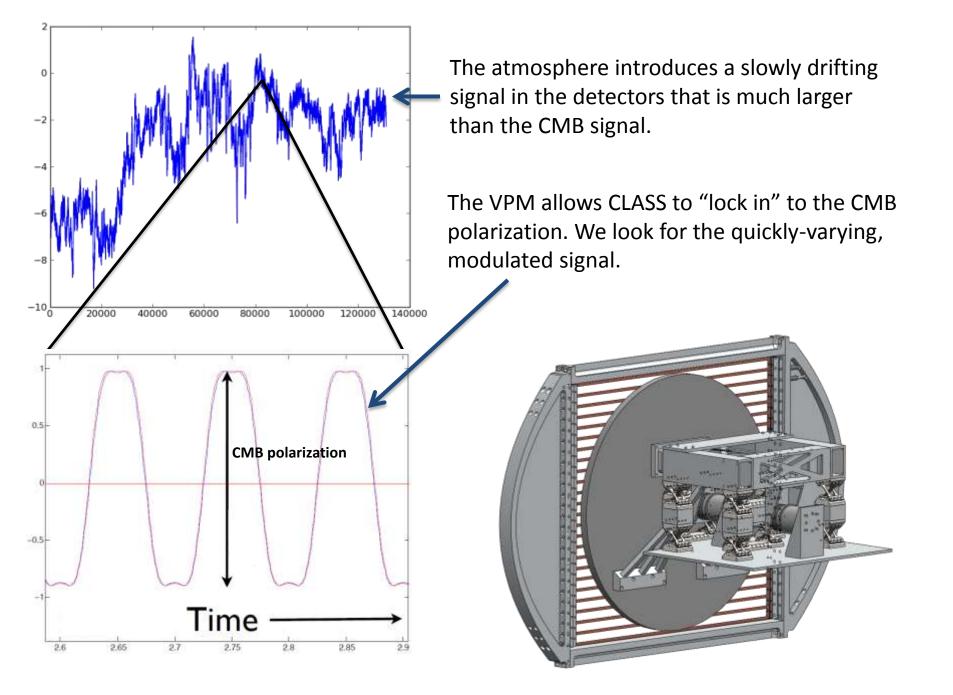
The VPMs consist of a polarizing wire grid in front of a movable mirror.

As the mirror moves, horizontal and vertical polarizations are phase-shifted relative to each other and recombined.

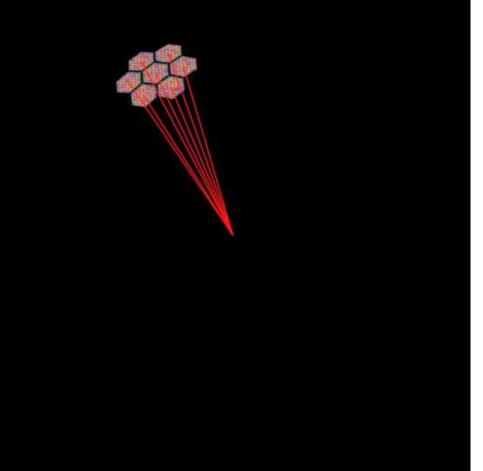
This changes linear to circular polarization, and vice versa. CLASS detectors are only sensitive to vertical polarization.

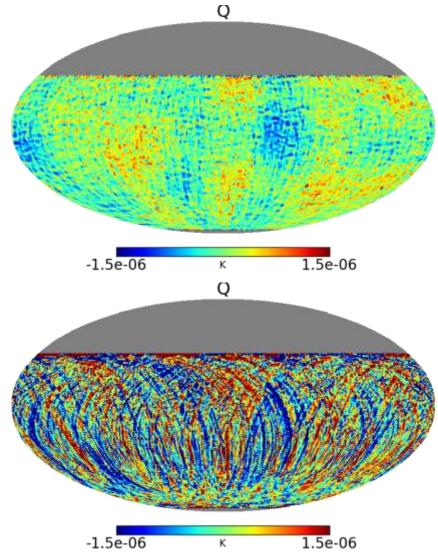
The CMB is linearly polarized (no circular polarization), so as the VPM mirror moves the CMB polarization signal is turned on and off.





The advantages of modulation

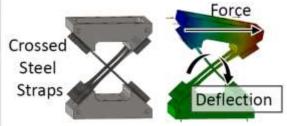




VPM development at JHU



- 1.5 miles of copper-coated tungsten wire.
- Wire grid under 1 ton of tension.
- Wires are wrapped on a cylindrical mandrel in a customized computer-controlled milling machine.





Questions?

