The BICEP2 *and* Keck Array

CMB polarization experiments

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Cosmology in Northern California
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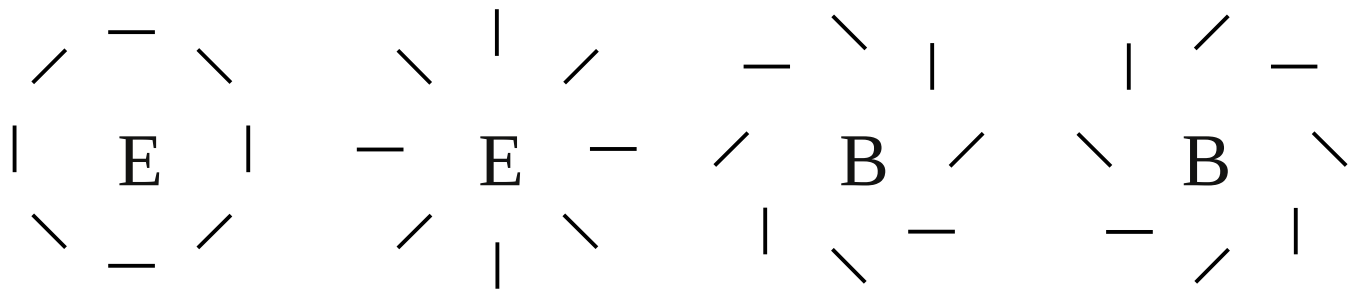
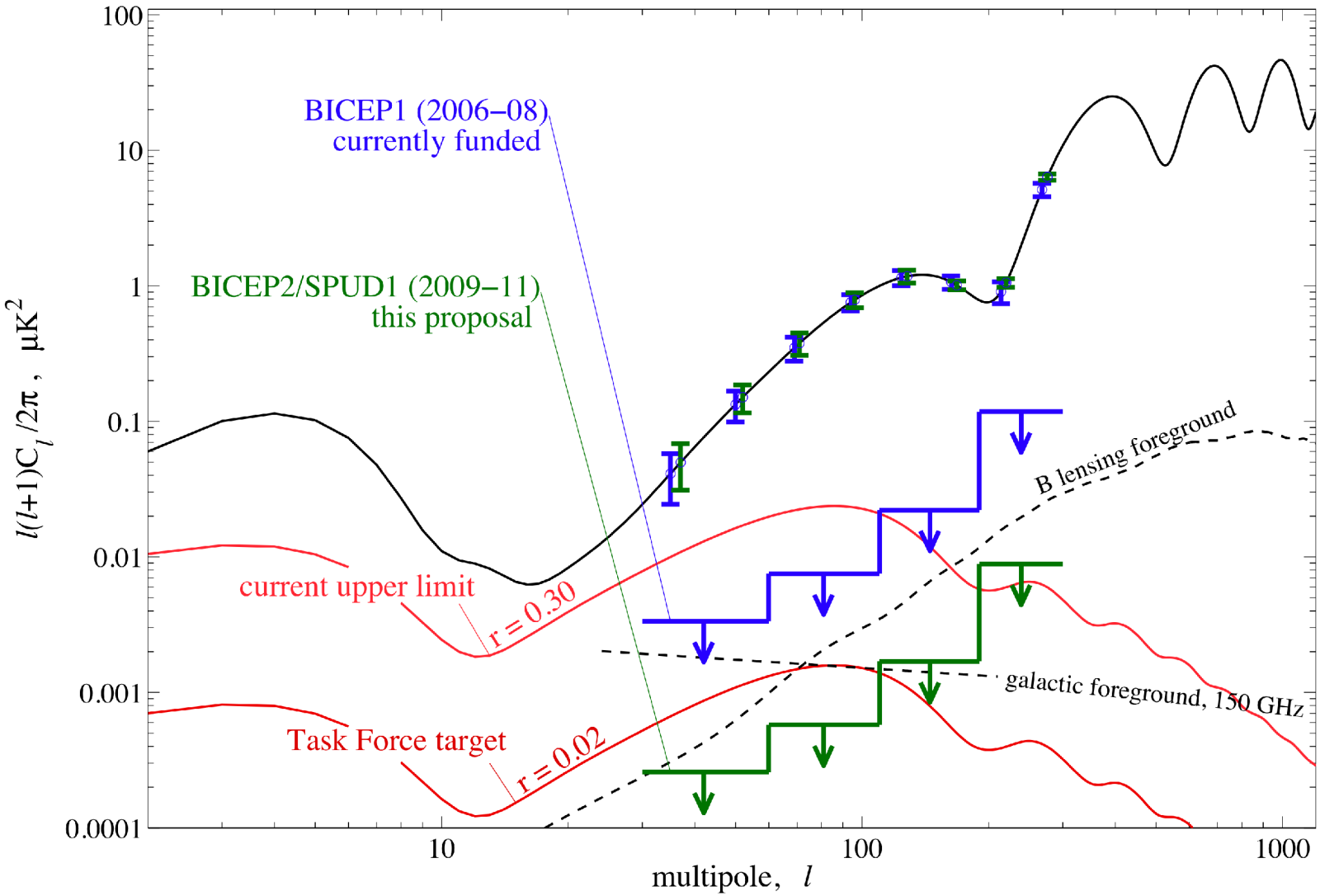
B modes – a "smoking gun" of inflation

- Inflation can explain flatness, homogeneity, isotropy of the universe.
- Generic prediction: primordial gravitational waves.
- CMB polarization:
  - "E modes" primarily from density fluctuations.
  - "B modes" a clean signature of gravity waves → inflation.

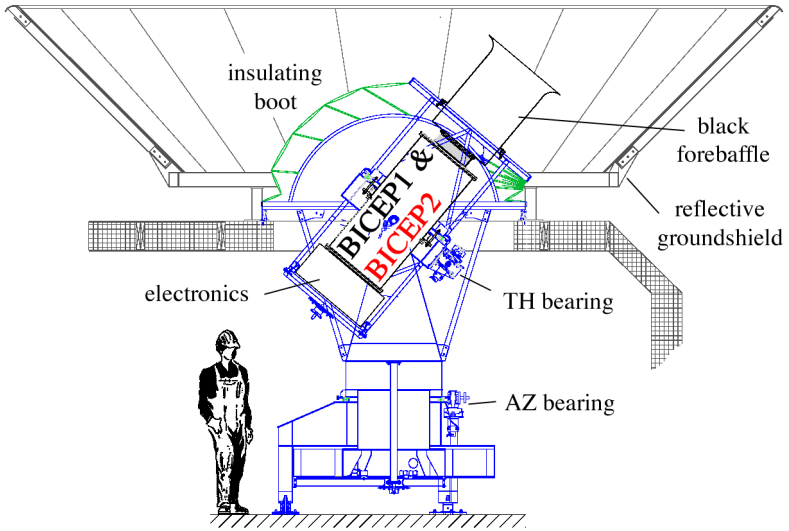


...but it's hard to see them.

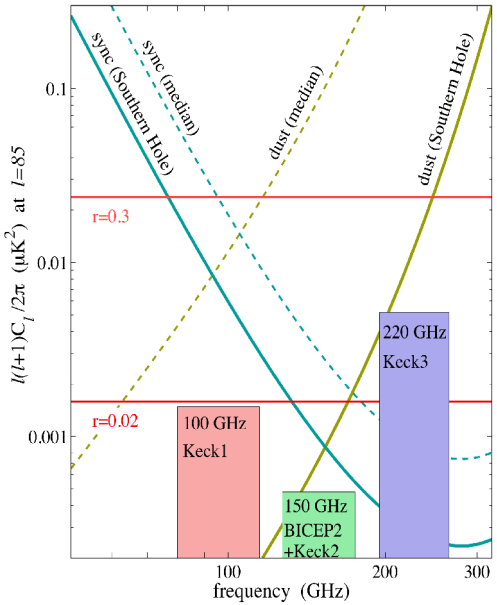


BICEP strategy

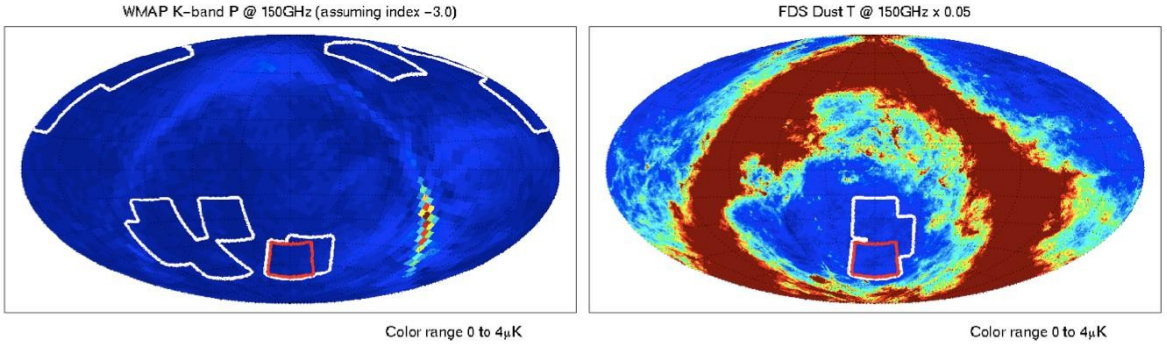
- Compact, simple design
- Small 30-cm aperture
- Just enough to resolve degree-scale anisotropies
- Use 150 GHz for lowest foregrounds
- Go very deep on the cleanest patch of sky
- Focus on control of systematics



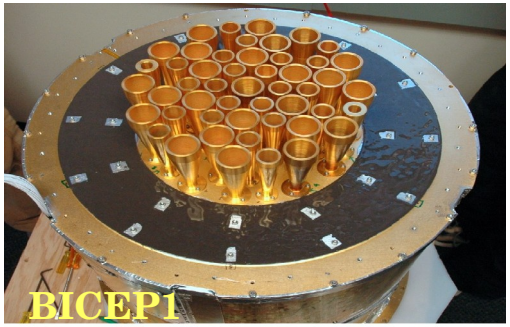
DSL BICEP platform (7500 lbs cap)

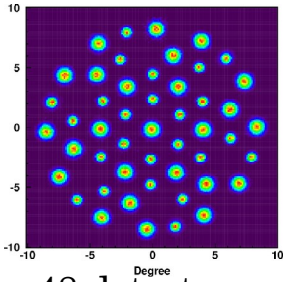


Clem Pryke & John Kovac

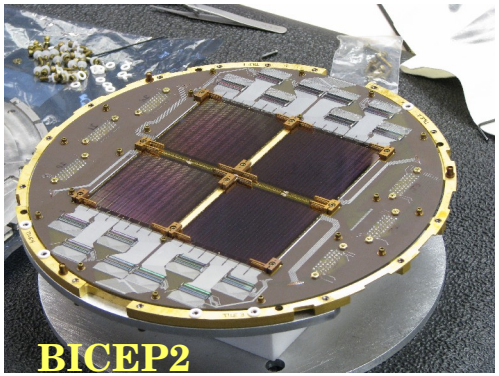


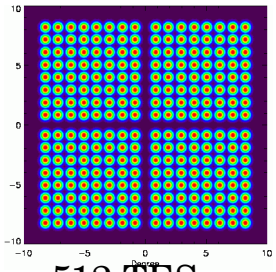
More detectors = more sensitivity



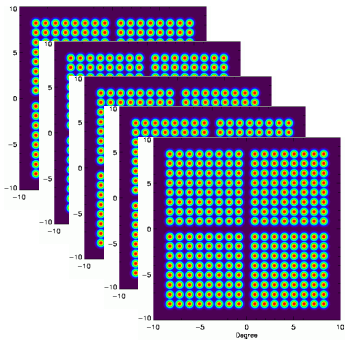


48 detectors
@ 150 GHz

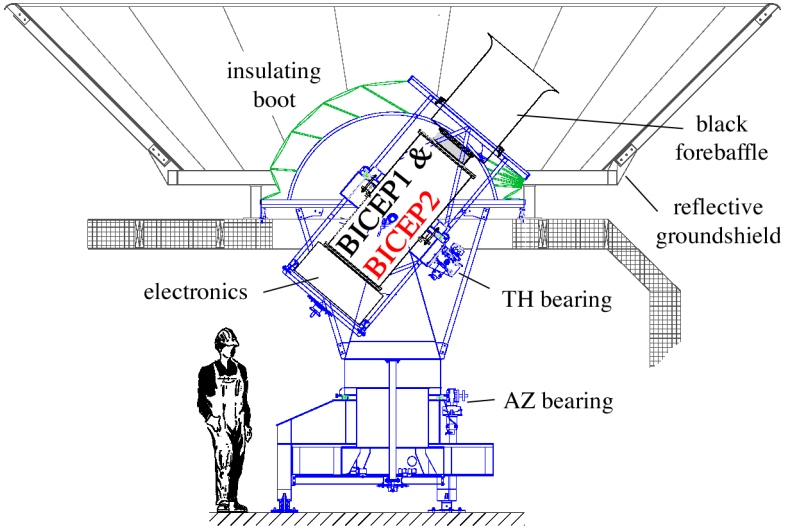




512 TESs
@ 150 GHz



3× BICEP2
(first year),
Up to 5×



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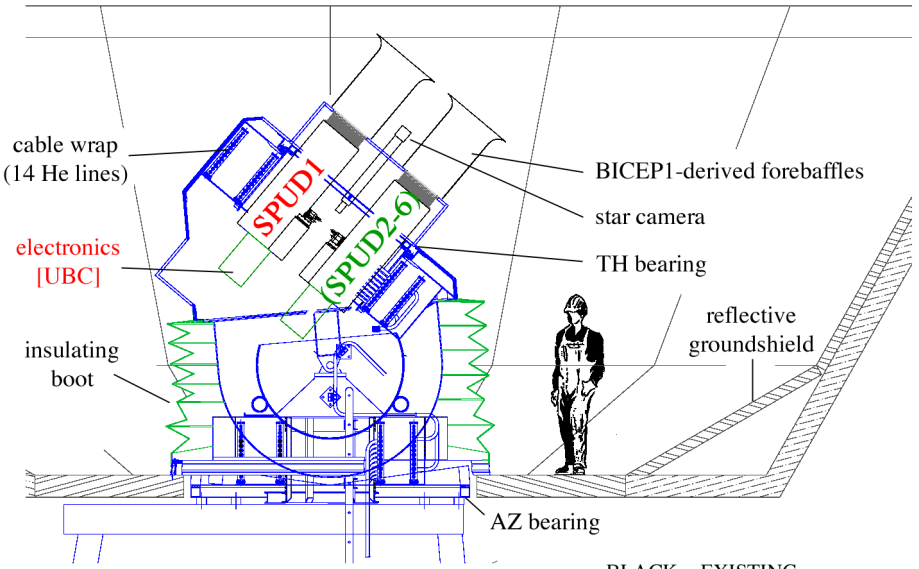
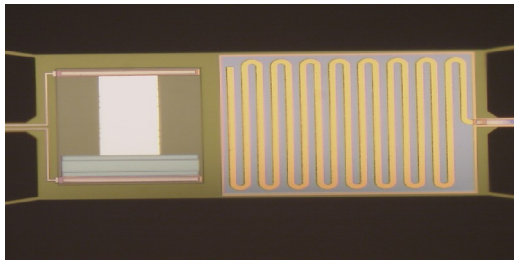


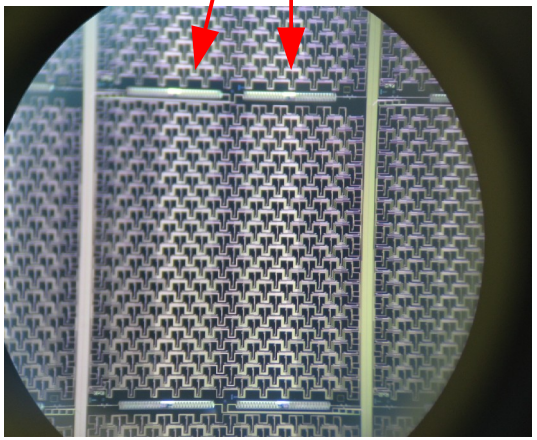
DASI tower (100,000 lbs cap)

BLACK = EXISTING
RED = FOR THIS PROPOSAL
GREEN = FUTURE PROPOSAL

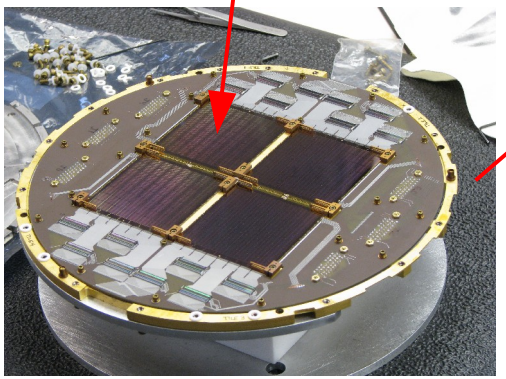
BICEP2 and Keck instruments



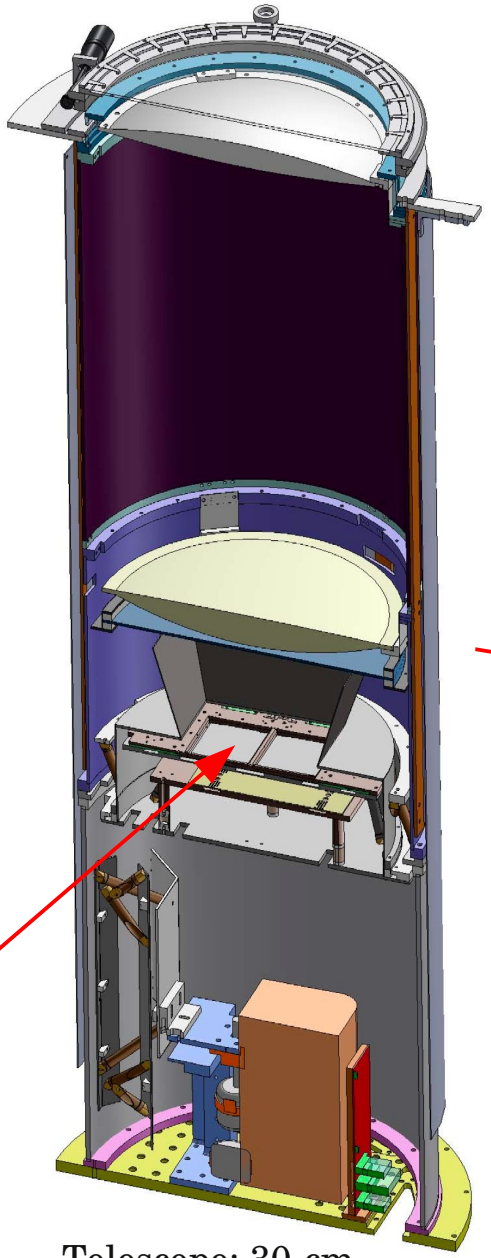
Ti TES detectors



Beam-forming antennas



Monolithic focal plane (250 mK)



Telescope: 30-cm refractor, optics at 4 K

Fast-scanning mount (5°/s)

Team BICEP2

Caltech
- *Andrew Lange*
- *Randol Aikin*
- *Justus Brevik**
- *Jeff Fillipini*
- *Sunil Golwala*
- *Viktor Hristov*
- *Angiola Orlando*
- *Marc Runyan*
- *Zak Staniszewski**
- *Grant Teply*

JPL
- *Jamie Bock*
- *Tony Bonetti*
- *Darren Dowell*
- *Hien Nguyen**
- *Anthony Turner*
- *Phil Wilson*

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- *John Ruhl*

CEA Grenoble
- *Lionel Duband*

NIST
- *Gene Hilton*
- *Kent Irwin*
- *Carl Reintsema*

Cardiff
- *Peter Ade*
- *Rashmi Sudiwala*

Harvard
- *John Kovac**
- *Chin-Lin Wong*

UBC
- *Mandana Amiri*
- *Bryce Burger*
- *Mark Halpern*
- *Matthew Hasselfield*

Minnesota
- *Clem Pryke*

UCSD
- *Jon Kaufman*
- *Brian Keating*

U Chicago
- *Erik Leitch*
- *Chris Sheehy*

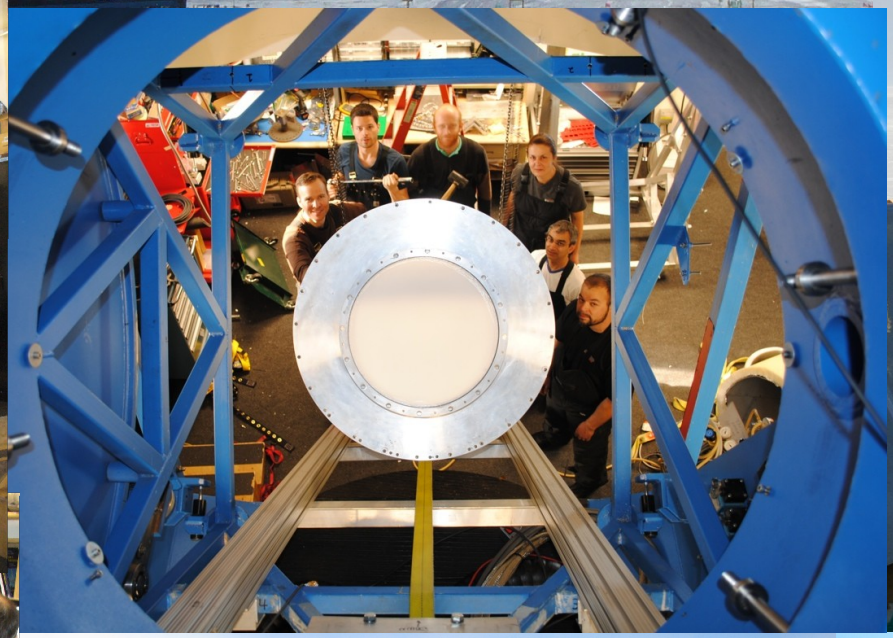
Stanford
- *Chao-Lin Kuo*
- *Walt Ogburn*
- *Sarah Stokes*
- *Jamie Tolan*

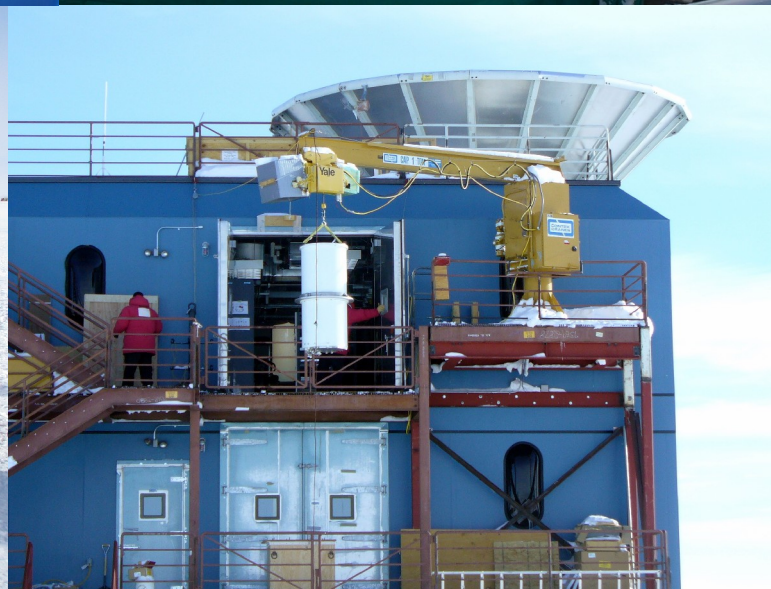
U. Toronto
- *Steve Benton*
- *Barth Netterfield*

South Pole
- *Steffen Richter******

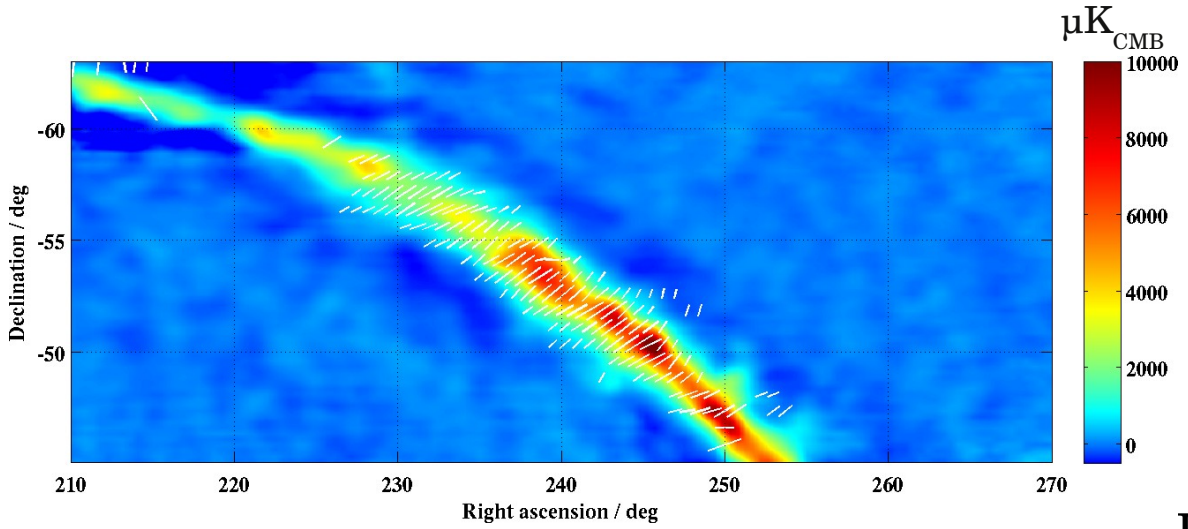
* *Winter at Pole*

BICEP2 - observing since Jan. 2010



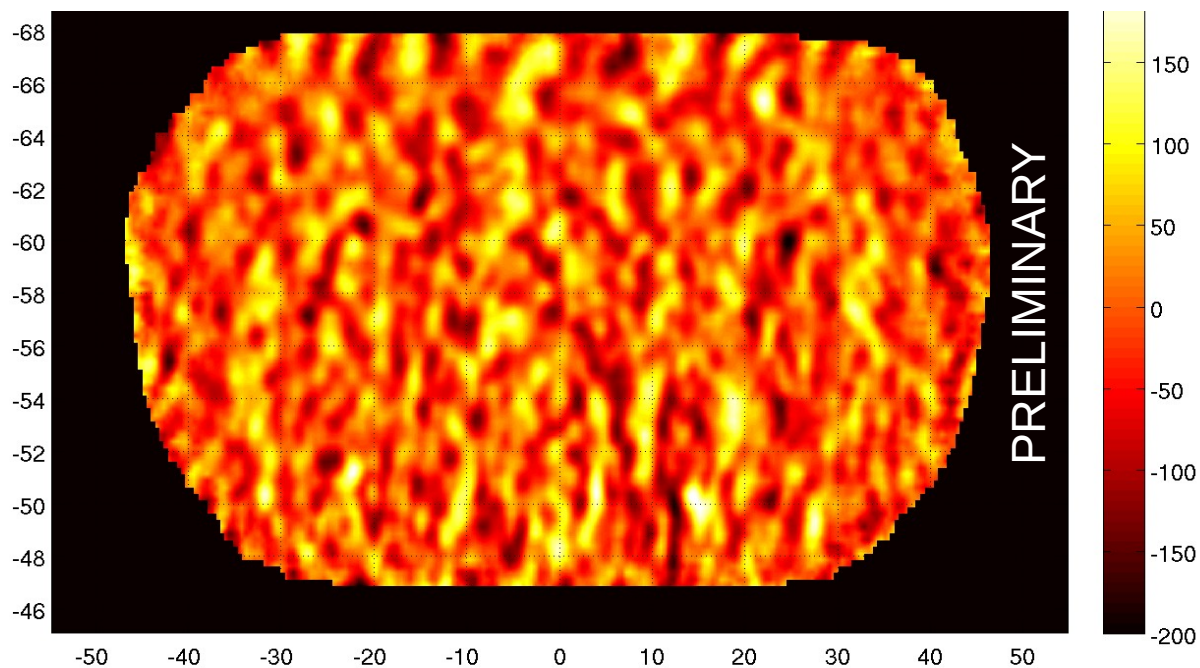


Preliminary BICEP2 maps



- Galactic bright field observed 6 hrs/3 days.
- Polarized at 1-3% because of spinning dust aligned in magnetic field of Milky Way
- BICEP2 clearly observes polarization

BICEP2 CMB (4 months)



- CMB temperature map
- 4 months of data
- Polarization analysis ongoing

Team Keck

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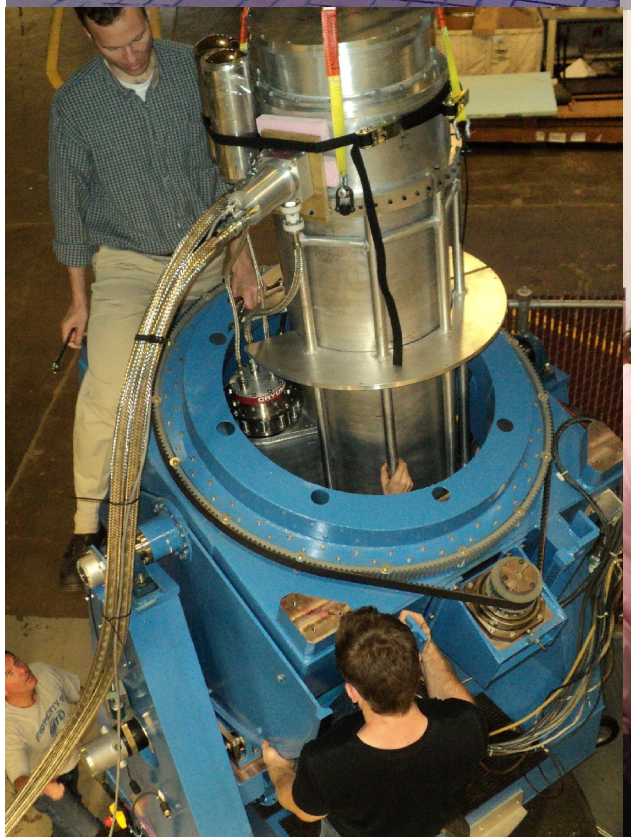
** Winter at Pole*



Conclusions

- BICEP2 is completing first year of data now
  - Meets sensitivity projections;
  - Initial CMB and galaxy maps look good,
  - Polarization maps in progress.
- Keck Array is deploying next 2 months!
- Systematics controllable down to r=0.01 or better
- Gain sensitivity by putting more detectors on the sky