BICEP2 and Keck Array: upgrades and improved beam characterization

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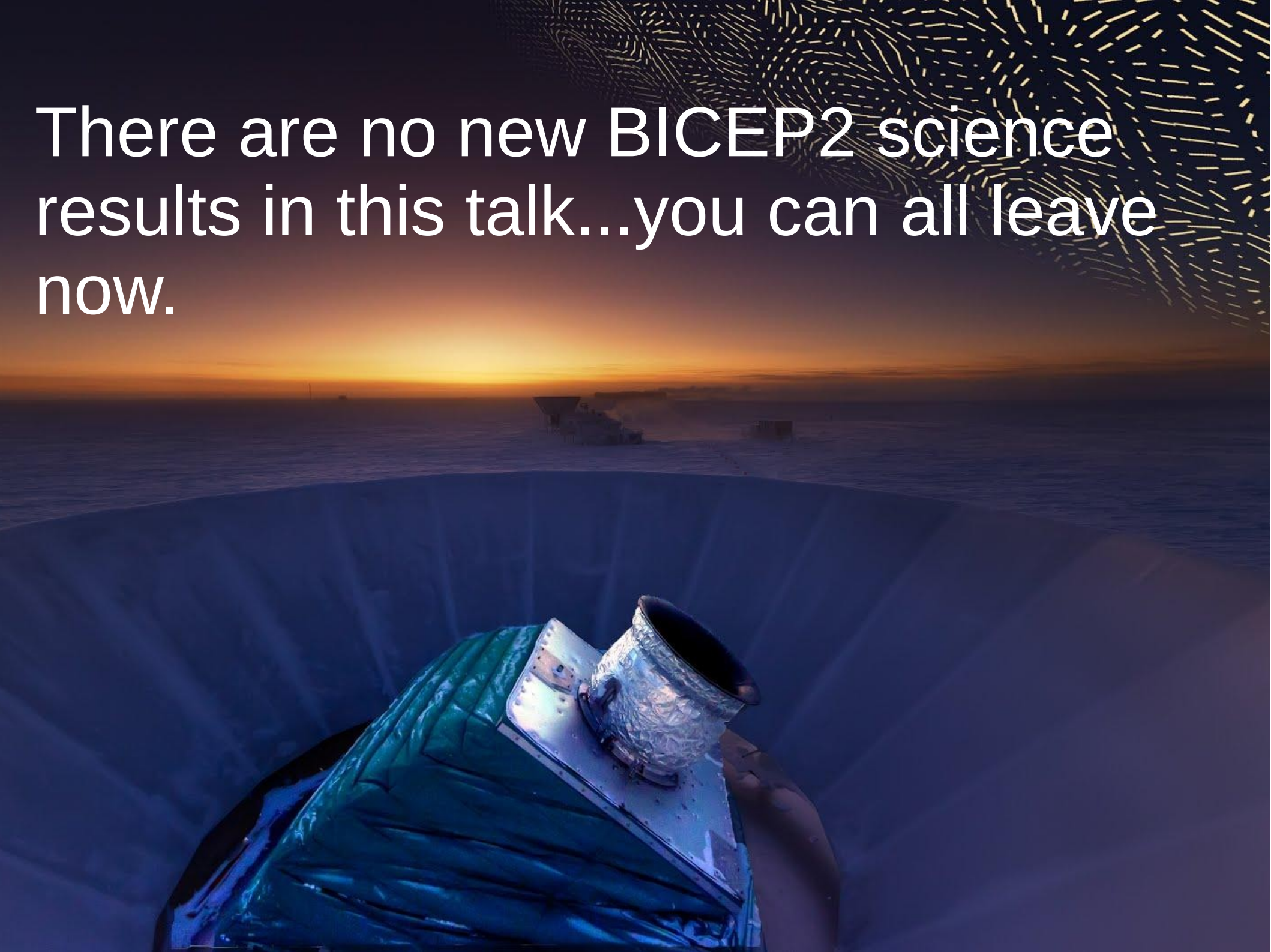
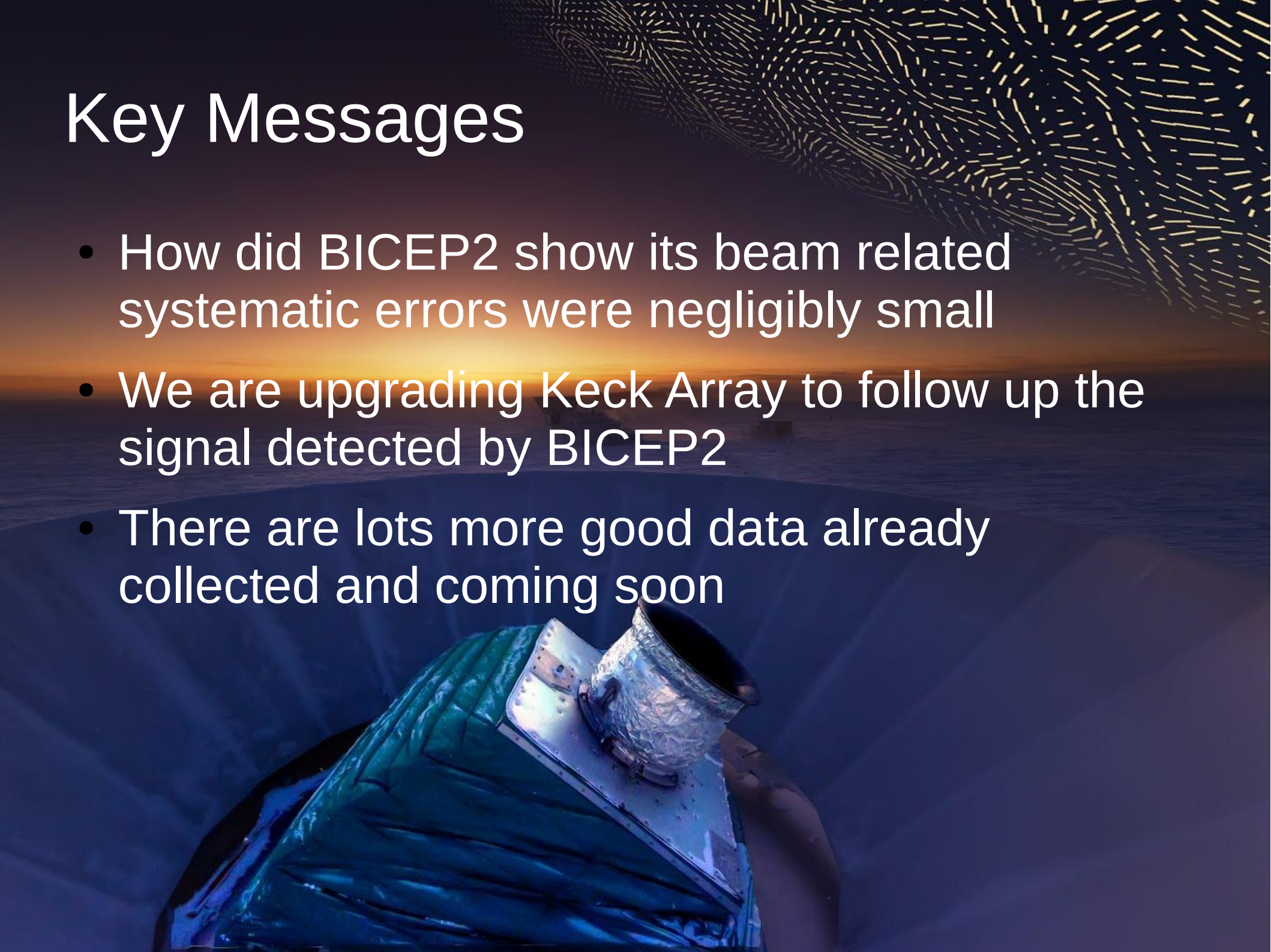

There are no new BICEP2 science results in this talk...you can all leave now.

Key Messages

- How did BICEP2 show its beam related systematic errors were negligibly small
- We are upgrading Keck Array to follow up the signal detected by BICEP2
- There are lots more good data already collected and coming soon



Outline of This Talk

- BICEP and Keck Program Overview
- Improvements in Beam Mapping
- Far Side Lobes and Reducing Forebaffle Loading
- Keck Array Sensitivity and Upgrades
- Deployment of 100-GHz Receivers for Keck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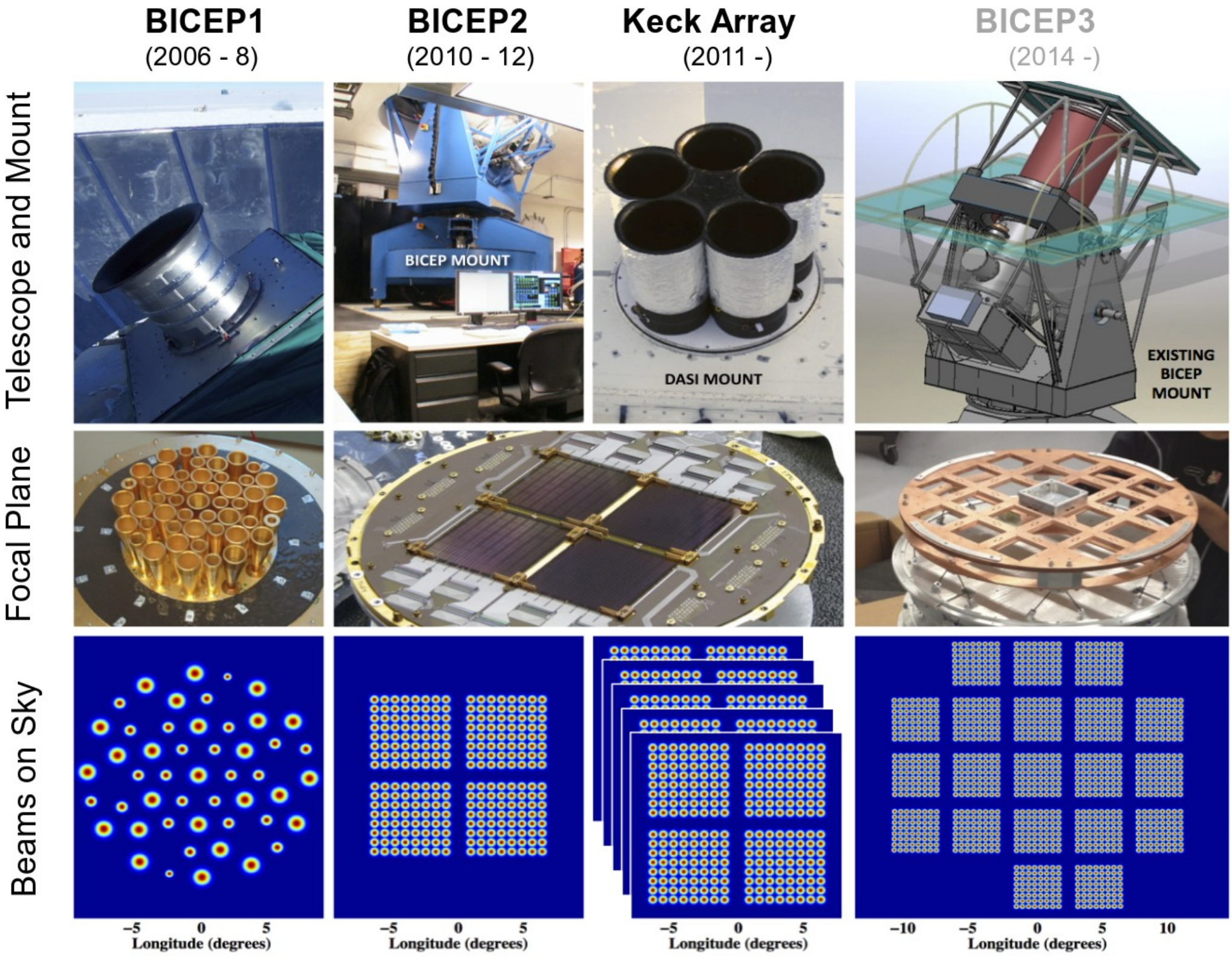

BICEP1
(2006 - 8)
BICEP2
(2010 - 12)
Keck Array
(2011 -)
BICEP3
(2014 -)
Telescope and Mount
BICEP MOUNT
DASI MOUNT
EXISTING BICEP MOUNT
Focal Plane
Beams on Sky
−5 0 5
Longitude (degrees)
−5 0 5
Longitude (degrees)
−5 0 5
Longitude (degrees)
−10 −5 0 5 10
Longitude (degrees)

Overview of BICEP1/2 and Keck Array

- All designed for measuring ell ~ 100 B-mode polarization signal from inflation
- All observe same low-foreground field from South Pole
- All have cold refracting telescopes: 26-cm aperture (far field is close!)
- All have boresight rotation
- All have absorptive co-moving forebaffles and stationary reflective ground shields

Characterize Far-field Beams with Artificial Sources

- Small aperture, masts, and flat mirrors allow far-field measurement
- Thermal choppers give high-fidelity, low-noise maps
- Amplified sources for polarization angle, far side lobes

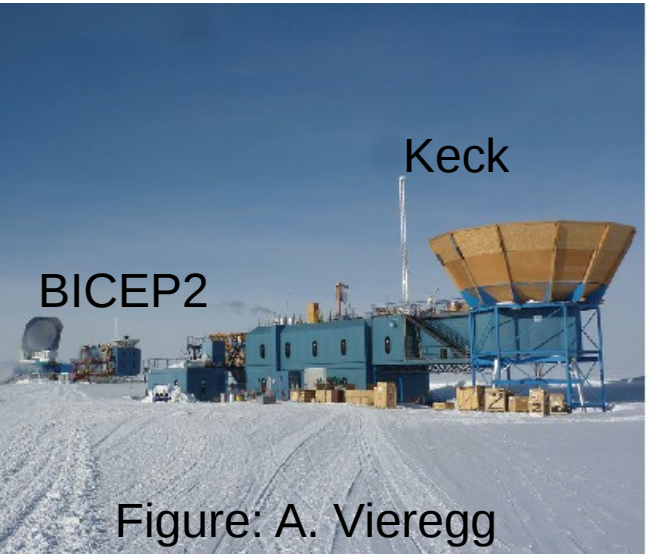
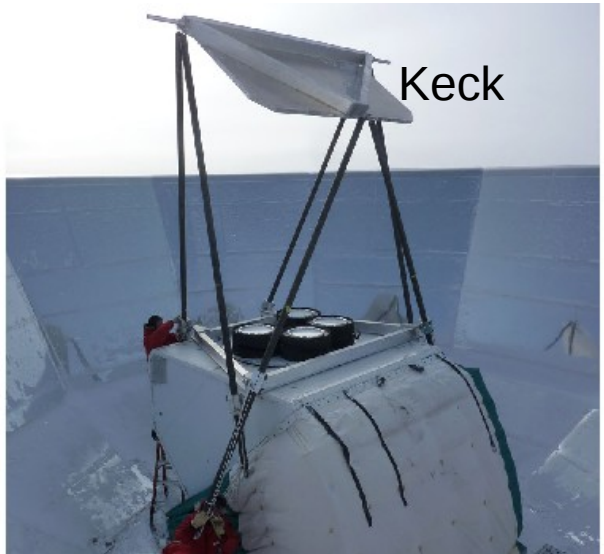
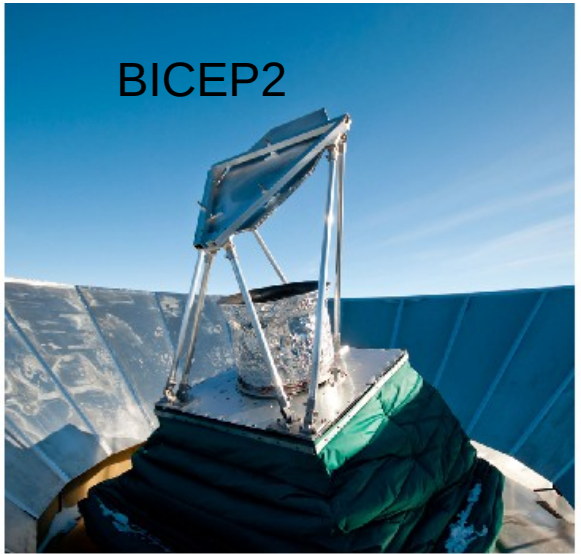


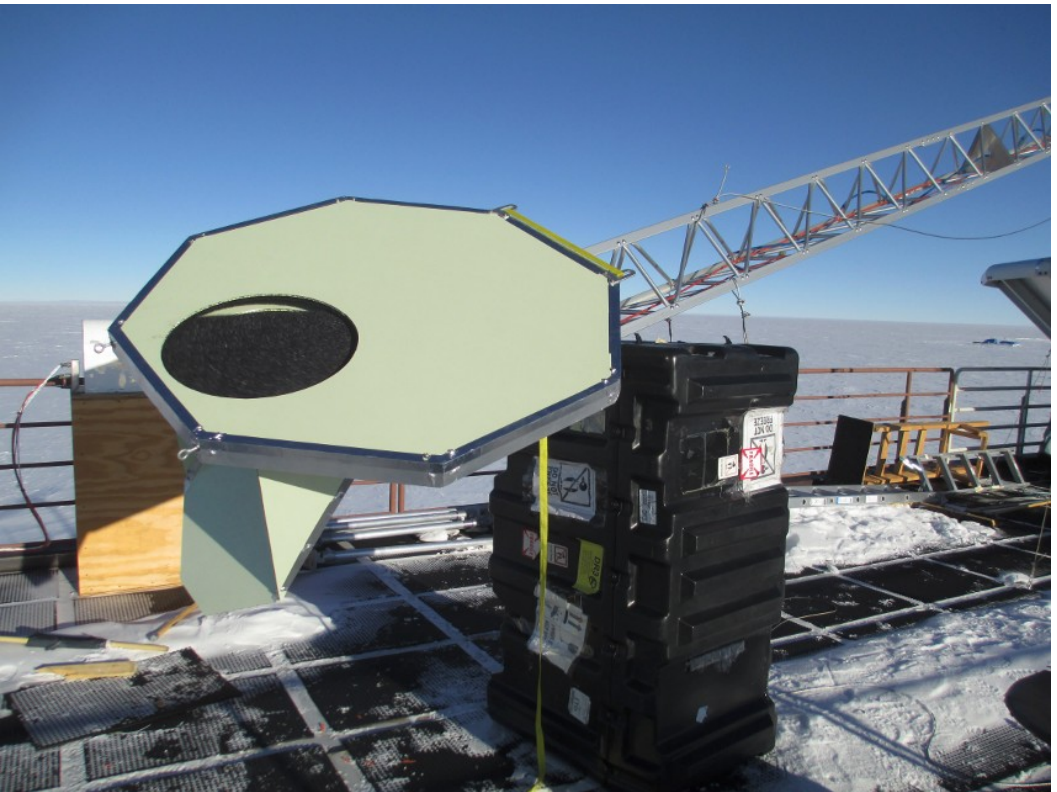
Figure: A. Vieregg





New thermal chopper made S/N low enough for BICEP2

- 45-cm aperture alternates between ~15 K sky and ~250 K Eccosorb at ~10 Hz
- ~3 times higher S/N per map than previous chopper



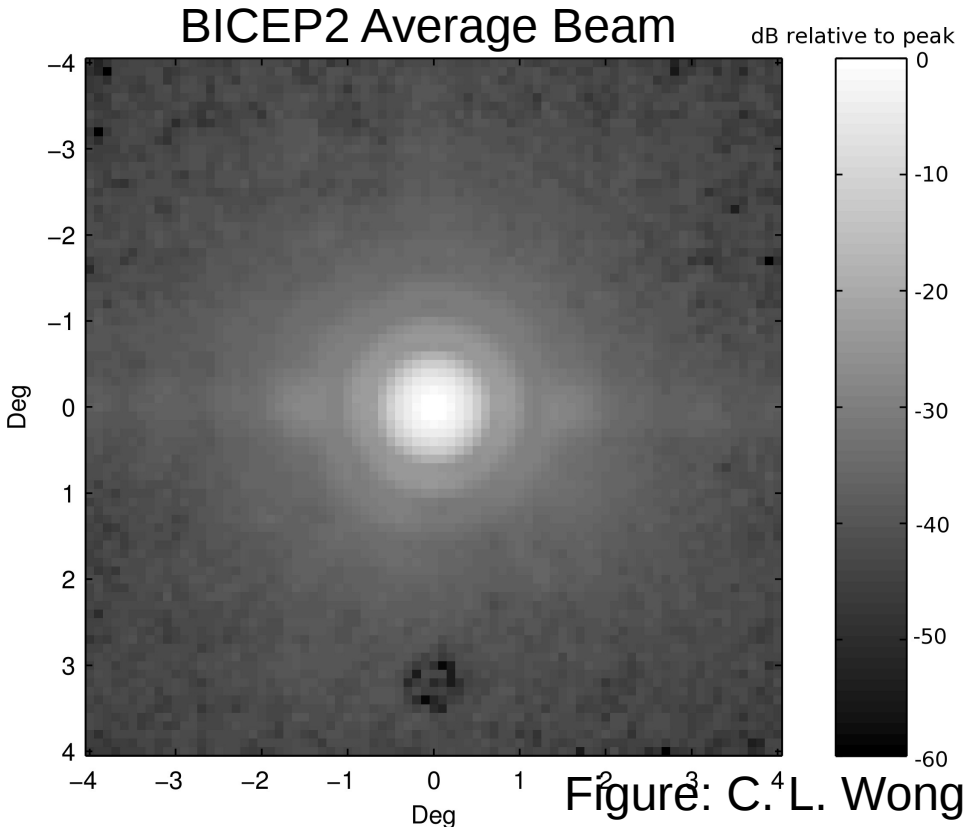
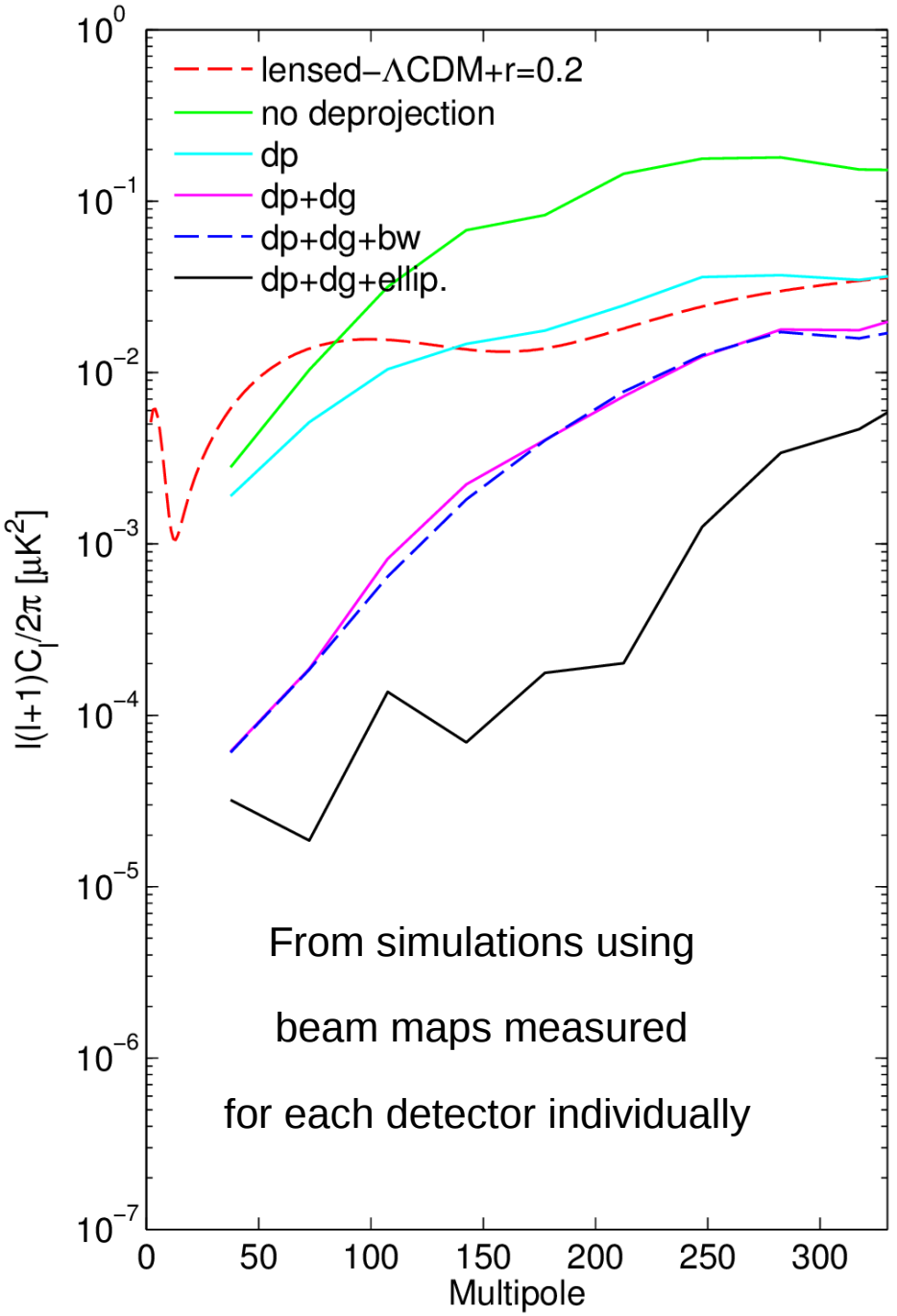
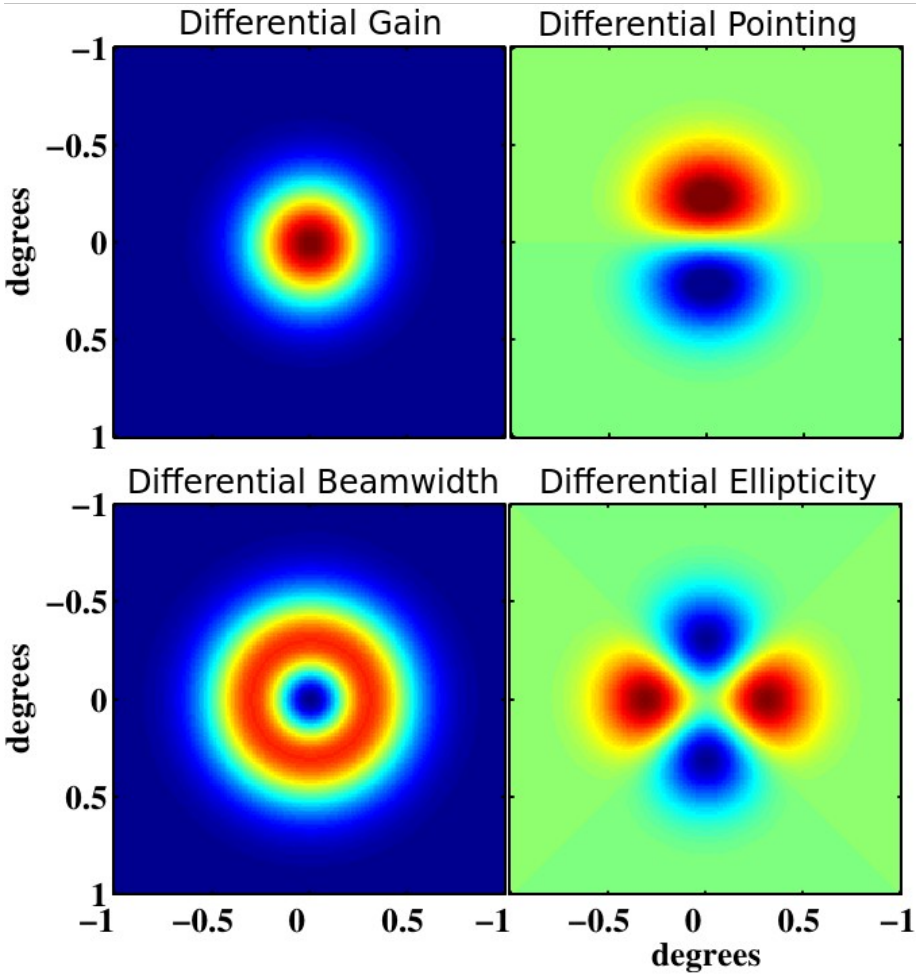


Figure: C. L. Wong

Systematics Removal: Deprojection



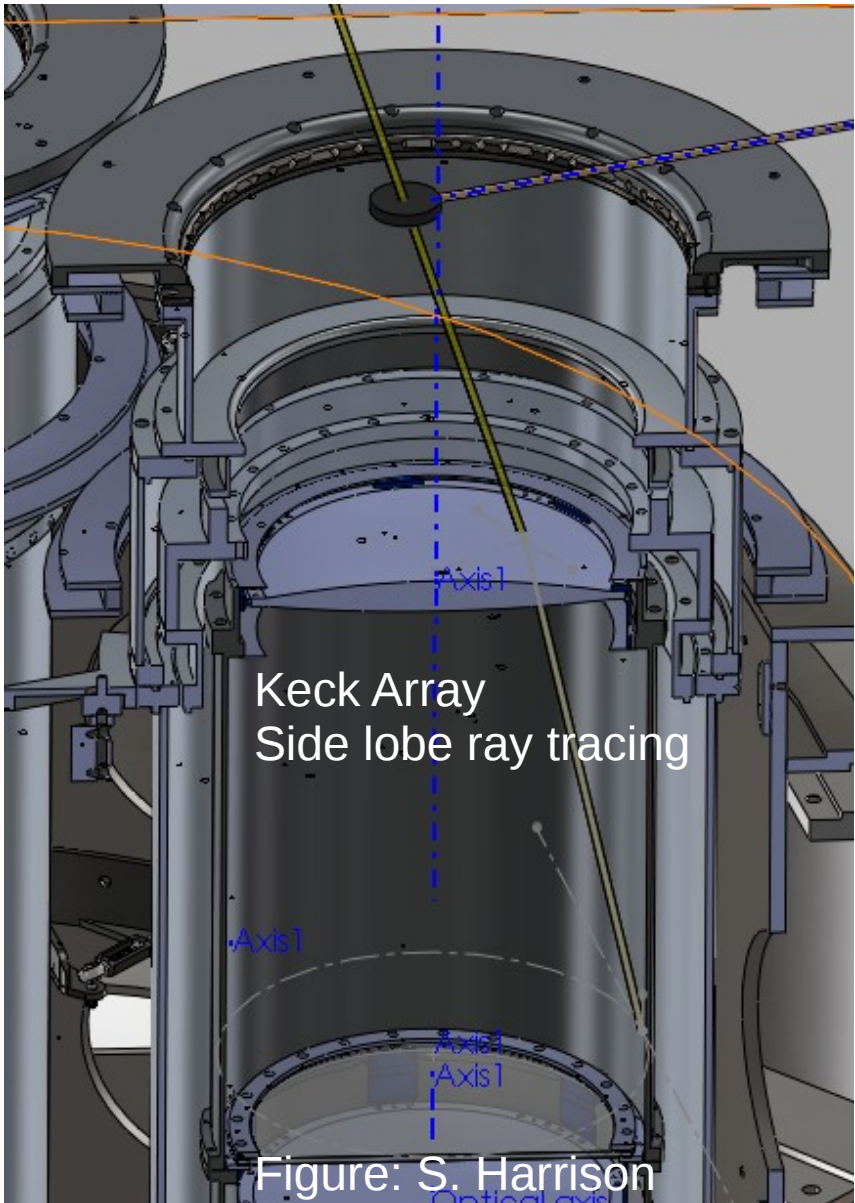
Technique developed to remove all types of leakage induced by differences of detector pair beam shapes



- Deproject diff gain and pointing (& subtract diff ellipticity)
- Use the Planck 143 GHz map to form template of the leakage
- Subtract the residual (equiv to r=0.001) from the data

Side lobe measurements identified a way to reduce Keck optical loading

- Forebaffle coupling contributed 5~10 K_CMB (3~6 K_CMB in BICEP2)
- Caused by reflections off inner telescope wall
- Lab measurements confirmed differences in shallow-incidence reflectivity between BICEP2 and Keck

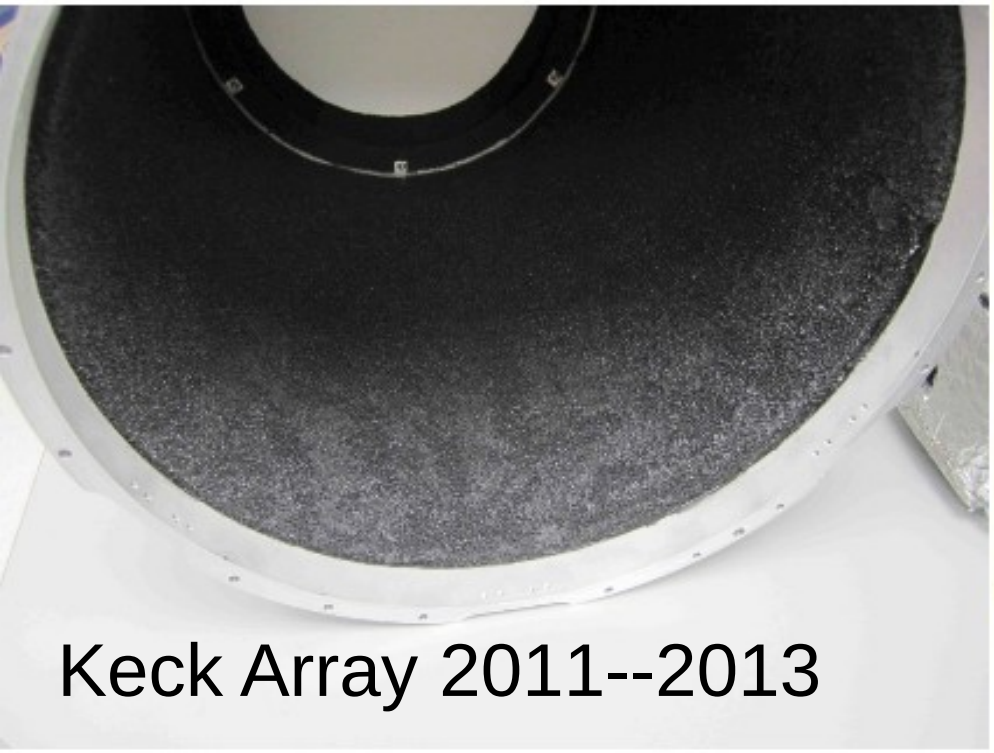


Keck Array
Side lobe ray tracing

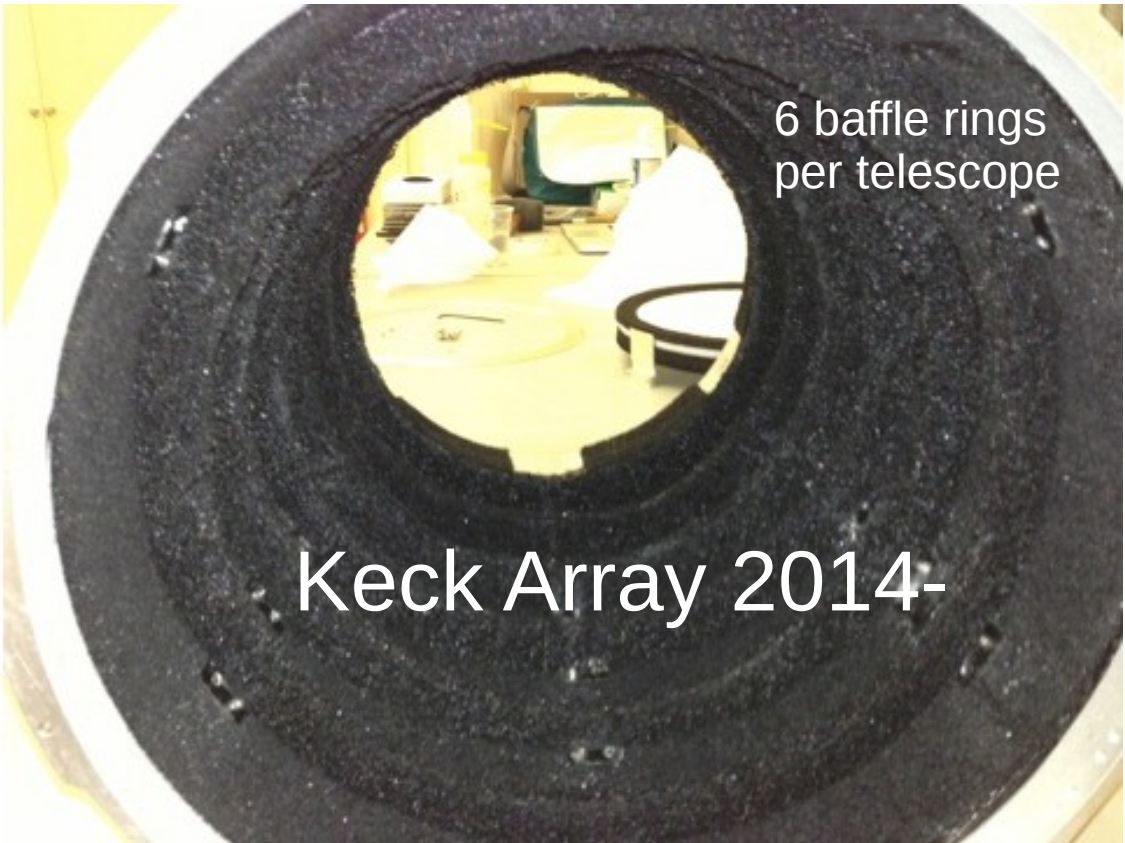
Figure: S. Harrison

Installation of internal baffles reduced loading

- Measured loading 2~4 K_CMB for Keck 2014
- Resulted in 5~10% improvement in sensitivity



Keck Array 2011--2013



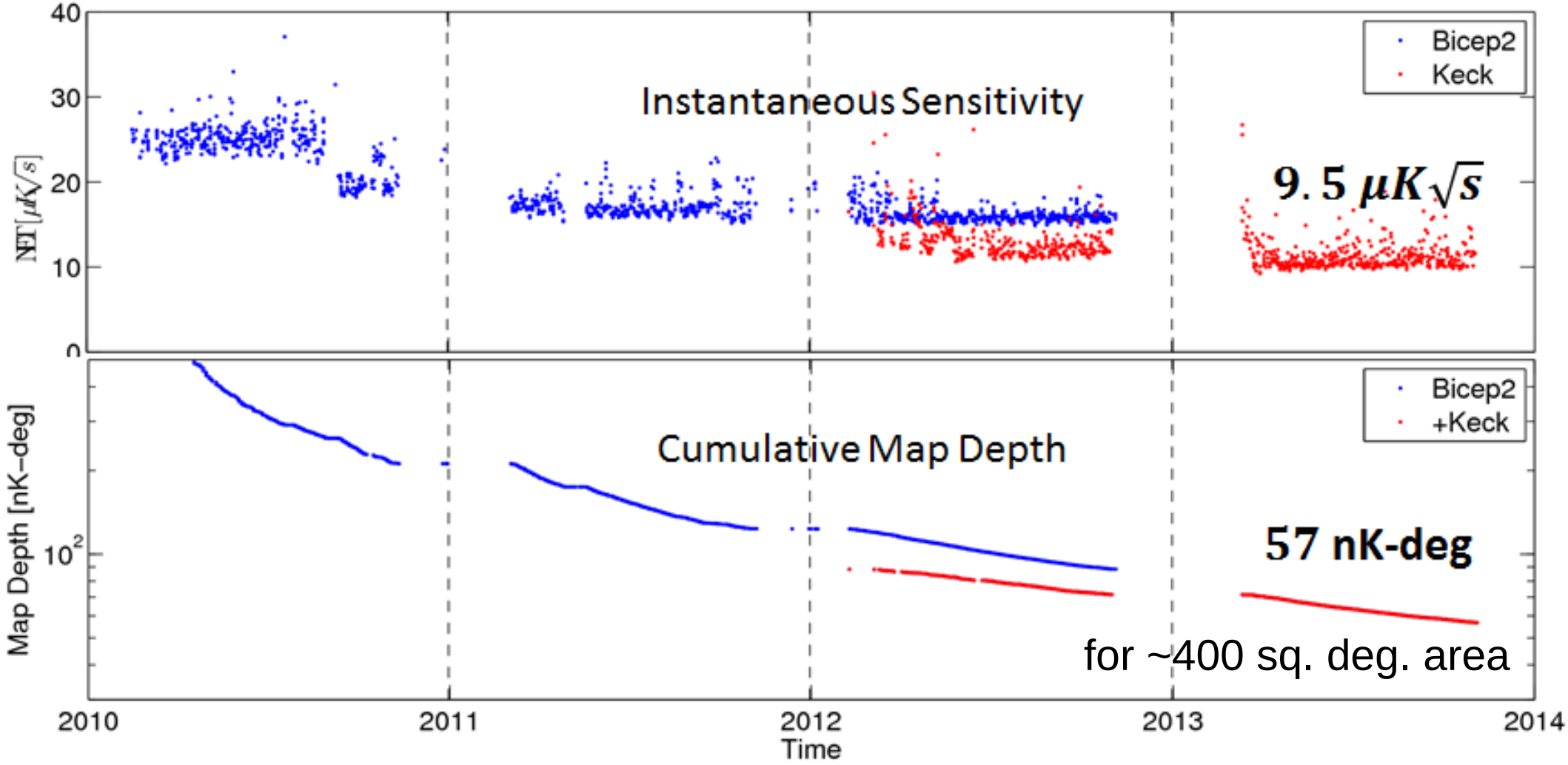
Keck Array 2014-

Keck Array Status

- Maps and sensitivity: 20 μK√s NET [2011] → 11.5 [2012] → 9.5 [2013]
- 2013 improvement: replaced 2.25 focal planes to improve sensitivity
- 2014 improvement: changed observing frequency of 2 receivers from 150 GHz to 100 GHz to improve constraint on frequency dependence of the signal

Bicep2 +Keck Array Sensitivity

For completed seasons (2010—2013), all at 150 GHz



Keck Array is going to get even better

- Observation funded through 2016
- Rapidly analyzing new data: ~3 months of 100-GHz data already deeper than 3 years of BICEP1 100 GHz → improvement of color constraint
- Increase map area to reduce sample variance
- Continue to adjust frequency coverage to optimize science return (100, 150 available. 220 GHz in development)

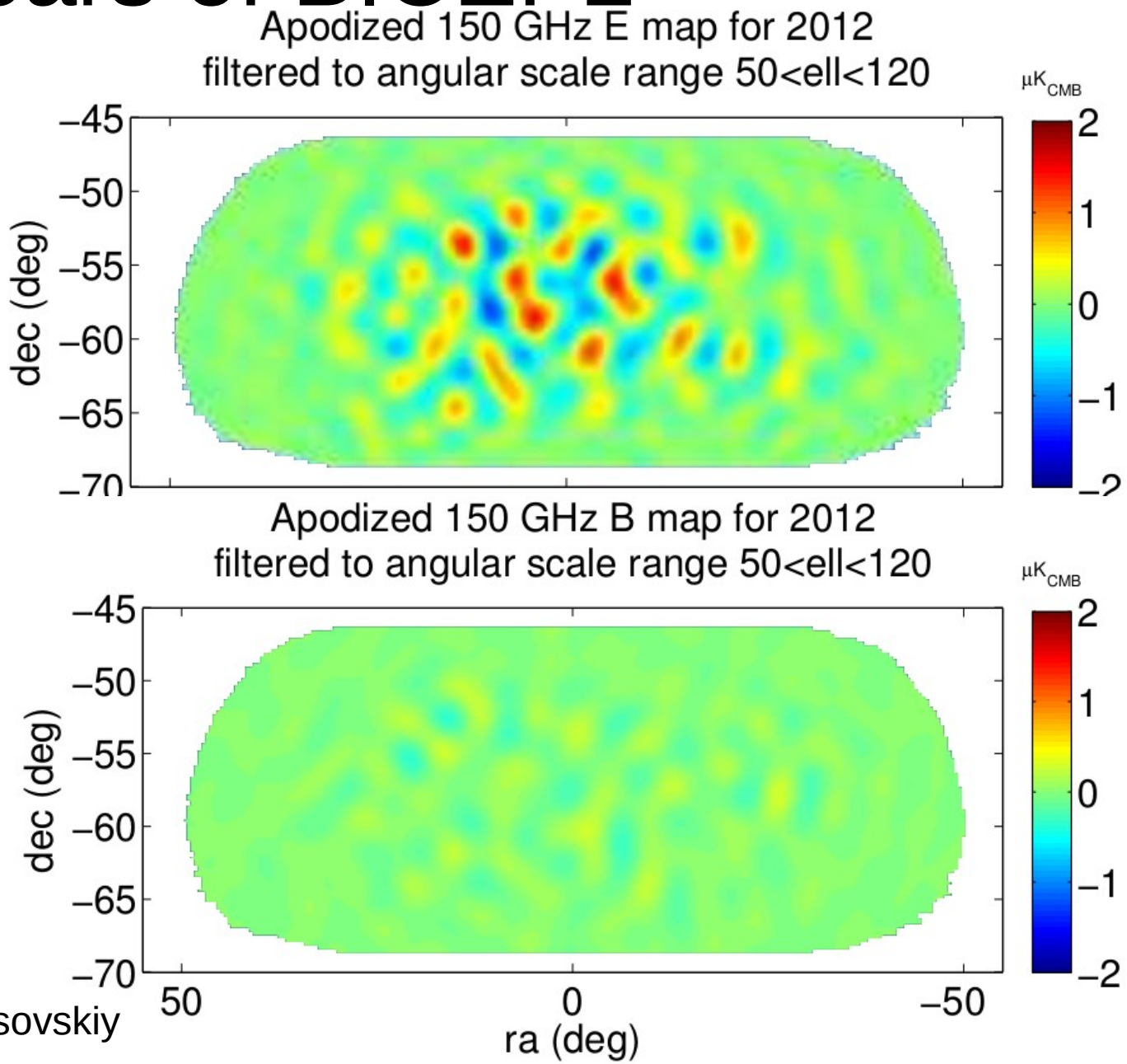
Summary and Conclusions

- High S/N Keck Array results at 150 and 100 GHz are coming
- Using the same systematic error reduction strategy as BICEP2
- More on BICEP/Keck in this conference: 9153-126 (K. S. Karkare poster tonight on spectral characterization) 9153-59, 9153-60 (Z. Ahmed and H. Hui talks tomorrow on BICEP3)

Extra Slides

Picture of BICEP2 telescope wall to go here

Keck 1-year (2012) maps are as deep as 2 years of BICEP2



Maps from Sarah Kernasovskiy