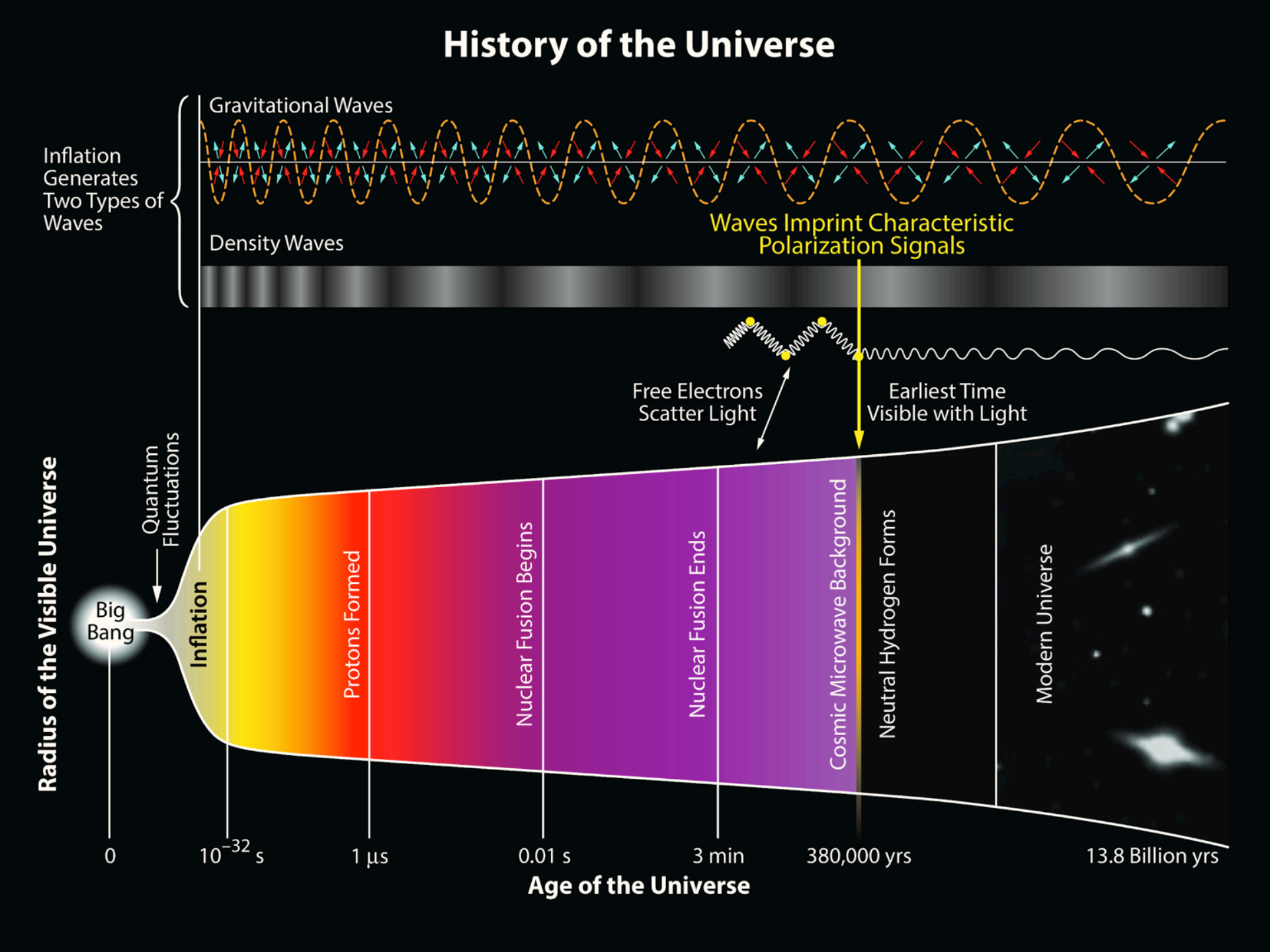
Remote Sensing the Universe as it was 14 Billion Years Ago

Clem Pryke (Physics)

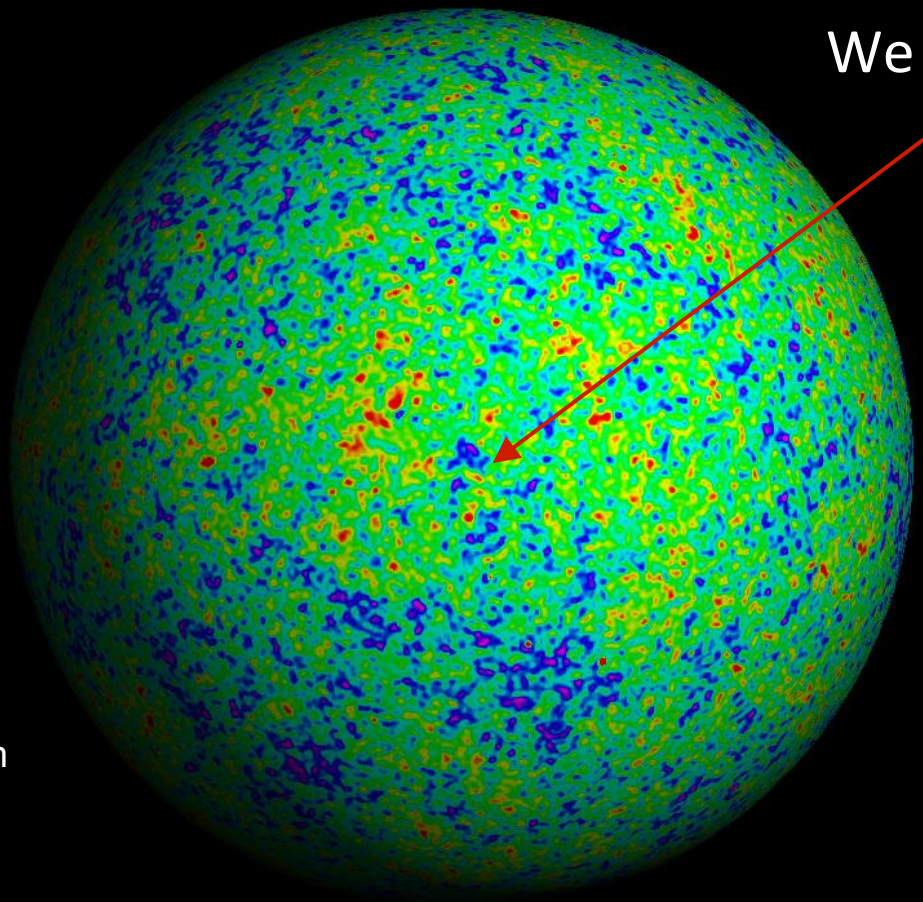
CERS Workshop

May 16 2018

History of the Universe



CMB Surface of Last Scattering



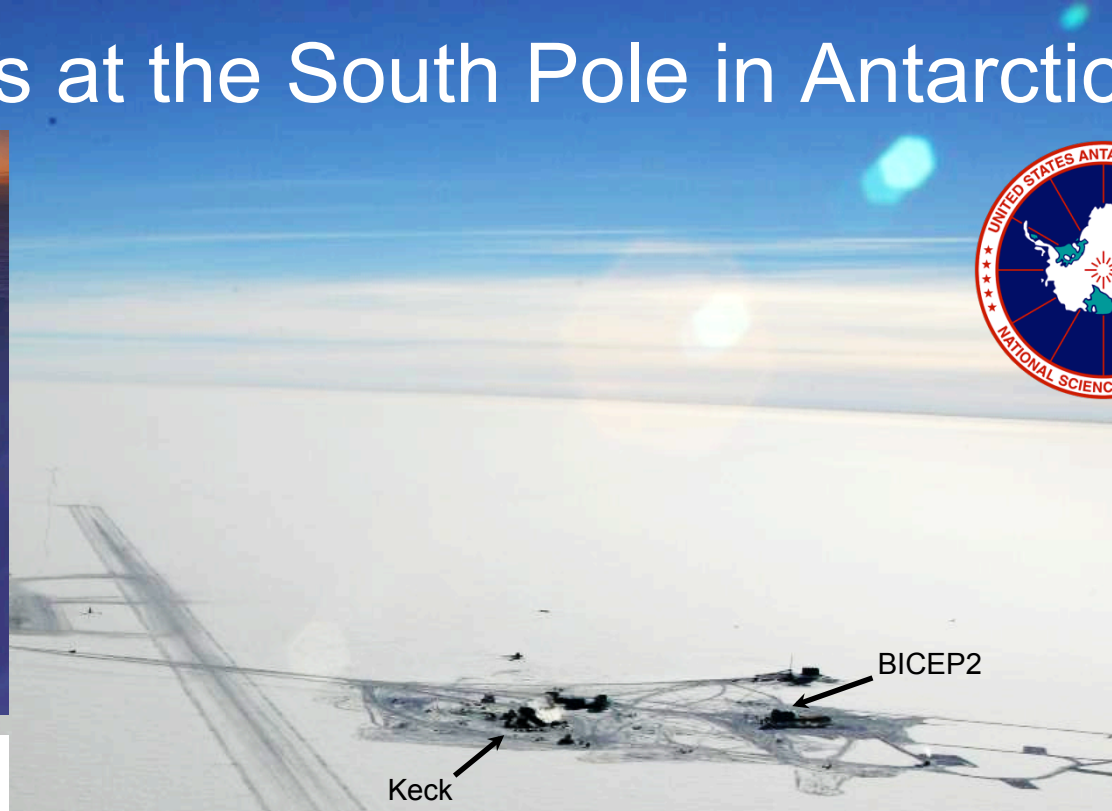
All sky map projected on
a sphere

Cosmic Microwave Background (CMB) is a sample of the density structure on a shell cut through the 380,000 year old Universe –

Using specialized radio telescopes we can measure it

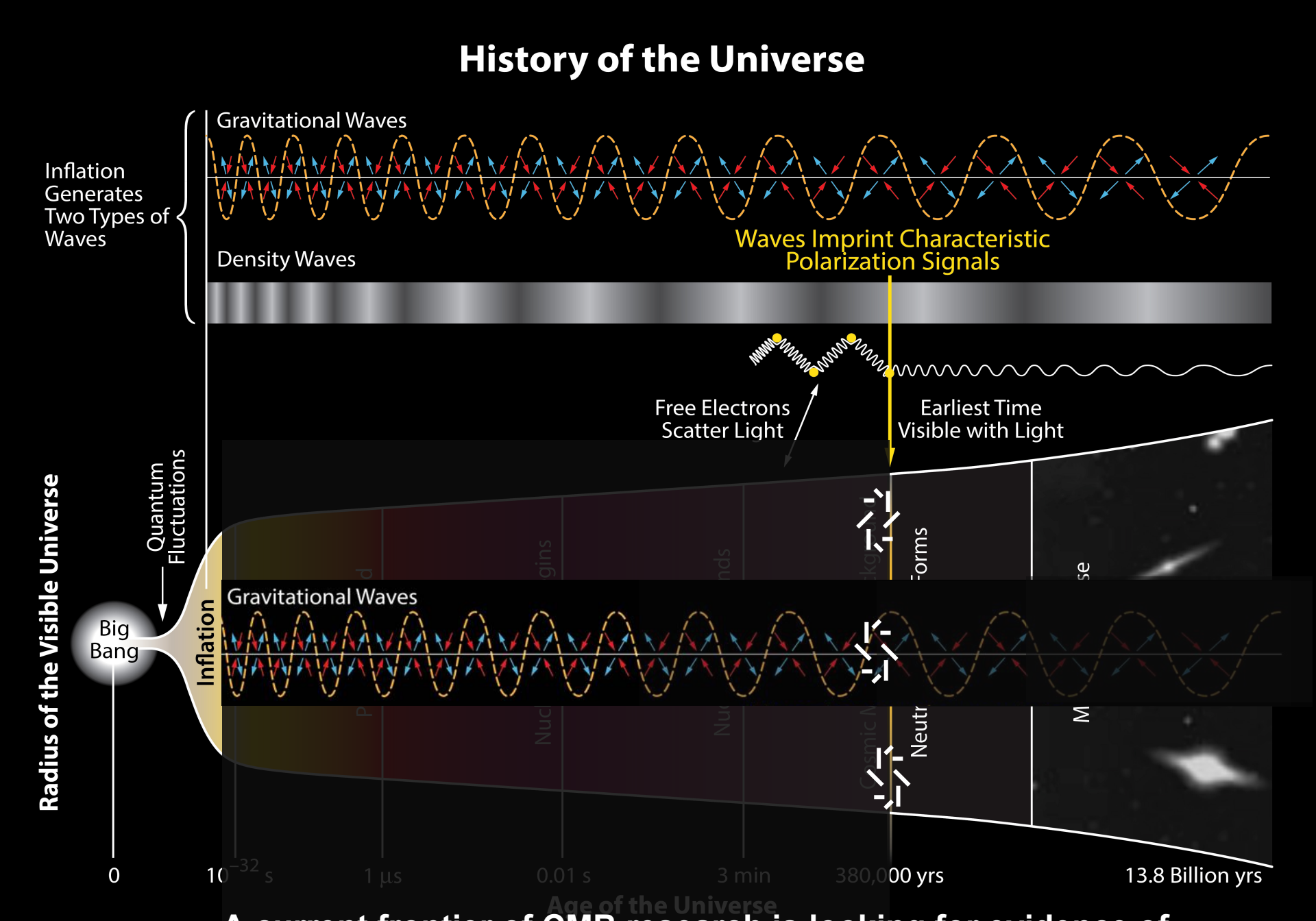
Our CMB Telescopes at the South Pole in Antarctic

Keck Array 2011-present



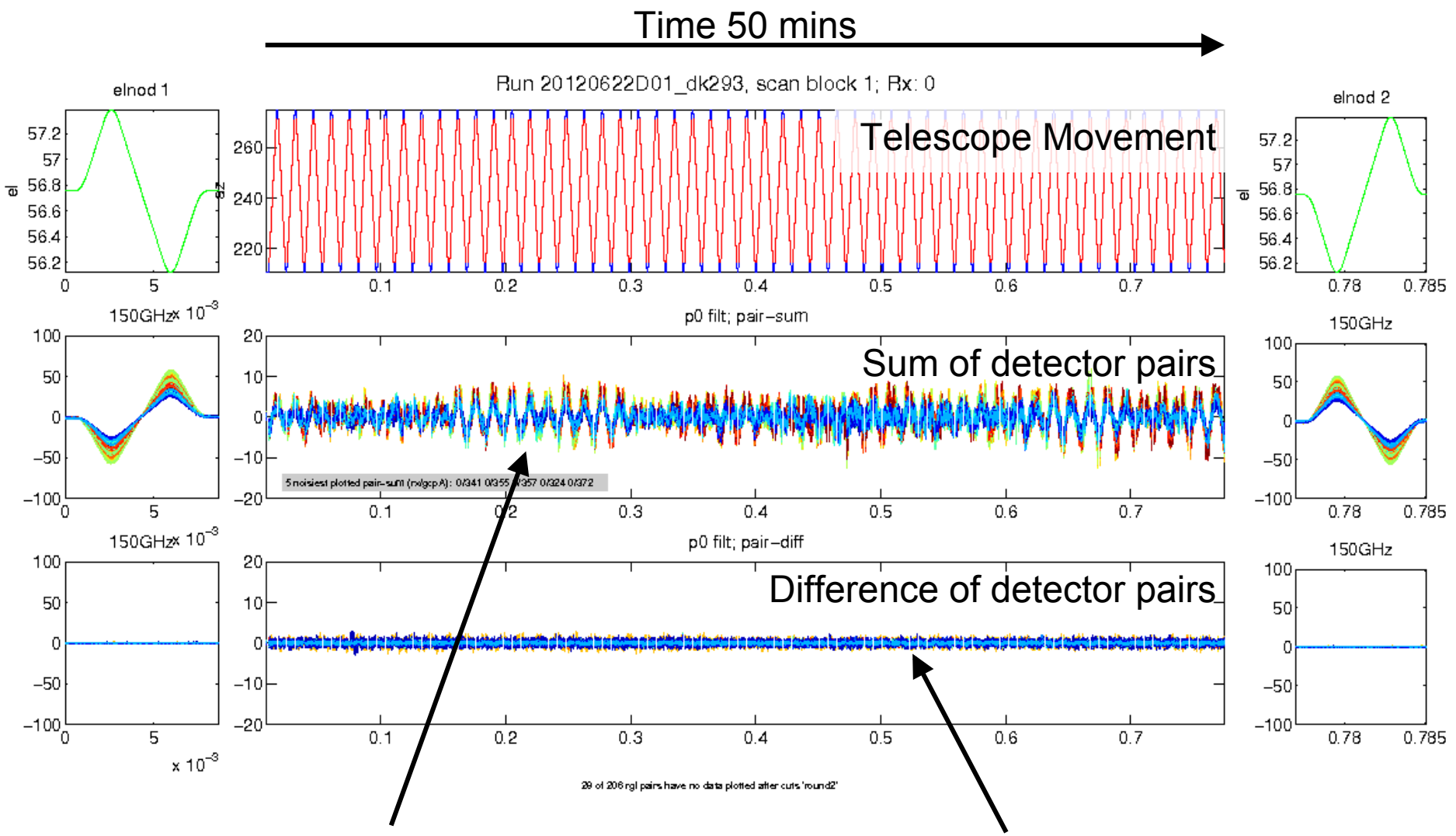
We have built and operated a series of increasingly sensitive instruments over more than a decade

History of the Universe



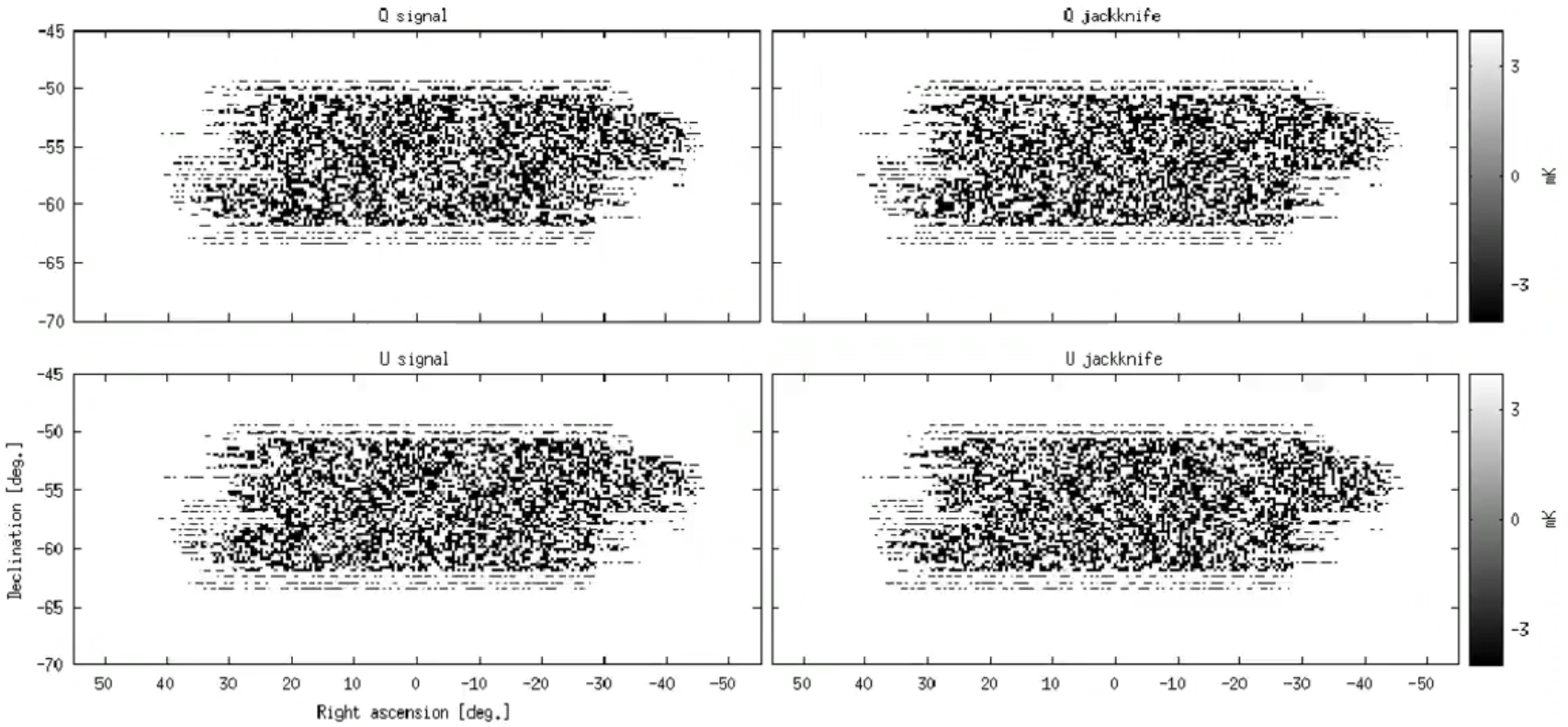
A current frontier of CMB research is looking for evidence of gravitational waves from the very beginning of the Universe

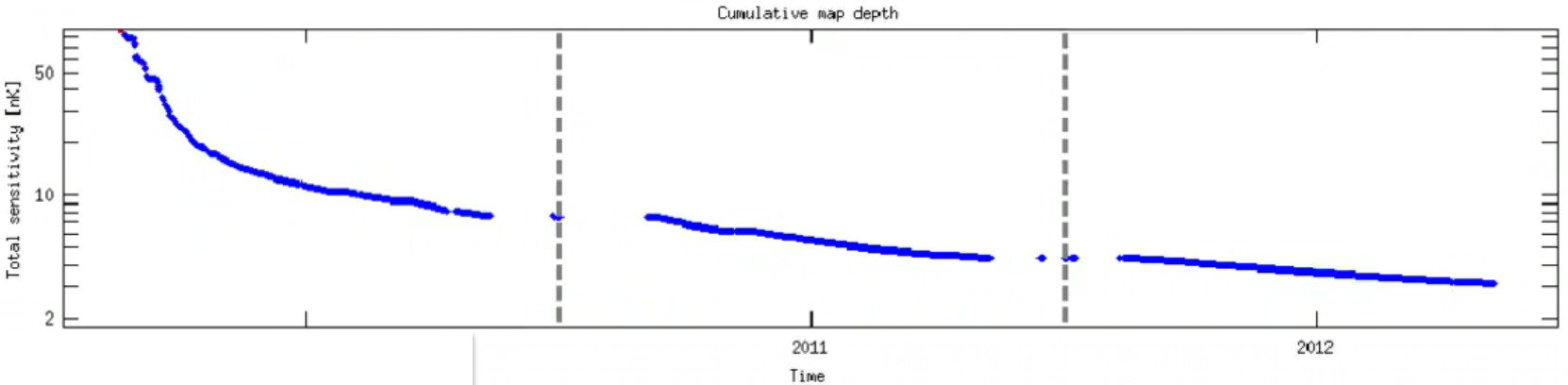
Raw Data – Record with 1000's of Channels for Years of Time



- Scanning over lumpy atmosphere → "clouds"
- Pair difference still clean → atmosphere is unpolarized

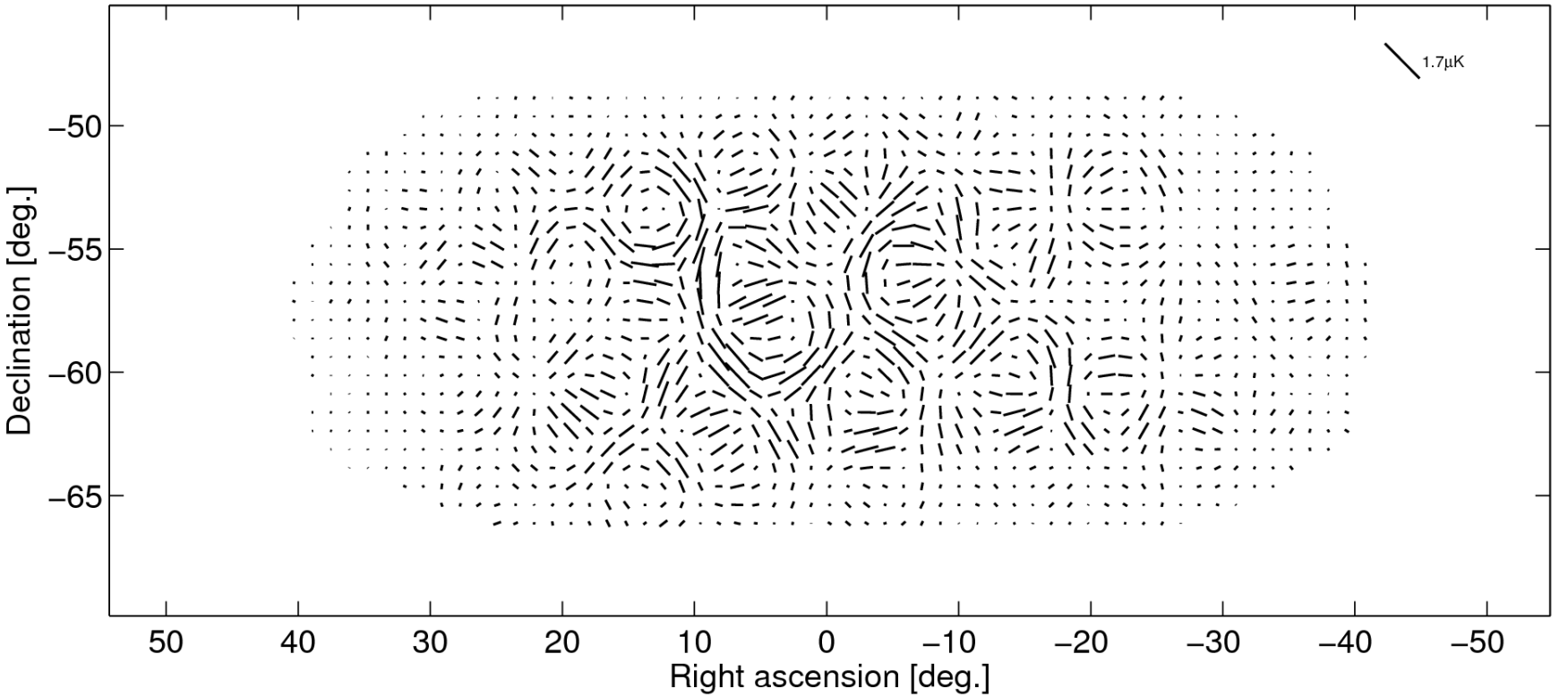
Compress 100's TB raw data to maps





Total Polarization Map

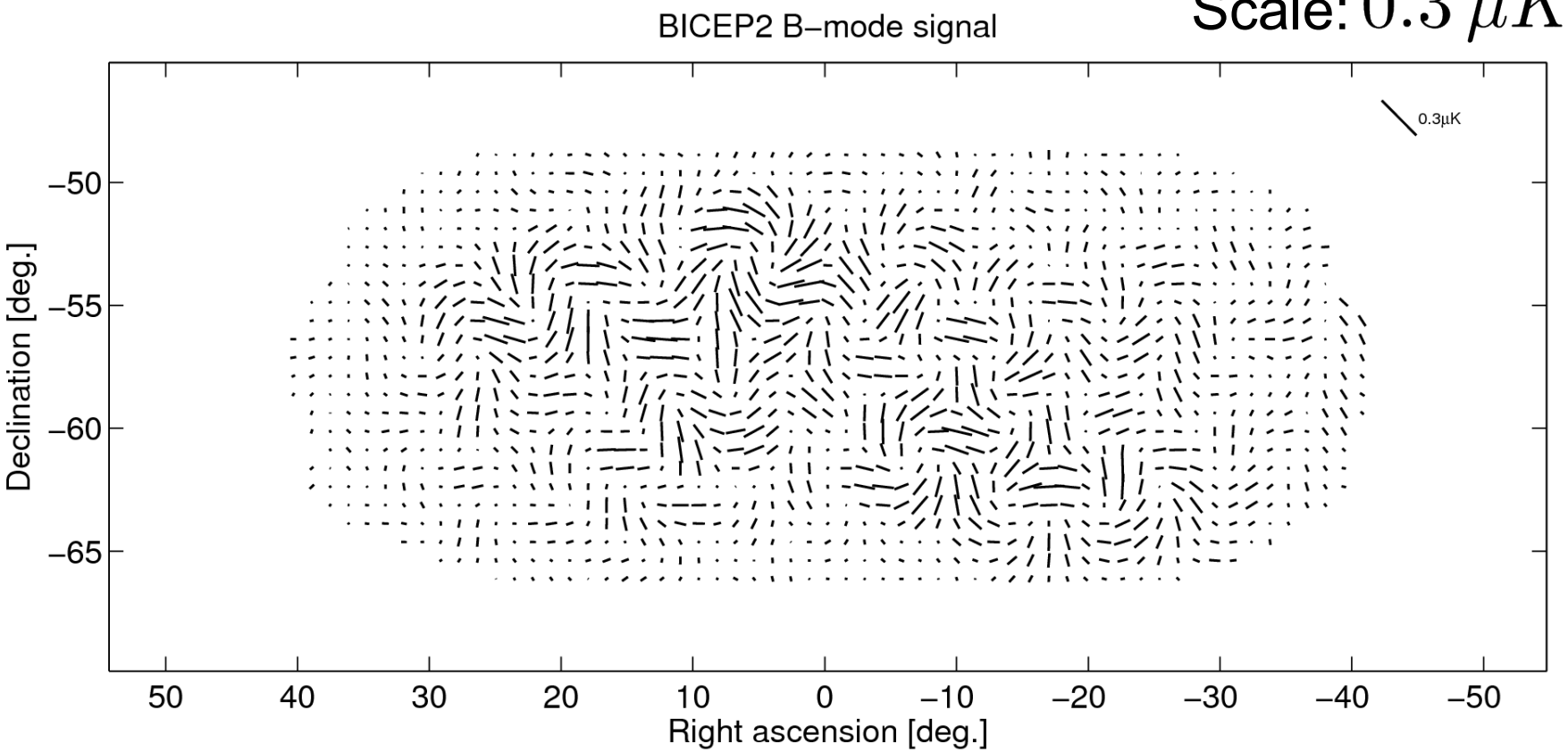
Scale: $1.7\ \mu K$



Make an ultra sensitive map of a small piece of the sky
E-mode dominated pattern – no obvious curl component

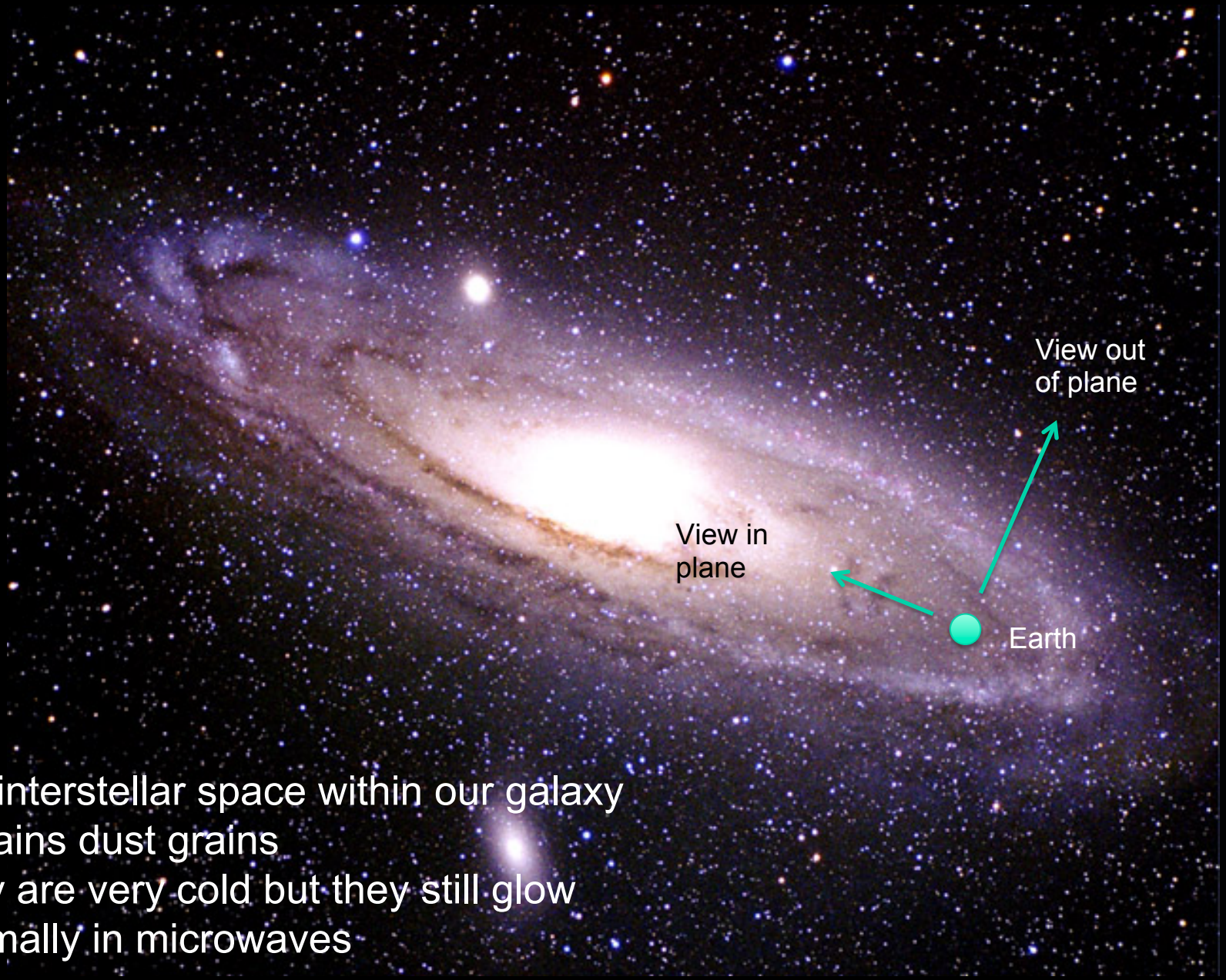
Extract B-mode Contribution

Scale: $0.3\,\mu K$



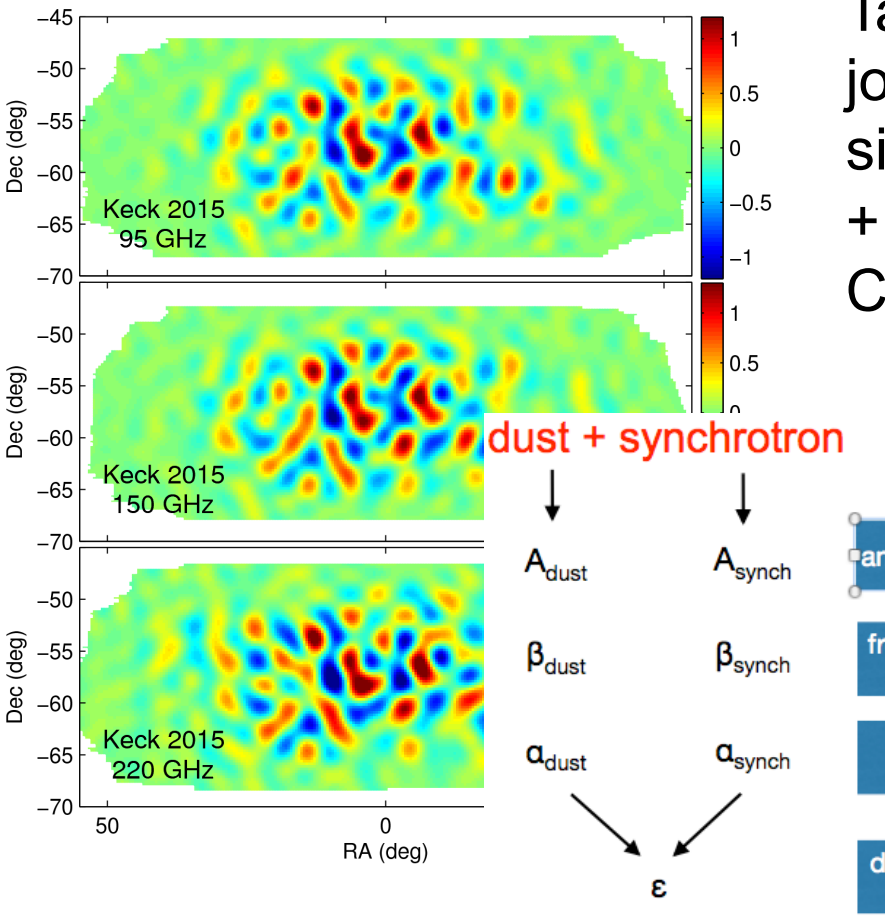
Use “matrix purification” technique to extract B-mode
Signal is tiny in both absolute and fractional sense –
need rigorous control of experimental systematics!

Unfortunately we are in a galaxy!

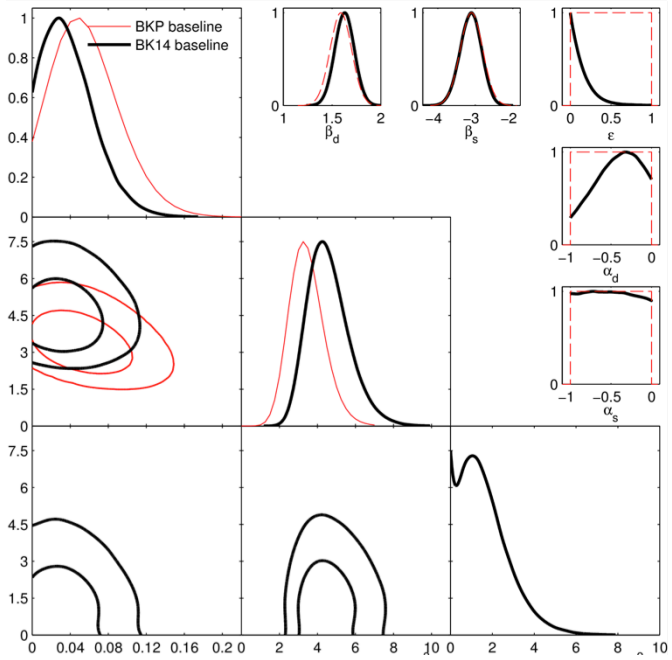


The interstellar space within our galaxy contains dust grains
They are very cold but they still glow thermally in microwaves

Maps at Multiple Frequencies, to Power Spectra, to Likelihood Analysis



Take cross spectra, and then the joint likelihood of all the spectra simultaneously vs. model for signal + foregrounds (after millions of CPU hours of simulations)



End up with basically one (very important) number! But must have rigorous uncertainty quantification.

What Might We Get Out of This Initiative?

- New ideas/methods to improve our analysis.
  - Machine learning algorithms for low level data selection/validation?...
  - New foreground separation algorithm ideas?
  - Direct likelihood analysis from maps to cosmological constraints?
  - More efficient methods?...

- Perhaps collaborations
  - Maybe joint funding proposals to NSF CISE programs?
  - (we always struggle to get enough resources for the very necessary data analysis)