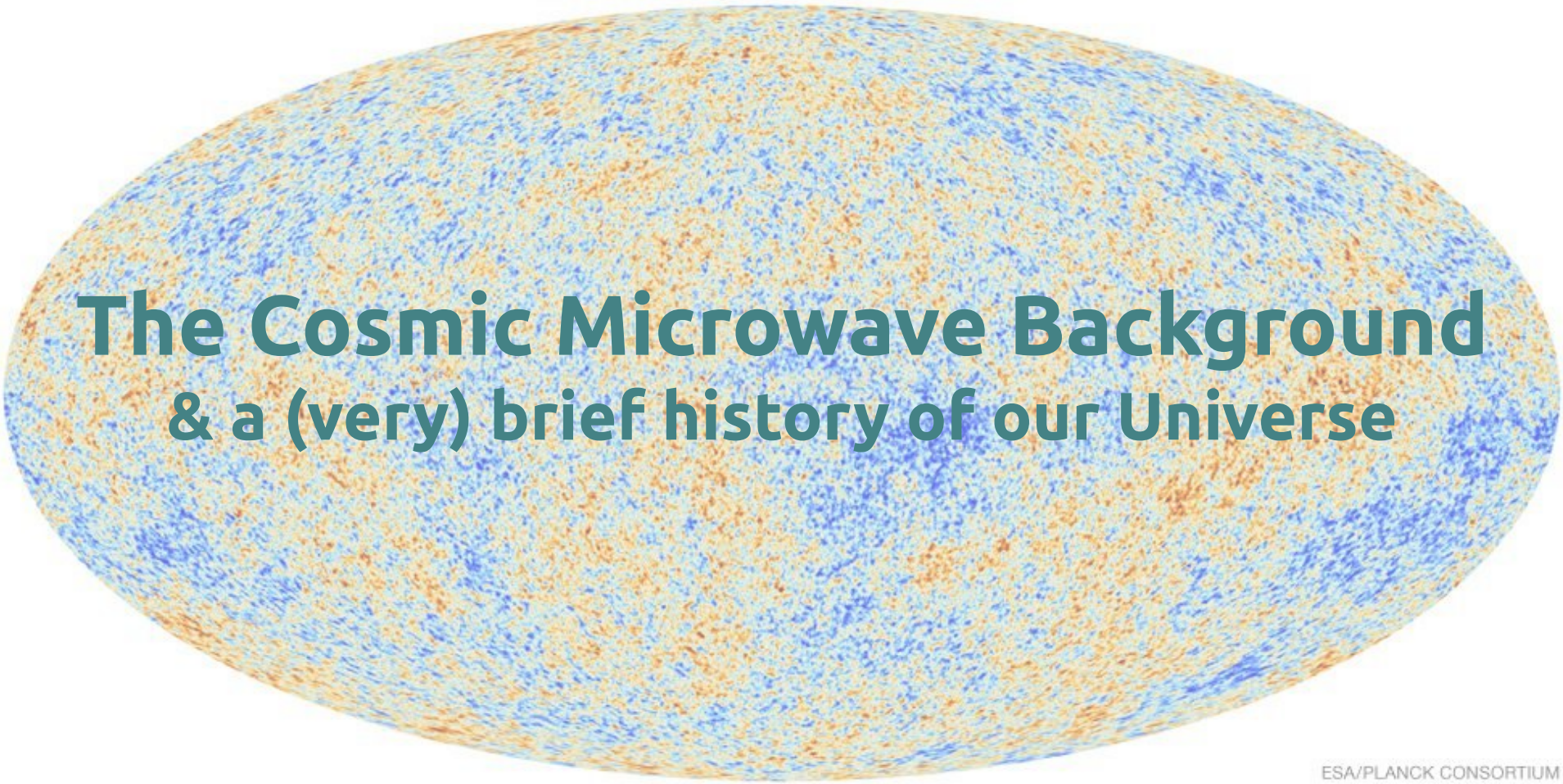
A journey to our cosmic origins

with the oldest light in the Universe

Clara Vergès, LBNL

QUARKNET

BERKELEY LAB



The Cosmic Microwave Background

& a (very) brief history of our Universe

ESA/PLANCK CONSORTIUM

The Big Bang – t = 0s

Hot & Dense

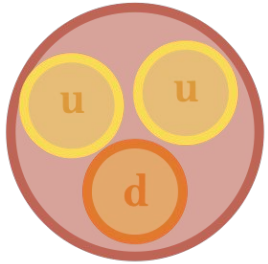
- Thermal agitation is extremely high
- All possible reactions are happening at the same time, nothing is stable

Expanding & Cooling

- Thermal agitation decreases
- Reactions start **freezing =** stop happening in both directions

Baryogenesis

Quarks = fundamental, sub-atomic particles that assemble to form **baryons**



proton

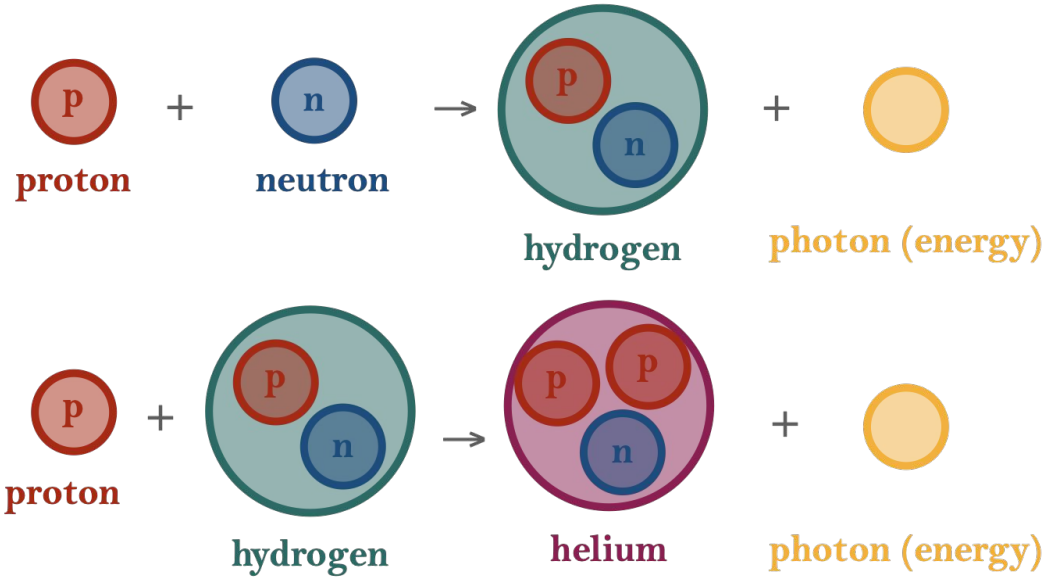
Baryons = assembly of 3 quarks - typically neutrons & protons

- Quarks are formed as independent particles, not yet bound into bigger particles
- Then as cooling continues, they start forming baryons

Primordial nucleosynthesis

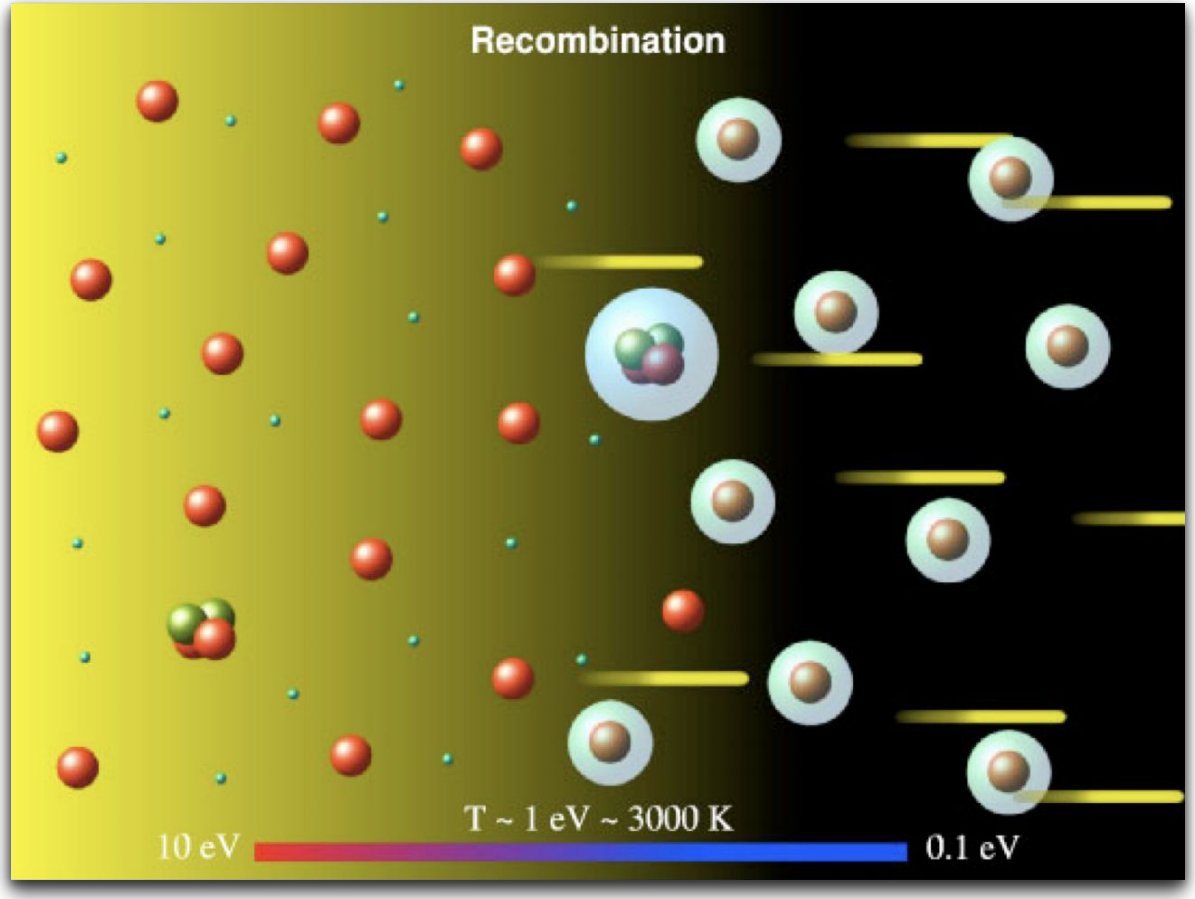
Nucleus = assembly of protons & neutrons

Primordial = initial, in the early Universe (opposed to stellar nucleosynthesis that happens in stars and forms heavier atoms)

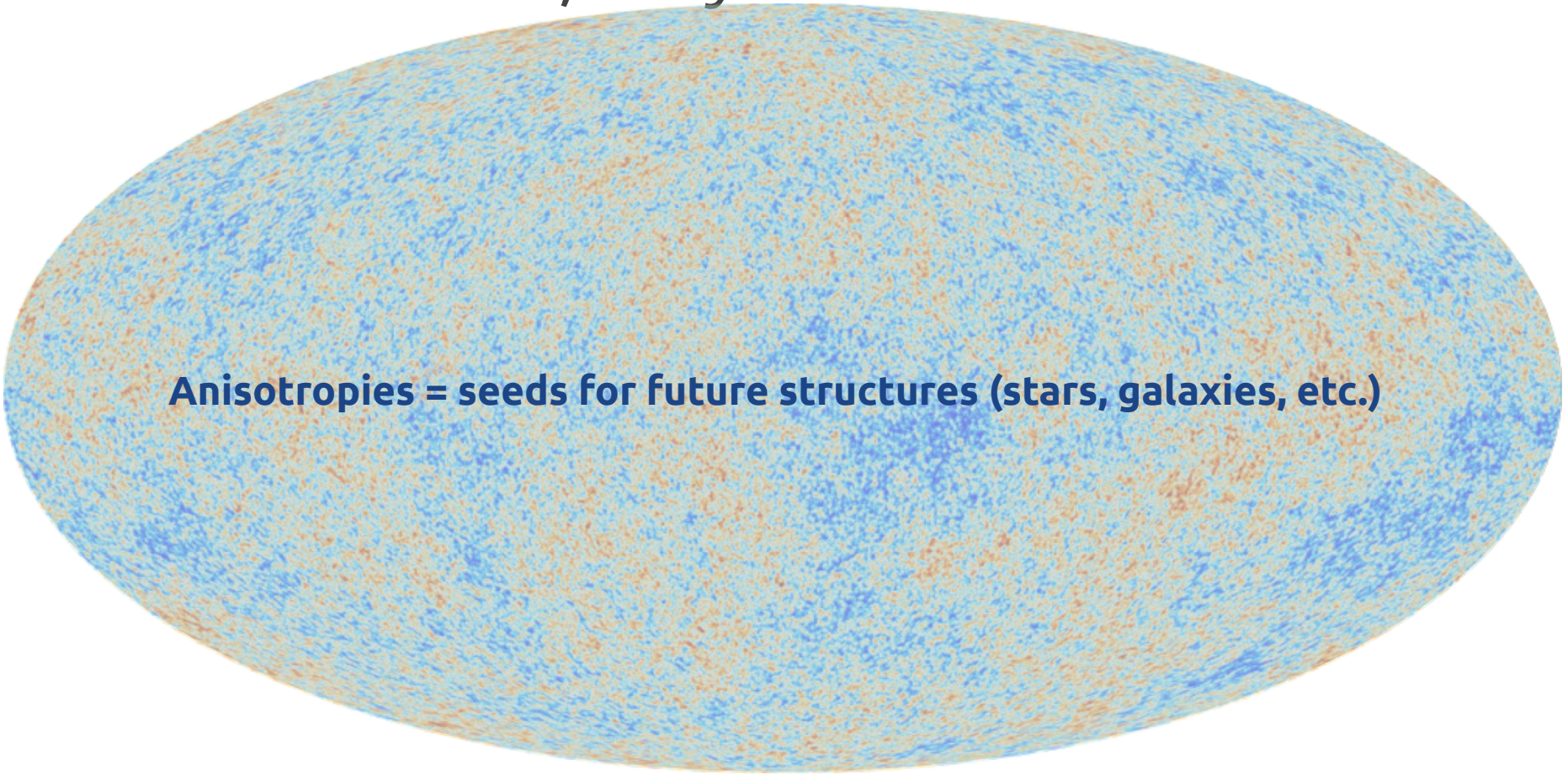


There is a total of 7 chain reactions happening in the early Universe to produce hydrogen & helium

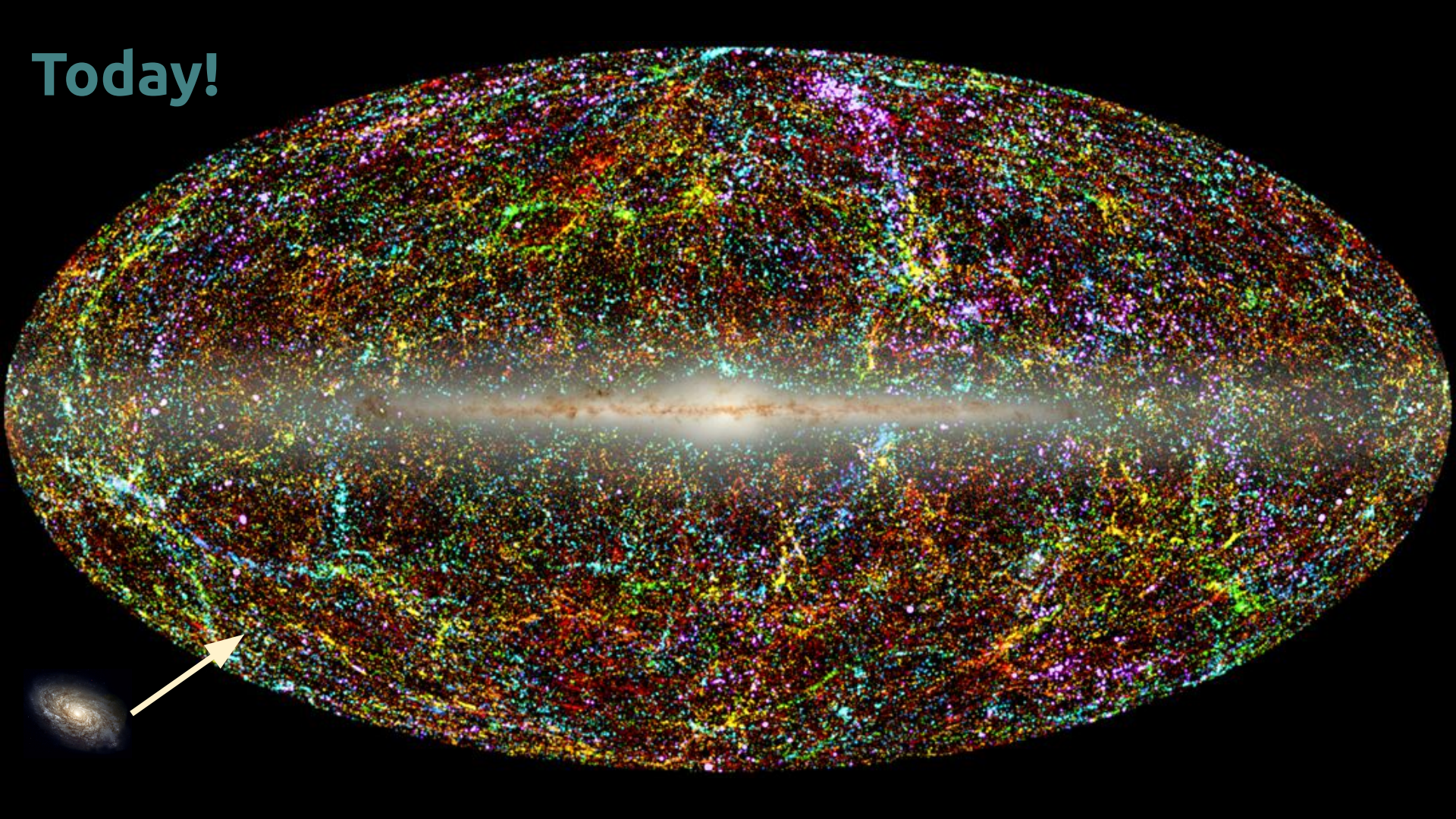
The recombination – t = 380,000 years



The CMB – t = 380,000 years

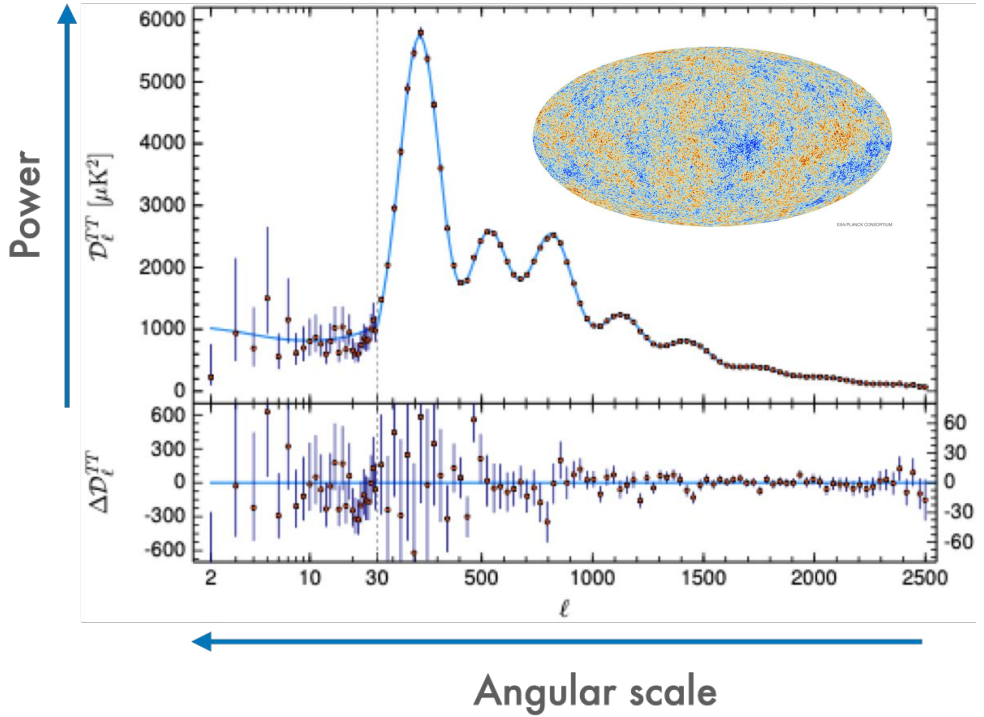


Today!



What is the Universe made of today?

- **5% baryonic matter = us!**
- **25% dark matter = "invisible" matter**
- **70% dark energy = a mysterious force that drives the Universe expansion**



https://chrisnorth.github.io/planckapps/Simulator/#

Cosmic mysteries…
and solution!

Initial conditions puzzle – I: homogeneity

Distance > age of the Universe x speed of light

Initial conditions puzzle – II: curvature

k > 0

k = 0

k < 0

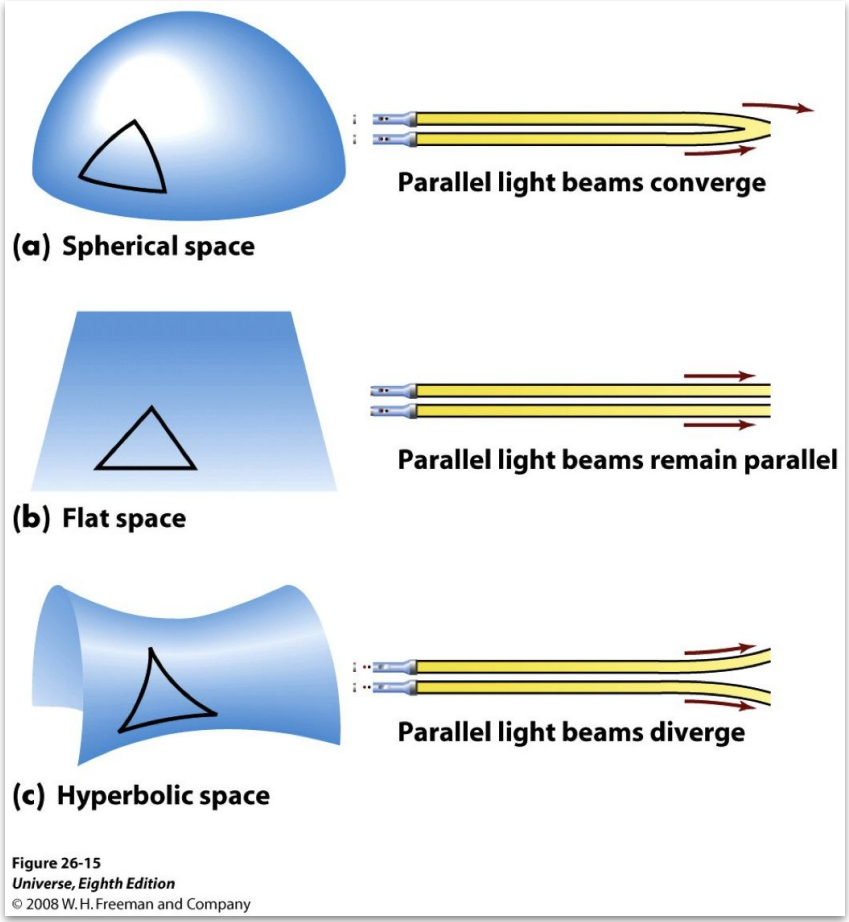
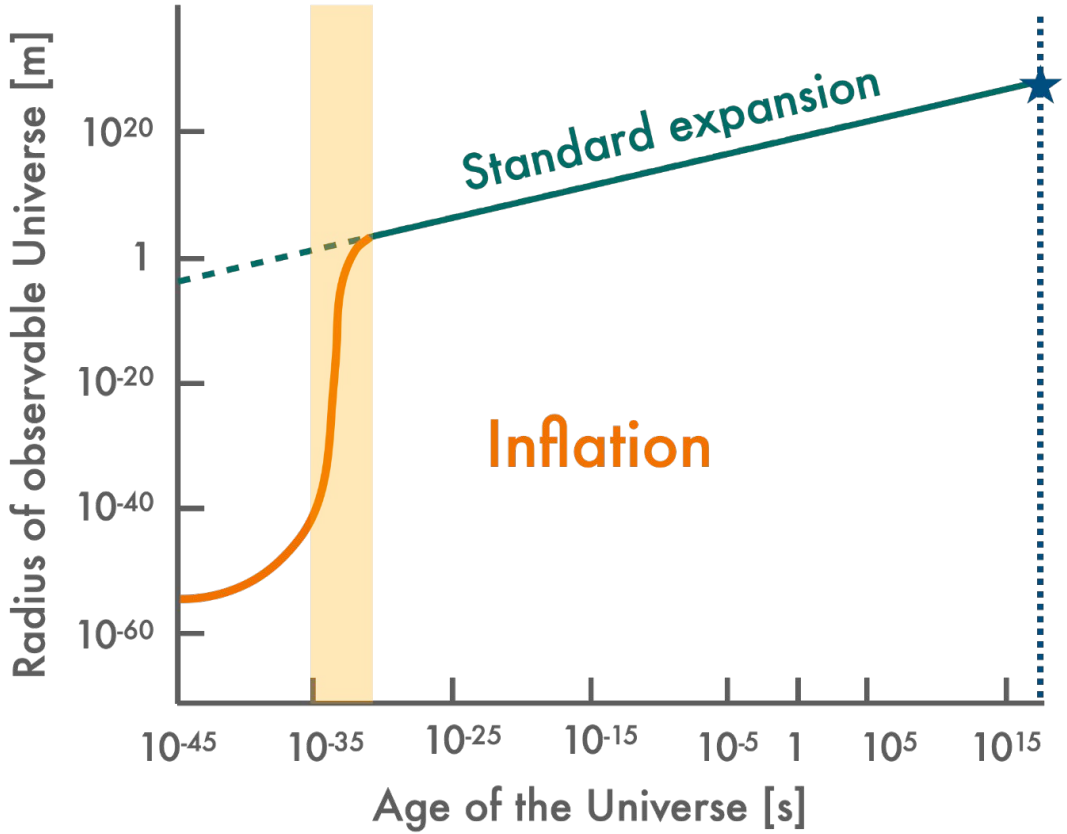
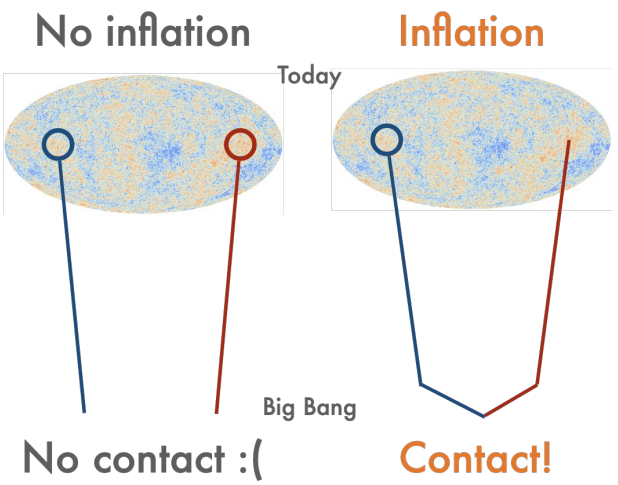


Figure 26-15
Universe, Eighth Edition

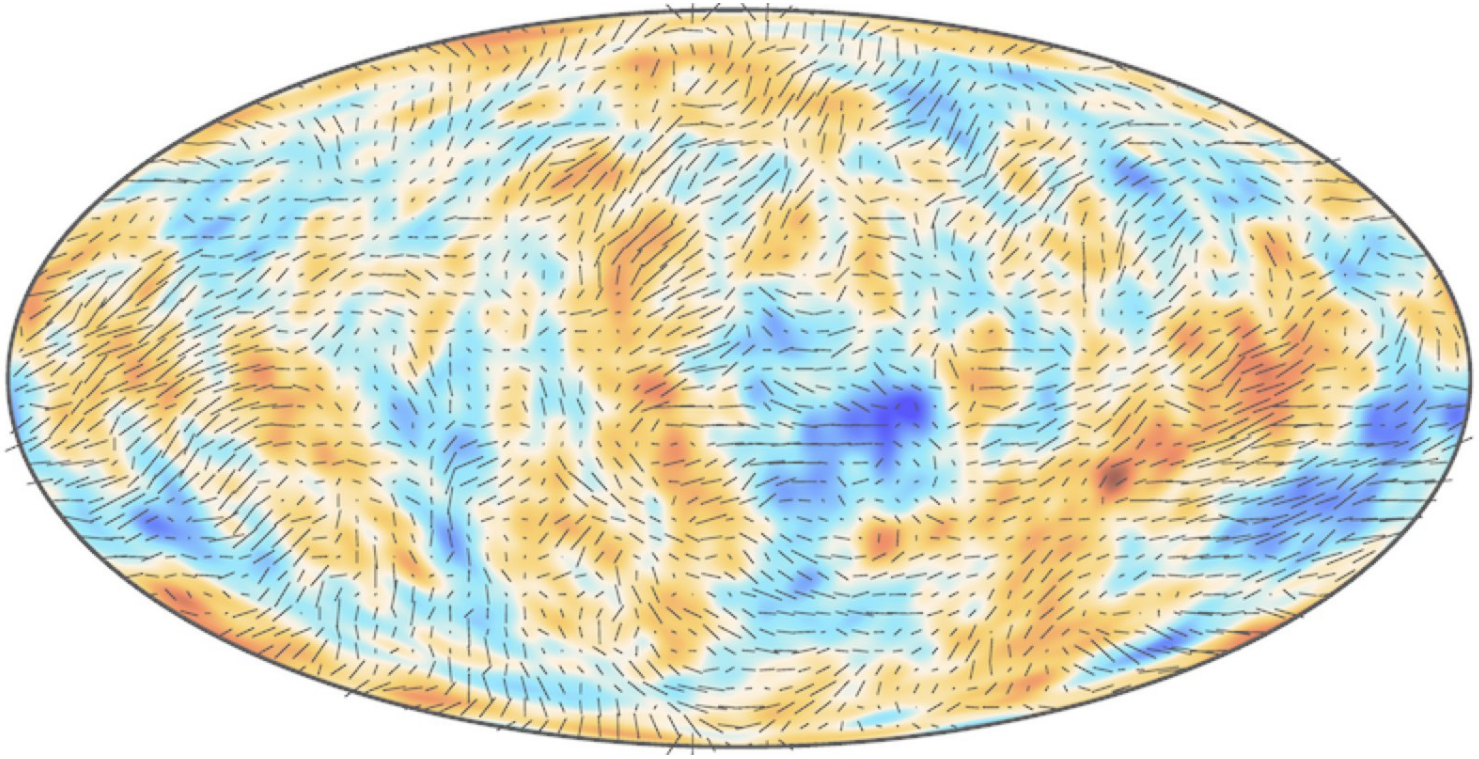
Initial conditions puzzle – solution!



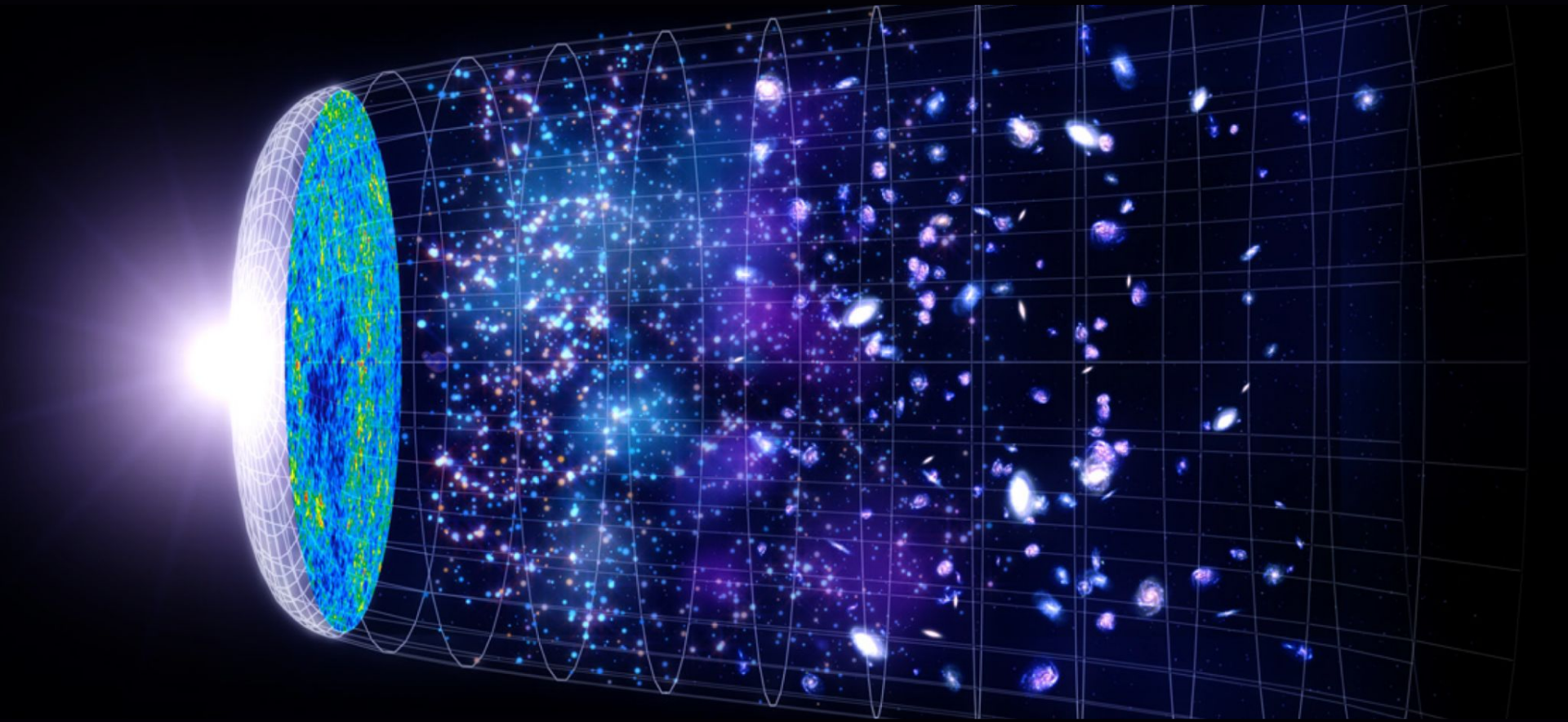
We are here - and now!



The CMB is our messenger for inflation!

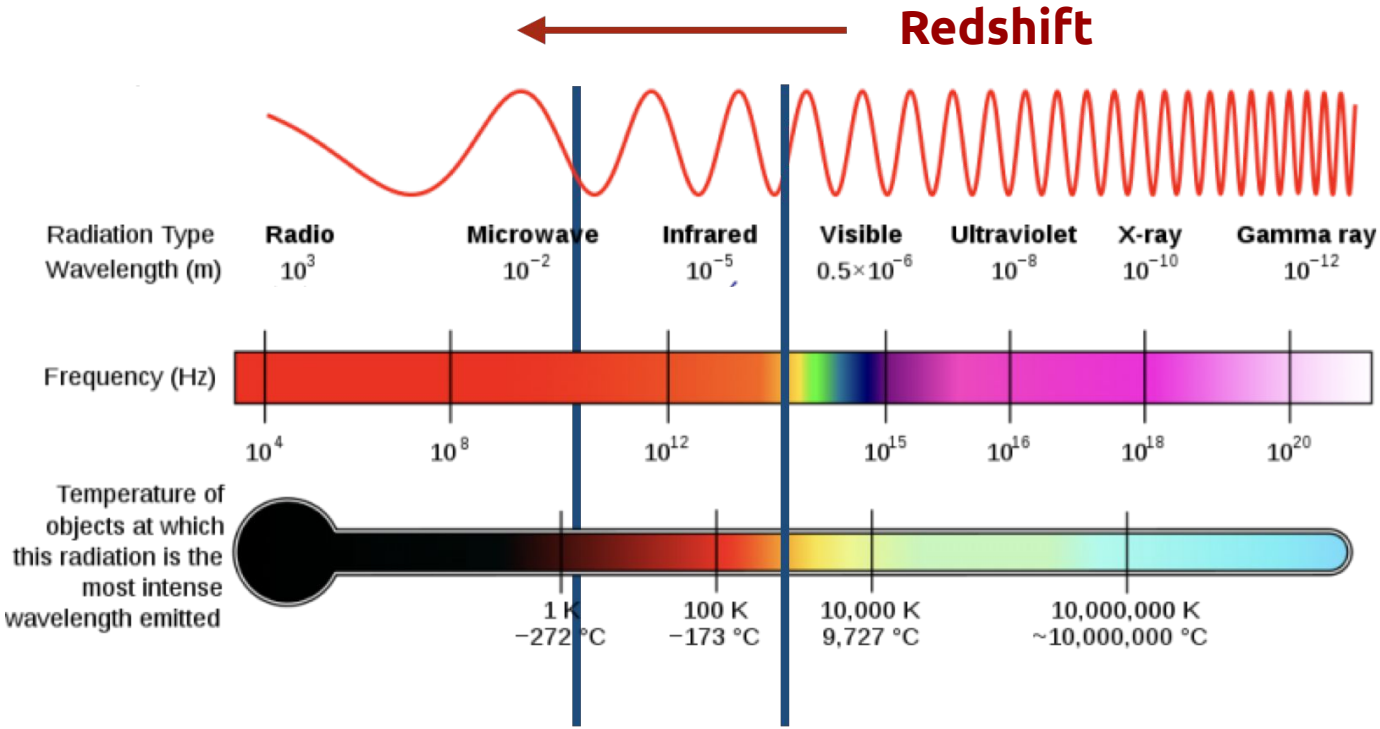


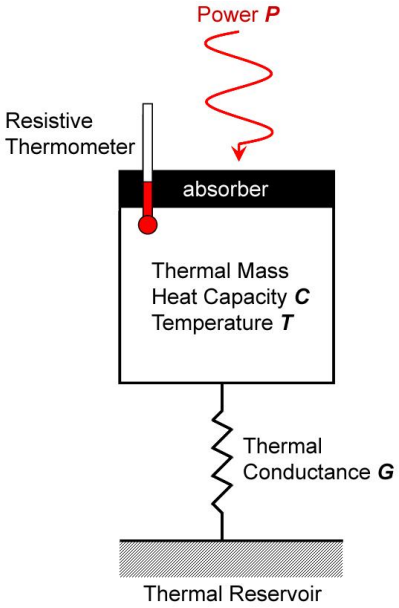
… and for many other things! 13.8 billion years to explore!



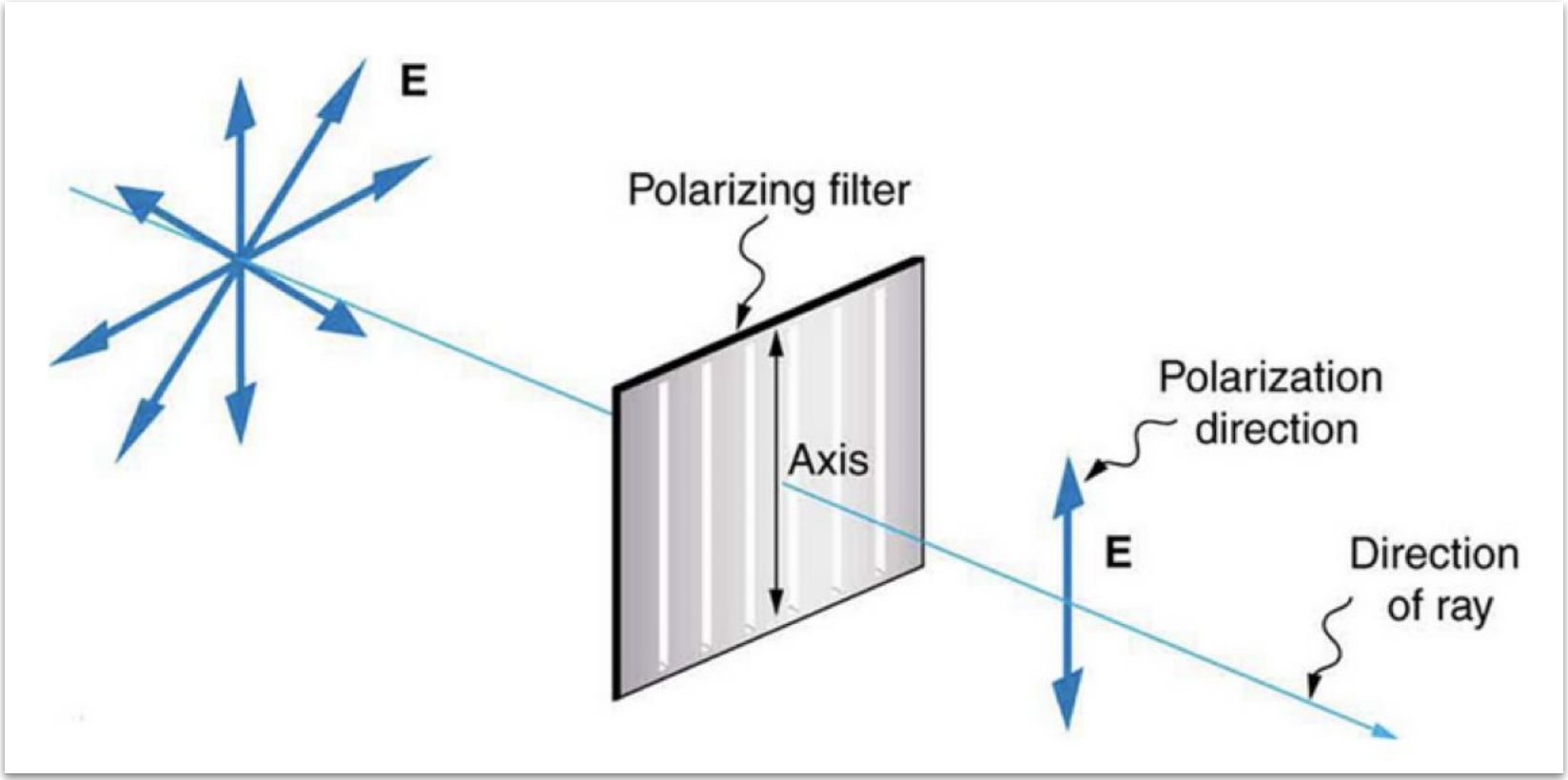
Measuring the CMB

Basic principle

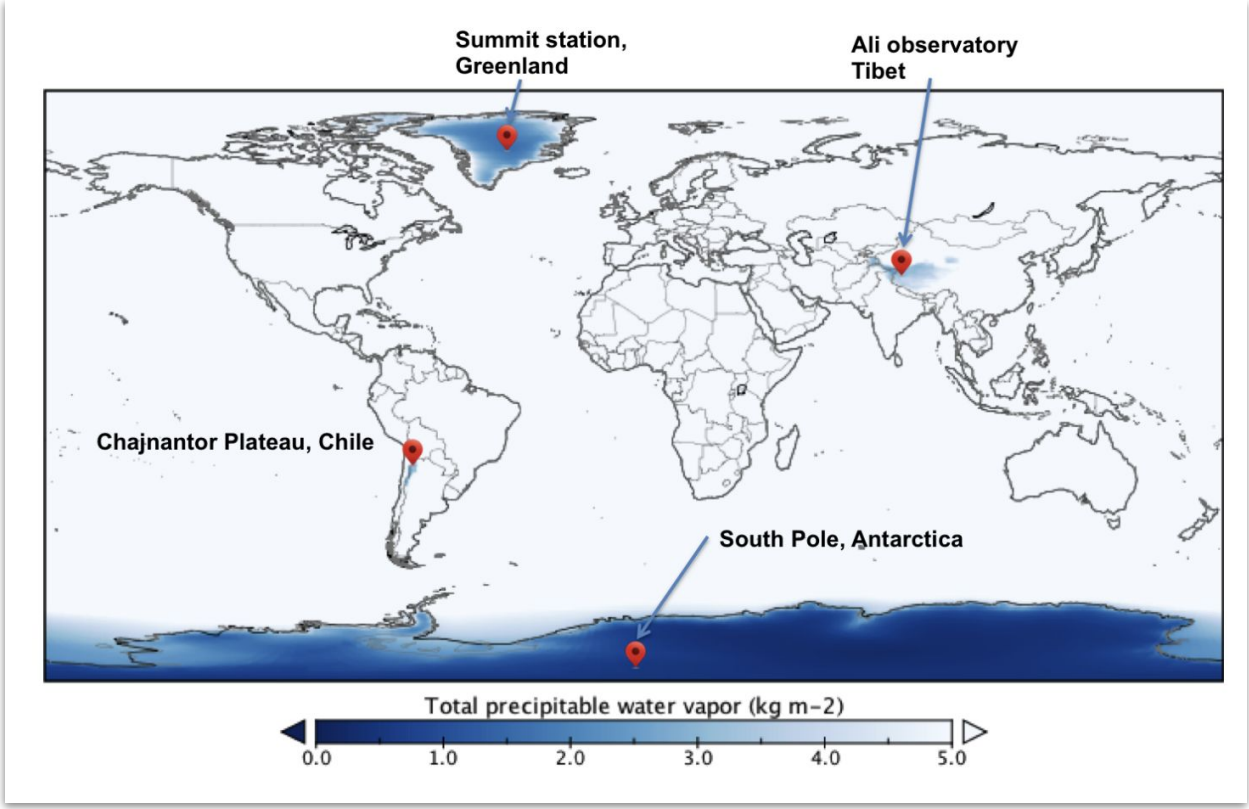




Polarisation

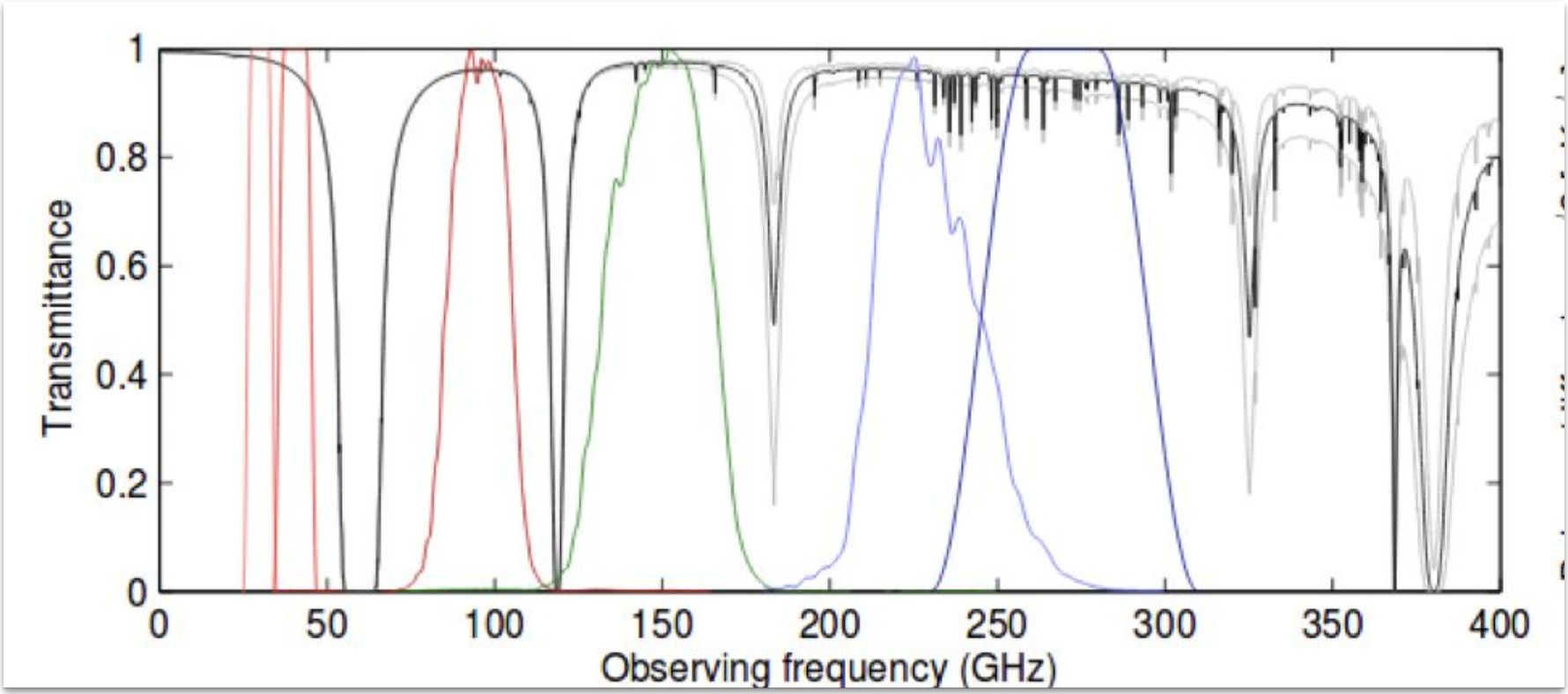


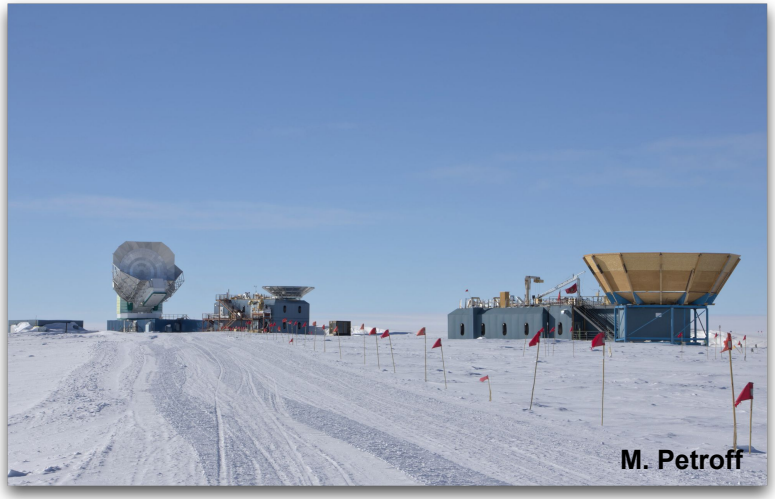
Where to go?



D. Barkats/BK collaboration

Still avoiding the atmosphere




M. Petroff

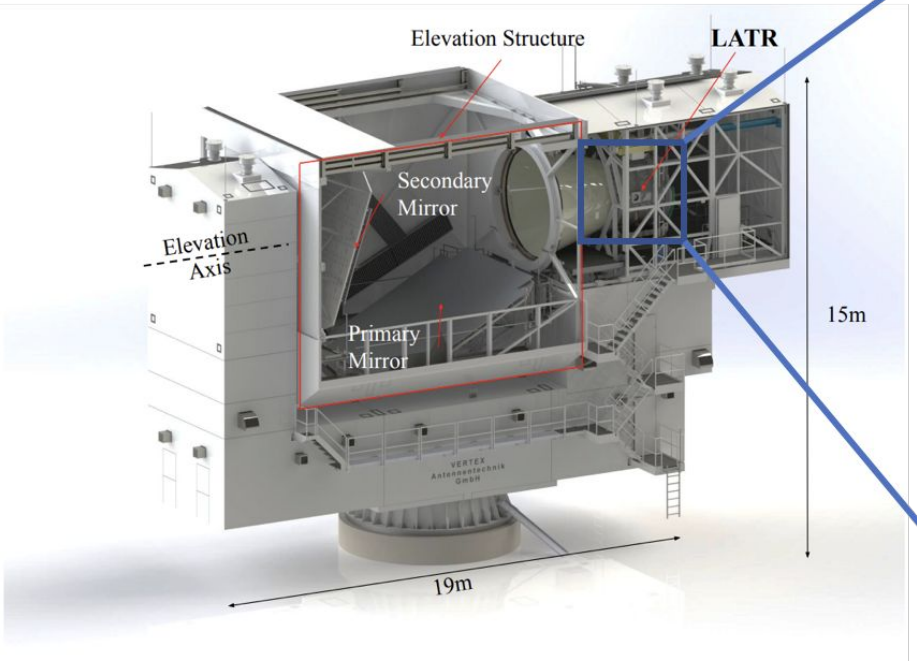

M. Petroff

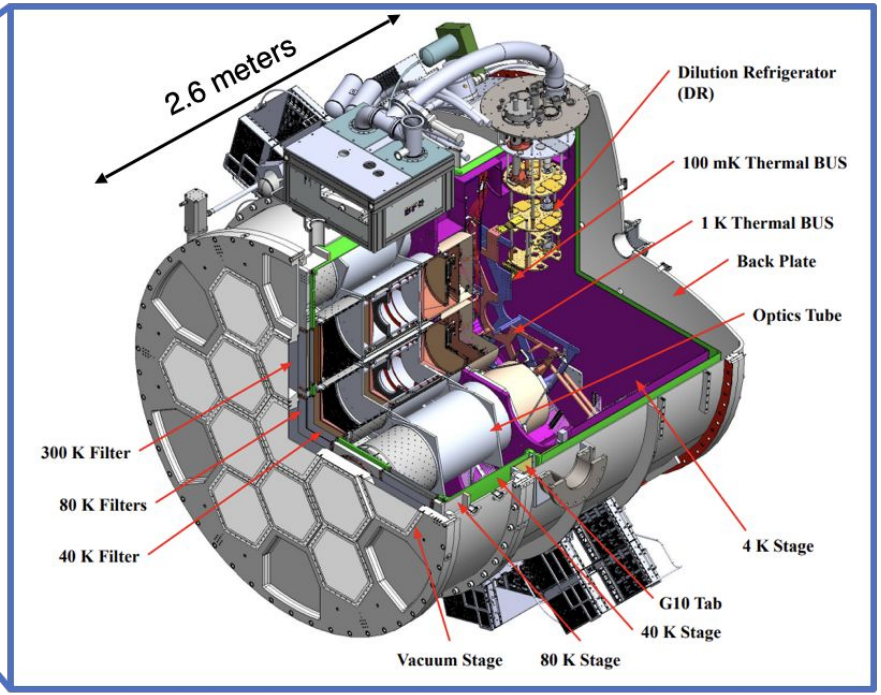

SPT Collaboration


C. Vergès

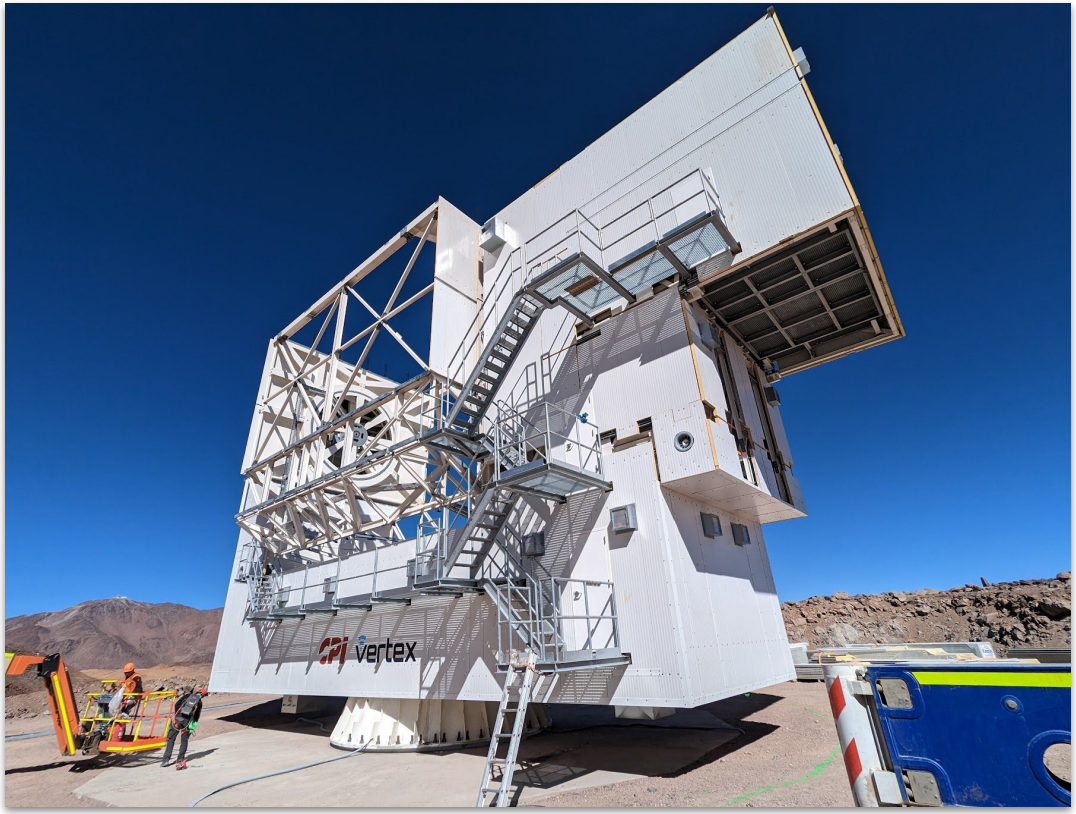

D. Kellner

Large aperture telescope



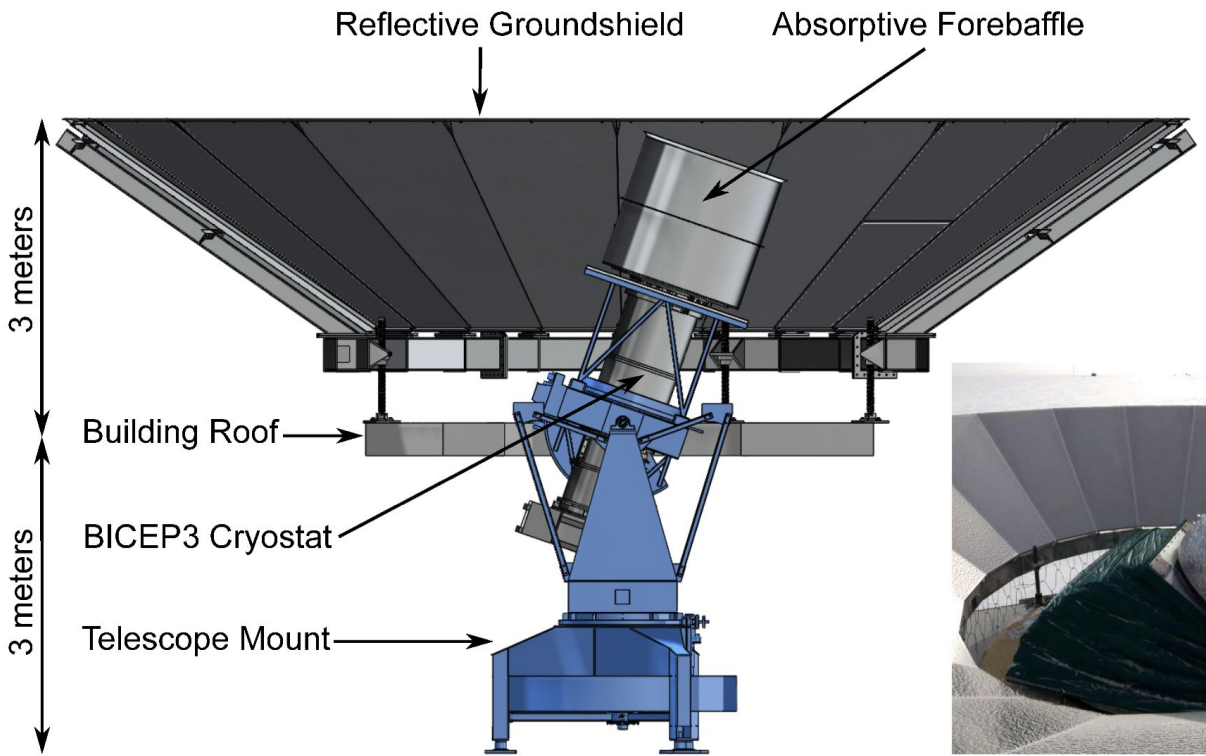


Large aperture telescope

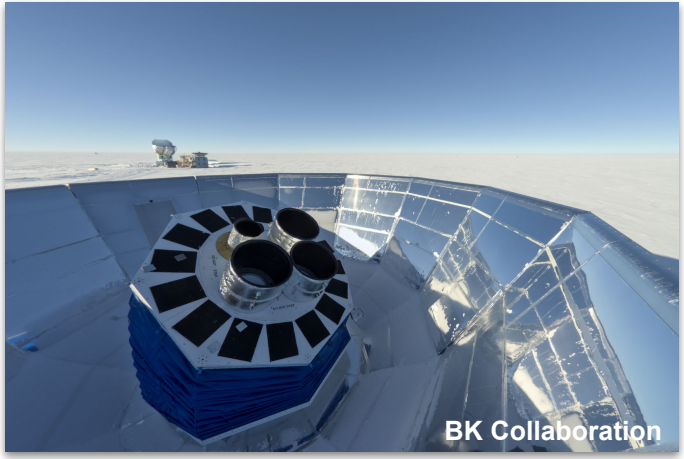


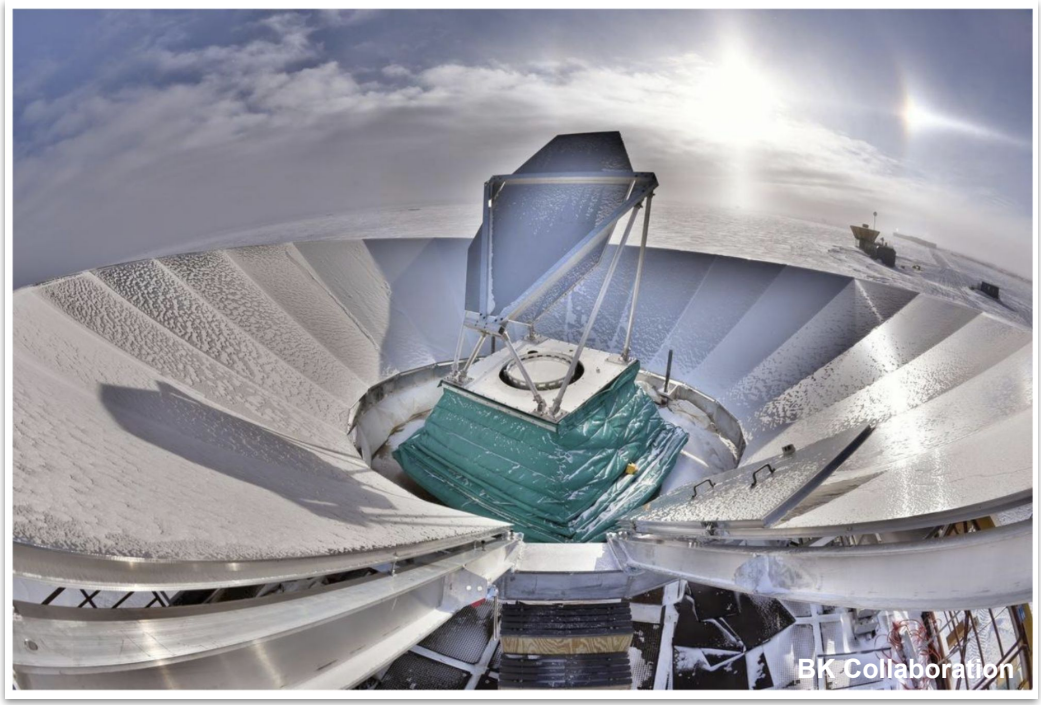
SO Collaboration

Small aperture telescope

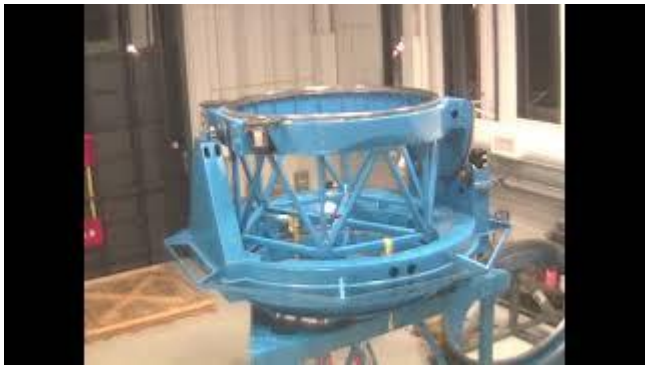


External view

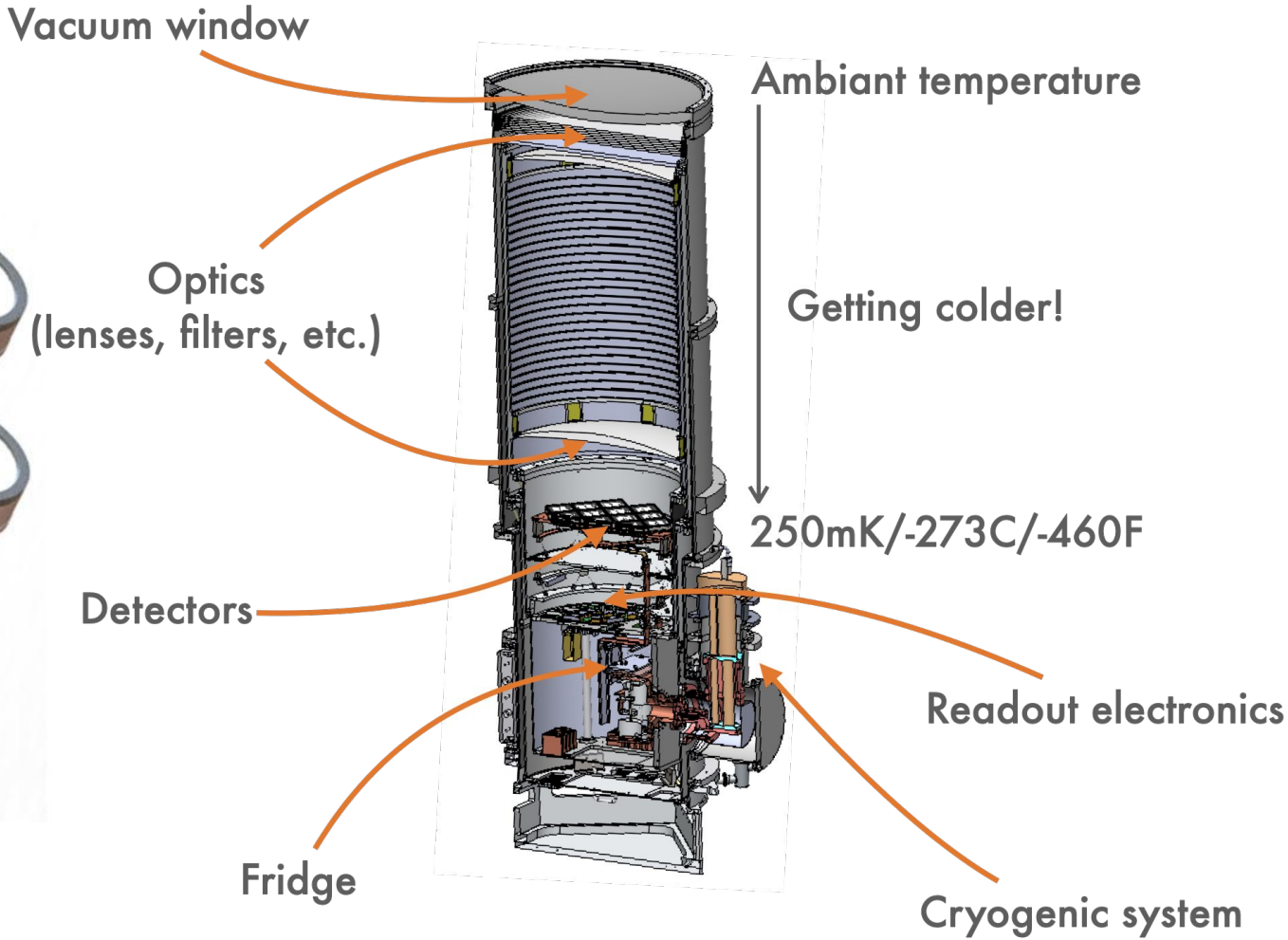




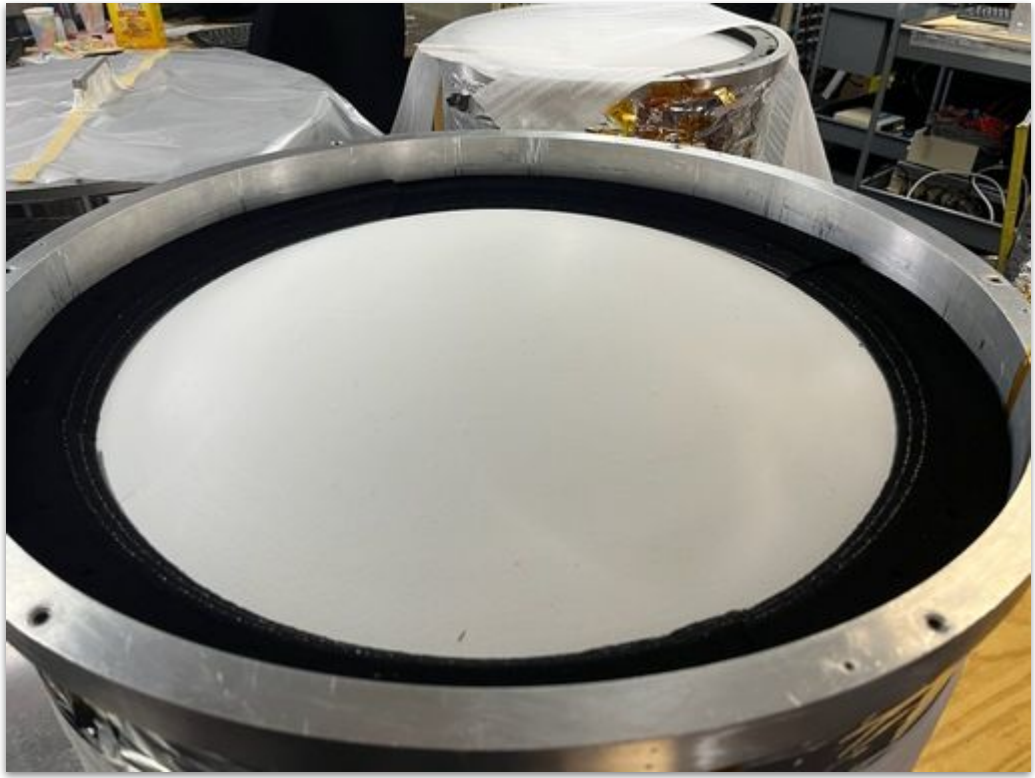
Tubes and mount



Inside a CMB telescope



Inside a CMB telescope



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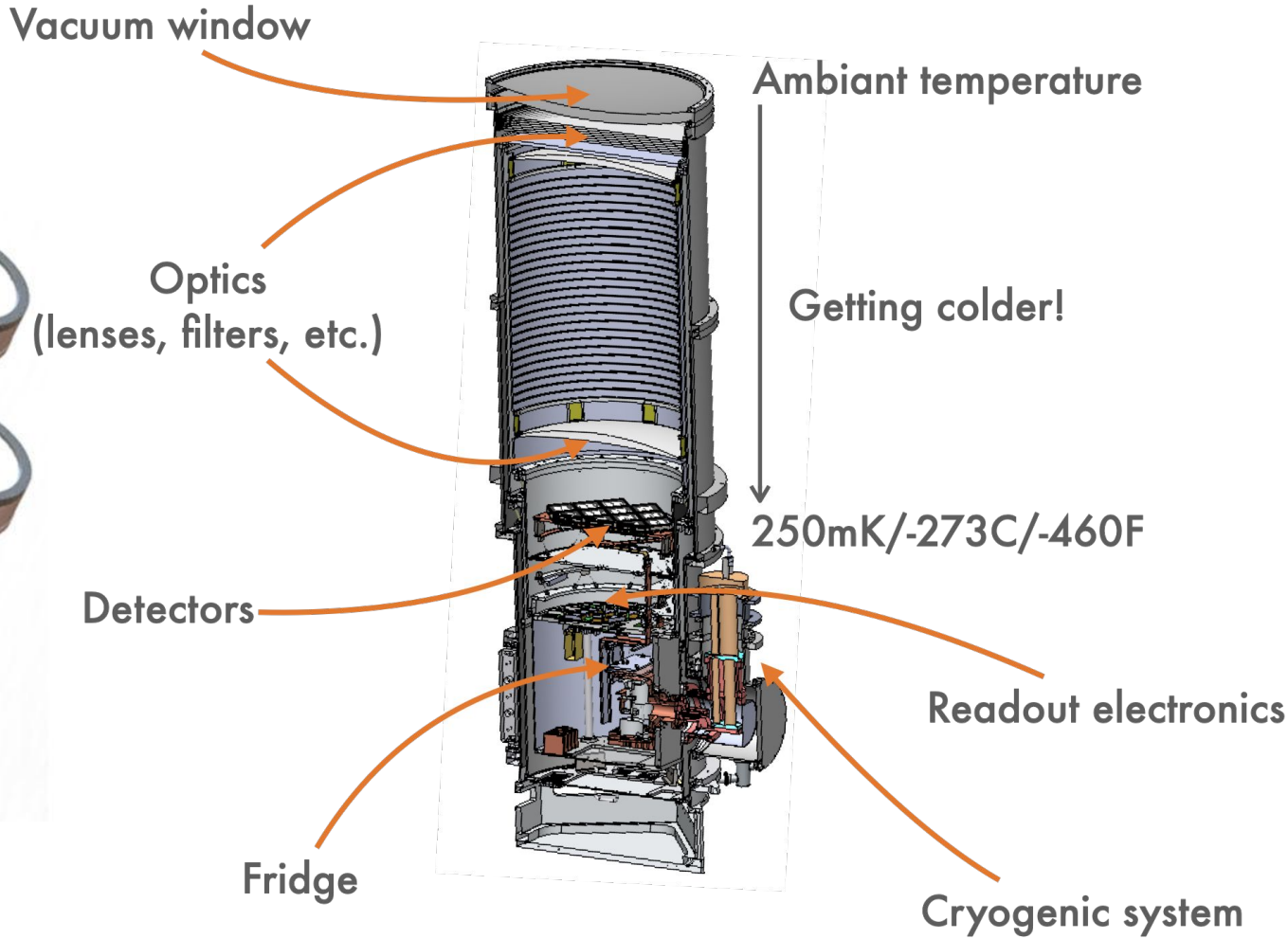
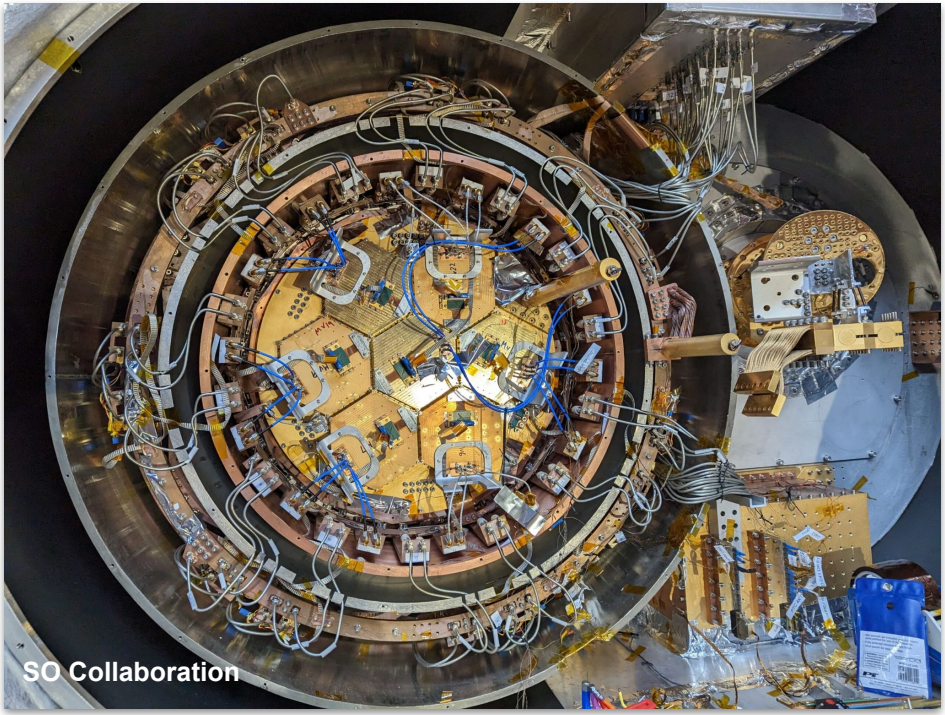
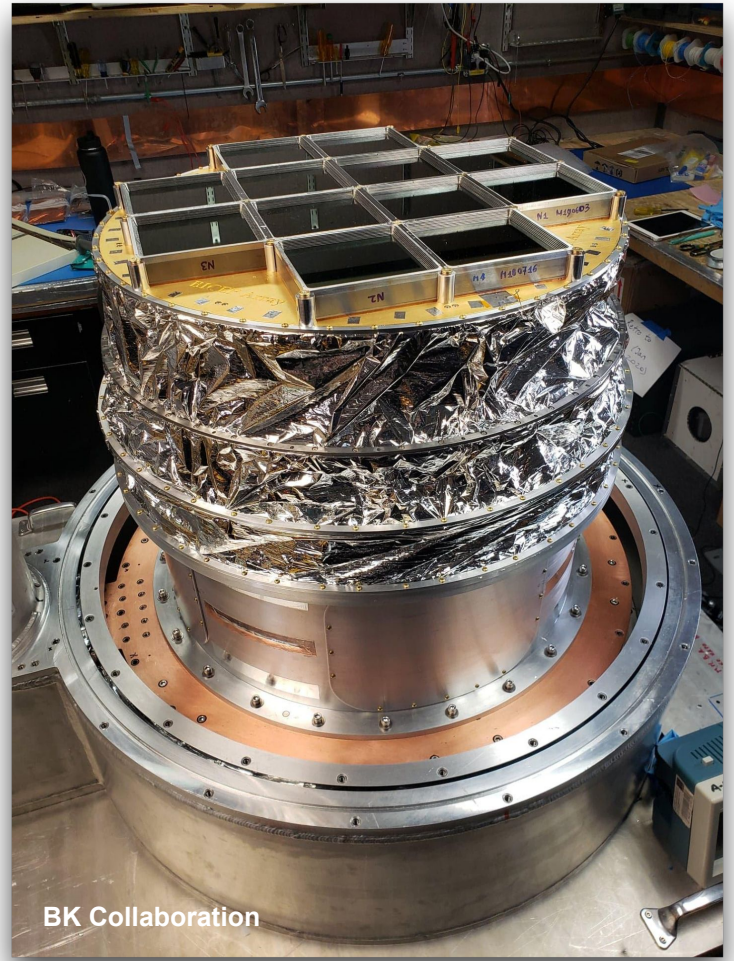
Small aperture telescope

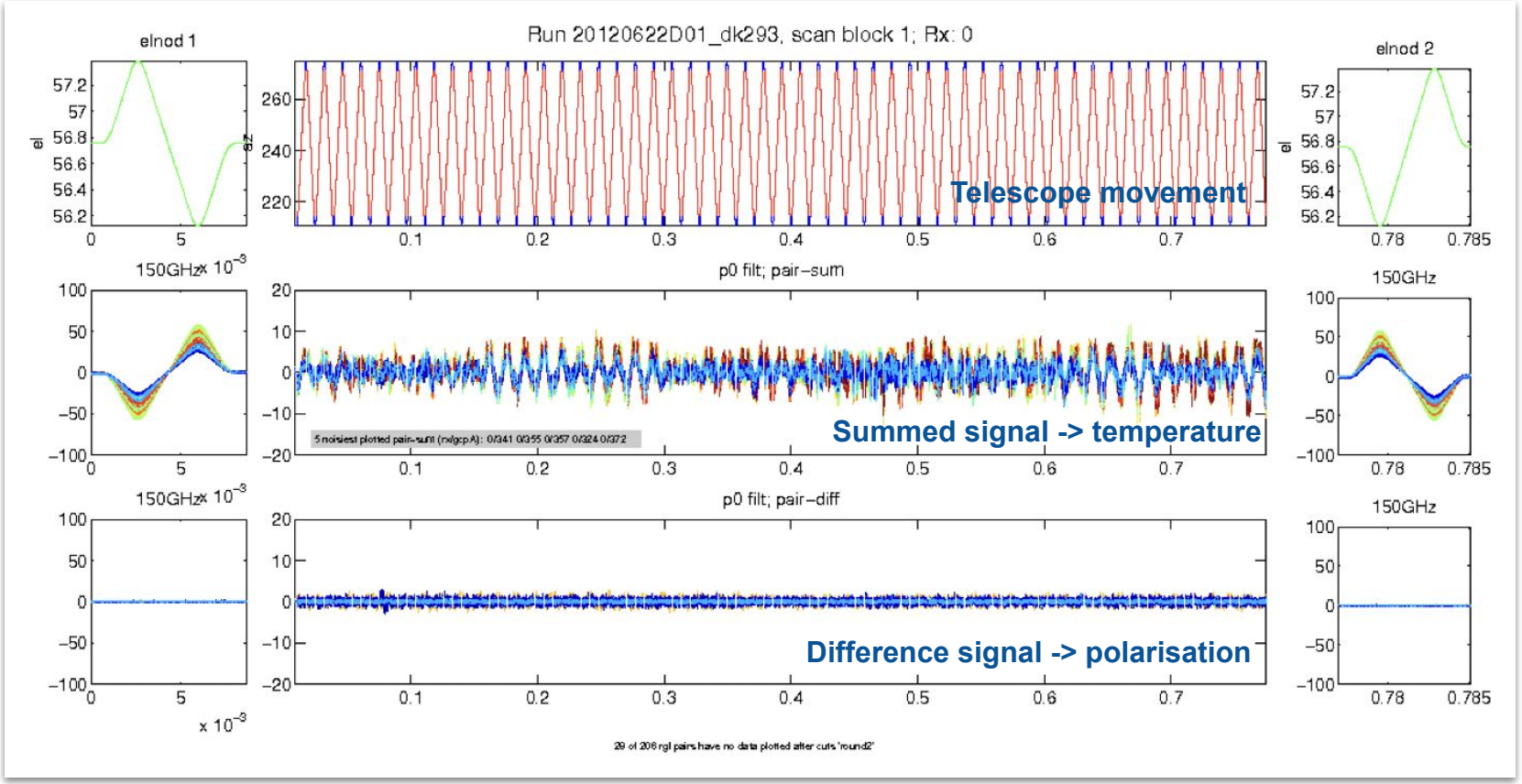


Inside a CMB telescope



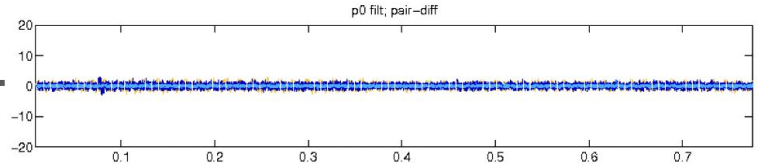


What do raw data look like?



BK collaboration

Making maps


p0 filt; pair−diff
20
10
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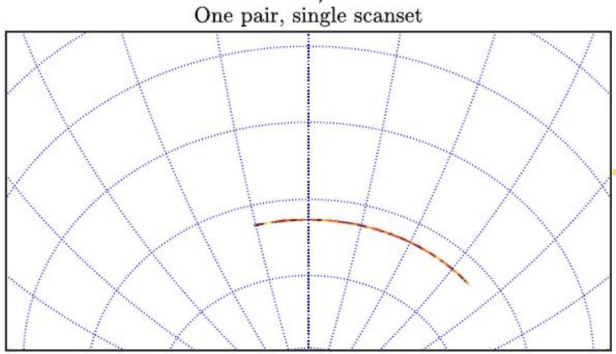
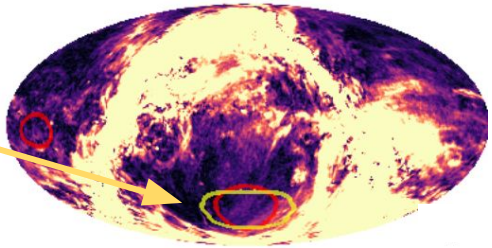
0.7


One pair, single scanset



Thank you!