CosPA2017 @Yukawa Institute for Theoretical Physics

The status of the development for Simons Array experiment

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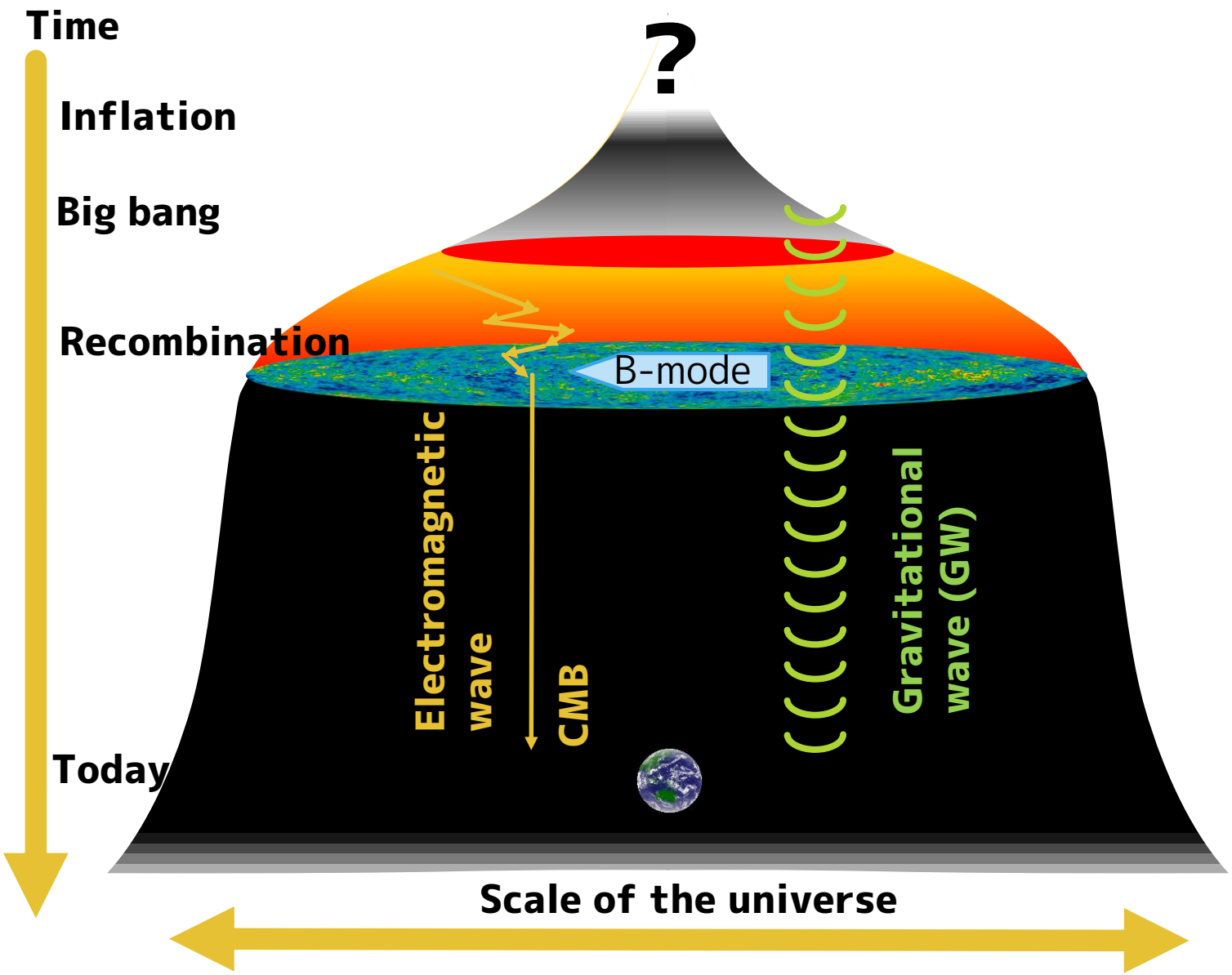
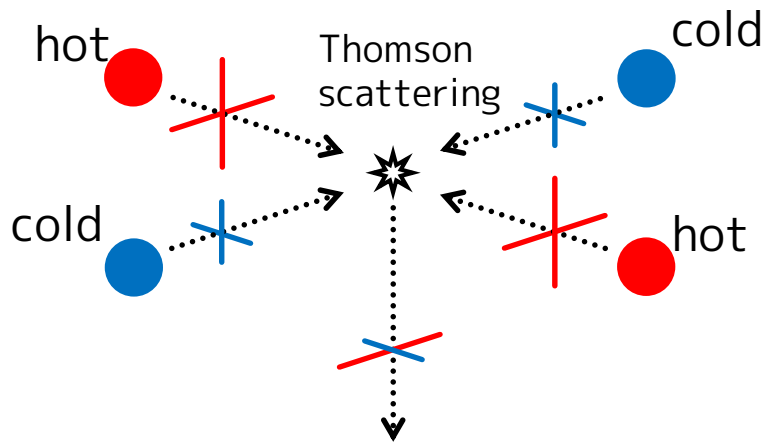
for POLARBEAR Collaboration

CMB observation

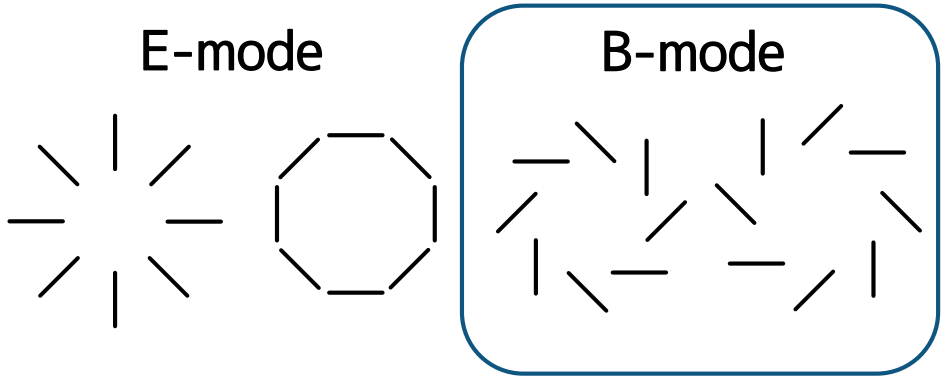


Polarization of CMB

Quadrupole distribution on last scattering surface makes polarization



Polarization pattern can be separated to 2 modes by parity.

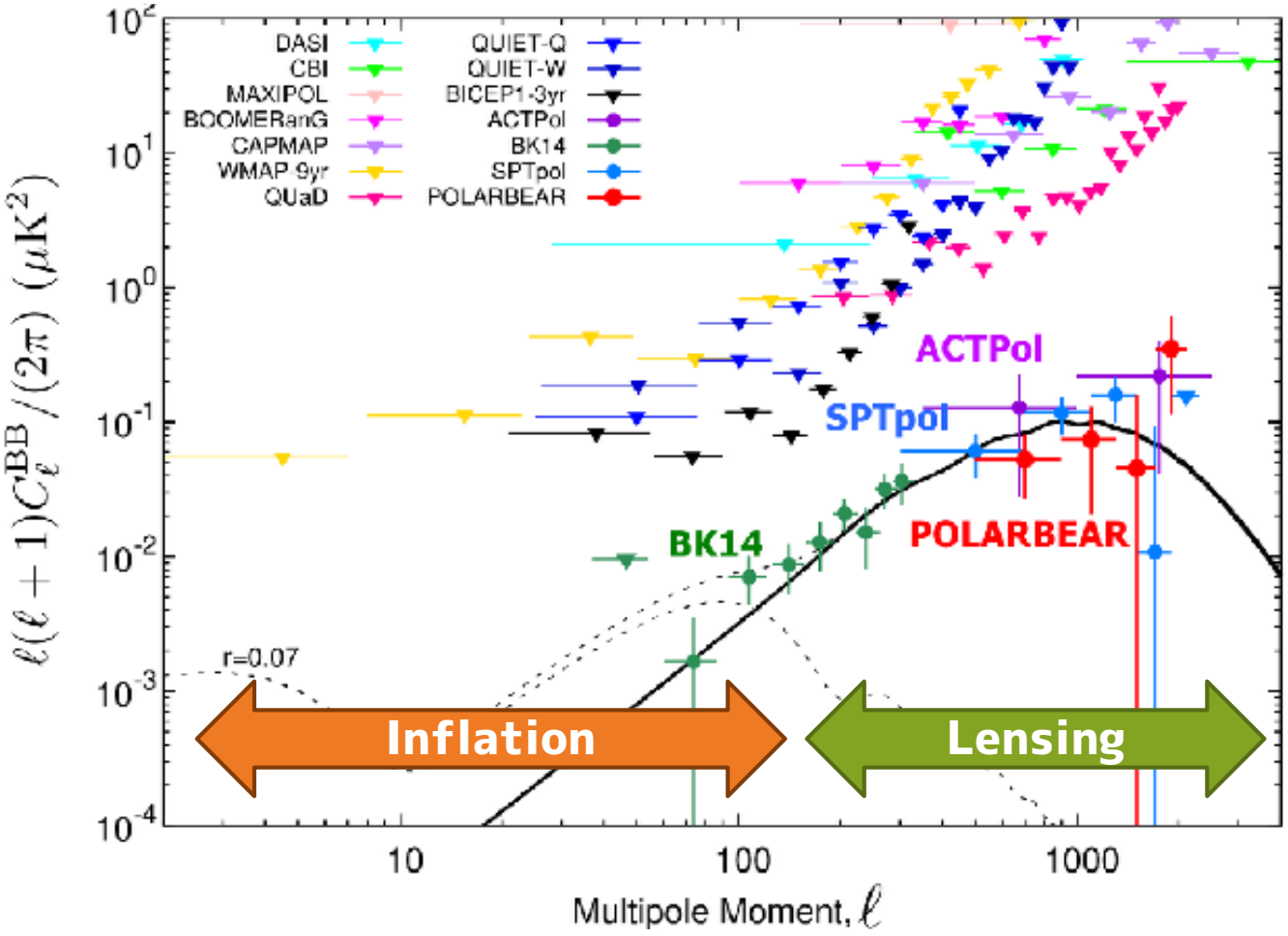


Status of CMB experiments

In recent years,

some experiments (include POLARBEAR) succeeded to observe B-mode polarization by **gravitational lensing**.

But, B-mode by **inflation** (primordial GW) has not been discovered yet.



POLARBEAR and Simons Array project

Site

- Chile Atacama
  - ~5200 m altitude
  - Very low humidity

Telescope

- Huan Tran Telescope (HTT)
  - 2.5 m primary mirror
  - 3.5’ resolution(150GHz)
  - Off-axis Gregorian

Collaboration

~100 researchers
~20 institutes
from 8 countries

POLARBEAR history

2011 : Construction finished

2012 : Start observation

2014-15 : First results published
- Lensing B-mode was found

2017 : Second results published

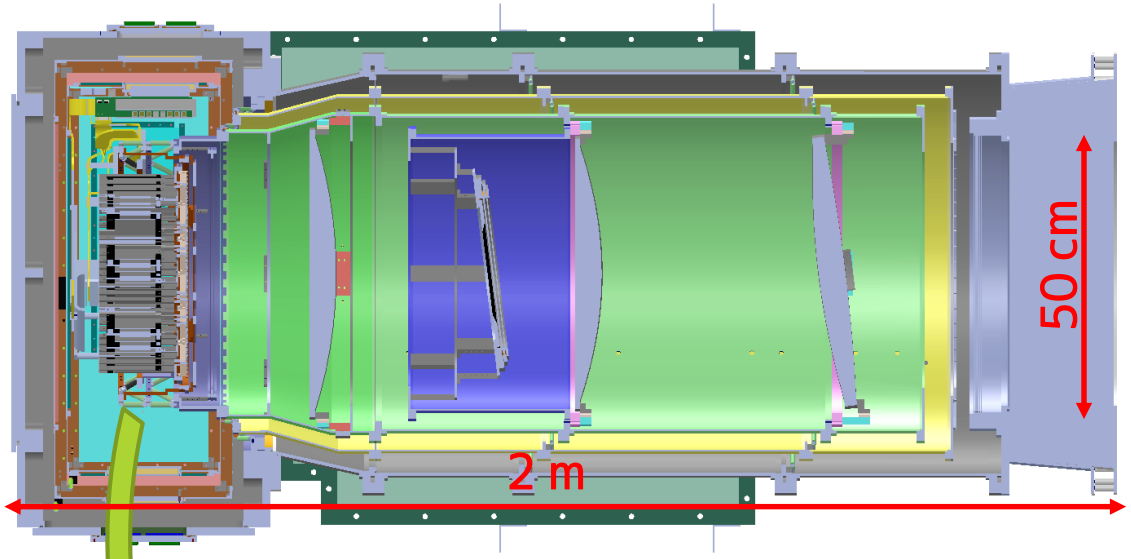
Phys.Rev.Lett., 112, 1302 (2014)
Astorophys.J., 794, 2, 171 (2014)
Phys.Rev.Lett.,113, 1301 (2014)
Astorophys.J., 809, 1, 63 (2015)
Phys.Rev.D, 92, 123509, (2015)

Astorophys.J., 848, 2, 121 (2017)

Upgrade to Simons Array

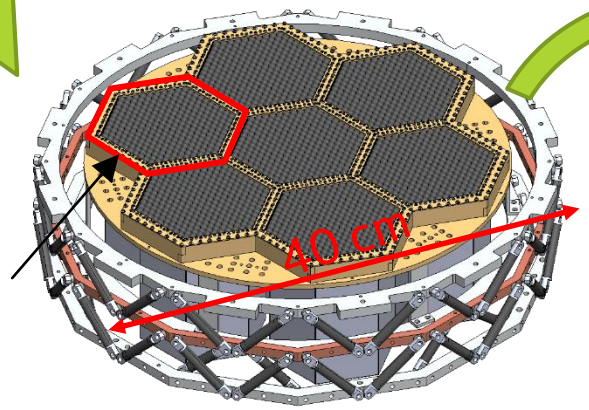
- Observation with 3 telescopes
- Extended focal plane to house 6 times more sensors
- Dichroic observation of 95/150 GHz (220/270 GHz : 3rd receiver) for better foreground removal.

POLARBEAR-2 receiver

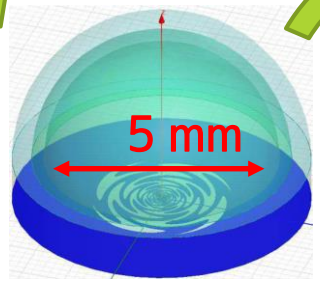


Cross-section of POLARBEAR-2 receiver cryostat

	PB-1	PB-2
Frequency [GHz]	150	95/150
Number of TES	1274	7588
Focal plane diameter [mm]	190	365
Angular resolution [min]	3.5	6.0 / 3.5 (95/150 GHz)
Field of view [deg]	2.4	4.8
Noise equivalent temp [μK√s]	23	4(combined)



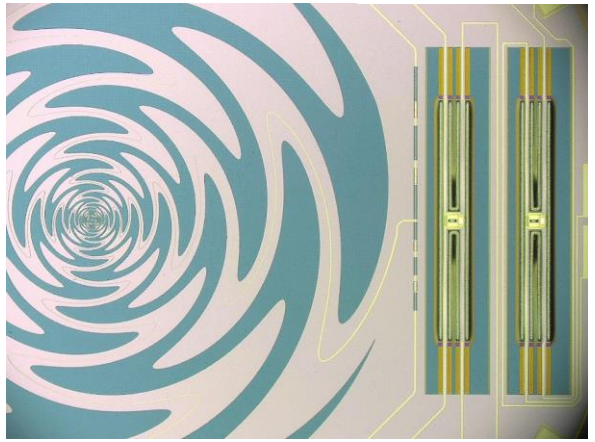
Focal Plane Detector



Lenslet and sensor

Sinuous antenna

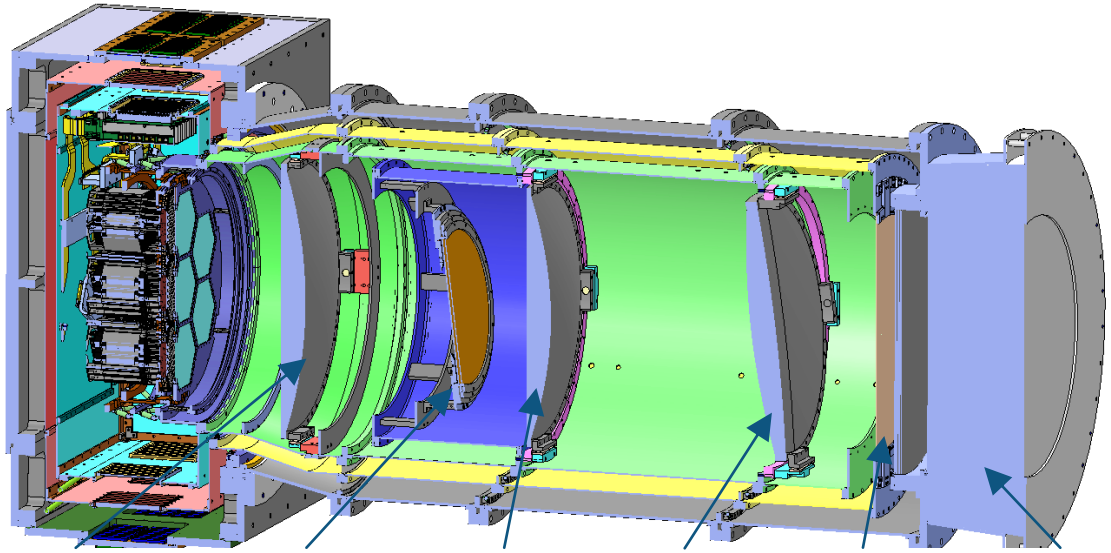
TES bolometer

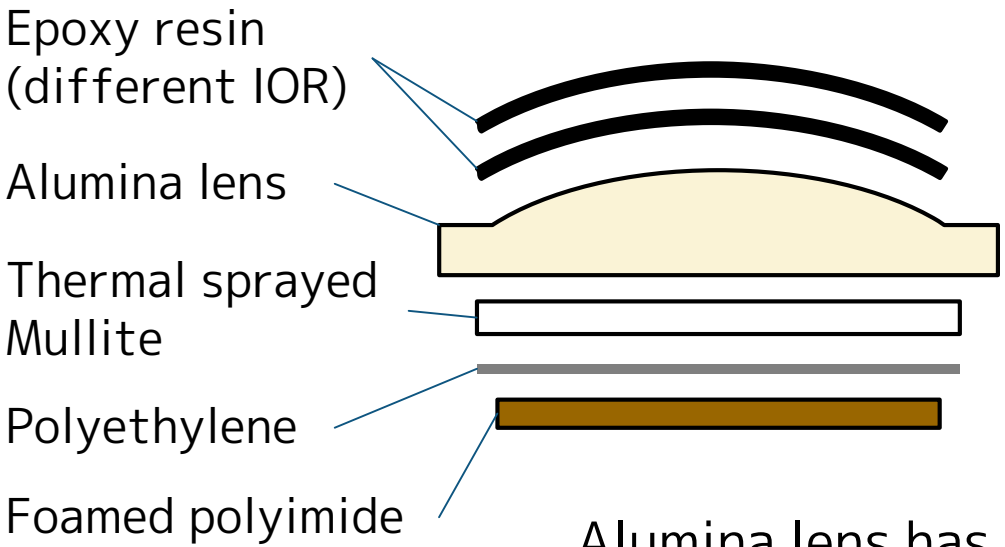


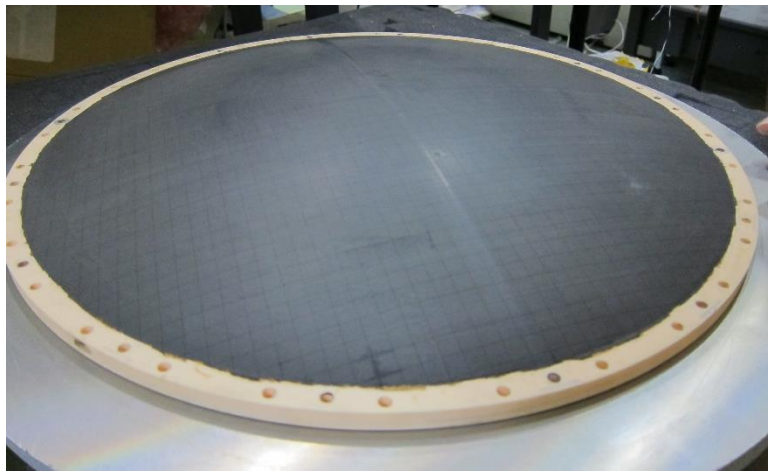
Close-up to sensor

Optics system

- **System to re-focus image on detector plane.**
- **Cryogenic system main components at 4K.**
- **Three alumina lenses which have high thermal conductivity.**
- **Now final performance test.**





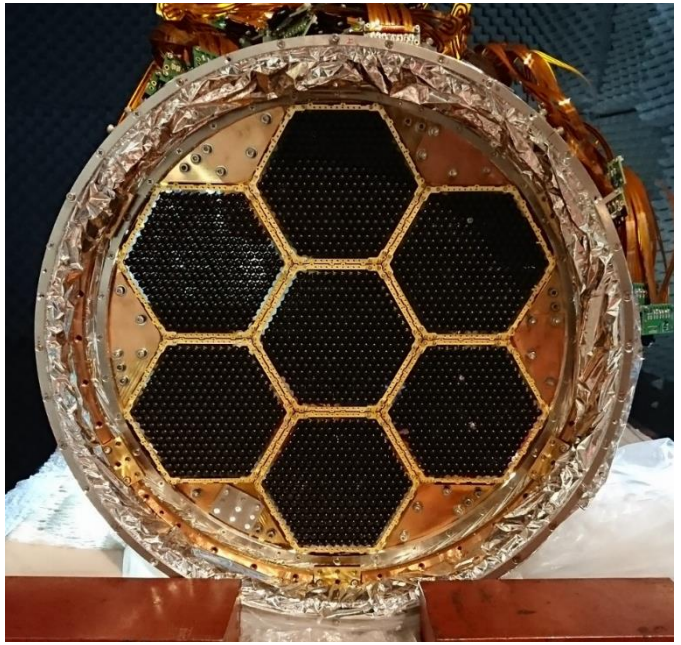


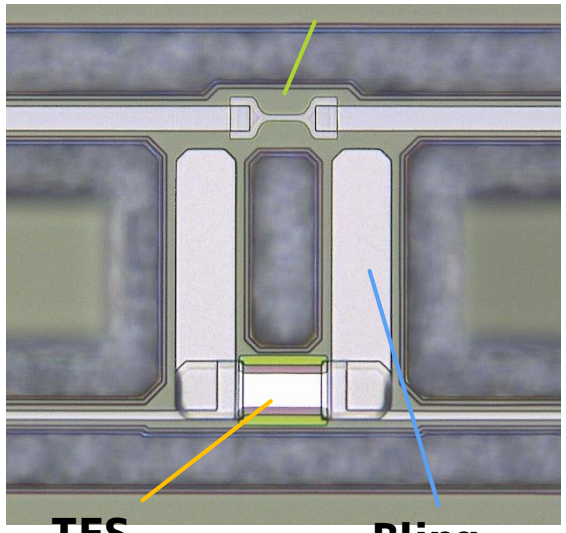
Alumina lens has two-layered Anti-Reflection coating

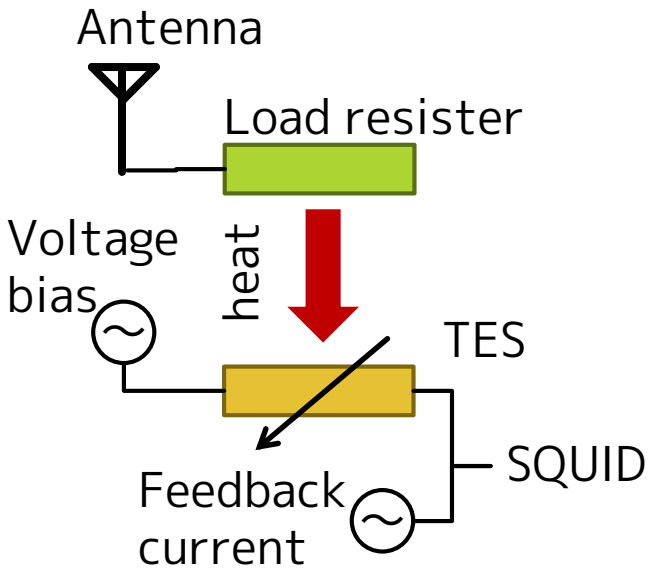
TES bolometer Detector

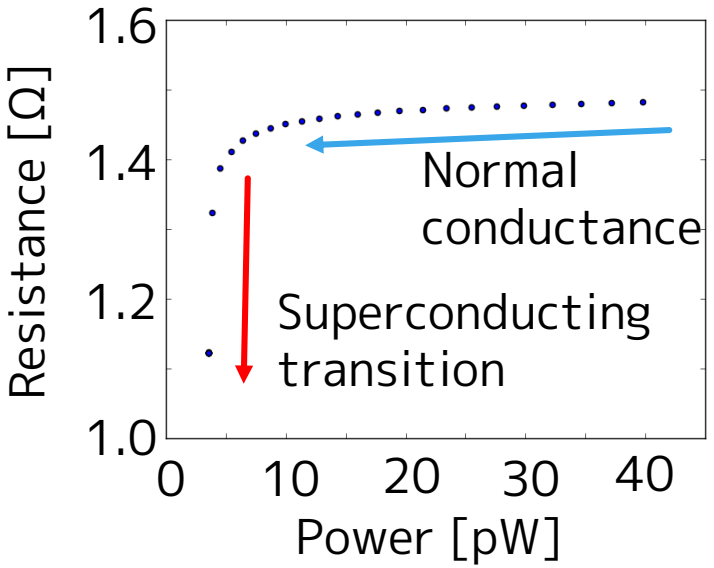
- **POLARBEAR-2 is designed to make photon noise limited detection with Transition Edge Sensor bolometer.**
- **Detector plane is cooled by He sorption refrigerator to 270mK.**
- **Final characterization of full-equipped detector array is progressing.**

Fully assembled detector



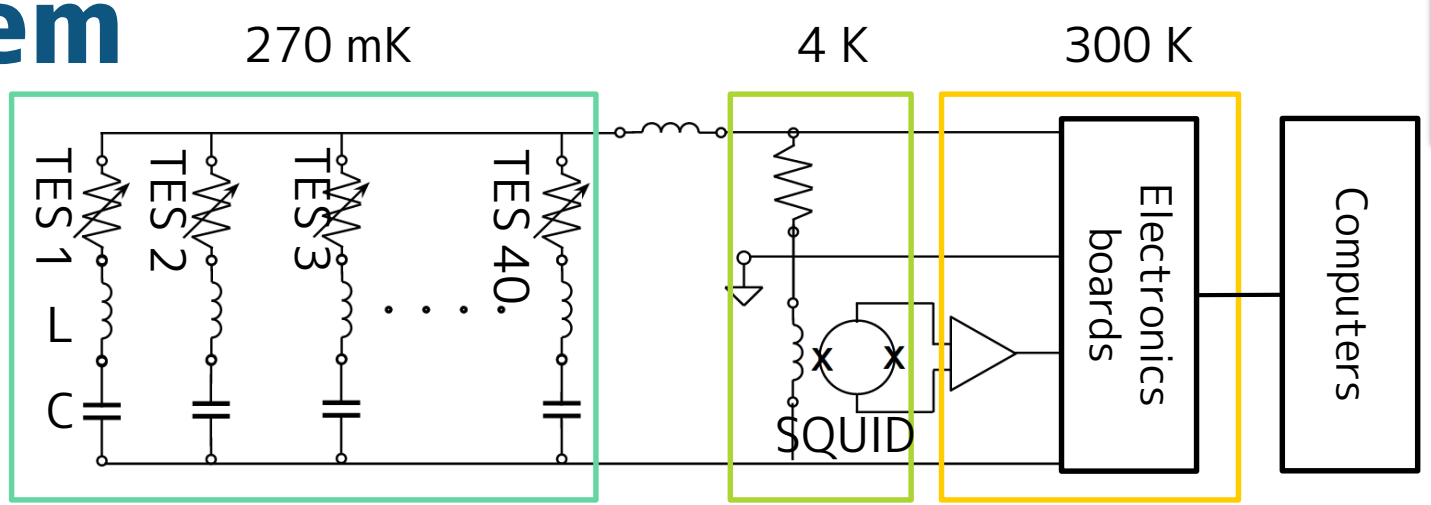


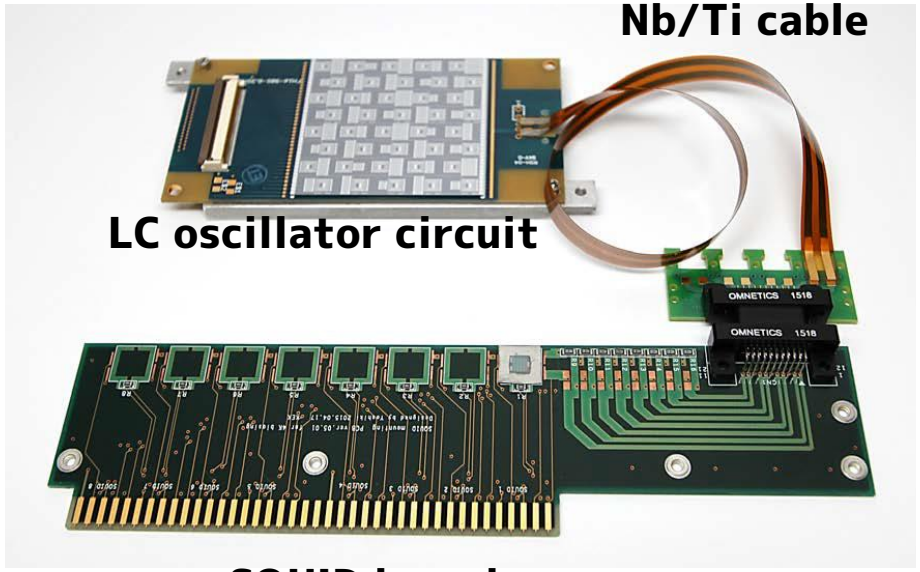


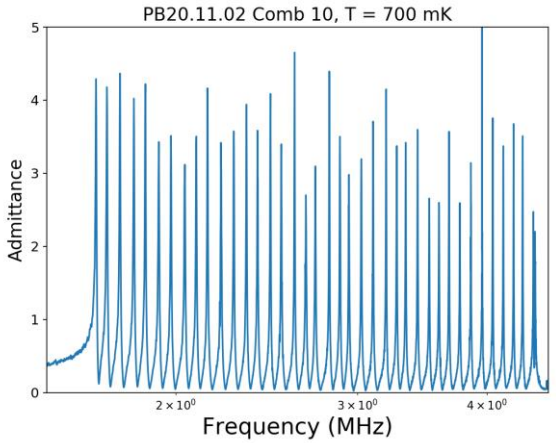


Read-out system

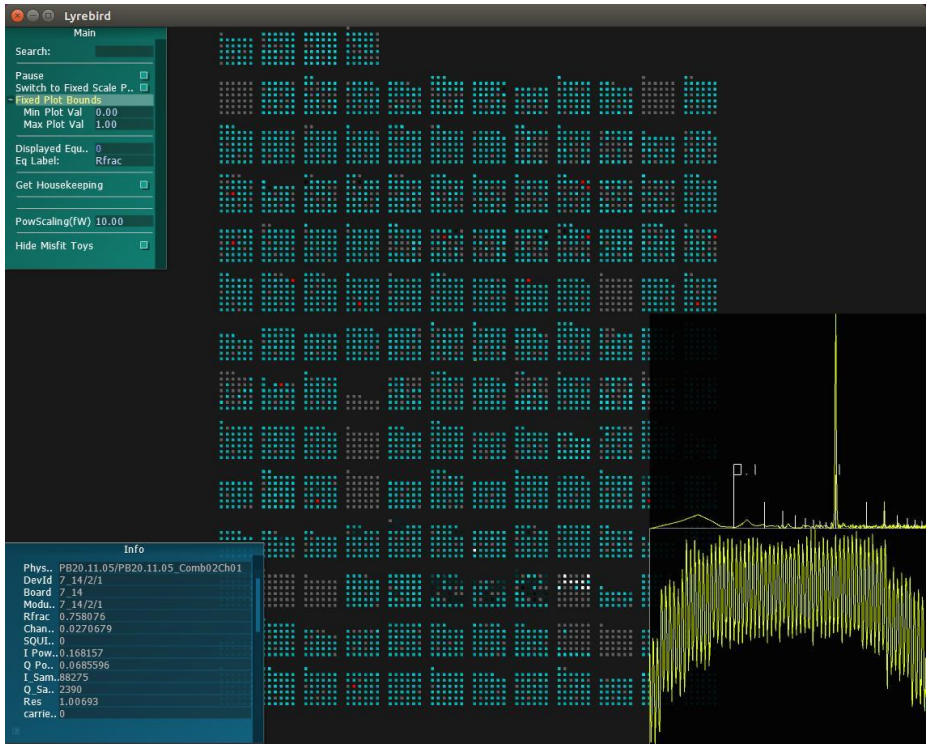
- **Digital Frequency-Division Multiplexing (DfMUX) method with 40 multiplexing factor**
- **Low noise amplification with SQUID**
- **Lab test is underway with mostly finalized system.**







40 peaks in frequency comb are seen.



Monitoring >6000 TES channels

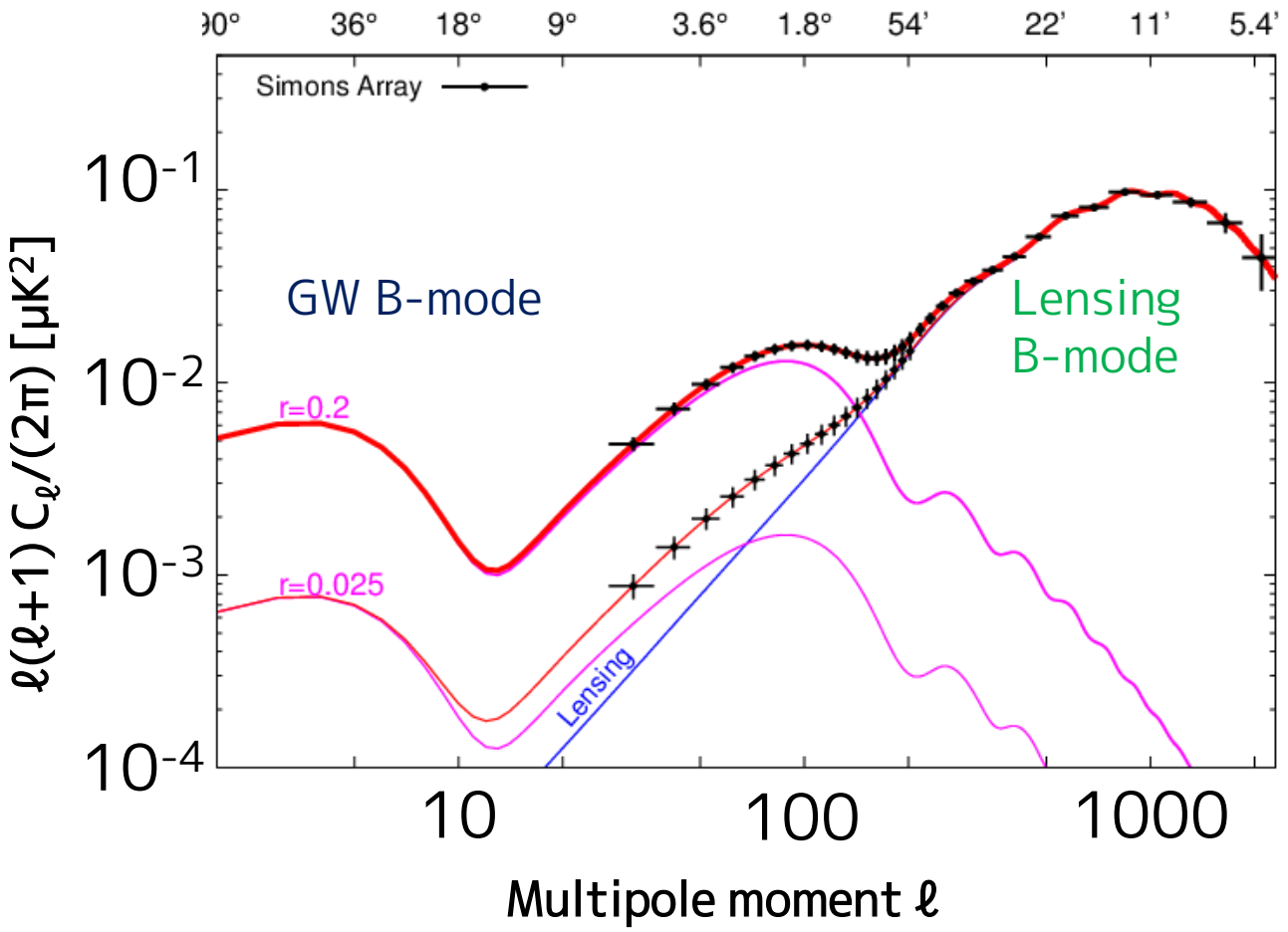
Status of Atacama site

- Second and third telescopes were build.
- First POLARBEAR-2 receiver will be deployed in 2018

Expected science

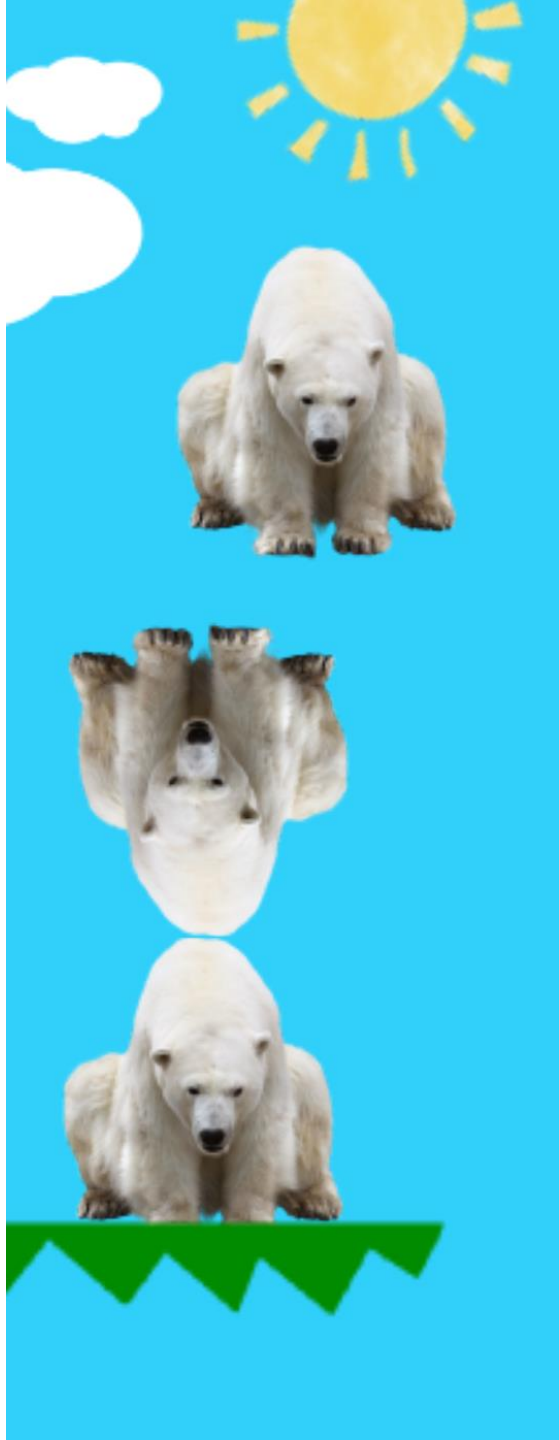
After 3 years observation
with 3 receivers.

- **From GW B-mode (low-ℓ)**
  - **tensor-to-scaler ratio "r"**
  - $\sigma(r)|_{r=0.1} = 0.006$
- **From Lensing B-mode (high-ℓ)**
  - **Sum of neutrino masses**
  - $\sigma(\Sigma m_\nu) = 40\ [\mathrm{meV}]$
    (combined with DESI BAO result)



Summary

- **Simons array experiment is an upgrade of POLARBEAR with 3 array of higher performance receiver.**
- **First POLARBEAR-2 receiver is being developed, and now in final stage of lab test.**
- **Deployment of first receiver is planned in year 2018.**



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