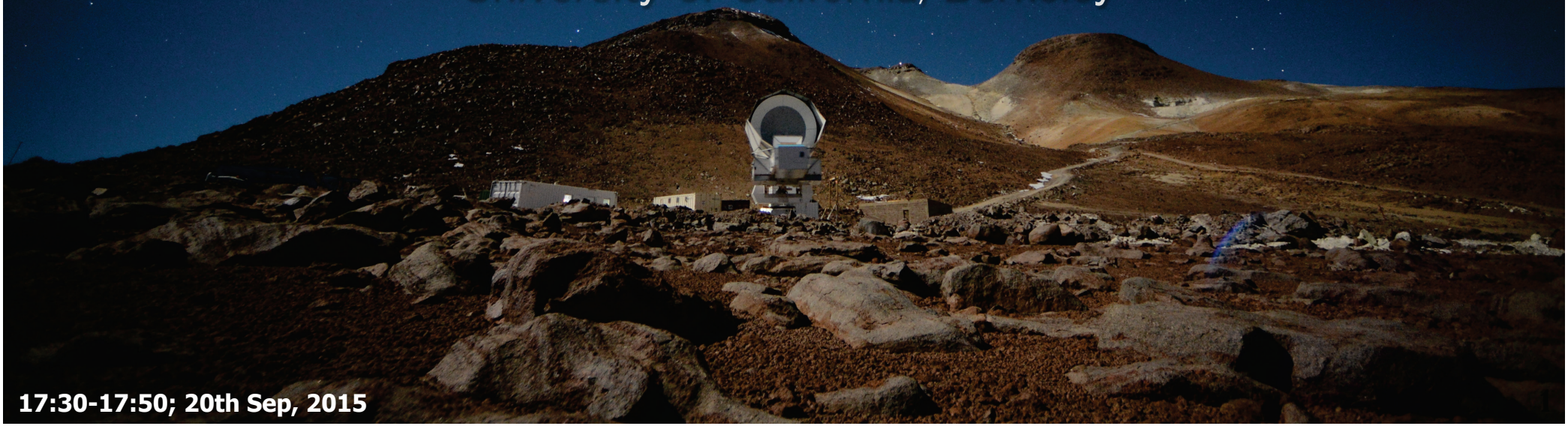
Accelerating Universe Kickoff Meeting

Latest Results of POLARBEAR & Future Measurements of B-mode Polarization with Simons Array & LiteBIRD

Yuji CHINONE (茅根裕司)

University of California, Berkeley



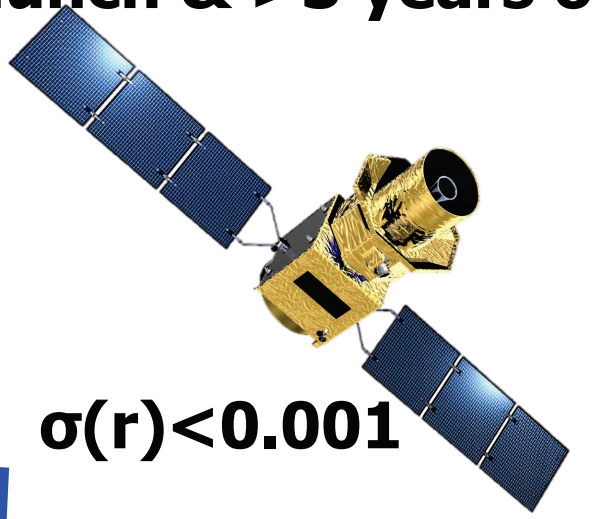
17:30-17:50; 20th Sep, 2015

- Relation & Synergy btw Ground-based experiments (POLARBEAR & Simons Array) and Satellite (LiteBIRD)
- Difficulty in Measuring B-modes @ Large Angular Scale
- Development & Validation to Solve it by POLARBEAR for Simons Array & LiteBIRD
- (New Result from POLARBEAR)

today

2015 → **202X** (2021?,2025?)

phase-A → **Launch & >3 years obs.**



development & design & construction

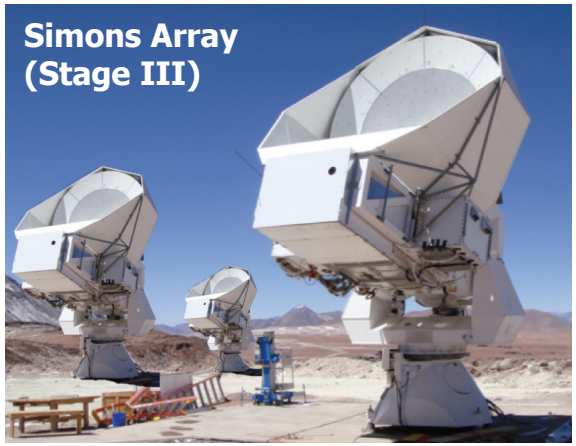
σ(r)<0.001

matured technologies tested
on ground will be used for satellite

Now

σ(r)<0.1

2016~



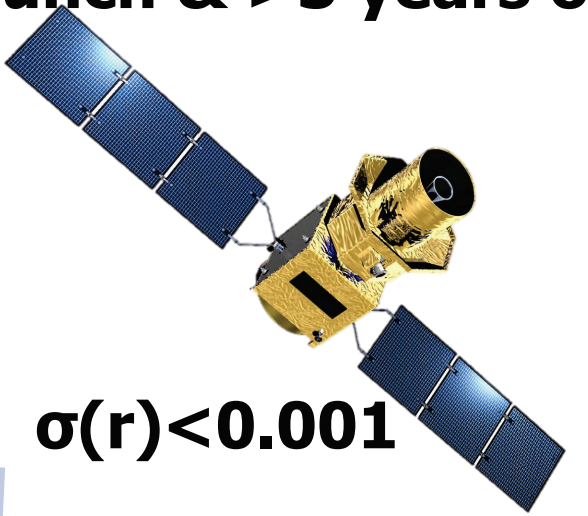
σ(r)<0.01; σ(Σm$_\nu$)~40 meV

today

2015 → **202X** (2021?,2025?)

phase-A → **Launch & >3 years obs.**

development & design & construction →



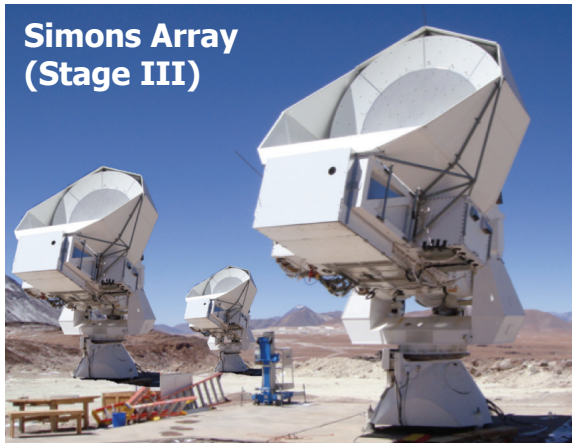
σ(r)<0.001

and ground exp. will keep
developing & using advanced technologies

Now

σ(r)<0.1

2016~

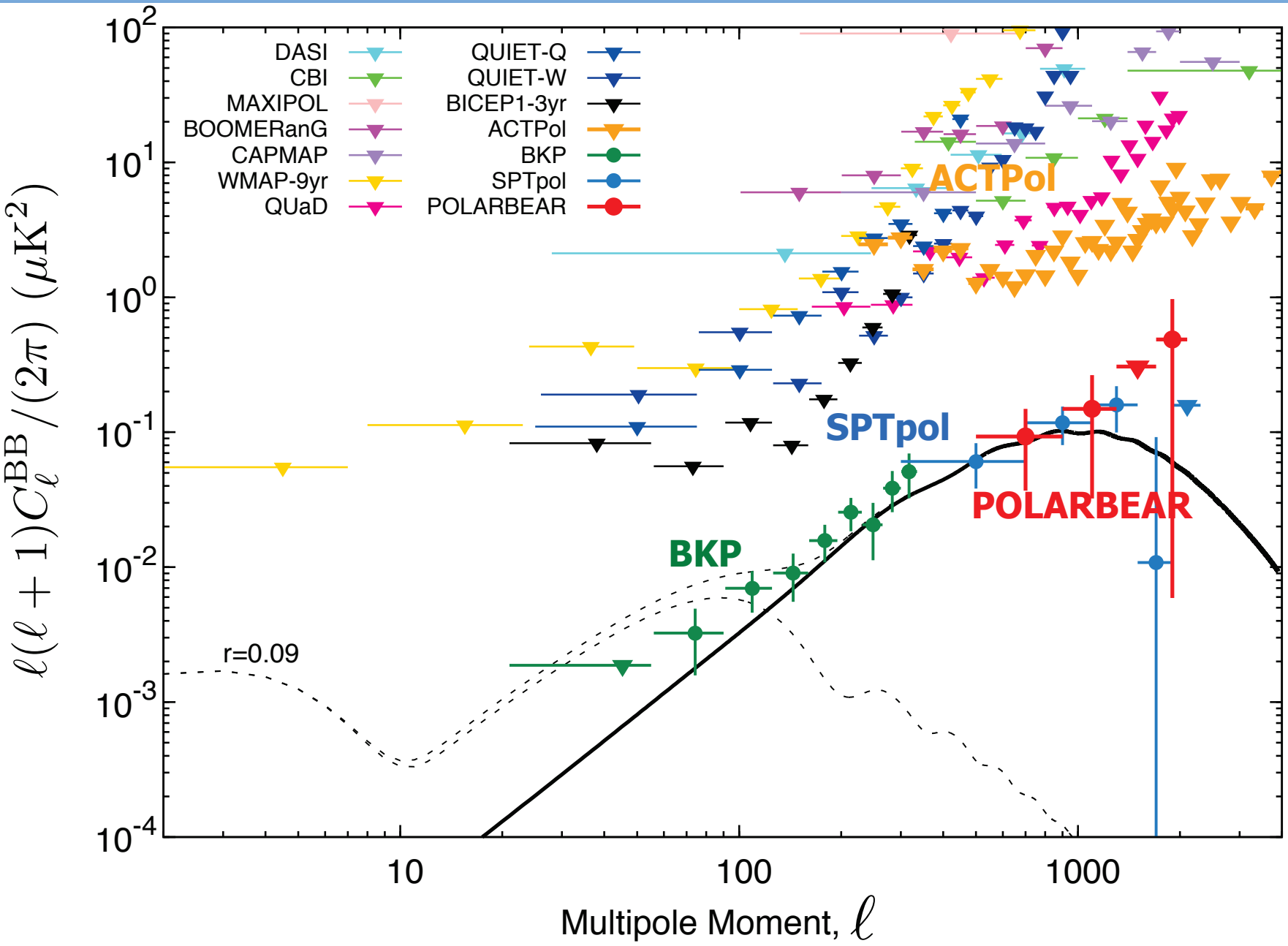


σ(r)<0.01; σ(Σm$_\nu$)~40 meV

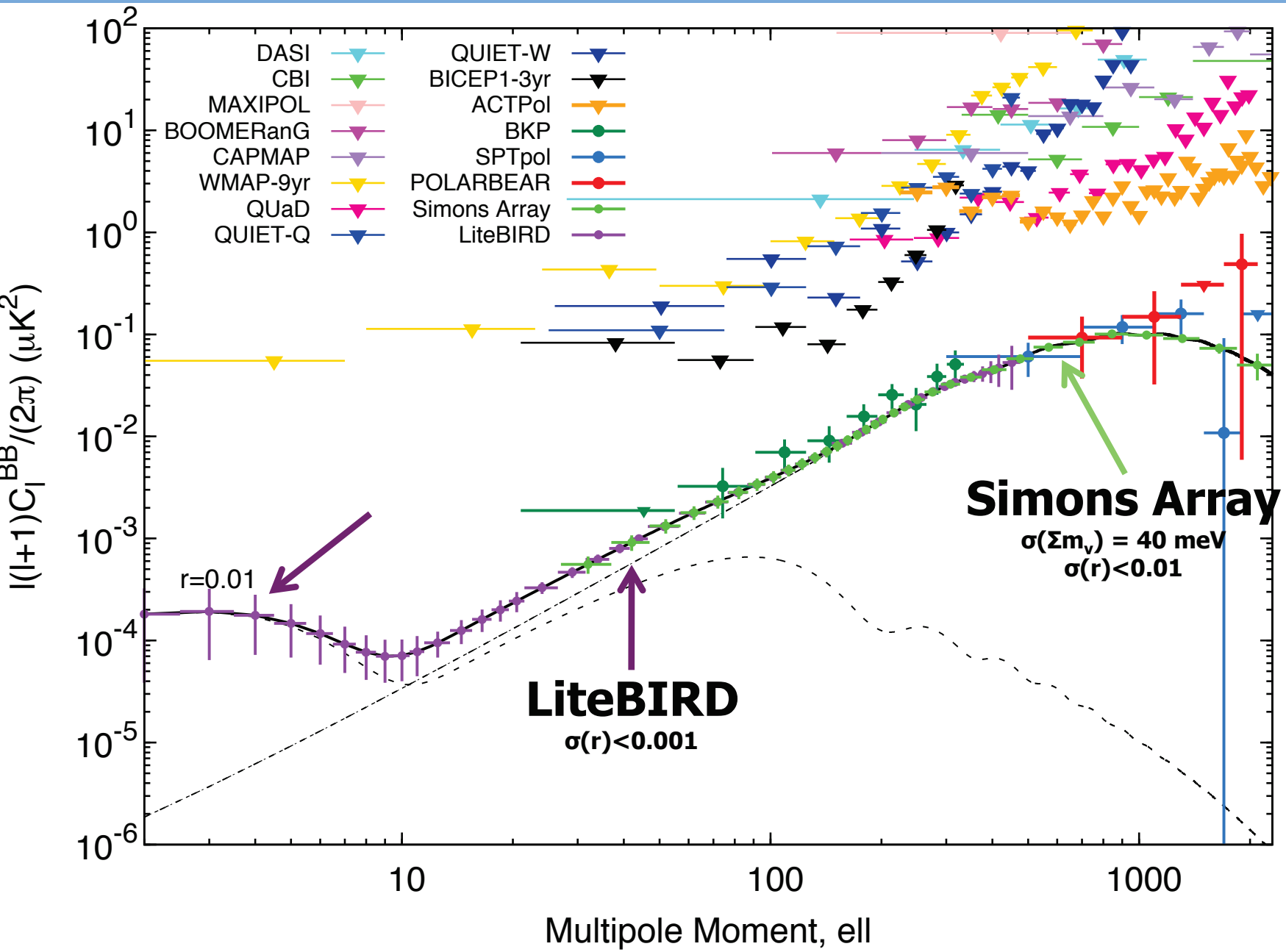
2020~

σ(r)<0.001; σ(Σm$_\nu$)~16 meV

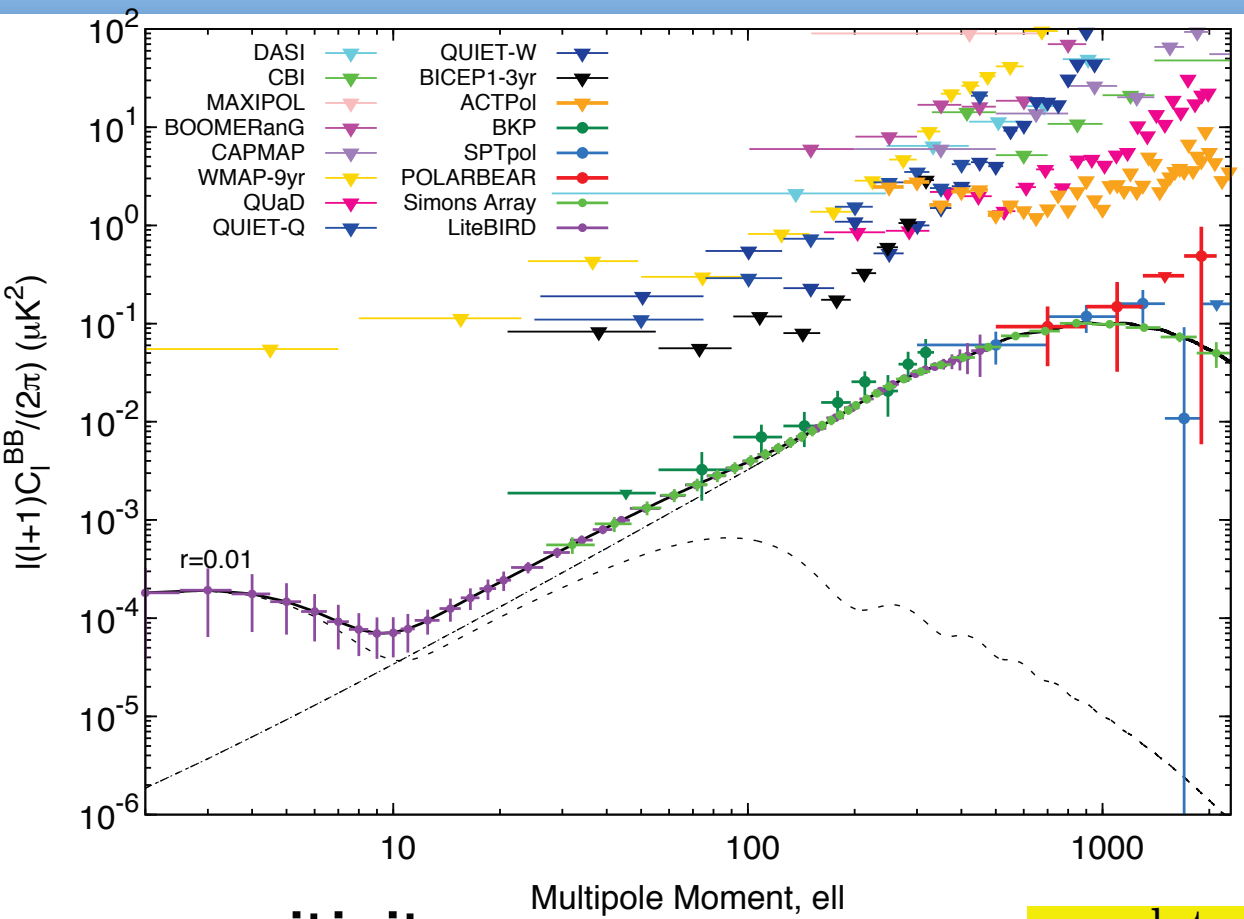
B-mode Power Spectrum Today



B-mode Power Spectrum in 2020's



Problem Must be Solved

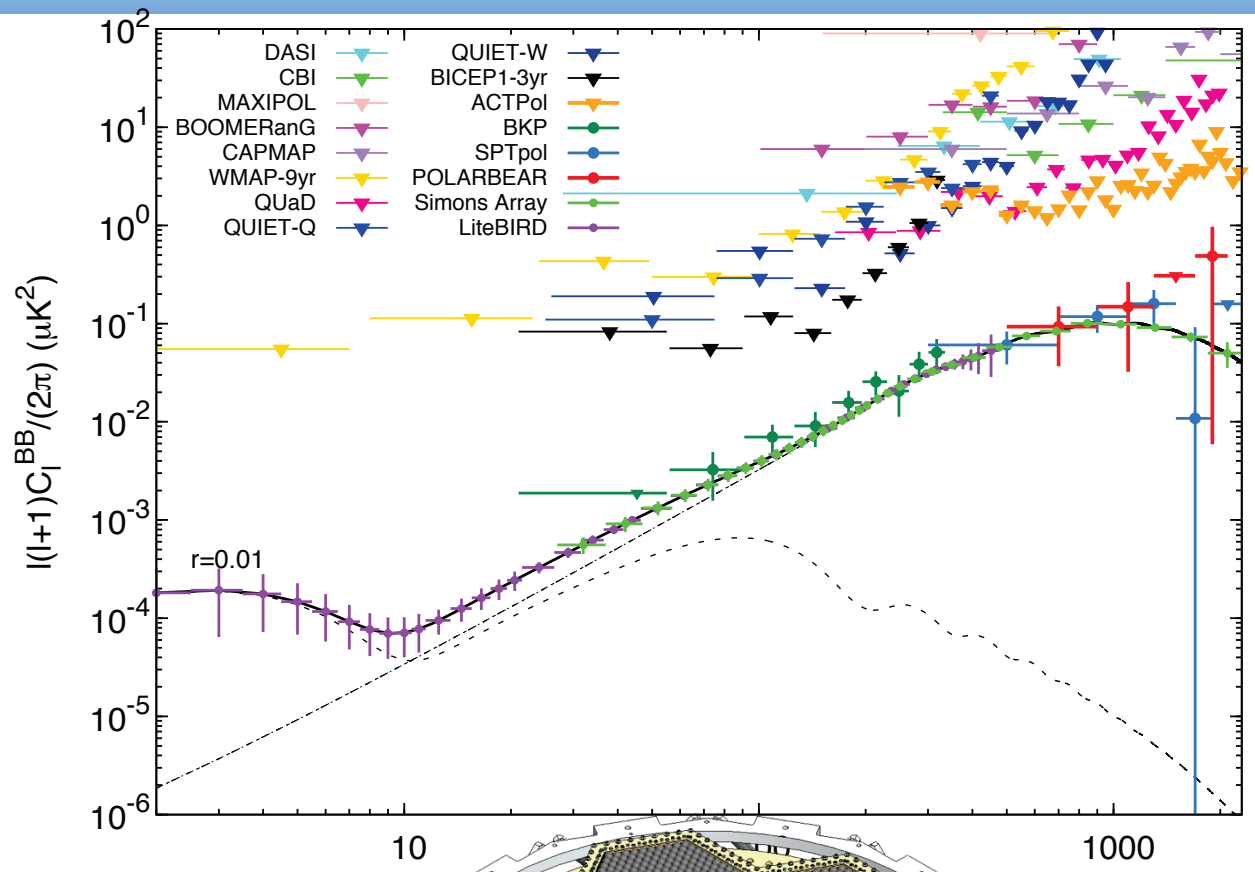


completely ideal case
e.g. white noise

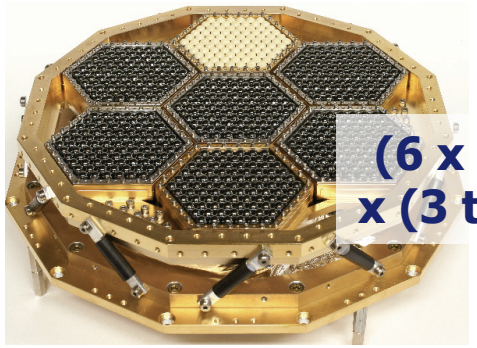
- Need more sensitivity
  - better & more detectors

$$\Delta C_\ell^{\rm det} \propto {\rm NET}_{\rm det}^2 / N_{\rm det}$$

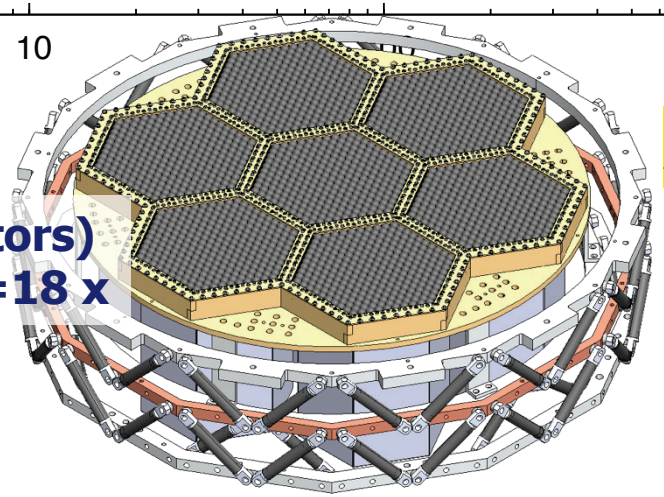
Problem Must be Solved



completely ideal case
e.g. white noise

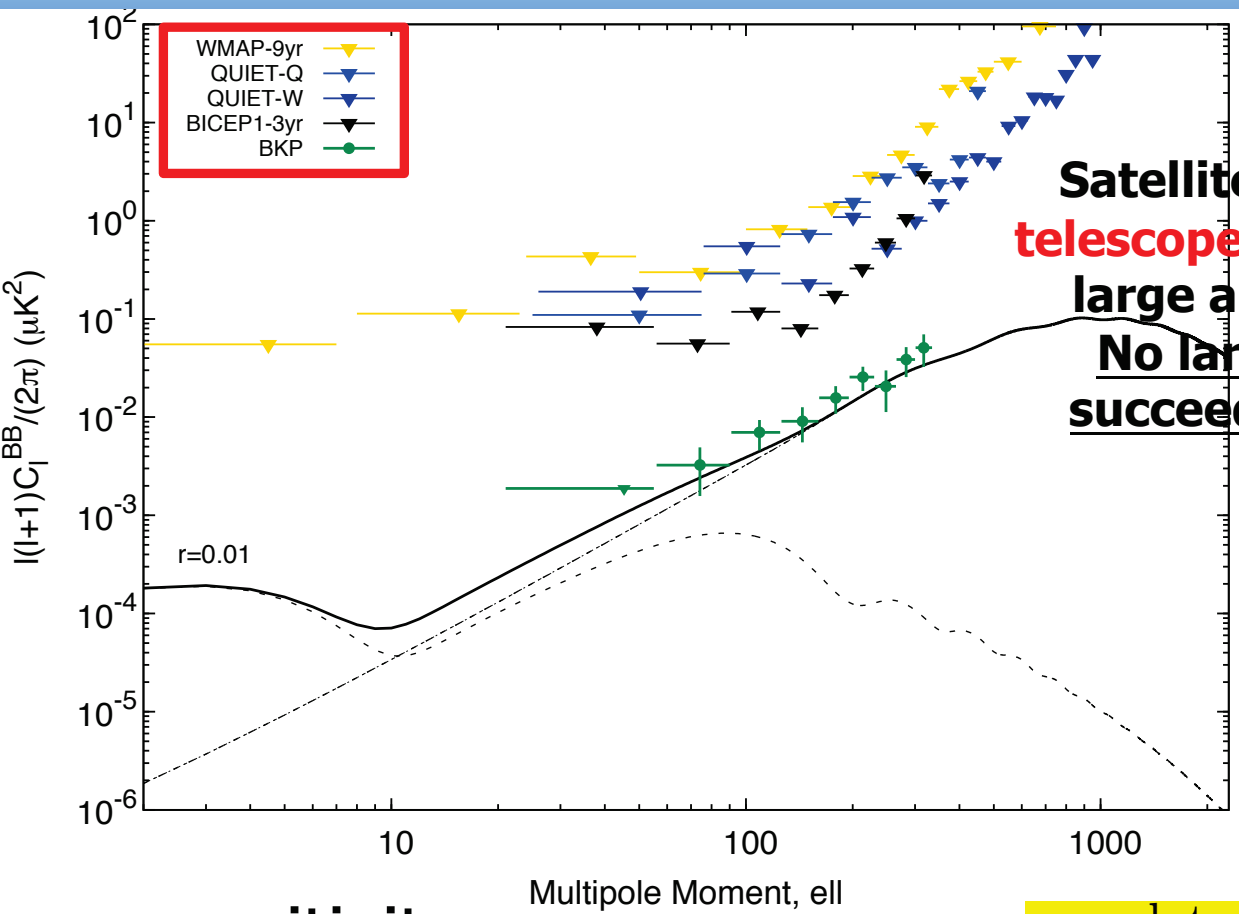


(6 x more detectors)
x (3 telescopes)=18 x



$$\Delta C_\ell^{\rm det} \propto {\rm NET}_{\rm det}^2 / N_{\rm det}$$

Problem Must be Solved



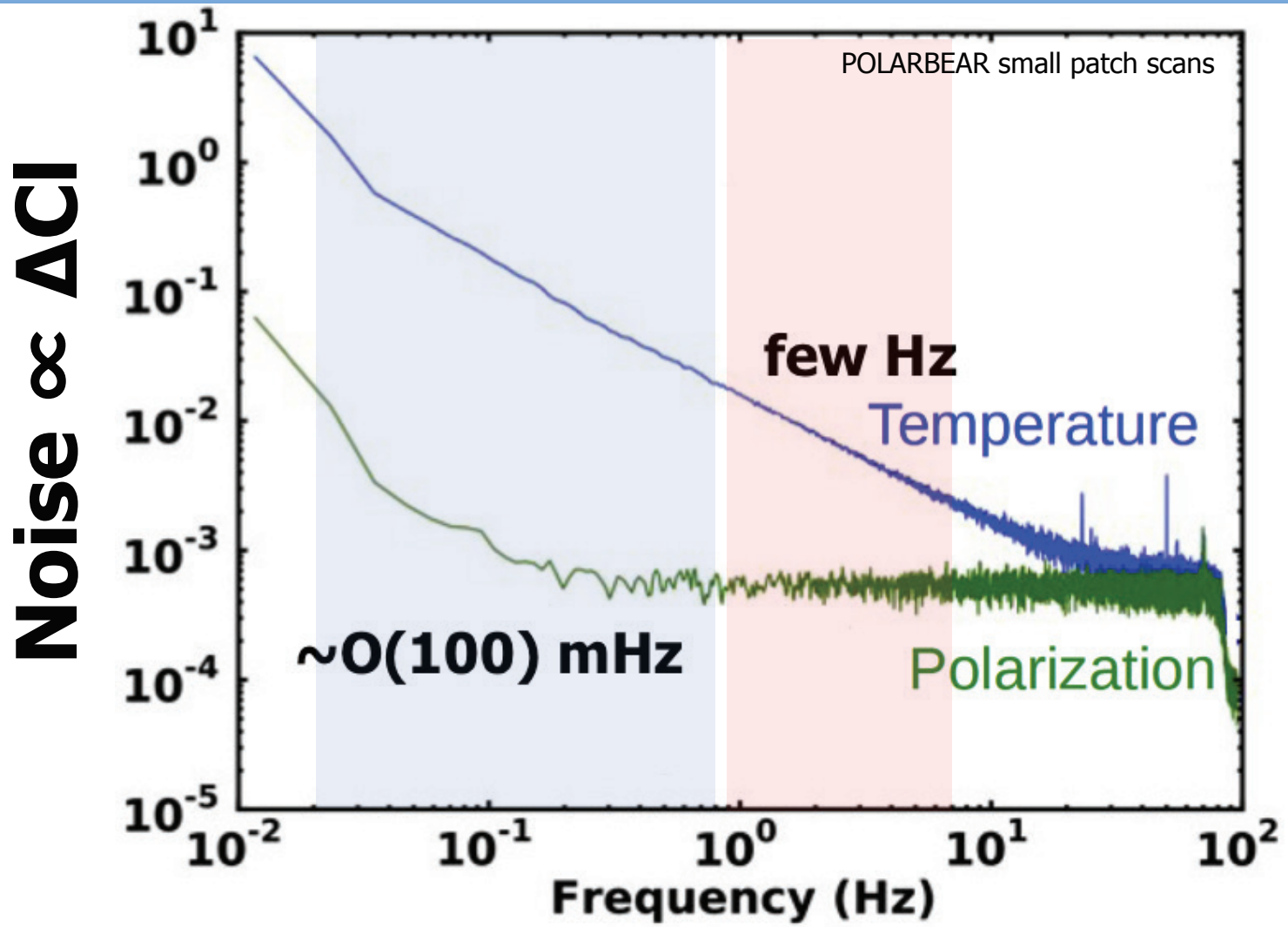
Satellite or only small telescope have measured large angular scales. No large telescope succeeded to do that

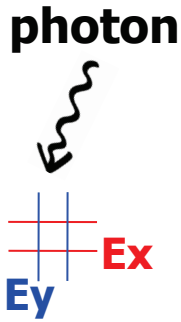
- Need more sensitivity
  - better & more detectors

$$\Delta C_\ell^{\rm det} \propto {\rm NET}_{\rm det}^2 / N_{\rm det}$$

- Need modulation techniques for large angular scales
  - must mitigate 1/f noise due to atmosphere and/or instrument

1/f Noise Performance Today



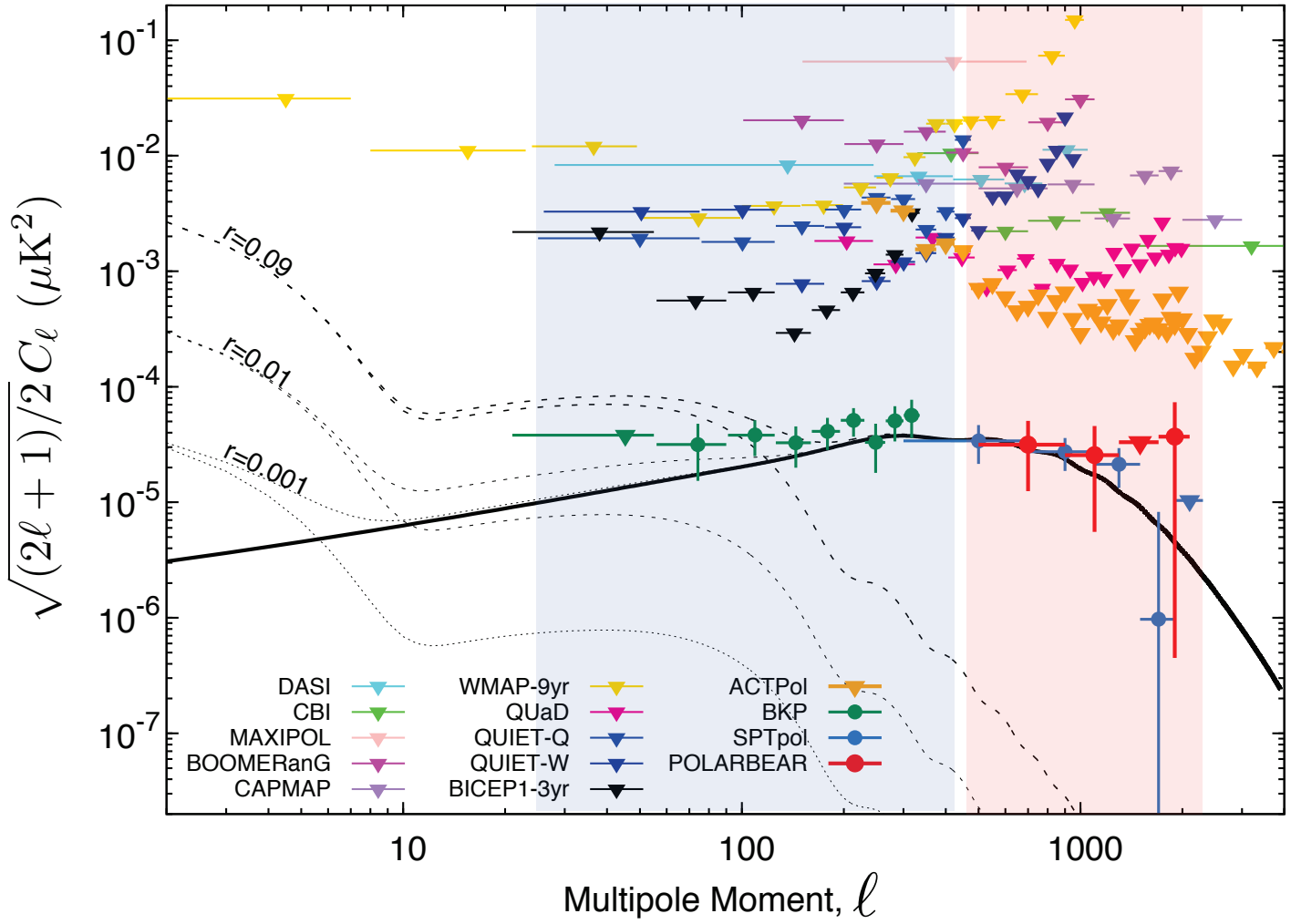


$I \propto Ex^2 + Ey^2$

$P \propto Ex^2 - Ey^2$

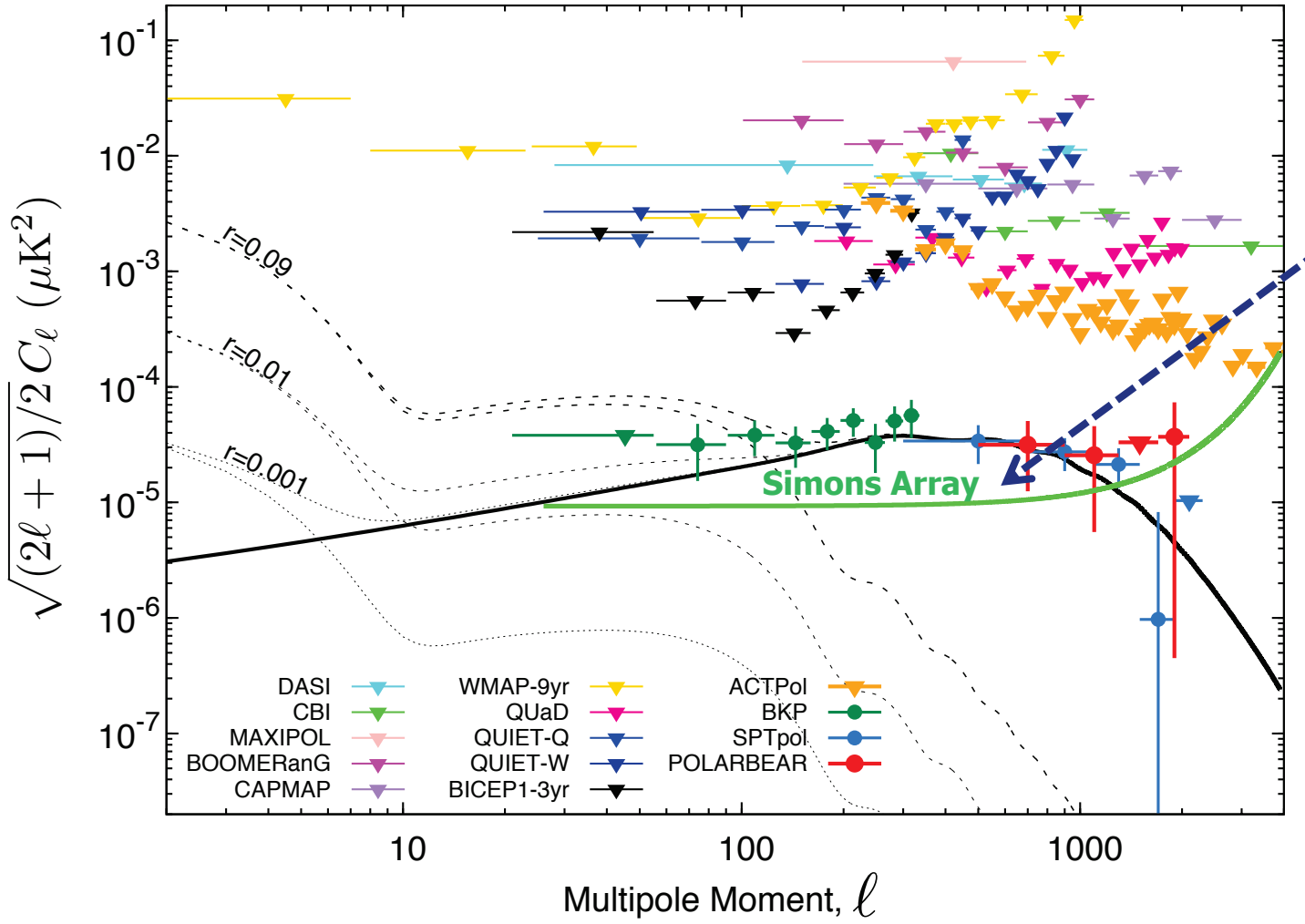
- Can suppress 1/f w/ diff. orthogonally-polarized pairs down to ~100 mHz
- Only a few Hz frequencies are effective/available

1/f Noise Performance Today



- Large telescope haven't measured B-modes @ large angle
- Must need a new technique for Simons Array

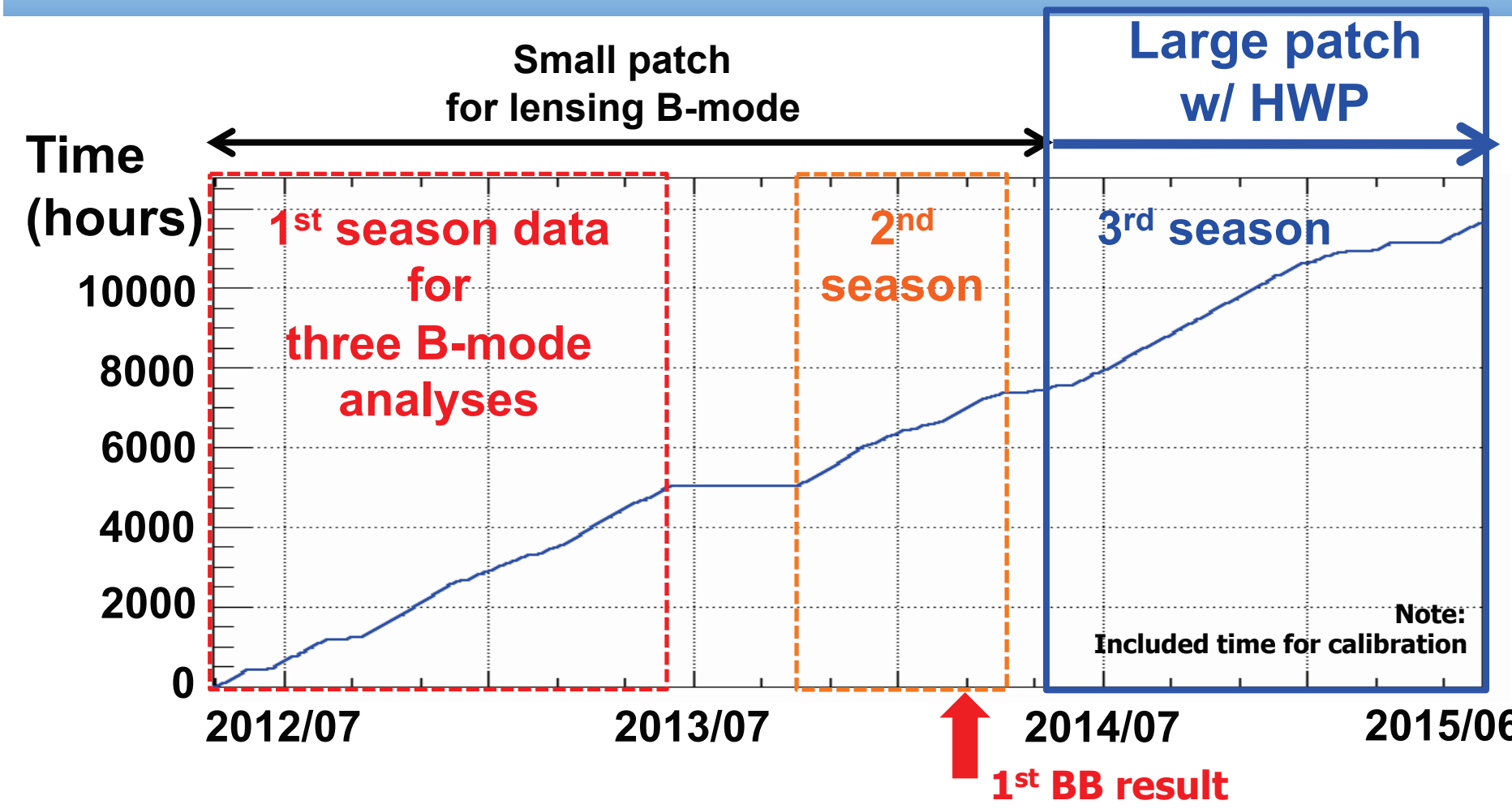
Requirement for Simons Array



Note:
white noise should be flat in this y-axis

- Forecast of SA assumes flat noise down to ell~25 (~10 mHz)
- Must need a new technique: Rotating Half-wave Plate

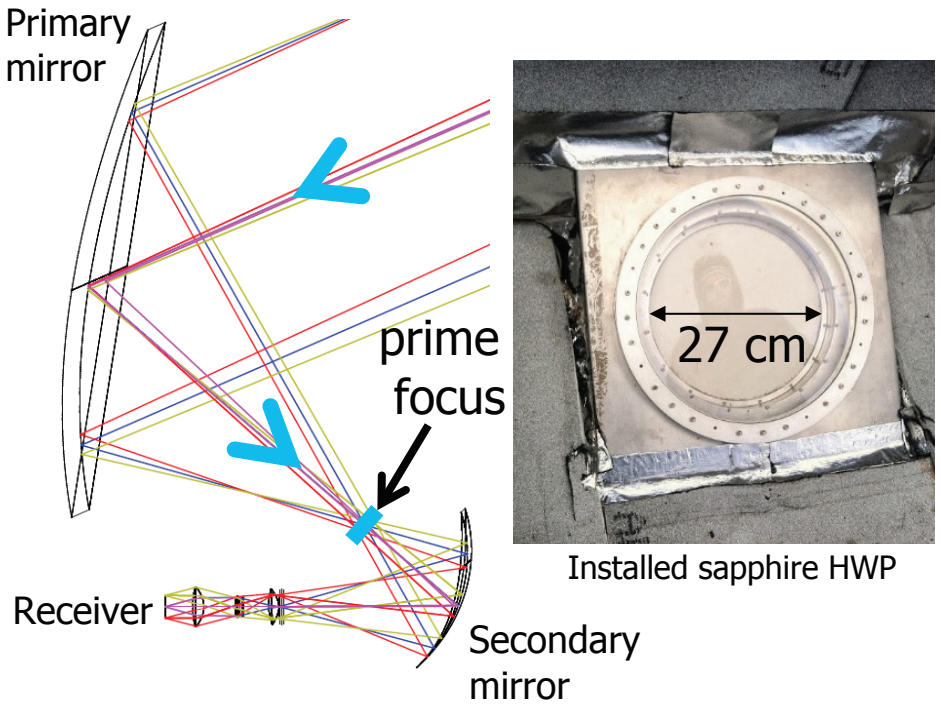
Status of POLARBEAR



- Finished small patch observation, then started wide patch w/ continuously rotating Half-wave Plate (HWP)

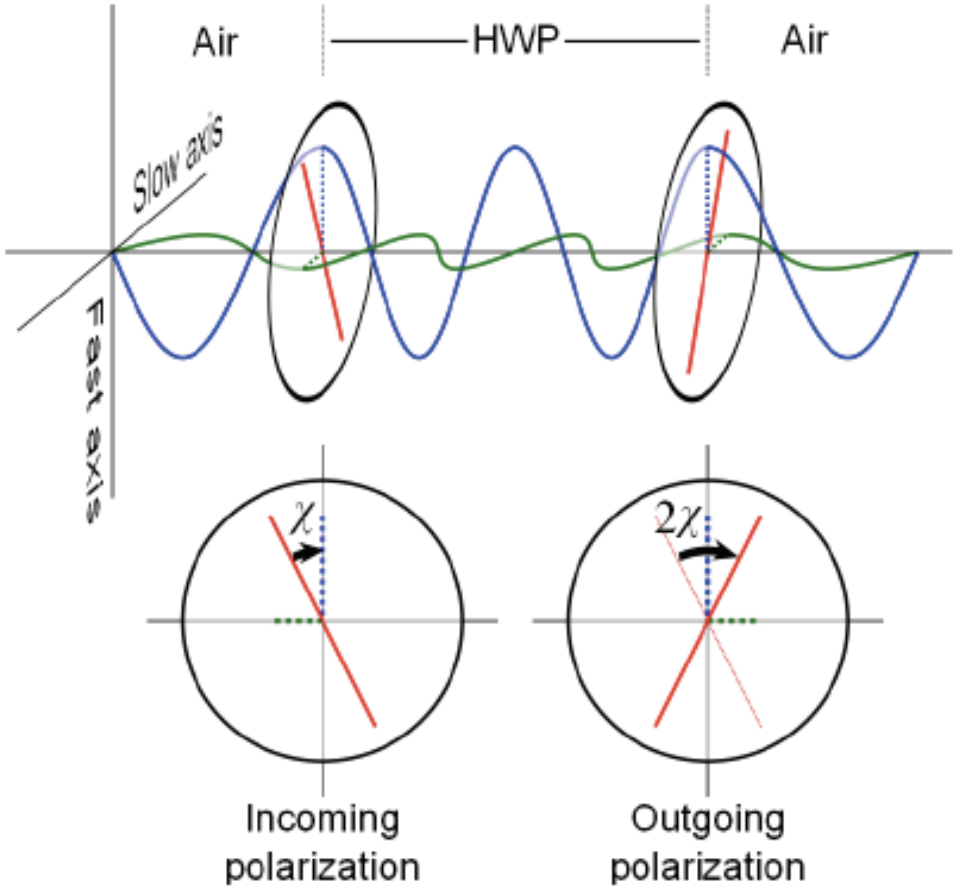
Continuously Rotating Half-wave Plate

HWP is optical element made of a birefringent material whose thickness is set to make the path difference between birefringent axes half of a wave length.



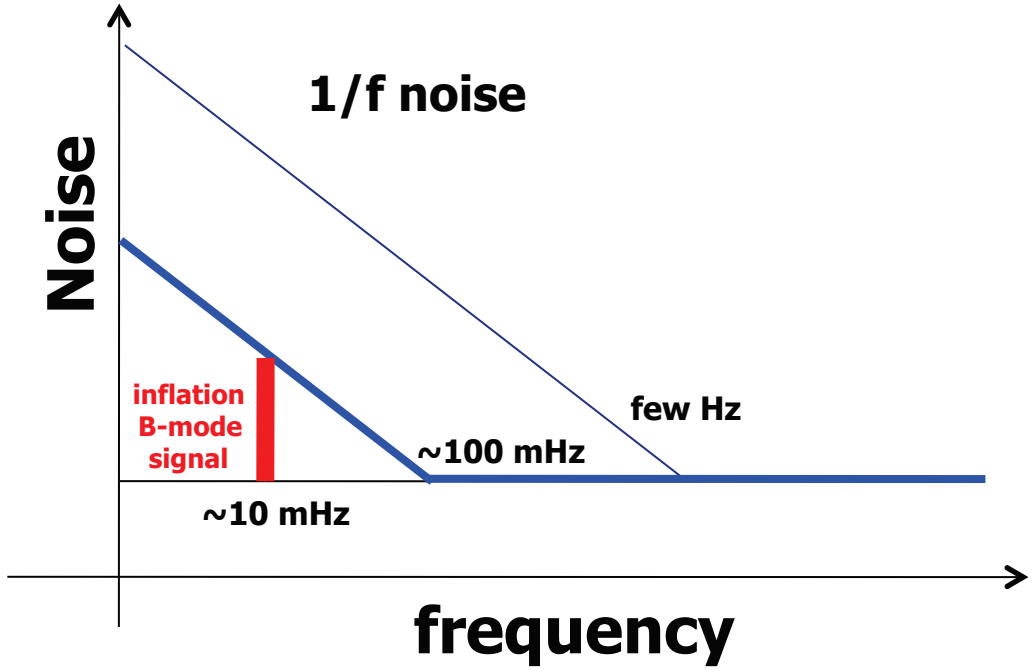
Installed sapphire HWP

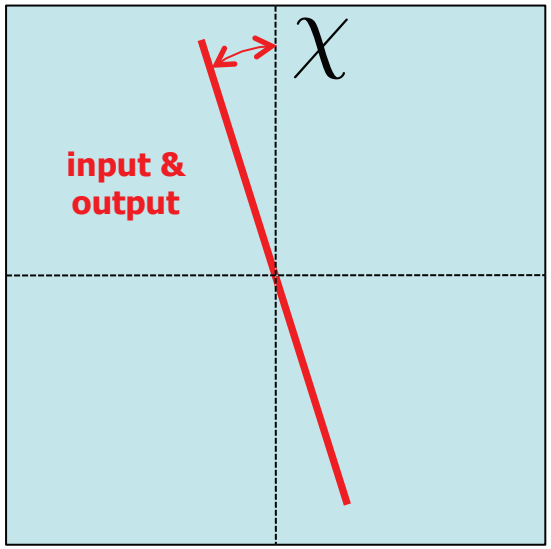
Kusaka et. al (2014)



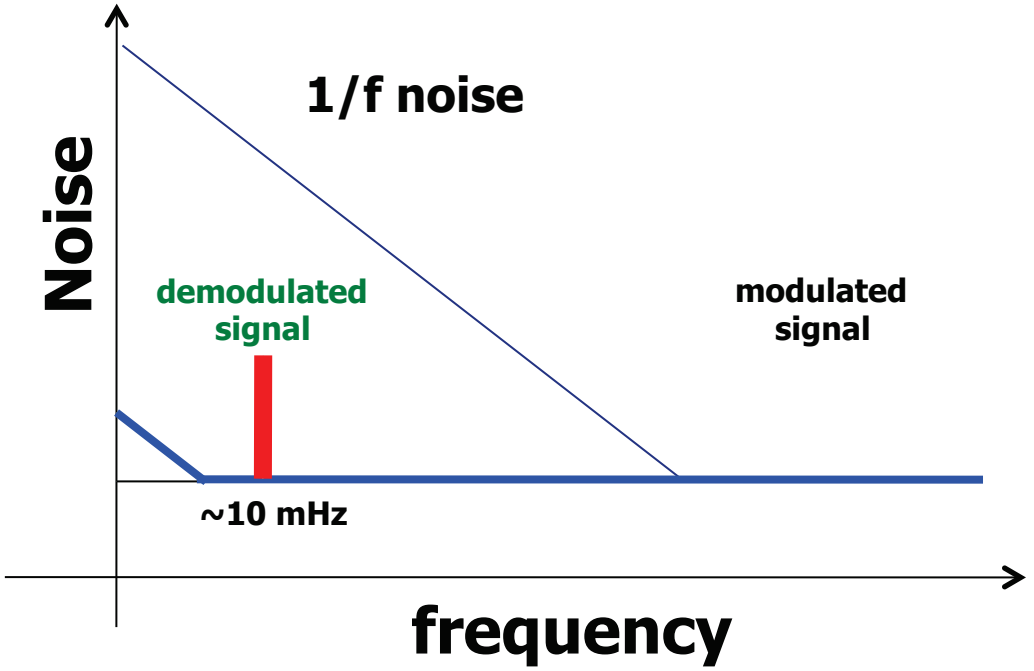
- Angle between HWP axis and incoming polarization is χ, thus polarization rotates by an angle of 2χ w/ HWP

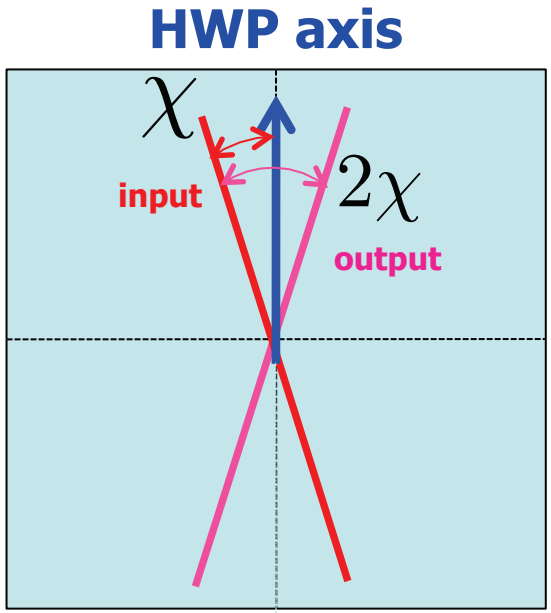
w/o HWP





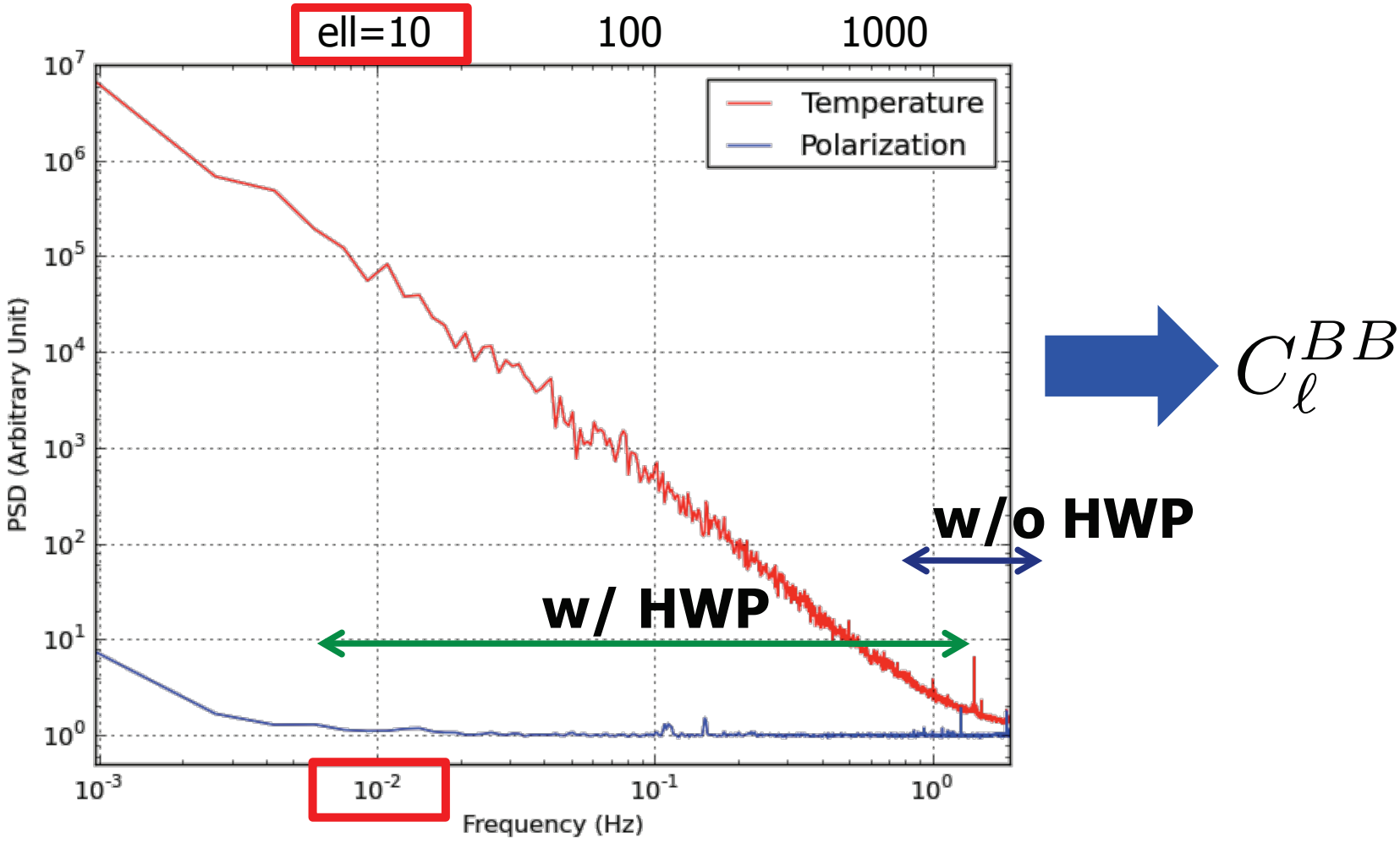
w/ rotating HWP





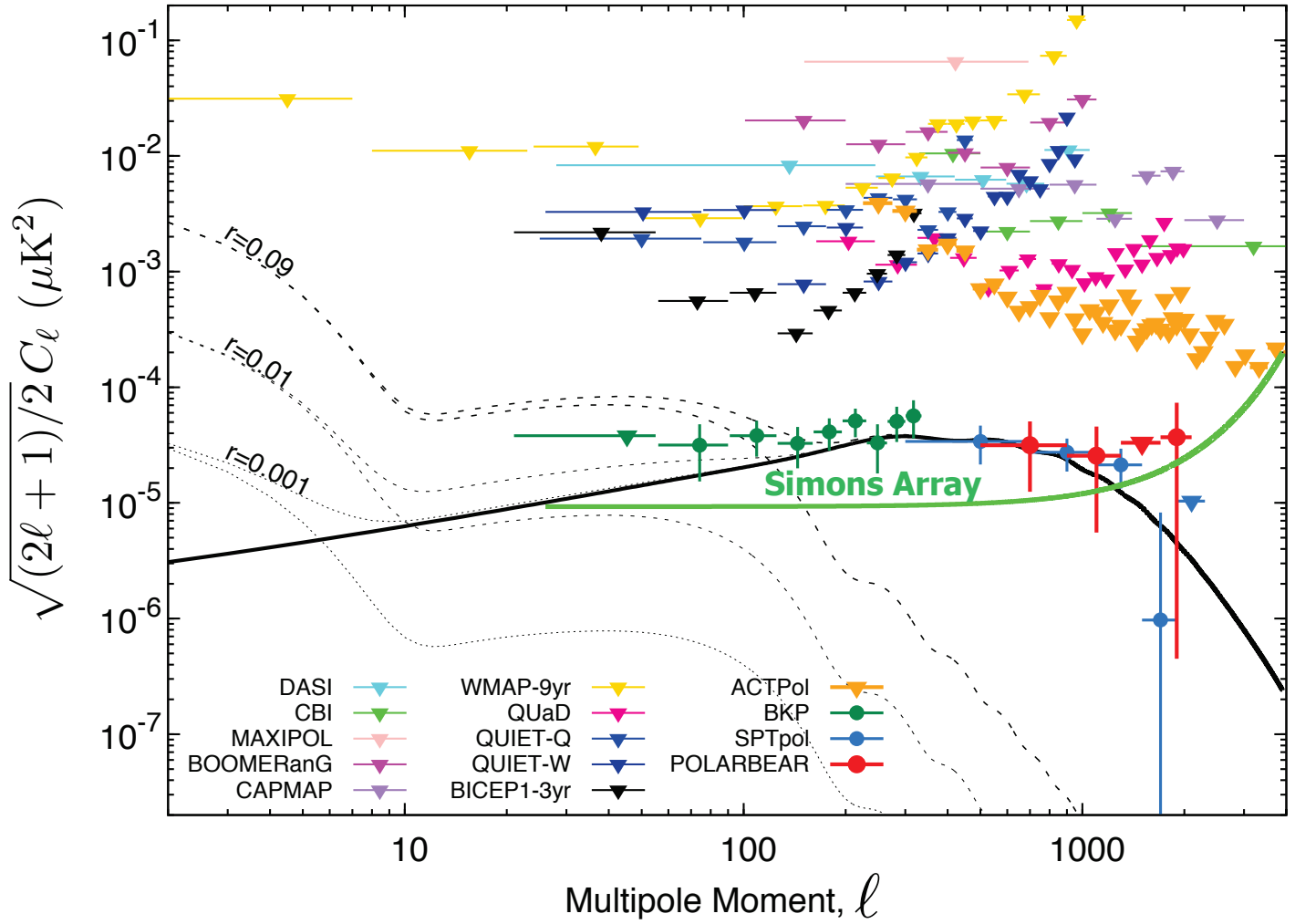
1/f Noise Performance w/Rotating HWP

analyzed by S. Takakura



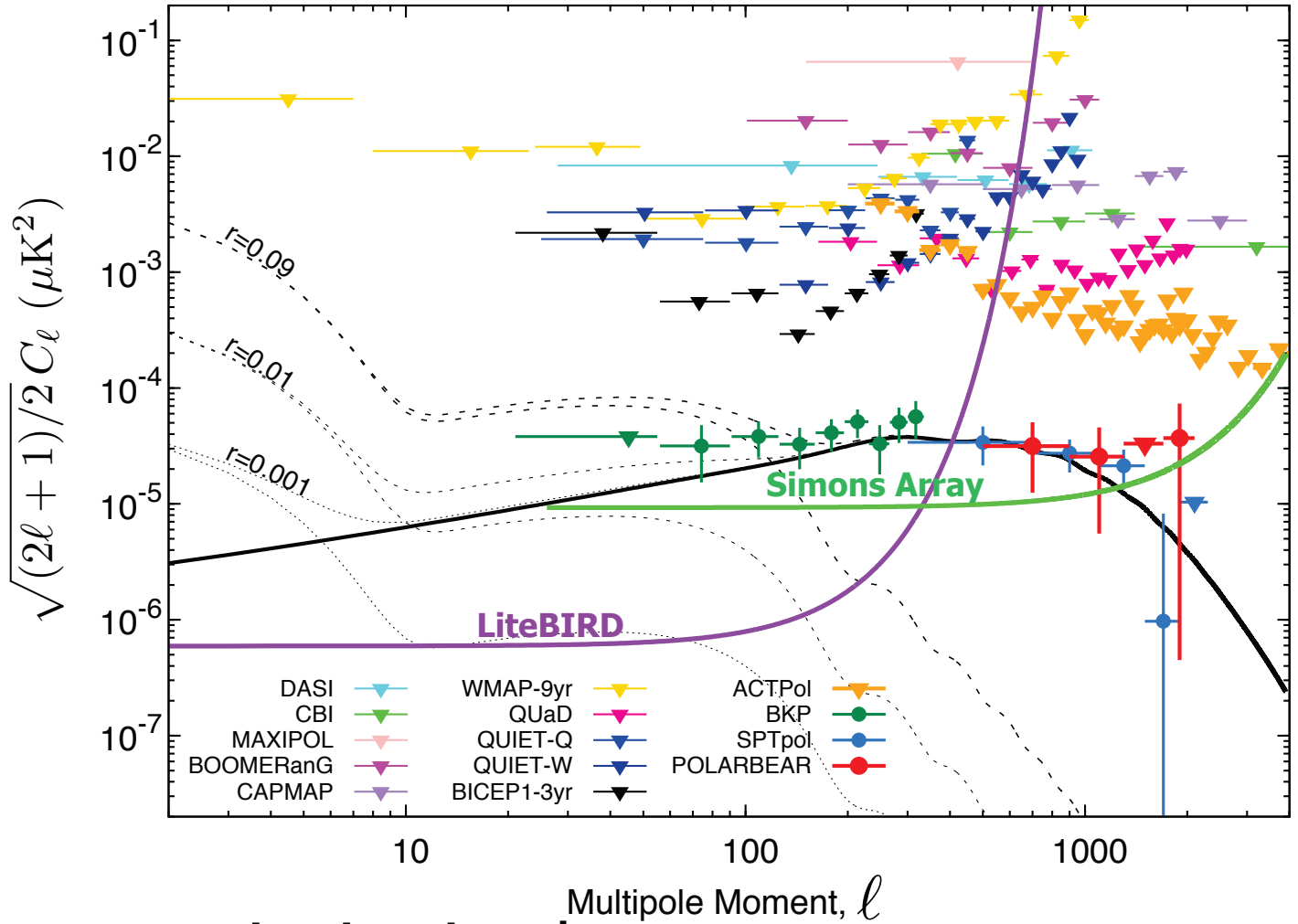
- Achieved order of magnitude improvement
- Now enough to measure B-mode spectra @ ell~10

Achievable Simons Array w/ Rotating HWP



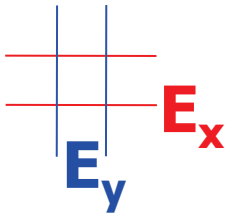
- Forecast is now reasonable w/ HWP; How about LiteBIRD?
- Satellite also may suffers from noise in low ell, e.g. Planck HFI

LiteBIRD w/ Rotating HWP

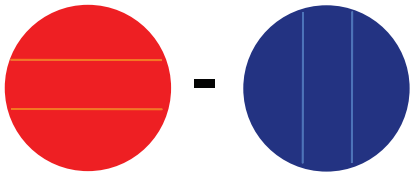


- To discover reionization bump, great care to suppress 1/f noise (<10 mHz) is required → need to develop & install HWP
  - HWP development & validation by PB is useful/essential for SA & LiteBIRD

One More Thing: Systematic Mitigation

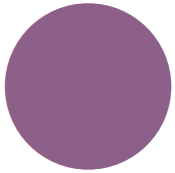


Pol. ∝ $Ex^2 - Ey^2$



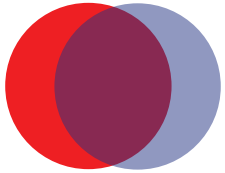
w/ beam

e.g. gaussian beam



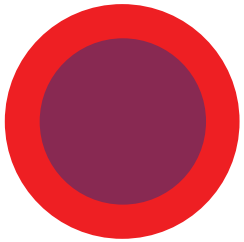
$g_x Ex^2 - g_y Ey^2$ (monopole)

differential gain



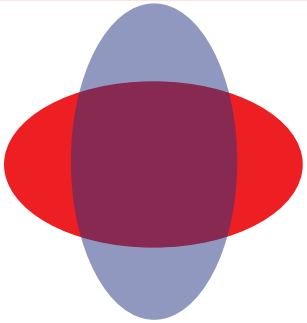
dipole

differential pointing



monopole

differential beam width



quadrupole

differential ellipticity

- The HWP makes it unnecessary to difference orthogonally-polarized paired detectors and every detector provides independent measurements of Q and U polarization, greatly **mitigating any "differential beam effects."**

Summary

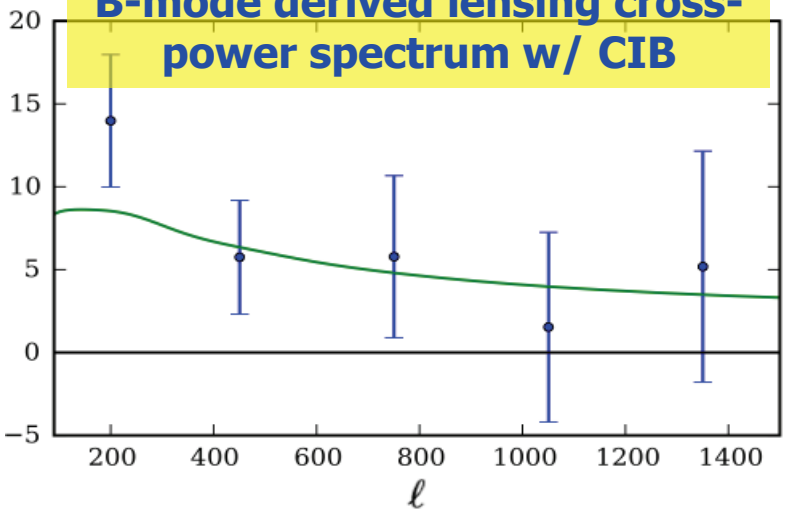
- Ground-based CMB keep developing technologies for B-modes
  - Satellite will use such matured instruments & technologies
- Hard for large telescope to measure B-modes @ large angular scale, then modulation technique, e.g. **HWP**, seems necessary
- **POLARBEAR is now demonstrating HWP & has achieved good performance**; **LiteBIRD also needs HWP** to achieve ultimate B-mode measurement especially @ large angular scale
- Such synergy among POLARBEAR, Simons Array, and LiteBIRD is important for the next 5 years and Shingakujyutu program is the best opportunity to forward it!

New Result from POLARBEAR

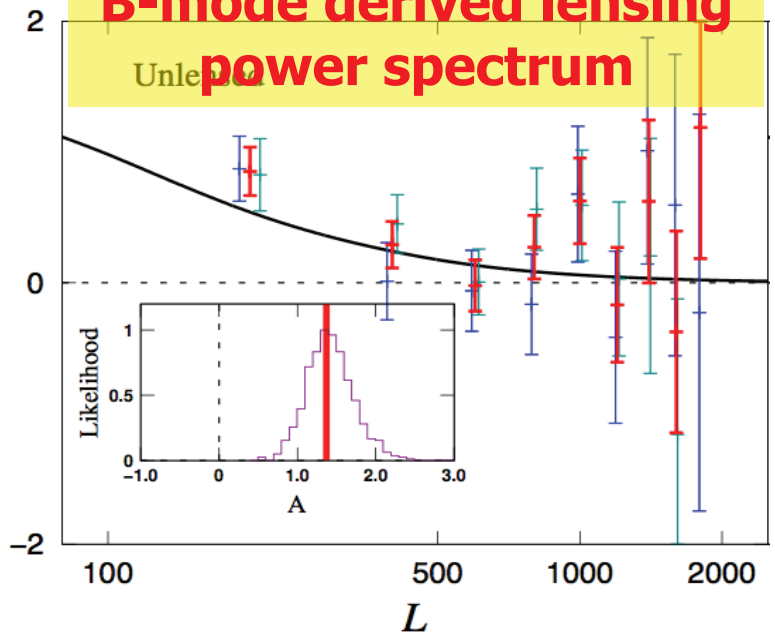
17:30-17:50; 20th Sep, 2015

Previous POLARBEAR Results

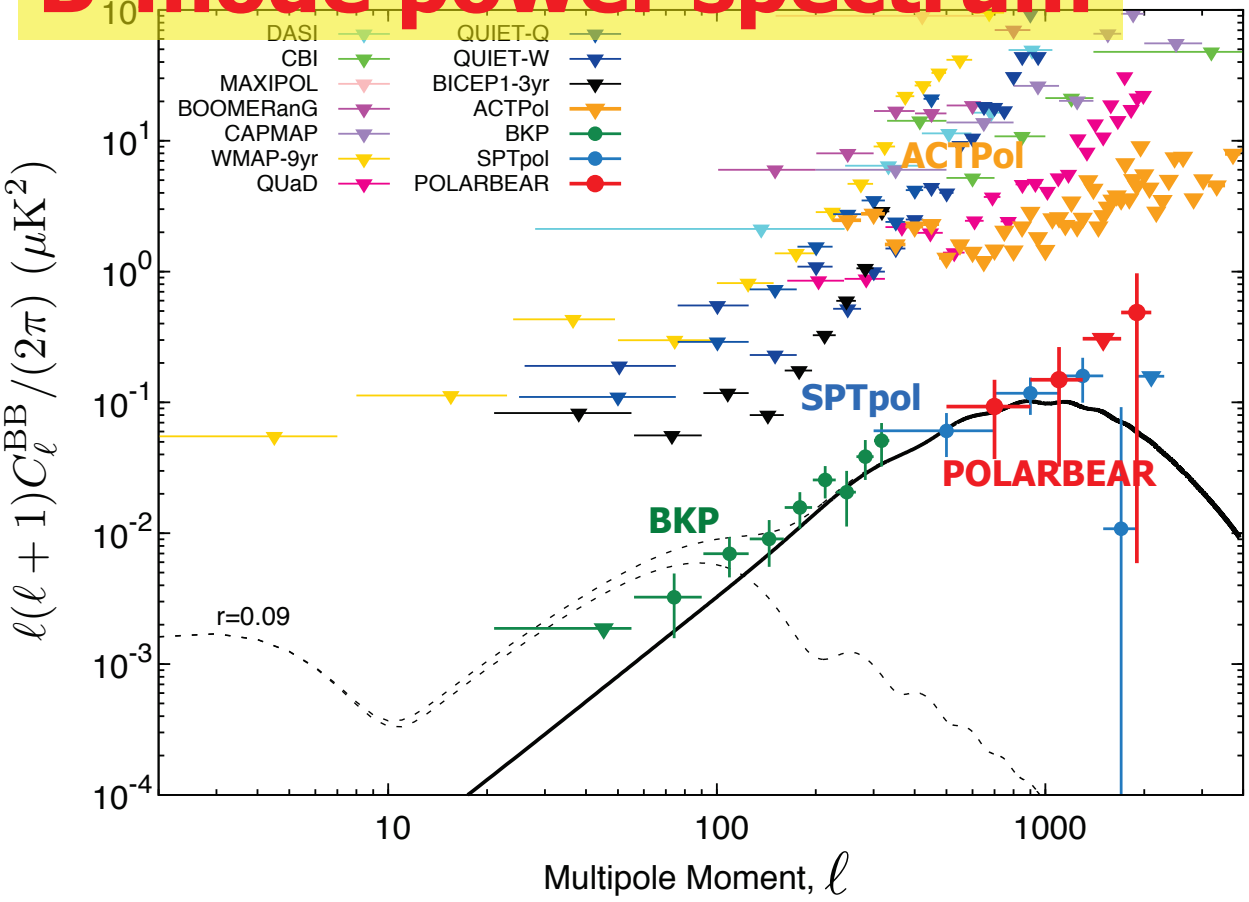
B-mode derived lensing cross-power spectrum w/ CIB



B-mode derived lensing power spectrum



B-mode power spectrum



Combined w/ dd & B-mode auto spectrum, rejection of the hypothesis that there are no lensing B-modes with 4.7σ confidence for a normal distribution

Cosmic Birefringence & Magnetic Field

New!

POLARBEAR Constraints on Cosmic Birefringence and Primordial Magnetic Fields

submitted last week; arXiv:1509.02461

- Some exotic physics can make "cosmological birefringence"
  - cosmic strings and other cosmic defects, supersonic bulk flows, **primordial magnetic fields**, and **parity-violating physics**…
- CB: PB's 4-pt correlation constrains **B_{1Mpc}<93 nG** (95% CL)
  - ~15 x better than <1380 nG by Planck
- PM: PB's 2-pt correlation constrains **B_{1Mpc}<3.9 nG** (95% CL)
  - as good as Planck (<4.4 nG)