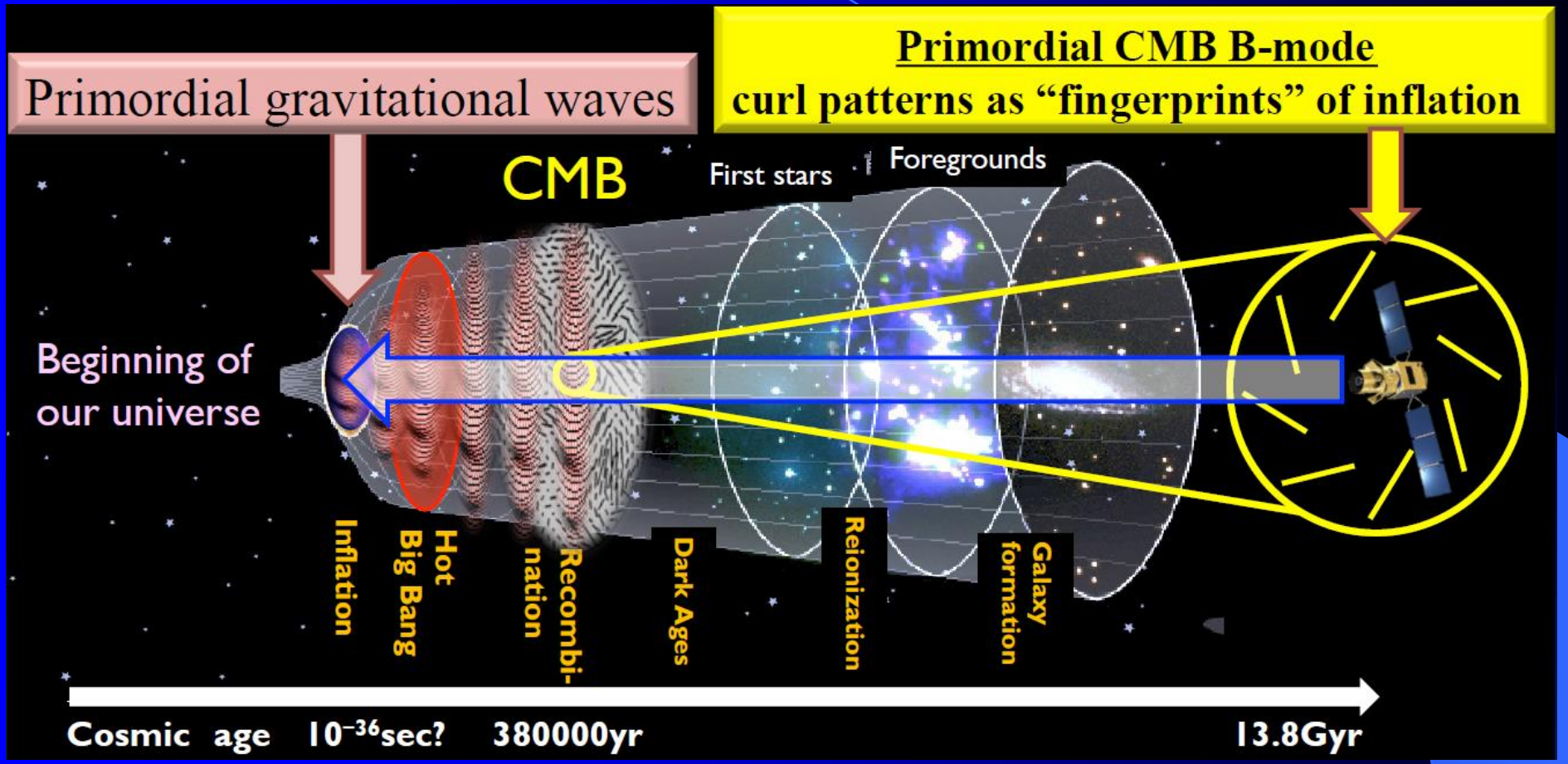
2016/10/31
7th KIAS workshop on Cosmology and Structure Formation

LiteBIRD

Lite satellite for the studies of B-mode polarization
and Inflation from cosmic background Radiation Detection

Ryo Nagata
with LiteBIRD collaboration

Probing cosmic inflation with cosmic microwave background (CMB) polarization



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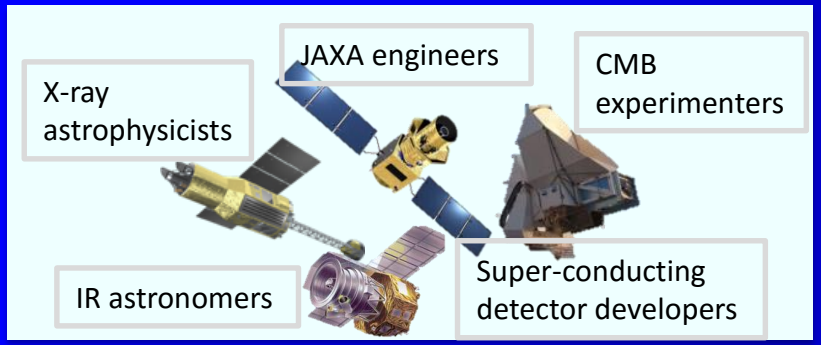
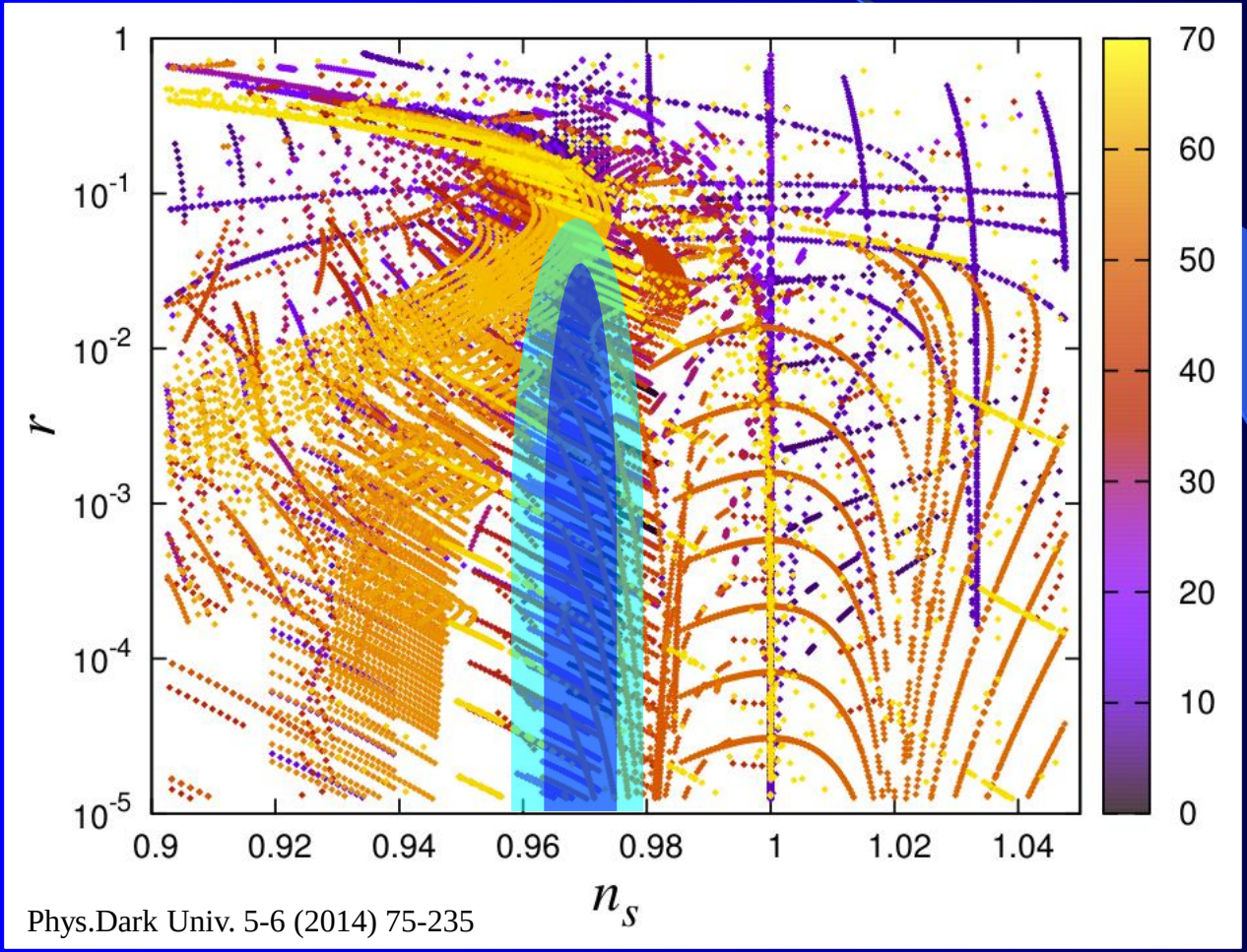


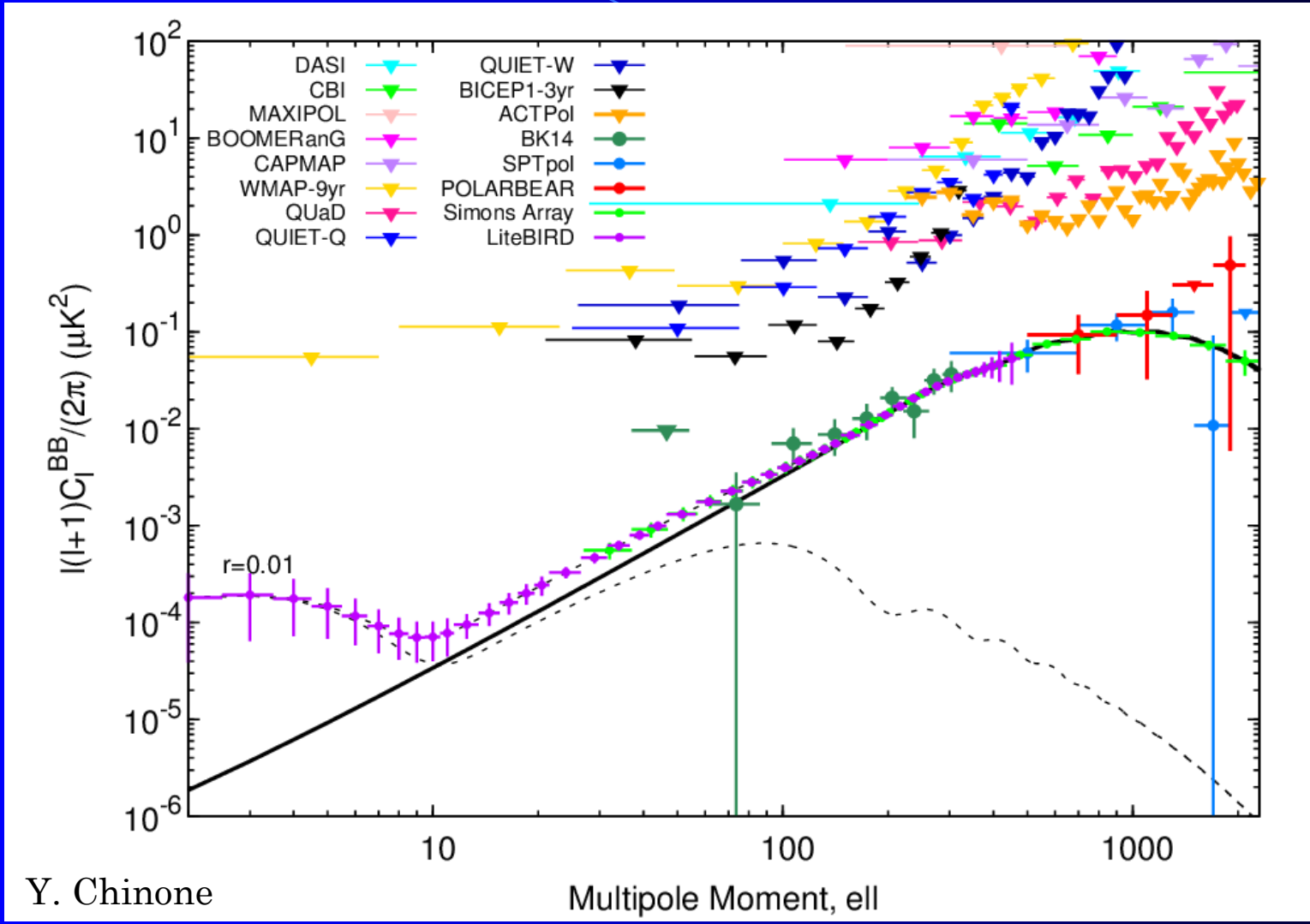
Inflation models

Single field slow-roll models
with canonical kinetic terms & smooth potentials



Phys.Dark Univ. 5-6 (2014) 75-235

Current status of CMB B-mode obs.



Mission success criterion

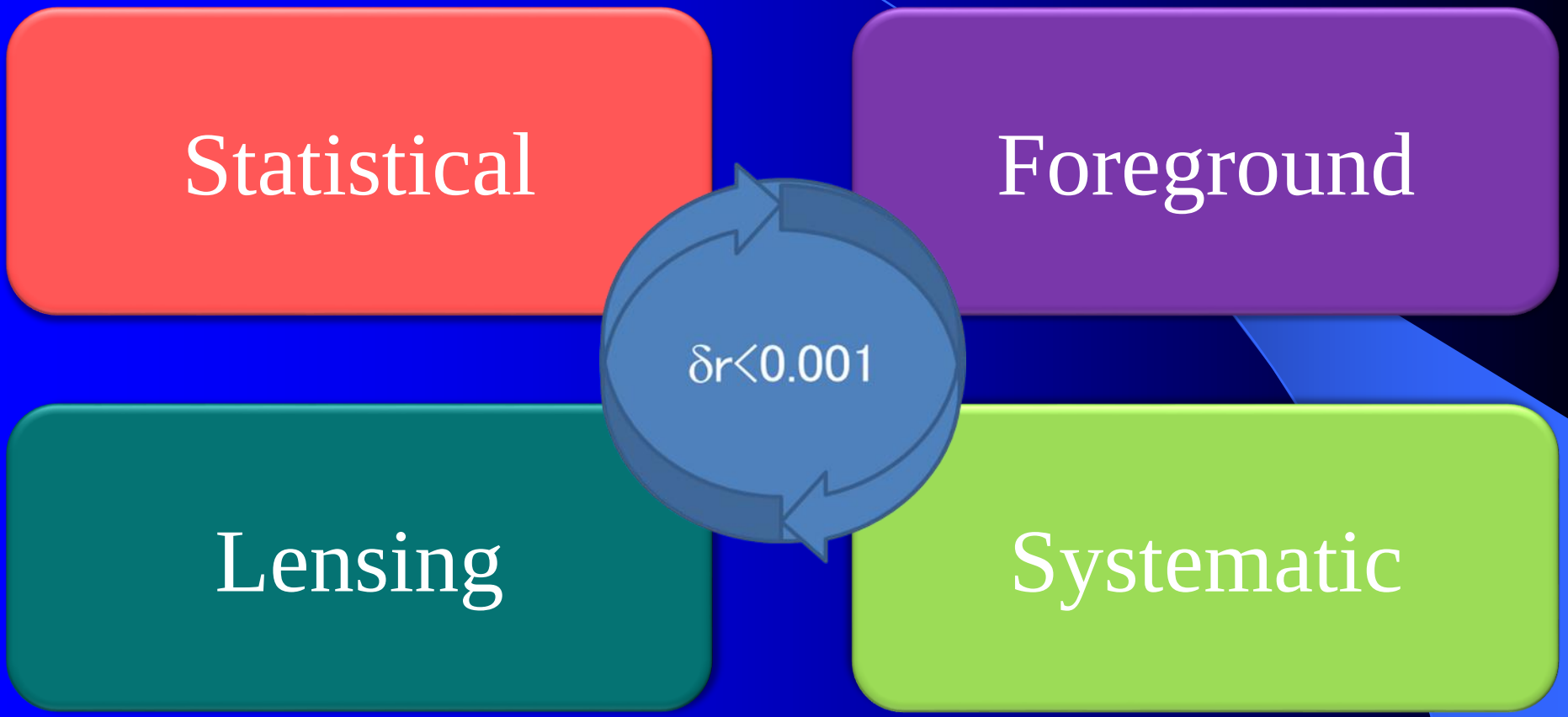
$$\sigma_r \leq 0.001$$

- Many models predict $r > 0.01$.
  - 10σ discovery
- Single field models with slow roll condition gives

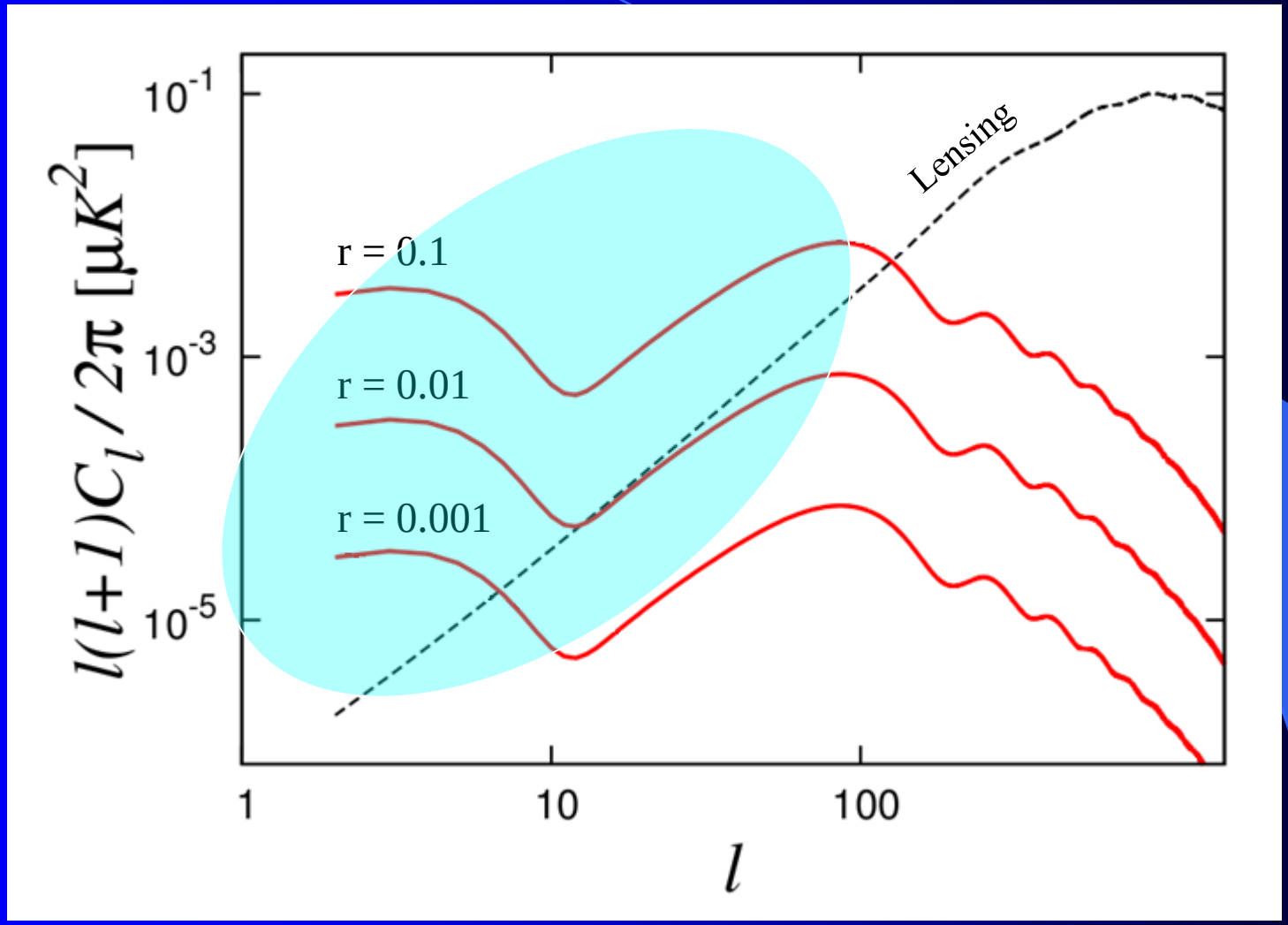
$$r \simeq 0.002 \left(\frac{60}{N}\right)^2 \left(\frac{\Delta\phi}{m_{pl}}\right)^2$$

N: e-folding, m_{pl}: reduced Planck mass

LiteBIRD error budget

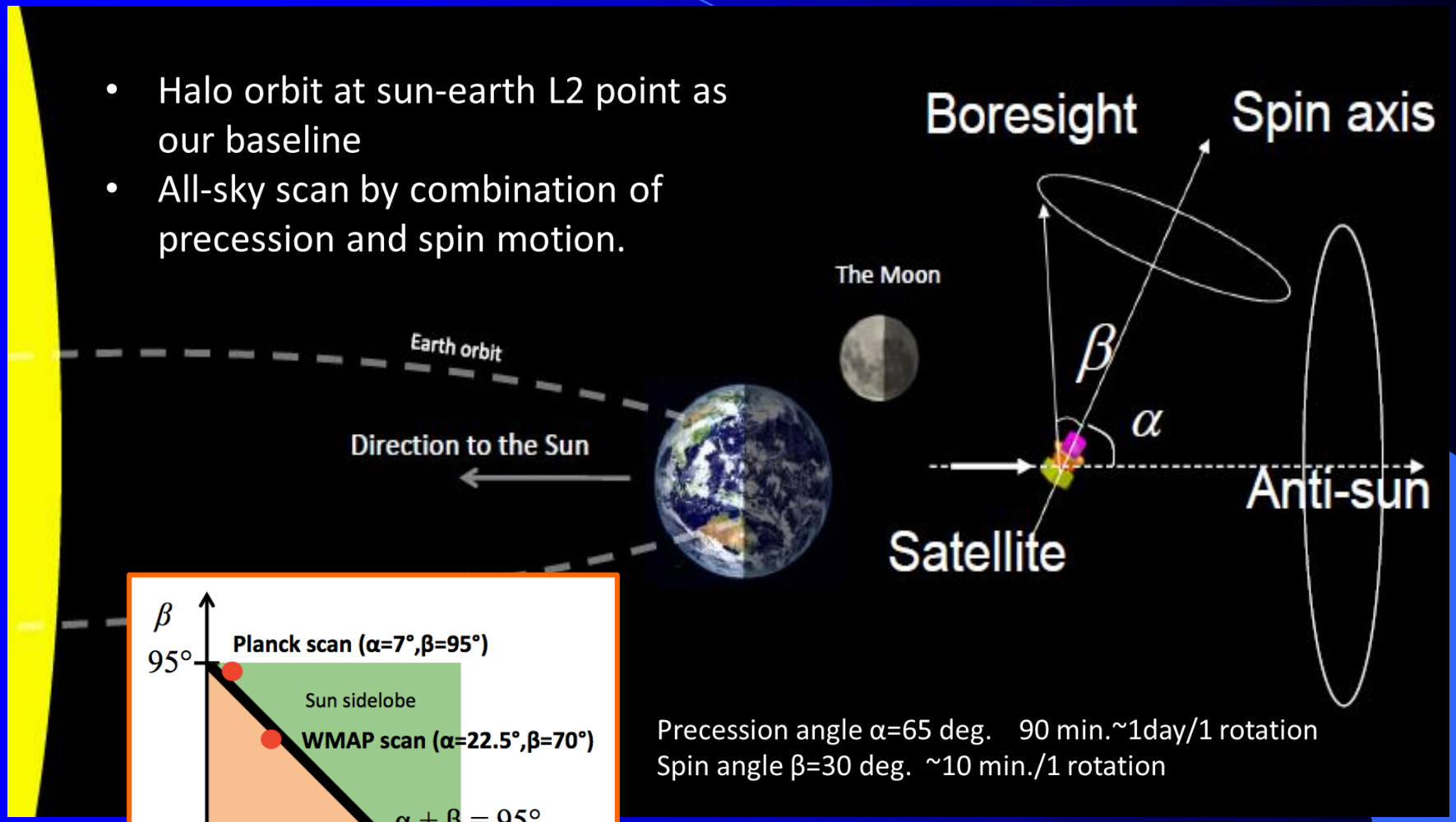


Observation strategy – (1)



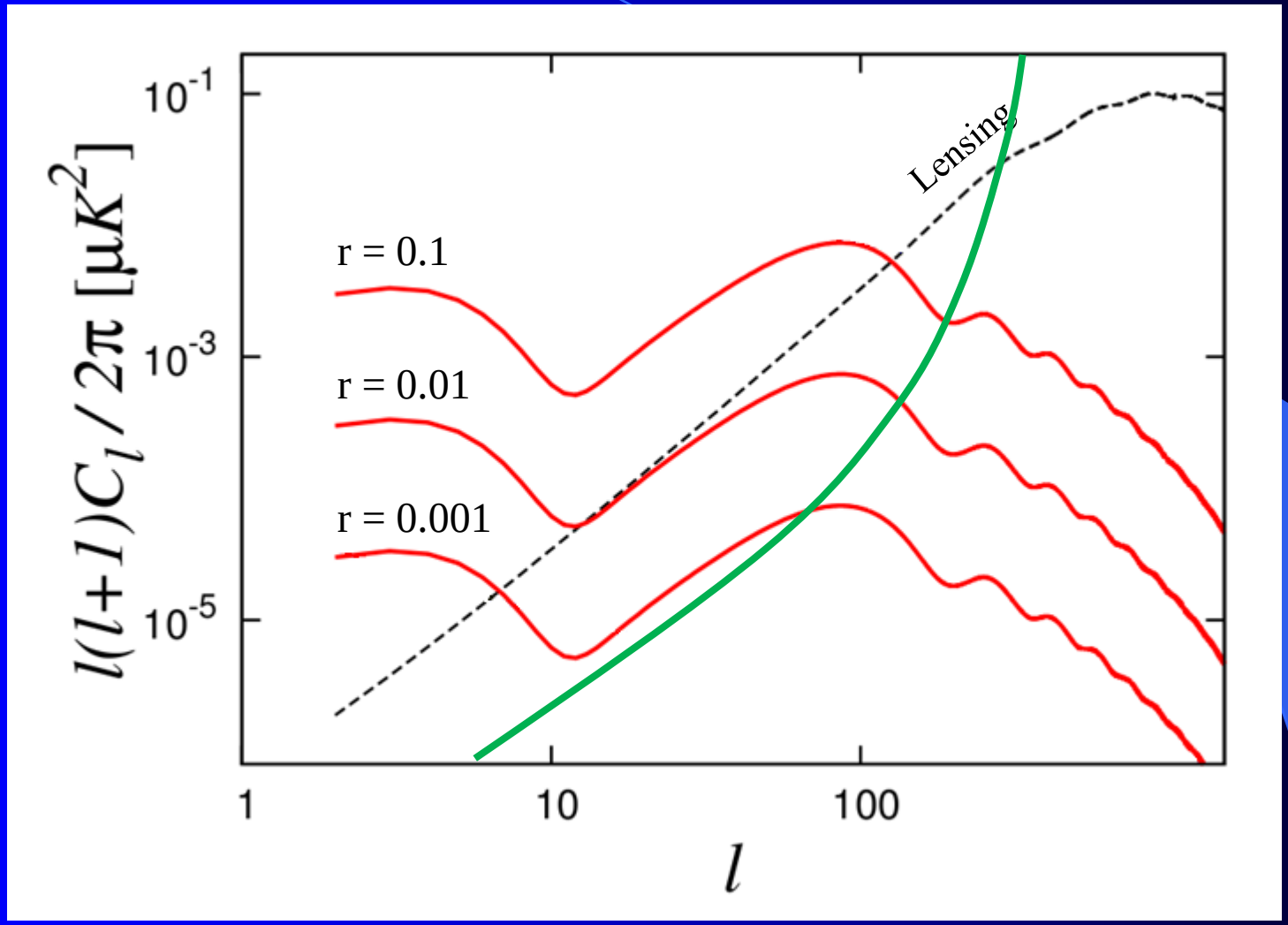
All-sky scan

- Halo orbit at sun-earth L2 point as our baseline
- All-sky scan by combination of precession and spin motion.



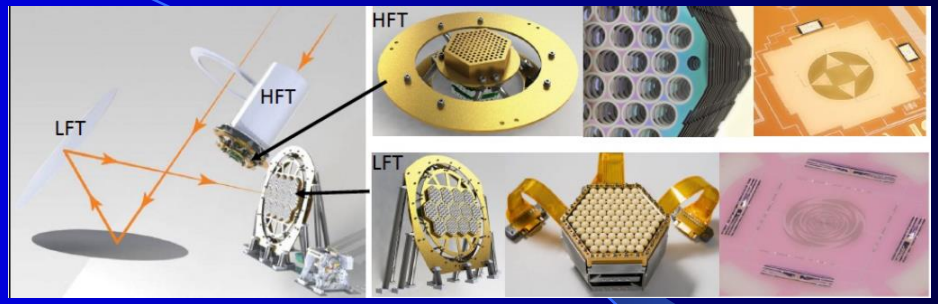
Precession angle α=65 deg. 90 min.~1day/1 rotation
Spin angle β=30 deg. ~10 min./1 rotation

Observation strategy – (2)



Sensitivity better than lensing floor

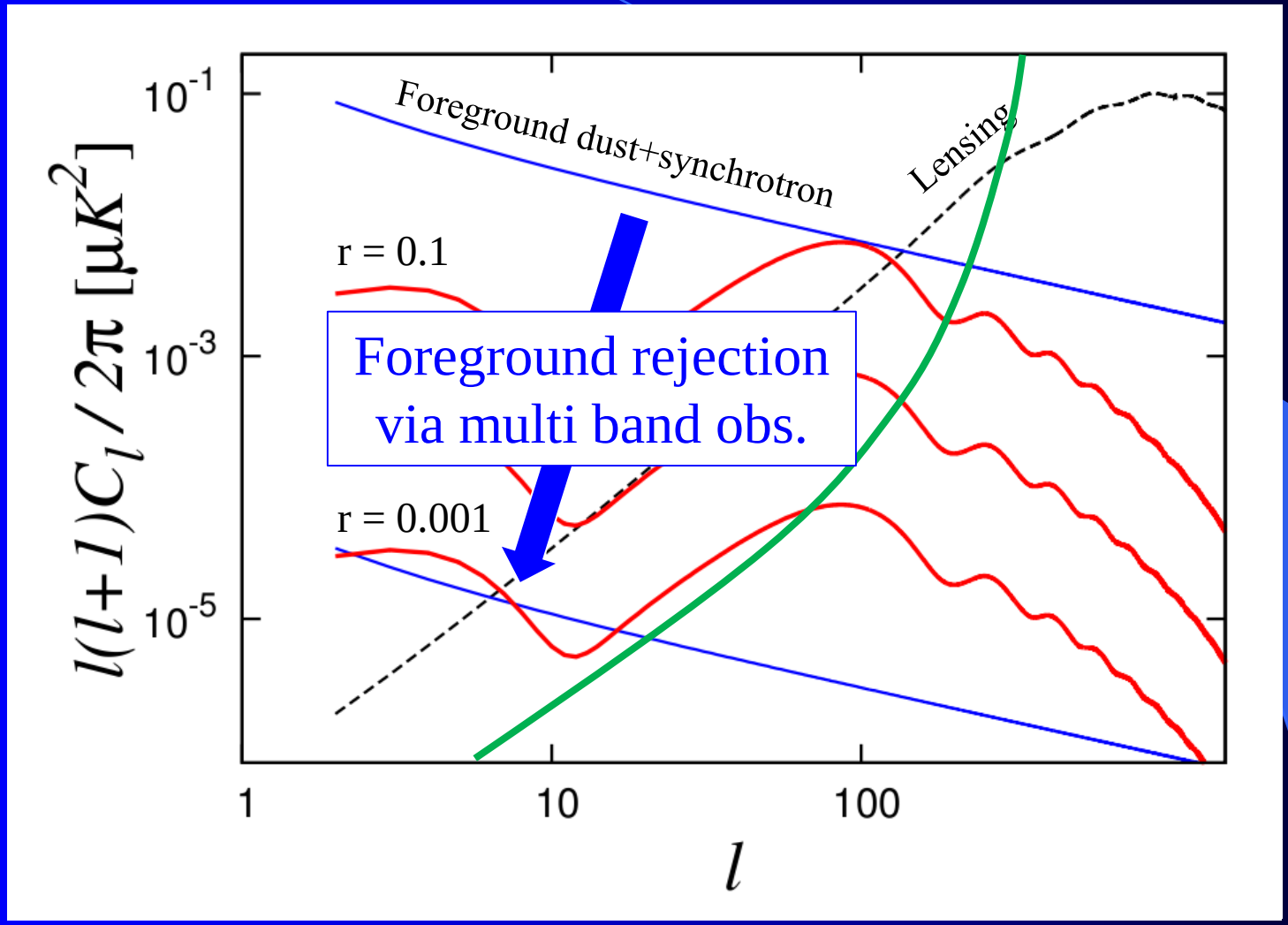
Statistical



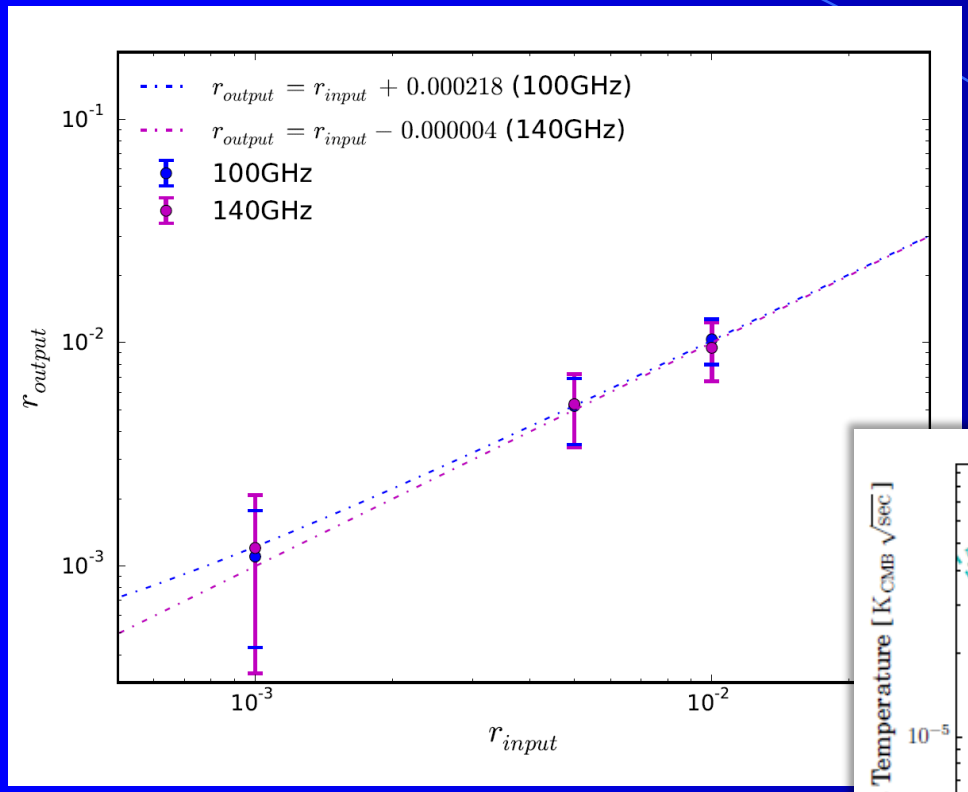
Band (GHz)	Bandwidth ($\Delta\nu/\nu$)	NEP (aW/$\sqrt{\text{Hz}}$)	NET (μK$\sqrt{\text{s}}$)	N_{bolo}	NET_{arr} (μK$\sqrt{\text{s}}$)	Sensitivity with margin (μK arcmin)
40	0.30	7.74	225.9	152	18.3	53.4
50	0.30	7.86	136.9	152	11.1	32.3
60	0.23	7.06	106.2	152	8.6	25.1
68	0.23	7.10	82.9	152	6.7	19.6
78	0.23	7.08	64.7	152	5.2	15.3
89	0.23	7.00	52.4	152	4.3	12.4
100	0.23	8.55	79.7	222	5.3	15.6
119	0.30	9.48	52.5	148	4.3	12.6
140	0.30	8.99	42.3	222	2.8	8.3
166	0.30	8.31	36.2	148	3.0	8.7
195	0.30	7.62	34.1	222	2.3	6.7
235	0.30	6.86	35.8	148	2.9	8.6
280	0.30	9.14	55.4	72	6.5	19.0
338	0.30	8.34	78.0	108	7.5	21.9
402	0.23	6.69	154.4	74	17.9	52.3
Total				2276		3.2

J. Low Temp. Phys. 184, (2016) 3, 824-831

Observation strategy – (3)

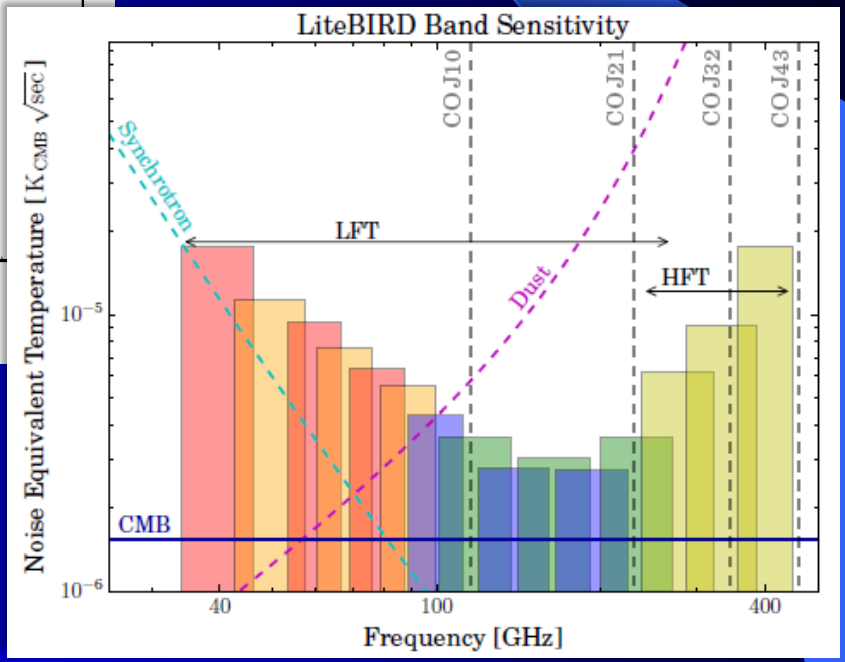


Frequency bands from 40GHz to 400GHz



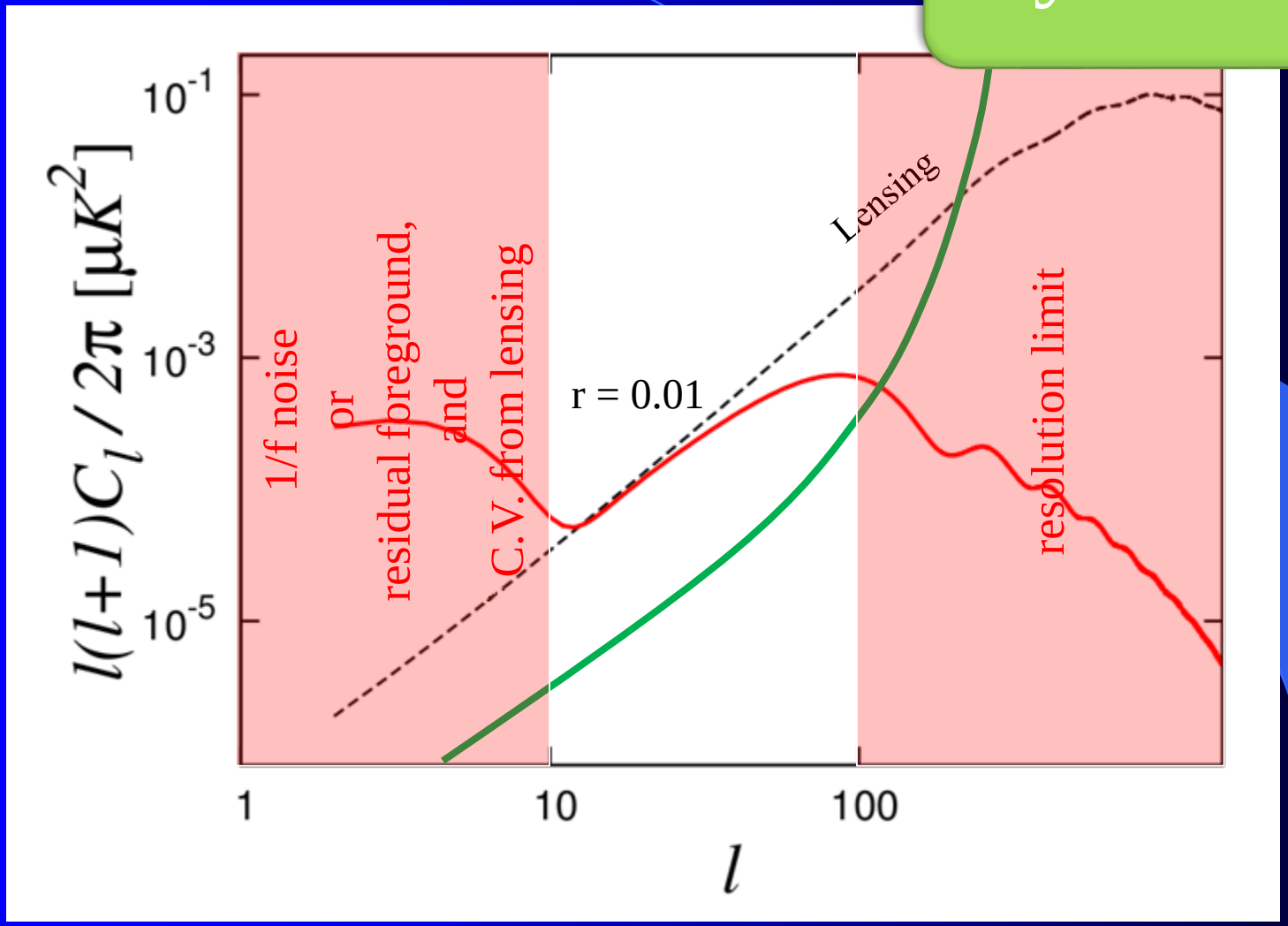
ApJ 737, 78 (2011)

Foreground



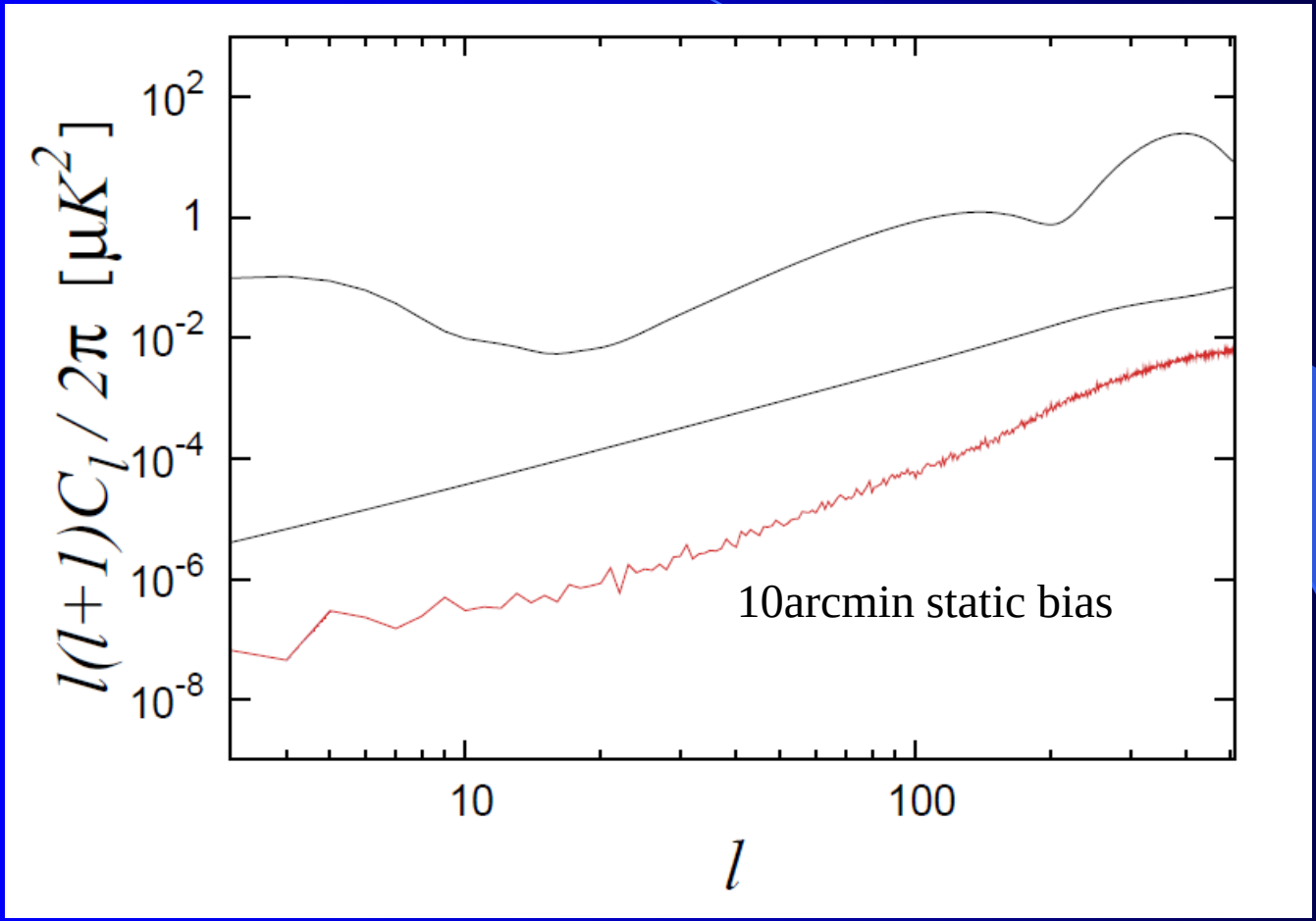
Sys. bias, estimated by rule of thumb

Systematic



Pattern distortion from pointing reconstruction error

Pointing knowledge



Pattern distortion from pol. angle error

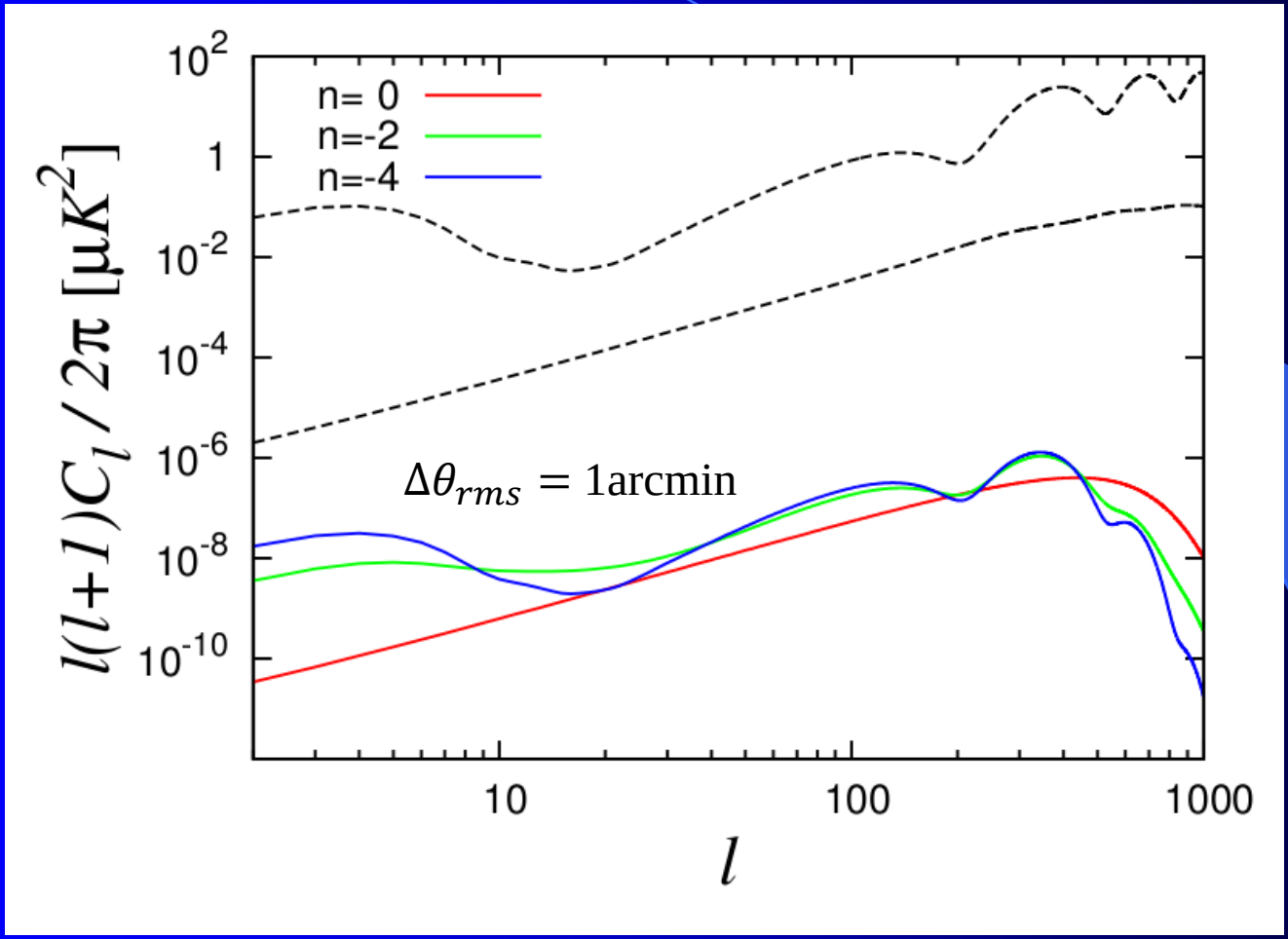
orientation error

attitude, optics, antenna mis-alignment …

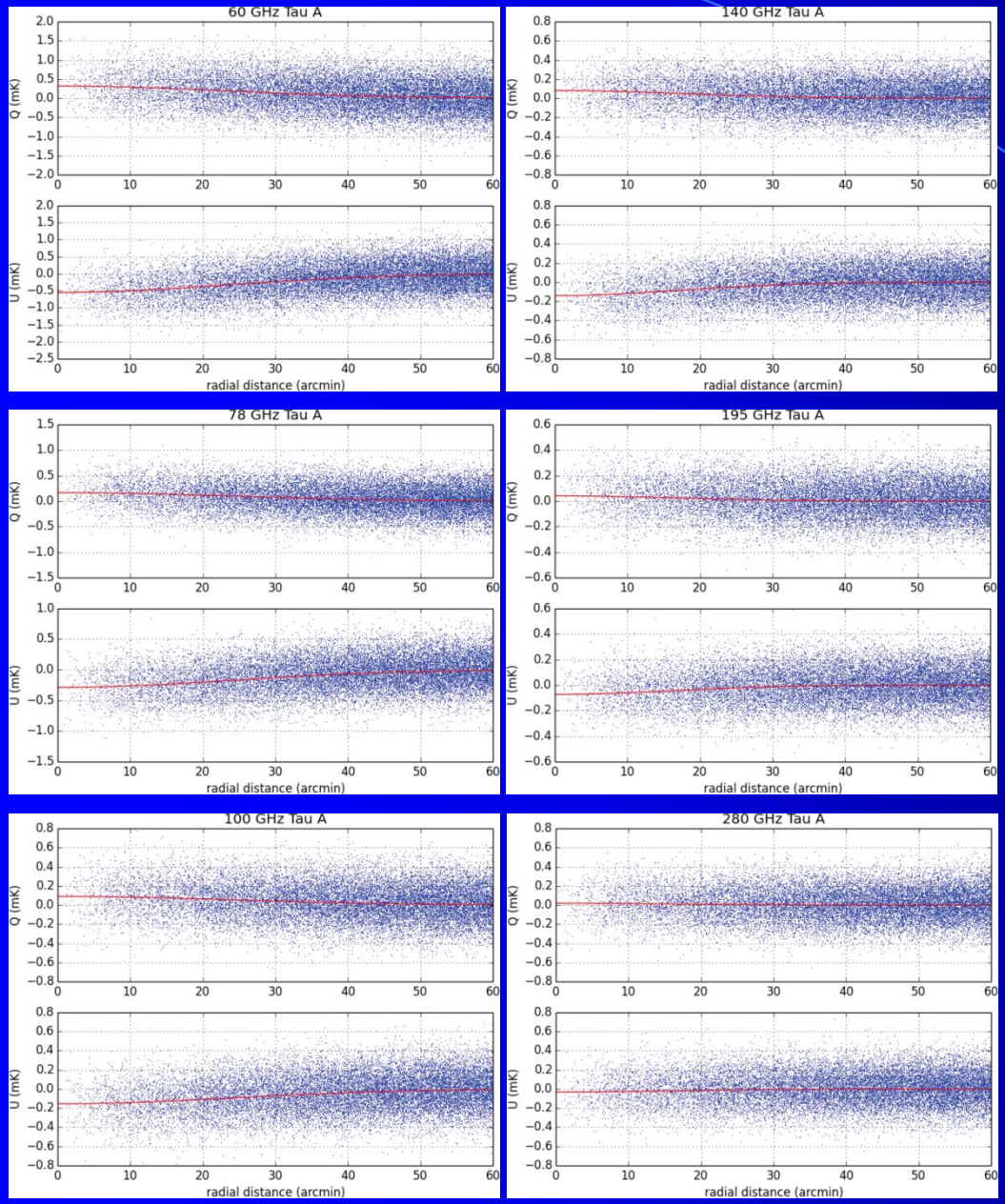
false B-mode

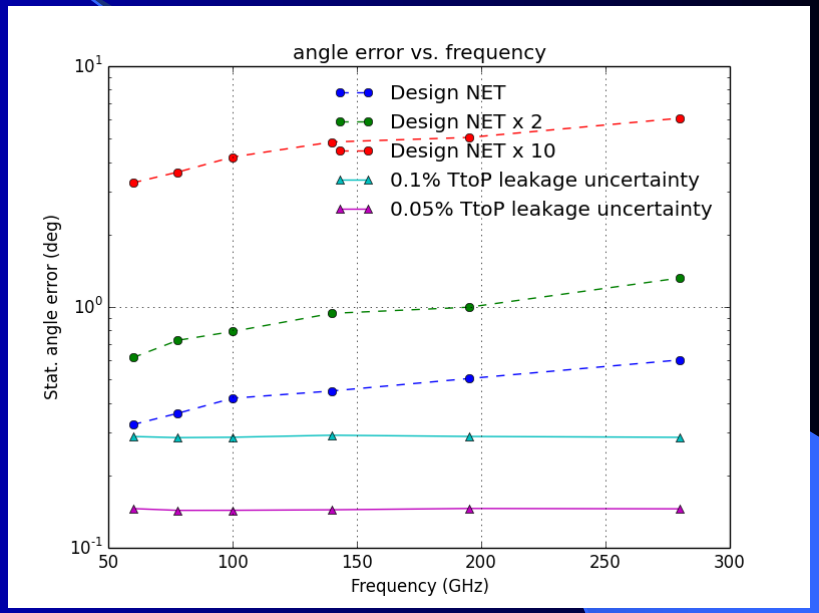
E-mode $\Rightarrow$ B-mode

Polarization angle



Some speculation about angle calibration

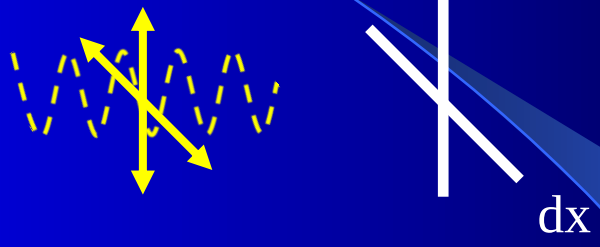




simulation by H.Nishino

Pair differencing pol. measurement

How to measure



dx = (non pol.) + **(pol.)**

dy = (non pol.) − **(pol.)**

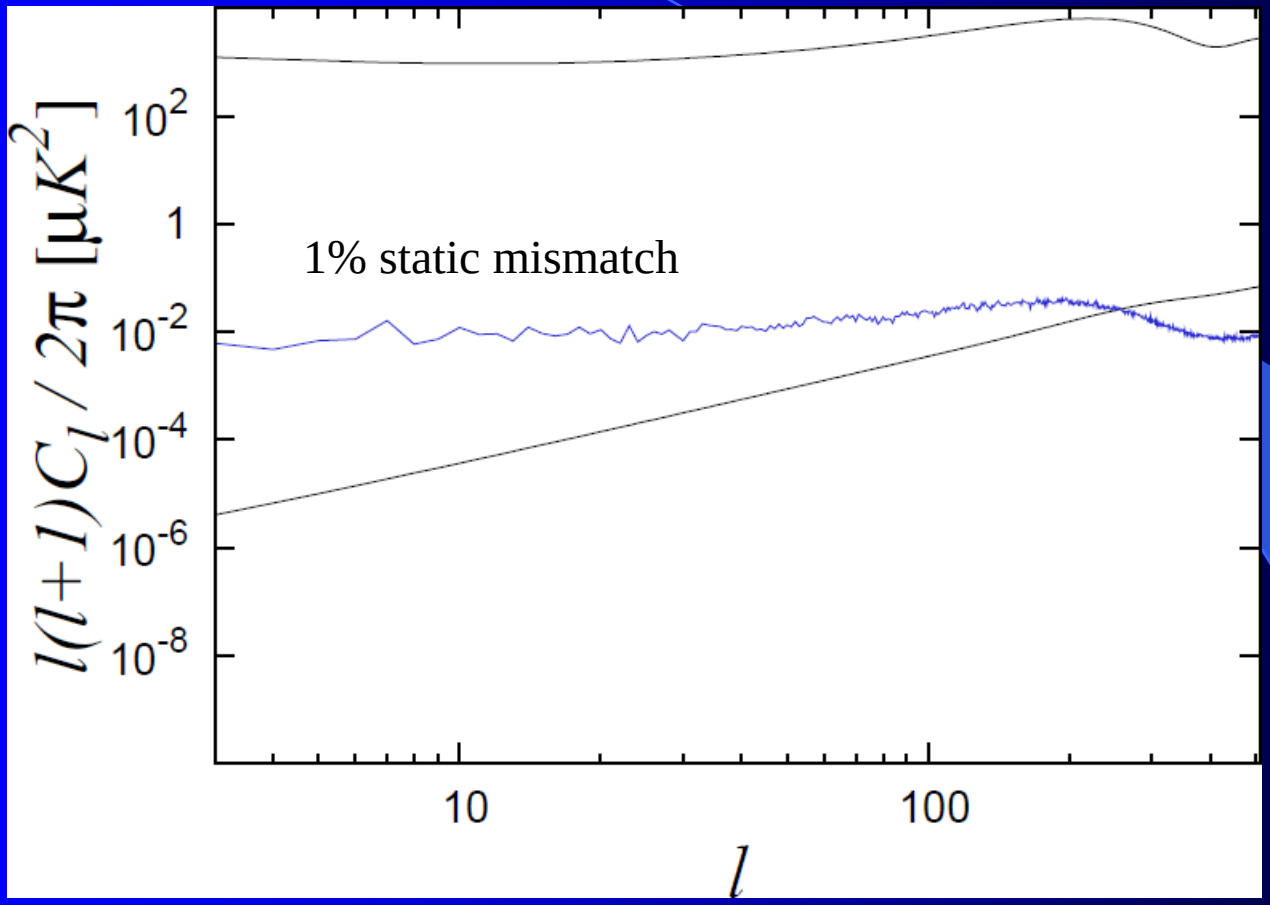
~~⇒ (dx − dy)/2 = (pol.)~~

Mismatch gives a residue

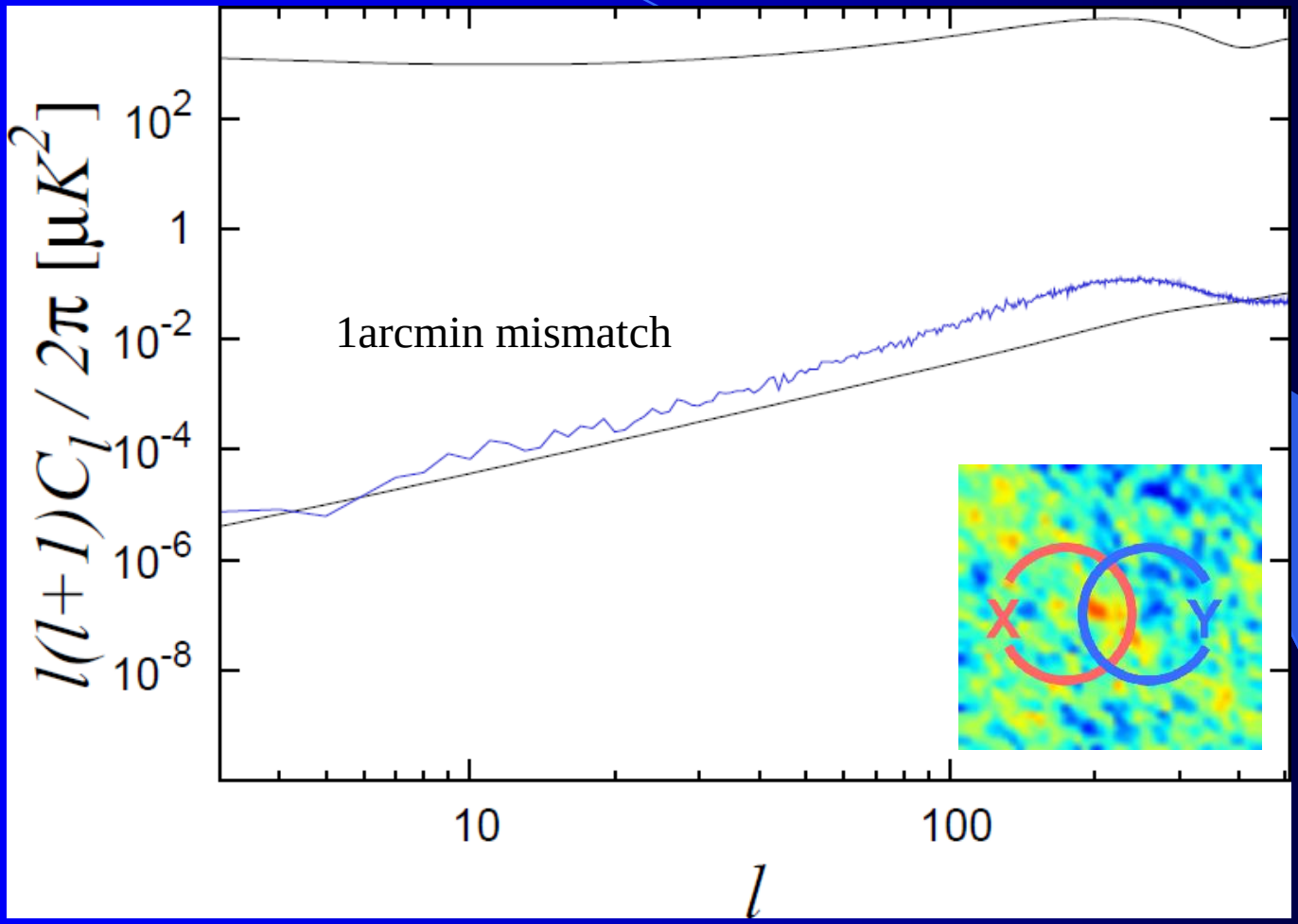
(non pol. **X**) − (non pol. **Y**) **≠ 0**

⇒ false polarization

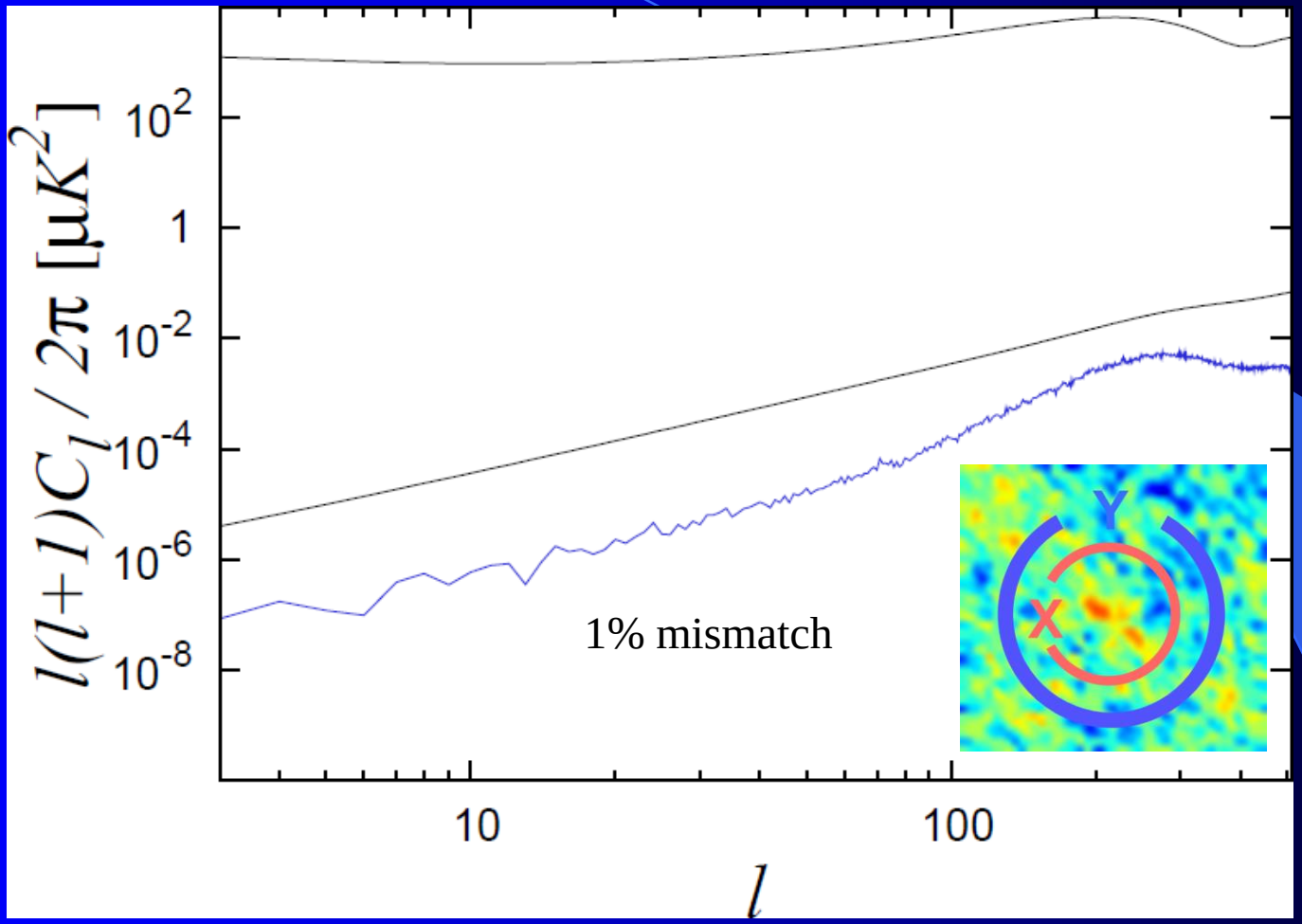
Gain mismatch



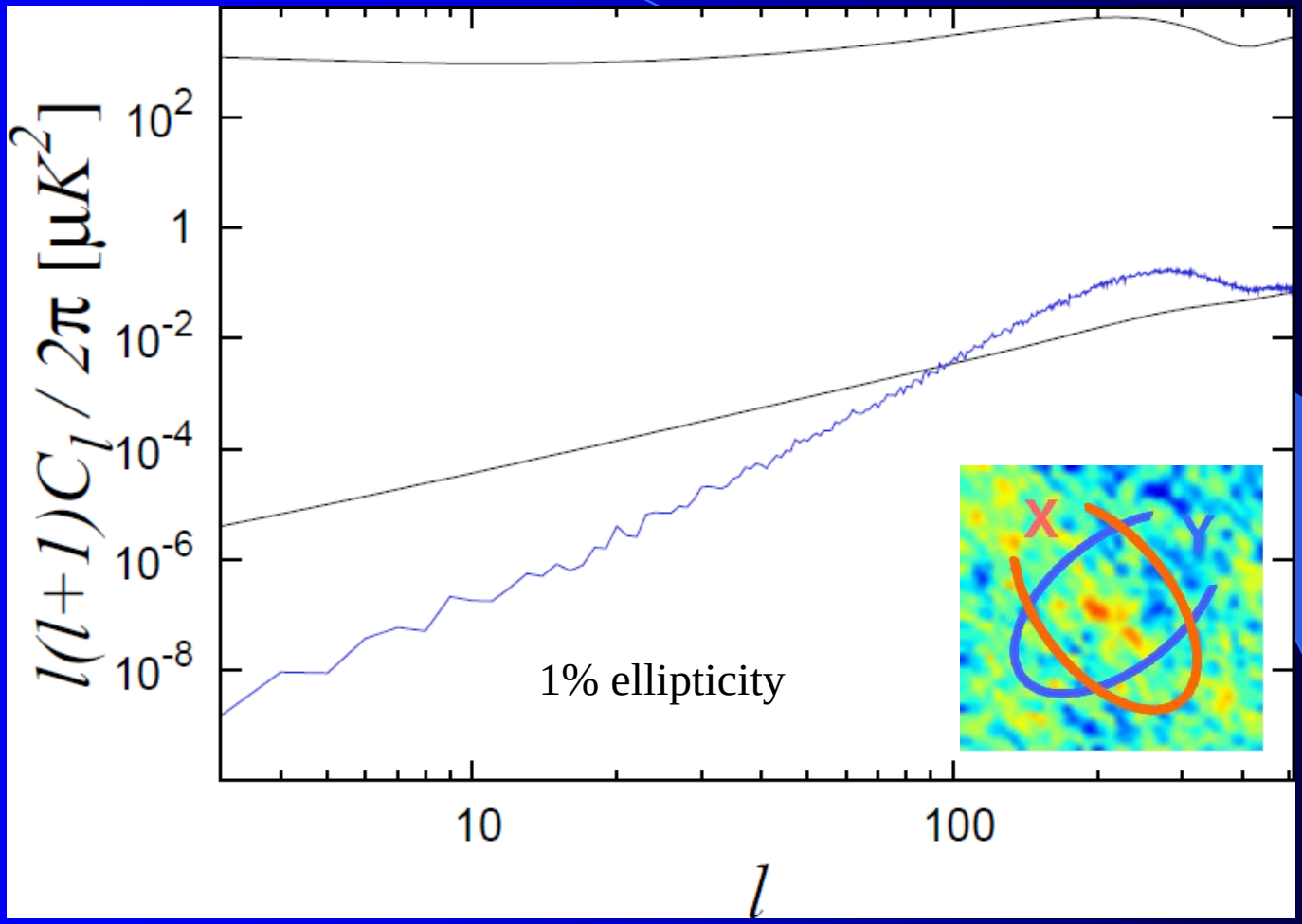
Mainbeam mismatch - beam pointing -



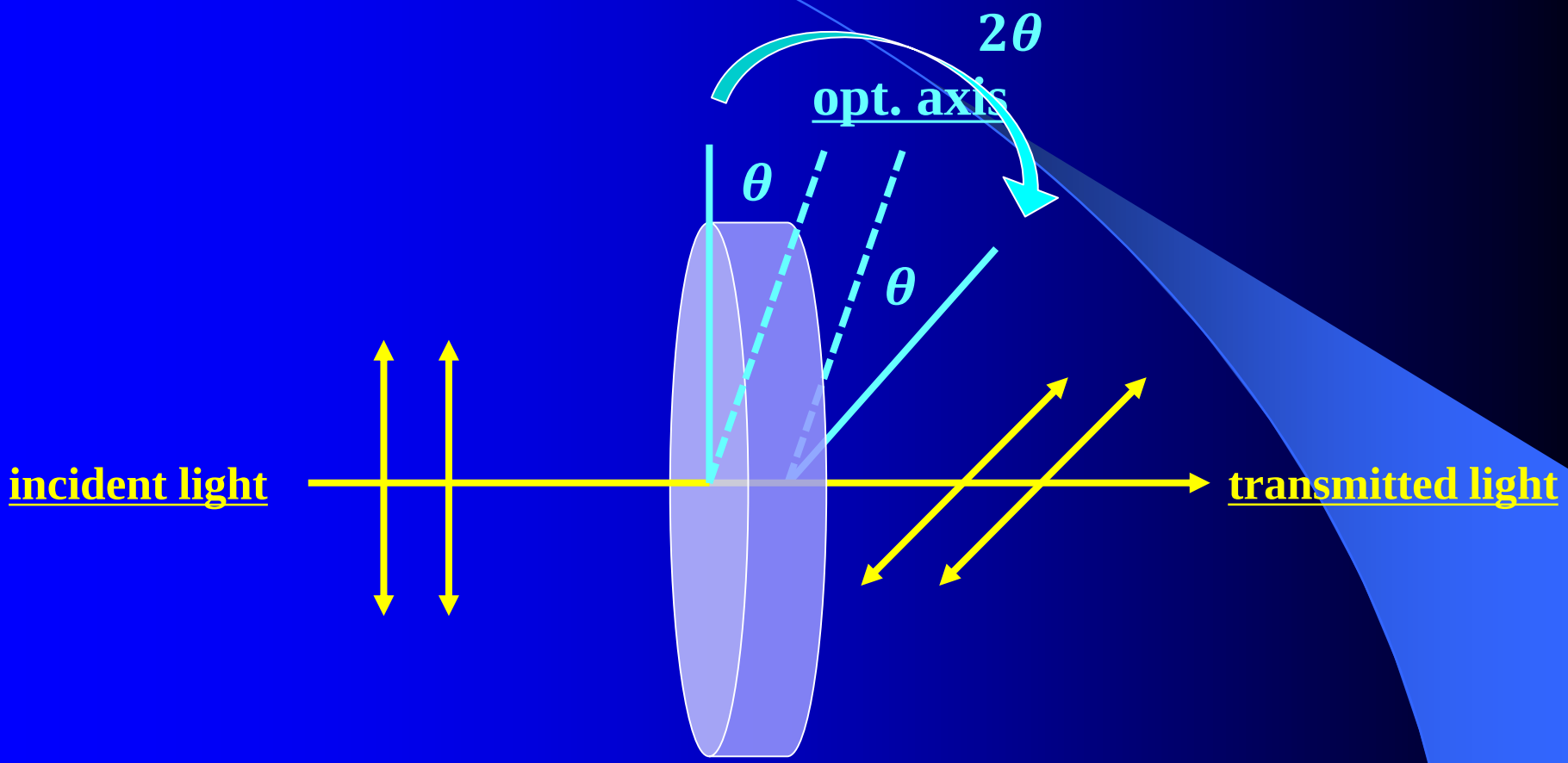
Mainbeam mismatch - beam width -



Mainbeam mismatch - beam ellipticity -

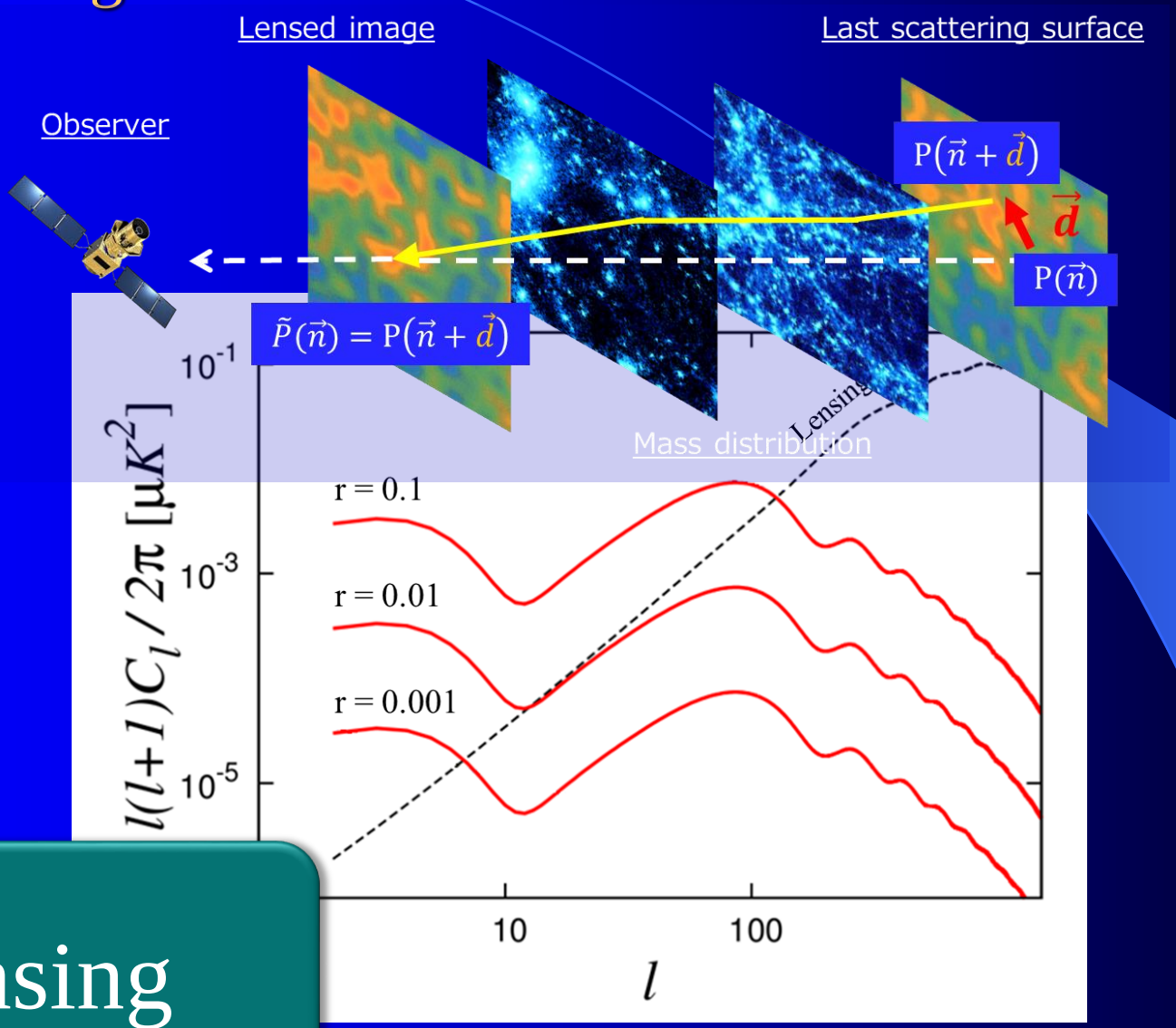


Pol. Modulator（continuously rotating HWP）



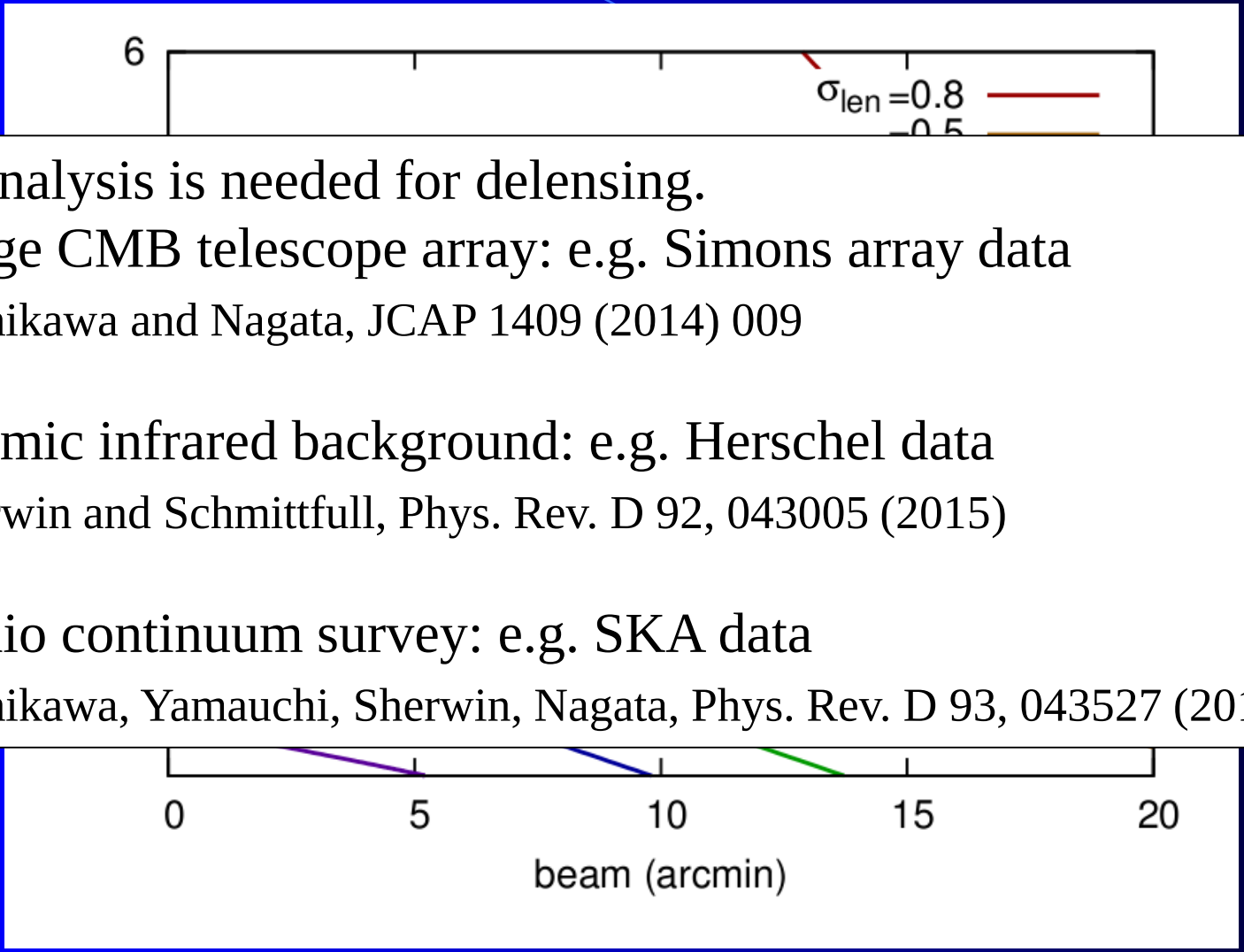
Only pol. component is modulated.

CMB lensing



Lensing

Delensing as extra success



Joint analysis is needed for delensing.

- Large CMB telescope array: e.g. Simons array data

  Namikawa and Nagata, JCAP 1409 (2014) 009

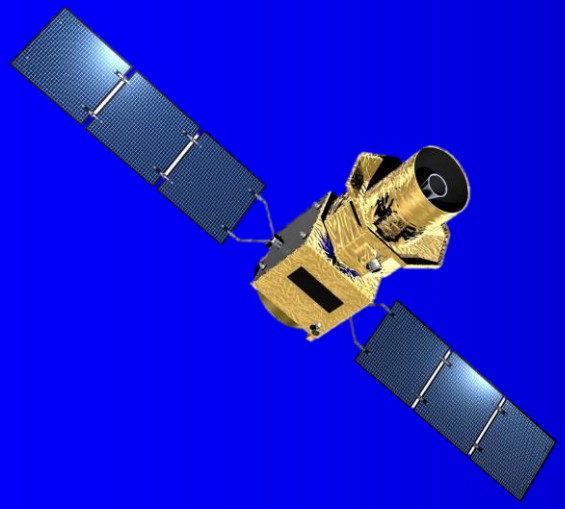
- Cosmic infrared background: e.g. Herschel data

  Sherwin and Schmittfull, Phys. Rev. D 92, 043005 (2015)

- Radio continuum survey: e.g. SKA data

  Namikawa, Yamauchi, Sherwin, Nagata, Phys. Rev. D 93, 043527 (2016)

Synergy with ground-based telescope array



×

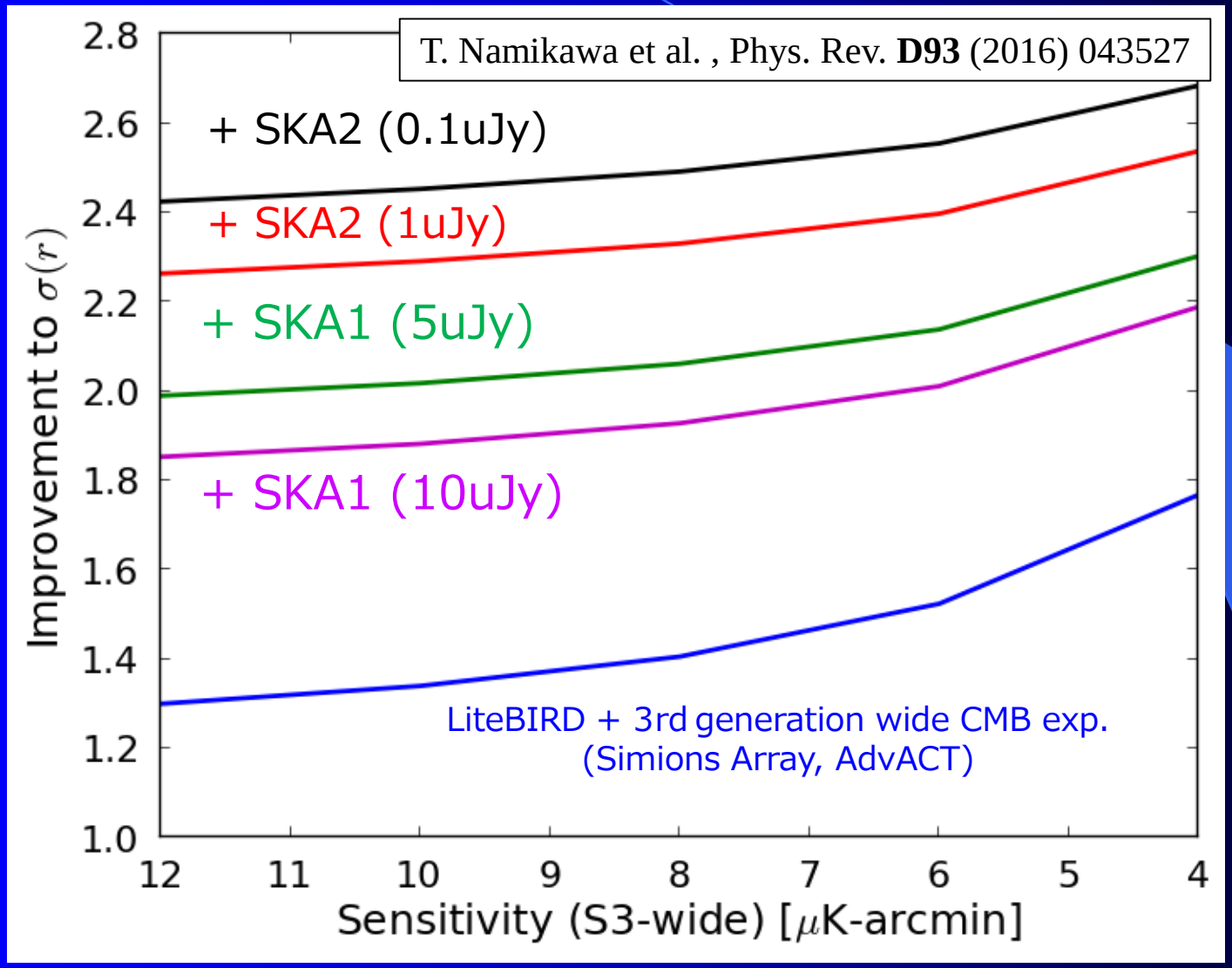
Satellite for ultimate r meas.
$\sigma(r)<0.001$
$2 \leq l \leq 200$

Telescope arrays on ground
$30 \leq l \leq \sim 3000$
e.g. Simons array, CMB-S4

Joint delensing analysis: Namikawa and Nagata, JCAP 1409 (2014) 009

Synergy with SKA

Delensing by use of high-z galaxy map as lensing mass tracer



Summary & current status

- CMB B-mode pol. is the key to the confirmation of cosmic inflation. LiteBIRD is a satellite designed to achieve $\delta r < 0.001$ by precise measurement of B-modes.

- LiteBIRD passed JAXA's initial down-selection and currently in phase-A1.

  - The US LiteBIRD team is working for sub-Kelvin cryogenics and the development of focal plane detectors.

  - The Japan-US JSGs are studying foreground rejection methods by use of multi band obs. and evaluating systematics requirements for designing the satellite and mission instruments.