LiteBIRD Kickoff

Lyman Page, July 2019

Congratulations on **LiteBIRD’s** selection!

- It is a mission with far reaching consequences that will greatly impact the physics and astronomy communities.
- It is a very important complement to ground-based CMB efforts.
- It will likely be unique for a long time.

Please pardon the basic nature in the following!

It is all known but perhaps worth repeating.

Success depends critically on:

Control of systematic errors to unprecedented levels.

Achieving the target detector sensitivity.

Based on past reviews, both are appreciated.

The measurement:

For $30<l<160$, the measurement is extracting a 9 nK *rms* signal (r=0.001) from a multicomponent, non-Gaussian field with correlated structure and ~100 nK rms at 70 GHz.

Picture of collaboration removed to reduce size.

For $2<l<10$, r=0.001 is a 6.4 nK *rms* signal with a ~200 nK rms foreground at 70 GHz.

Bennett et al. 2013, WMAP 9 year maps.

WMAP on low-l polarization

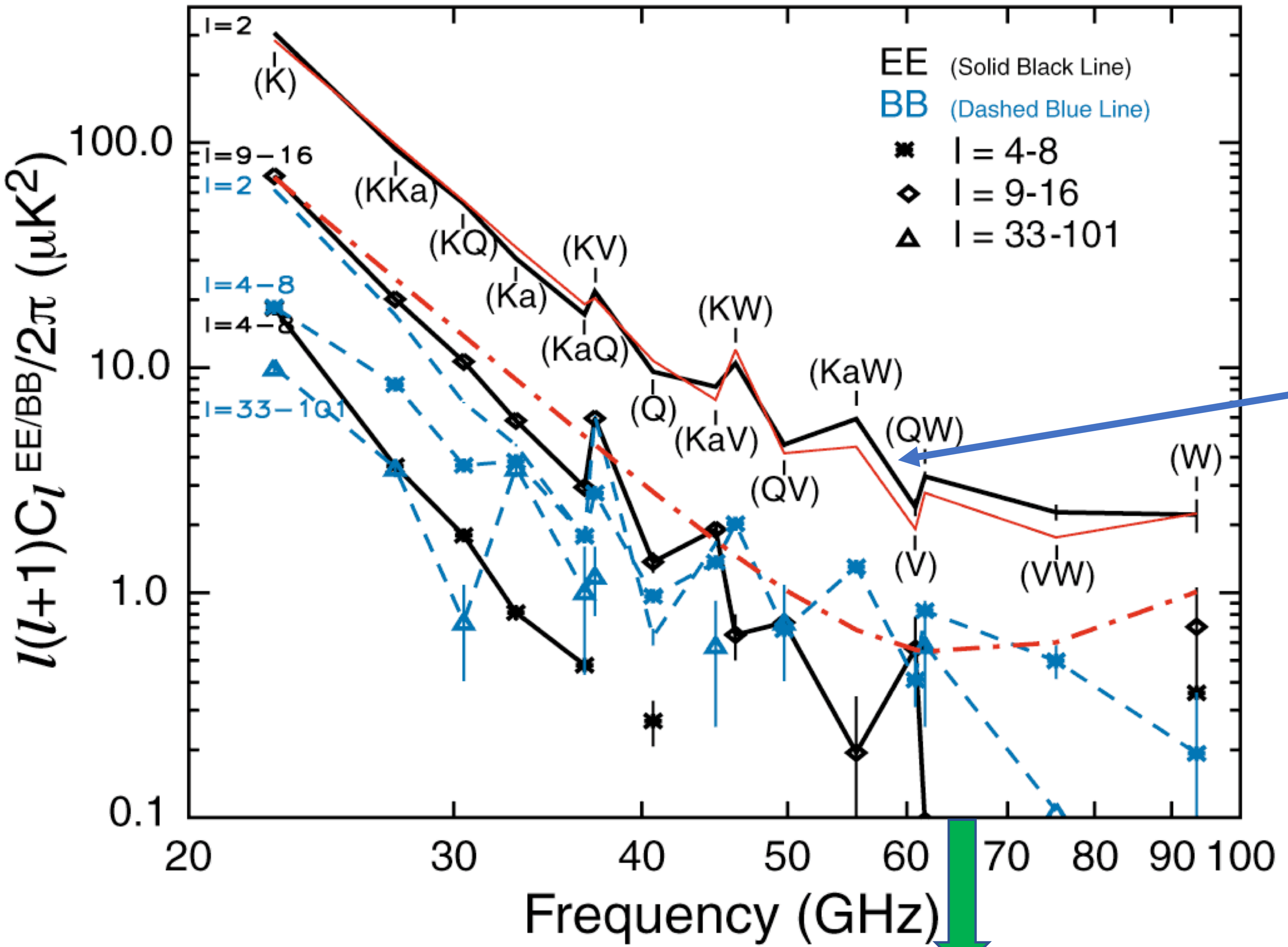
Not optimized for polarization even though we briefly discussed dedicating one W-band channel to it at one point.

Cleanest band was V (60 GHz).

In the cosmological analysis we did not use EE for l>10.

There is still some residual dust contamination for l>10 in public spectra but is can be understood as dust emission as in Choi & Page, 2015.

Antenna temp.



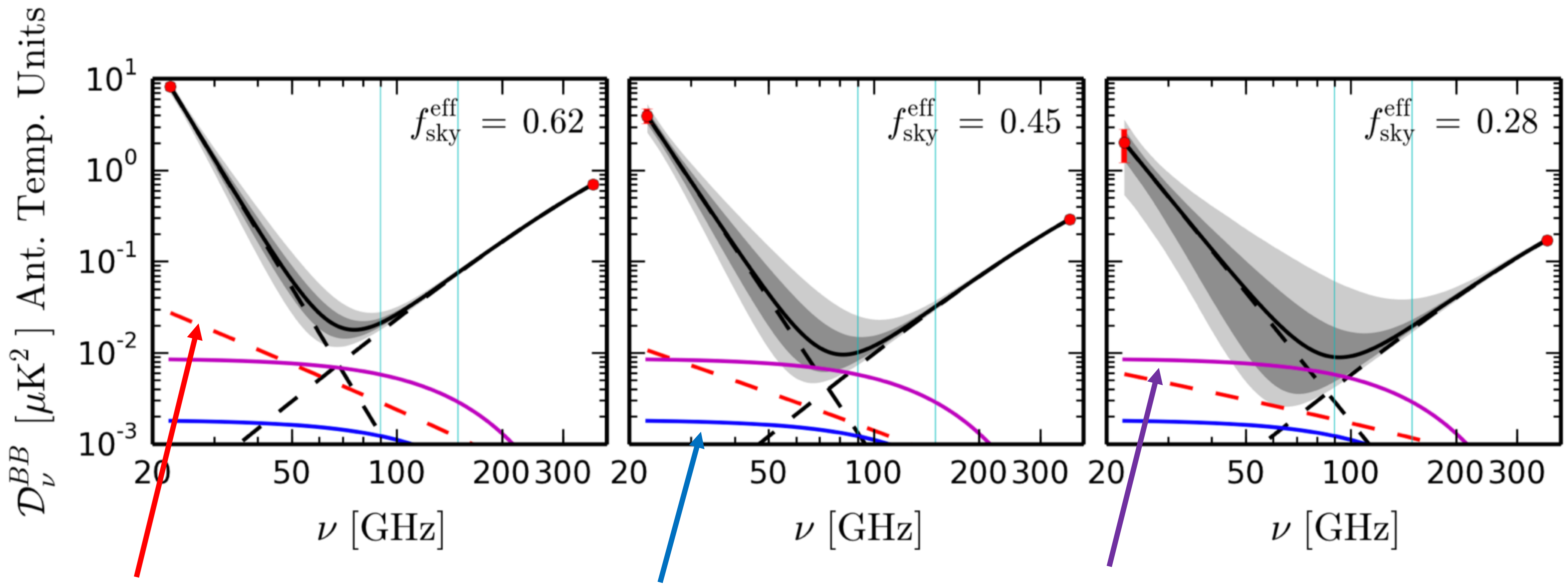
Page et al. 2007, WMAP

- r=0.001 1000X lower!

Spectra of 74% of the sky before any cleaning.

- Jagged due to correlations with dust emission. Red is a model.
- ~Noise floor (by eye)
- There seems to be a window in synchrotron in the 4<l<8 range.
- WMAP did not have good sensitivity to dust pol.

A modern version, now with Planck, for 50<l<110



Red dash: dust correlated component

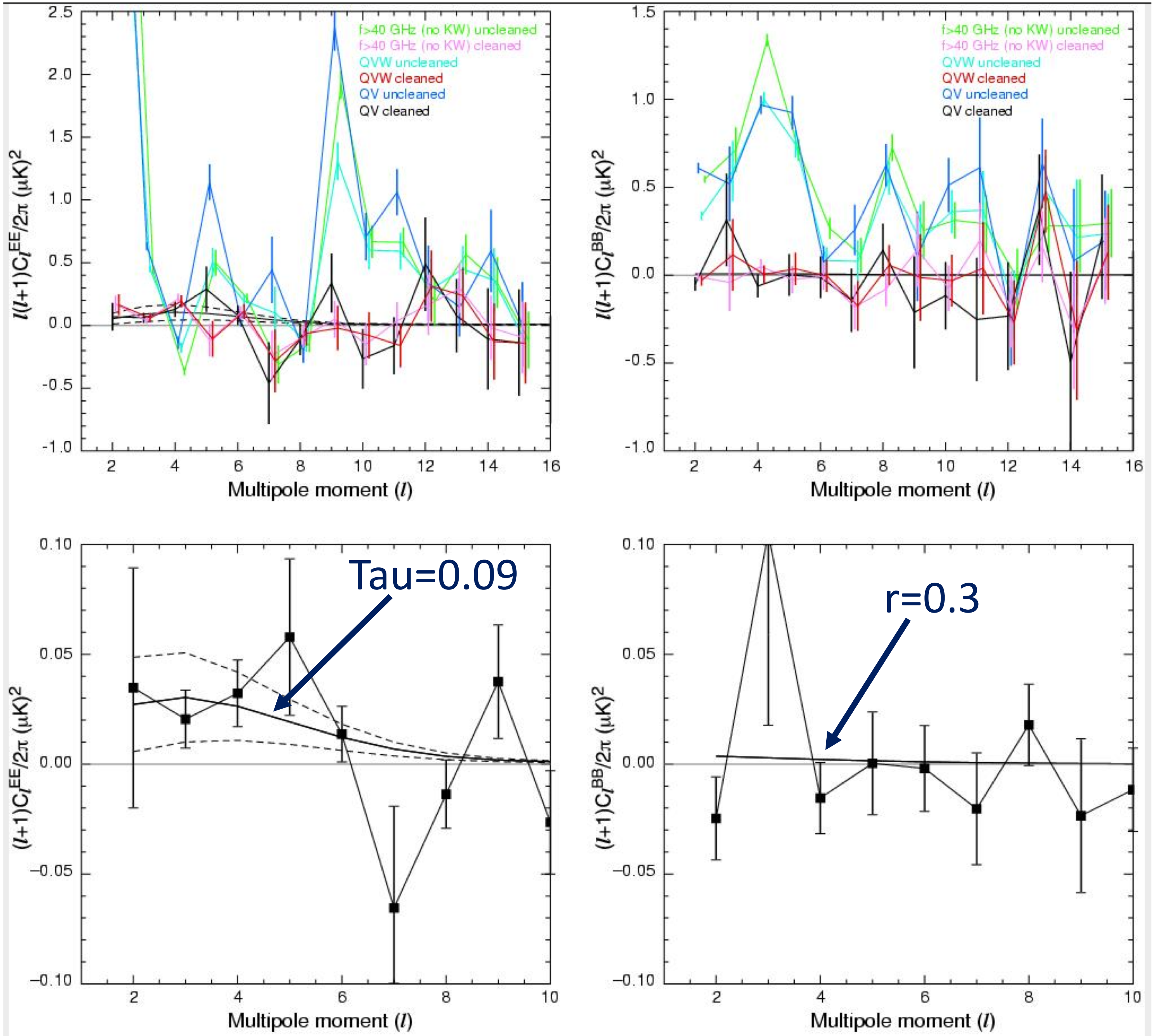
Blue: lensing BB (ant. temp)

Magenta: lensing BB plus r=0.1 signal.

Choi & Page 2015, WMAP + Planck

LiteBIRD might get lucky, we don't yet know!

Low-ell analysis



- All analyses done with the full covariance matrix. Only stat errors shown.
- Different cleaning combinations.
- Note again EE foreground “window”
- LiteBIRD BB should be similar to the blue line for 74% of the sky.
- Chose the cleaned Q+V bands as this was felt to be the safest.

Page et al. 2007, WMAP

Coverage

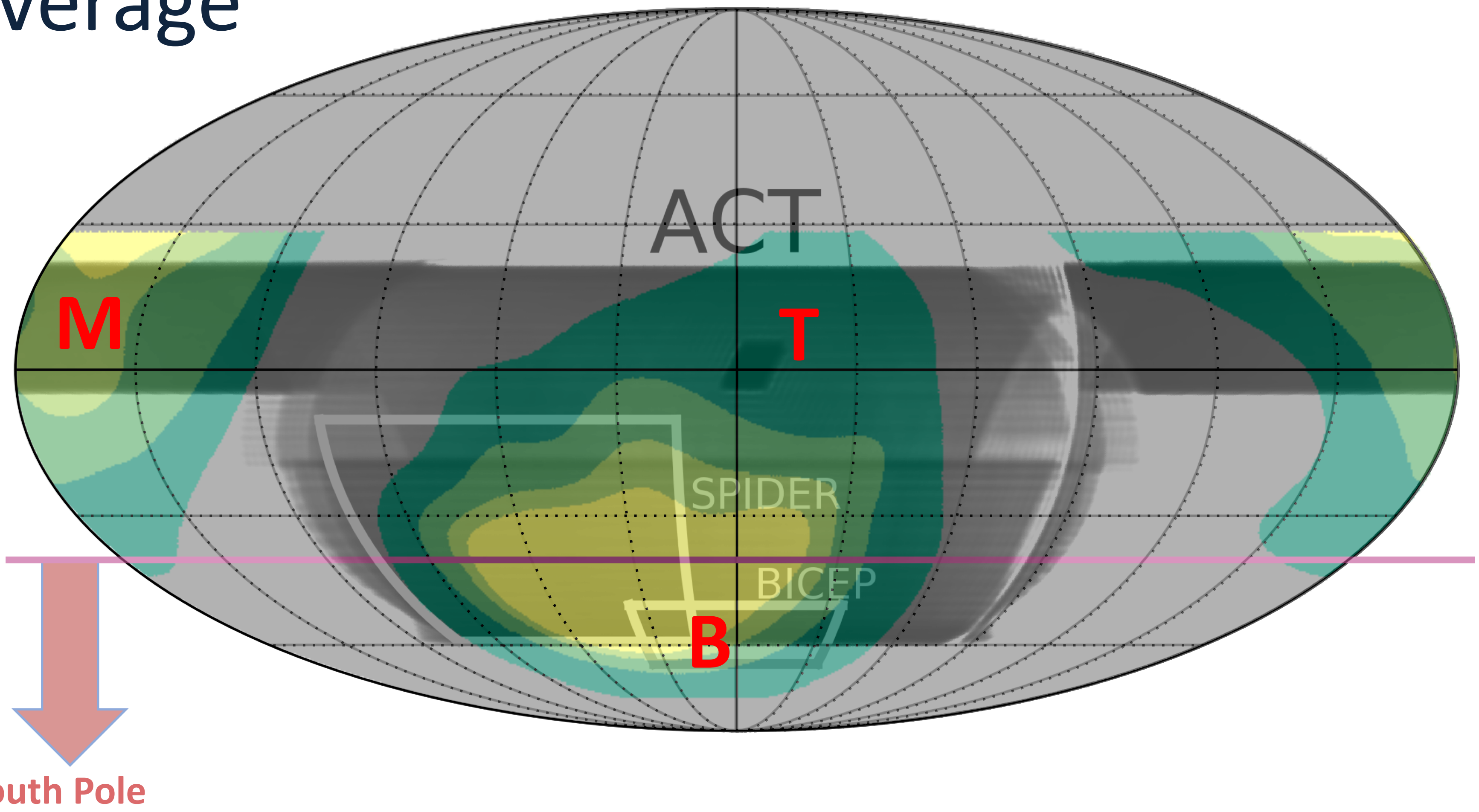
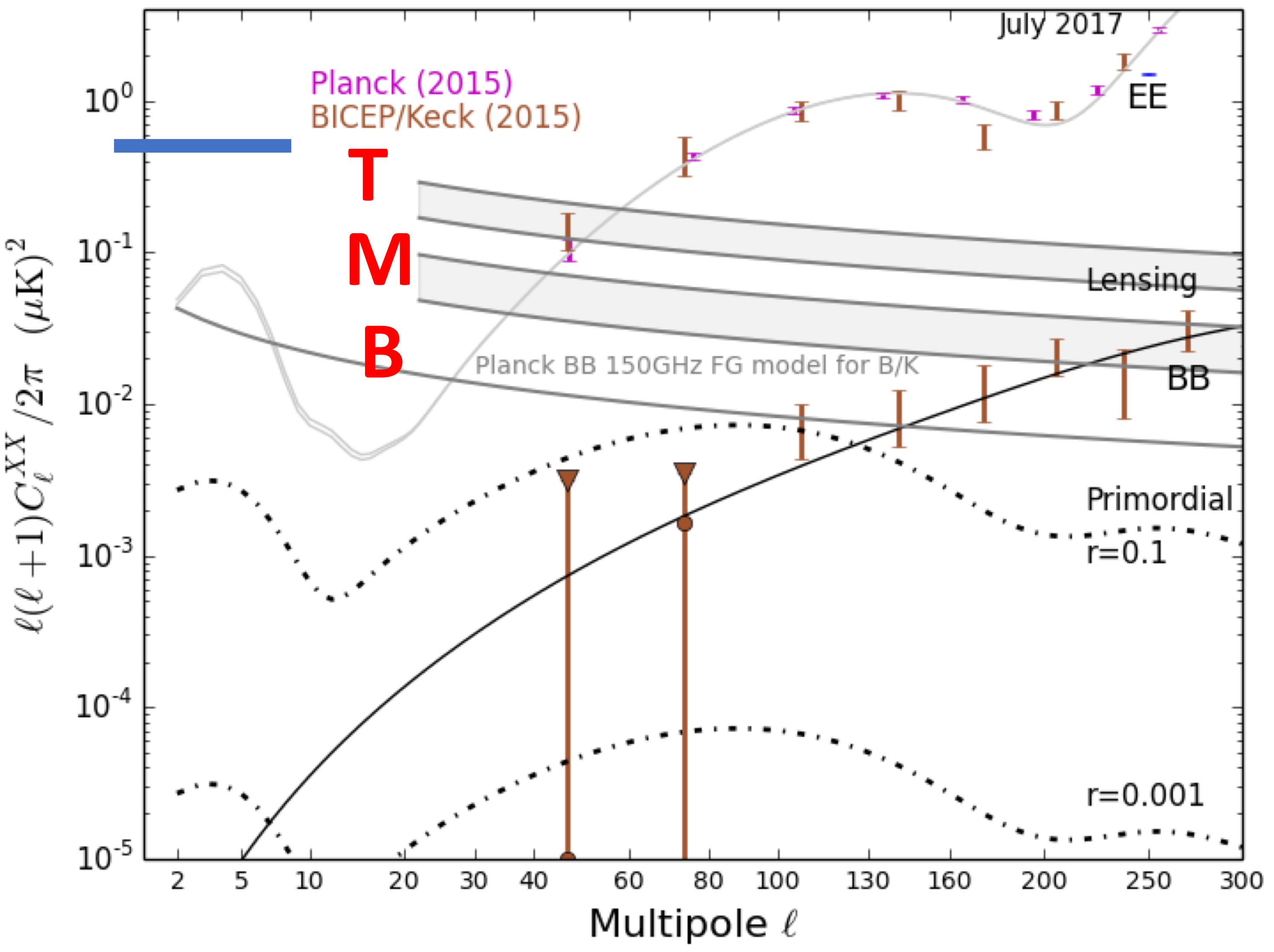


FIG. 3: Sky masks used in the analysis, corresponding to the cleanest 2000, 4000, 8000 and 16000 deg^2 of the sky accessible from Chile in terms of foreground contamination.

David Alonso, Oxford

Foregrounds at 150 GHz, power ~4x lower at 70 GHz

BB WMAP level for 74% of the sky.



The most important things to take advantage of with a space mission:

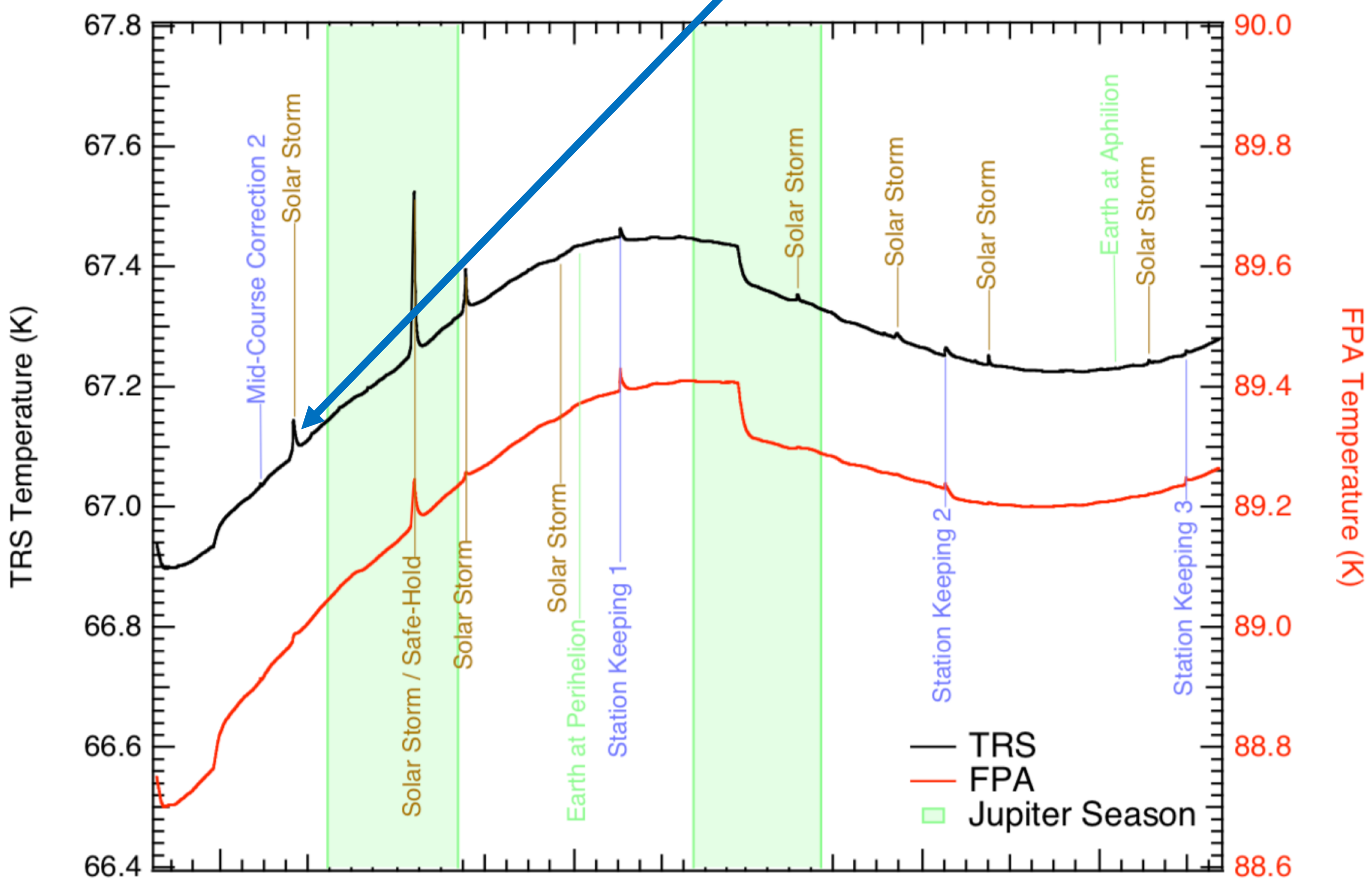
- Stability: allows for a deep assessment of systematic errors.
- Repeatability: need to prove signals are stable.
- Full sky coverage with heavily crosslinked scans.
- Sun/Moon/Earth (ground) in the far sidelobes.
- Calibration on dipole.

Can you coat the HWP so it emits in the IR?

Thermal stability

First (?) bolometric detection at L2!

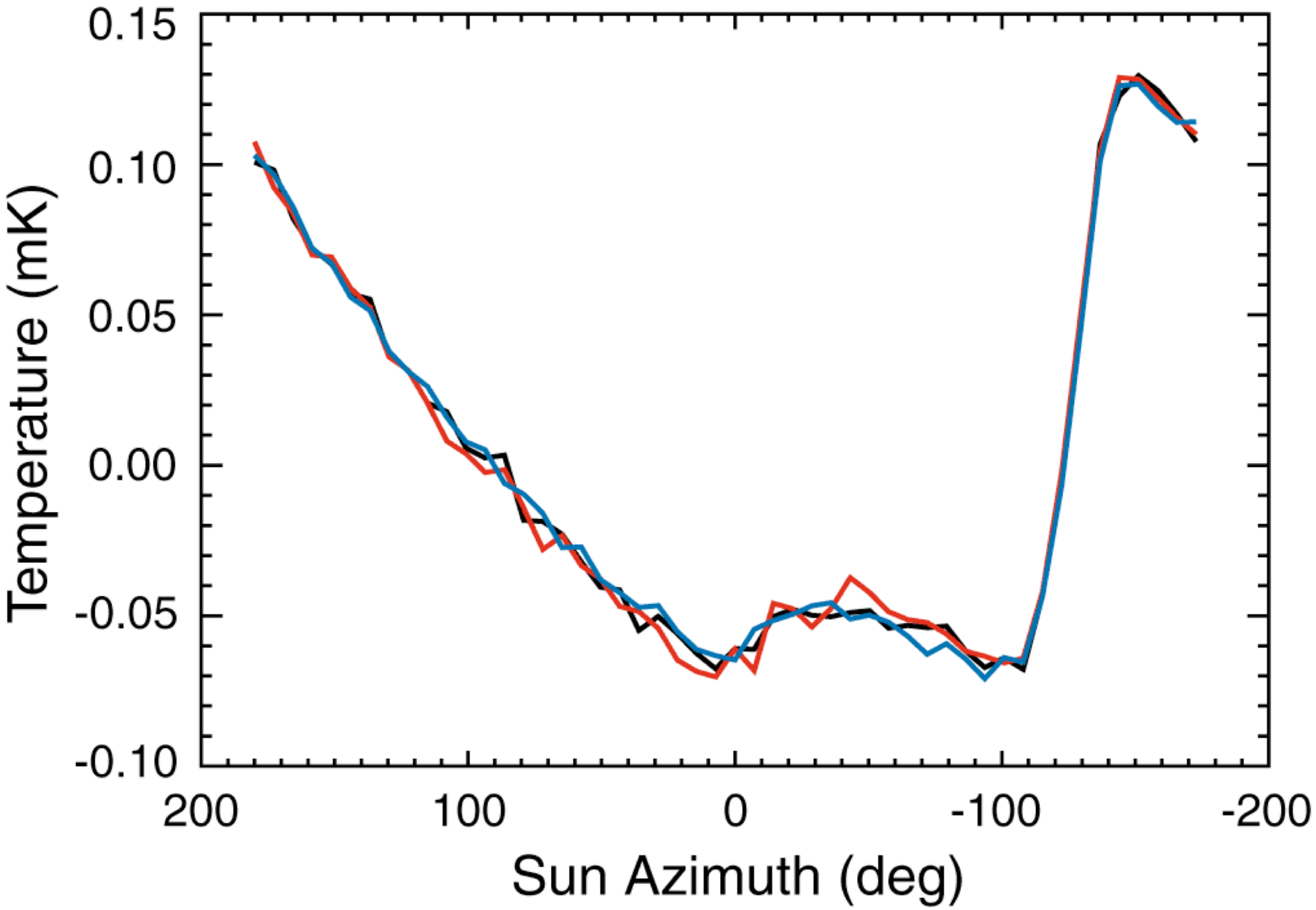
TRS: Thermal Reflector System (the primaries)



FPA: Focal Plane Assembly, where the amplifiers lived.

You will see solar storms in the HWP!

Limon et al. 2010. WMAP's first year thermal profile.



Temperature of primary binned in solar azimuth.

Year 1

Year 2

Year 1

Jarosik et al. 2007.

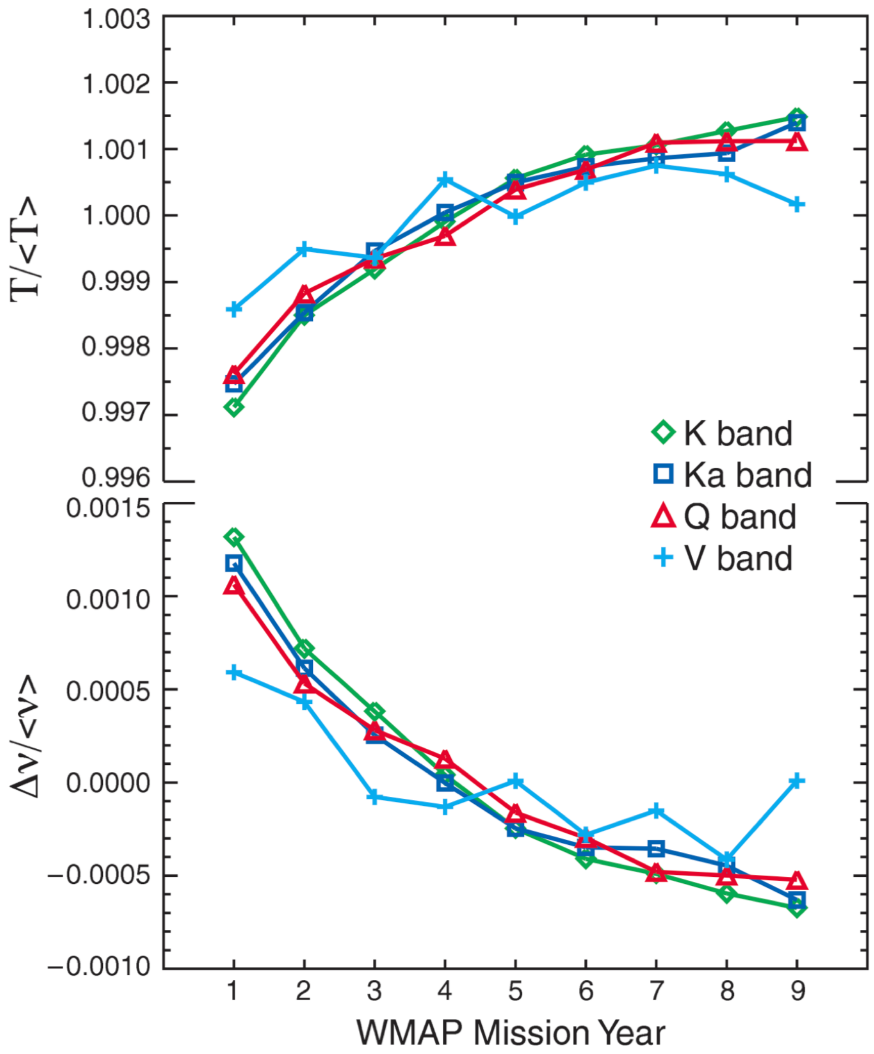


Fig. 44.— Top - Measurements of the year-to-year fractional brightness variation of the Galactic plane in *WMAP* skymaps, obtained by correlating Galactic plane signal in each single year map with Galactic plane signal in the nine-year map. There is a small dependence of these variations on spectral index, which shows that they are caused by variations in effective *WMAP* band center frequencies over the mission. Bottom - The year-to-year fractional variation of *WMAP* band center frequency derived from Galactic plane brightness variations measured for selected spectral index bins.

At a low level, lots of things change. They need to be checked. In this case, central frequencies drifted.

Especially important for LiteBIRD because many effects multiply a large foreground signal.

Bennett et al. 2013.

Some other lessons learned:

The importance of knowing your beam profile cannot be overstated. The “beams” enter in multiple subtle ways.

In addition to pre-flight maps, make in-flight far-sidelobe maps on the Moon. Cleaning the galaxy in the sidelobes likely important.

Measure near-lobes on the ground.

Measure passbands in multiple ways (coherent+FTS).

The polarization angle orientation changes across a band.

Detector Sensitivity NET

60 GHz	90 GHz	140 GHz	195 GHz	280 GHz		
69	**44**	**37**	**53**	**86**	$uKs^{1/2}$	**LiteBIRD** concept design, Tables 6.2 and 6.4 and LB Wiki via Adrian.
…	**56**	**50**	**73** (220 GHz)	…	$uKs^{1/2}$	Planck, best achieved, and these are slow detectors.
46	**27**	**32**	**50** (220 GHz)	**67**	$uKs^{1/2}$	Estimate for satellite from Jon Gudmundsson (Feeney et al. 2016)
35	28	30	45 (220 GHz)	70	$uKs^{1/2}$	"Best possible from space" rough parametric estimate from LP
69	**38**	**28**	**70**	**56**	$uKs^{1/2}$	From PICO design study, another worked example (Hanany et al. 2019)

$uKs^{1/2}$ relative to CMB

NB: On WMAP, Pospieszalski's 60 and 90 GHz amplifiers did not exist. HEMT chips came from Hughes Research Labs with help from Loi Nguyen.

To Complement LiteBIRD on the ground

ACT/PBSA/SPT/SO/S4

NEXT RELEASE, 2013-2016, DR2, "soon"

Will add 30 GHz receiver in 2020, e.g., high res for LiteBIRD, ++

Picture of collaboration removed to reduce size.

Status of activities in Chile

- ACT operating. Now has 11 seasons of data taking and 3rd generation of camera, ``AdvACT.”
- Polarbear/Simons array now has 3 telescopes with PB-2 receivers coming on line.
- ABS is done.
- CLASS has been taking data at 40 GHz since 2016 and recently installed a 90 GHz mount and receiver.

Coming soon, plans…

- SO will deploy a 6 m LAT, “Large Aperture Telescope” following the Niemack design (AO, 2016)
- SO will deploy 3-4 SATs, “Small Aperture Telescopes,” for B-mode searches.
- CCAT-prime will deploy the same telescope design as SO but at a higher altitude to focus on the CMB and higher frequencies.
- CLASS will finish deploying full suite of receivers at 40,90,150 & 220 GHz.
- Polarbear/Simons Array will finish deploying two more new receivers.

Picture of collaboration removed to reduce size.

SIMONS OBSERVATORY COLLABORATION

It’s Happening!

- One new 6m large-aperture telescope (LAT) in Chile
- Three small-aperture telescopes (SATs) in Chile for B-modes

Jim and Marilyn Simons

HEISING-SIMONS FOUNDATION

Sensitivities for f=0.4 per $arcmin^2$

	90 GHz	150 GHz	
ACT ~B/K ~SPT	19 $uK/(\eta\tau)^{1/2}$	18 $uK/(\eta\tau)^{1/2}$	Notes: Based on measured ACT noise for 50^o elev and for 1.3 mm pwv.* +220,30,40 GHz
SO	7.4-5.3 $uK/(\eta\tau)^{1/2}$ Baseline-goal	9.2-5.8 $uK/(\eta\tau)^{1/2}$ Baseline-goal	Notes: Full atm model, 7/13 OTs. &w/ 30,40,220,270 GHz. From: 1808.07445v1
S4	2 $uK/(\eta\tau)^{1/2}$	2 $uK/(\eta\tau)^{1/2}$	Notes: Based on SO "goal" but with more detectors. Total: 2x19 OT. &w/20,30,40,220 ,280, GHz. From S4 site.

LiteBIRD ~3 uK-am but for 3 years

η Is observing efficiency, 20-30%, and τ is duration in years

* The pwv is <1.3 mm 20% of the year, <2 mm 50% of the year

Science Forecast Matrix: Selected New Experiments

From posted papers.

	Simons Observatory	CMB-S4	CLASS	LiteBIRD	PICO
Funded?	yes (Simons Foundation)	no (NSF / DoE)	yes (NSF)	In progress (JAXA)	no (NASA)
Est. first light	2021	2027	2016 (actual)	2027	
Ang. scales	$\ell > 30$	$\ell > 30$	$\ell < 200$	$\ell < 200$	$\ell > 2$
(**B/K**:0.03) $\sigma(r)$	2×10^{-3}	0.5×10^{-3}	6×10^{-3}	1×10^{-3}	0.1×10^{-3}
(**P**:0.4) $\sigma(N_{eff})$	0.06	0.03			0.03
(**P**:0.007) $\sigma(\tau)$			0.003	0.002	0.002
(**P**:240) $\sigma(\Sigma m_\nu)$ [meV]	30	26			15

~x2 better with LB

"Goals"

From Aurelien Fraisse

There is a lot more exciting science in the CMB and LiteBIRD will have an essential role in it!