Design Validation: Technical to Measurement

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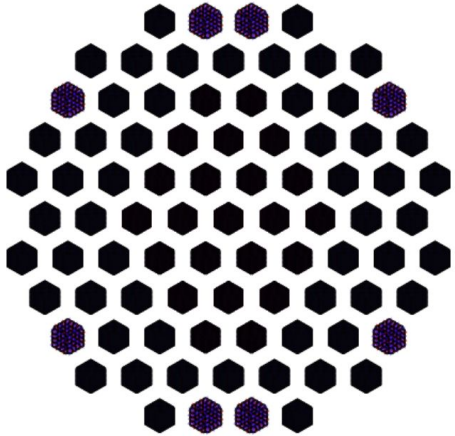
CMB-S4

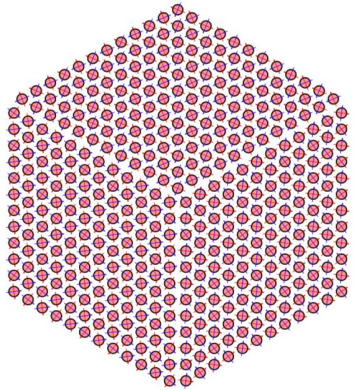
Presentations

- *Sara Simon*: Instrument model
- *Colin Bischoff*: Some BICEP/Keck perspective on systematics
- *Sigurd Naess*: Systematics - ACT perspective
- *Yuji Chinone*: Systematics - POLARBEAR/Simons Array perspective
- *Tom Crawford*: Systematics - SPT perspective

Instrument model (Sara Simon)

- Instrument definition is codified into a set of dictionaries output to a human-readable file (toml) that describe bands, wafers, tubes, telescopes, detectors and readout
- Can be edited at the instrument *and* individual detector level
- The elevation-dependent noise model is derived using the BoloCalc code but we could also call the code directly once the interface is streamlined
- See here for the design tool instrument model parameters and definitions
- How can we develop a mechanism that guarantees the instrument model is kept up-to-date? Once the design is written down, changes can only occur through the Change Control Board



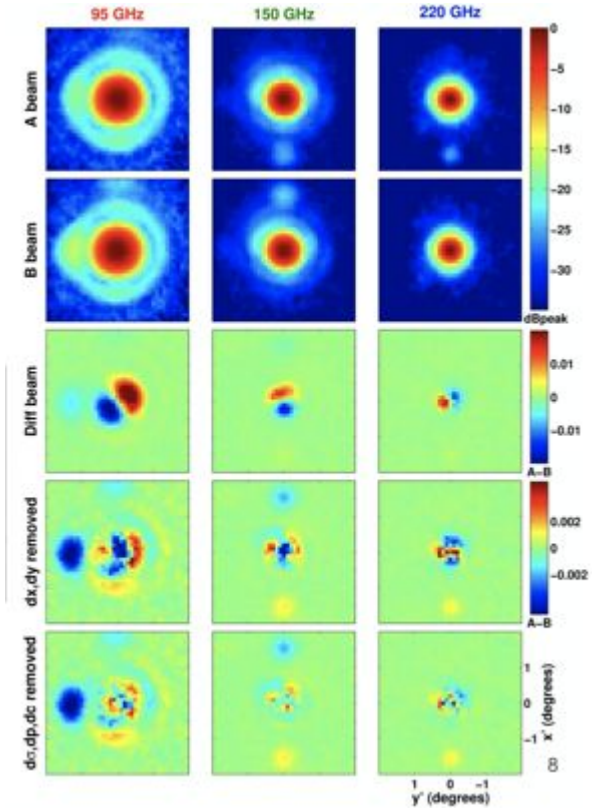


Some BICEP/Keck perspective on systematics (Colin Bischoff)

- For historical perspective, Hu, Hedman & Zaldarriaga (2002) is a great example on how difficult it is to solve systematics before the experiment
- Intensive calibration is required for systematic mitigation
- Lots of time and effort spent on pointing and beam mismatch

Summary / recommendations

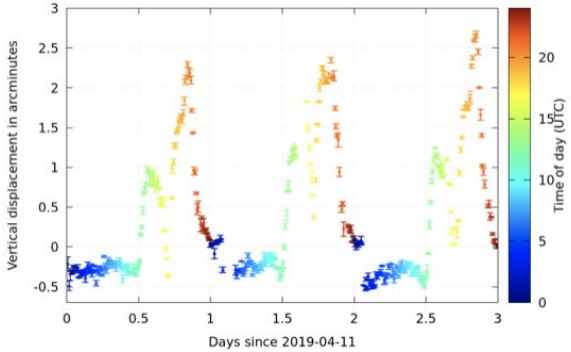
- Use experience of Stage 2 and 3 experiments on instrumental systematics, calibration, and analysis mitigation.
- **Ground CMB-S4 systematics simulations in actual data from existing experiments. This means more analysis of current data in many cases!**
- Before adding a systematic to the simulations, need to consider how this will be addressed through calibration and analysis mitigation. It is easy to corrupt the maps with systematics, hard to restore them to science quality. This is an argument against including systematics in “mainline” data challenges / in favor of including them in focused studies.



Quick tour of main ACT Systematics (Sigurd Næss)

- Near and far side lobe issues can be mitigated through engineering
- Scan-synchronous signal (ground/thermal/magnetic) the most significant systematic
- Useful lessons learned from daytime observations

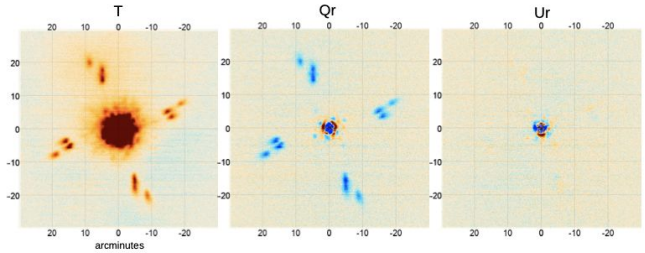
Day-time pointing errors



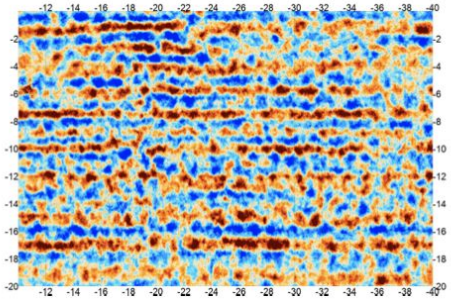
- Up to 3 arcmin pointing error during day
- Caused by mirror deforming under Sun's heat
- Easy to fix by measuring location of bright point sources

Little Buddies

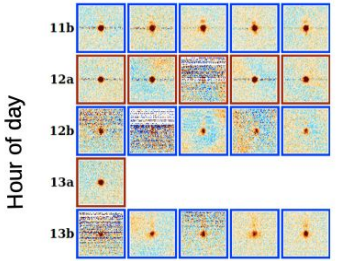
0.1% of beam peak, 1% of beam power, 100% polarized
Caused by interference/moiree pattern in optical filters
Handled by modeling as N displaced and scaled copies of main beam



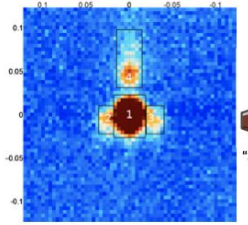
Example of ground in maps



Day-time beam issues



Hard to model and expensive to fully fix
Current approach: characterize seaon-average effect



"Spaceship beam"

Region	Flux	Relative	Frac
1	83.5	100%	71%
2	8.5	10%	7%
3	8.6	10%	7%
4	16.9	20%	14%

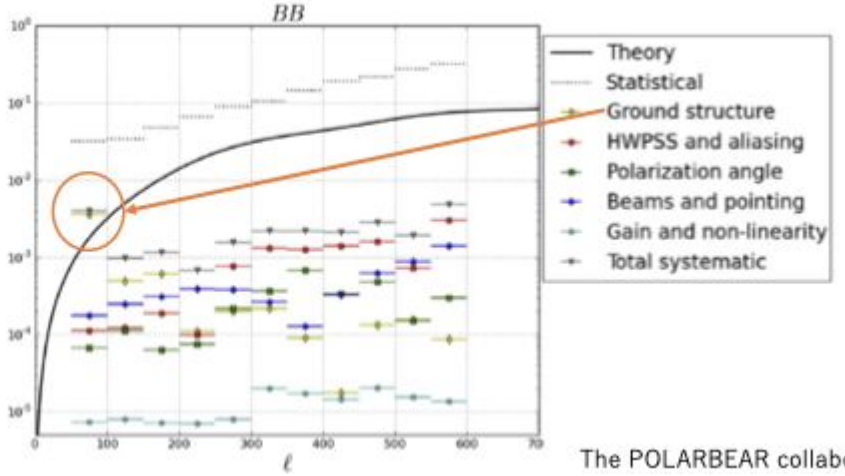
So about 71% of the power is in the main beam.

Systematics: POLARBEAR/Simons Array perspective (Yuji Chinone)

Scan-synchronous signal:

- Comes from sidelobe/ground pickup, magnetic pickup, telescope vibrations, atmosphere, (ice) clouds etc.
- Is one of the worst systematics in POLARBEAR low-ell results.
- Can be effectively suppressed with design
- Can be mitigated with filtering but at a cost to signal
- High el vs. low ell jackknife test is very sensitive to ground pick-up

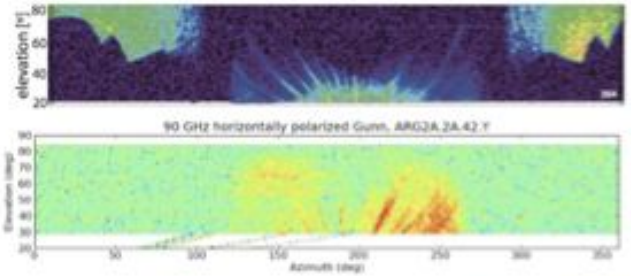
In PB, the residual depends on time-variation of the ground



The POLARBEAR collaboration et. al., ApJ (2020)

Systematics: The SPT Perspective (Tom Crawford)

- Systematics are discovered during design, testing/commissioning, and sometimes only after making maps, taking the power spectra and estimating parameters
- They are mitigated by redesigning hardware, changing observing strategy and in analysis.
- Targeted simulations of design choices (all the way to parameter estimation) can help inform design.
- Think hard about ways to mitigate systematics using data that comes for free ("self-calibration") and can take the place of long, painful calibration campaigns.



Panel-gap sidelobe images from SPT/ACT "Lessons Learned" talks, SLAC 2017.