Systematics: The SPT Perspective

Tom Crawford

Design Validation: Technical to Measurement Parallel

Guiding Questions From Reijo

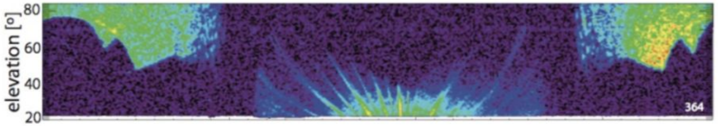
- How and when were systematics discovered?
- How are systematics mitigated?
- What should CMB-S4 do differently?
- Which systematics should we be most concerned about? Can they be translated into technical requirements?
- What to do about systematics that may be mitigated in processing? Should there be technical requirements on both pre and post mitigation levels? Can we simulate mitigation techniques that haven't been implemented?

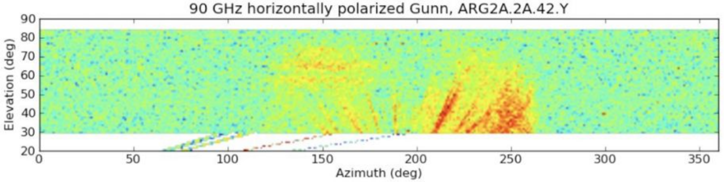
How and when were systematics discovered?

- Sometimes in design phase---i.e., we “discovered” some systematics by learning lessons from earlier experiments.
  - ACT and SPT were the first large telescopes built from the ground up to be dedicated CMB instruments.
  - Some examples of lessons learned in that era: Off-axis optics (no secondary struts in the beam), fast scanning.
- Sometimes in testing / commissioning.
  - E.g., found that perfect, repeatable dead-reckoning pointing from test build didn’t work at Pole.
- Sometimes not until we’d made maps of the sky, or power spectra of those maps, or null tests to check those power spectra, or tried to do parameter estimation.
  - Comparing E-mode maps and spectra to Planck and LCDM predictions showed our polarization efficiency measurement from dedicated observations of a lab-made polarized source were 6% (~4 sigma) off.

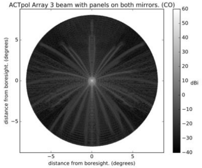
How are systematics mitigated?

- Sometimes by redesigning hardware.
  - Mitigated optical xtalk by blackening surfaces inside SPT-SZ cryostat.
  - Mitigated large-scale “over the primary” sidelobe by improving baffling around beam exiting Rx cabin.
- Sometimes by modifying observing strategy.
  - Mitigated effect of panel-gap sidelobes by avoiding pointing main beam within ~60d of Sun.
- Sometimes in analysis.
  - SPTpol readout-related xtalk mitigated by measuring xtalk matrix using observations of bright sources and multiplying CMB-field TOD by inverse of this matrix.





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



What should CMB-S4 do differently?

- Definitely learn from any specific avoidable systematics in previous experiments.
  - E.g., ACT and SPT both see substantial sidelobes from primary panel gaps, so monolithic mirrors are suddenly very attractive.
- Targeted simulations of design choices (all the way to parameter estimation) can help inform design.
  - Learning from SPTpol xtalk, for SPT-3G Amy B. handed me a zillion different potential detector readout / band / physical position configurations with the expected xtalk among them, and I folded those through to bias in power spectra (though not all the way to parameters).
- 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.
  - E.g., SPTpol on-the-ground polcal was hard and expensive, and sky-based "self-cal" appears to work at least as well.

Which systematics should we be most concerned about? Can they be translated into technical requirements?

- The "high-ell" CMB-S4 LAT goals like N_eff and delensing have been remarkably resilient to the types of systematics we have encountered in SPT. We have to think more about what's going to bite us when we dig another factor of a few in map noise.
  - Example: The beam Fisher group in maps2cell is trying to put a technical requirement on knowledge of beams for N_eff, and the nominal goal for "temperature" beams will be pretty easy to reach with CHLAT measurements of point sources. But we're probably missing something.
- To use the SPLAT data to constrain degree-scale PGW B modes, we need to start thinking of the SPLAT like a SAT, and that's going to make all of this way harder.

What to do about systematics that may be mitigated in processing? Should there be technical requirements on both pre and post mitigation levels? Can we simulate mitigation techniques that haven't been implemented?

- Well that sort of took the whole slide...