LAT Noise

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Excuses

- Original charge: “The deliverables here are presumably those that describe uniform coverage white noise maps: a sky fraction and a noise level to be assumed at each frequency.”
- Noise team only started worrying about full N(ell) about 2 weeks ago.
- The “white noise” charge was interpreted as the following questions:
  - What are the ingredients for map noise level, and have numbers been set in a reasonable way?
  - Do the CDT noise levels make sense? There’s a disconnect with the Simons Observatory (SO) projections.

White Noise

- One way to factor the white noise level inputs is:
  - Effective per-detector NEP
    - For CDT, this was based on ACTPol achieved NEP.
  - Detector count
    - A knob to turn.
  - Observing time (calendar)
    - A knob to turn.
  - Observing efficiency
    - For CDT, this was based on SPTPol end-to-end instrument efficiency (inputs are calendar time, array NET, and integrated map noise).

- The apparent discrepancy bewteen S4 CDT and SO was traced to:
  - mostly: **effective per-detector NEP**. (CDT: 300 uK rtsec; SO: 380 uK rtsec) (60% faster in CDT)
    - Mike Niemack explained this on Thursday; this has led to more detectors and/or more telescopes to get to 1 uK arcmin.
  - also: **observing efficiency** was ~20% higher in S4 projection than SO assumption.

White Noise

- Observing Efficiency.
  - Estimates from ACTPol, SPT, Polarbear, BICEP give total annual efficiency (i.e. usable data per yielded detector-year) in the range of 17% - 30%.

- Detailed breakdown of efficiency:
  - $E_{weather}$: fraction of time that weather is acceptable
  - $E_{overhead}$: fraction of observing time spent on CMB
  - $E_{quality}$: fraction of good-detector data that is not rejected
  - E_{uptime} : fraction of good weather time that telescope is working

Fundamental vs. tweakable factors

(Maybe also E_{yield} ? But that's more of the detector group's problem/risk/opportunity.)

White Noise

- E.g. Chilean site, based on APEX observations and ACT practices...
  - $E_{weather}$ = 56% [9 months per year, and PWV < 3mm 57% of that time]
  - $E_{overhead}$ = 85% [Calibration ops, regular maintenance, etc.]
  - $E_{quality}$ = 80% [One can always identify the worst 20% of the data.]
  - E_{uptime} = ?? [Dirty Laundry parameter. Not available.]

- For Chilean site, we should be discussing the relative cost of snow removal and LATs – they both will affect mapping speed.

LAT: Chile vs. South Pole

- Not yet clear whether same efficiency of observation can be assumed for South Pole and Chile.

- Achieved results: 20-25%
  - And these are improveable. For example, these achieved efficiencies include fridge cycling (in some cases) and snow storm downtime (in others).

- Current recommendation is to continue with 25% assumption. [Downtime mitigation will need to be discussed on the techinical side.]

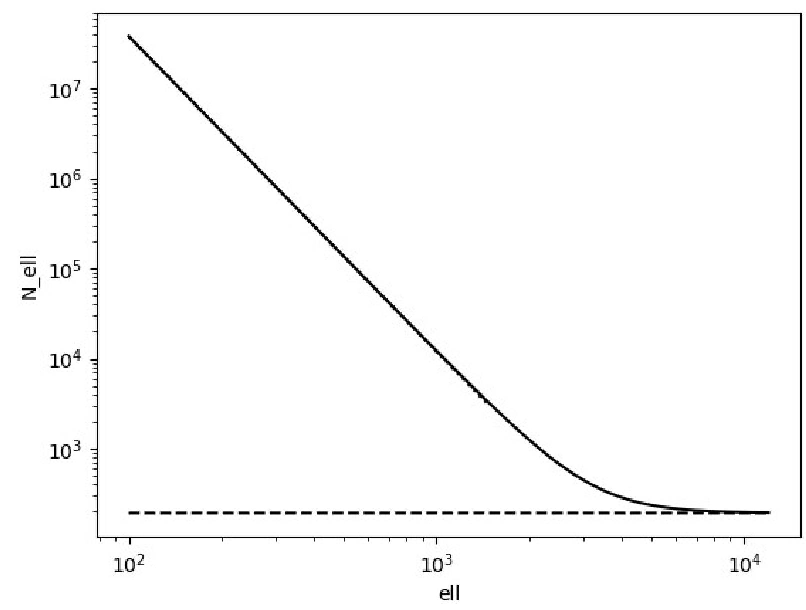
Modeling N_{ell}^{TT}

- For LAT, the large scale noise is due to atmosphere.

- Consider single channel map from ACT (e.g. deep56 pa2 150ghz).
  - Take the map noise curve (with beam not deconvolved). Decompose it as:

$$N_\ell = N_{\rm red}\left(\frac{\ell}{\ell_{\rm knee}}\right)^{\alpha_{\rm knee}} + N_{\rm white}$$

  - Scale N by the effective observing time *t*. This *t* is easily found because the map white noise should scale into the array NET (which we know from instrument characterization.)
  - So now we have the atmosphere, in the same units as the array sensitivity.

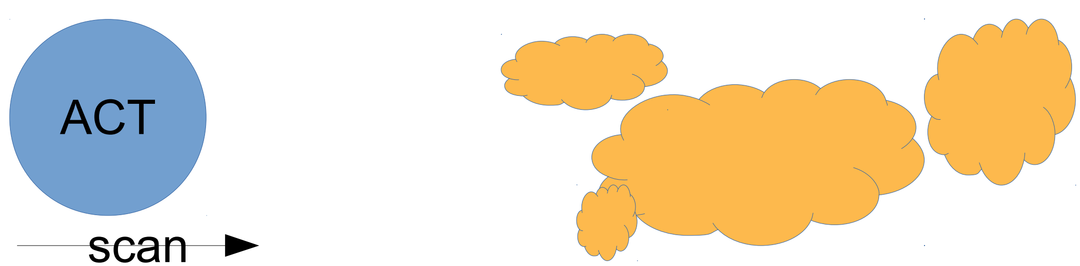


- Looking at several different seasons and detector arrays in ACT, the atm. noise level is quite consistent.

- We have done this for 90 and 150 GHz; numbers are in the SO forecast paper.

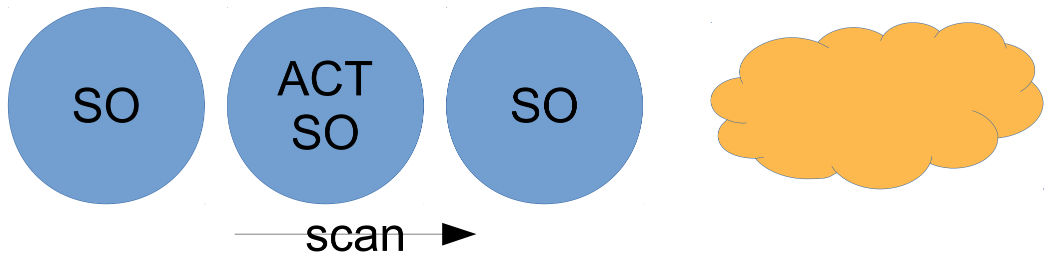
Modeling N_{ell}^{TT}

- Extrapolation to S4 LAT?
- The atmospheric noise curve measured in ACTPol should be expected to apply to any other telescope that:
  - has similar passbands to ACT → yes
  - has the same size of focal plane (each ACT array is about 0.9 deg in diameter) → no
  - observing in the Atacama, at a similar range of elevations as ACT. → yes, yes, no
- The dependence on focal plane size is because the atmosphere has spatial correlation that changes more quickly on small scales than it does on large scales.
  - Consider a detector array scanning over features of various sizes...

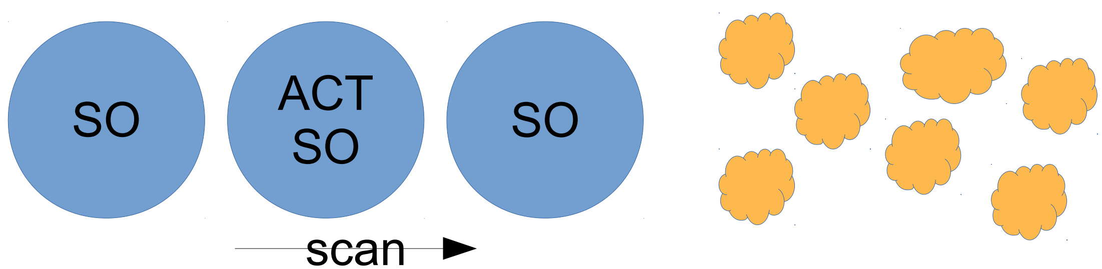


Modeling N_{ell}^{TT}

- Add some new detectors. This does not help us with large scale blobs in the atmosphere. They change only slowly in time. All detectors see the same blob.



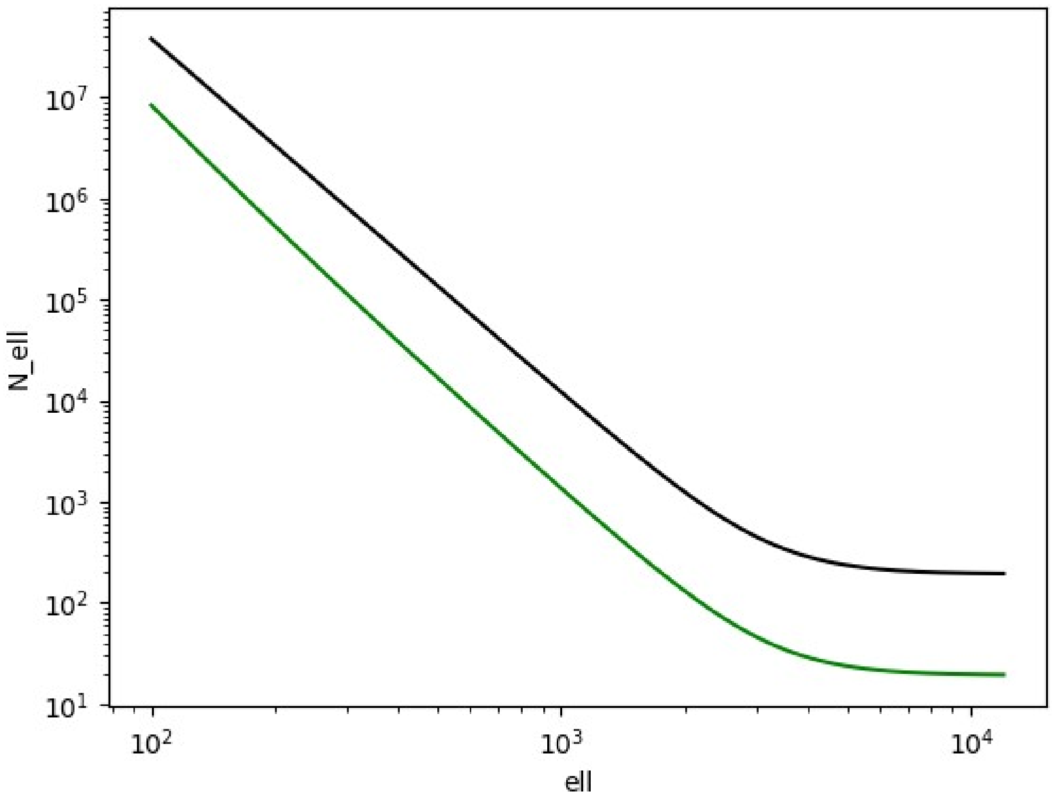
- But the smaller scale structure is changing more rapidly. Different detectors see different realizations of noise; that's good.

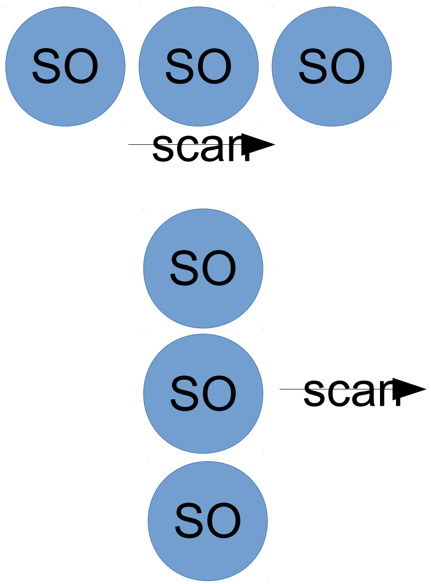


(Note that a simple constant velocity "moving sheet" model for the atmosphere has this property. A blob moves to a new location in time blob_size / v_wind.)

Modeling N_{ell}^{TT}

- Let's go to 10x detector count, increasing total FOV from ~1 degree to ~3 degrees:
  - We should see less improvement in noise as we approach ell ~ 1/(3deg).
  - Exact form of the cross-over depends on scan strategy and layout of detectors.





For SO, we decided each optics tube is basically independent.
Each optics tube is larger than ACTPol tubes. By about a factor of 3 in area. We split the difference on this and allowed atmosphere to attenuate by a factor of 2.

Modelling N_{ell}^{PP}

- Origin of low ell PP noise is not understood.
  - It may be coupled to the atmosphere, but not in a simple way (gain issues, e.g.)

- Does PP noise average down with number of detectors?
  - Perhaps yes, because:
    - Optics tubes each have separate optical elements and thermal links – polarized noise will be incoherent between tubes.
    - Detector-local 1/f can induce polarization noise, but it will not be strongly correlated across the array, even within an optics tube.
  - Perhaps no, because:
    - External polarization contamination (ground pickup) will be common to all detectors.

- For SO, we have been somewhat optimistic, and permitted polarization noise to average down cleanly with the detector count.

> *LAT polarization:* Again we fix $N_{\rm red} = N_{\rm white}$. We find that $\ell_{\rm knee} = 700$ and $\alpha_{\rm knee} = -1.4$ approximates the ℓ-dependence of the uncertainties on the polarization power spectrum achieved by ACTPol (Louis et al. 2017) in Chile at 150 GHz, and is consistent with data from POLARBEAR without a continuously rotating half-wave plate (POLARBEAR Collaboration 2014a, 2017). We use

- Having thought more about this, I would be more comfortable with carrying both “optimistic” and “pesismistic” cases here, and seeing what difference it makes.

Modelling

- Can we do better than this?
  - Chile vs. South Pole – get some South Pole data in there?
  - Better treatment of spatial-temporal correlations? A fun project, within reach. But still will take time, and will not change the game much.
  - In polarization... significant investigations would be needed to understand polarization contamination better. They should be done; but it's an open-ended exploratory problem.