What Does It Mean To Talk About an Ultimate CMB Mission?

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Designing Future CMB Experiments
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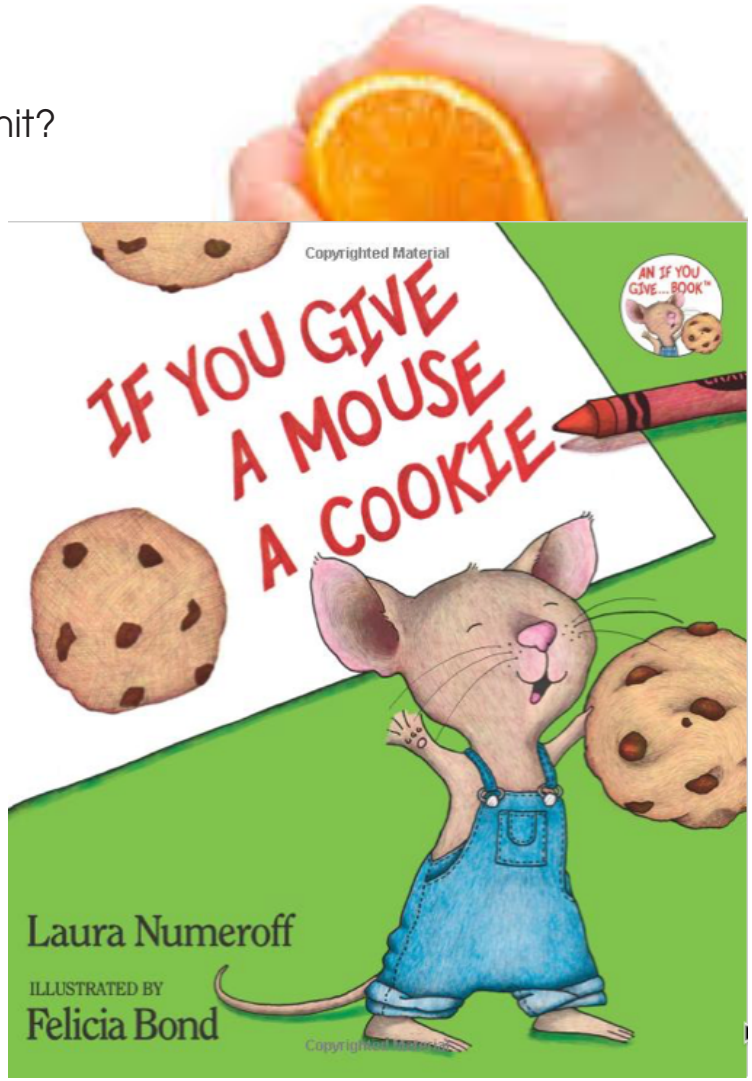


That Way Lies. . .

Why?

Why?

- Cost constraints are good!

But Also. . .

- Taking too big a step from one mission to the next is dangerous

  (Hardware, software, mission design)

  - Extrapolation is risky. The farther, the riskier.
  - A guess about a too-big step will wind up in a different place than the sum of several intermediate steps
  - Risk is money

Example — I

"Data analysis" for CMB experiments is dominated by the search for and mitigation of systematic errors, and the removal of foregrounds (including lensing).

This will be even more true in the future.

Example — II

Systematics and foregrounds don't come wrapped in pretty packages with labels on them. They come all jumbled up, mixed together, interacting with each other, and making a general mess.

The first and often hardest part is to figure out what the problems are.

Example — III

- You may be able to tell that you have problems from power spectra, but a lot of information is lost in going from maps to power spectra. Sooner or later (and it *will* be sooner!), you will be trying to sort things out in maps.

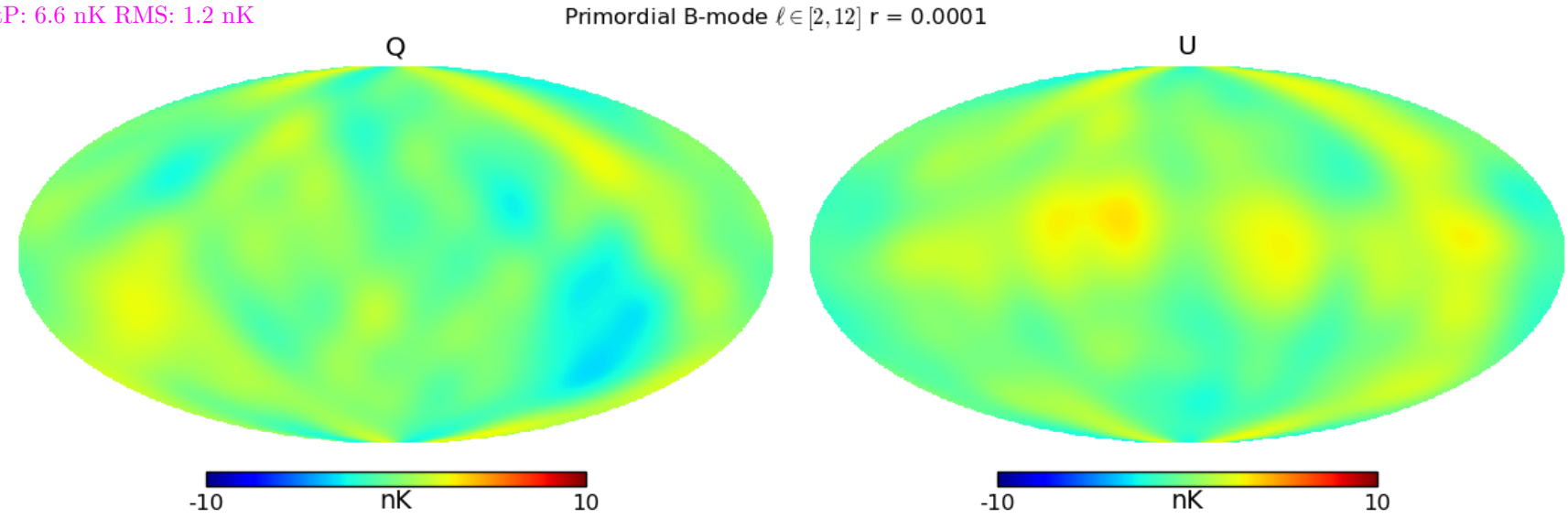
> IT'S THE NOISE LEVEL IN THE MAPS THAT MATTERS ULTIMATELY, NOT IN THE POWER SPECTRA.

- How can you tell that a systematic effect has been identified and (hopefully!) corrected?
  - An instrumental cause is identified
  - Simulations including that instrumental behavior show that the effect on the data is as observed
  - Simulations confirm that whatever mitigating action is taken produces a good outcome

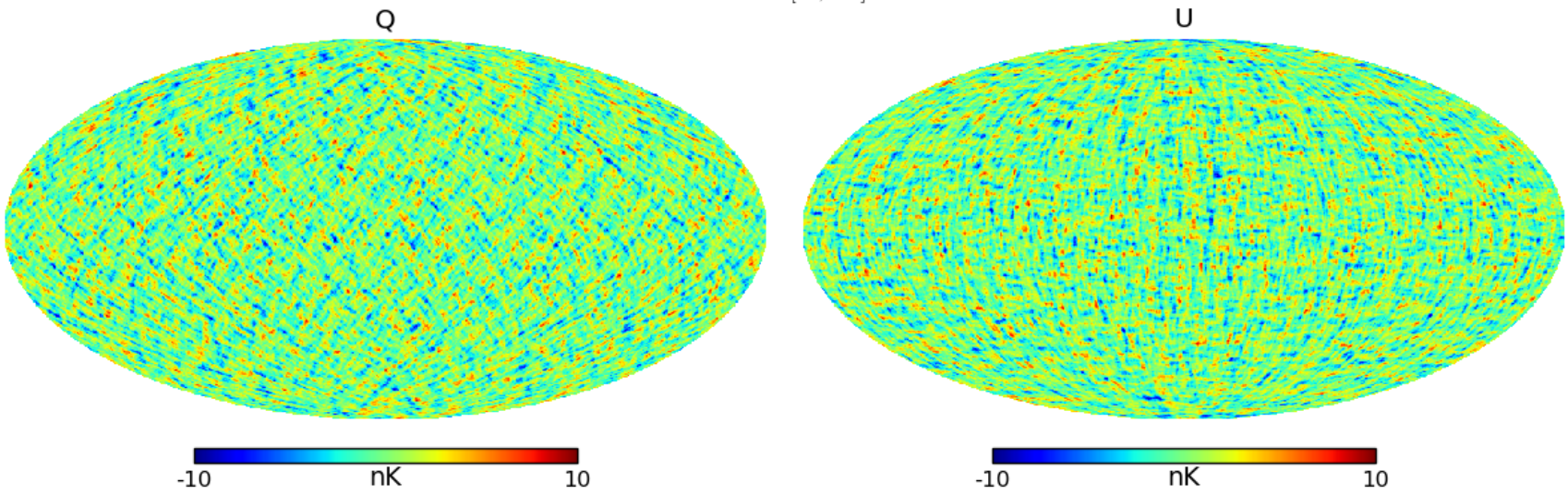
> TOD SIMULATIONS ARE GENERALLY REQUIRED TO REPRESENT INSTRUMENTAL SYSTEMATICS.

$r = 0.0001$ B mode

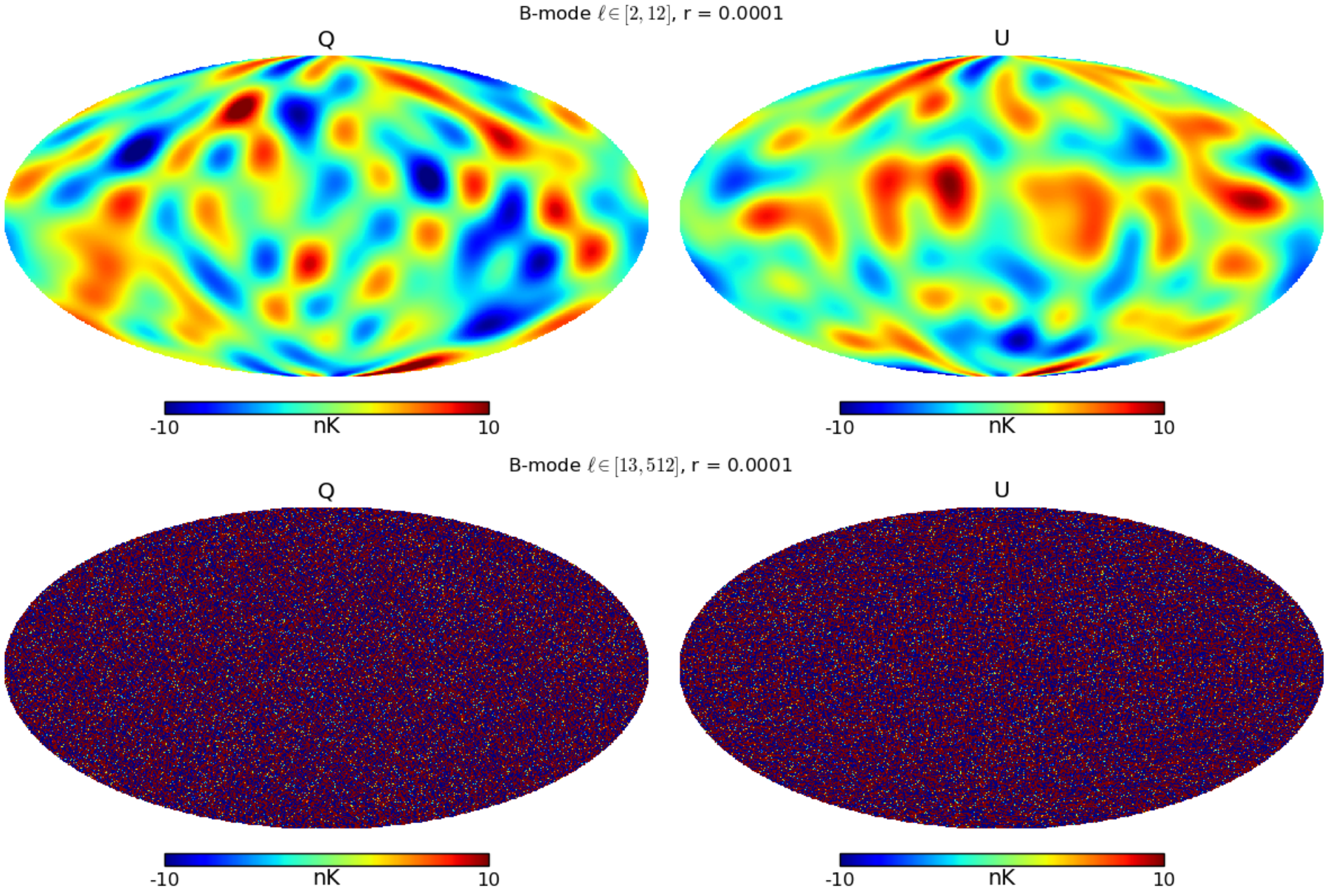
PtP: 6.6 nK RMS: 1.2 nK



PtP: 21.358 nK RMS: 2.221 nK



$r = 0.0001$ B mode, plus lensing

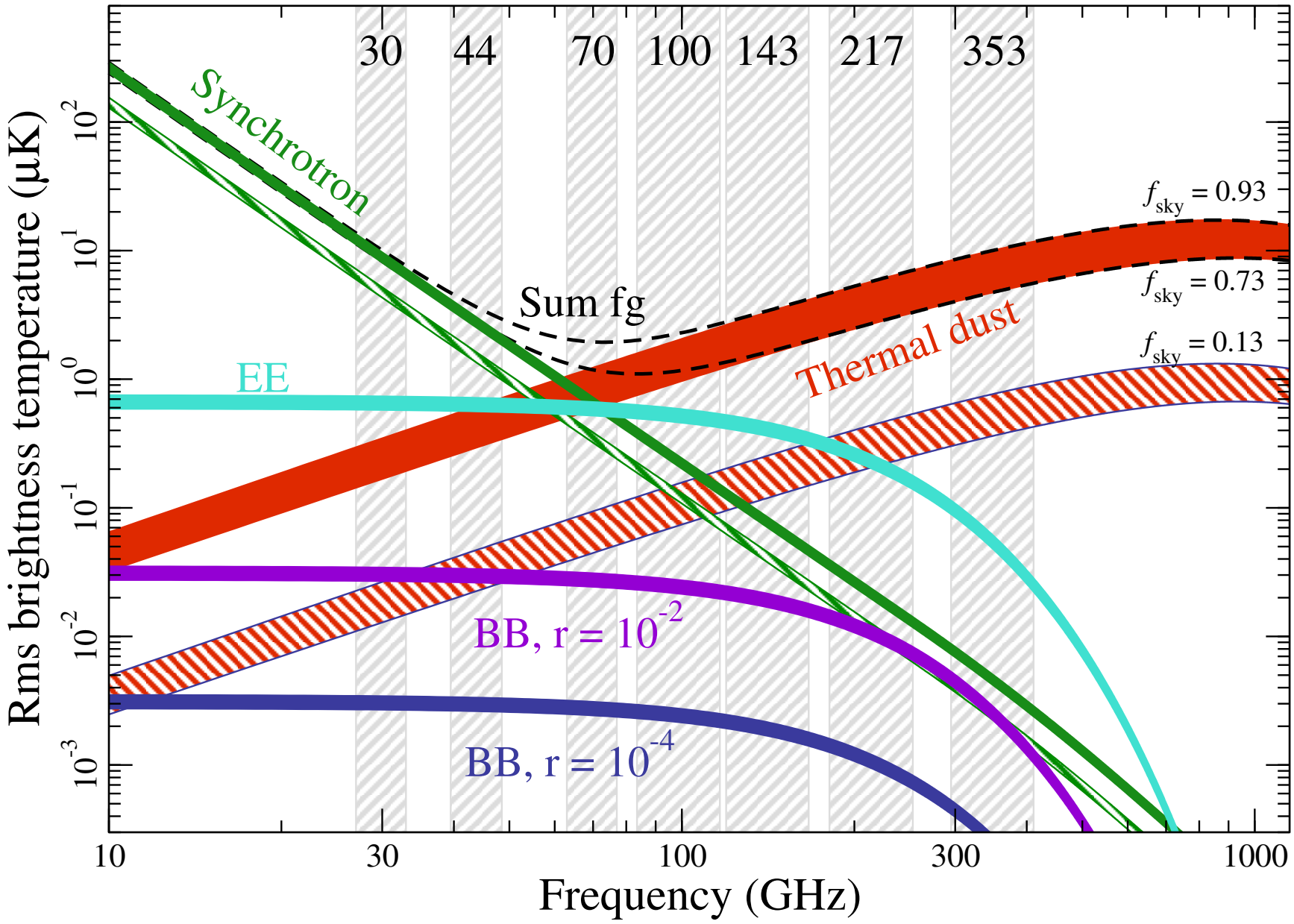


Example — IV

$$\boxed{r = 0.0001 \leftrightarrow 1\,\mathrm{nK}!!}$$

This is not a mathematical statement, just a reflection of reality!

Polarized Foregrounds!



Example — V

There is no escape from foregrounds, neither the "low frequency" ones ("synchrotron") nor the "high frequency" ones ("dust").

Example — VI

If $r = 0.0001$ is the goal, then "everything" spurious must be controlled to 1 nK or better

- All systematics
- All foregrounds
- All interactions between systematics and foregrounds
- Etc.

Another Possibility

- The CMB is a mature field. Three space missions. A large number of sub-orbital experiments.
- The next steps will be difficult and expensive, whether on the ground or in space
- We have to demonstrate science value per dollar!

- An "ultimate" mission is one where we can show with high fidelity what we will be able to measure
  - Time-ordered data reflecting instrument and mission performance

    Systematics

    Foregrounds

    Everything

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That's what we need to work on!