Foreground challenges for measurements of spectral distortions

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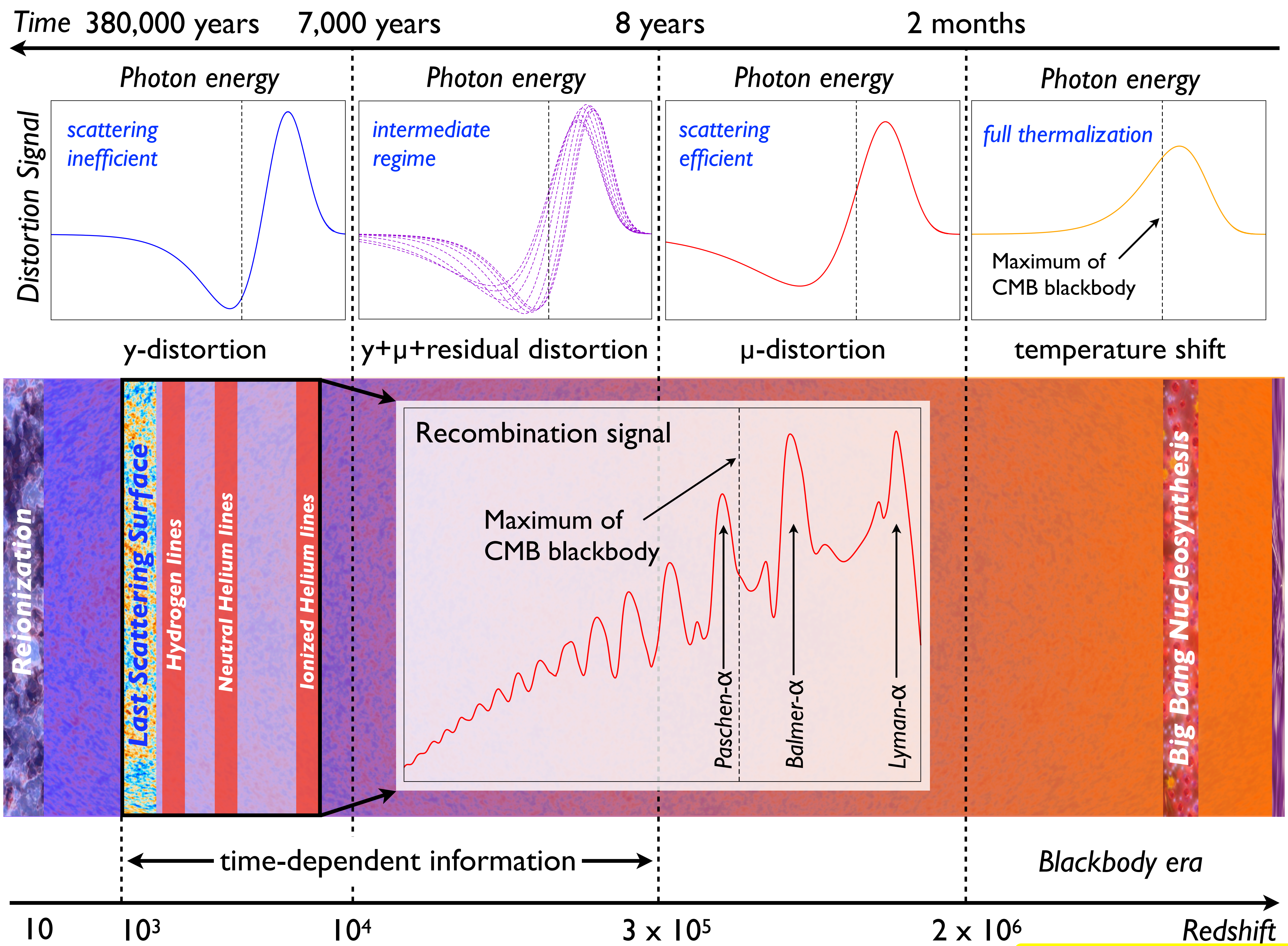
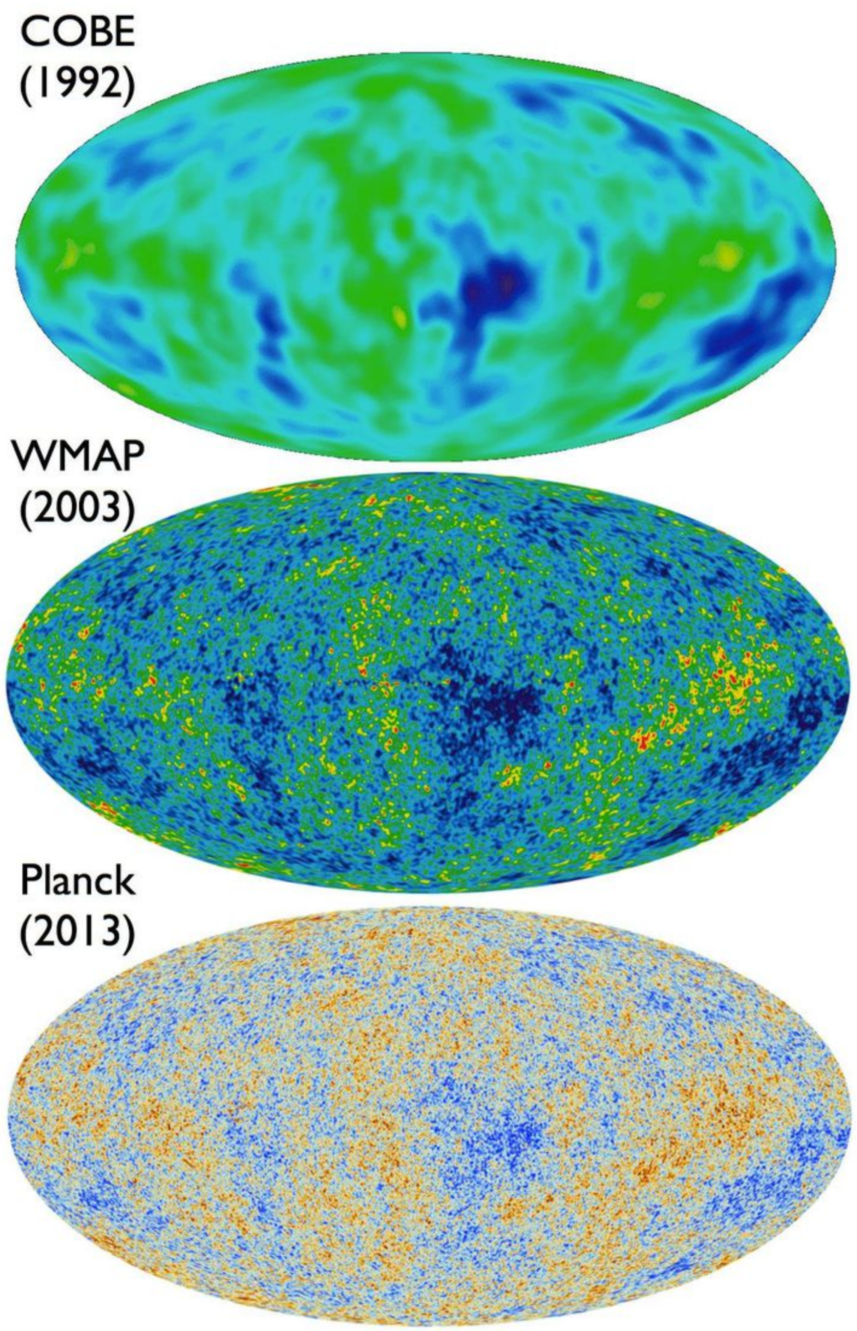
Lightening recap of spectral distortions



Voyage 2050 white paper: arXiv:1909.01593

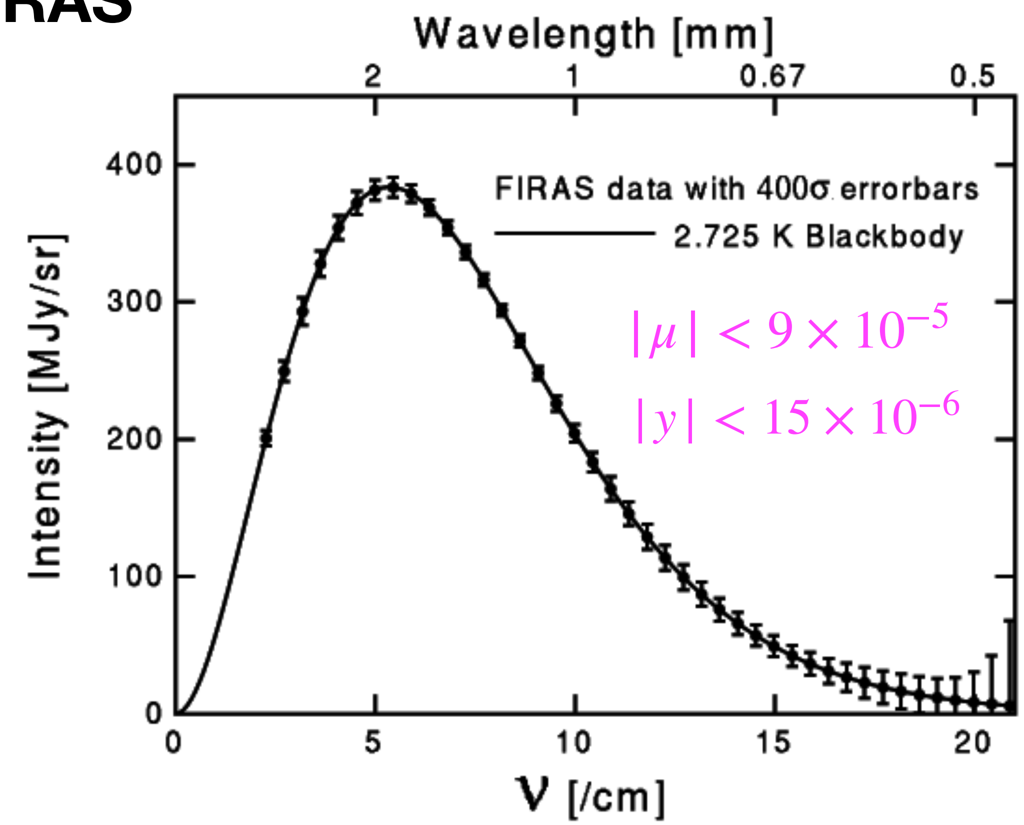
CMB: Spectral distortions vs Spatial anisotropies

PROGRESS



B-modes, lensing, etc…
LiteBird, AdvAct, SPT-3G, SO, etc…….

COBE/FIRAS



?

Stalled for 25 years….

There exists a **definite signal**
(unlike B-modes)
But a **challenging measurement**
(like B-modes)

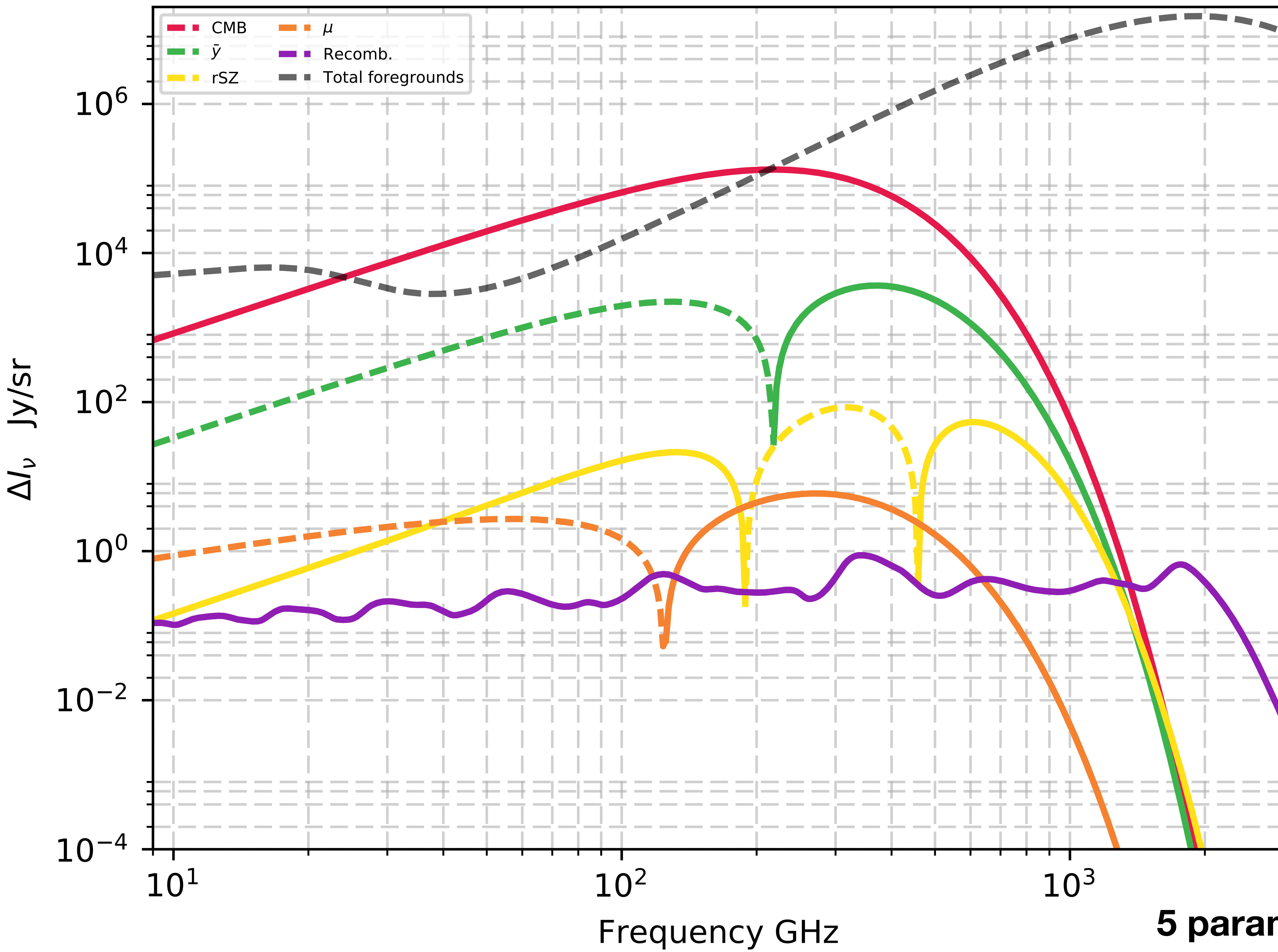
Requirements for "measuring" spectral distortions?

- **Sensitivity (~ 0.01 Jy)**
- **Many many channels (~20-100s)**
  (think spectroscopy)
- **Good channel calibration (absolute calibration not essential.)**
- **Sky coverage**

Why?

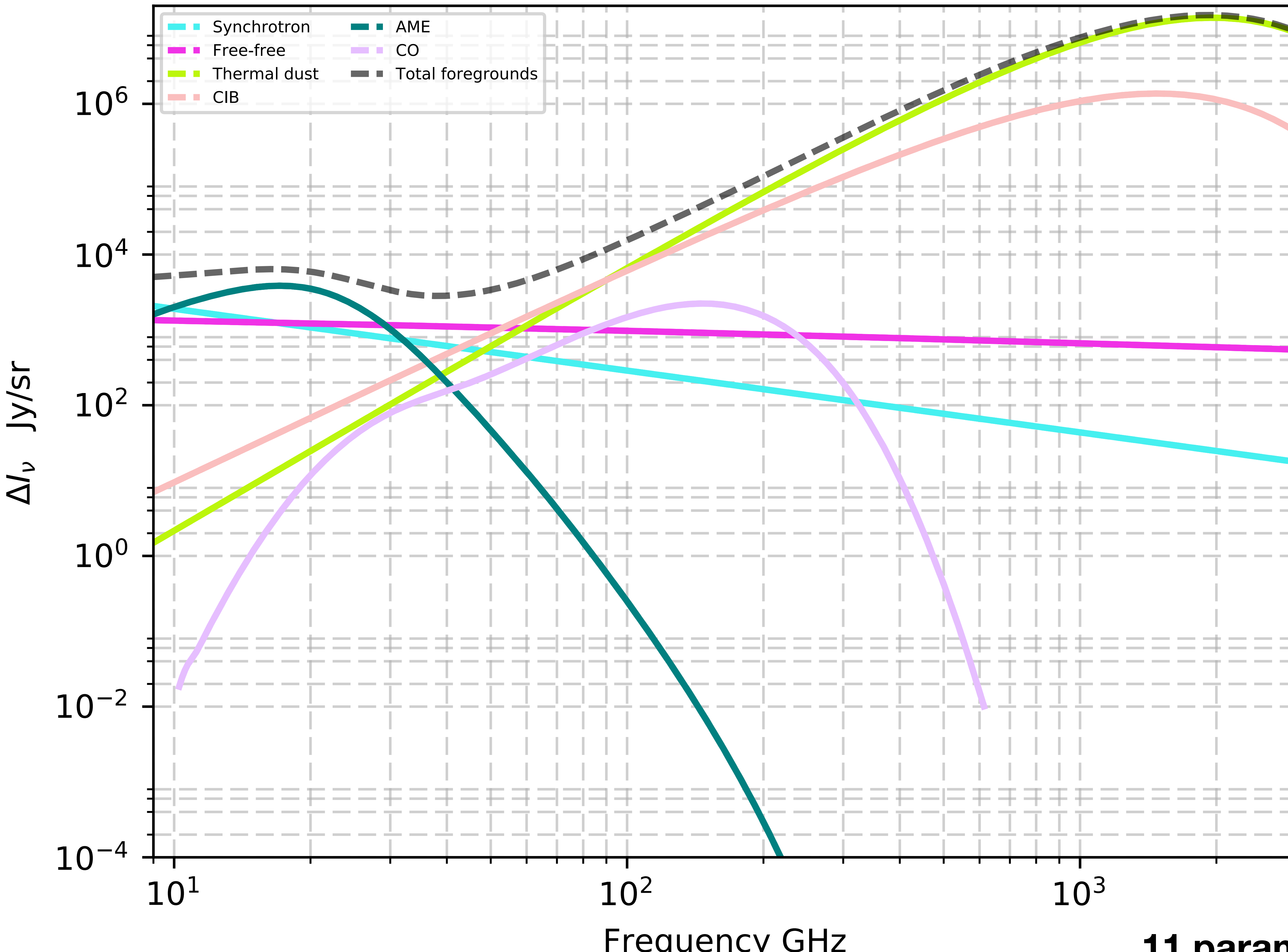
- **Signals are small!**
- **Many many foregrounds (+ ones we have not seen yet)**
- **Variation in signals are small.**
- **In principle, single pixel measurement is enough. But, sky coverage is expected to help with mitigating the foregrounds challenge.**

Visualizing the signal space



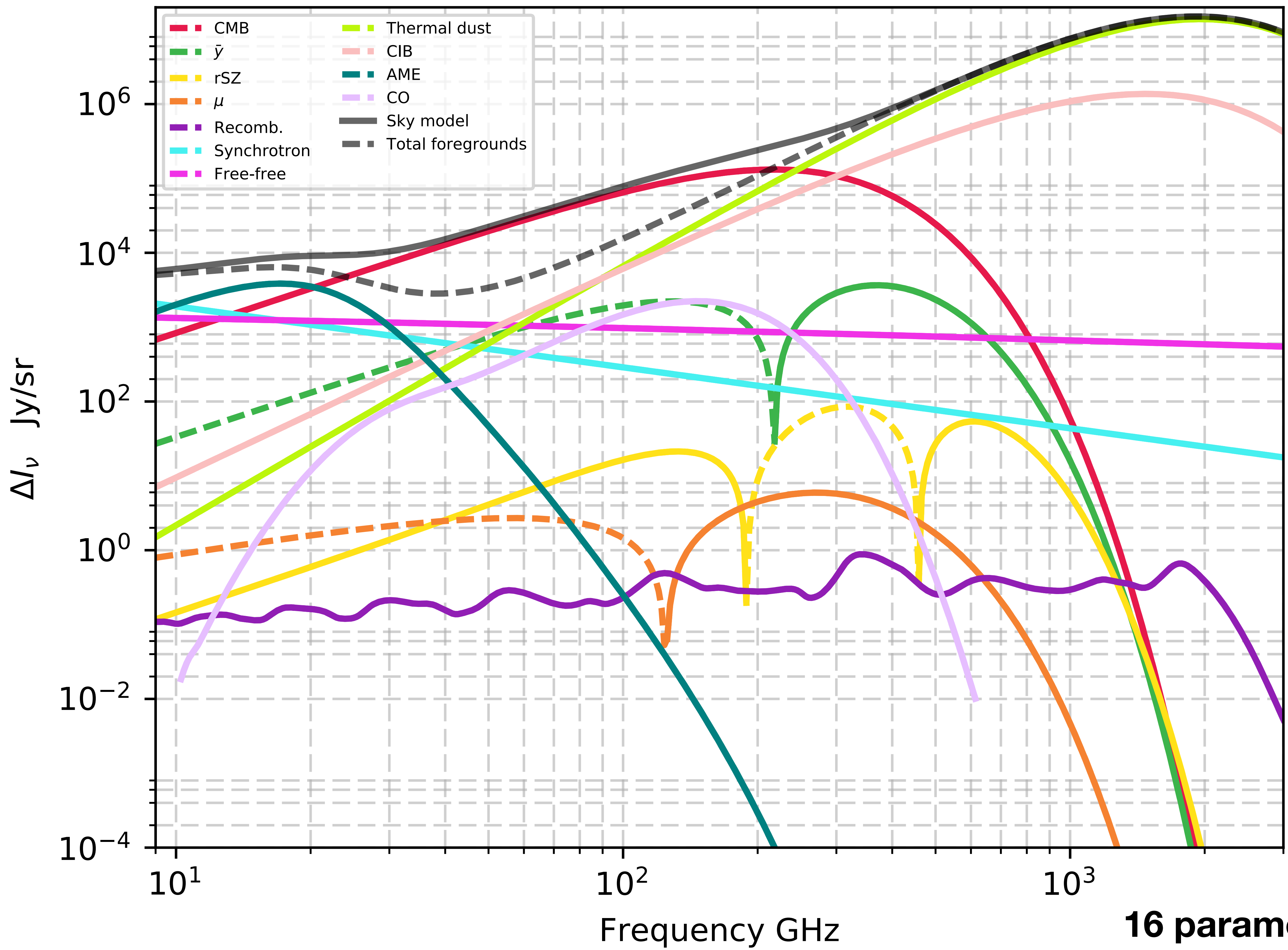
5 parameter model

Visualizing the foregrounds space



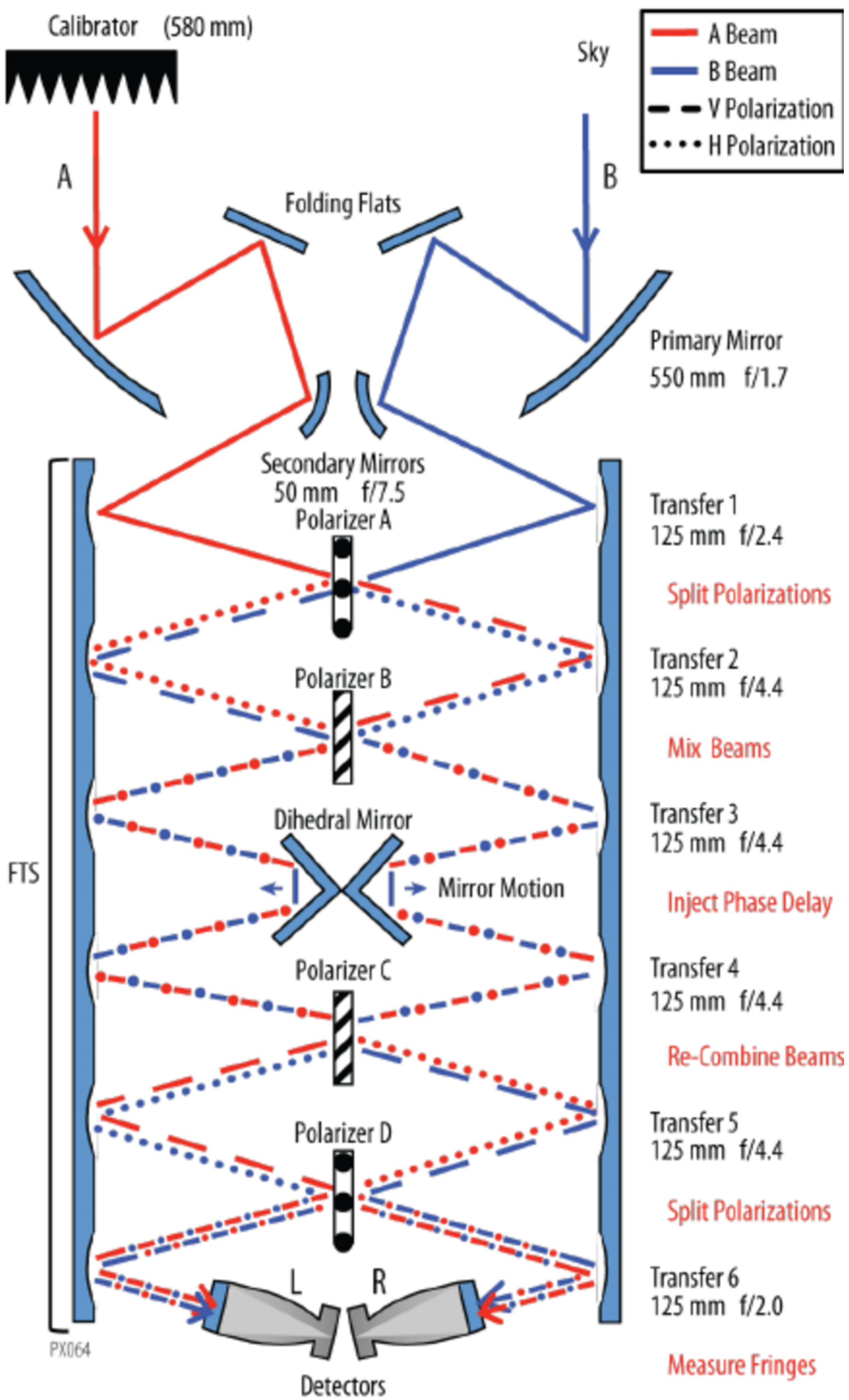
11 parameter model

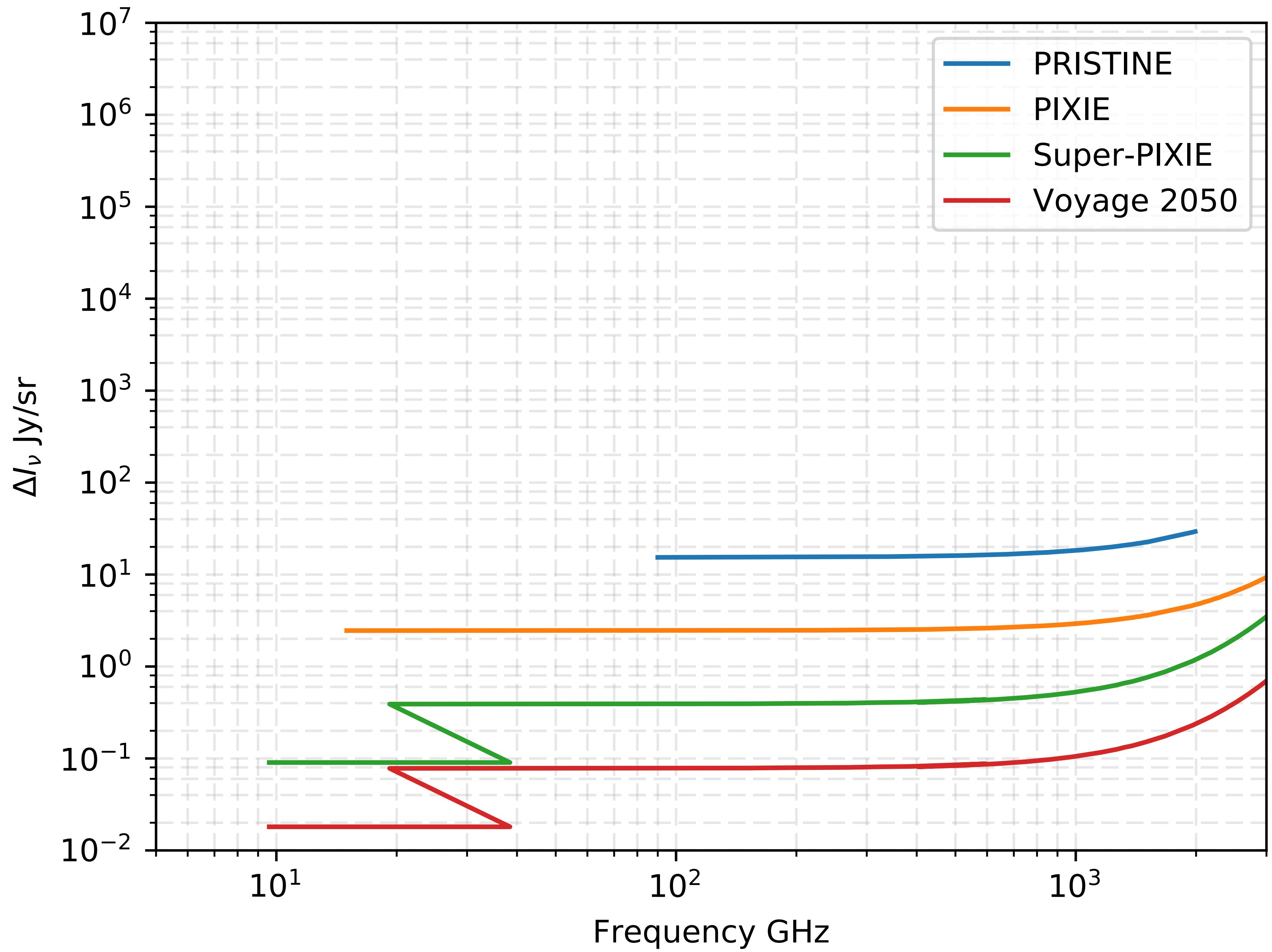
Here's a "BASIC" model for our data



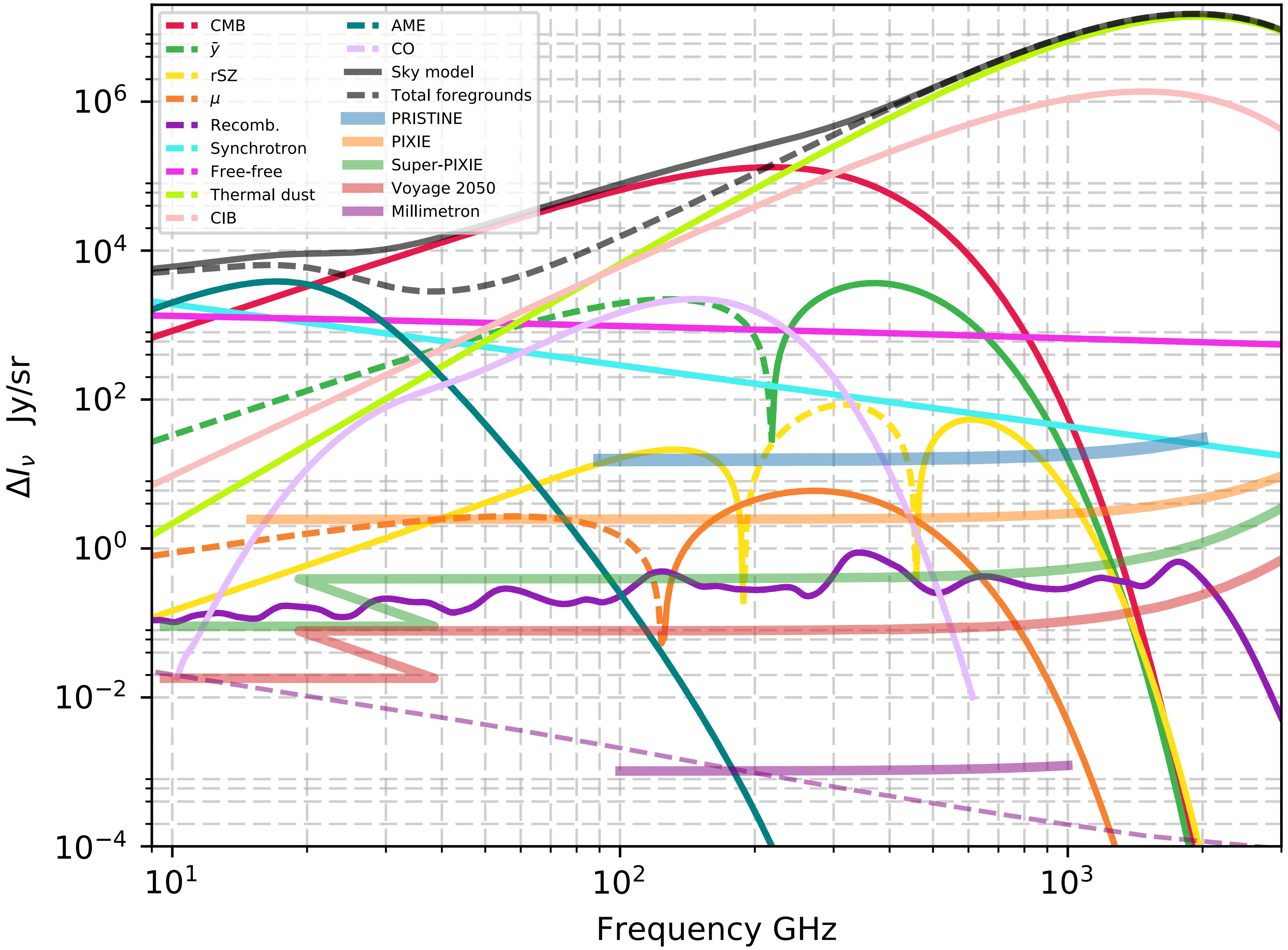
16 parameter model

FTS concepts targeting spectral distortion measurements





Data model and forecasting procedure



Non-linear optimization problem

$$d_\nu = \sum_c A_c S_\nu^c(\vec{\alpha}) + n_\nu$$

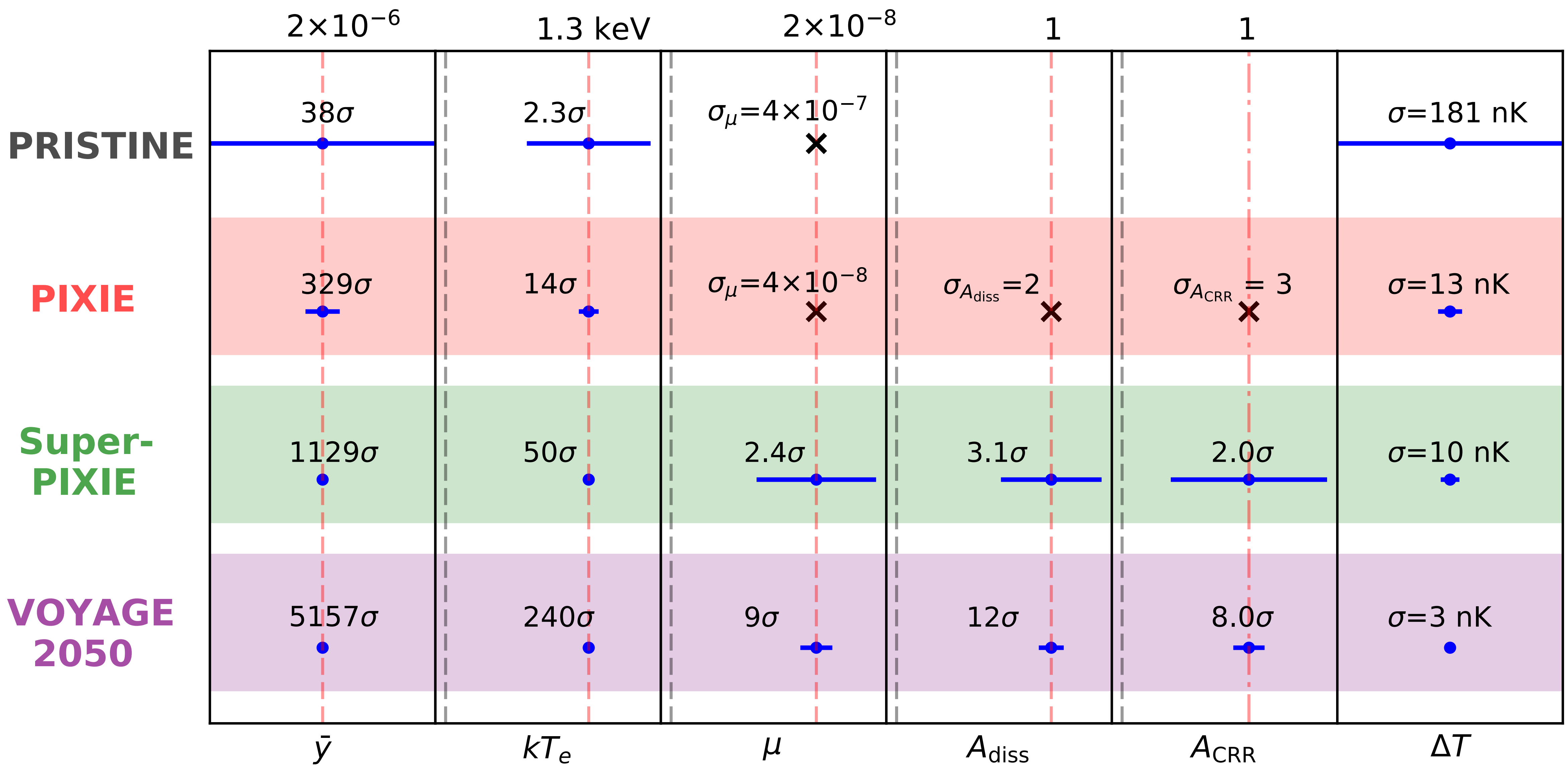
Linearize

Fisher analysis

SNR forecasts

M. Abitbol, J. Chluba, J. C. Hill and B. R. Johnson et. al. MNRAS (2017) 471 (1): 1126-1140

Voyage 2050

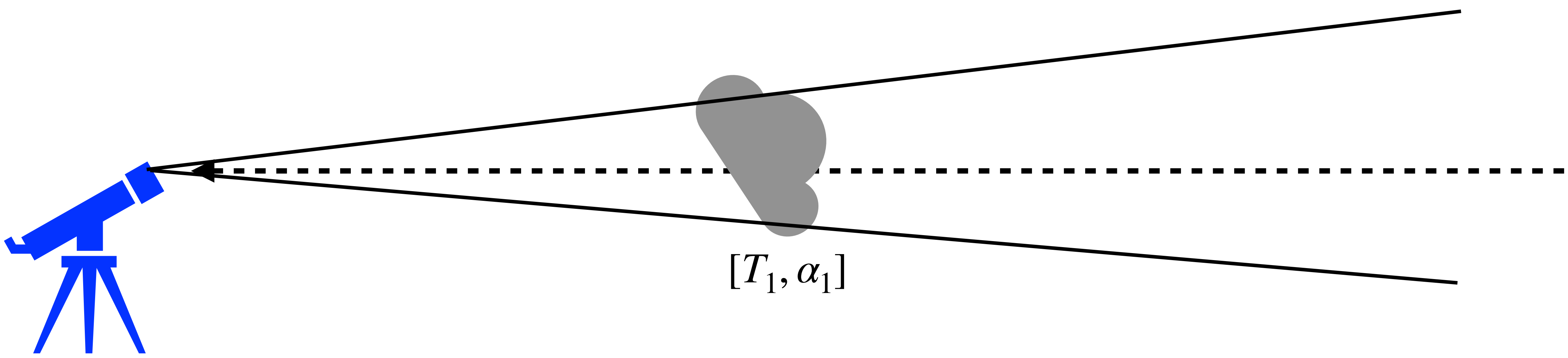


Voyage 2050 white paper: arXiv:1909.01593

Observers assumption (current)

Each cloud emits a modified black body spectrum.

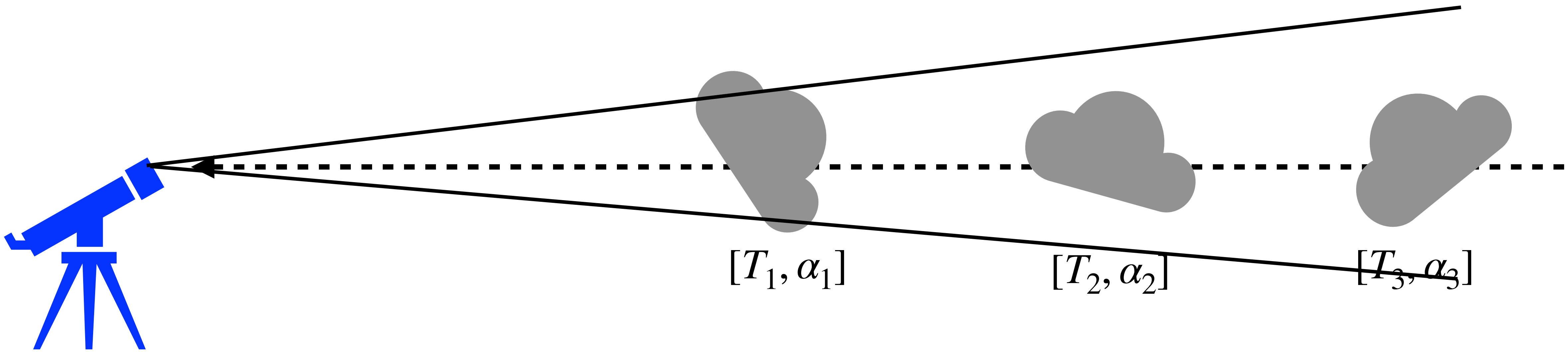
$$B_\nu(\alpha, T) = A\frac{2h\nu^3}{c^2}\left(\frac{\nu}{\nu_0}\right)^\alpha \frac{1}{e^{\frac{h\nu}{kT}} - 1}$$



Reality in nature

Each cloud emits a modified black body spectrum.

$$B_\nu(\alpha, T) = \frac{2h\nu^3}{c^2}\left(\frac{\nu}{\nu_0}\right)^\alpha \frac{1}{e^{\frac{h\nu}{kT}} - 1}$$



$$S_\nu = \int \frac{dI}{ds} ds \neq B_\nu(\alpha', T')$$

What are moments?

The real world dirty details!

Describing SED resulting from sum of modified black bodies:

$$S_\nu = \int \frac{dI}{ds} ds = \int B_\nu(\alpha, T) P(\alpha, T) d\alpha dT$$

Building on top of the simple parametrization:

$$S_\nu = \sum_{m,n} \partial_\alpha^m \partial_T^n B_\nu(\alpha_0, T_0) \boxed{\int (\alpha - \alpha_0)^m (T - T_0)^n P(\alpha, T) d\alpha dT}$$

Moments of the distribution function

$$S_\nu(\alpha_0, T_0, A, p_\alpha, p_T, p_{\alpha\alpha}, p_{\alpha T}, p_{TT}, \cdots) \simeq A B_\nu(\alpha_0, T_0)$$
$$+ p_\alpha \partial_\alpha B_\nu(\alpha_0, T_0) + p_T \partial_T B_\nu(\alpha_0, T_0)$$
$$+ p_{\alpha\alpha} \partial_\alpha^2 B(\alpha_0, T_0) + p_{\alpha T} \partial_\alpha \partial_T B(\alpha_0, T_0) + p_{TT} \partial_T^2 B(\alpha_0, T_0)$$
$$+ \cdots$$

Measuring moments

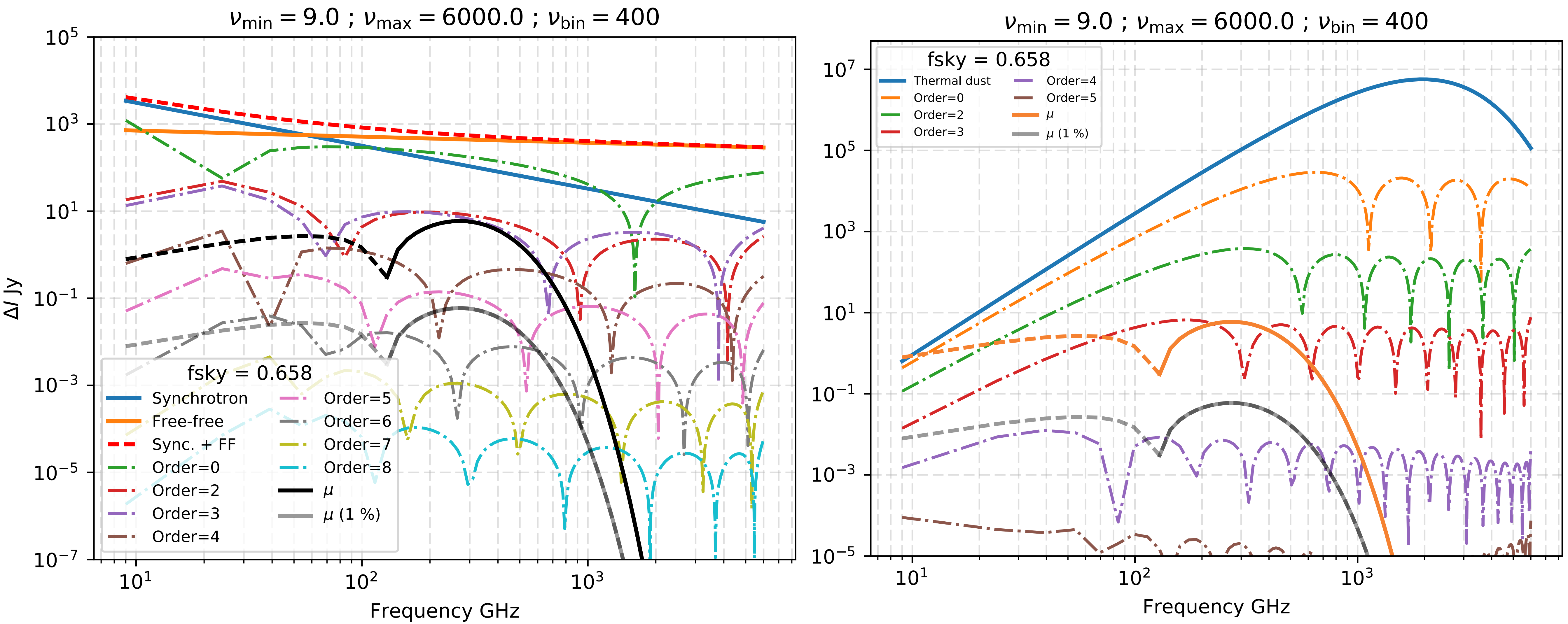
Spectro-Spatial

$$S_\nu(\alpha_0, T_0, A, p_\alpha, p_T, p_{\alpha\alpha}, p_{\alpha T}, p_{TT}, \cdots) = \sum_i \overrightarrow{B}_{\nu i}(\alpha_0, T_0)\mathscr{M}_i + \epsilon_i$$

A deconvolution problem: need to solve both for the **kernel** as well as the **map**.

J. Chluba, J. C. Hill & M. H. Abitbol, MNRAS, Vol. 472, Iss. 1, 1195-1213

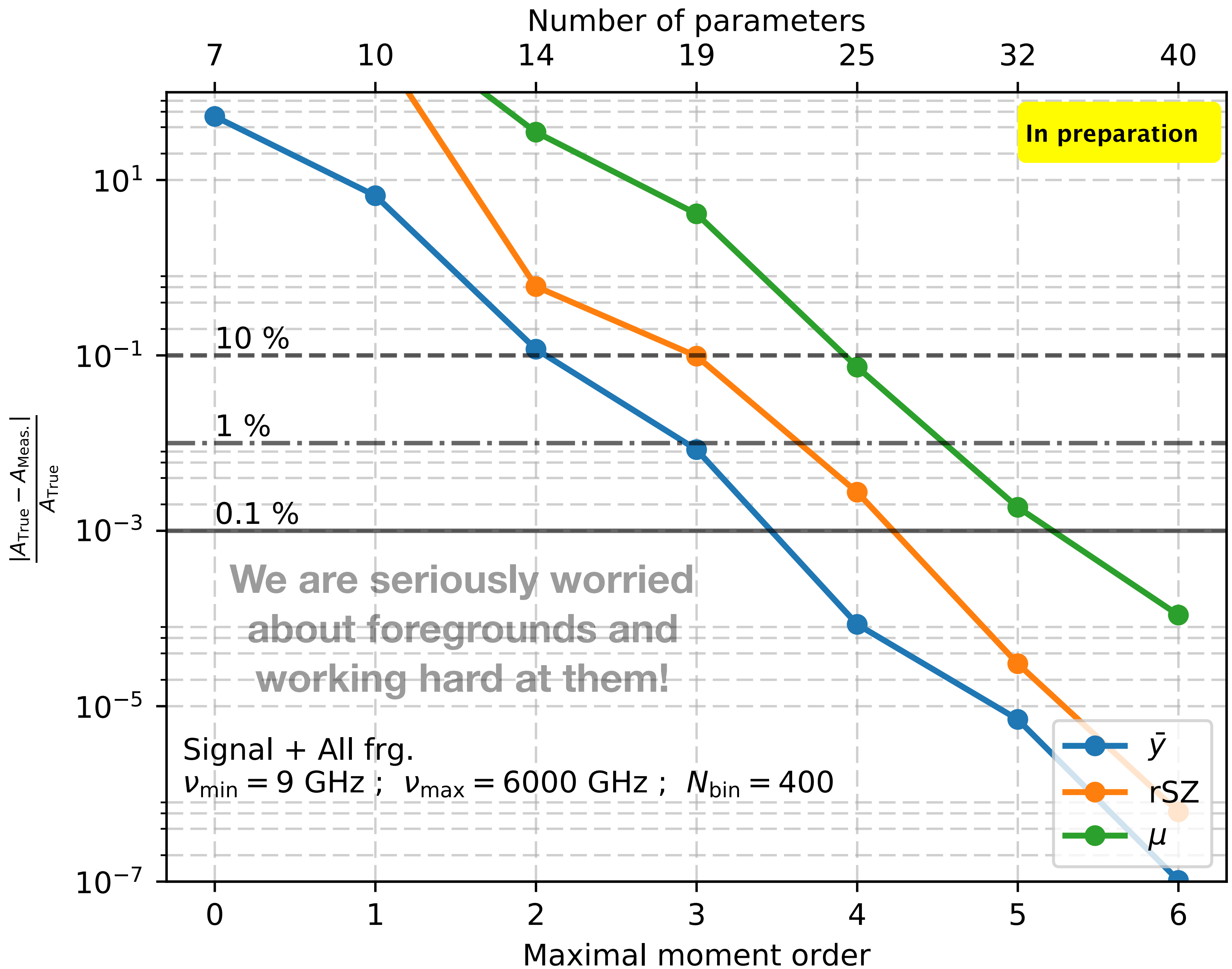
How many moments to model foregrounds to desired accuracy?



- **SED evaluated from sky sims. generated using Python Sky Model (fsky=0.66)**
- **These moments are generated from spatial averaging.**
- **One expects similar order of magnitude moments arising from line of sight averaging**

Forecasts including all necessary moments (no noise)

IN PRINCIPLE DEMONSTRATION OF REAL WORLD SUB-PERCENT LEVEL MEASUREMENTS OF SPECTRAL DISTORTIONS



This is way beyond currently attempted precision foreground modeling !

- Given current understanding of foregrounds, in principle it might be possible to measure spectral distortions.
- Need to foresee, yet unseen foreground components (eg. Moments for extra-galactic CO, AME ??)
- How to explore spatial information on foregrounds?
- Millimetron could present exciting possibilities for spectral distortion science.