Institut Lagrange de Paris

LPNHE PARIS

Forecasting statistical and systematic uncertainties of parametric component separation

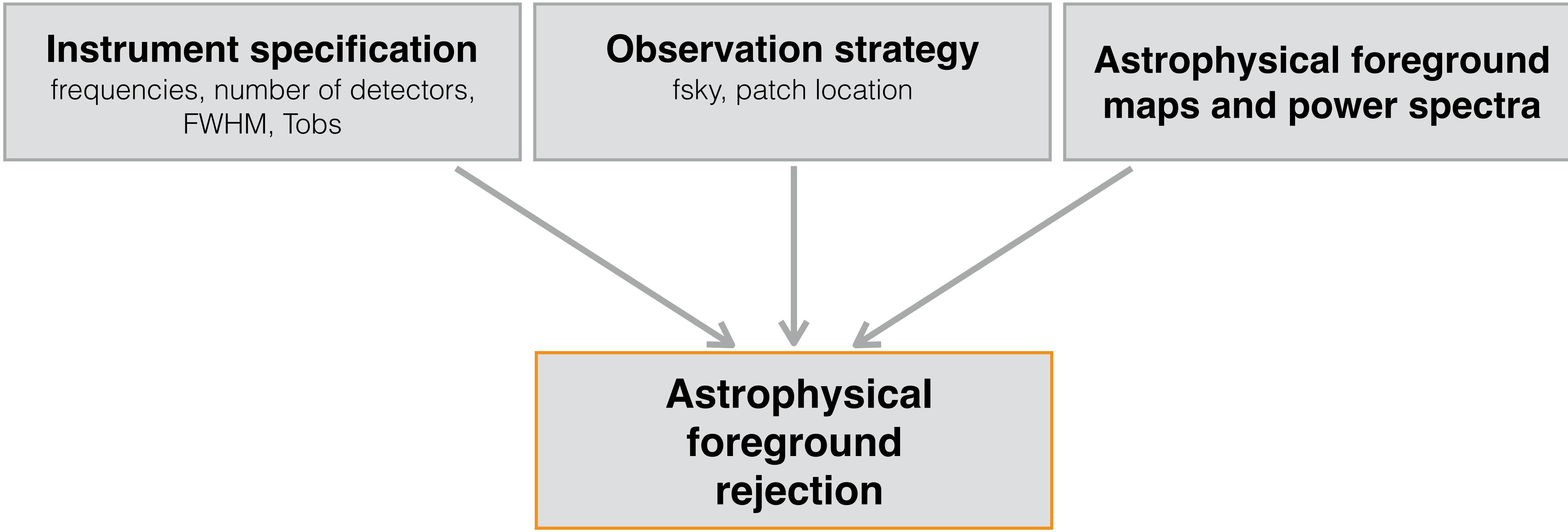
Josquin Errard (ILP) in collaboration with **Davide Poletti** and **Radek Stompor** (APC)

Towards a next space probe for CMB observations, CERN, May 2016

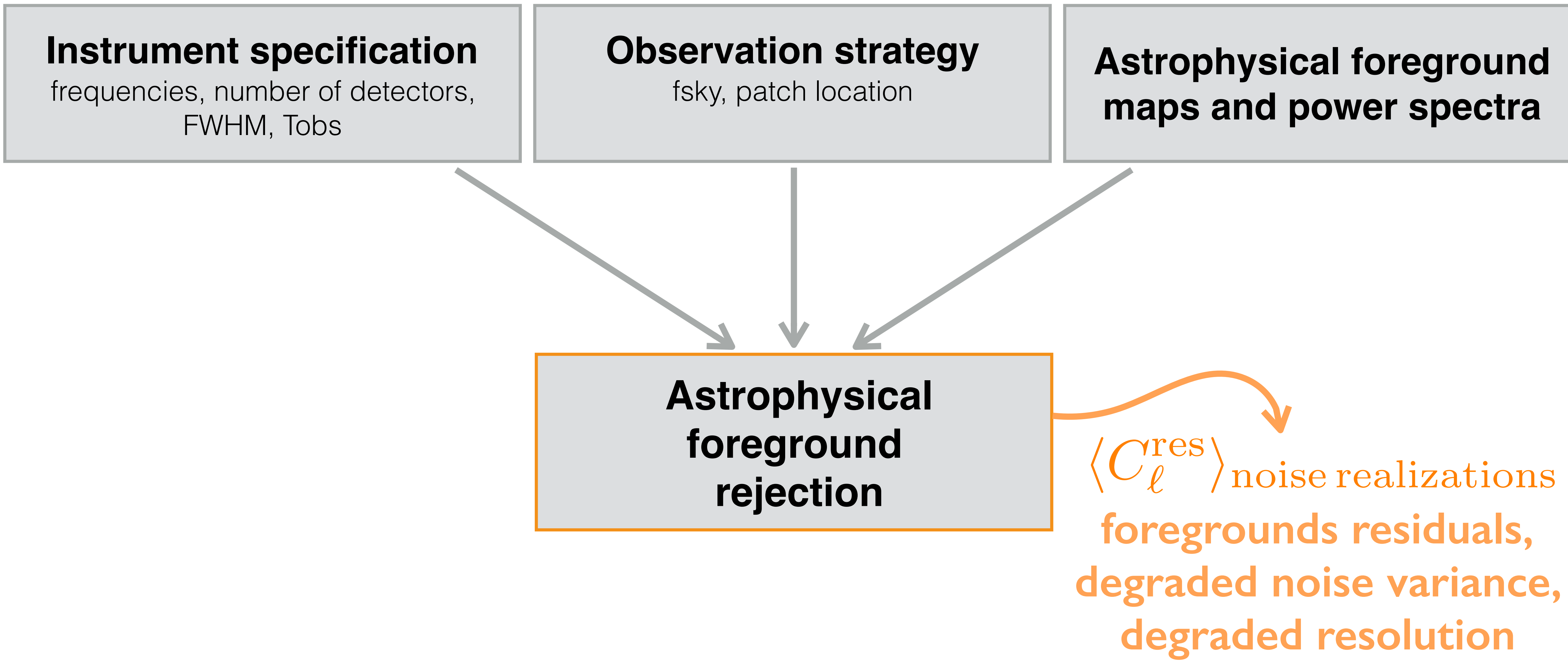
Outline of the Errard et al (2011+12+16) approach

Instrument specification	Observation strategy	Astrophysical foreground maps and power spectra
frequencies, number of detectors, FWHM, Tobs	fsky, patch location	

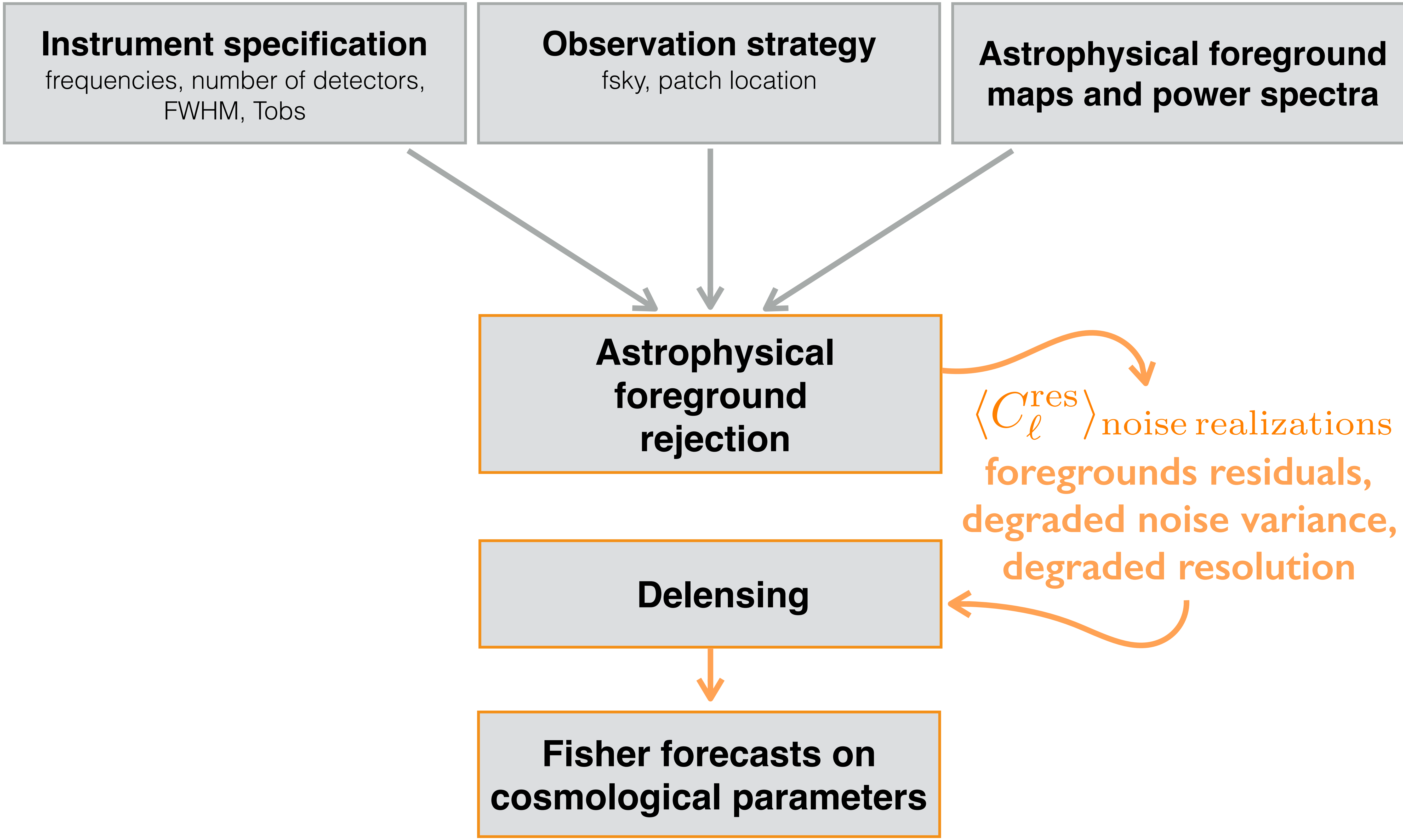
Outline of the Errard et al (2011+12+16) approach



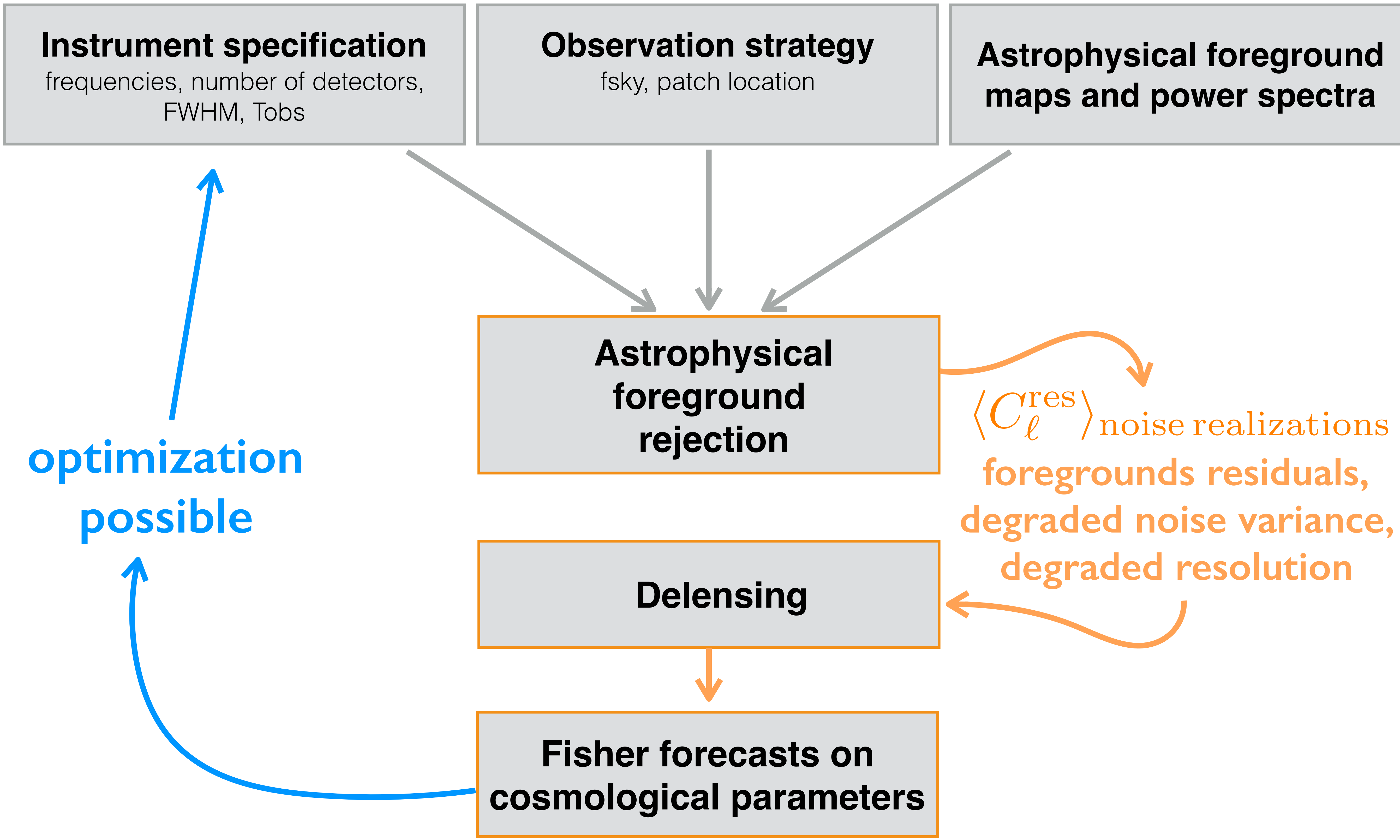
Outline of the Errard et al (2011+12+16) approach



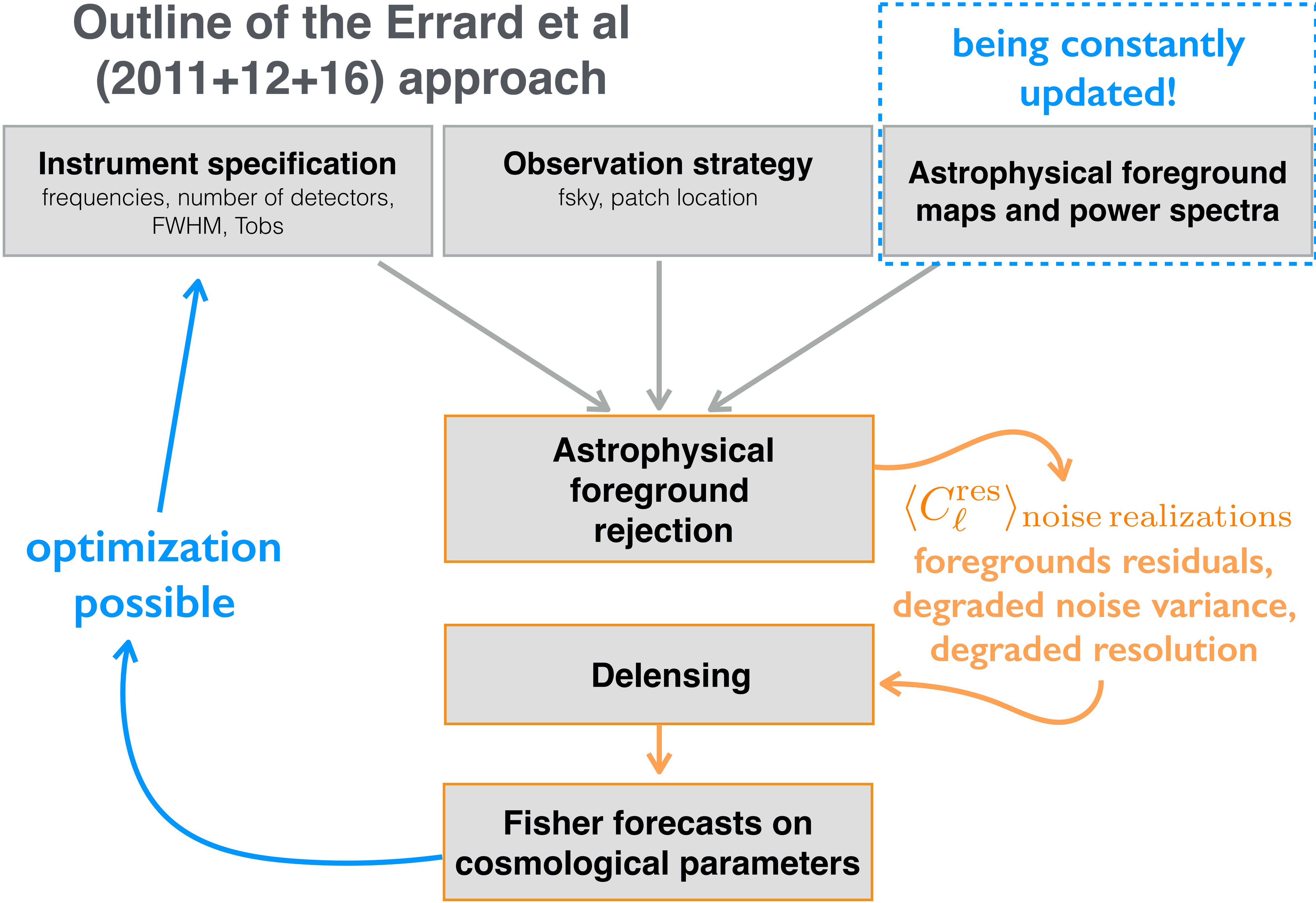
Outline of the Errard et al (2011+12+16) approach



Outline of the Errard et al (2011+12+16) approach



Outline of the Errard et al (2011+12+16) approach



Errard, Feeney, Peiris and Jaffe (JCAP, 2016)

➔ http://portal.nersc.gov/project/mp107/index.html

CMB4CAST GROUNDS

Errard, Feeney, Peiris and Jaffe (JCAP, 2016)

➔ http://portal.nersc.gov/project/mp107/index.html

CMB4CAST GROUNDS

➔ We usually look at statistical foregrounds residuals, i.e. residuals due to the imperfect determination of spectral parameters because of the finite sensitivity of the instrument. In such case, **the parametrization of the mixing matrix is always assumed to be correct.**

➔ In addition, these foregrounds residuals are treated as an extra variance term for the estimation of cosmological parameters (as it is done in current forecasts for *e.g.* CMB-S4)

Errard, Feeney, Peiris and Jaffe (JCAP, 2016)

➔ **http://portal.nersc.gov/project/mp107/index.html**

CMB4CAST GROUNDS

➔ We usually look at statistical foregrounds residuals, i.e. residuals due to the imperfect determination of spectral parameters because of the finite sensitivity of the instrument. In such case, **the parametrization of the mixing matrix is always assumed to be correct.**

➔ In addition, these foregrounds residuals are treated as an extra variance term for the estimation of cosmological parameters (as it is done in current forecasts for *e.g.* CMB-S4)

➤ **HOWEVER, real sky might not match the assumed modeling**

Errard, Feeney, Peiris and Jaffe (JCAP, 2016)

→ **http://portal.nersc.gov/project/mp107/index.html**

CMB4CAST GROUNDS

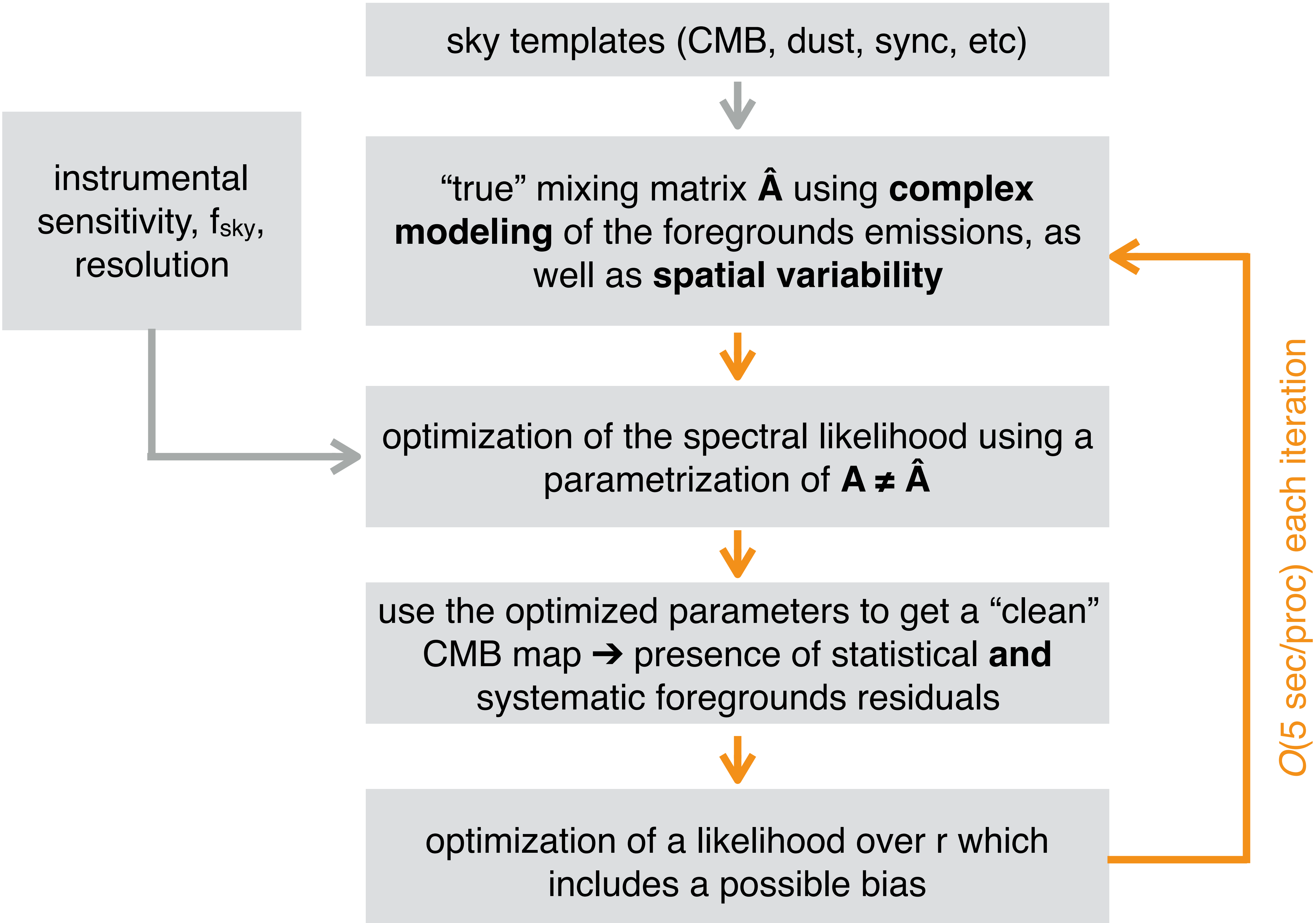
➔ We usually look at statistical foregrounds residuals, i.e. residuals due to the imperfect determination of spectral parameters because of the finite sensitivity of the instrument. In such case, **the parametrization of the mixing matrix is always assumed to be correct.**

➔ In addition, these foregrounds residuals are treated as an extra variance term for the estimation of cosmological parameters (as it is done in current forecasts for *e.g.* CMB-S4)

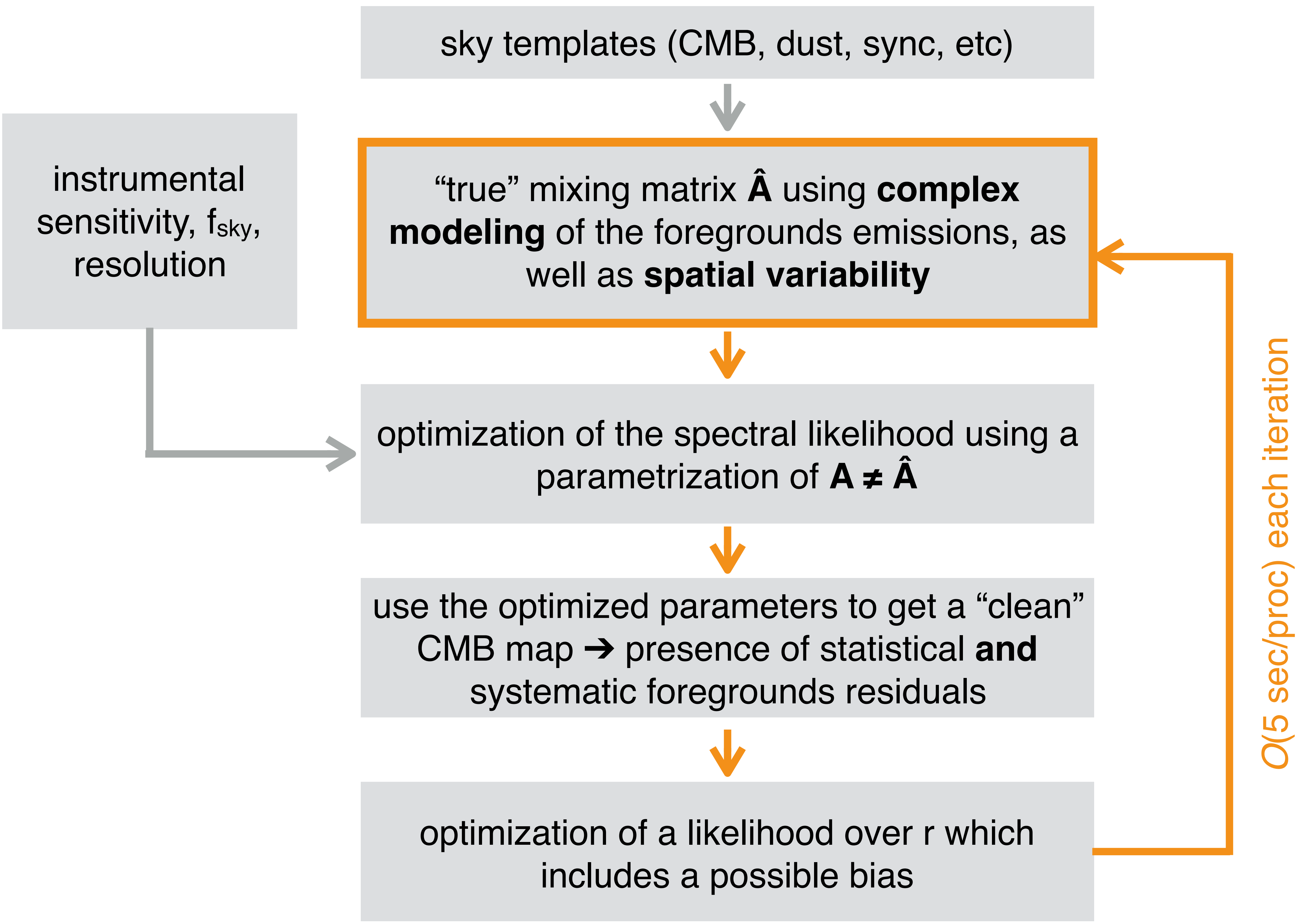
➤ **HOWEVER, real sky might not match the assumed modeling**

➔ The presented formalism takes into account the presence of both statistical **and** systematic foregrounds residuals, and evaluates the possible bias in the estimation of cosmological parameters

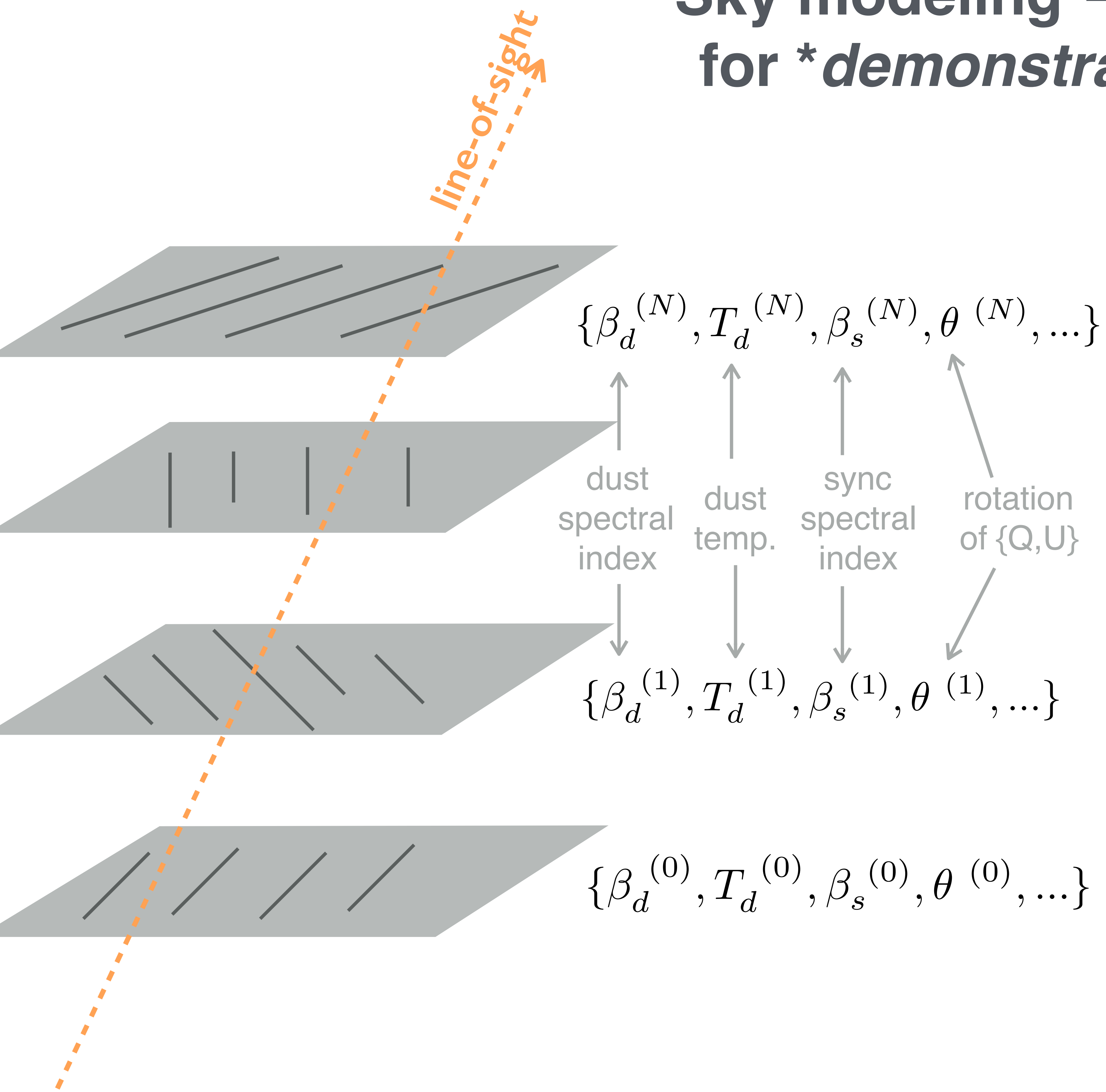
Outline & methodology



Outline & methodology

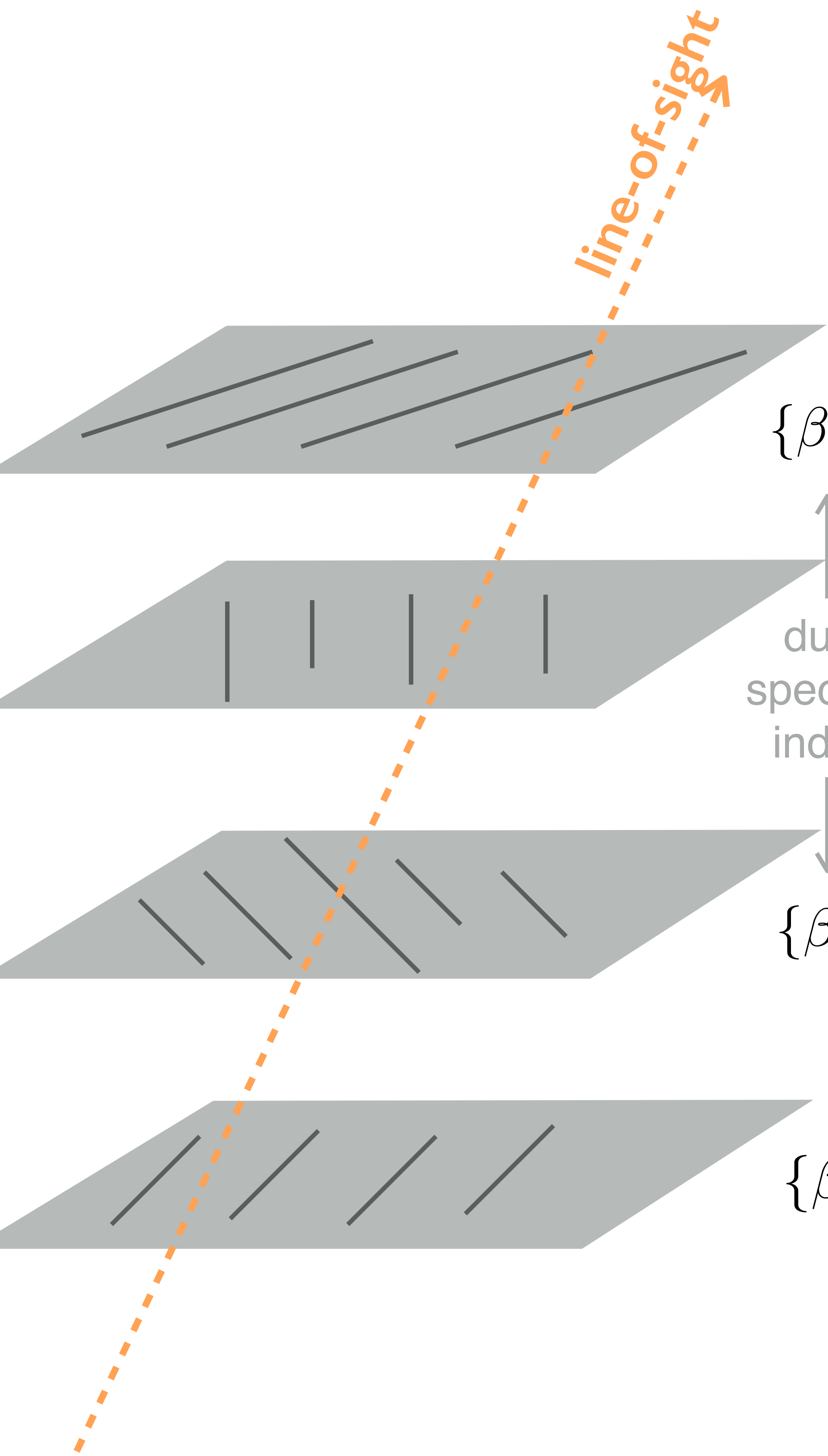


Sky modeling — a toy example, for **demonstration** purposes



Josquin ERRARD, CERN, May 2016

Sky modeling — a toy example, for **demonstration** purposes



N=4 in our study, *cf. Bracco (2014)*

$$\{\beta_d^{(N)}, T_d^{(N)}, \beta_s^{(N)}, \theta^{(N)}, \ldots\}$$

dust spectral index | dust temp. | sync spectral index | rotation of {Q,U}

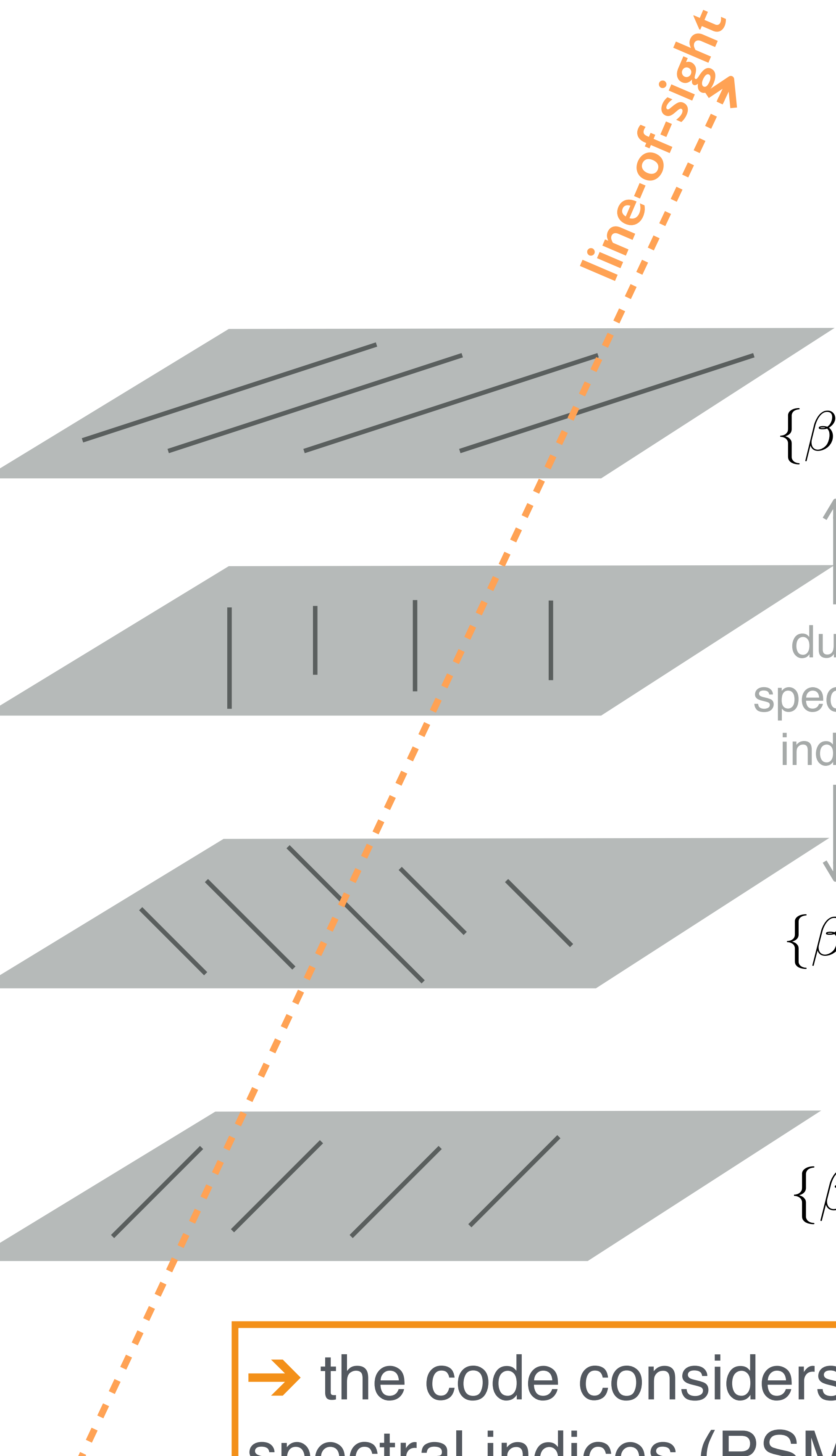
$$\{\beta_d^{(1)}, T_d^{(1)}, \beta_s^{(1)}, \theta^{(1)}, \ldots\}$$

$$\{\beta_d^{(0)}, T_d^{(0)}, \beta_s^{(0)}, \theta^{(0)}, \ldots\}$$

Each "spectral" parameter of each layer is drawn from a Gaussian distribution centered around fiducial model (**β_d=1.59, T_d=19.6K, β_s=-3.1**), with a standard deviation proportional to a parameter α

Josquin ERRARD, CERN, May 2016

Sky modeling — a toy example, for **demonstration** purposes



N=4 in our study, *cf. Bracco (2014)*

$$\{\beta_d^{(N)}, T_d^{(N)}, \beta_s^{(N)}, \theta^{\ (N)}, \ldots\}$$

dust spectral index | dust temp. | sync spectral index | rotation of {Q,U}

$$\{\beta_d^{(1)}, T_d^{(1)}, \beta_s^{(1)}, \theta^{\ (1)}, \ldots\}$$

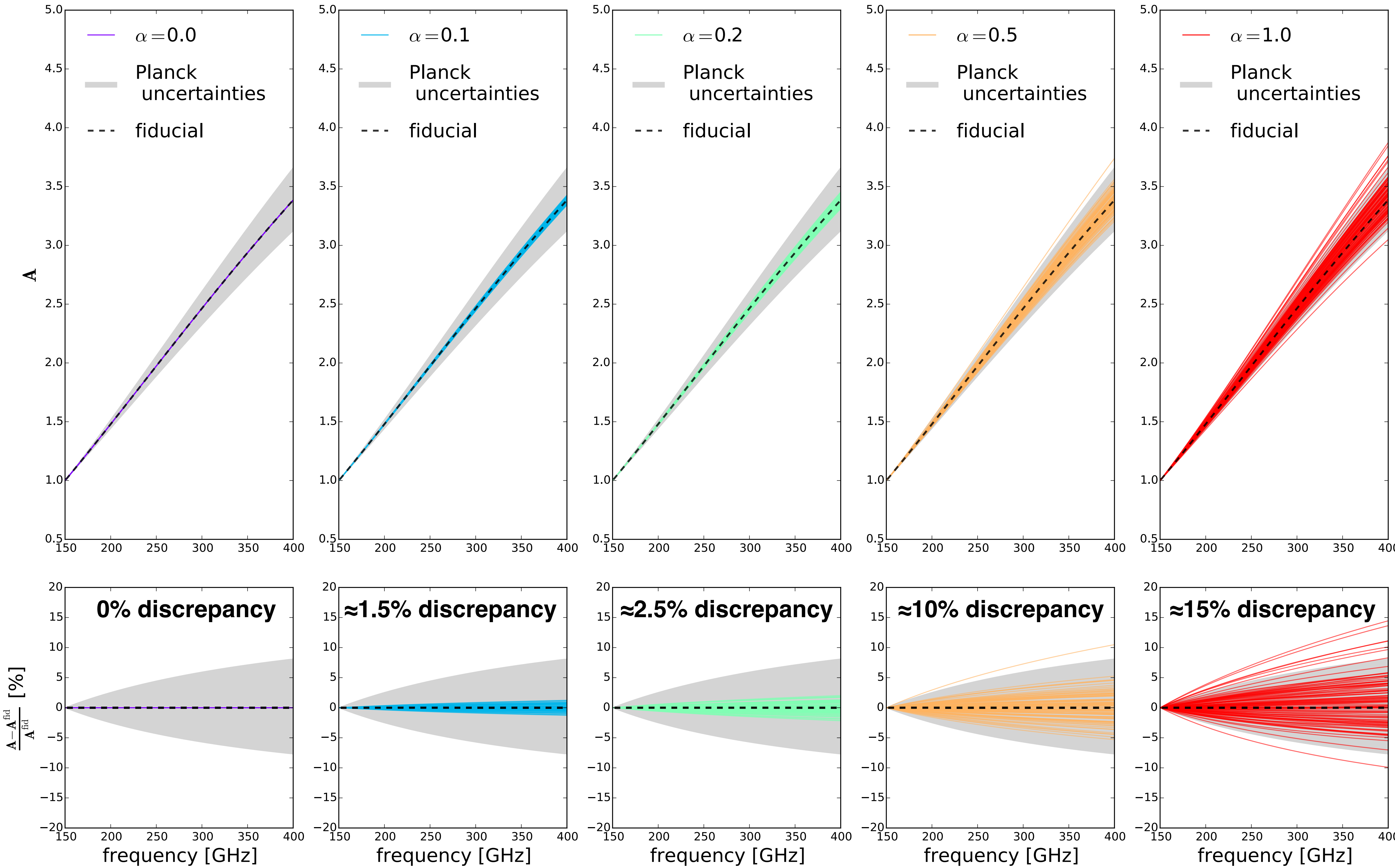
$$\{\beta_d^{(0)}, T_d^{(0)}, \beta_s^{(0)}, \theta^{\ (0)}, \ldots\}$$

Each "spectral" parameter of each layer is drawn from a Gaussian distribution centered around fiducial model (**β_d=1.59, T_d=19.6K, β_s=-3.1**), with a standard deviation proportional to a parameter α

→ the code considers **spatial variations** for the dust and synchrotron spectral indices (PSM maps for β_d and β_s) — *e.g.* Stolyarov et al (2005)

Example of dust scaling law realizations, assuming various dispersions amplitude compared to fiducial scaling laws

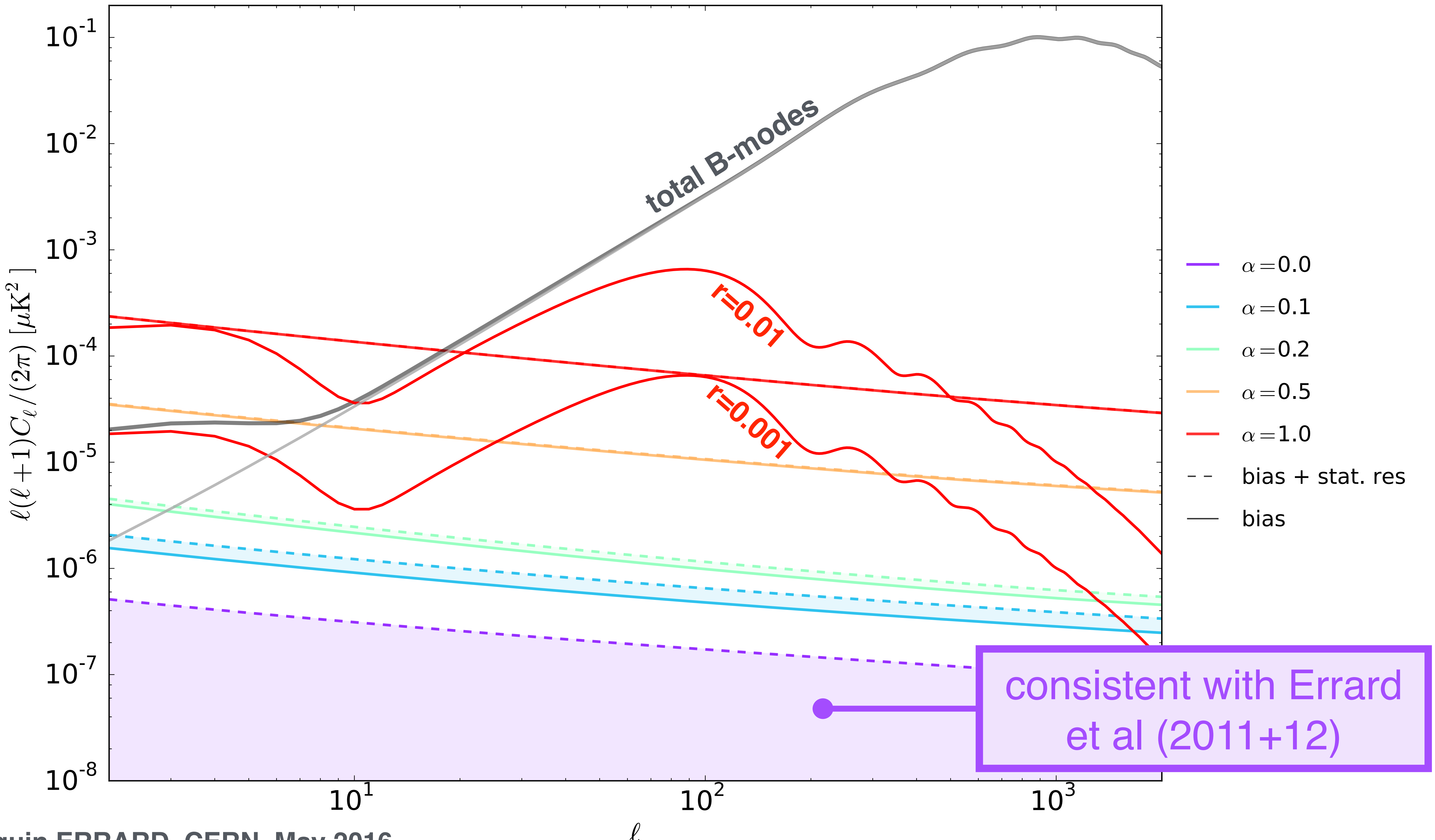
100 simulations for each α value



Josquin ERRARD, CERN, May 2016

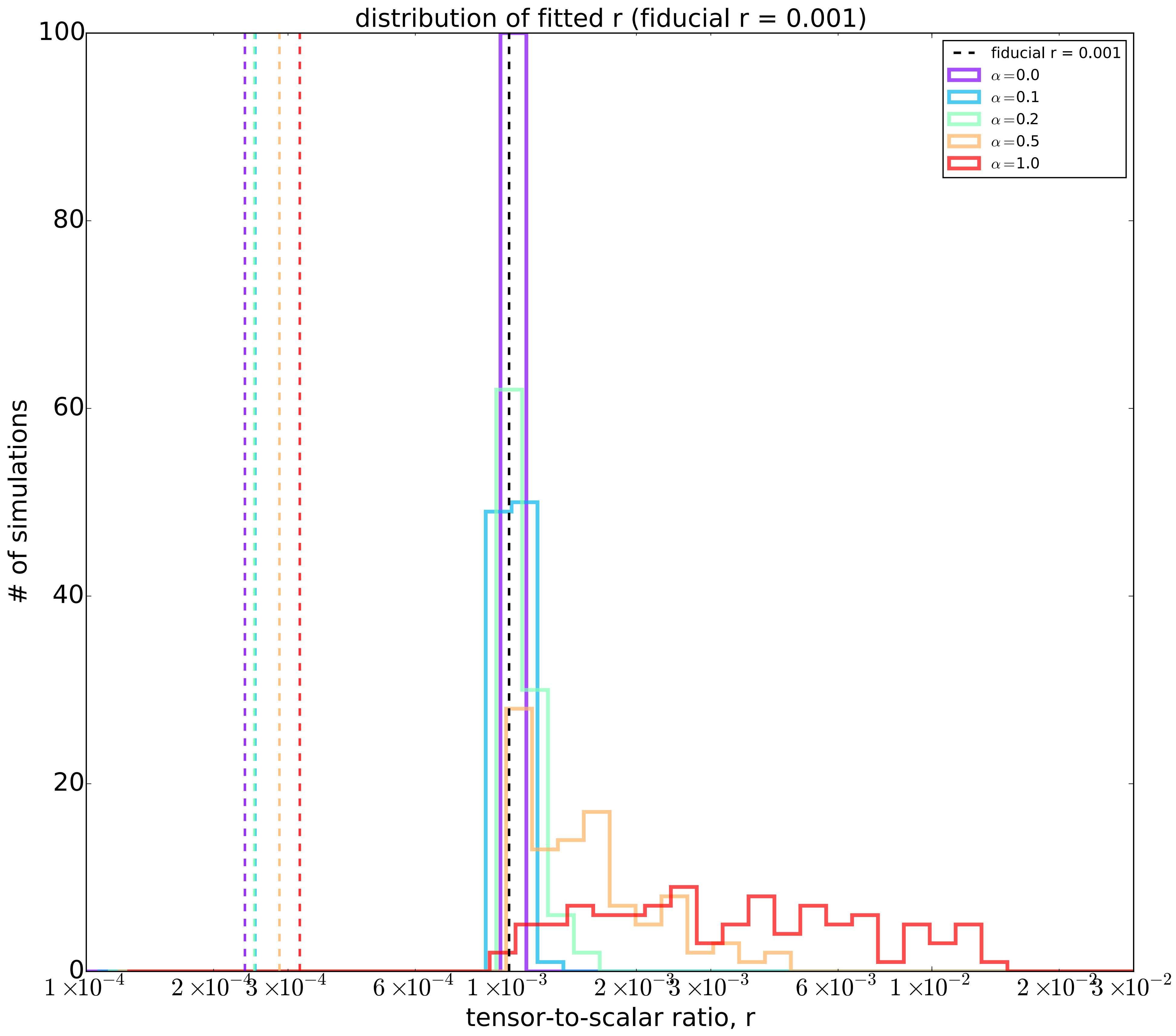
impact on the estimation of tensor-to-scalar ratio (I)

residuals curves below are averaged curves — but the case-to-case variations *are* important

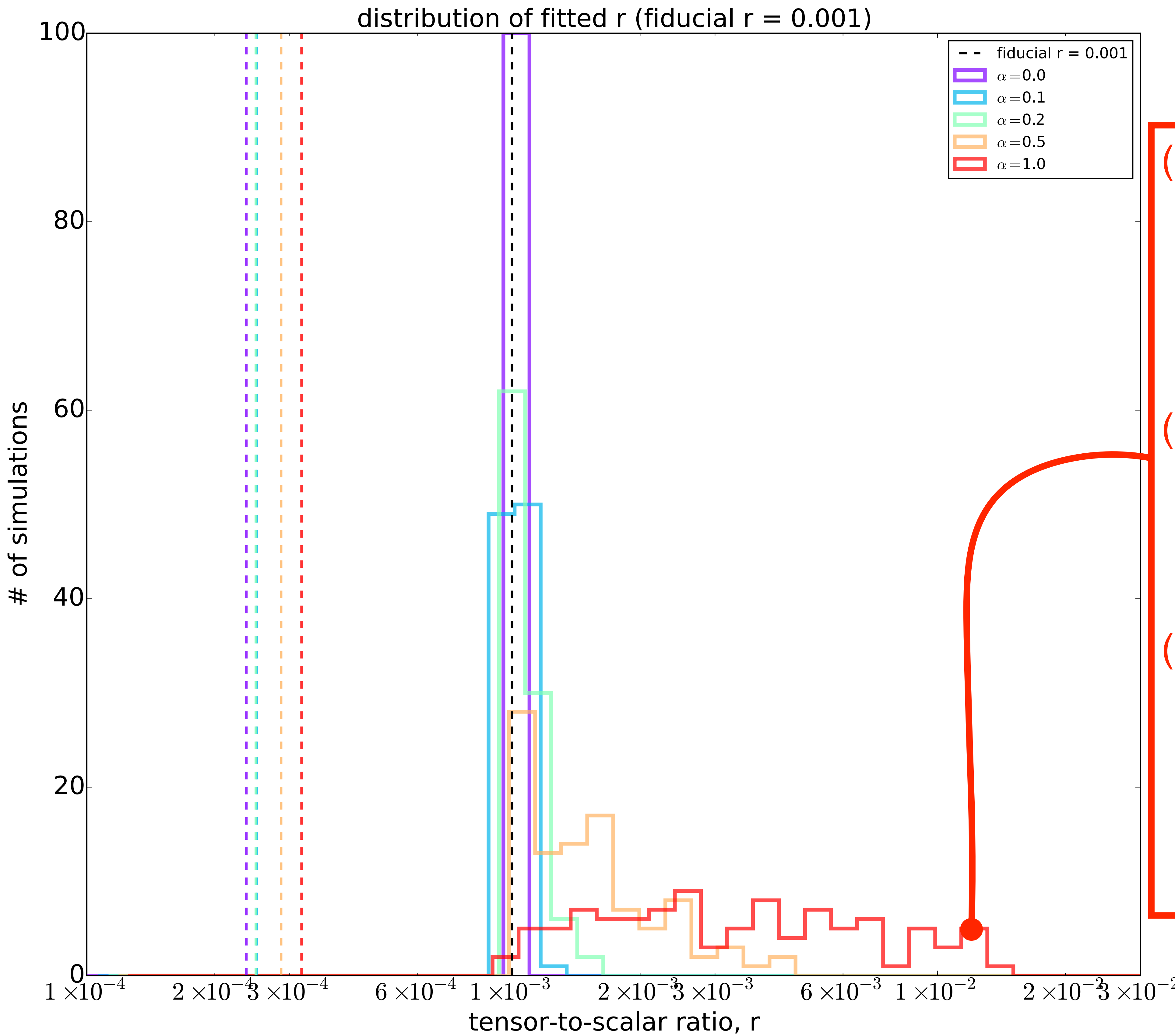


Josquin ERRARD, CERN, May 2016

impact on the estimation of tensor-to-scalar ratio (II)



impact on the estimation of tensor-to-scalar ratio (II)



(1) an average of these distributions makes little sense as each histogram has very long tail

(2) there are cases which lead to very large biases ➤ **details of the modeling are the key!**

(3) it might be possible to resolve these bad cases by introducing more parameters ➤ need for effective **'goodness-of-fit' statistics**

Conclusions

I have presented a new general formalism which allows for a consistent

- estimation of the **systematic and statistical foregrounds residuals** for a given instrumental design;
- evaluation of the resulting **bias and uncertainty on cosmological parameters**.

Features of the implementation:

- **numerical efficiency** (sky simulation ➔ comp sep ➔ estimation of r ~ O(5 sec)/proc) — not limited by values of ℓ_{max};
- obtained results are **averages** over noise realizations (and doing many sky simulation is cheap);
- applicable to **any sky model** as the input, allowing for arbitrary scaling relations and their spatial variability;
- applicable to **any set of cosmological parameters**;
- can be trivially extended to include iterative delensing as in Errard, Feeney et al (2016);
- can accommodate many spectral parameters as driven by the data at hand.