Ubercal, GAIA & cadences

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Survey uniformity

- Why do we (DESC) care about survey uniformity ?
- Flux calibration
  - Primary flux reference(s) in specific locations on the sky
  - Flux scale must be transported on the full survey footprint
  - Essential for SN cosmology, target accuracy ~ 1 mmag
- Specific calibration error modes on the sky ?
  - may affect PZ determinations
  - at specific scales that are relevant for cosmology ?

Questions

- Main question is
  - How well can we transport the flux scale carried by a handful of flux reference on the entire sky ?
- Technical questions are
  - For a given cadence, can we solve the ubercal problem ?
  - Does interlacing DDF obs help improving the calibration ?
  - Are some dithering patterns significantly better than others ?
  - What is the impact of non-photometric sequences on solution ?
  - Are there specific error modes, at specific scales that have an impact on the analyses ?
  - Will adding GAIA help ?

Cadences

- Minion 1016

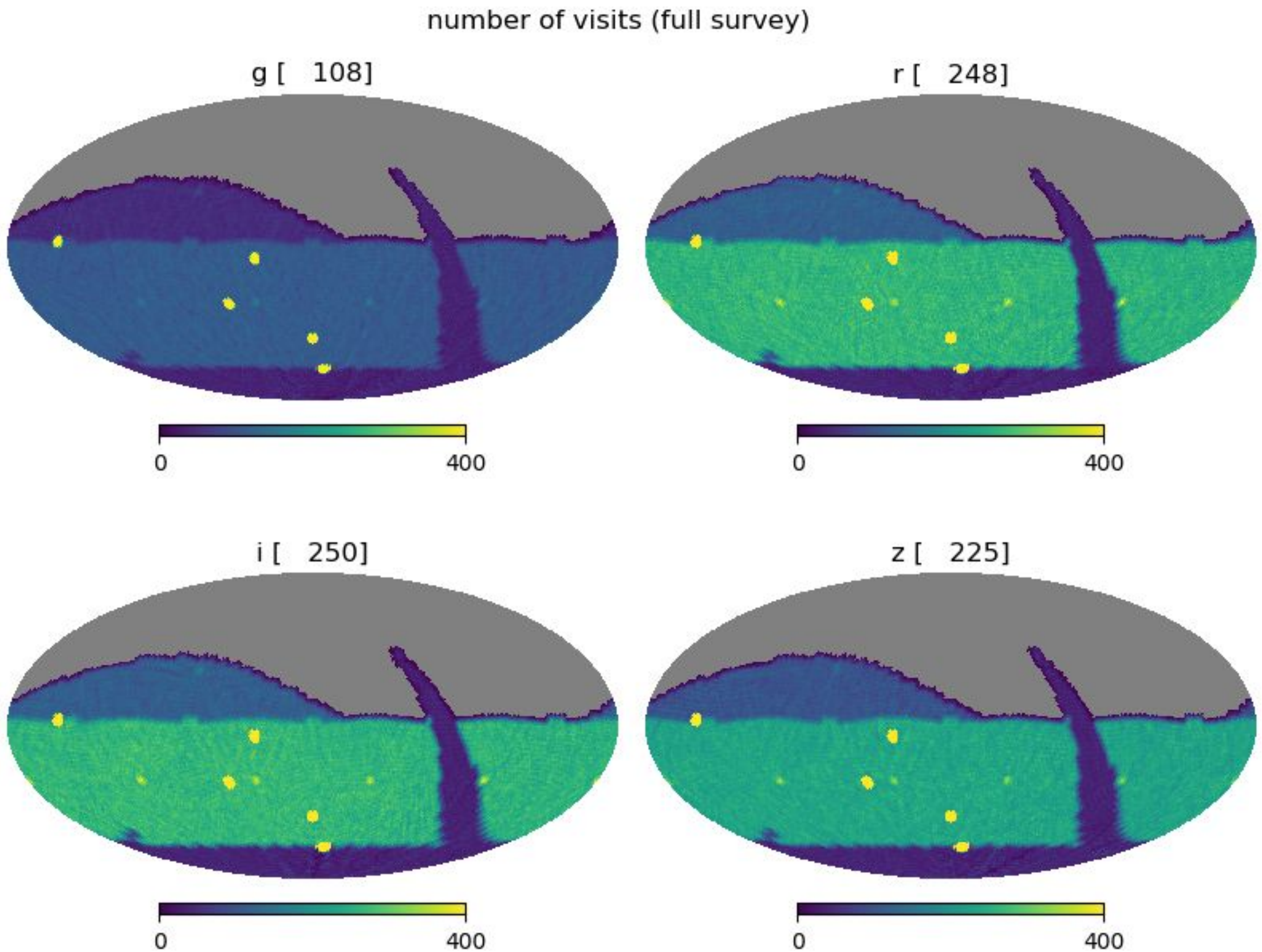
Non rolling cadences

- Feature
- “Feature - half mask”
- “Feature - ⅔”

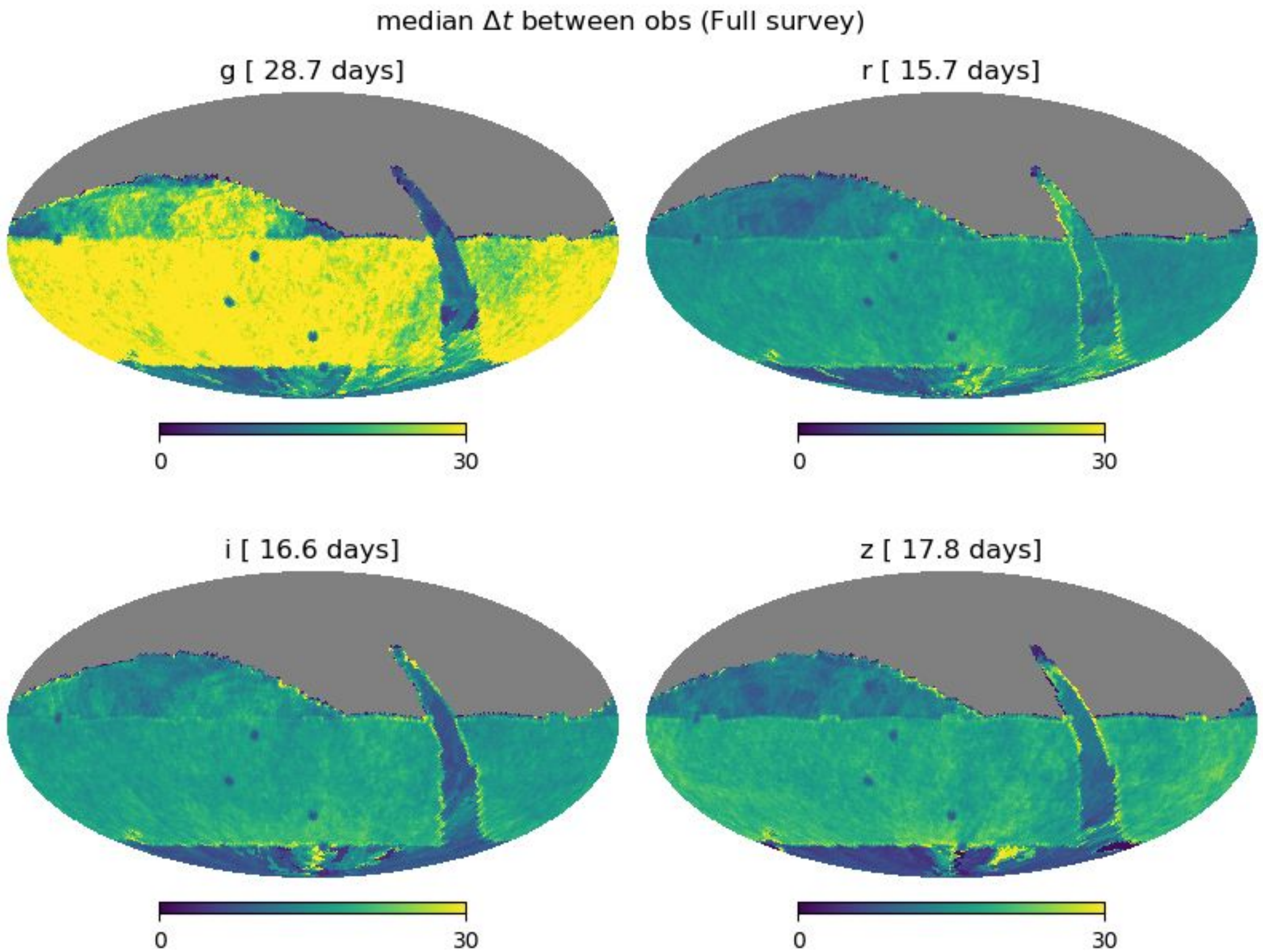
Rolling cadences

- AltSched
- AltSched rolling

Similar total #visits & survey depth



Very different cadence / obs strategy



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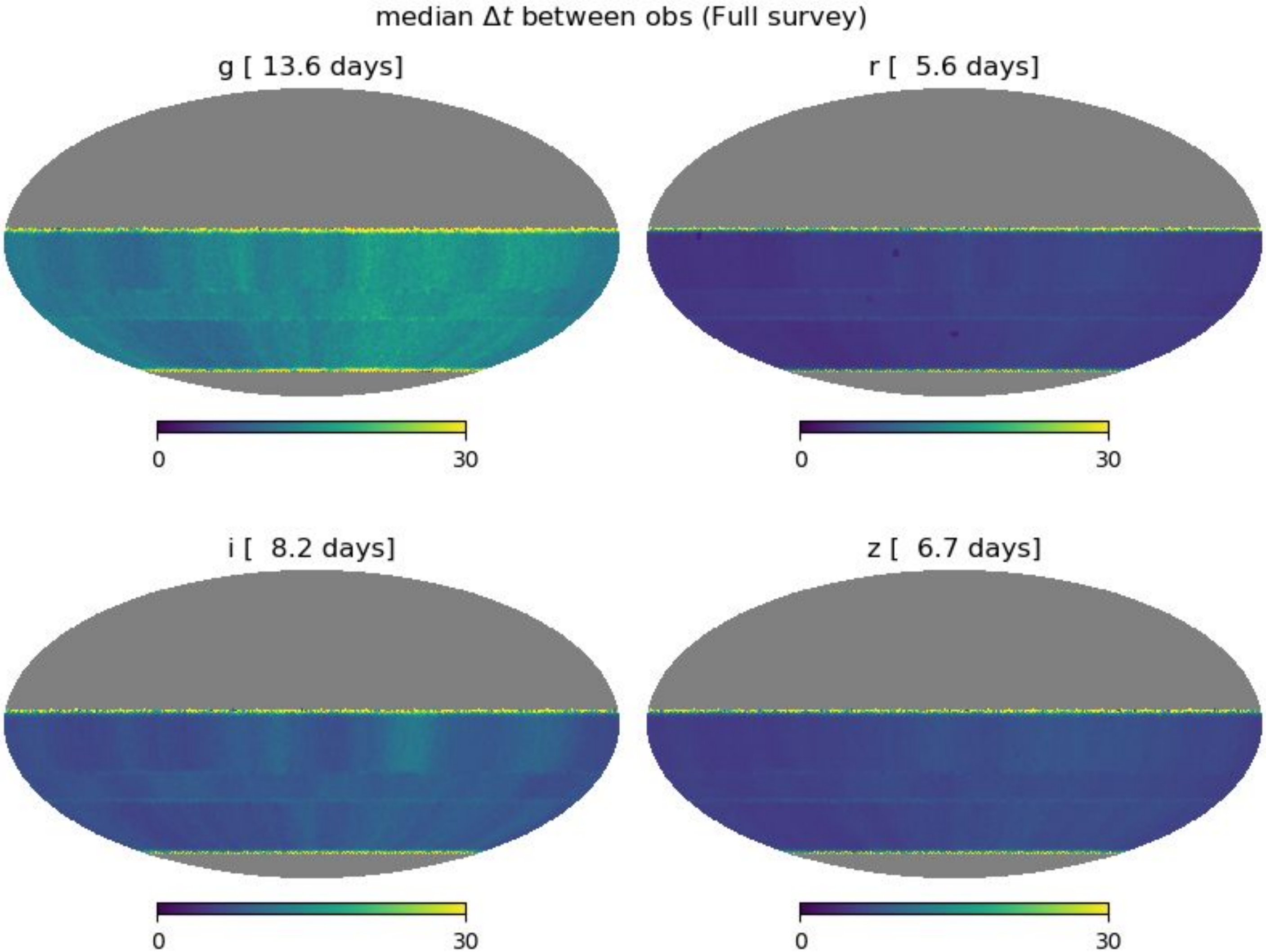
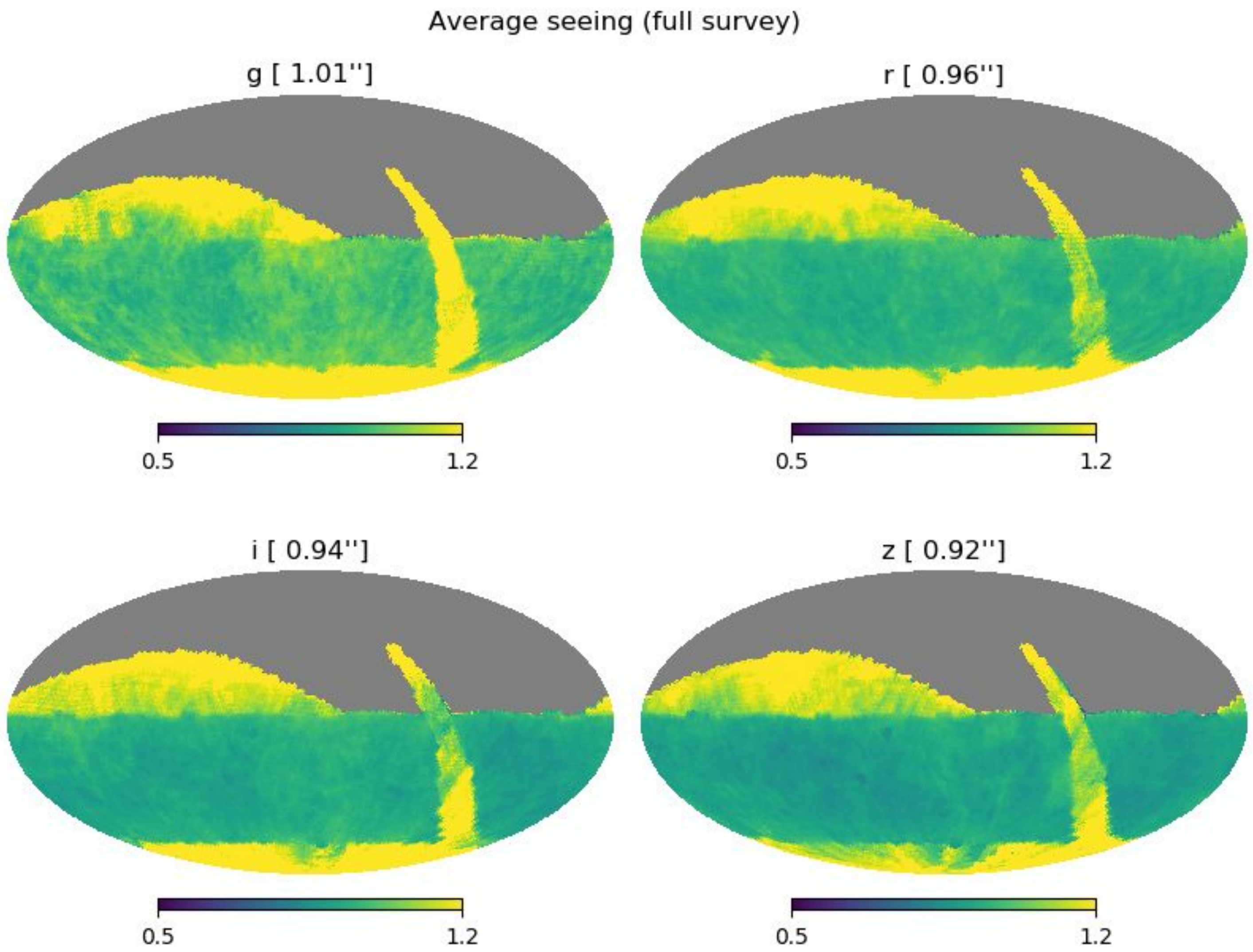
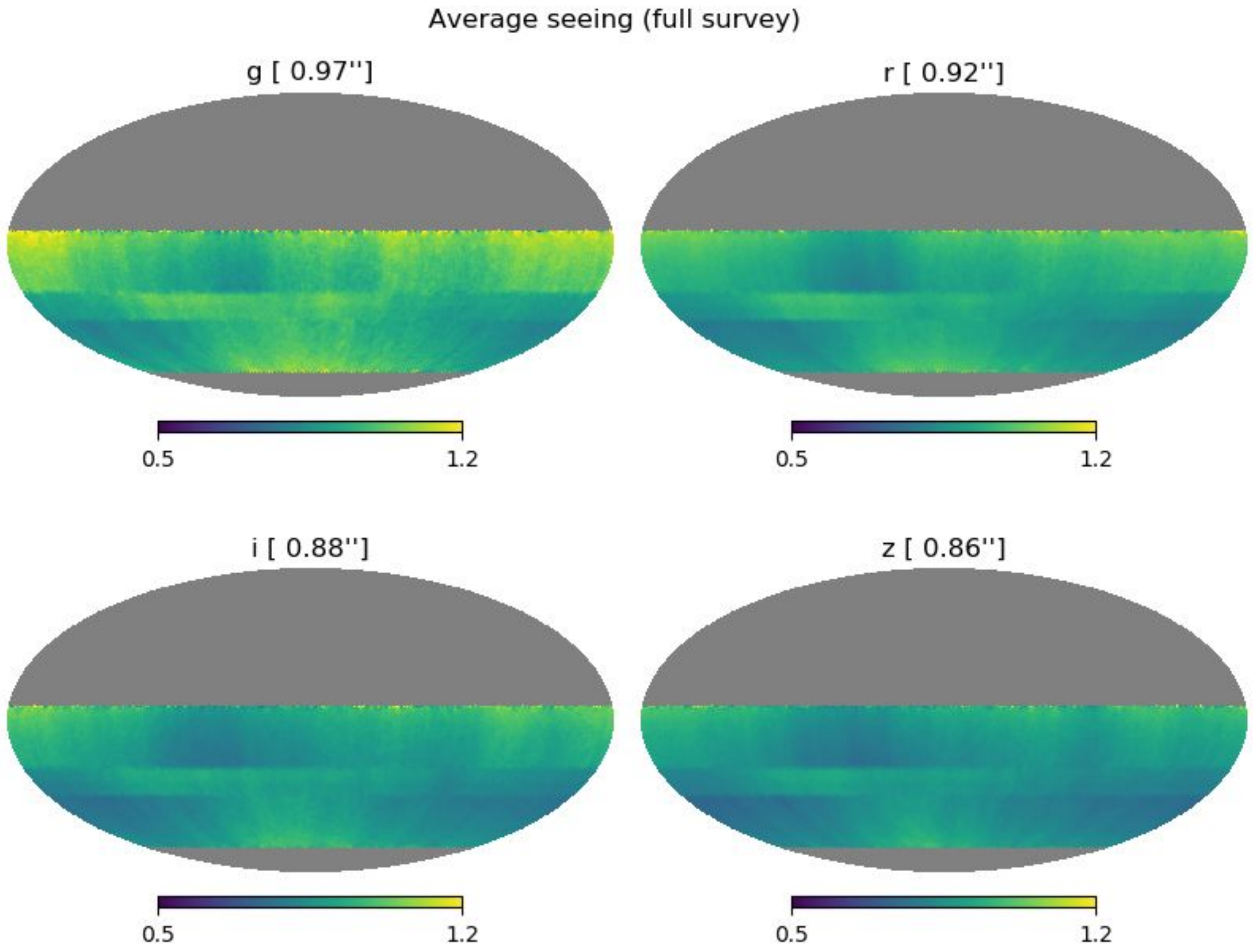


Different mean obs conditions



Different mean obs conditions



Ubercal-like model

$$m_i = m + ZP_{\mathrm{exp}} + \delta ZP_{\mathrm{cell}}$$

Measurement

Calibrated mag

Exposure ZP

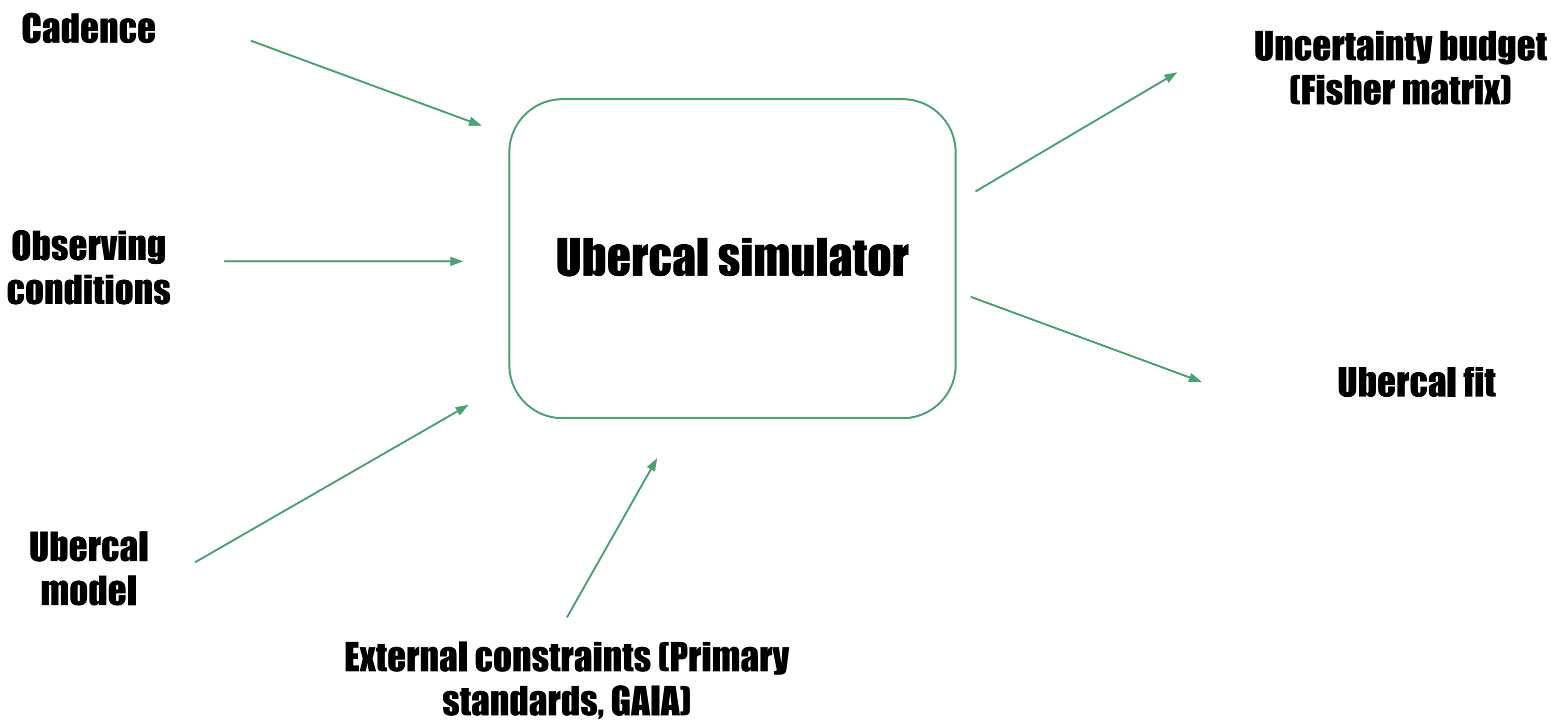
Uniformity map

~ 1 / month ?
~ 1 / week ?
~ / day ?

- Fitting simultaneously:
  - Calibrated magnitudes
  - Calibration parameters (ZP + uniformity maps)
- With constraints from
  - Primary references
  - Future uniform star catalog (GAIA ?)

Padmanabhan 2008
Schlafly et al, 2015
Burke & Rykoff, 2017

Fast ubercal simulator

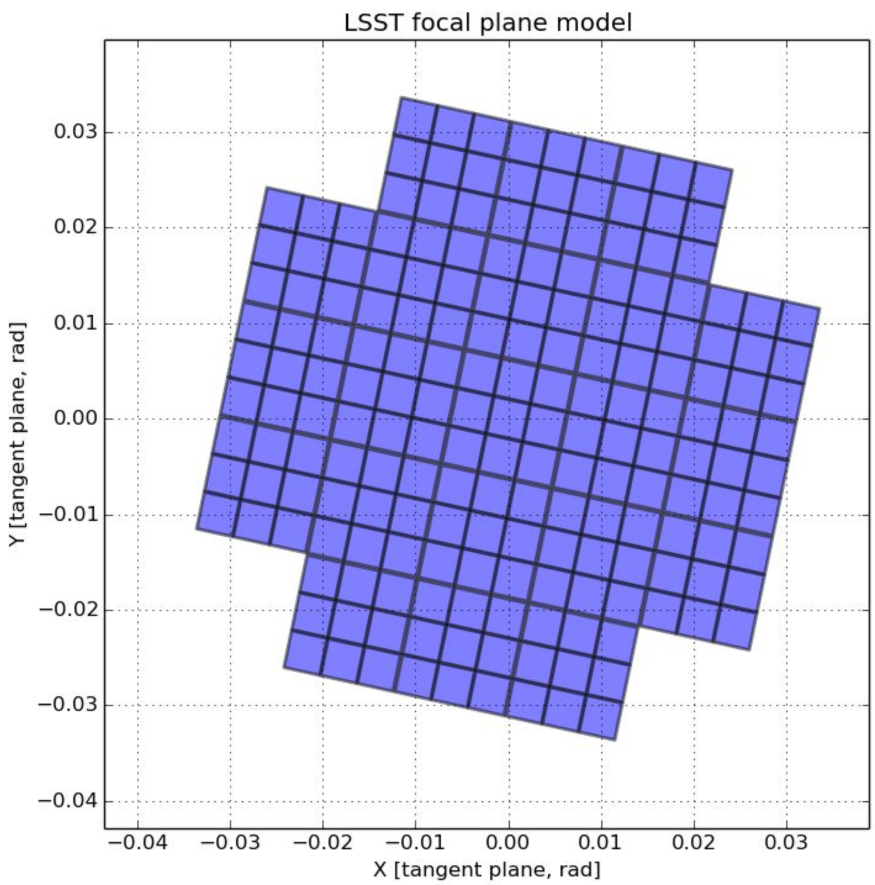


Method

- Pixellize the sky (with healpix)
    - Use pixels instead of star
    - nside ~ 1024 -> ~ 5,5 10^6 “stars” in the LSST footprint
- Implement a focal plane model
- Choose a measurement error model
- From a cadence, determine
    - For each exposure,
    - which healpix pixel was observed,
    - in which cell of the focal plane
- Build & invert the fisher matrix of the fit
    - Large (~ 5,5 Mstars)
    - … but very sparse

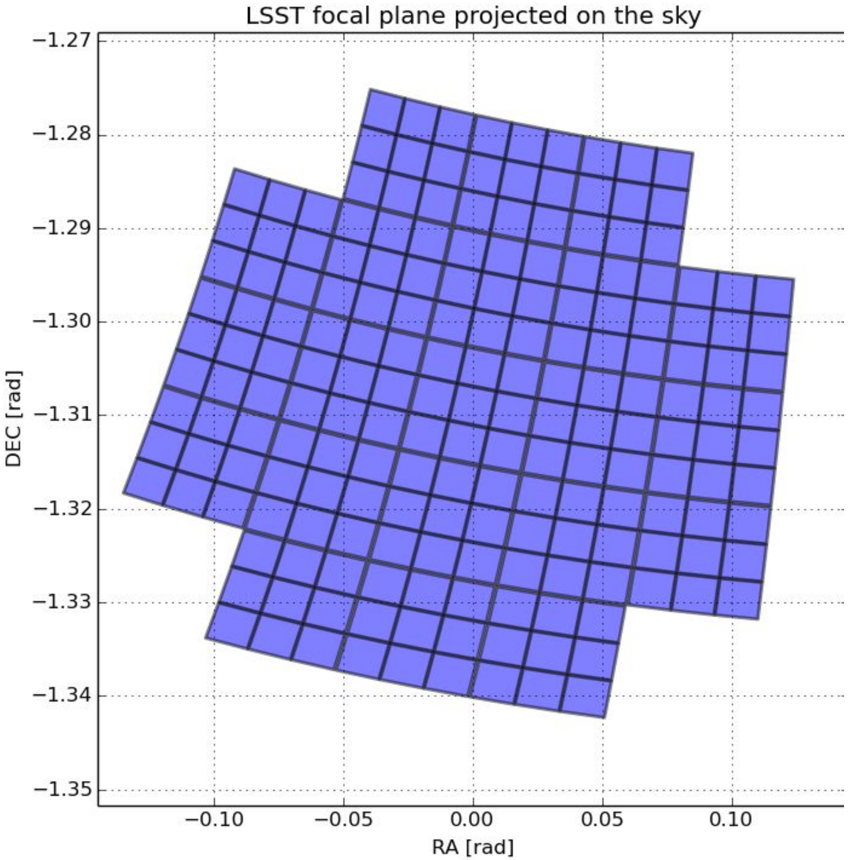
For the real ubercal
(using stars),
see E. Rykoff (FGCM)
F. Feinstein’s talk

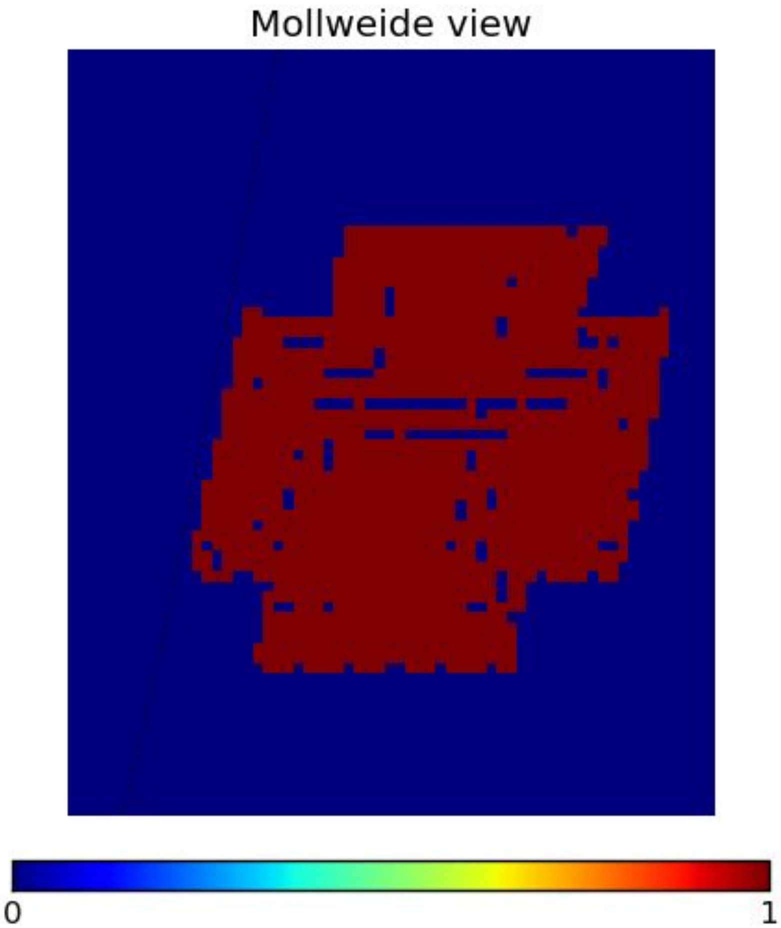
Focal plane model



- 21 rafts of 9 CCD each
- 1 independent cell / CCD
  - 189 cells
- Change the uniformity solution ~ every month
- Can define smaller pixellization

Projected on the sky





Measurement = star_i in cell_j for exposure k

Ubercal Fisher matrix

$$F = J^T W J$$

Very large
($6\,10^6$ x $6\,10^6$)
but sparse
(its inverse is not)

Measurement uncertainties

Model derivatives

- 10 minutes / core / yr of survey to build Fisher matrix from cadence files
- ~ 30-40 minutes to perform cholesky decomposition $F = LDL^T$

For 2 yrs of survey
and 1 phot flat every 2 weeks

Gives access to covariance matrix

Compressing the fisher matrix information

- Monte-Carlo inversion

$$m_{\rm cal} - m_{\rm true}$$

  - Generate O(1000) realizations of the ubercal "residuals"
  - This can be done easily, because we have the cholesky factorization of F

$$R = \left(L^{-1} D^{-1/2}\right)^T X \qquad \text{with } X \sim \mathcal{N}(0, 1)$$

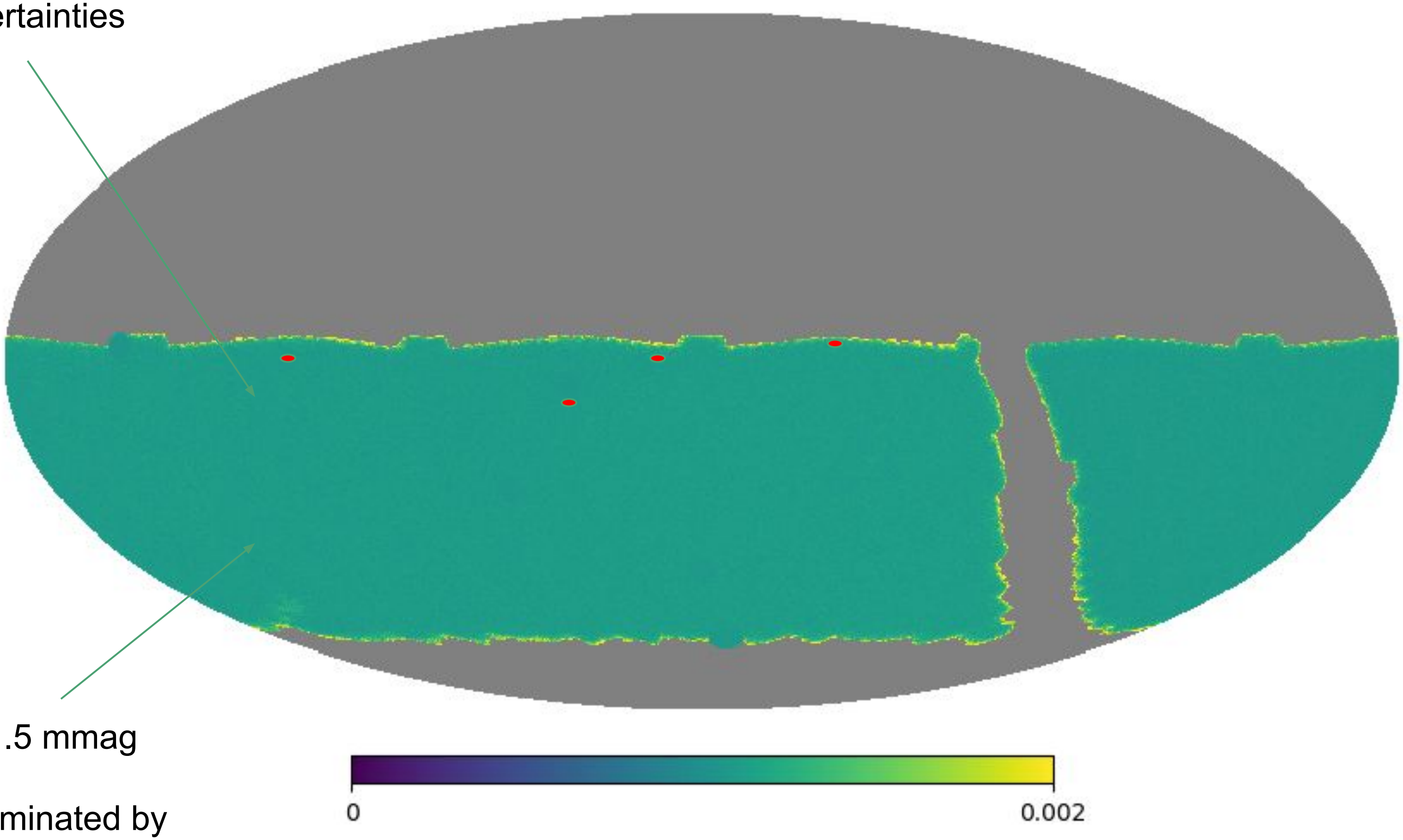
- With nside=1024, takes < 1-s per realization
- Then compute and stack
  - Diagonal errors
  - power spectrum
  - or correlation function

Preliminary results

- Ingredients
  - cadence
  - Measurement error model :
    - assume 2 mmag / superpixel : shot noise + flat field error
  - Location + number of primary standards
  - No gaia-like catalog (for the moment)
- For 1 year of survey taken alone
  - AltSched-like cadences and Minion 1016 give solutions
  - “Feature” & “feature rolling” generally not well connected
- When combining together at least 2 years of survey
  - Problem is well behaved

Minion 1016

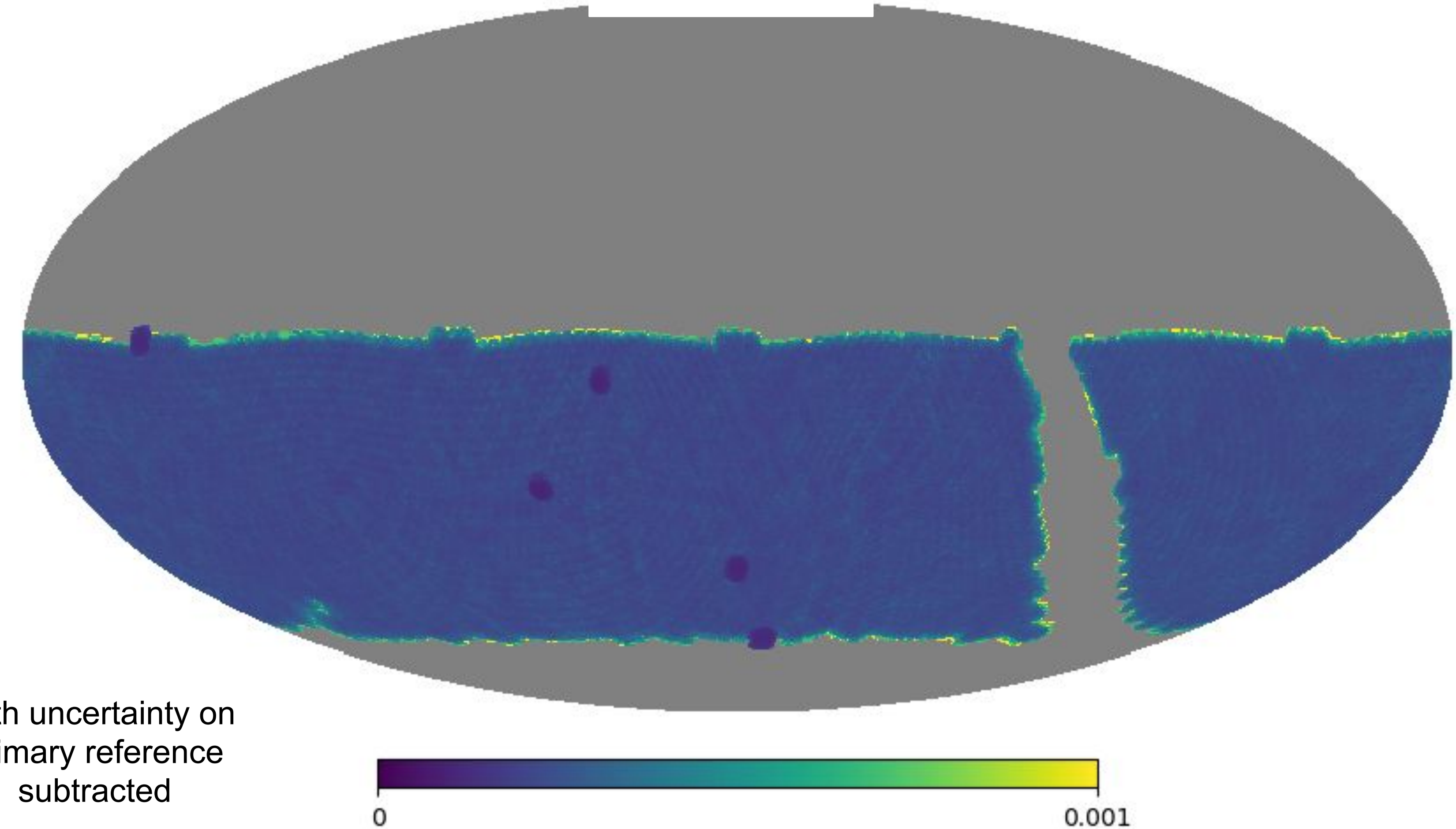
Diagonal uncertainties



1.5 mmag

Dominated by uncertainties on primary flux references

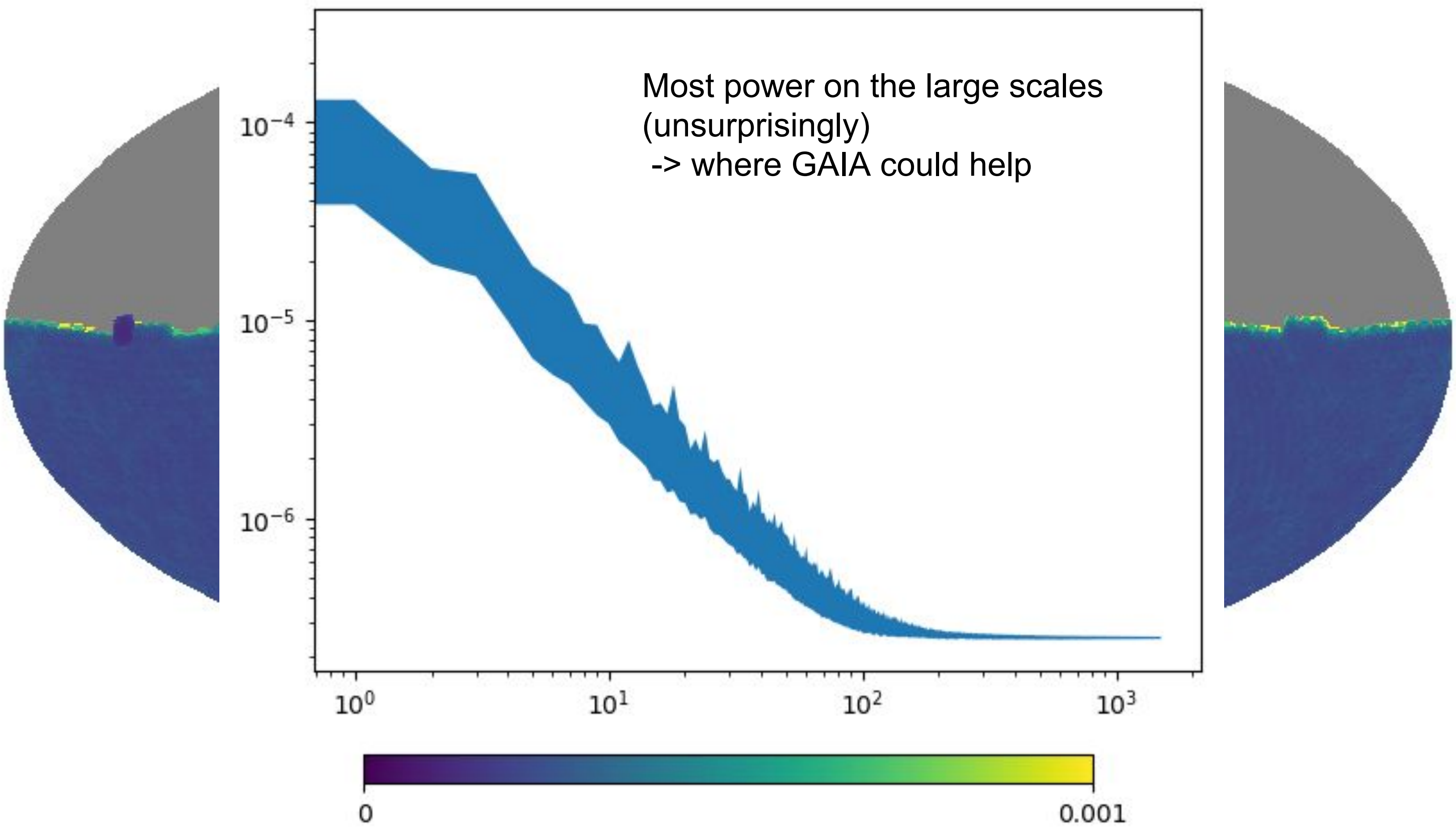
Minion 1016



With uncertainty on primary reference subtracted

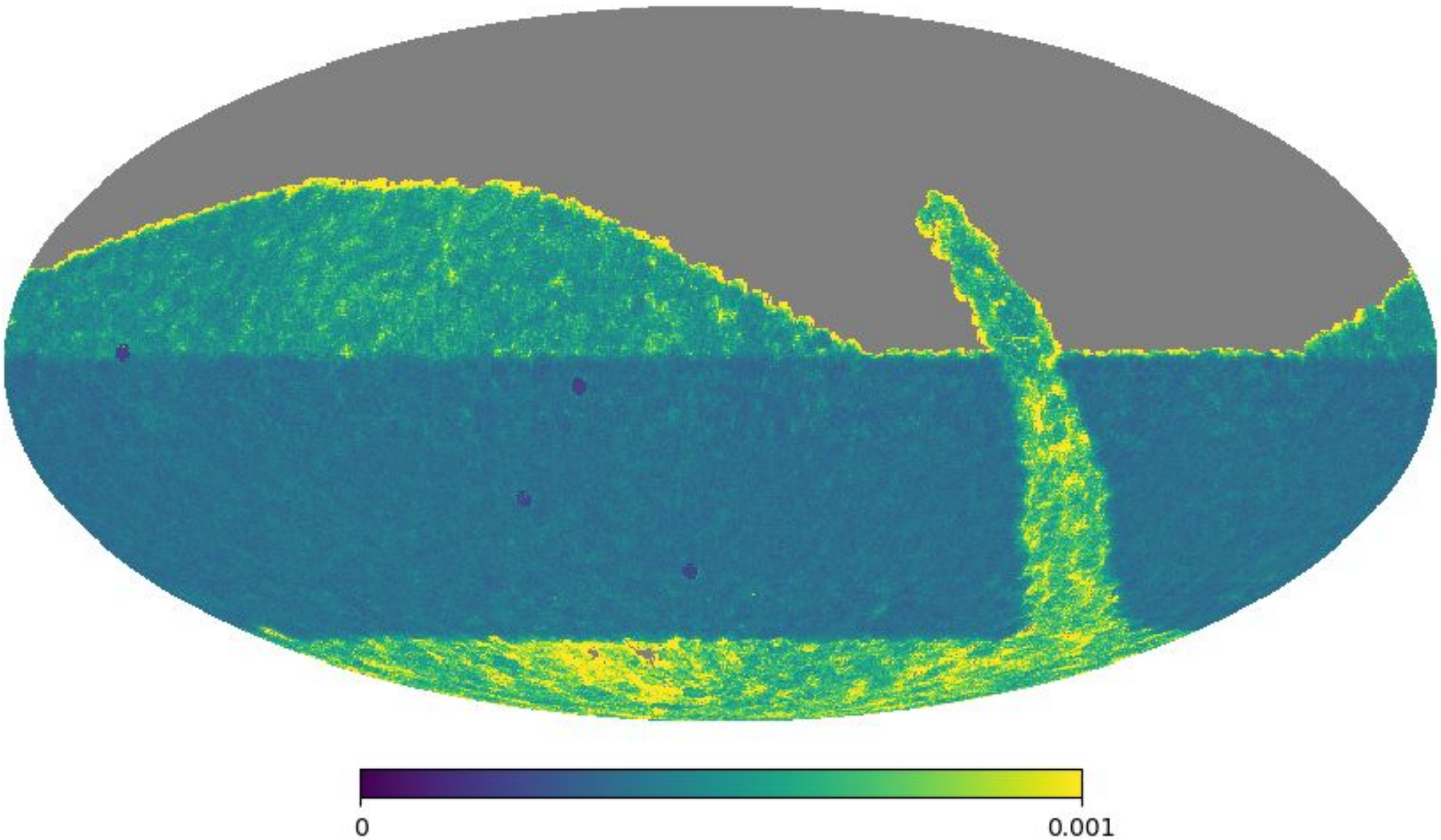
<< 1 mmag

Minion 1016

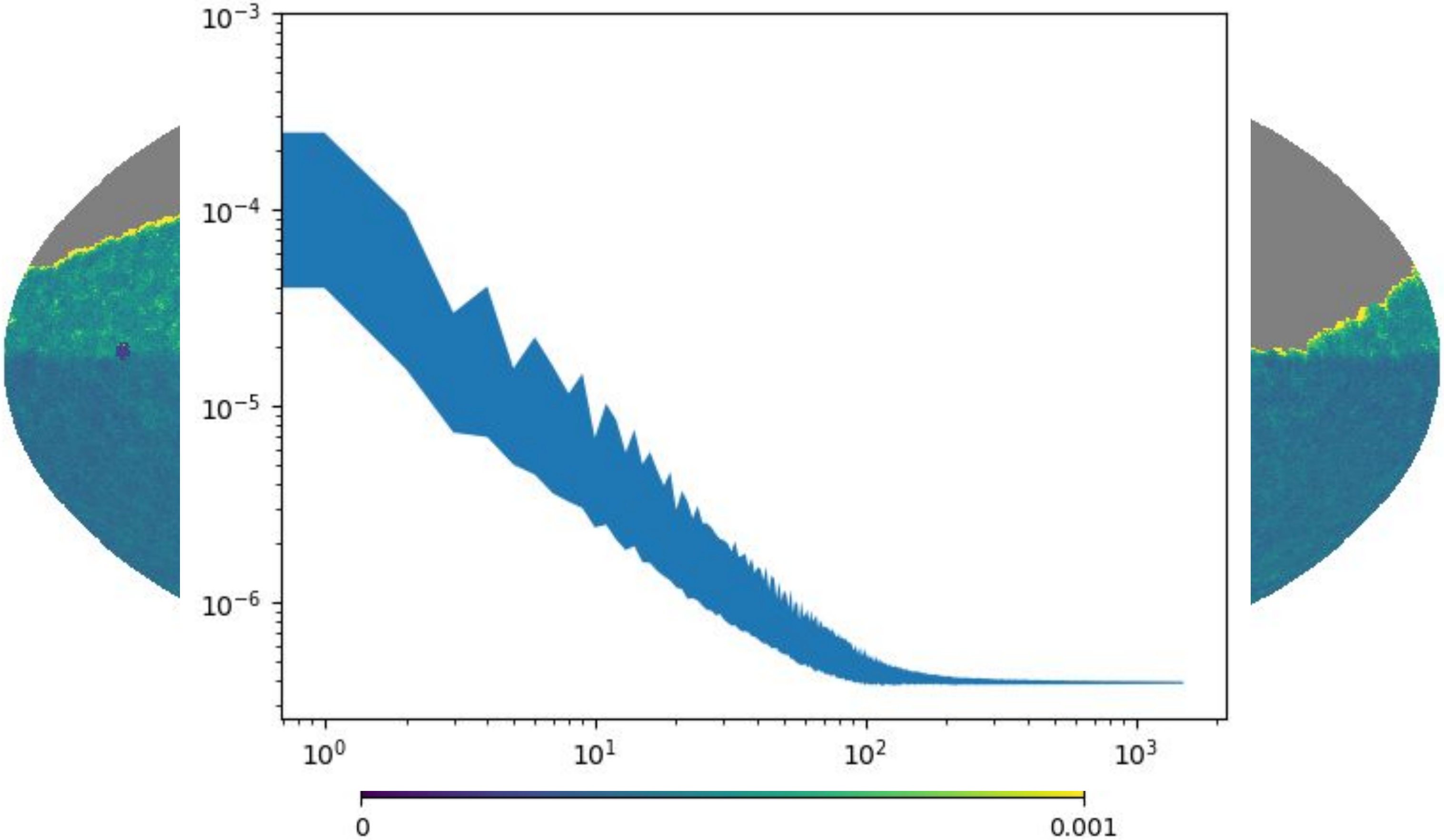


Most power on the large scales
(unsurprisingly)
-> where GAIA could help
10^{-4}
10^{-5}
10^{-6}
10^0
10^1
10^2
10^3
0
0.001

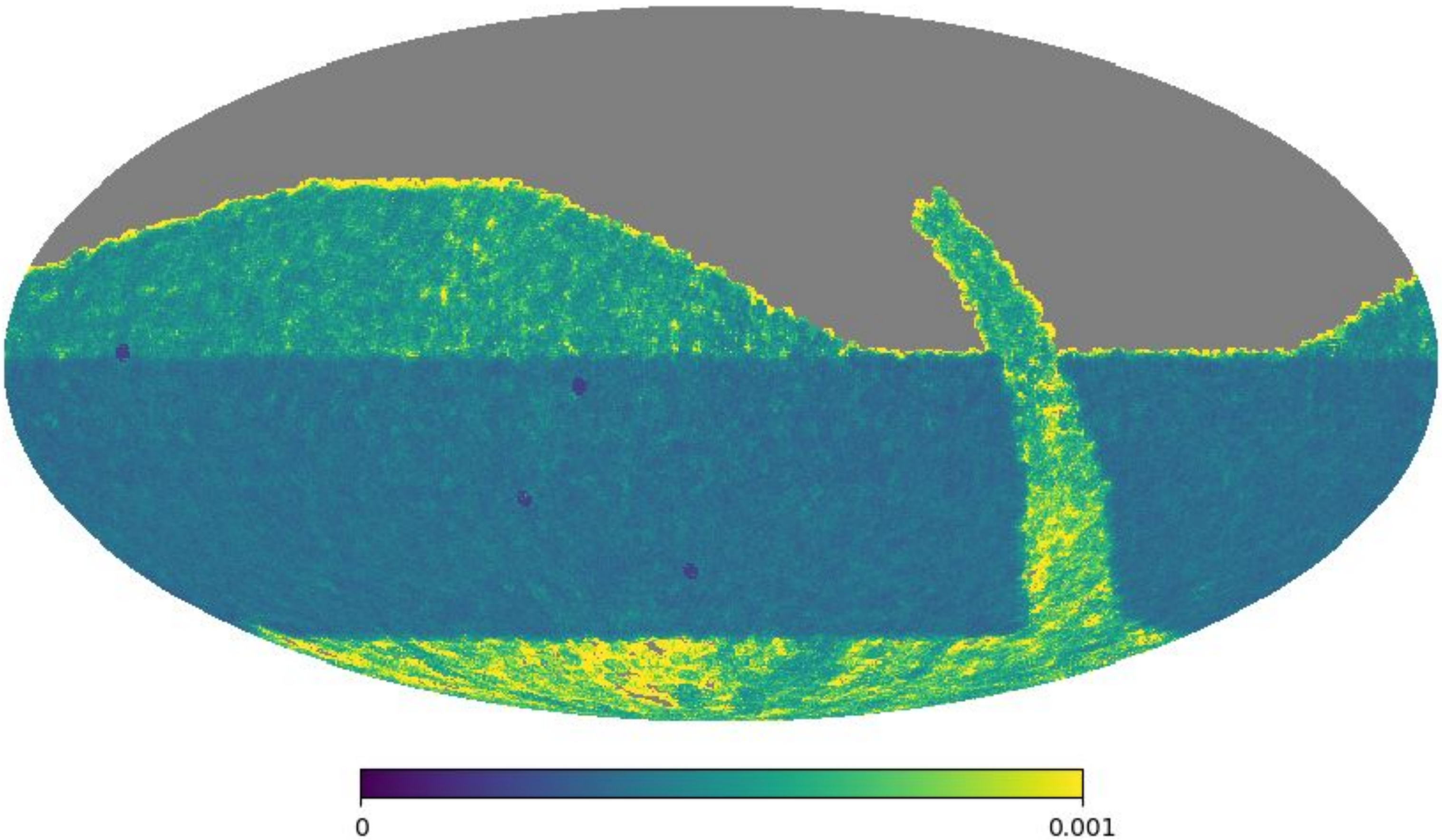
Feature baseline



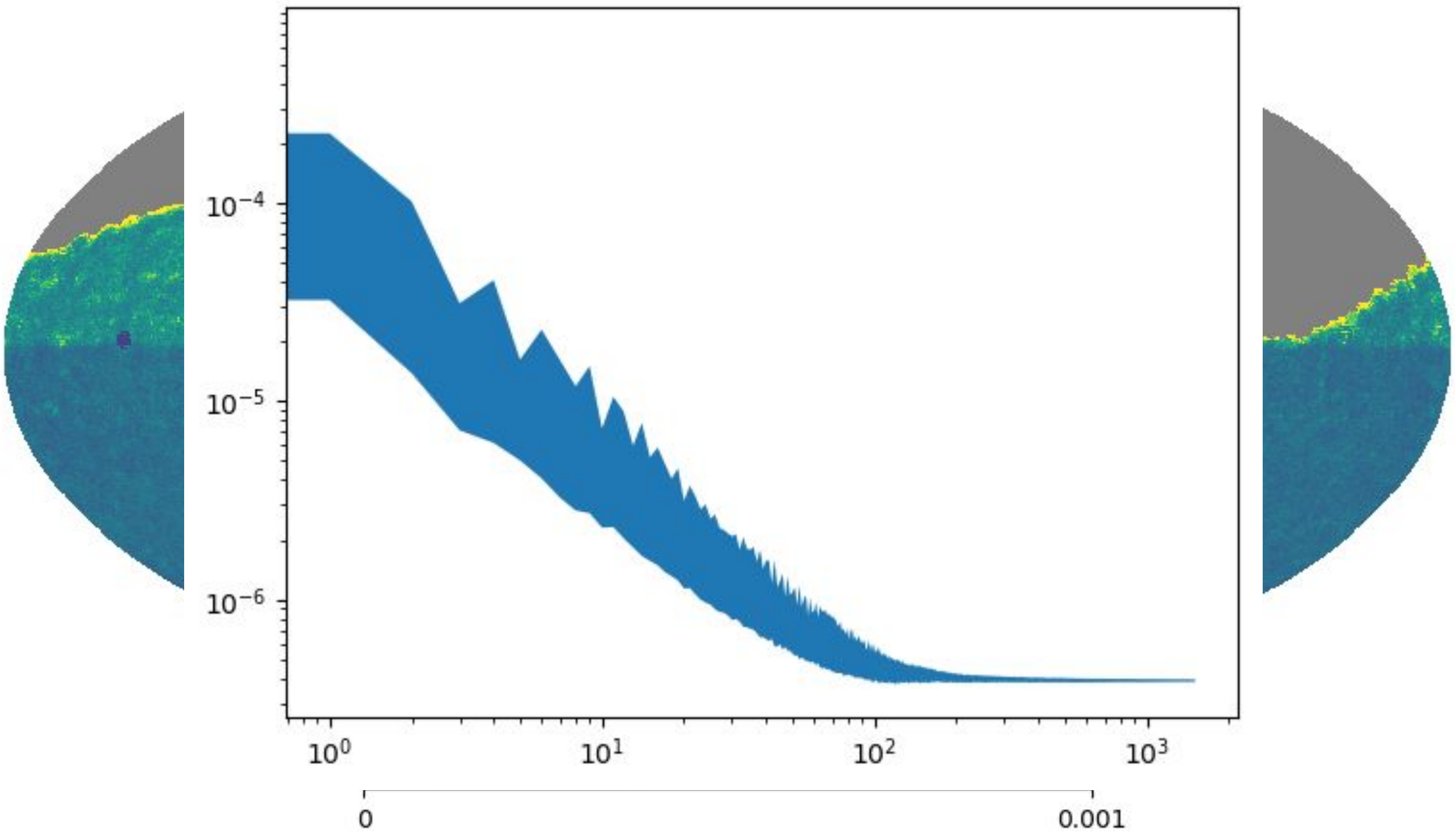
Feature baseline



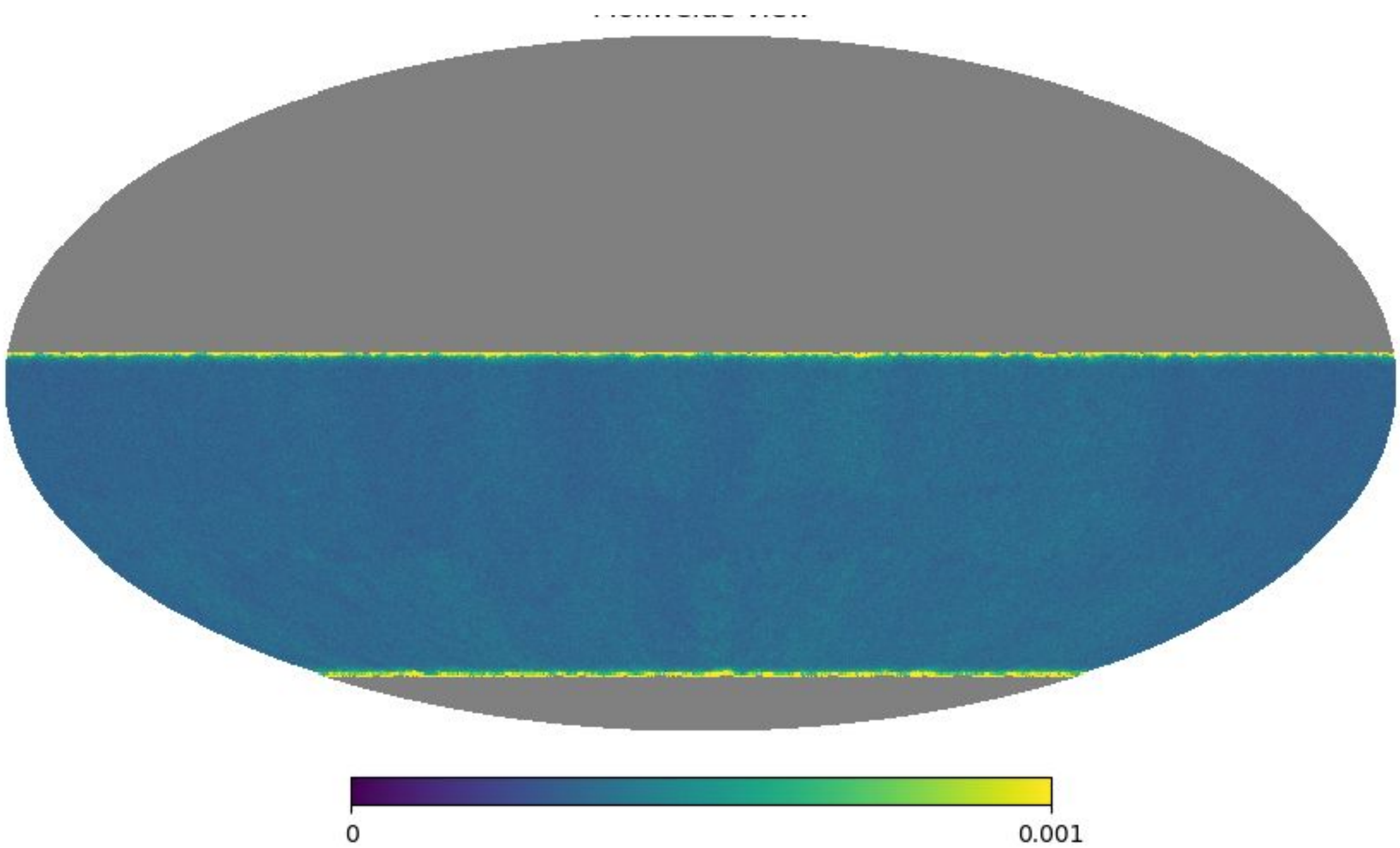
Feature rolling



Feature rolling



AltSched



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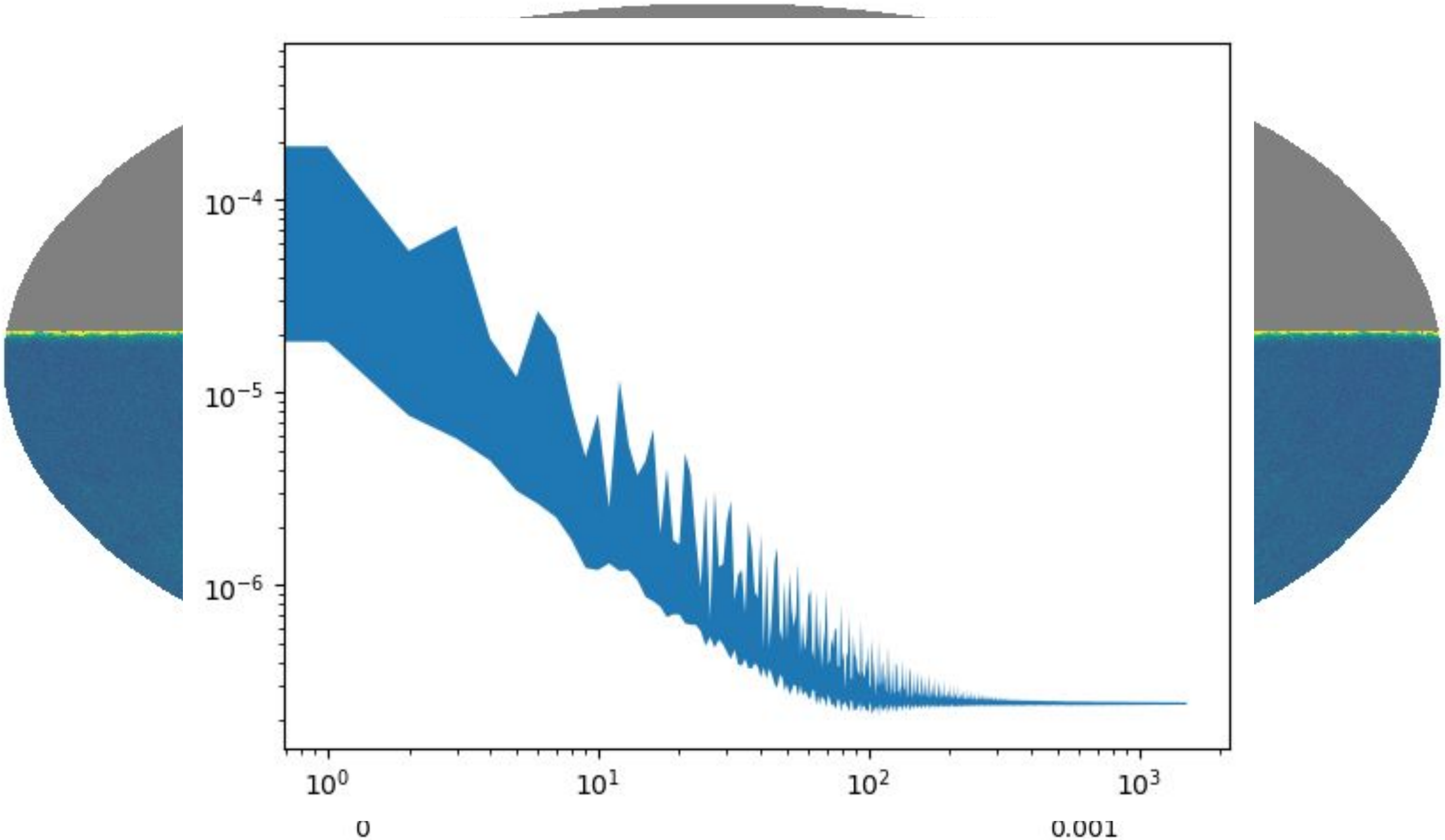
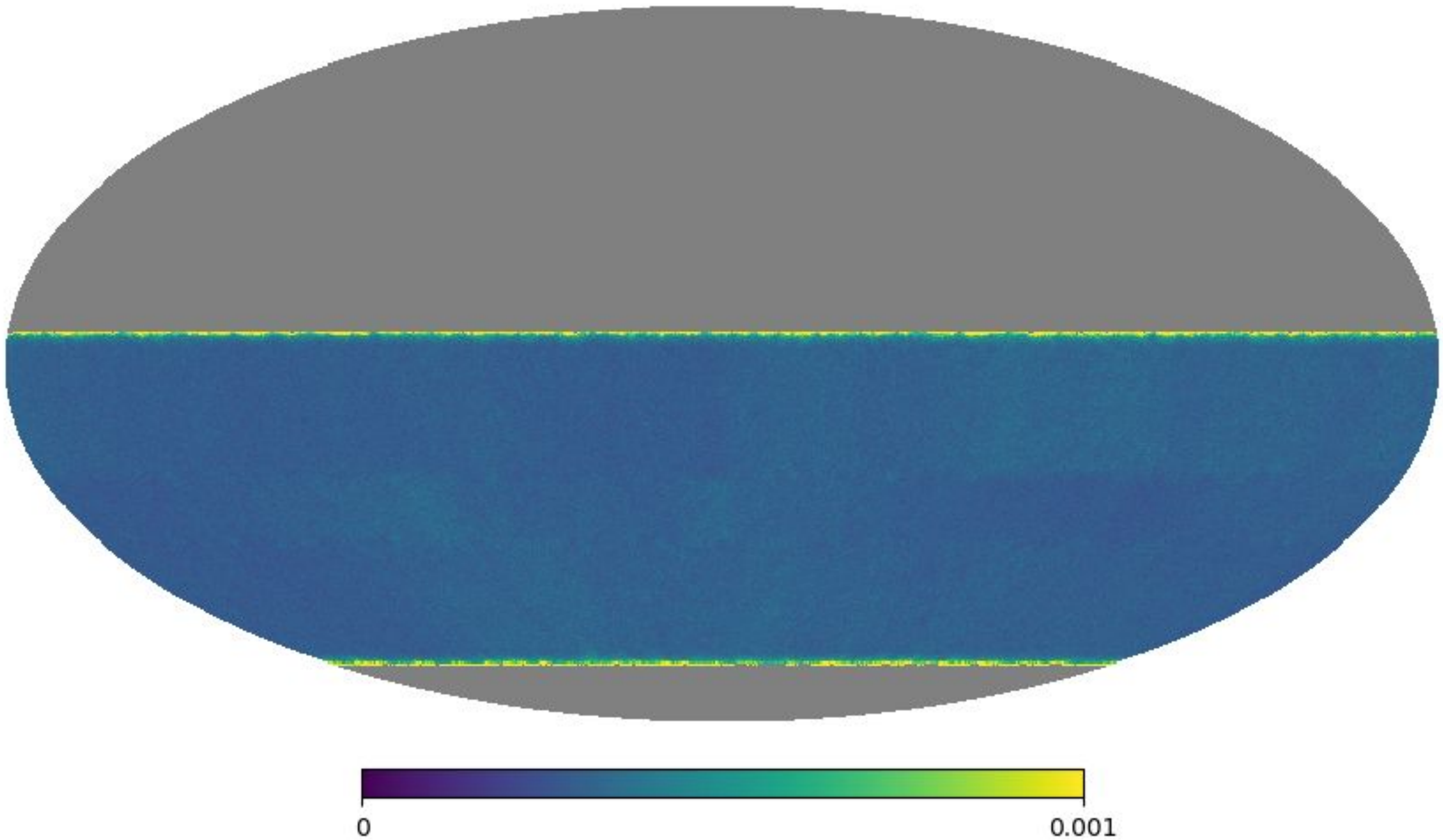
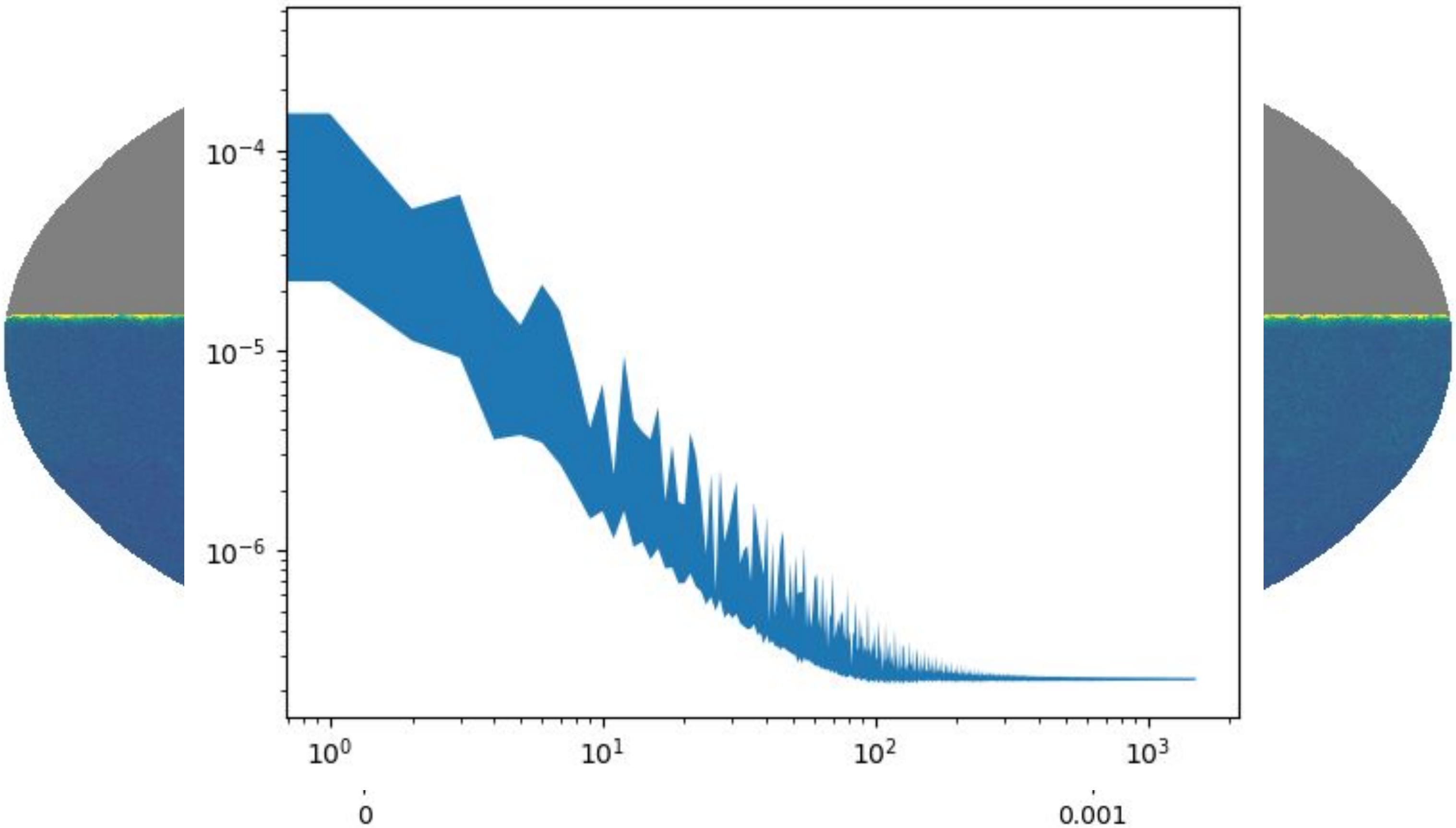


AltSched rolling



AltSched rolling



- With 2 years of survey
  - cadences proposed so far allow one to solve our ubercal-like problem, presented above
  - This is excellent news
  - -> all contributions to survey non-uniformity will be:
    - Instrument signature effects that vary faster than model
    - Chromatic effects that cannot be absorbed by a gray term
    - Pbs with outlier detections

Performing the fit explicitely

$$\hat{\theta} = (J^T W J)^{-1} J^T W y$$

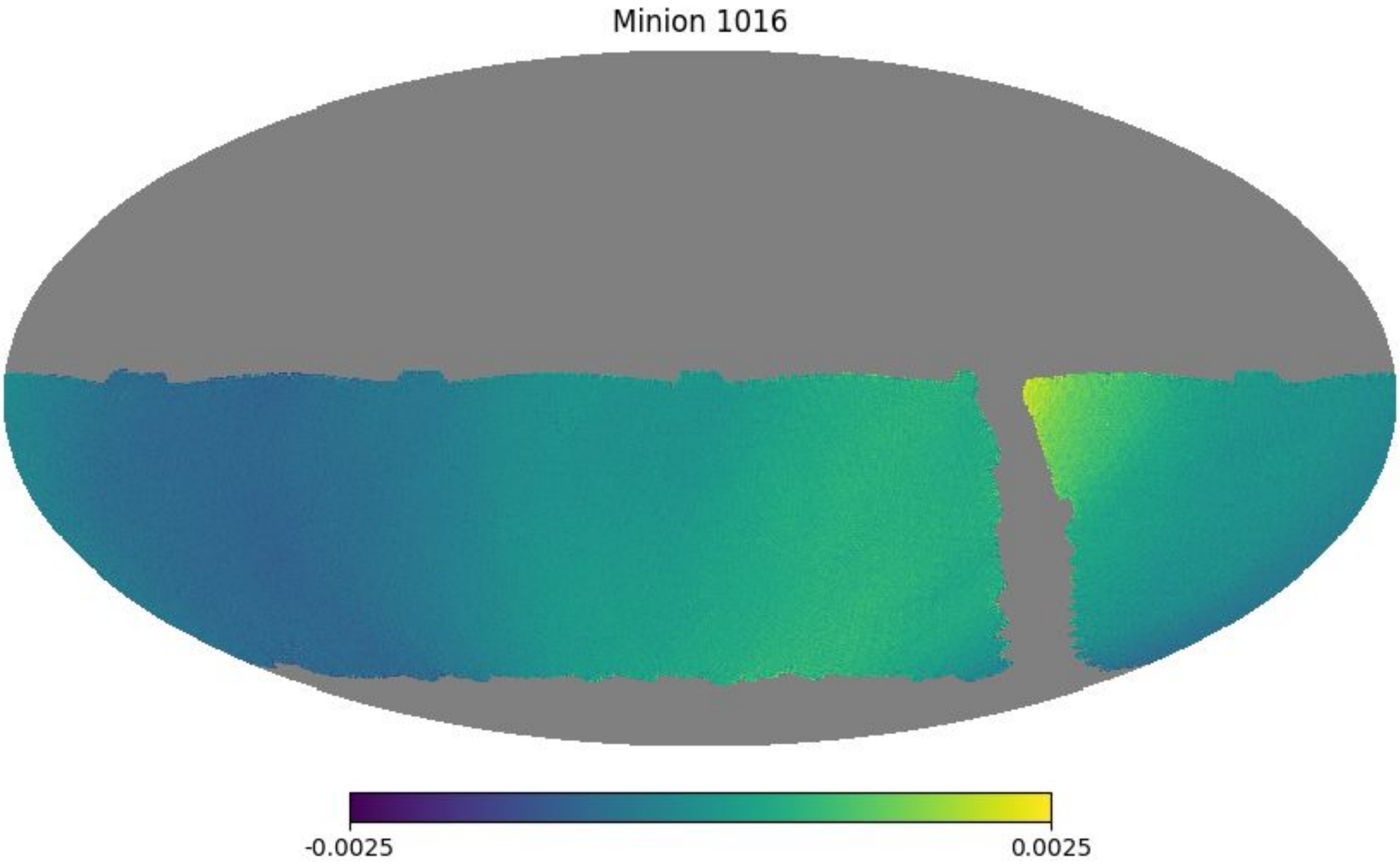
Solution
(mags & ZP)

We have its LDLT decomposition already

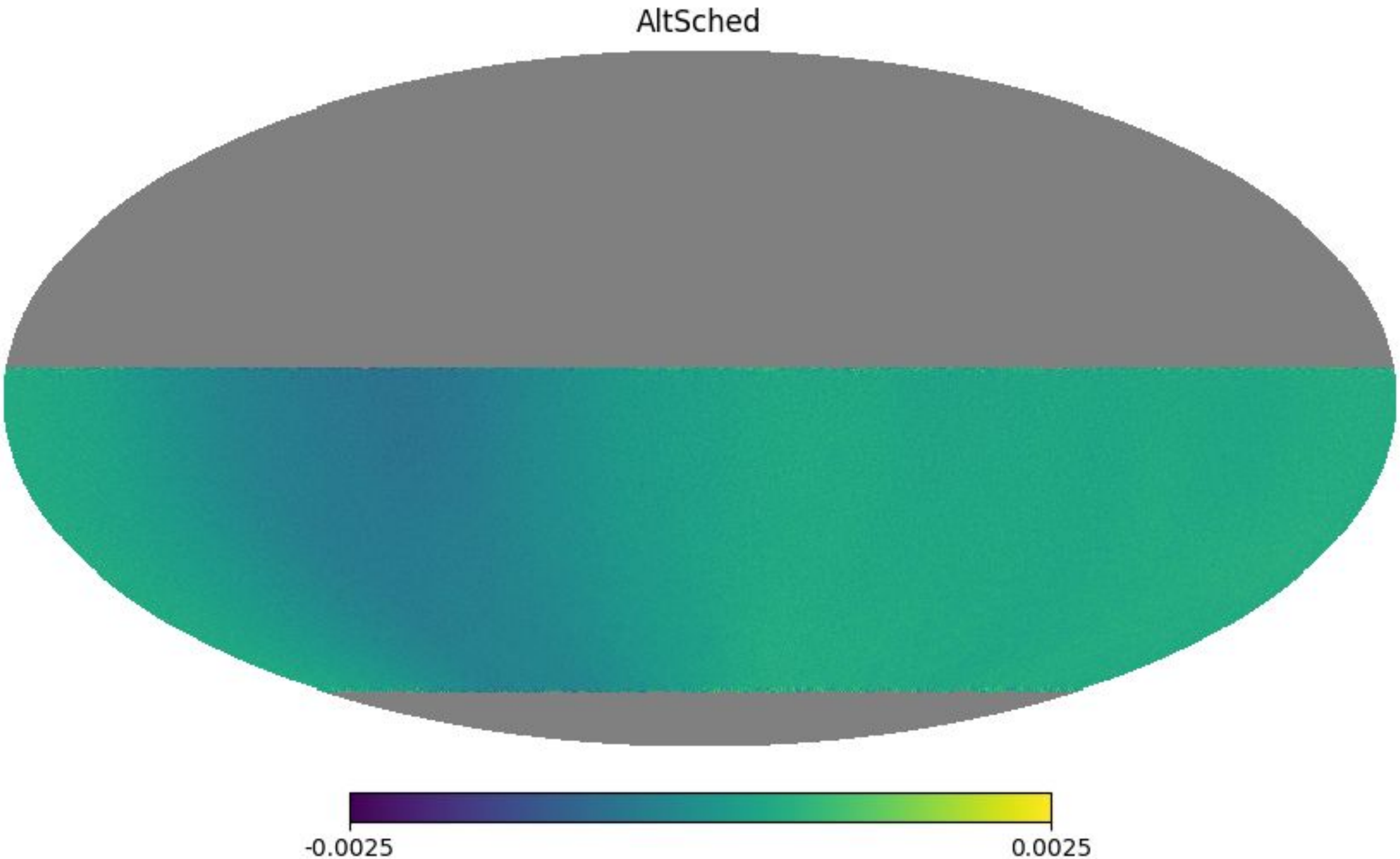
measurements

- Plug in
    - measurement systematics model
    - Errors on instrumental effect removal
- See effect on calibrated magnitudes
- Preliminary exploration with gain variations:
    - Assume monotonic gain variations along the night, up to 0.2%

Minion 1016



AltSched



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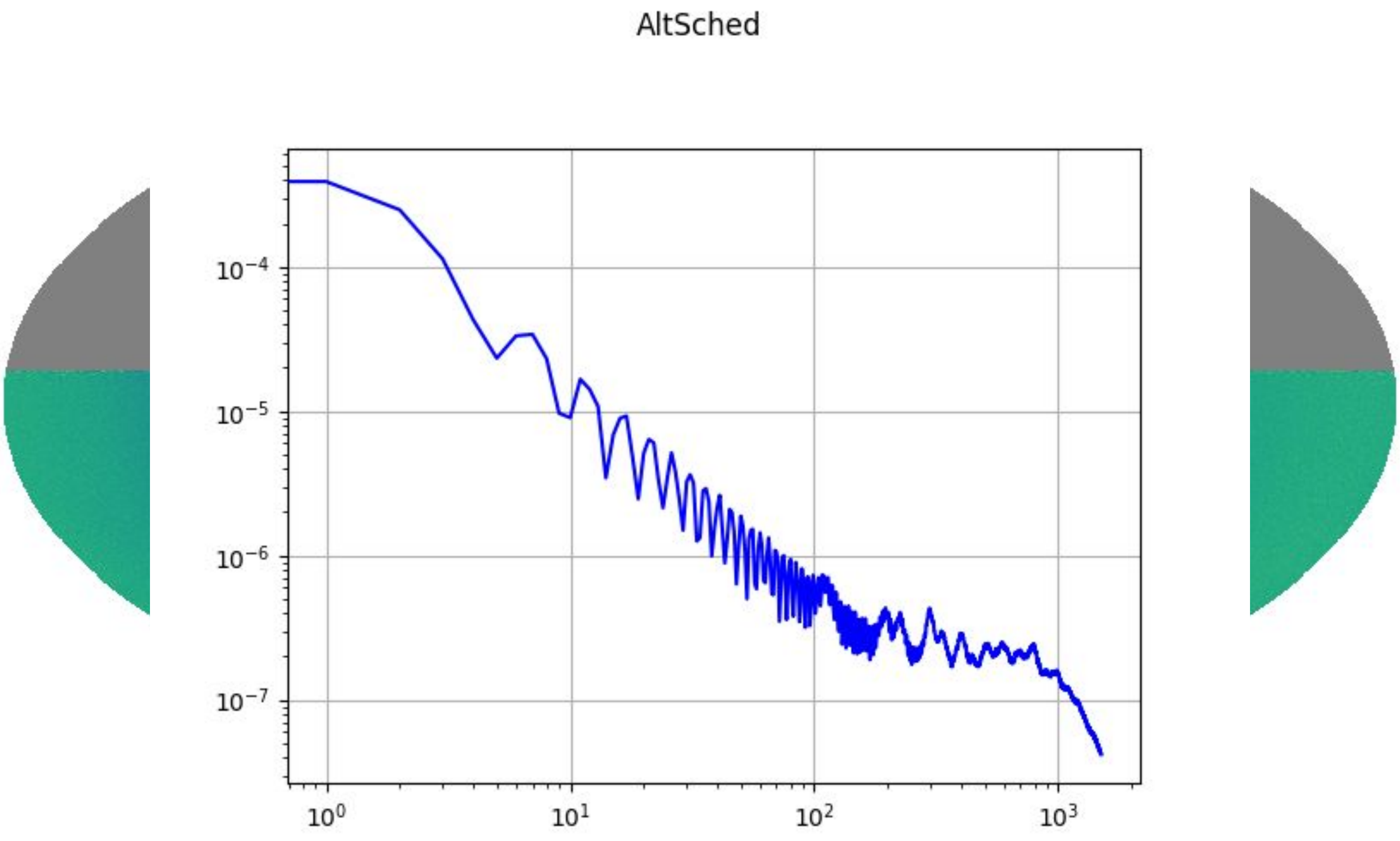
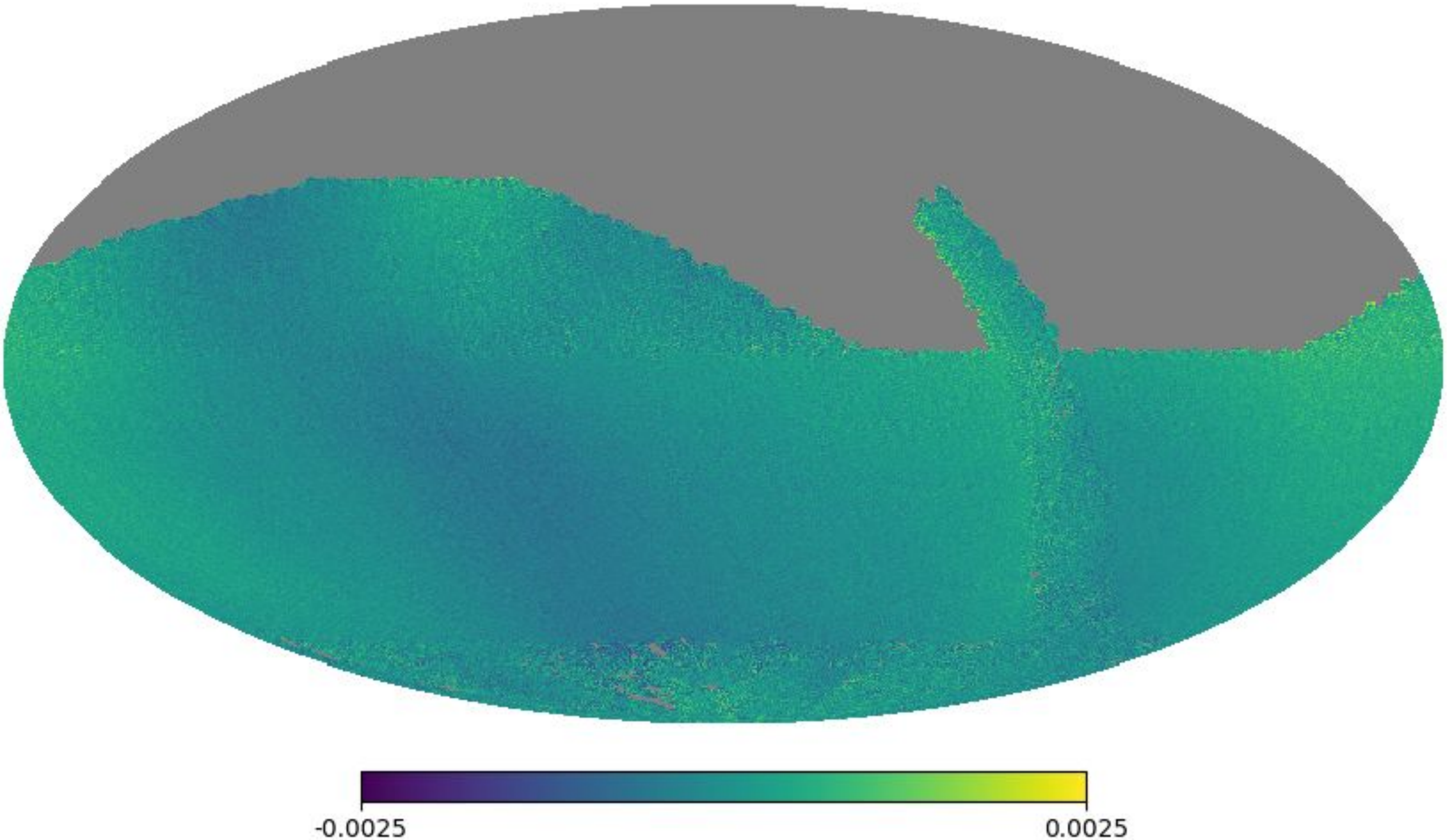
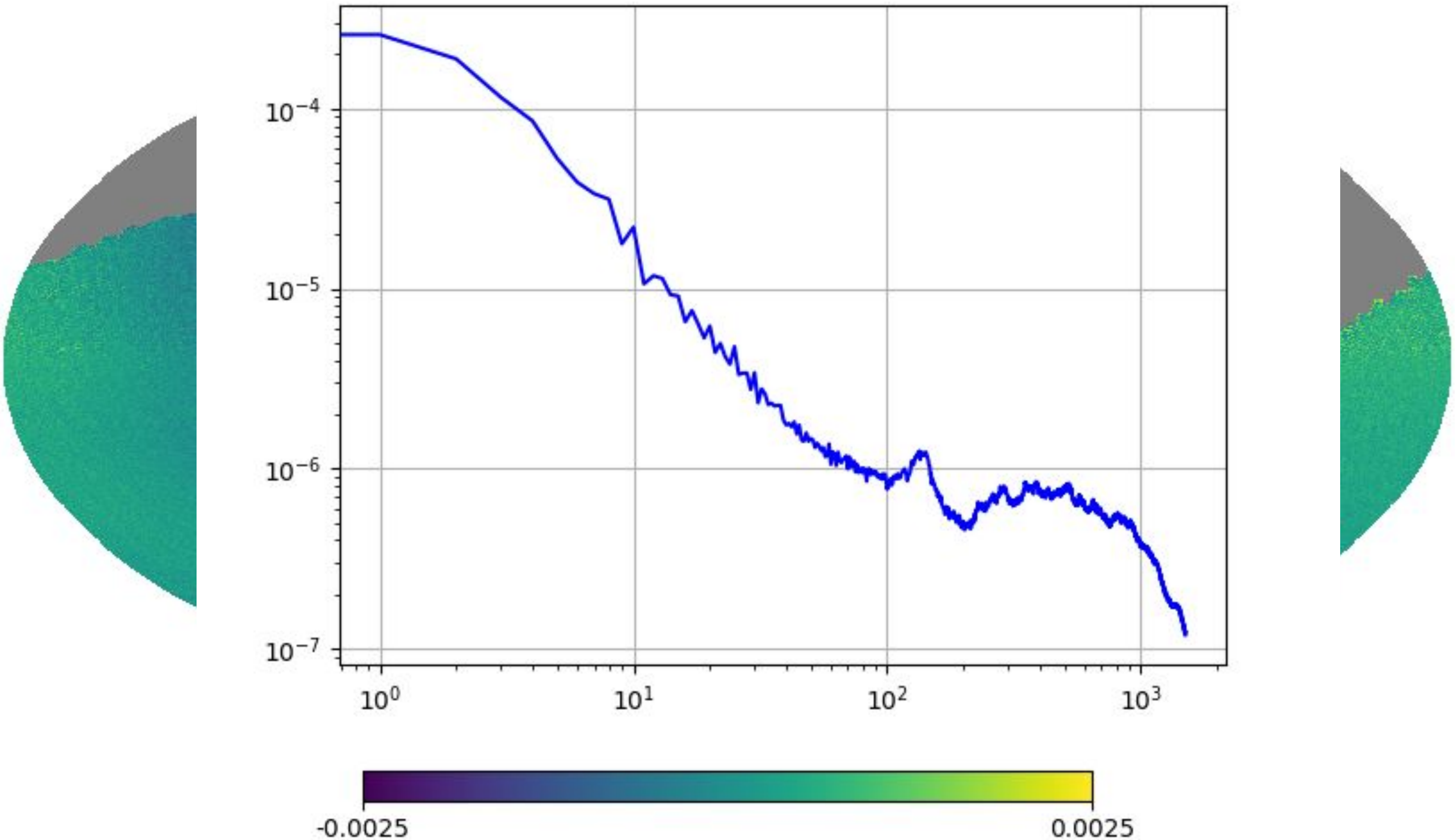


Feature baseline



Feature



Conclusion / work ahead

- We have a pipeline
  - that can absorb and produce results for all cadences (~8 hrs)
- Now plug in realistic model of
  - Realistic Calibration plan
    - frequency of flat field updates
    - Number of standards, location of standards
  - Instrument signature correction errors
  - Chromatic effects (atmosphere,)
- Go up in resolution (nside=2048 + down to amplifier scale)
- Simple modifications of cadence to rigidify the 1 yr solution
- GAIA