Cadence studies

N. Regnault, P. Gris et al

(many thanks to D. Rothchild and P. Yoachim, E. Rykoff, C. Stubbs and many others for past and future helpful discussions)

LSST DESC
Dark Energy Science Collaboration

Metrics

SN cosmology

- Cosmology metrics
  - DETF figure of merit
  - Using SNe to probe LSS

⇓

- How many *well sampled* SNe ?
  - Sampling quality requirements from Photo-id & distance measurements
- Redshift limit of SN survey
  - z above which measurement error > SN intrinsic dispersion

Survey uniformity

Light pipeline & ubercal toy model, to evaluate

- If we can fit a ubercal solution
  - After 1, 2... 3+ year(s)
- The quality of the ubercal solution
  - Fisher matrix studies
  - Multiple fits
- How cadence can be tweaked
  - To improve ubercal errors

GAIA may help ! (PCWG pop-up session on Thursday)

Three cadence families

White paper call

- Baseline 2018a
- Kraken 2026 (new baseline)
- Colossus 2665
- Pontus 2002 (very wide WFD)
- Colossus 2664
- Colossus 2667 (1 visit / night)
- Pontus 2489
- Kraken 2035
- Mothra 2045
- Pontus 2502
- Kraken 2036
- Nexus 2097

No ditherings in released files (added after the fact with MAF)

http://astro-lsst-01.astro.washington.edu:8080/?runId=1

Jan 2018 simulations
(Tests of the feature scheduler)

- Minion
- Feature baseline
- Feature rolling ½
- Feature rolling ⅔
- ~6 more

Released files come with ditherings

AltSched

- AltSched
- AltSched rolling
- AltSched wide

AltSched's own dithering scheme

http://www.rothchild.me:8080

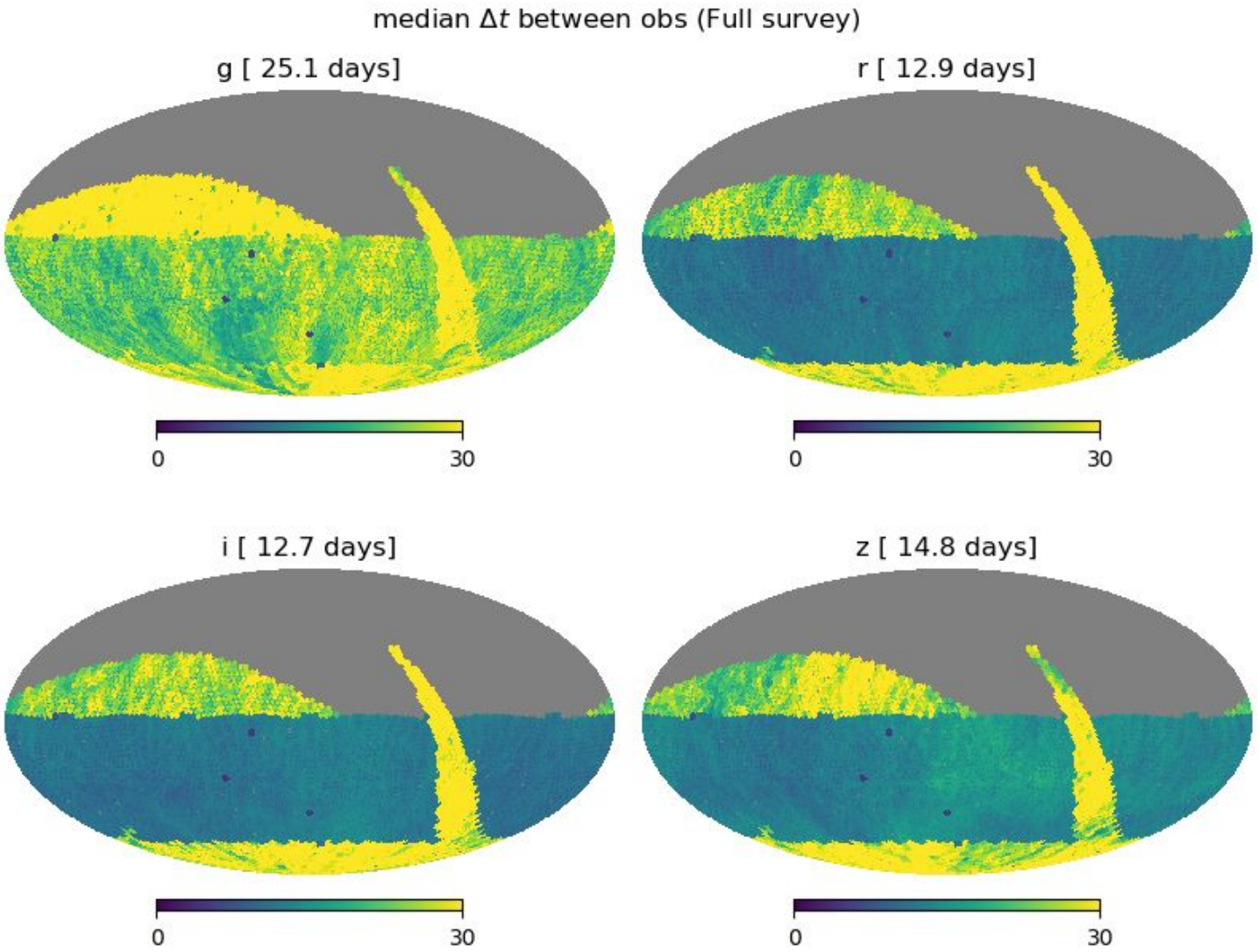
Three cadence families

- All give very similar metrics
  - Number of visits per filter per healpix superpixel
  - Total survey depth
  - Average image quality
  - …
- … but cadences differ very significantly w.r.t
  - Median interval between visits for a given field
  - Filter allocation strategy
  - Integrated depth in a ~ 45 days time window
  - ...

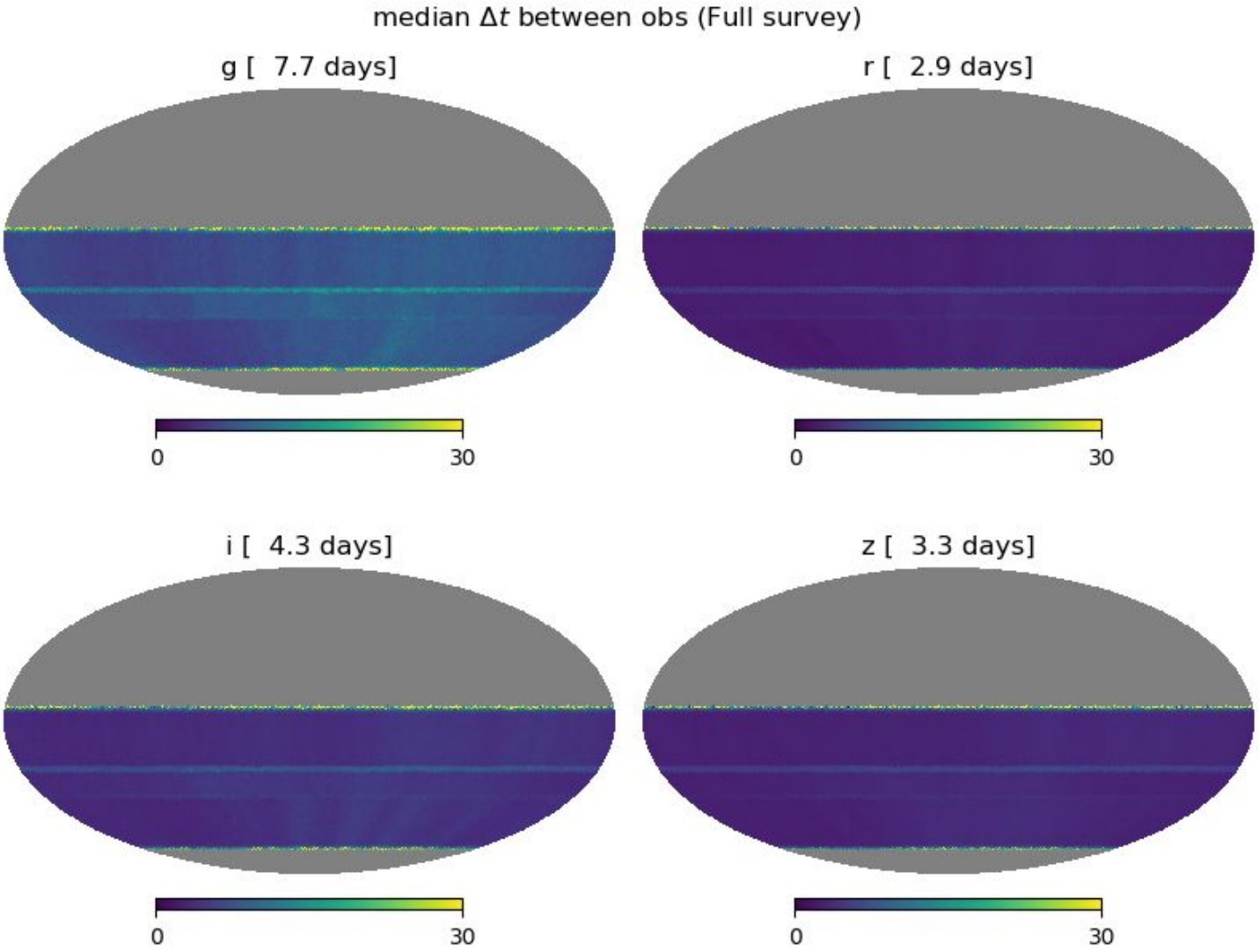
This is what matter for survey uniformity

Matters for SN science and survey uniformity

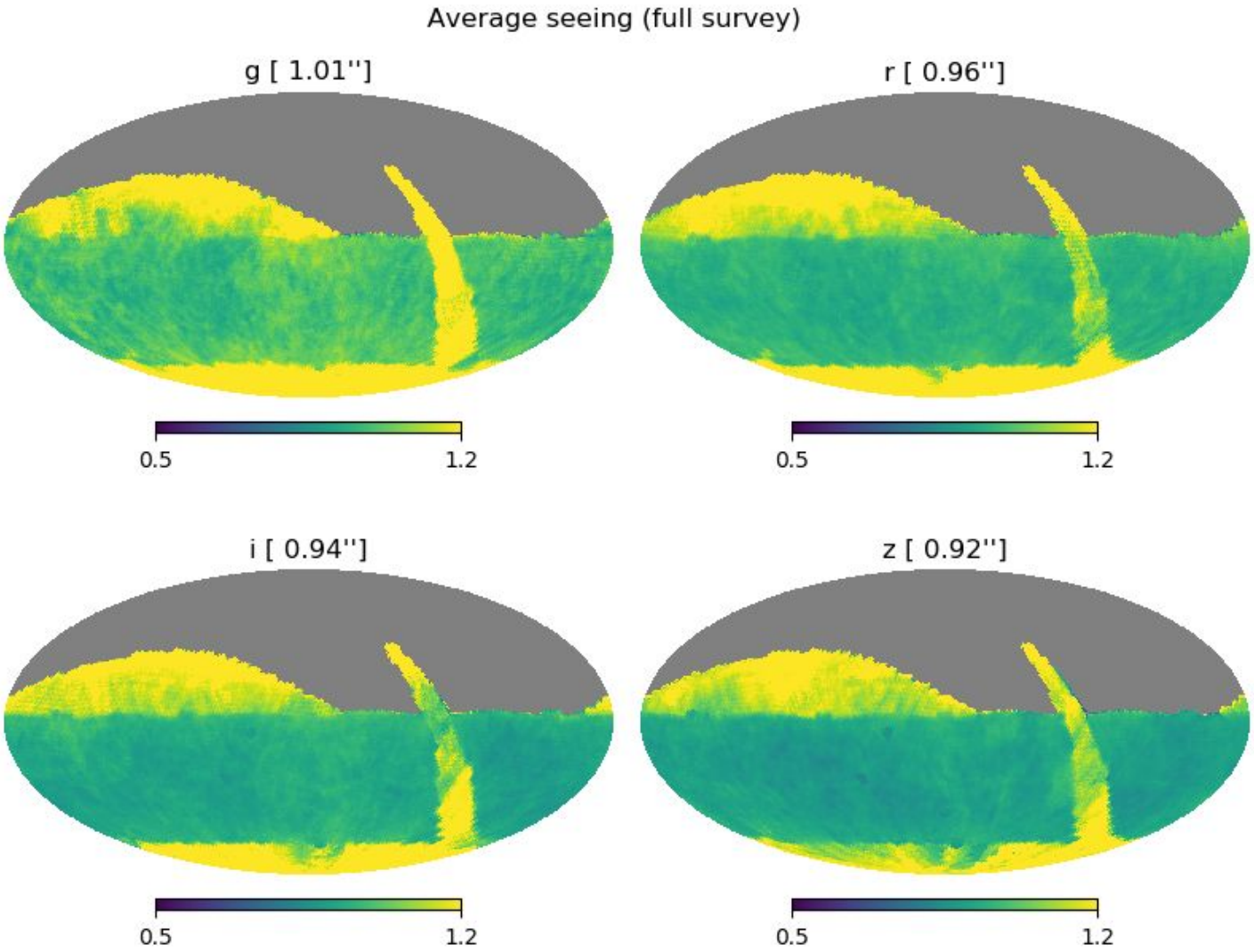
Example


median Δt between obs (Full survey)
g [25.1 days]
r [12.9 days]
i [12.7 days]
z [14.8 days]
0
30
0
30
0
30
0
30

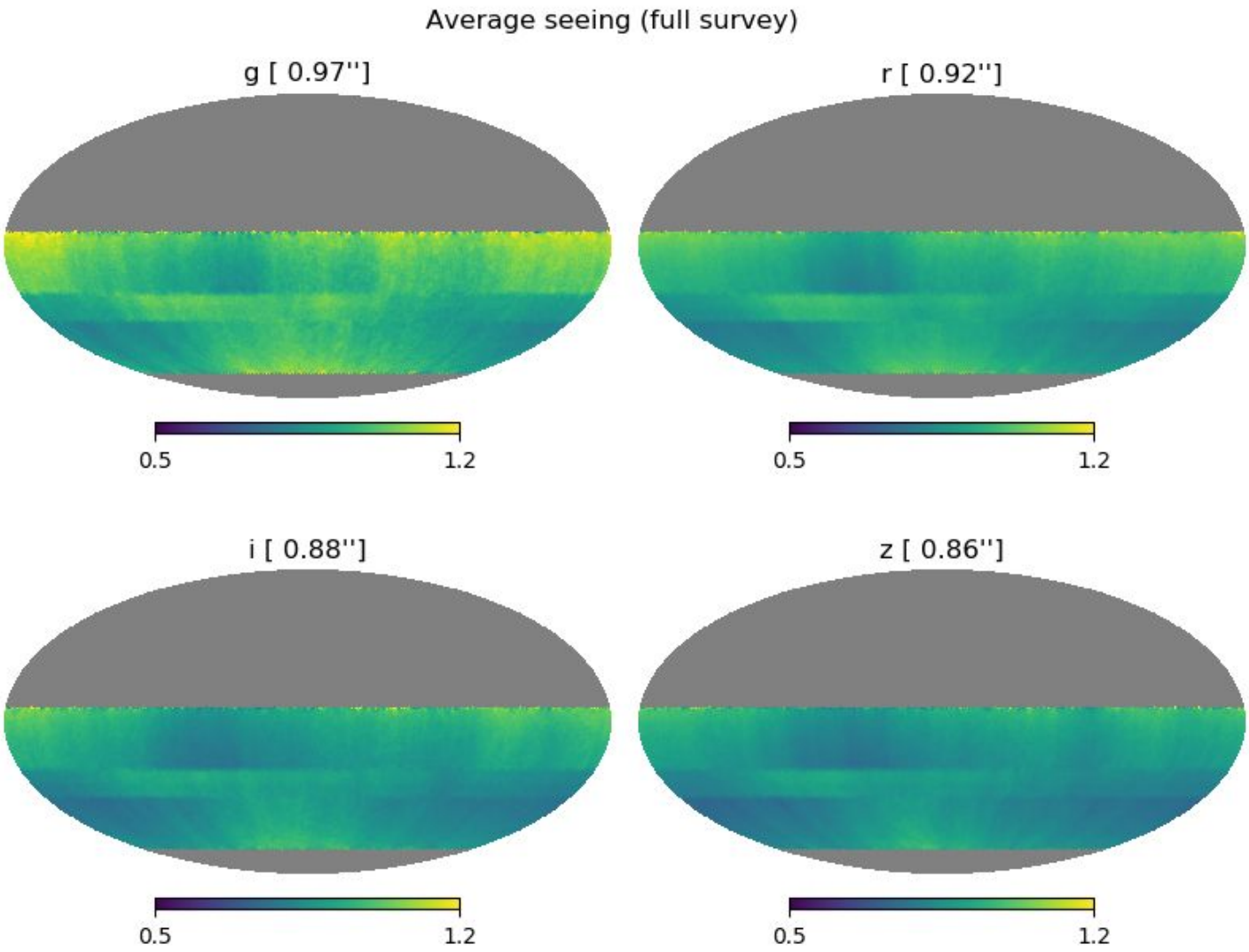
Example


median Δt between obs (Full survey)
g [7.7 days]
r [2.9 days]
i [4.3 days]
z [3.3 days]
0
30
0
30
0
30
0
30

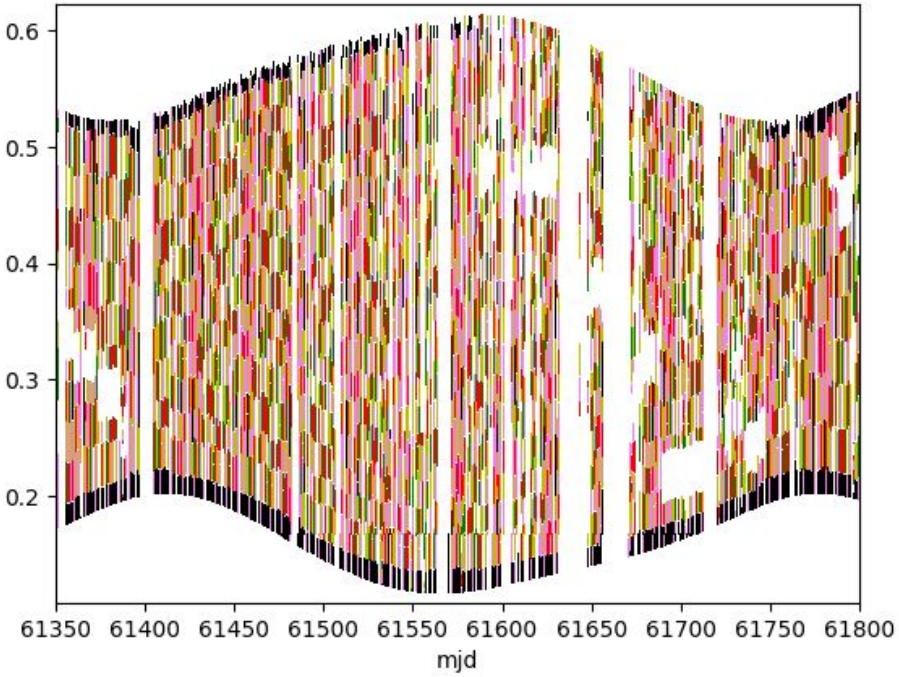
Different mean observing conditions



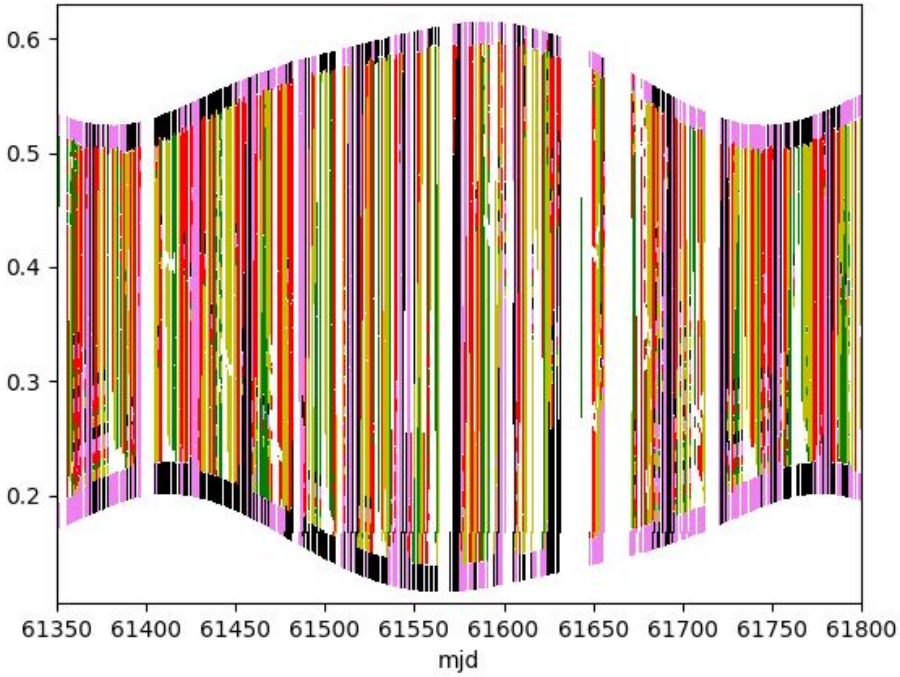
Different mean observing conditions



Different filter allocation strategies



AltSched rolling



Minion 1016

Guarantees that each field observed in
At least 2 bands during a given night

Keep observing in a given filter over long durations

Global filter allocation

name	# visits					
	u	g	r	i	z	y
Minion 1016	181479	246667	538936	541688	493206	446306
	7.4%	10.1%	22.0%	22.1%	20.1%	18.2%
Feature baseline 10 yrs	159252	245015	503803	506598	474436	415687
	6.9%	10.6%	21.9%	22.0%	20.6%	18.0%
Feature rolling half mask	161705	248253	498985	500143	468829	407239
	7.1%	10.9%	21.8%	21.9%	20.5%	17.8%
Feature rolling twoThird	168475	249395	485866	487889	458198	392546
	7.5%	11.1%	21.7%	21.8%	20.4%	17.5%
AltSched	170952	221660	570519	376786	529925	177866
	8.3%	10.8%	27.9%	18.4%	25.9%	8.7%
AltSched Rolling	158792	203909	567306	376261	556285	186852
	7.7%	9.9%	27.7%	18.4%	27.1%	9.1%

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

- Goal:
  - Verify that survey cadences released so far allow us to constrain a ubercal solution
- 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 ?
  - Are some dithering patterns significantly better than others ?
  - Are there specific error modes, at specific scales that have an impact on the analyses ?

Ubercal toy model

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

Measurement

Calibrated mag

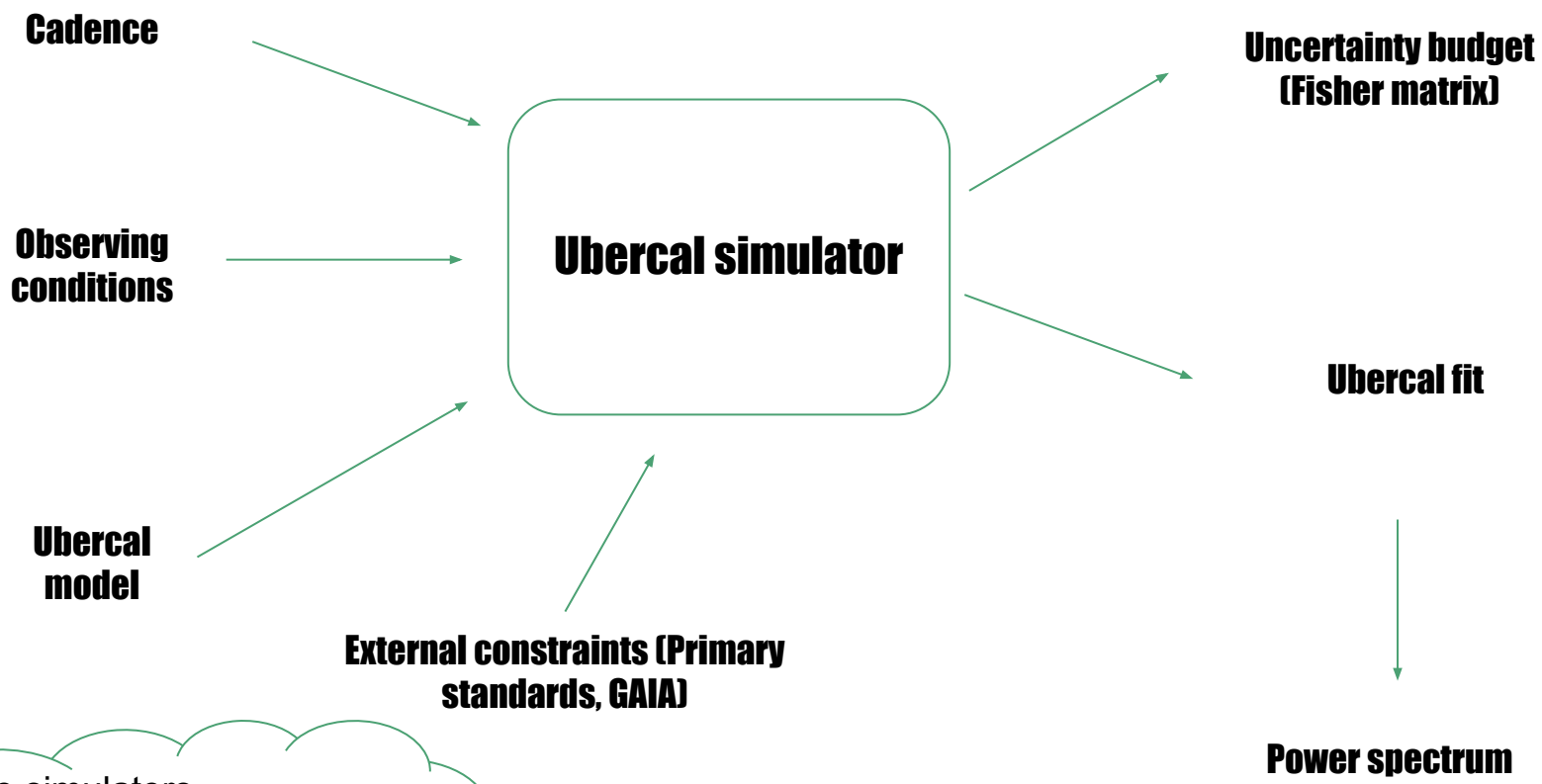
Exposure ZP

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 ?)

Fast ubercal simulator



Two simulators available so far:
- Using healpixs (NR)
- Using stars

(F. Feinstein et al)

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 $F = LDL^T$

~ 1.5 hours For 2 yrs of survey
and 1 phot flat every month

Gives access to covariance matrix

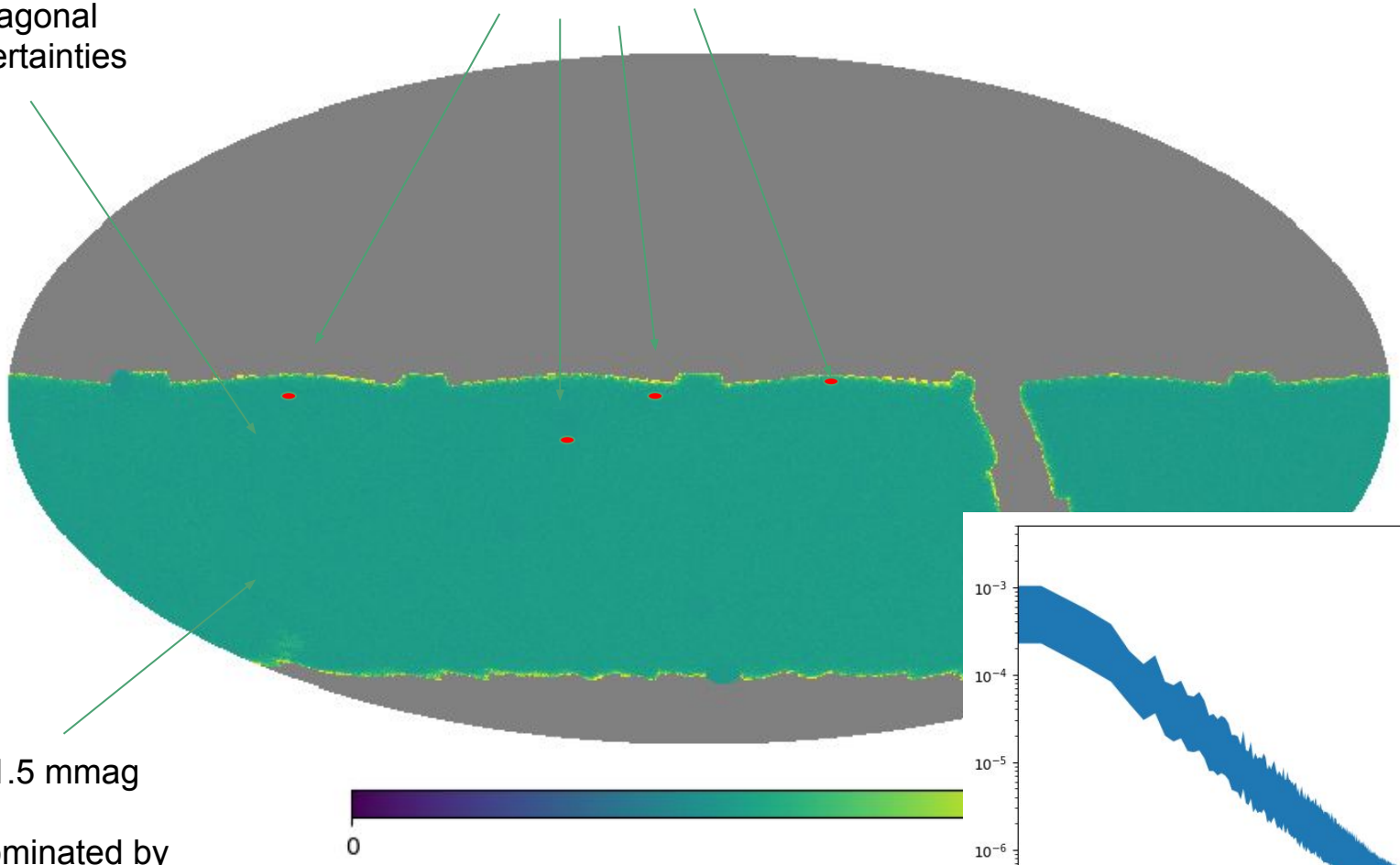
Results

- Have performed systematic checks of all cadences available
  - 35 cadences (OpSim, Feature/SLAIR, AltSched)
  - Measurement error model:
    - assume 2 mmag / superpixel (shot noise + flat field error)
  - with / without dithers
    - -> random dithers obtained from Humna Awan (DESC)
  - with flux references in the DDFs / equatorial location

Output

Equatorial standards

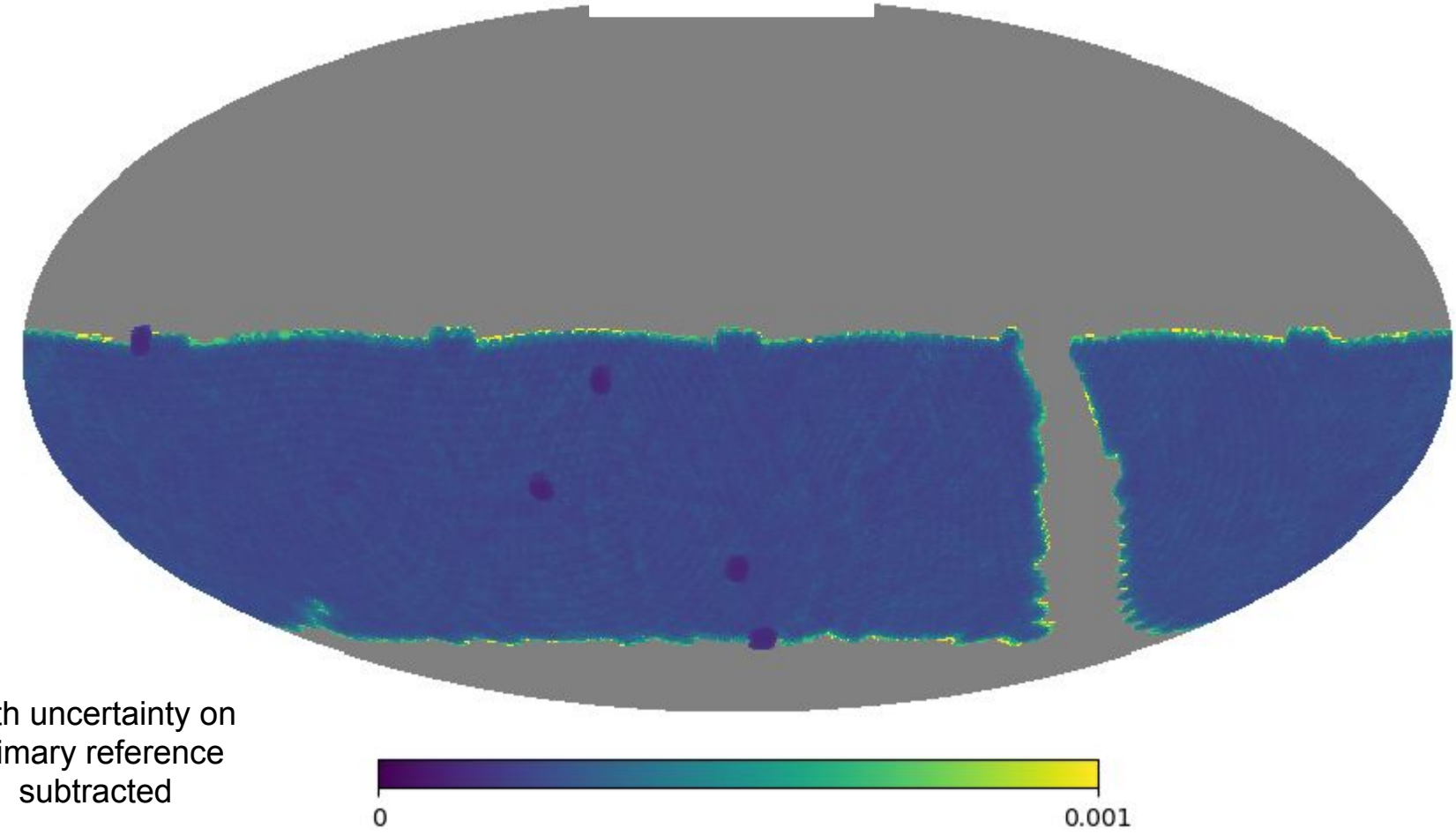
Diagonal uncertainties



1.5 mmag

Dominated by uncertainties on primary flux references

With uncertainty on primary refs subtracted



With uncertainty on primary reference subtracted

<< 1 mmag

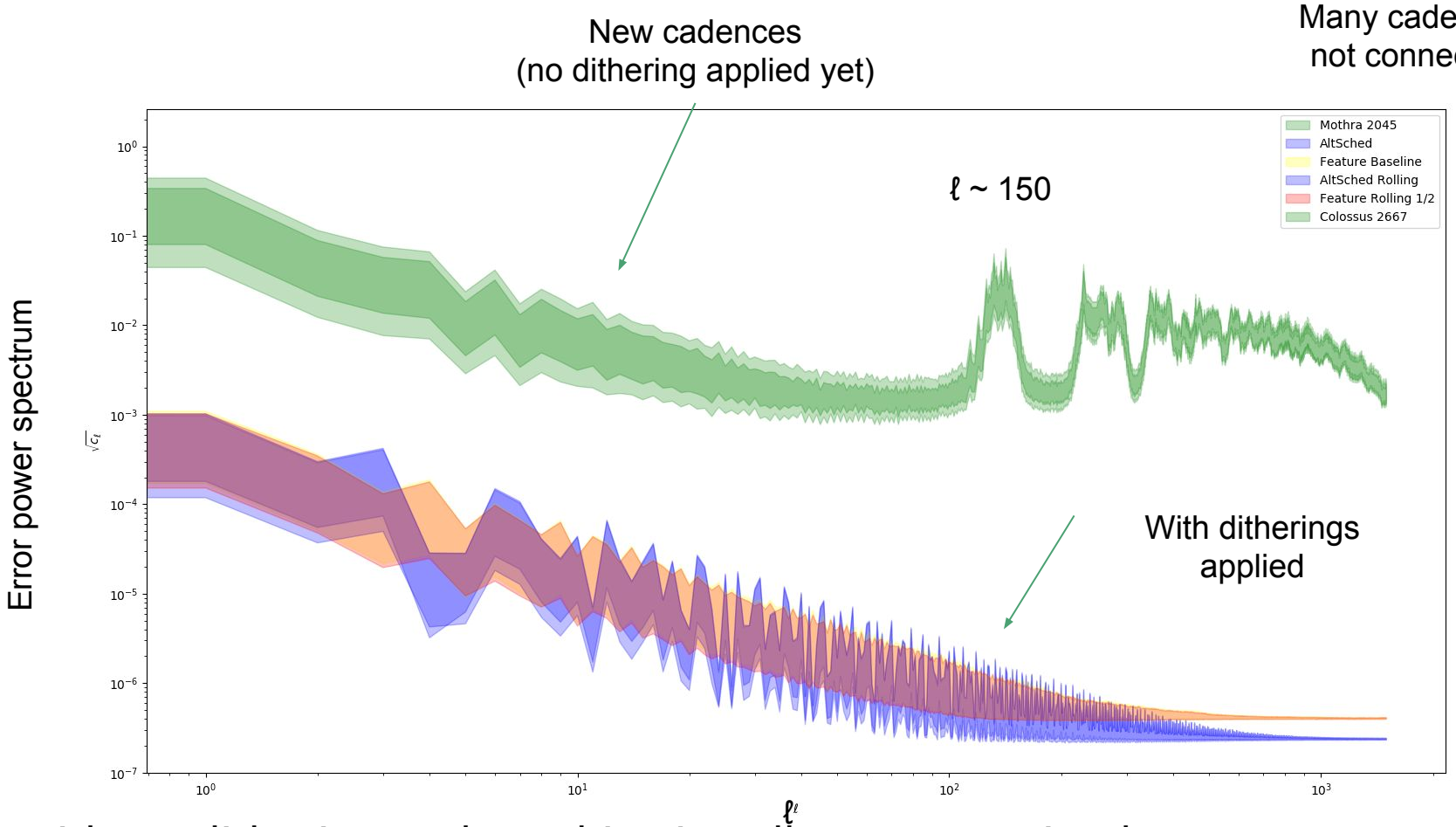
Minion 1016

Results

- After one year of survey
  - 25% of all cadences do not allow to obtain a ubercal solution
  - All are rolling cadences
  - Adding flux references in DDF's helps only marginally
  - All non-rolling cadences are well connected
- After 2 years of survey
  - All cadences that do not yield a "problem too large for cholmod" have a solution,
  - Working on a fix that will drastically reduce the size of the problem passed to cholmod (and the speed of the fit),
- A good dithering pattern is key

Ditherings are essential

(with 2 years of survey)

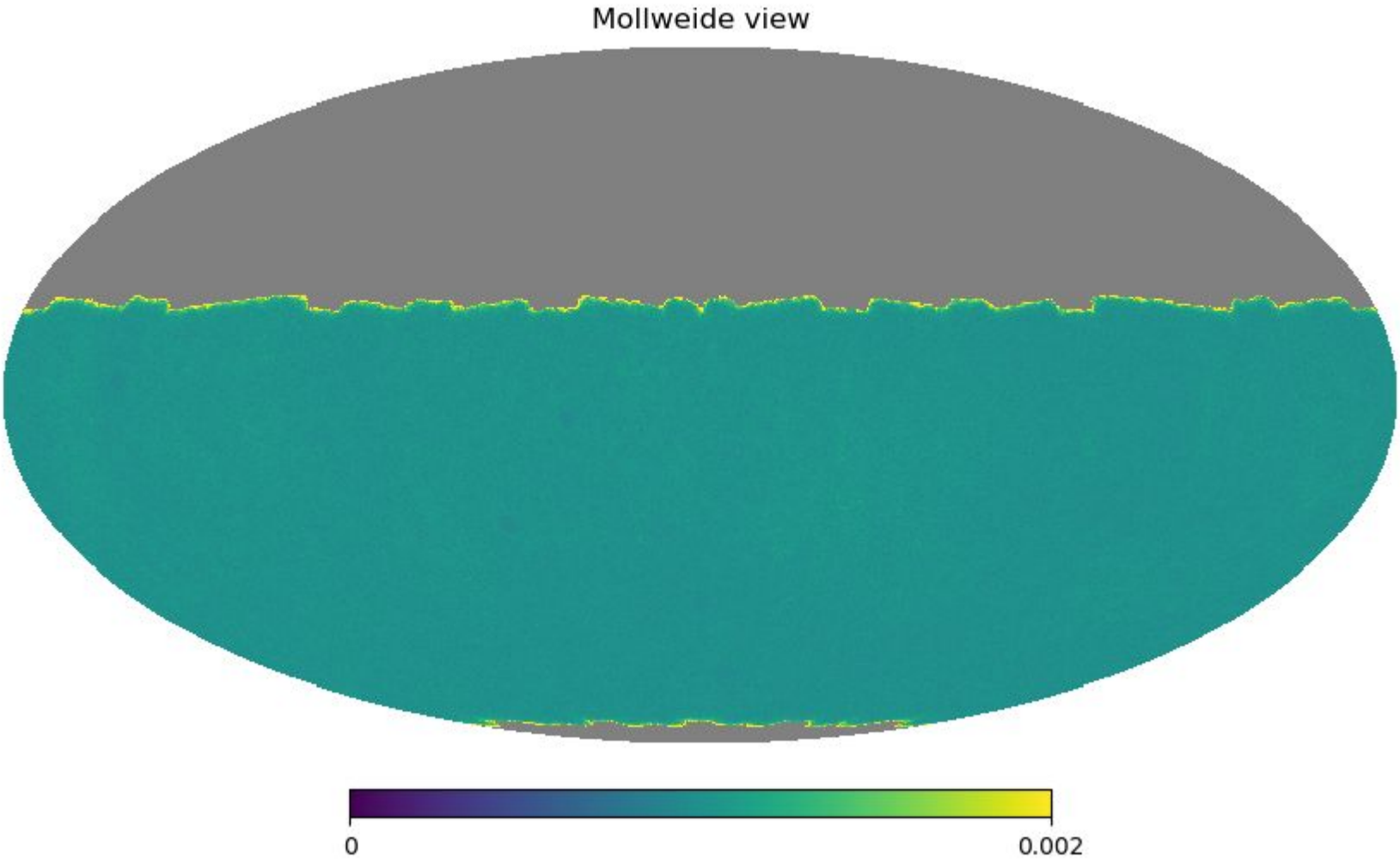


- without ditherings, ubercal is virtually unconstrained
- with large error modes at specific locations

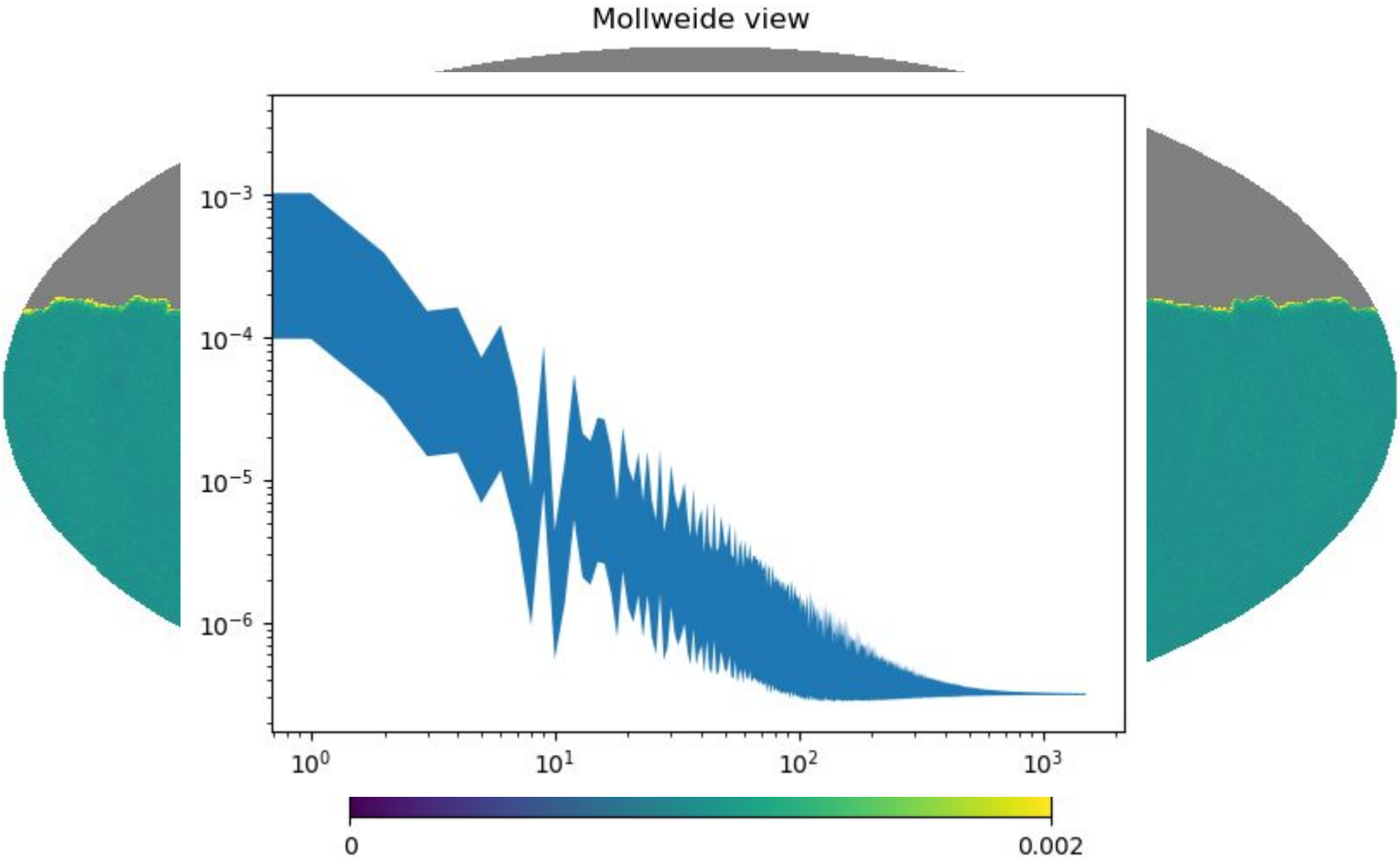
Results

- Propagation of measurement noise only
  - Yields final uncertainties below 1mmag
  - (dominated by uncertainties of measurement of flux refs)
- When the standard ditherings have been applied
  - no specific error modes can be seen in the uncertainty spectrum

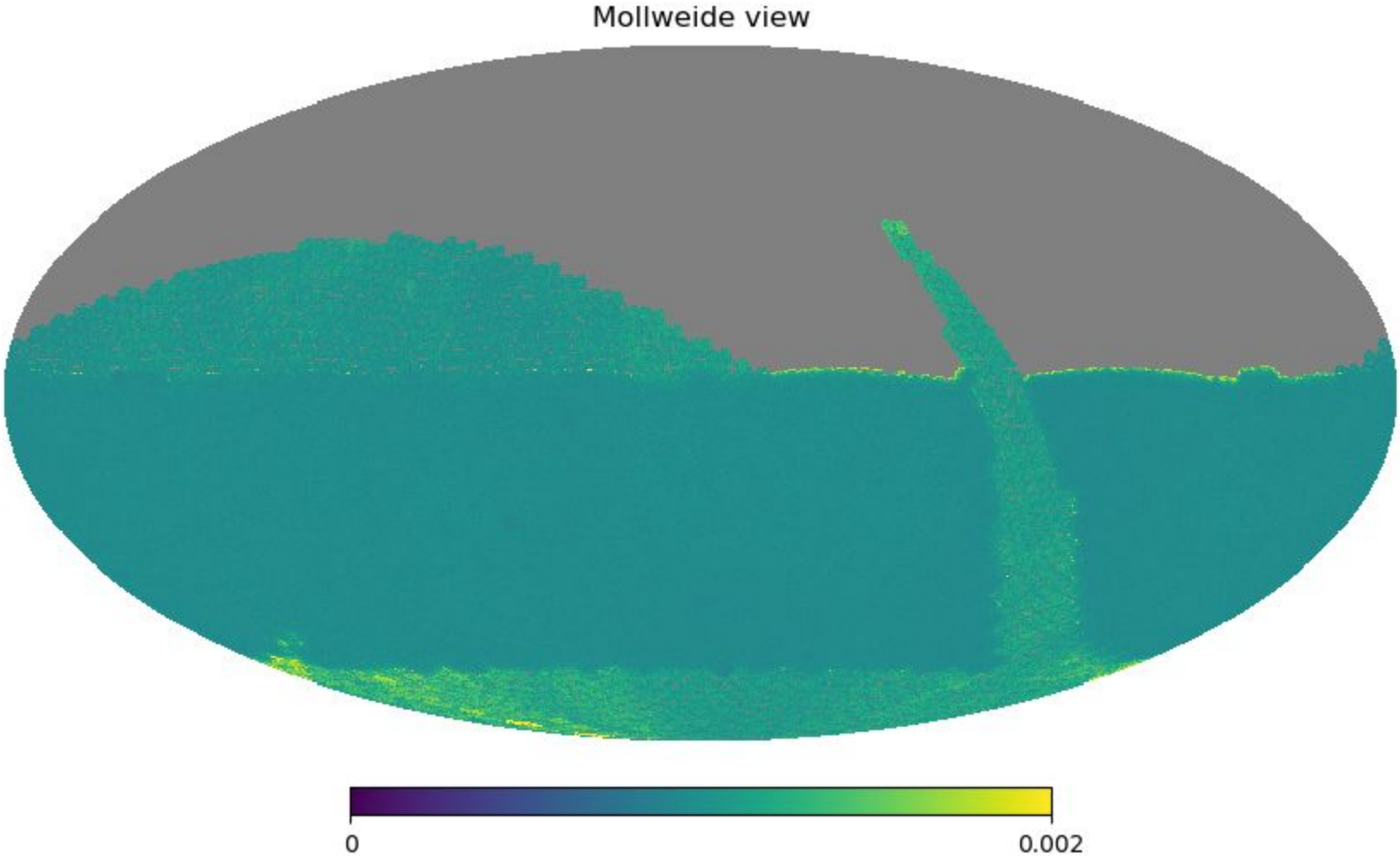
Example: Pontus 2002



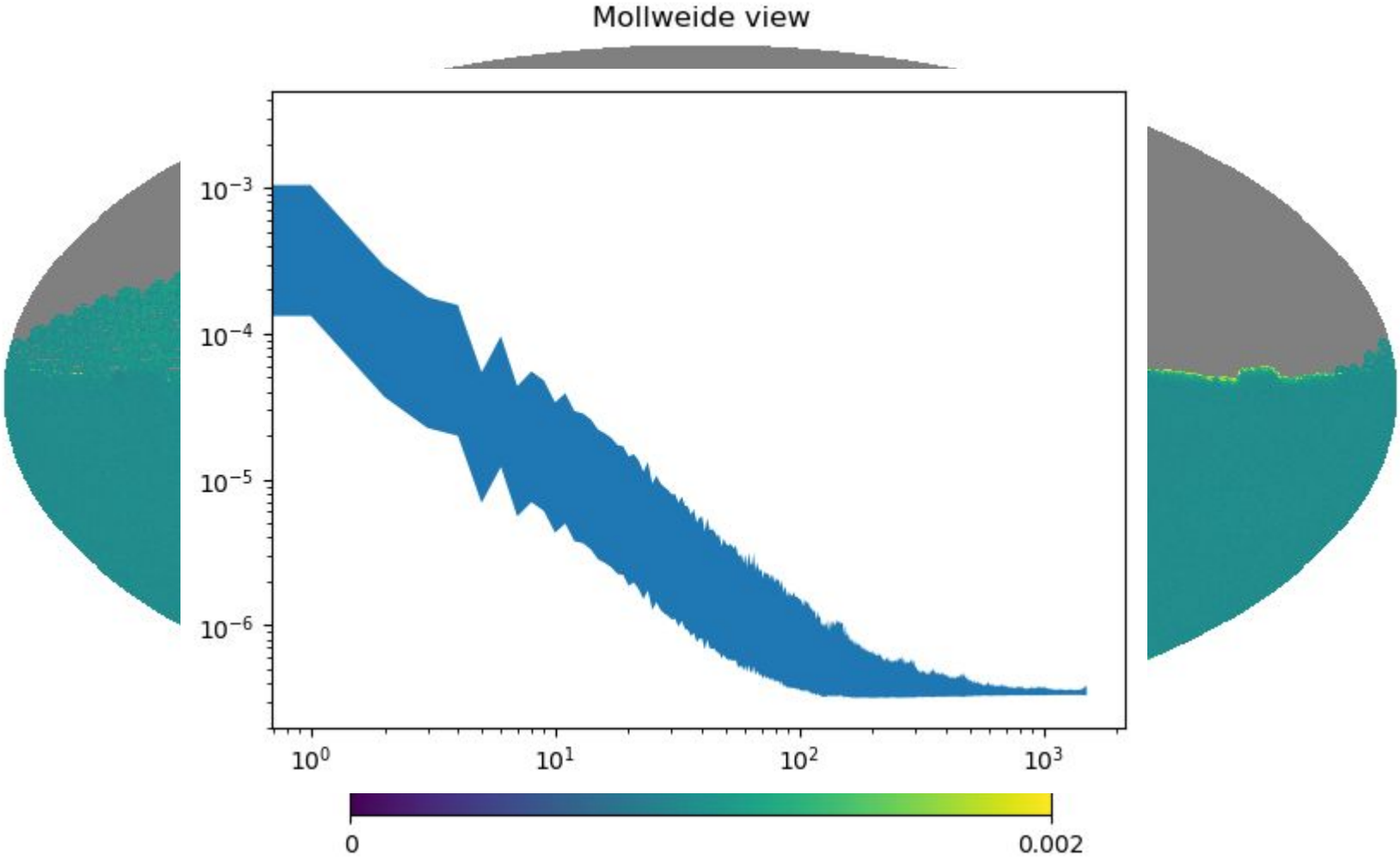
Example: Pontus 2002



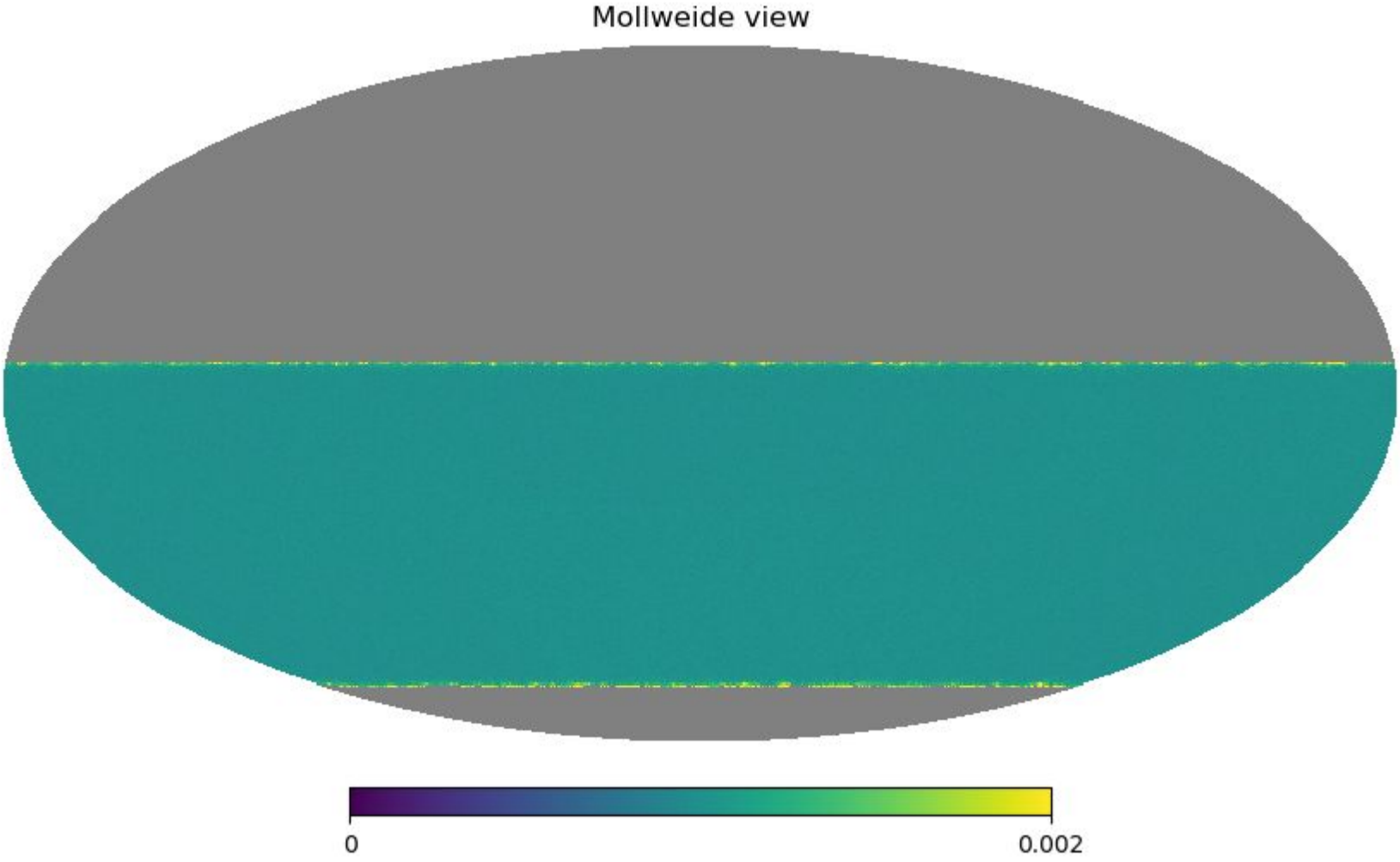
Example: Kraken 2042



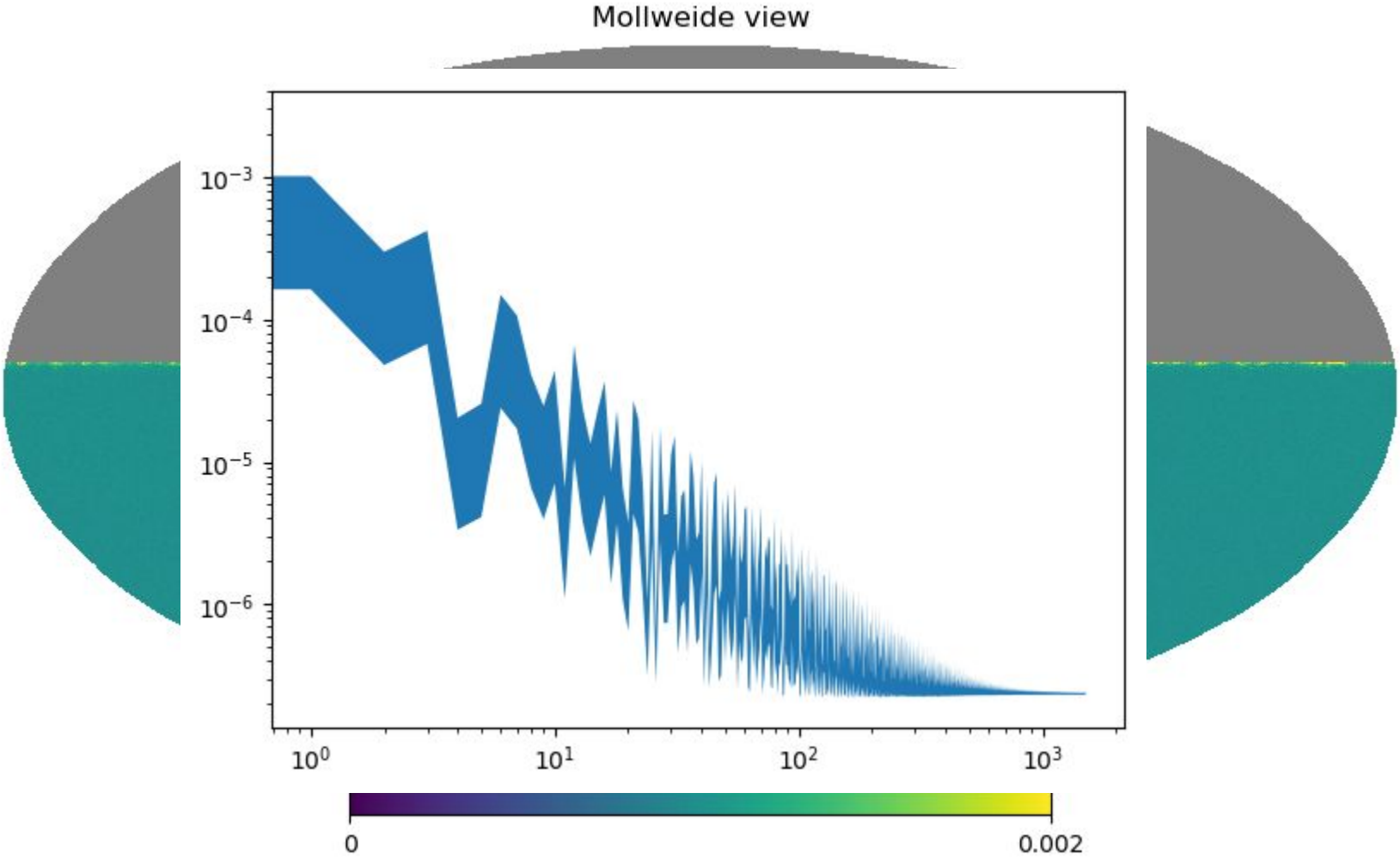
Example: Kraken 2042



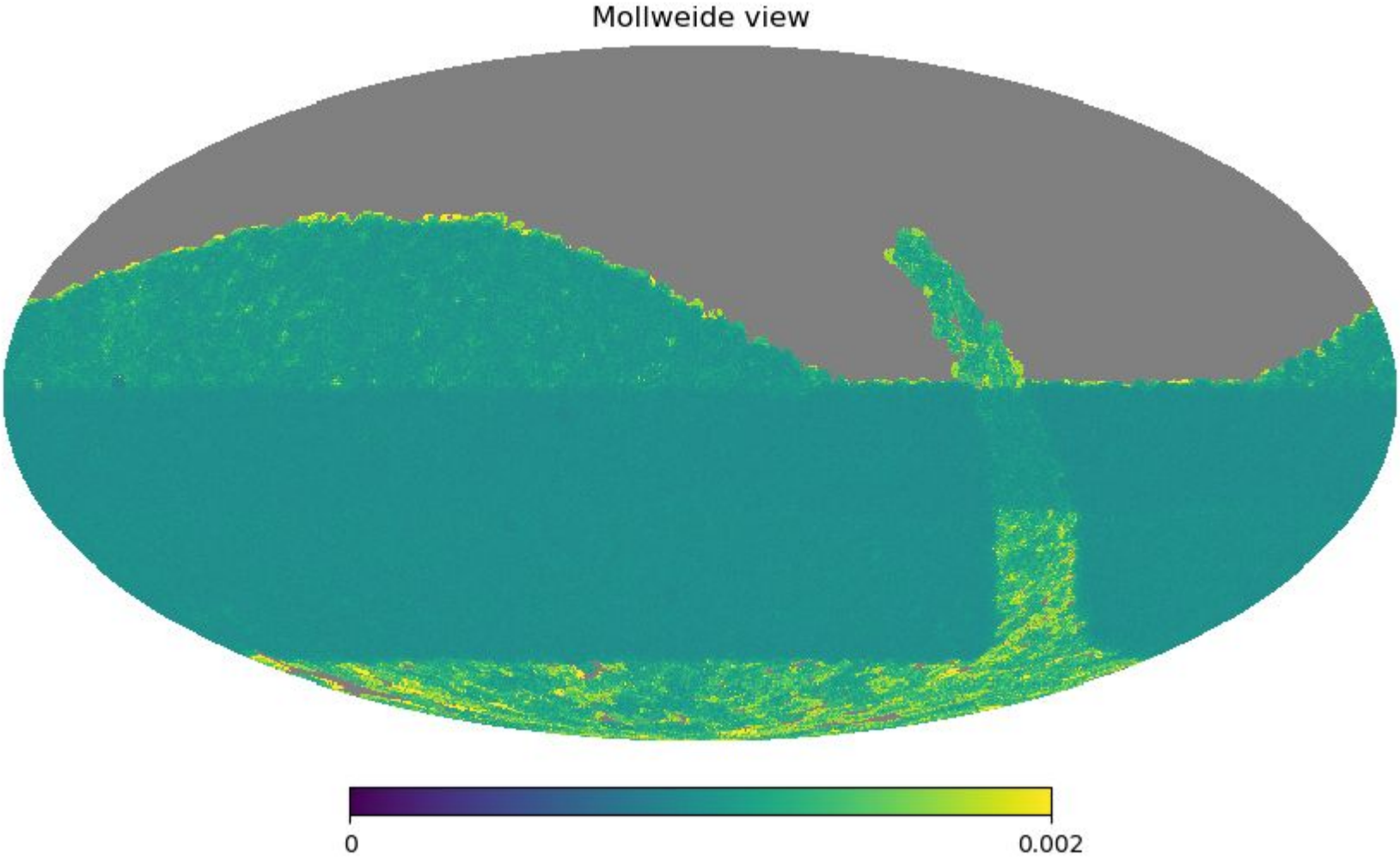
Example: Altsched rolling



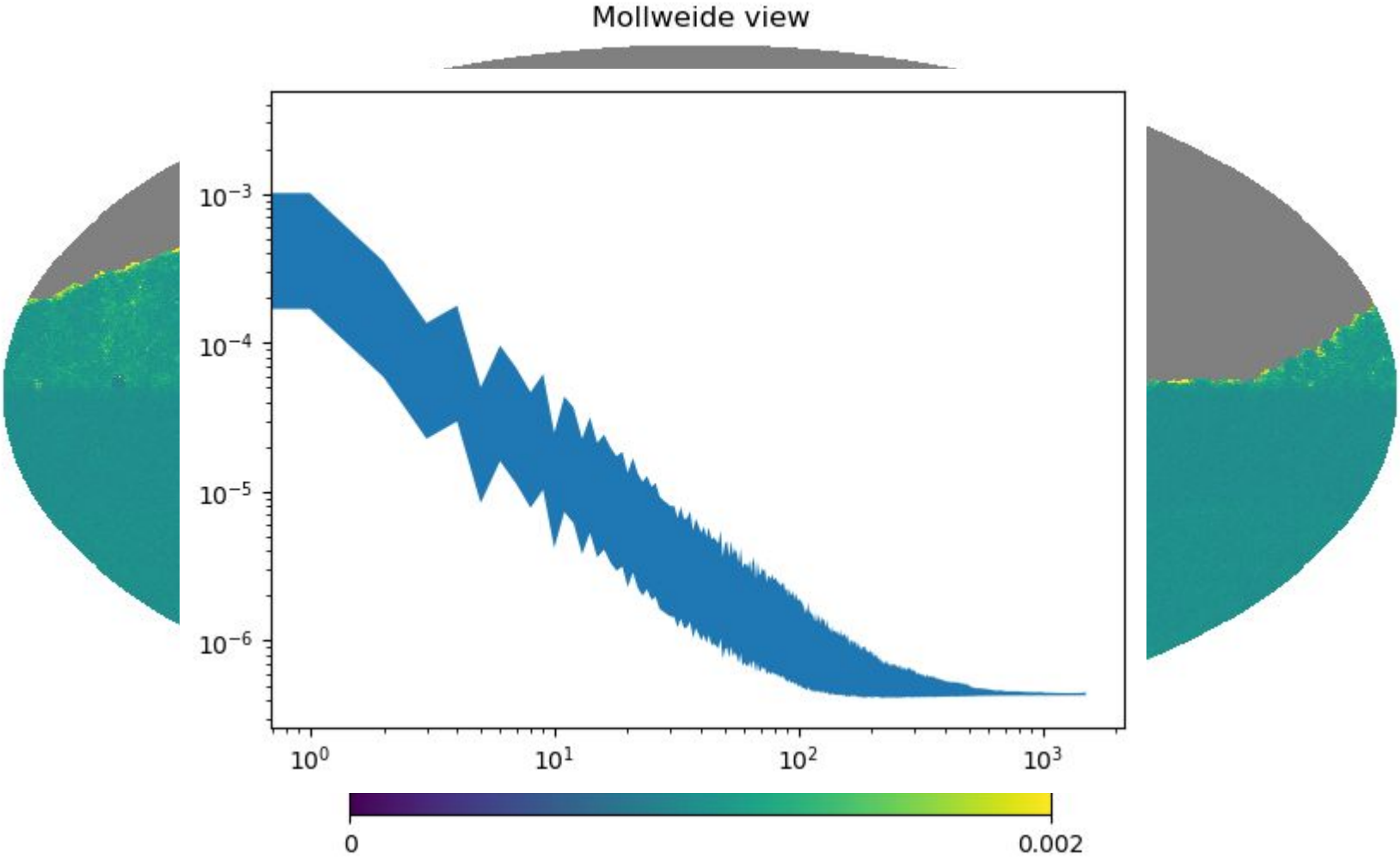
Example: Altsched rolling



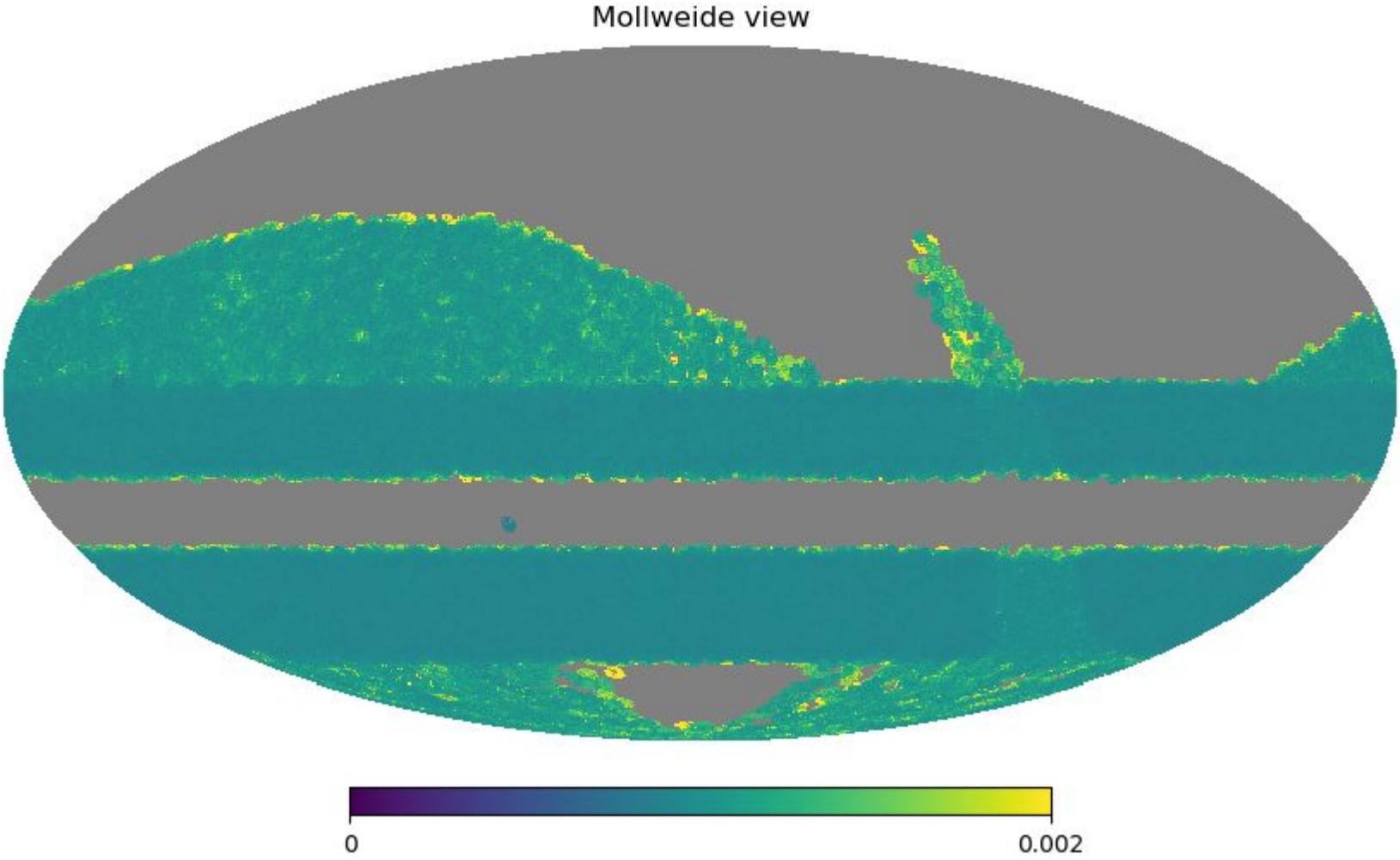
Example : Feature rolling 1/2



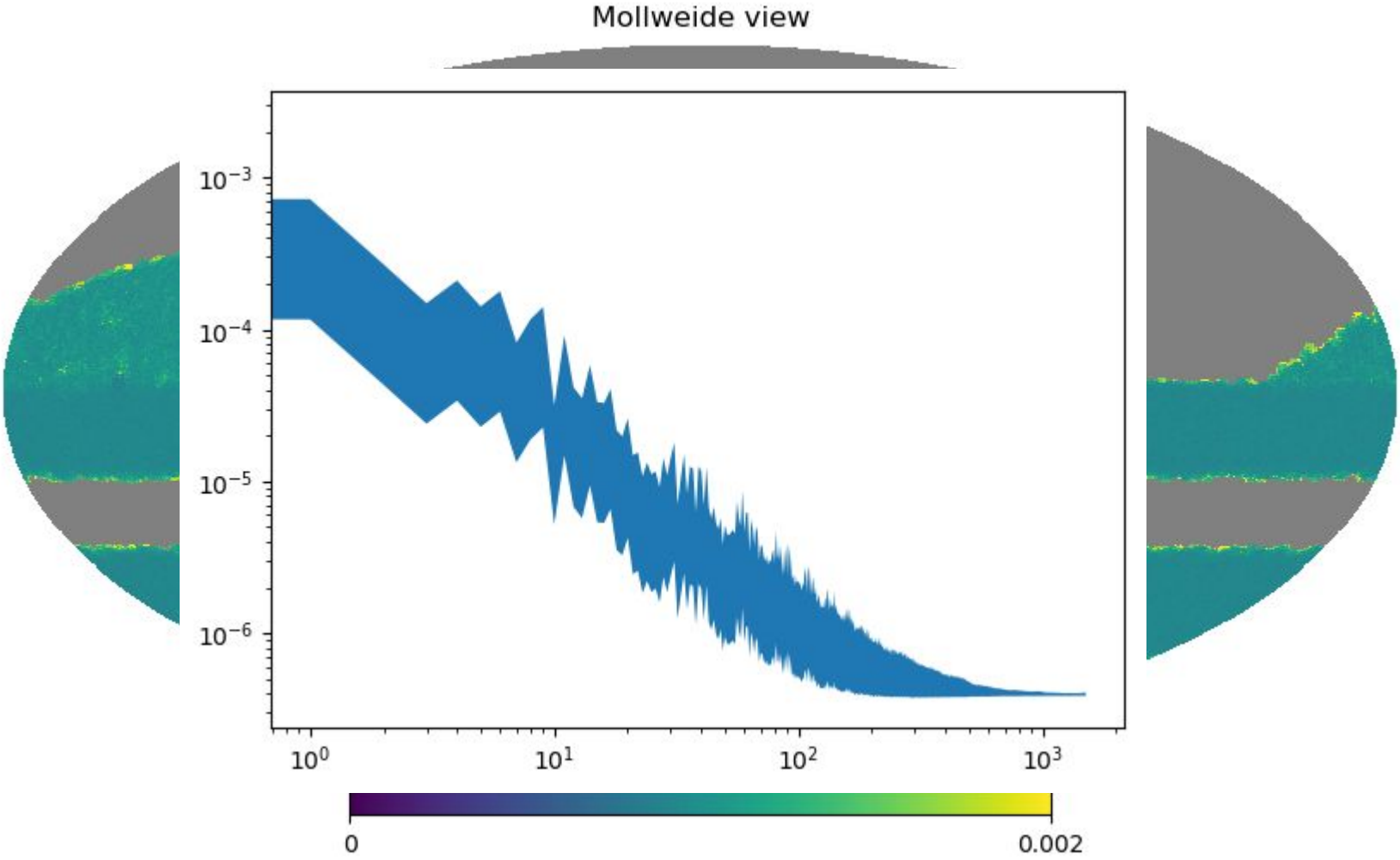
Example : Feature rolling 1/2



Example : Feature rolling 2/3



Example : Feature rolling 2/3

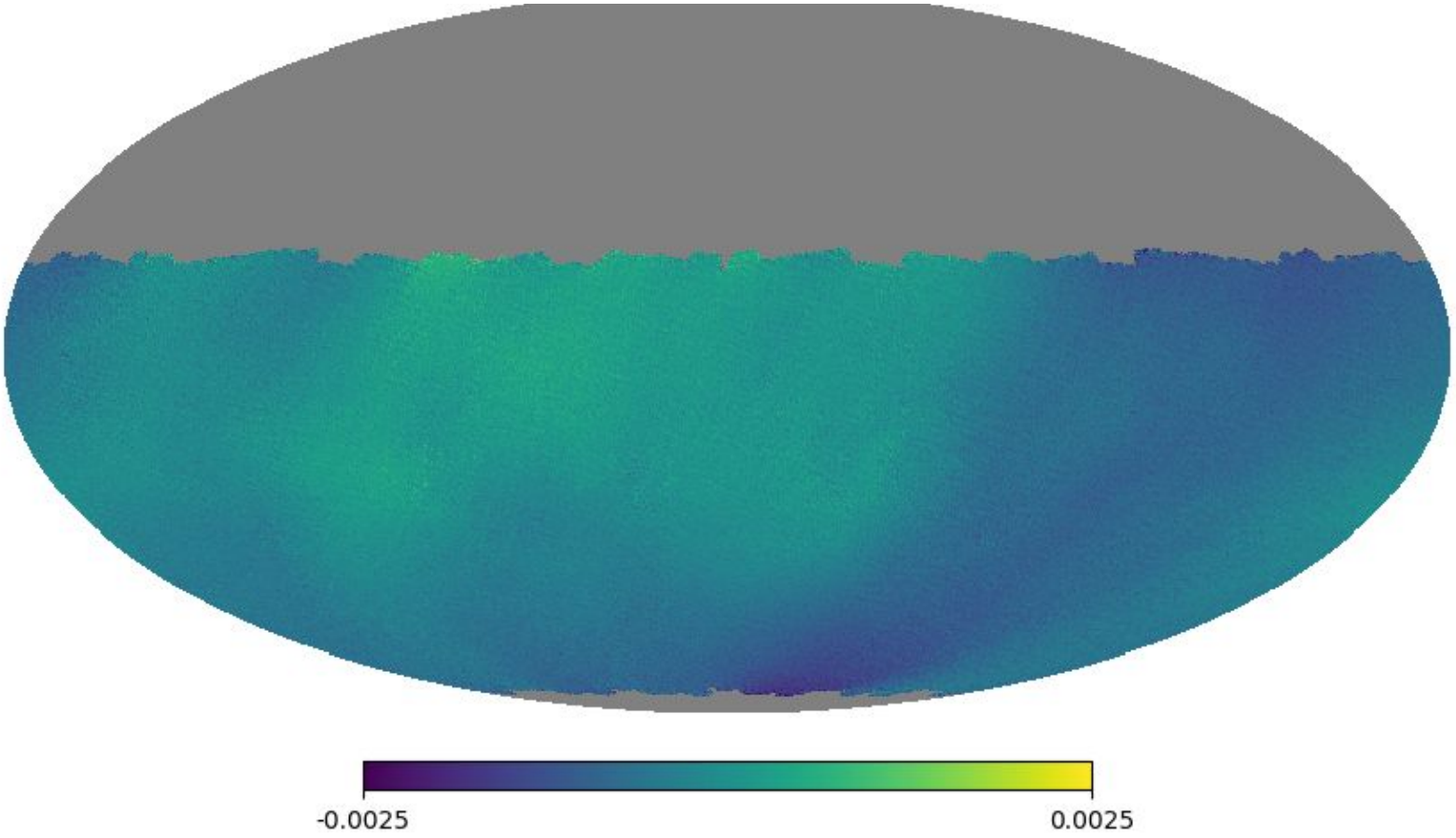


Adding instrumental / seasonal drifts

- How does the ubercal fit behave if we add:
  - Systematic (periodic) instrumental variations (e.g. variations of gains throughout the night, following the same pattern)
  - Sharp variations of aperture flux estimates
  - Seasonal variations of flux estimates
- Does this root-n down ?
- Is it detectable in the data ?

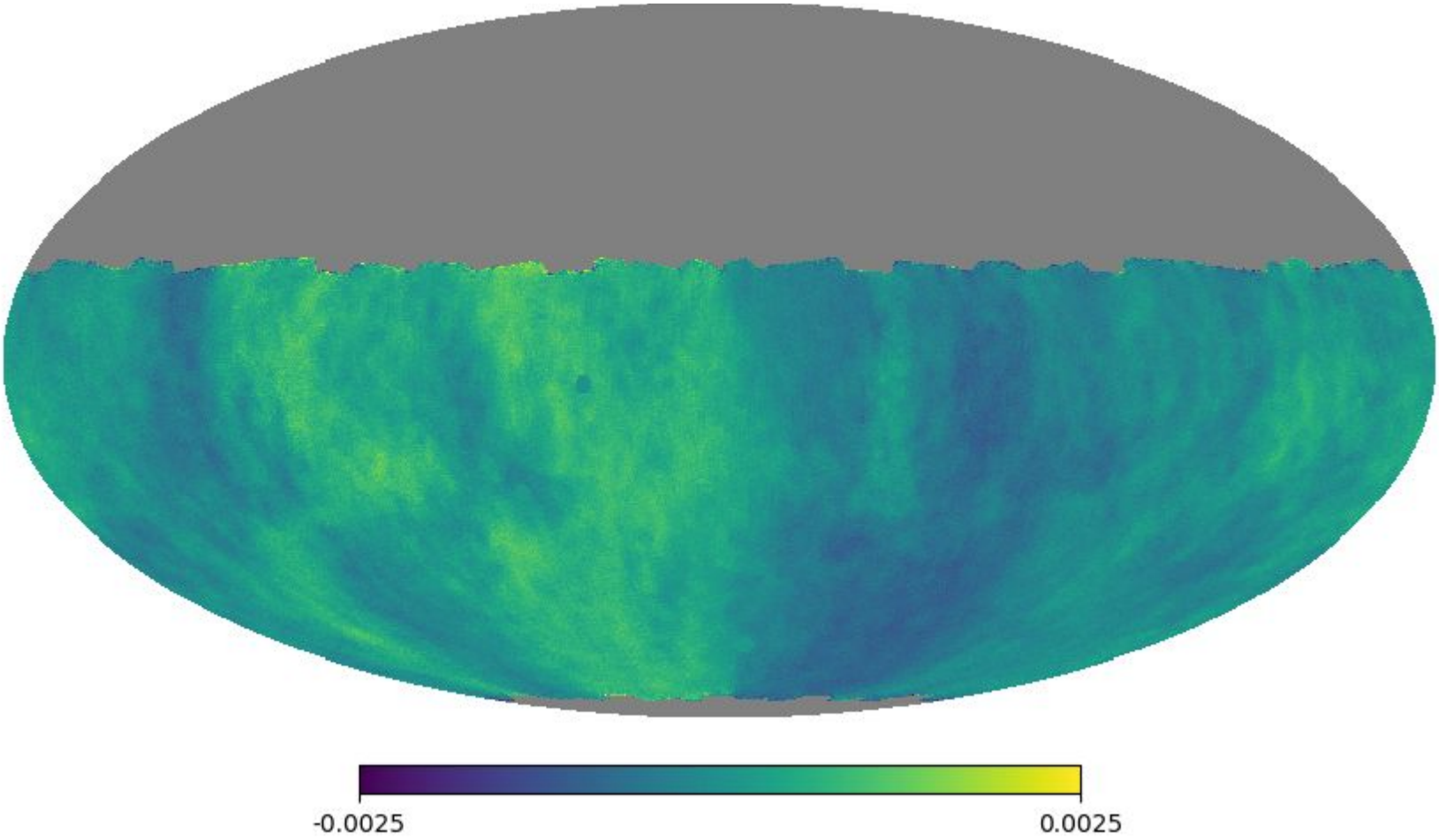
Example : Pontus 2002

- ~ 0.2% peak-to-peak linear variations throughout the night



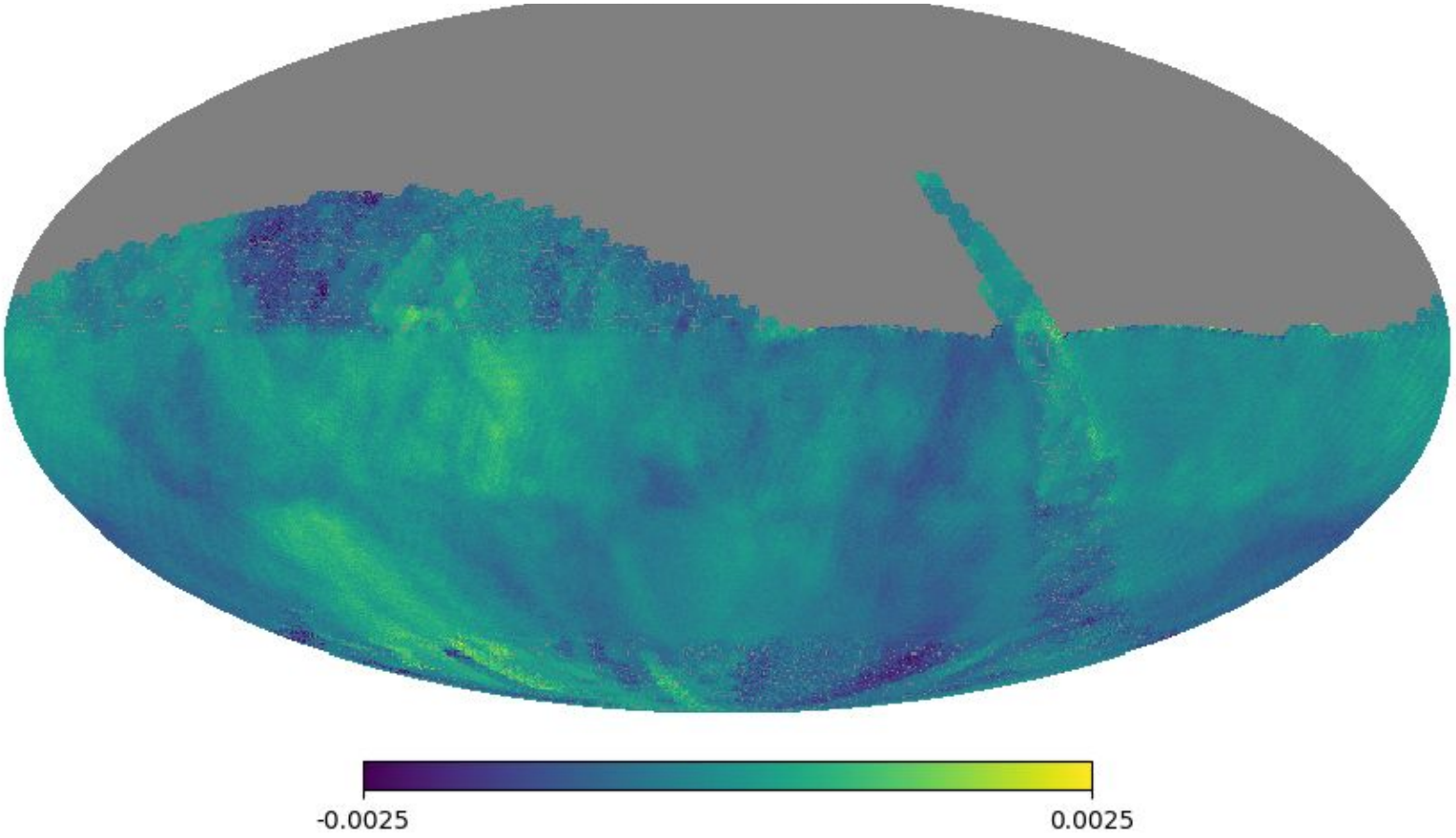
Example : Pontus 2002 (2 years)

- ~ 0.2% peak-to-peak linear variations throughout the night



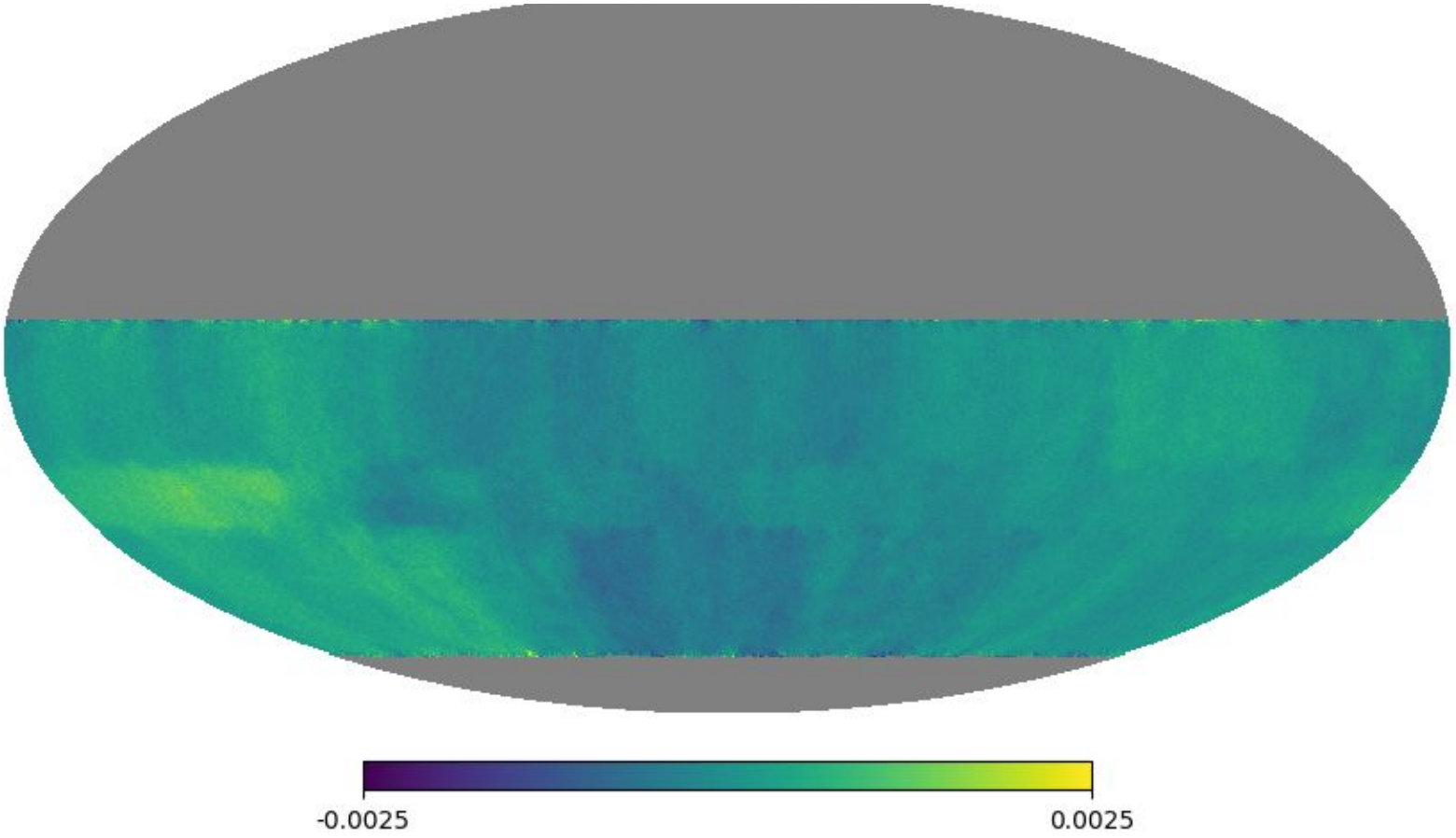
Example : Kraken 2042

- ~ 0.2% peak-to-peak linear variations throughout the night



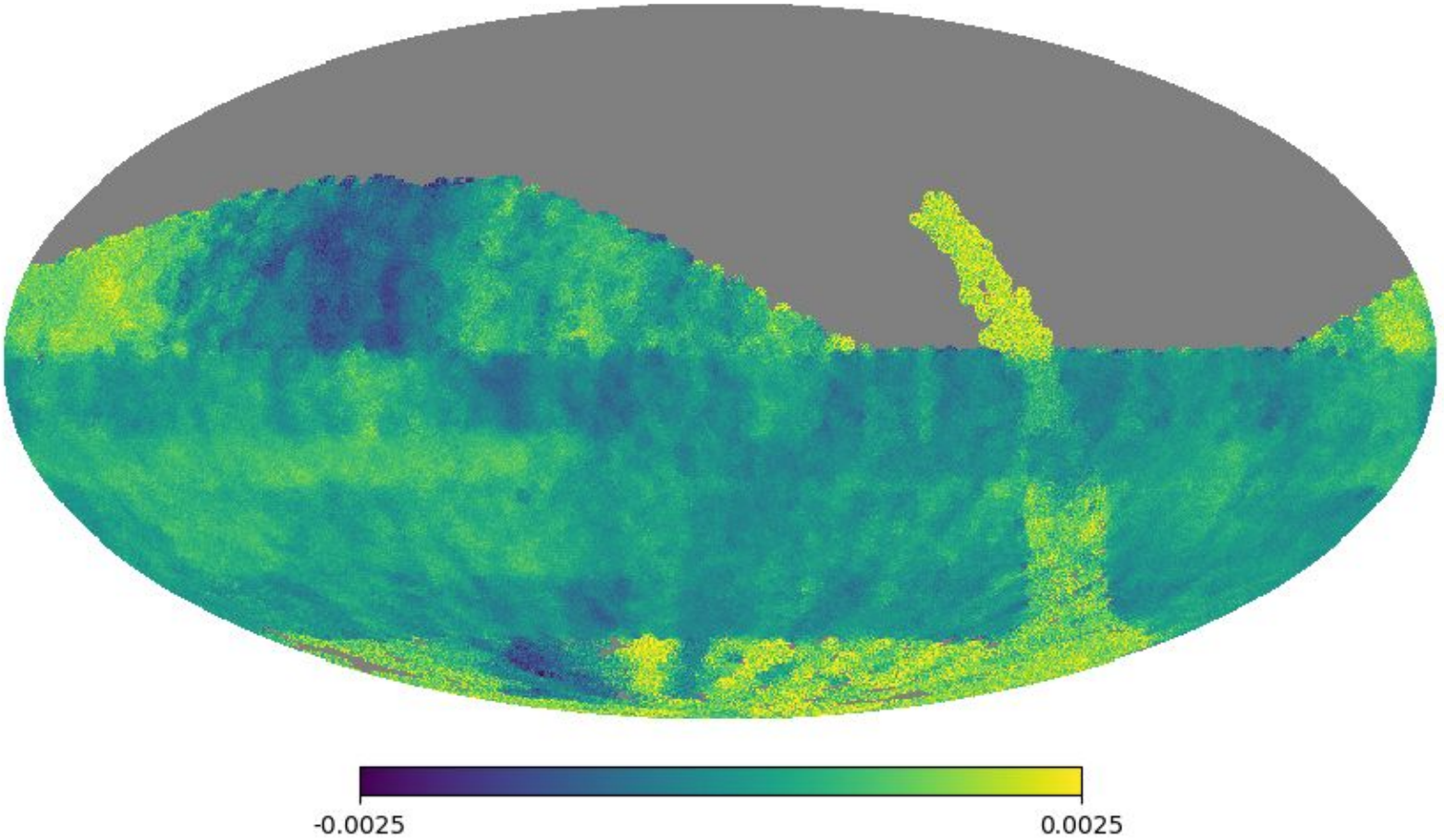
Example : Altsched rolling

- ~ 0.2% peak-to-peak linear variations throughout the night



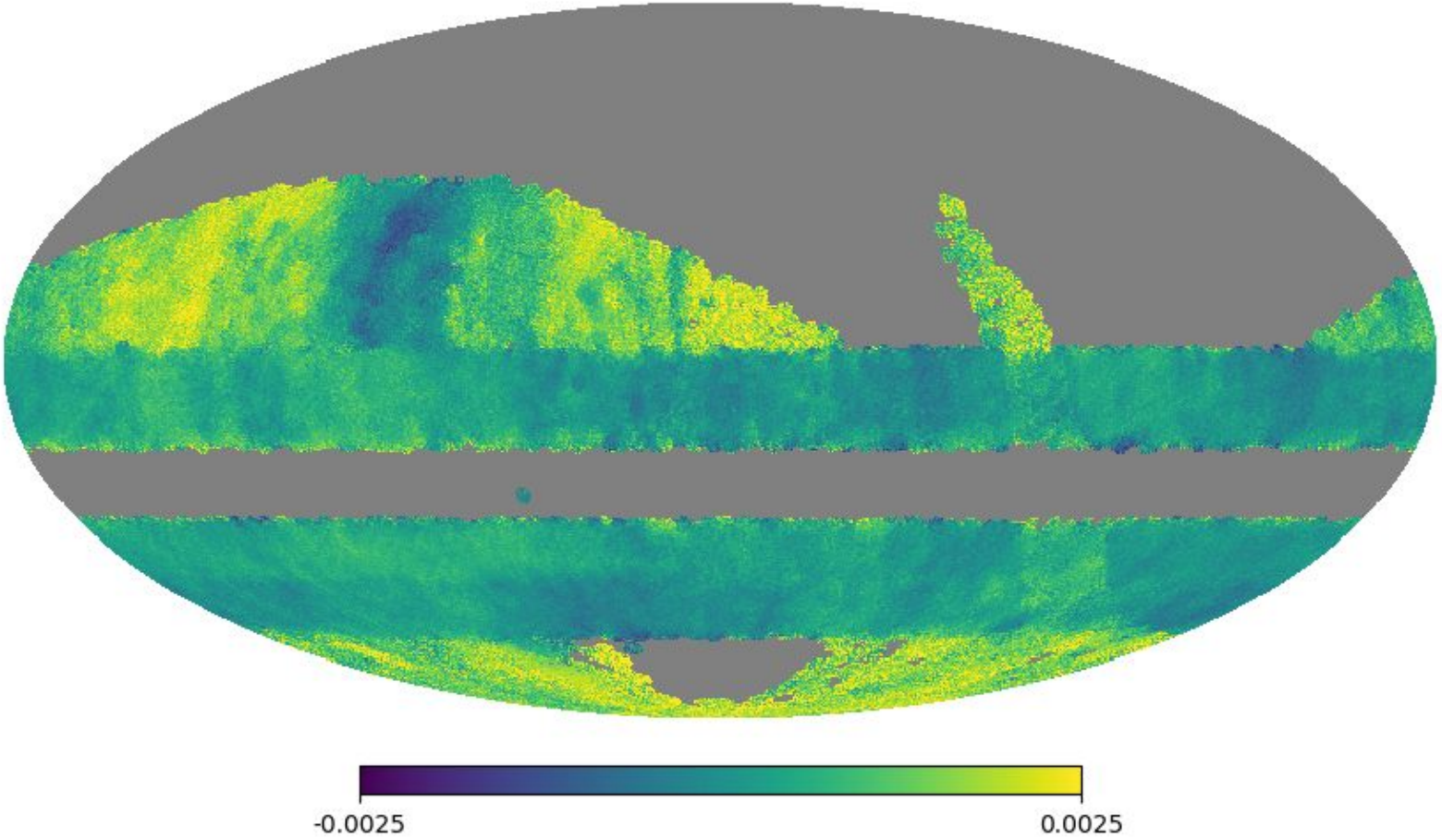
Example : Feature rolling 1/2

- ~ 0.2% peak-to-peak linear variations throughout the night



Example : Feature rolling 2/3

- ~ 0.2% peak-to-peak linear variations throughout the night



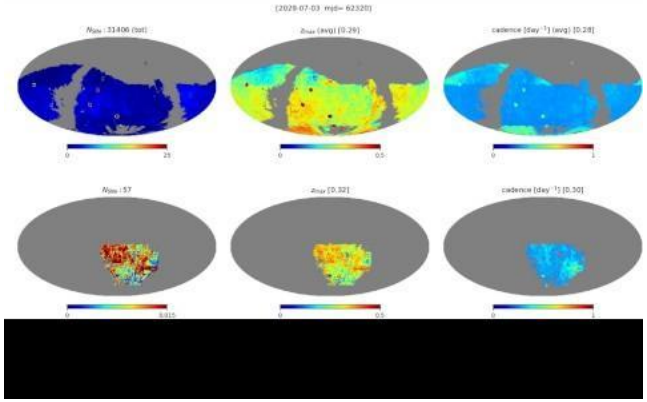
Conclusion & work ahead

- All non-rolling cadences yield an ubercal solution after 1 year of survey (good news)
- It seems that all cadences yield an ubercal solution after 2 years of survey (final answer soon for the cholmod-resistant cadences)
- As long as we have good dithering patterns
  - Photon noise contribution is totally negligible
  - Obs strategy does not leave specific pattern in error budget coming from measurement noise
- Adding instrumental or seasonal drifts leaves an inprint
  - not absorbed by the (very resilient) ubercal model
  - that is specific to the cadence
  - Can such variations be detected in the data during ubercal fit (ongoing investigations)

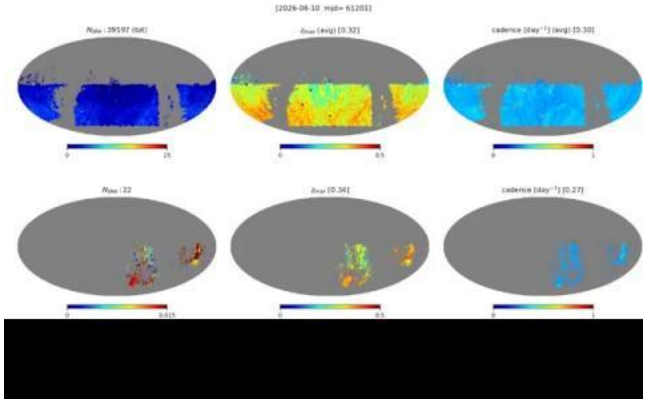
Backup slides

Examples

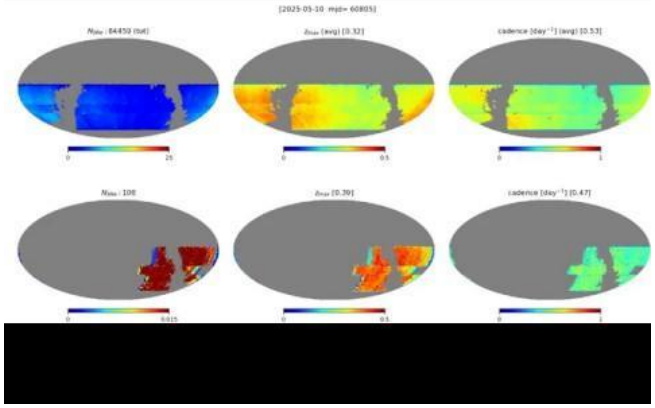
Minion



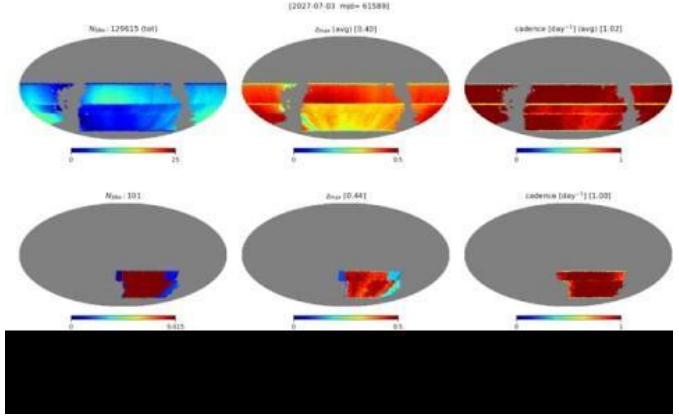
Baseline 2018



AltSched



AltSched rolling

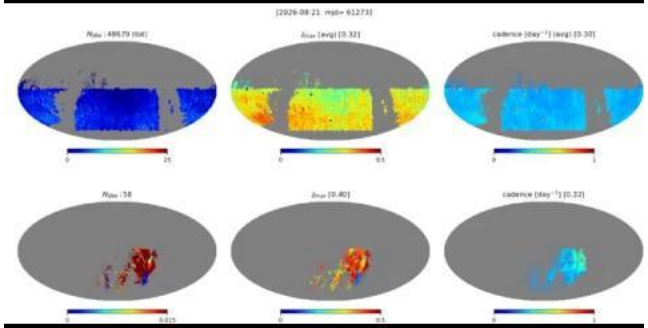


http://supernovae.in2p3.fr/~nrl/lsst_sn_cadence/

Examples

New baseline candidate

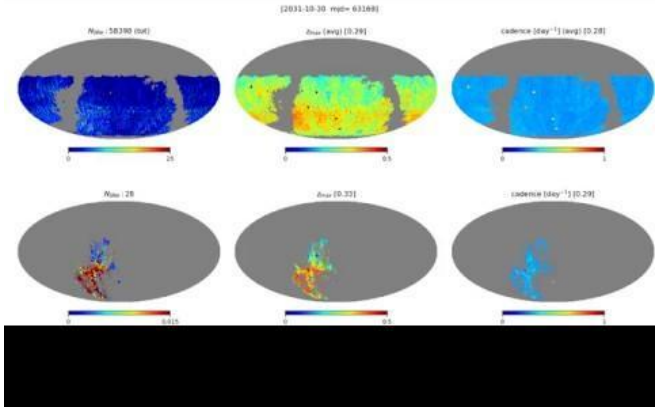
Kraken 2026



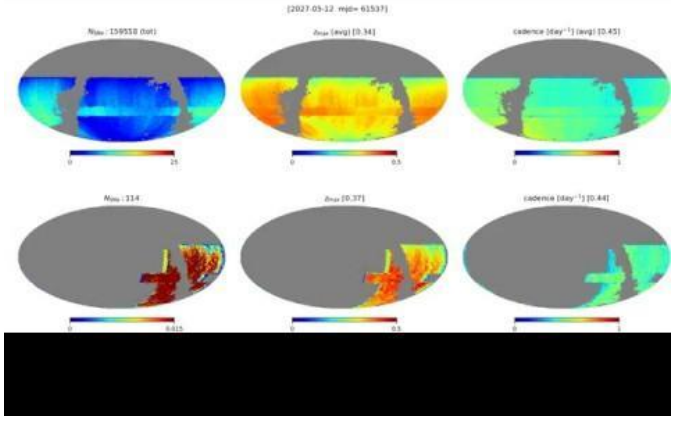
Very wide WFD
Altsched experiment
By P. Gris, with guidance and help from D. Rothchild

Very wide WFD

Pontus 2002



AltSched rolling



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