BeyondPlanck

WP8: Systematic effects

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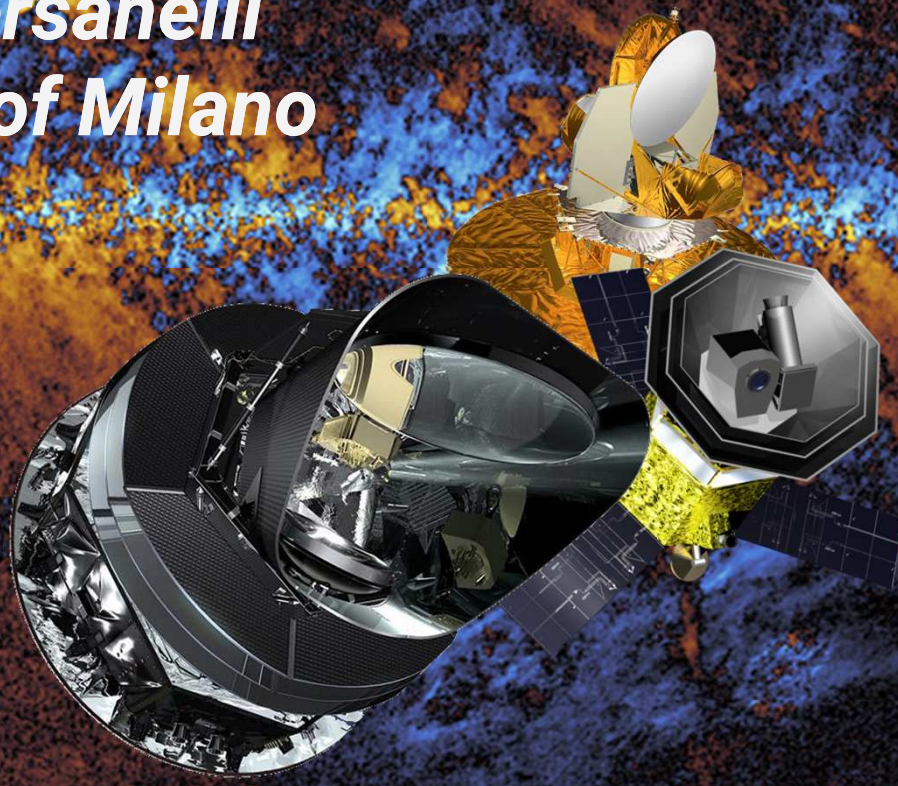

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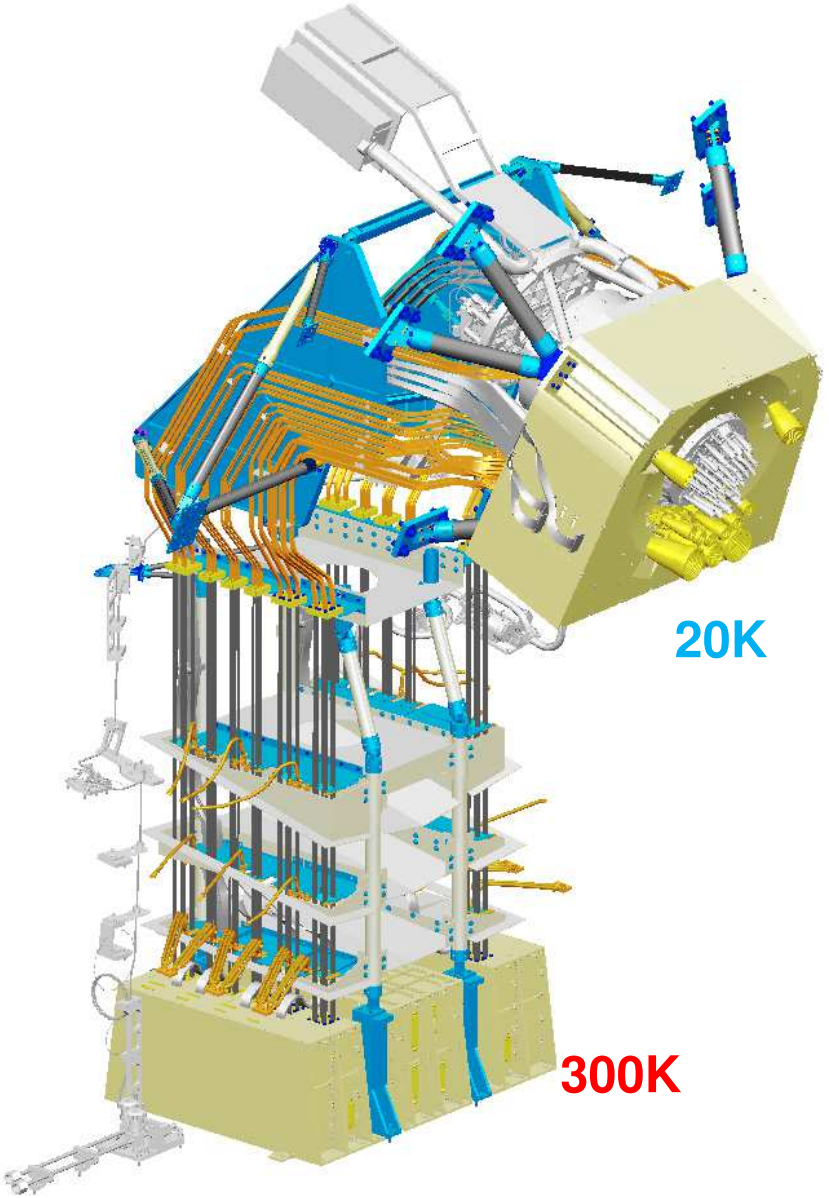
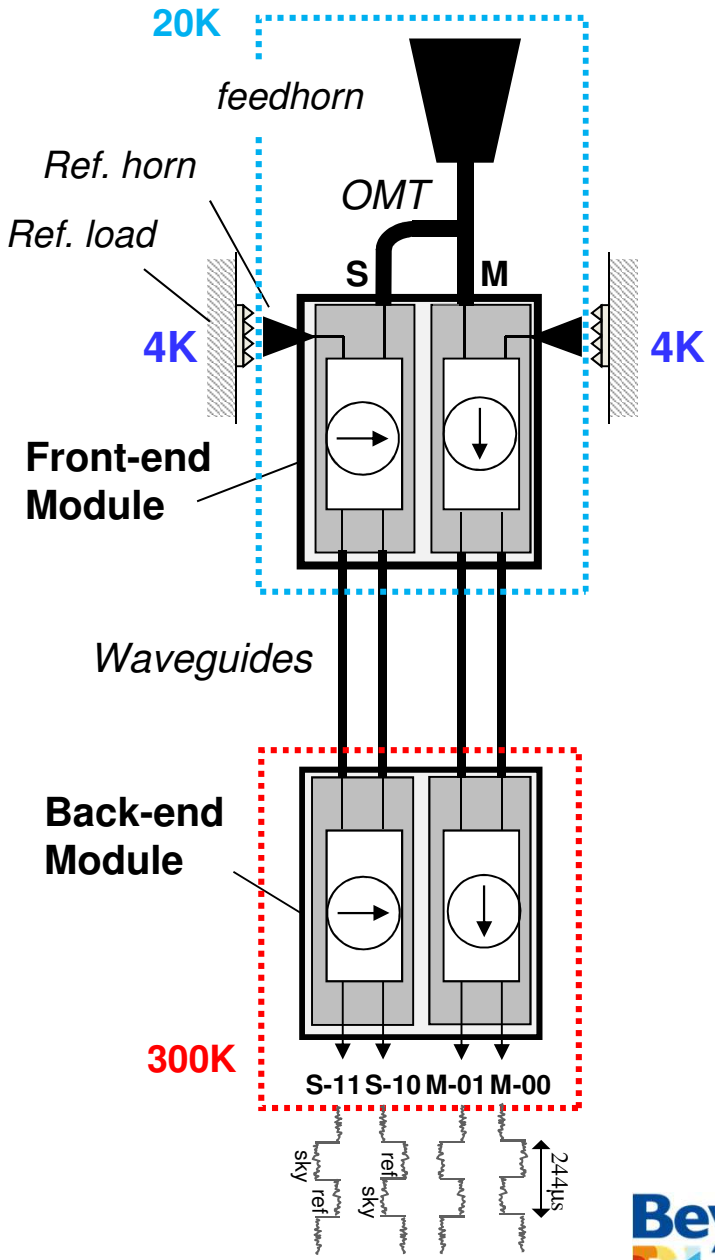
The Low Frequency Instrument

European Commission





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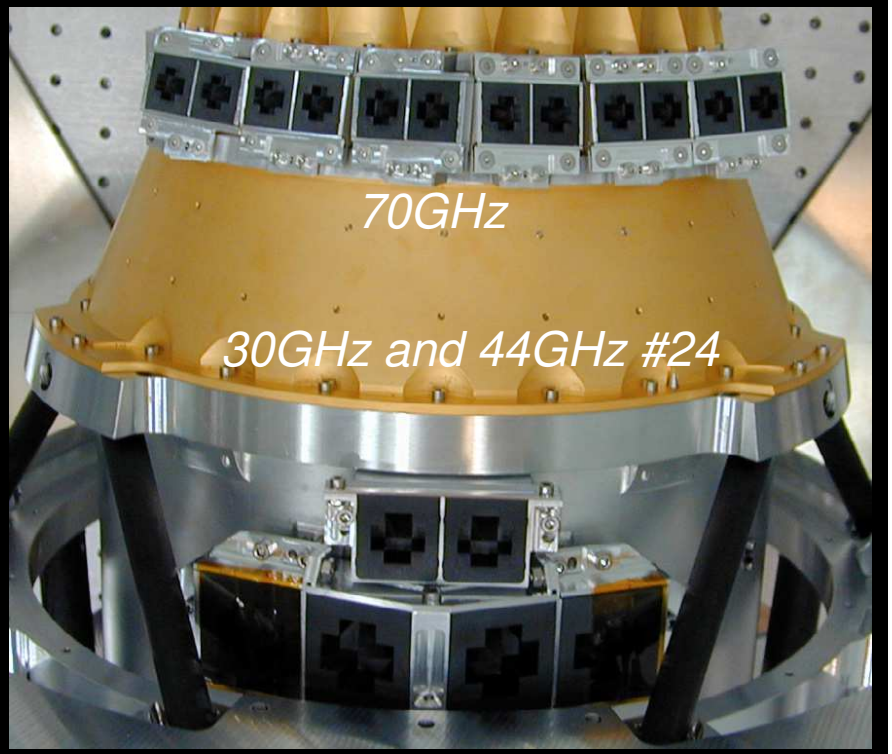
The Low Frequency Instrument

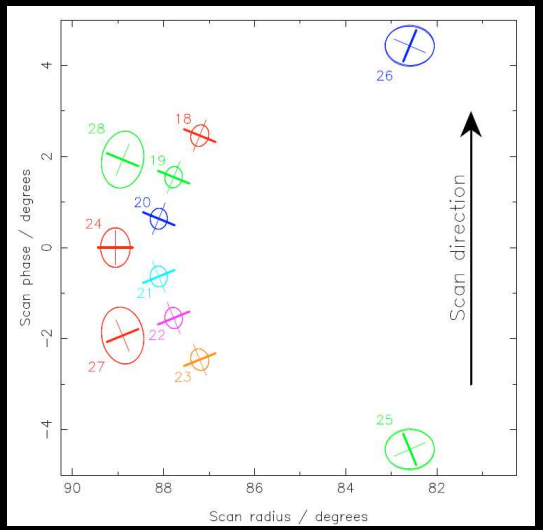
LFI
30 GHz
44 GHz
70 GHz

LFI 4K reference loads



HFI 4K box

Projected angles in the sky optimized to extract Q and U Stokes parameters



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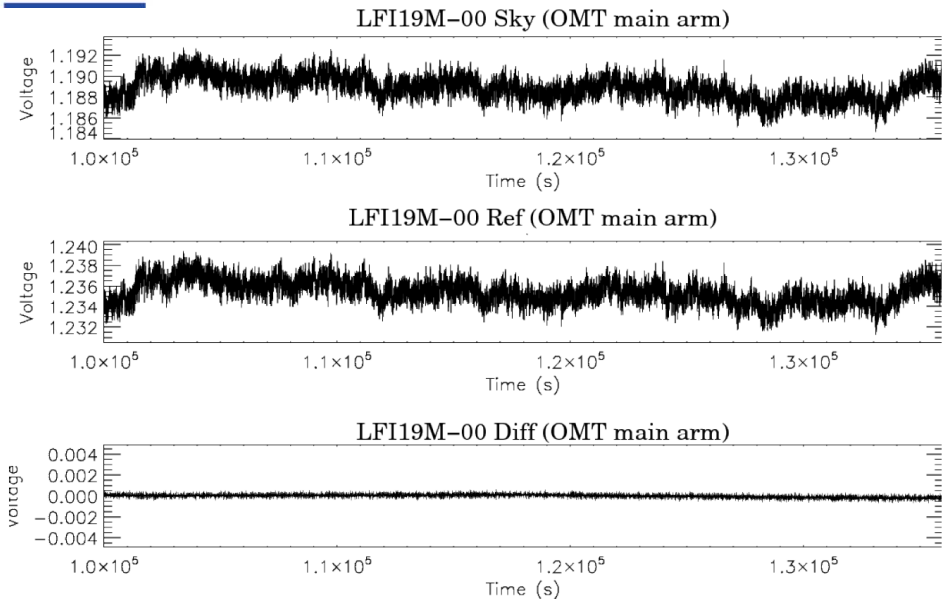
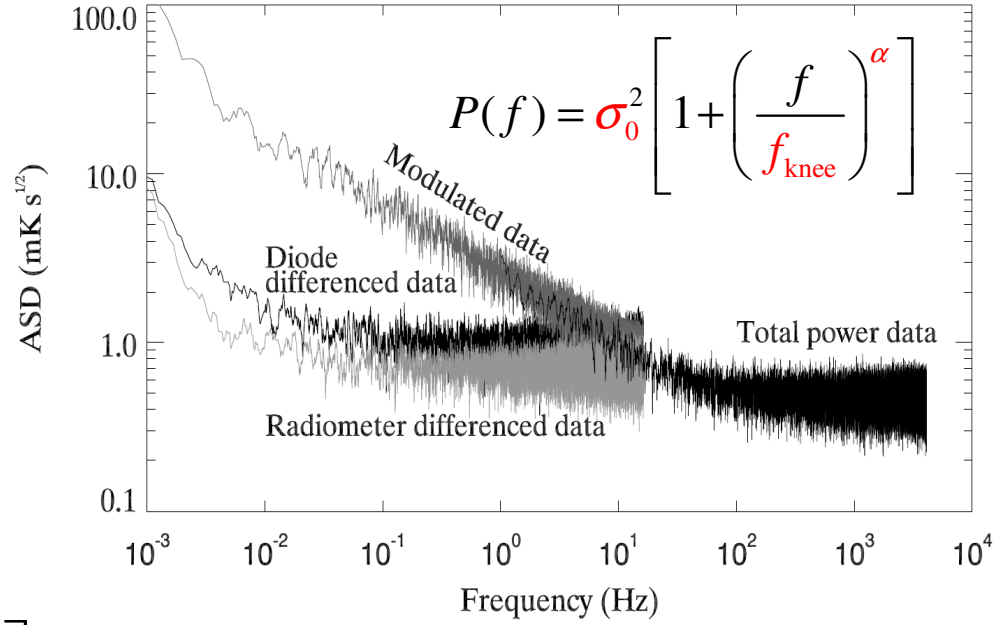
LFI receiver signal model





$$\langle p \rangle \cong G k_{\rm B} \Delta\nu \left[T_{\rm sky} + T_{\rm sys} - r(T_{\rm load} + T_{\rm sys}) \right]$$

Gain modulation factor $r = \dfrac{T_{\rm sky} + T_{\rm sys}}{T_{\rm load} + T_{\rm sys}}$

$$\sigma_0 = k_{\rm R} \frac{T_{\rm sys} + T_{\rm target}}{\sqrt{\Delta\nu_{\rm eff}\,\tau}}$$

Radiometer diff. $k_{\rm R} = \sqrt{2}$

DPC analysis assumed a stationary noise

Fit of fixed parameters $(\sigma_0, f_{\rm knee}, \alpha)$ for each radiometer throughout the mission

BeyondPlanck fits noise parameters every stable pointing period (PID, ~1h)

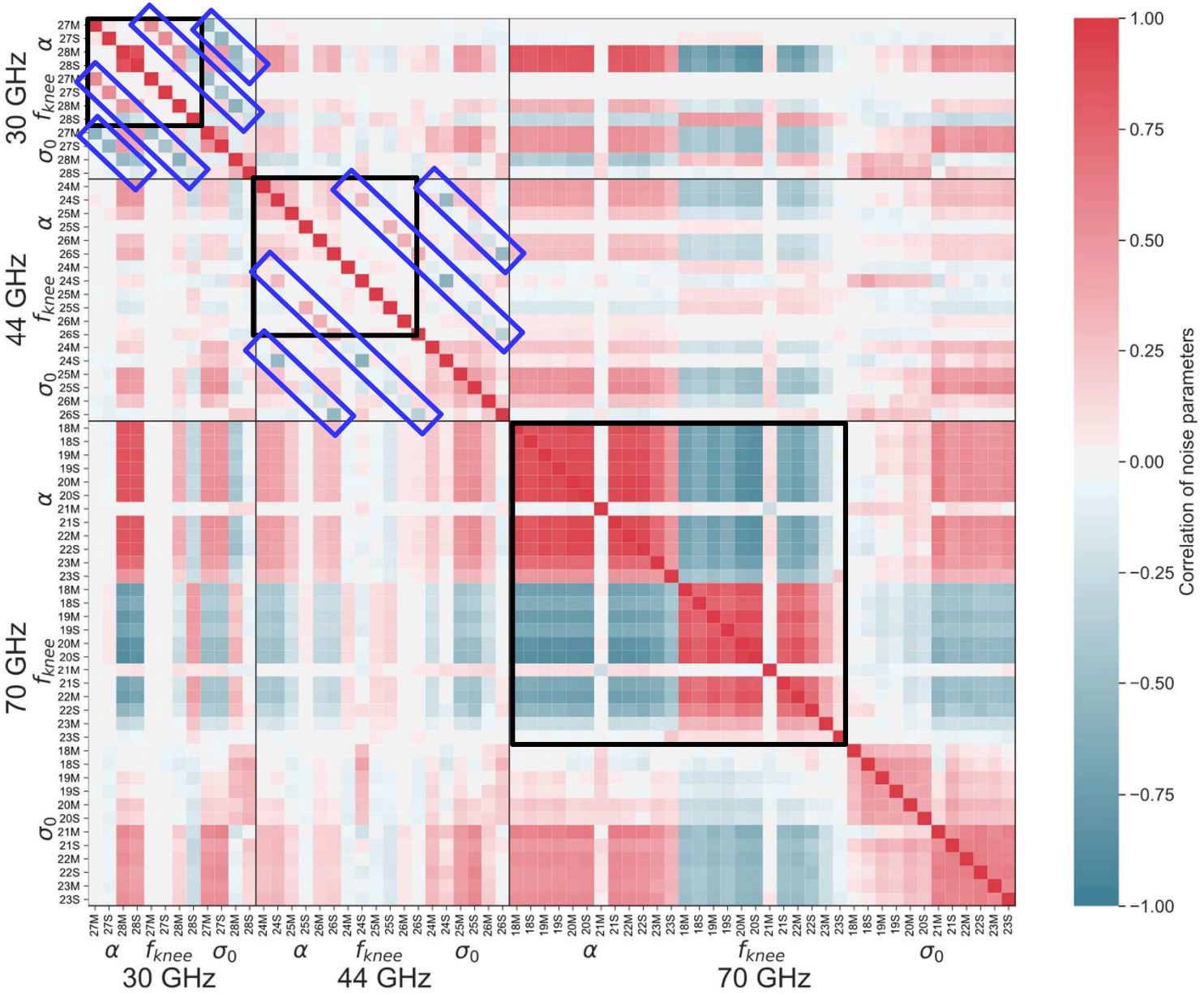
Increase of total number of noise parameters
from 66 to about 3,000,000

Inter-radiometer correlations

Ihle et al. (2020)

European Commission

Correlation between averaged Gibbs samples of noise parameters for each PID



70GHz:

Common mode in $f_{\rm knee}, \alpha$ correlated noise between all radiometers

(outliers 21M, 23S)

→ Envirnoment dominated

Thermal effects?

30-44GHz:

- Weak common mode;
- Correlations $f_{\rm knee}, \alpha, \sigma_0$ within single radiometer

→ the dominant source of 1/f noise is within single radiometer

RF/Electrical effects?

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Correlation with H/K parameters

Ihle et al. (2020)

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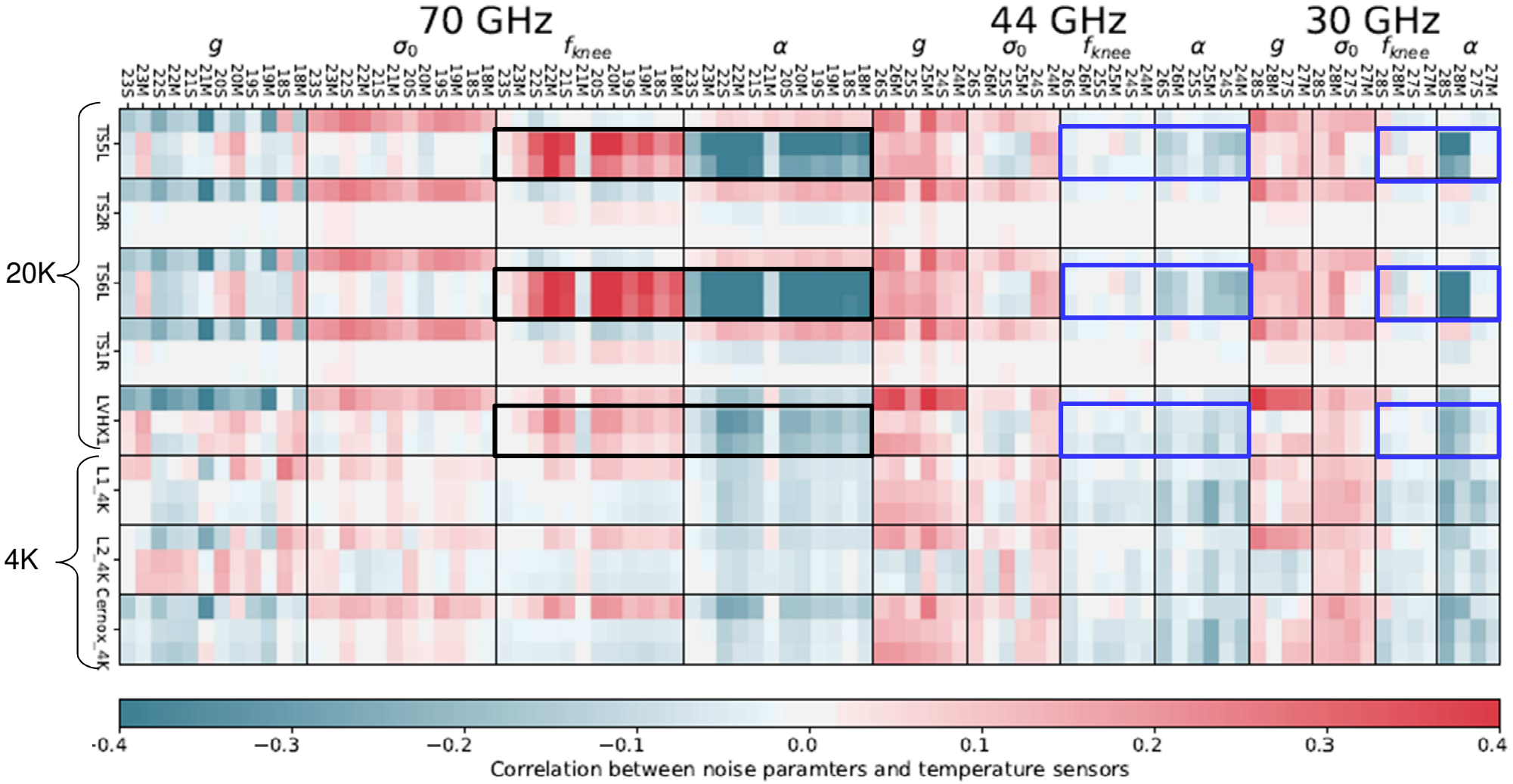
(Planck H/K: Tech Note by C. Franceschet)

Correlate T sensors with $\sigma_0, f_{\rm knee}, \alpha$

(for each sensor: value, rms, peak-to-peak)



70 GHz: rms and p-p of T_{20K} correlate with $f_{\rm knee}$ and anti-correlate α (*steeper spectrum*)

→ 1/f noise dominated by residual thermal fluctuations in 20K stage

30-44 GHz: Much weaker systematic correlations with temperature H/K

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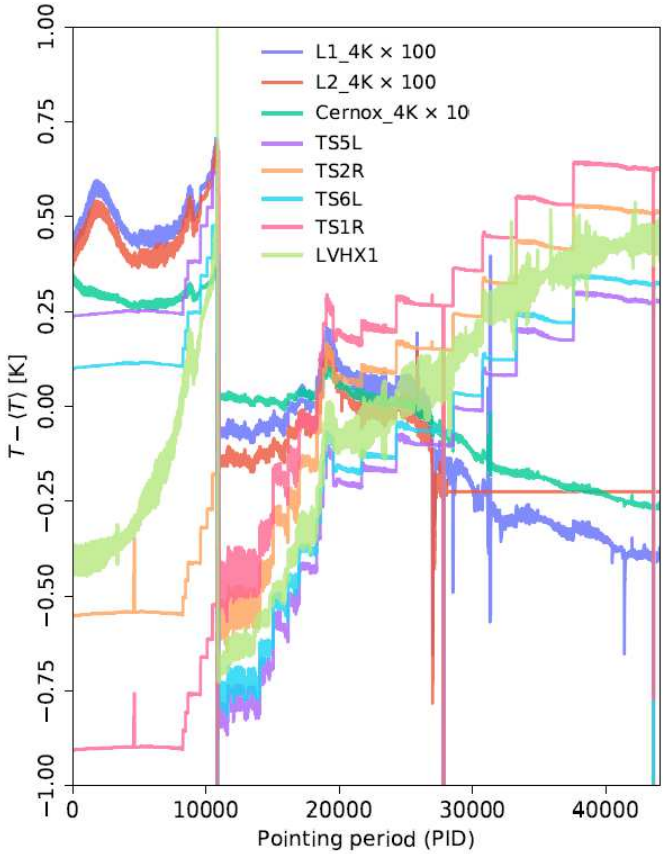
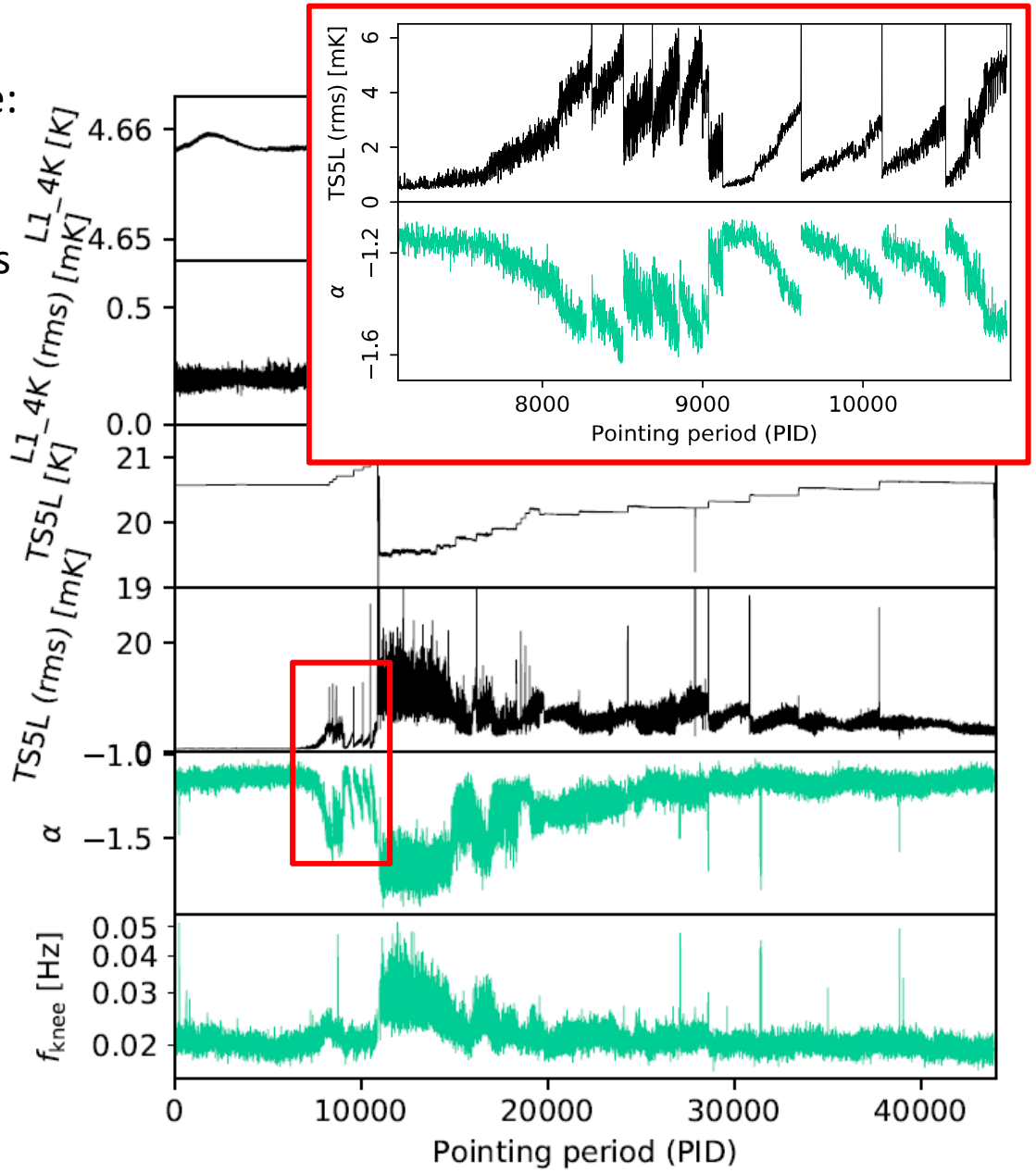
Thermal effects

Ihle et al. (2020)

Known thermal changes in Planck focal plane:

- «Switch-over» between nominal and redundant 20K sorption cooler (PID 11,000)
- Aseries of step-like power input adjustments to optimize performance





Strong correlation between T_{20K} fluctuations (rms) and 70GHz α, f_{knee}

Fitting noise model parameters

Ihle et al. (2020)

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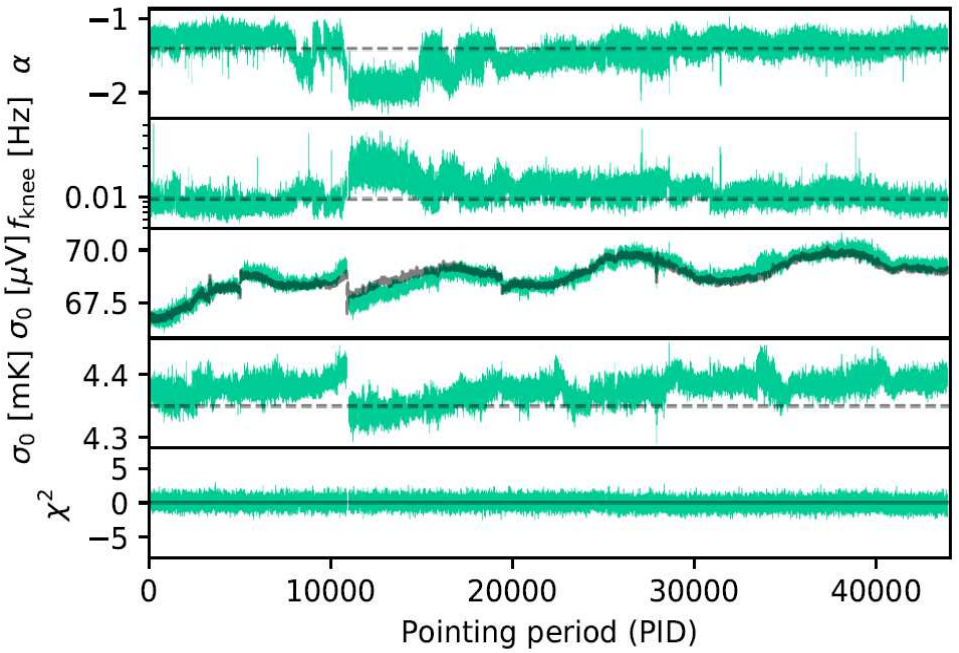
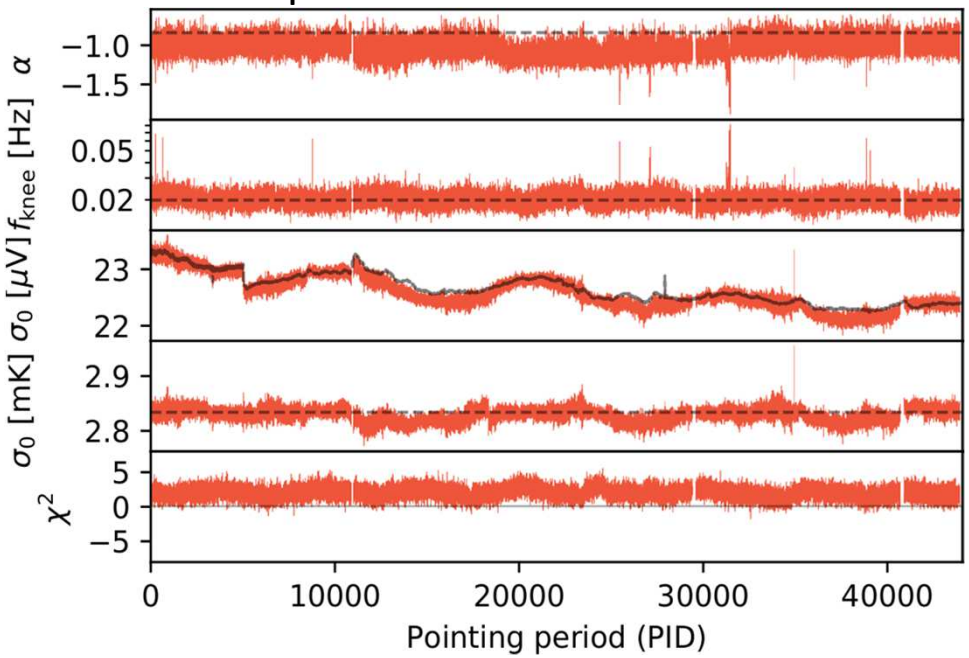
Noise parameters for 70GHz 22M



Noise parameters for 44GHz 25M



Good fit with 3-parameters model (no χ2 excess)

Signature of instability following switch-over

χ2 excess of 2-3 sigma

Additional noise component not captured by 3-parameters model

Uncalibrated noise → Gain

- Up-ward (down-ward) trend at 70GHz (30-44GHz) dominated by 300K stage
- Seasonal variations with opposite phase due changing Sun-Earth distance

$$\Delta V_{\rm out} \propto \phi_{\rm BEM} \Delta T_{\rm 300K} (T_{\rm sys} + T_{\rm N})$$

$$\phi_{\rm BEM,70GHz}[{\rm V/K}] > 0$$

$$\phi_{\rm BEM,30\&44GHz}[{\rm V/K}] < 0$$

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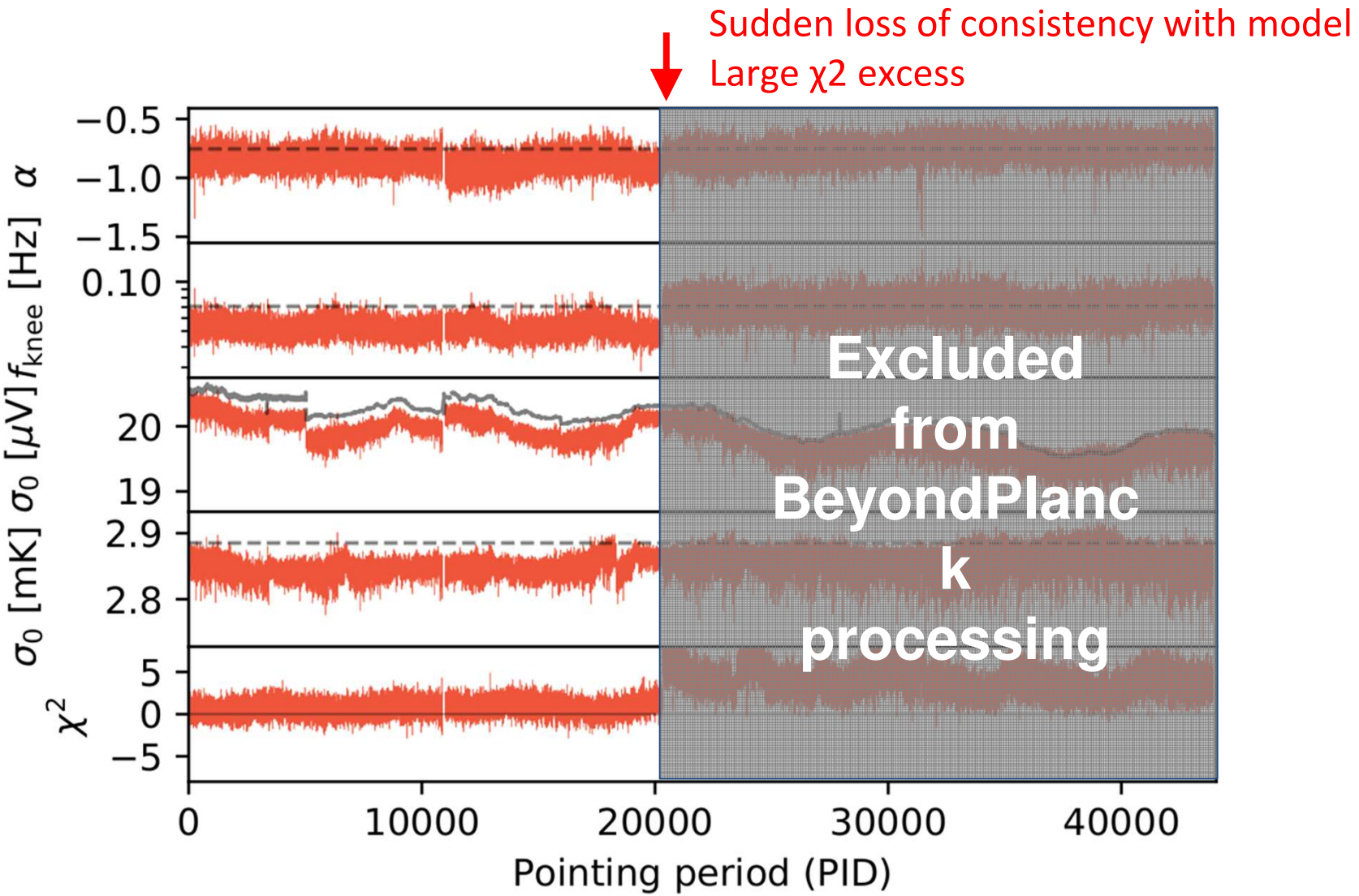
Fitting noise model parameters

Ihle et al. (2020)

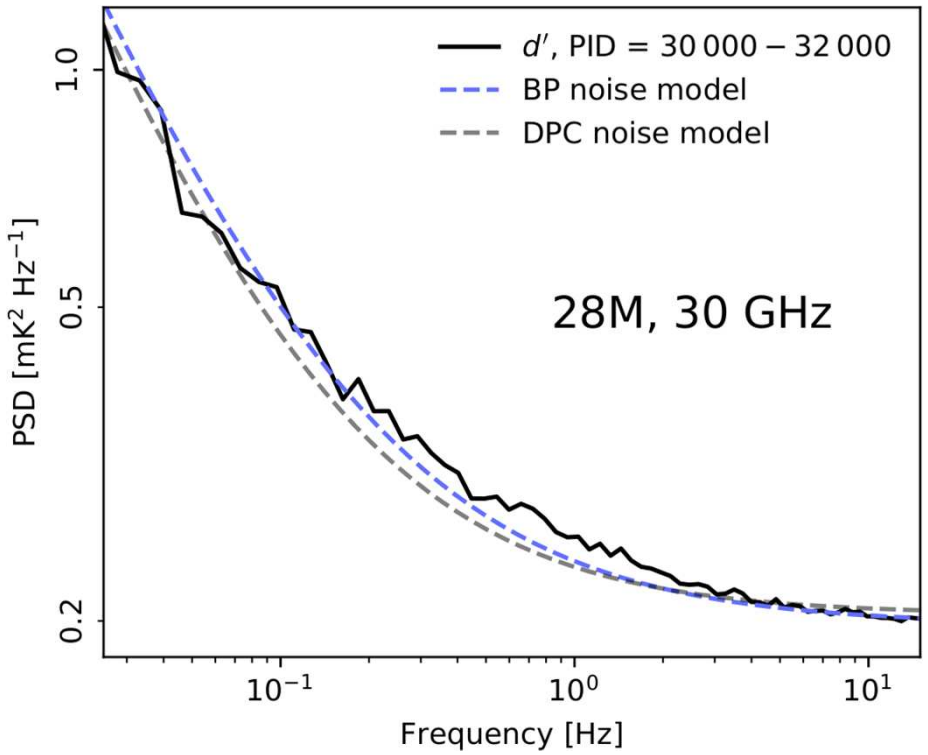
Correlated noise parameters for 44GHz 26S radiometer

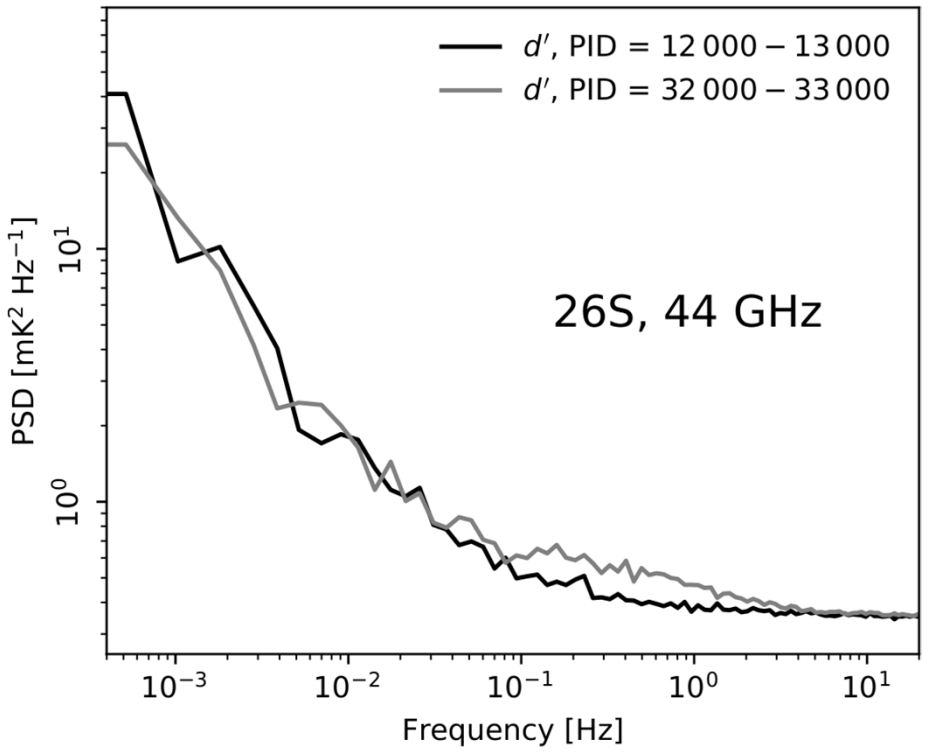


Ihle et al. (2020)

Outstanding issues: 1/*f* model at 30 and 44 GHz

Ihle et al. (2020)



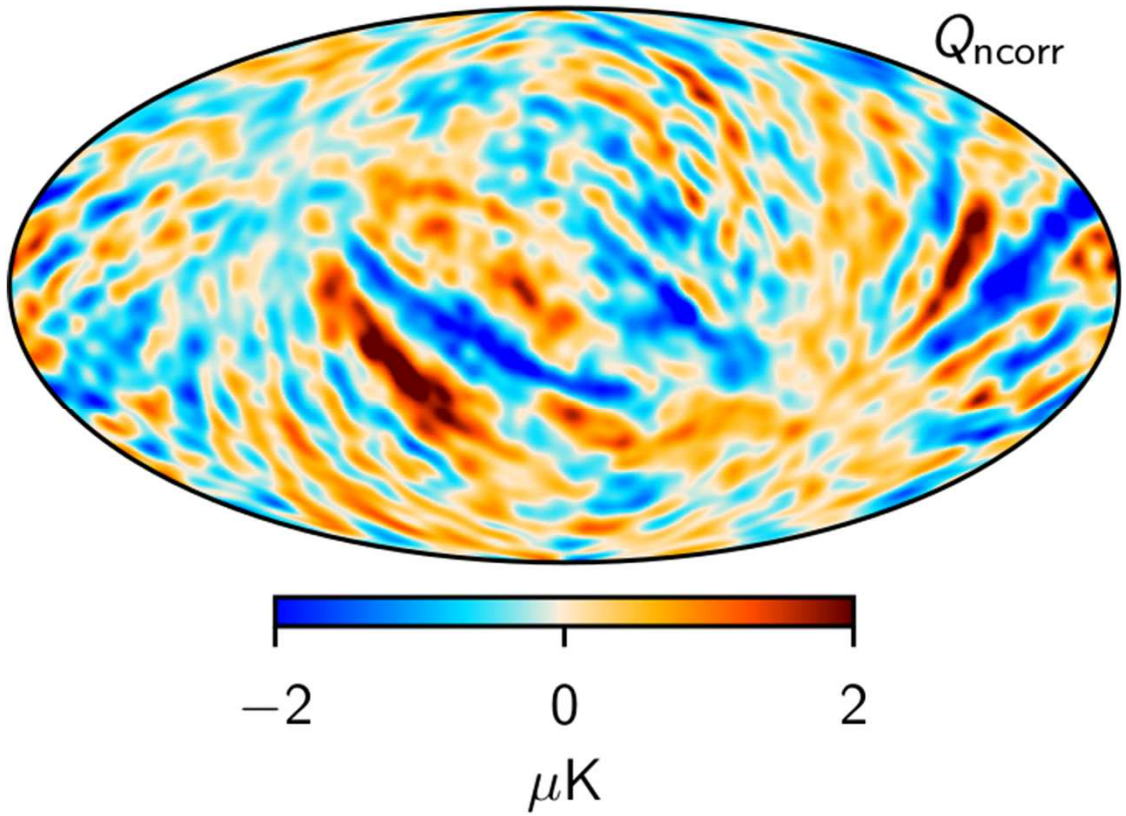


- Correlated noise is fitted using a standard 1/f model: $P(f) = \sigma_0^2 \left[1 + \left(\frac{f}{f_{\rm knee}} \right)^{\alpha} \right]$
- Significant and time-variable **excess between 0.1 and 5 Hz**, corresponding to angular scales beween **1 and 60 degrees on the sky**
  - *Appears non-thermal in origin. Investigation on-going*
  - *Electrical issue? (correlate with LNA and PhSw H/K info)*
  - *External transients affecting electronics? (cosmic rays, solar flares)*

Outstanding issues: Stripes in 44 GHz

Ihle et al. (2020)

Correlated noise map at 44 GHz in Q polarization



- Residual stripes in Southern hemisphere
- Origin not yet understood, but being actively investigated
- Seems associated with poor gain model for some Planck scanning rings
  - *Sub-optimal processing mask?*
  - *Undetected gain jumps?*

WP8: Systematic effects – Conclusions

Ihle et al. (2020)

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WP8 OBJECTIVE:

«Understanding and quantifying residual systematic errors in the final data products after full processing. This work will partly take place inside the main infrastructure and partly outside. Generally speaking, this work will revolve around understanding the behaviour of the instrument in light of the most up-todate models, and determine how and why they differ. Thus, the typical mode of operation will be to establish an imperfect model of a given instrumental effect; project this into time-ordered data process those data through the pipeline; and quantify the residuals.**»**

- The BeyondPlanck approach allowed for deeper investigation of LFI instrumental effects
- The results achieved set the basis for further improvements:
  -- refined LFI noise model
  -- search for time-correlation of 44GHz residual stripes with RF/electrical disturbances or external events
- Sampling instrumental parameters (e.g. gain, bandpass, …) jointly with foregrounds is a key feature for future B-mode experiment

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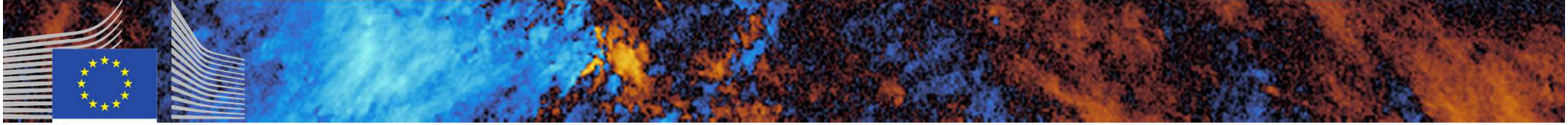

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WP8: Systematic effects

Institution	EU	In kind
University of Milano	0.9	5.6
Total	**6.5**	
Budgeted	**4**	
Deviation	**+2.5**	

Strongly interconnected with several other WP's

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The BeyondPlanck collaboration

European Commission

EU-funded institutions

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- "*BeyondPlanck*"
  - COMPET-4 program
  - PI: Hans Kristian Eriksen
  - Grant no.: 776282
  - Period: Mar 2018 to Nov 2020

Collaborating projects:

- "*bits2cosmology*"
  - ERC Consolidator Grant
  - PI: Hans Kristian Eriksen
  - Grant no: 772 253
  - Period: April 2018 to March 2023
- "*Cosmoglobe*"
  - ERC Consolidator Grant
  - PI: Ingunn Wehus
  - Grant no: 819 478
  - Period: June 2019 to May 2024