

# Thermal Stability in Precision Cosmology Experiments: The Planck LFI Case

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# Planck/LFI

- Produce full sky CMB maps with an angular resolution, at 70 GHz, of about 13 arcmin and a sensitivity per pixel, of few  $\mu\text{K}$ .
- Cryogenically cooled low noise detectors
- Accurate control of systematic effects at  $\mu\text{K}$  level



# Systematic effects

- Beam distortions
- Straylight
- Thermal effects
- Intrinsic instrumental effects
- Pointing

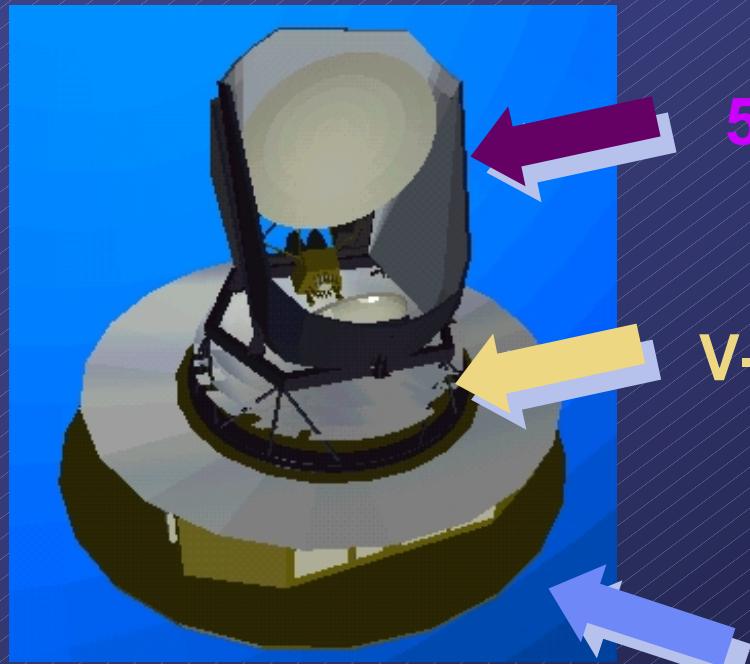
# Systematic effects



- Thermal effects



# Thermal environment



50 K telescope environment

V-grooves at different temperatures

300 K stage

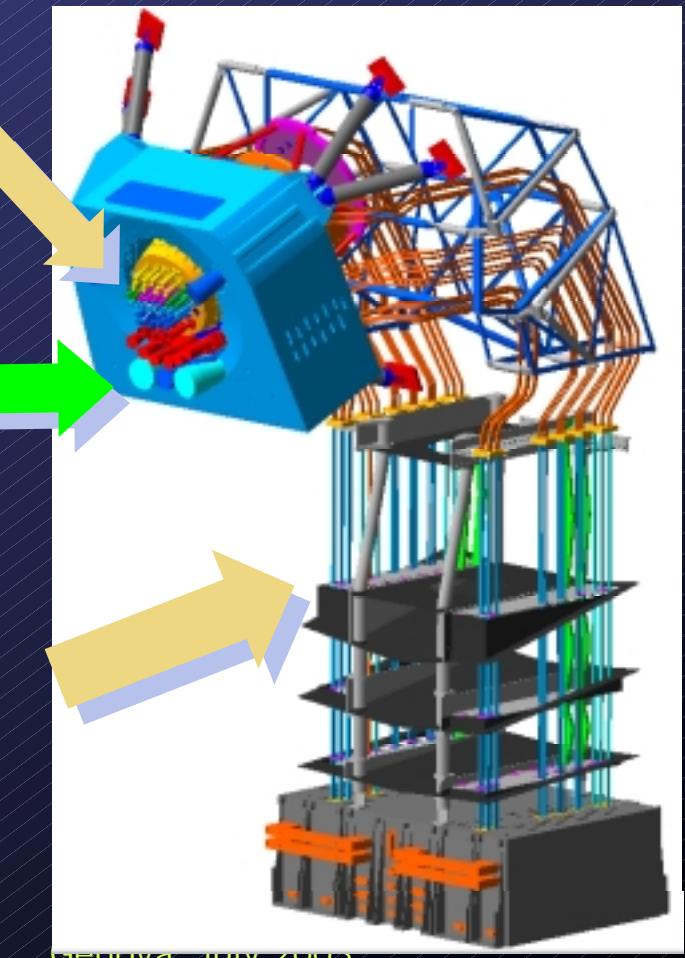


# Thermal environment

4 K HFI focal plane  
0.1 K HFI bolometers

20 K LFI focal plane

LFI waveguides from 20 K to 300 K



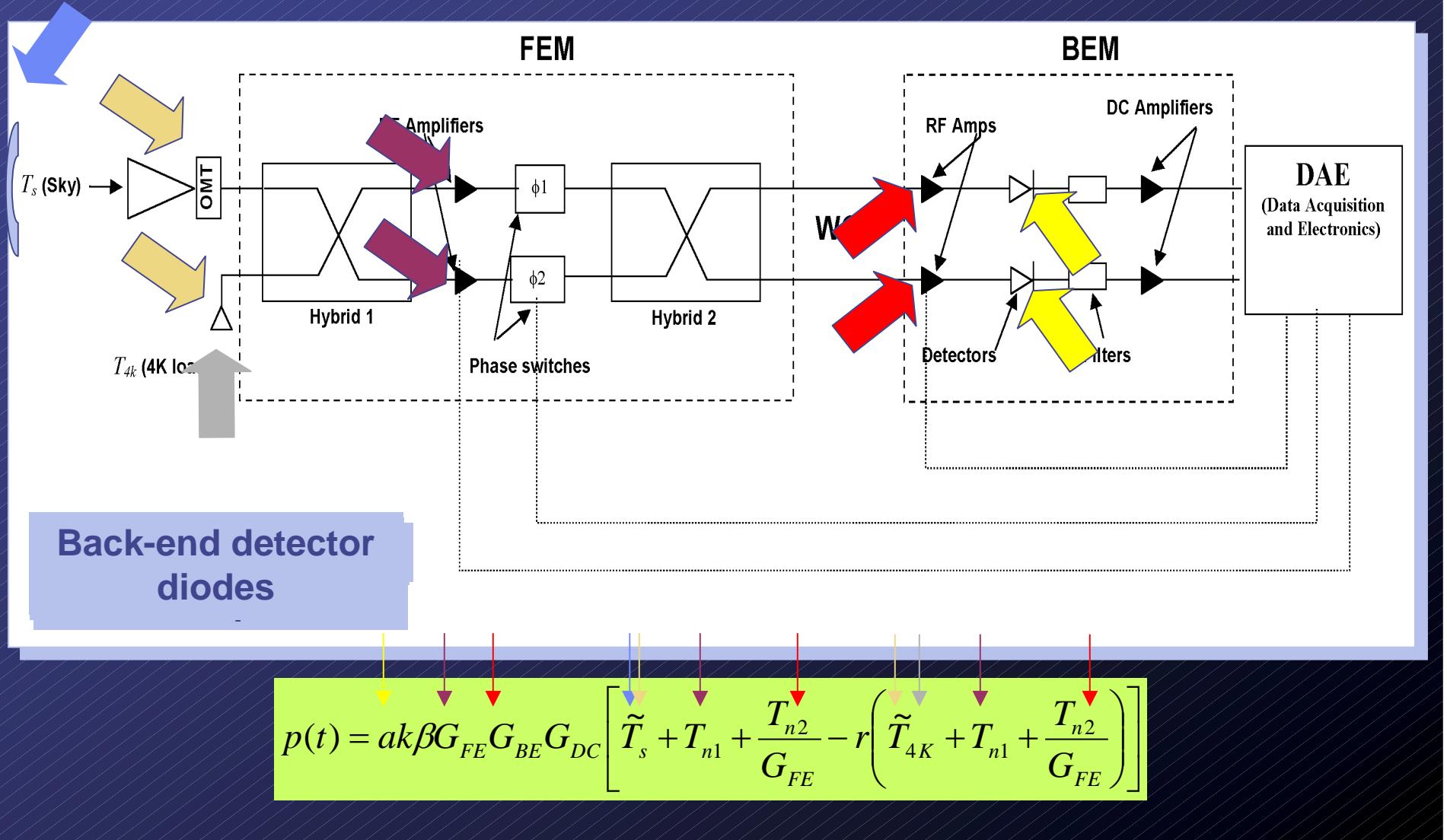
# Requirements on max systematics from thermal effects



- The global contribution from spin-synchronous thermal fluctuations in each pixel will be less than  $\pm 0.8 \mu\text{K}$
- The global contribution from other periodic thermal fluctuations in each pixel will be less than  $\pm 1.1 \mu\text{K}$

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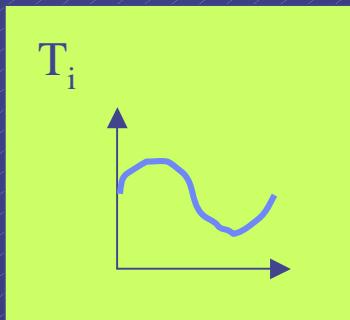
# Sensitivity of LFI radiometers to thermal fluctuations





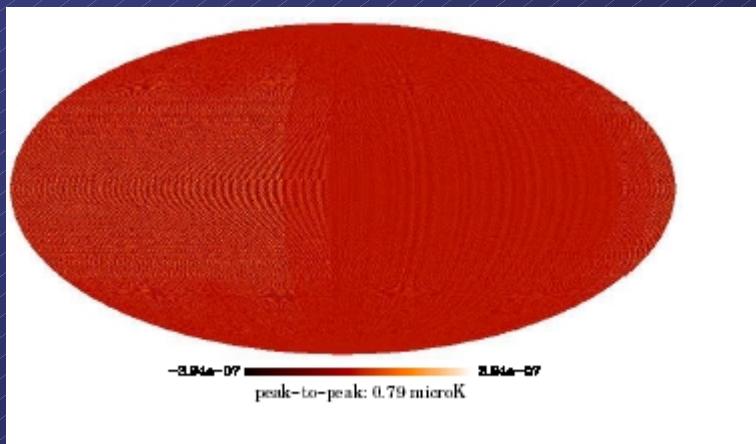
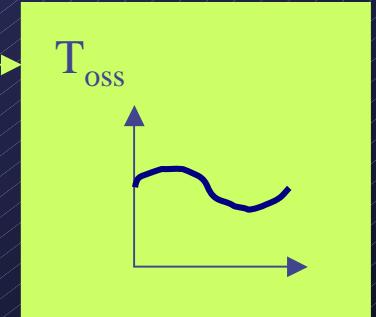
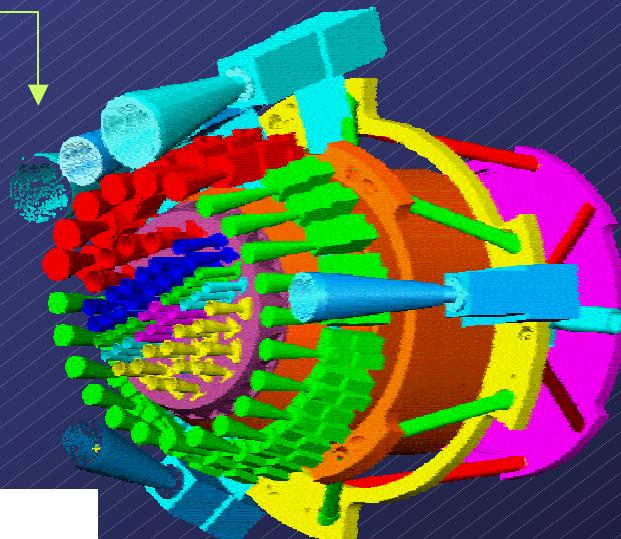
# Fluctuations propagation

Mechanical damping



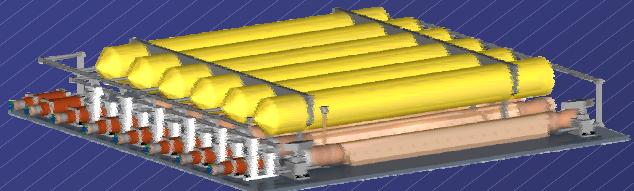
Transfer function:

$$\frac{\partial p}{\partial T_s} \delta T_s = \frac{\partial p}{\partial T_i} \delta T_i$$

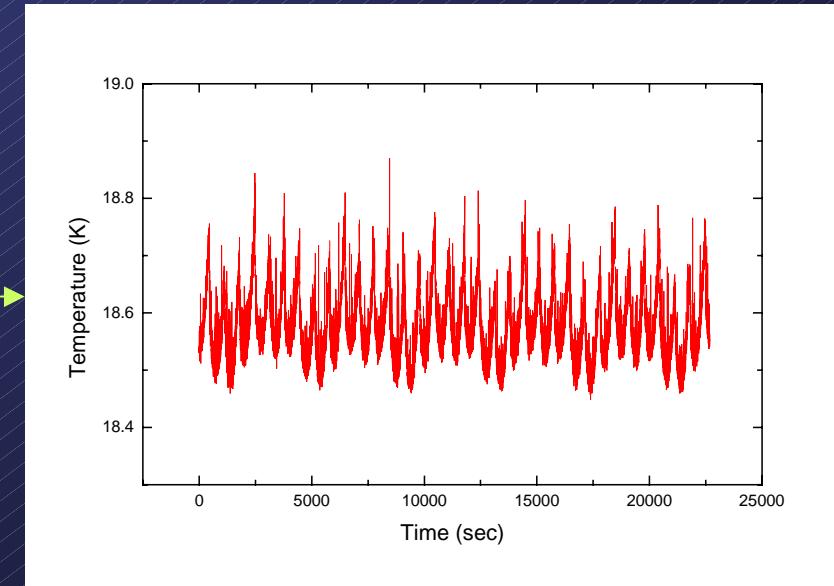


Maps

# Fluctuation sources: sorption cooler



Single bed cycle: 667 sec  
Full cycle : 4000 sec



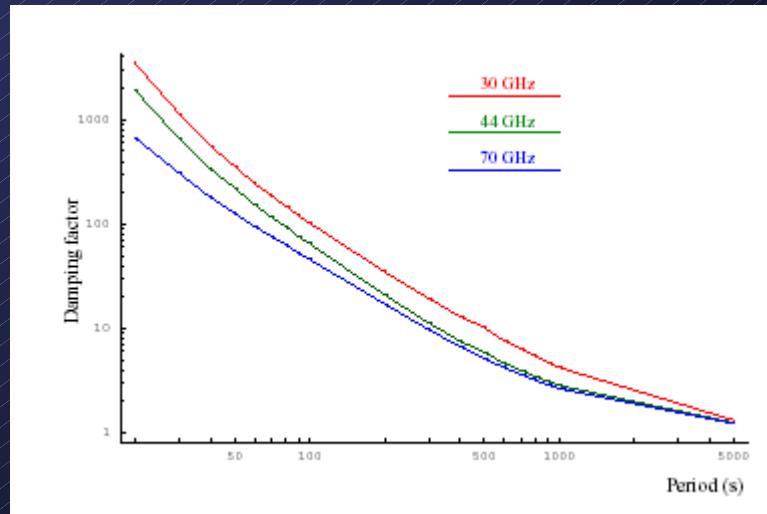
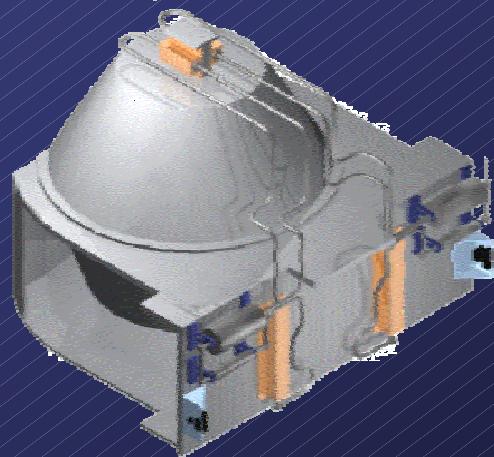
# Fluctuations propagation

- Sorption cooler

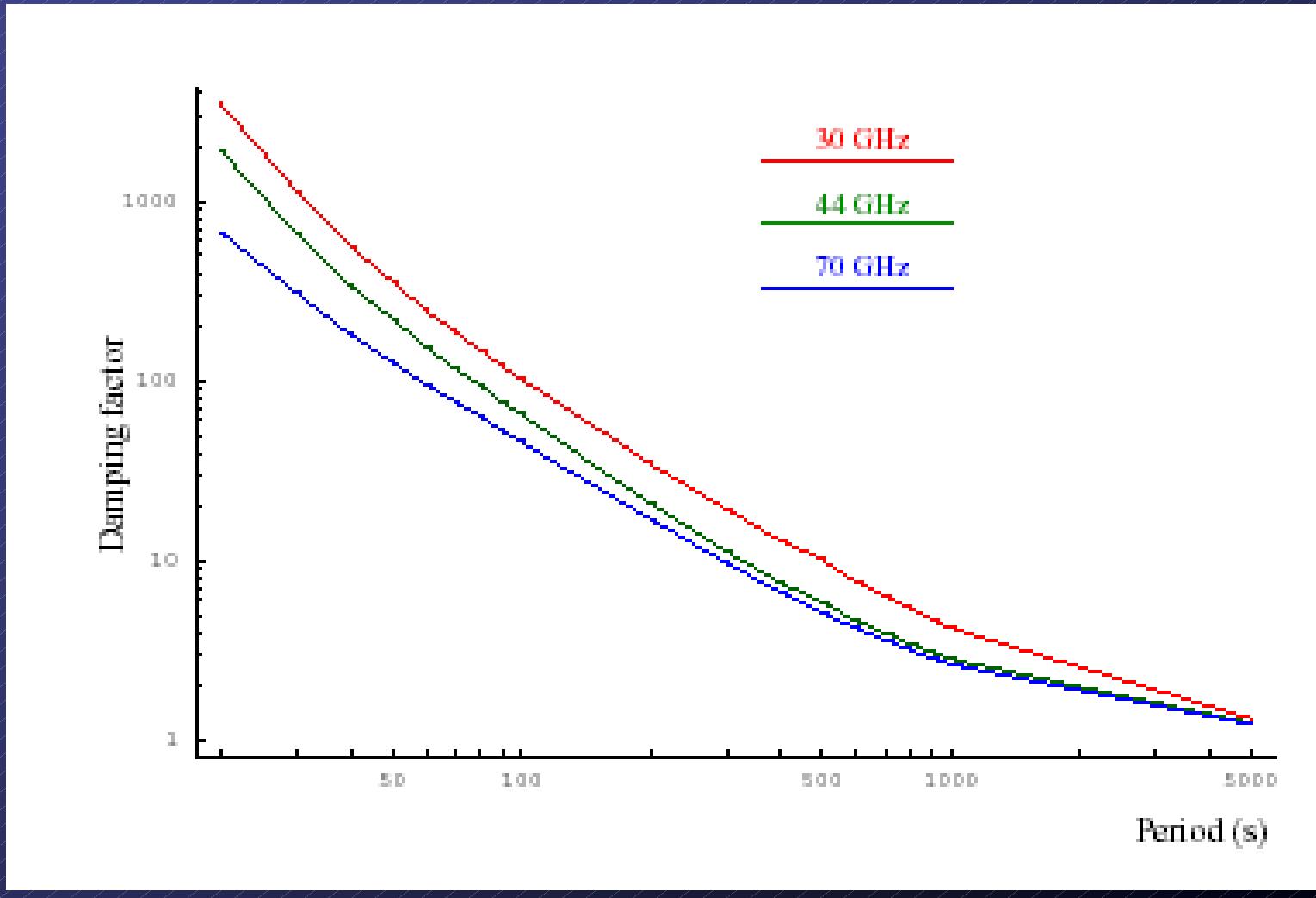


Front end

Thermo-mechanical damping  
Low pass filter



# Fluctuations propagation



# Transfer function for front-end temperature fluctuations

$$T_f = L_{\text{feed-OMT}} \left\{ \left( 1 - \frac{1}{L_{\text{feed-OMT}}} \right) - r \left( 1 - \frac{1}{L_{4K}} \right) + \left[ \tilde{T}_s + T_n - r(\tilde{T}_{4K} + T_n) \right] \frac{\ln(10)}{10} \frac{\partial G_{\text{dB}}}{\partial T_{\text{phys}}} + (1 - r) \frac{\partial T_n}{\partial T_{\text{phys}}} \right\}$$

Term arising from temperature fluctuations at Feed - OMT level

Term arising from temperature fluctuations at reference horn level

Dependence of gain on physical temperature

Dependence of noise temperature on physical temperature

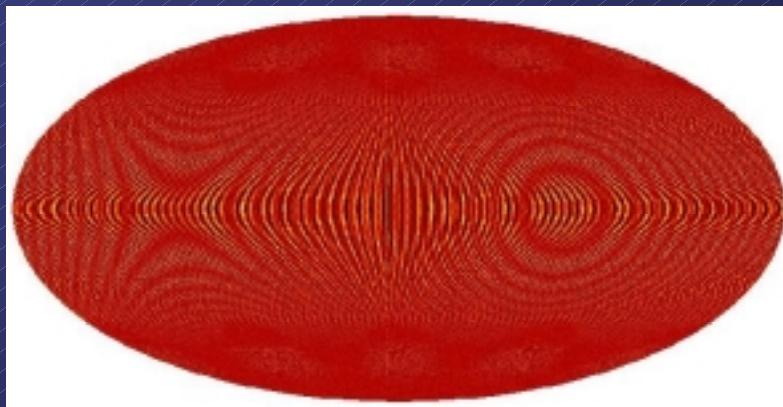
Values of  $T_f$  for  $\partial G / \partial T_{\text{phys}} \sim 0.05 \text{ dB/K}$  and  $\partial T_n / \partial T_{\text{phys}} \sim 0.8 \text{ K/K}$

30 GHz	44 GHz	70 GHz
0.17	0.13	0.08



# Data Analysis

- Map Production

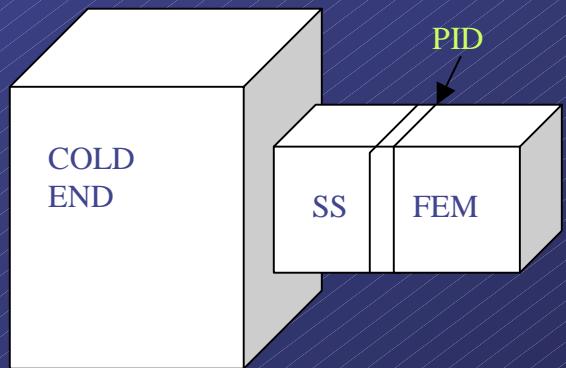


- Destriping

Too high level: 5.3 to 8.1  $\mu\text{K}$  in the maps !

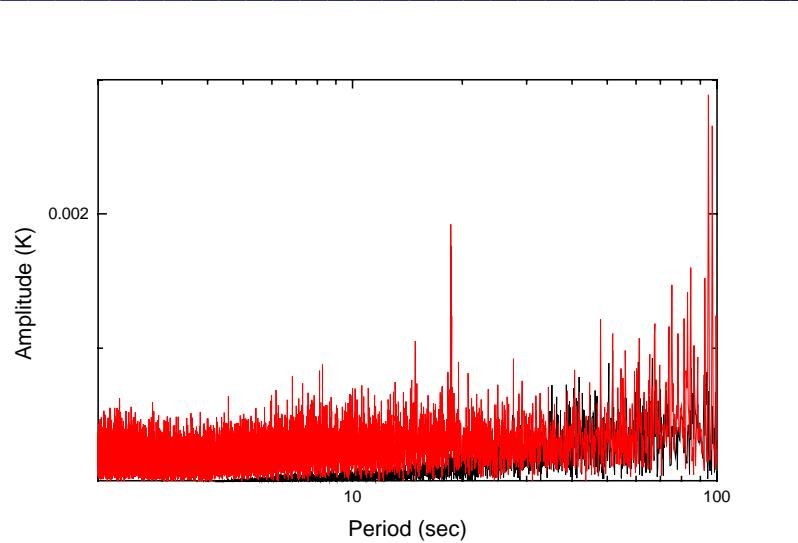
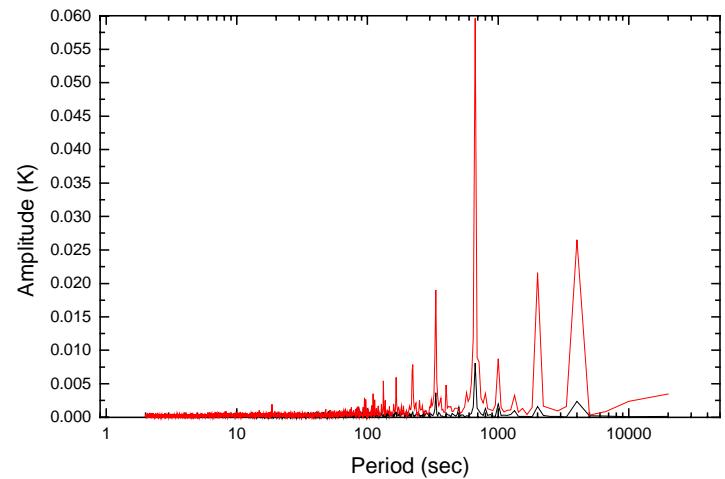


# Hardware solution: active T control



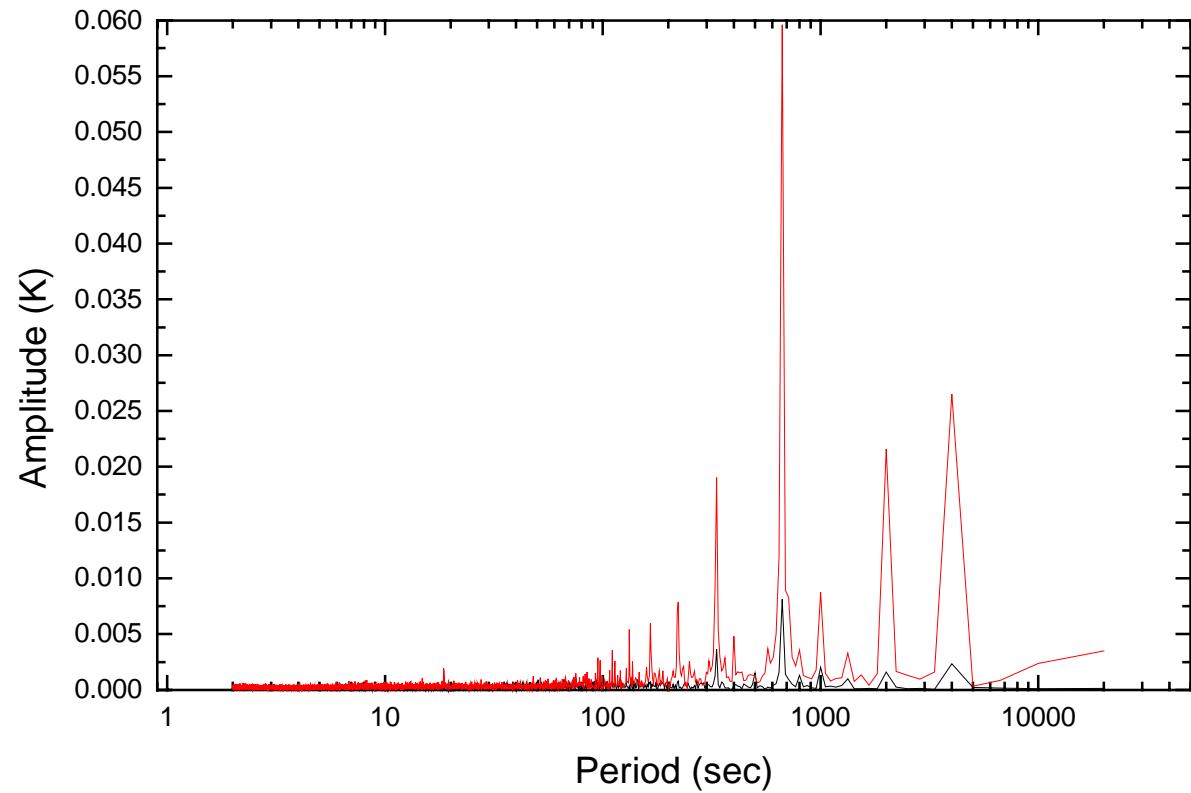
- Mechanical constraint
- Low power (about 100mW)
- Limited thermal break

# Hardware solution: active T control

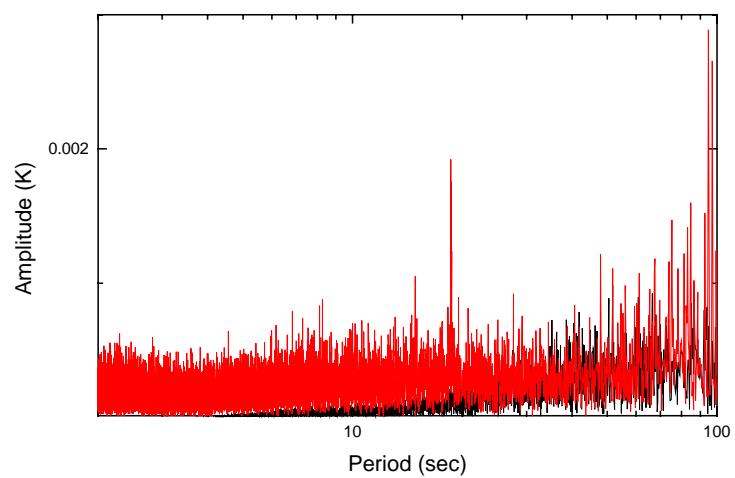
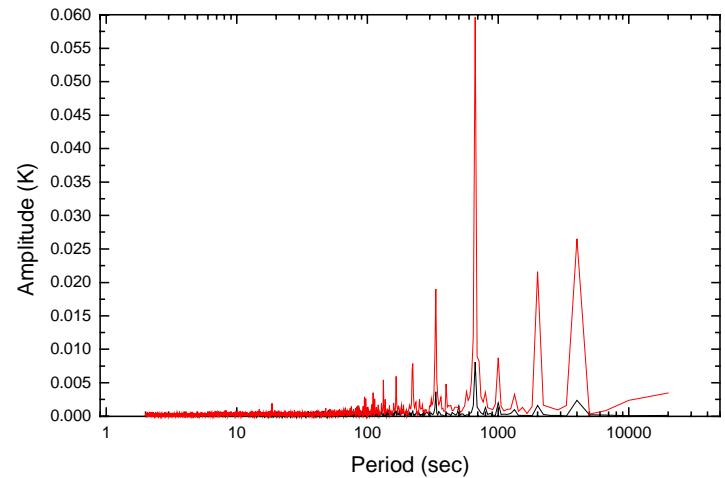




# Hardware solution: active T control



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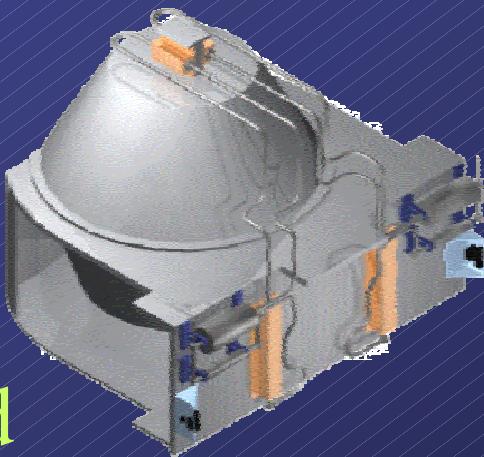


Frequency (GHz)	30	44	70
$\delta T$ p-p ( $\mu K$ ) Before destriping	11.1	10.4	14.6
$\delta T$ p-p ( $\mu K$ ) After destriping	0.65	0.65	1.00

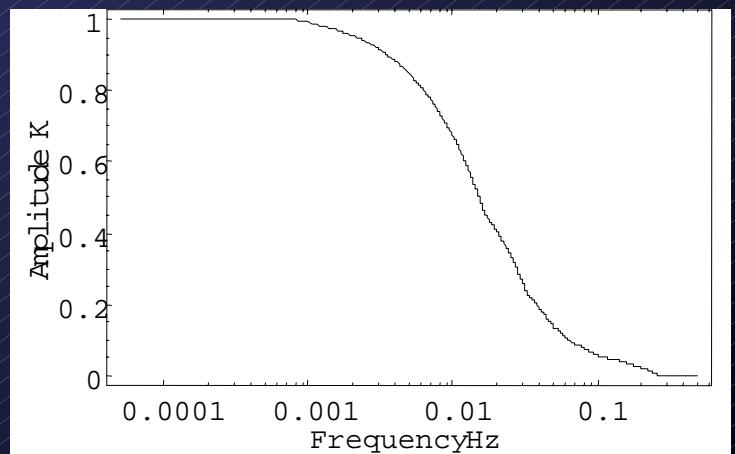
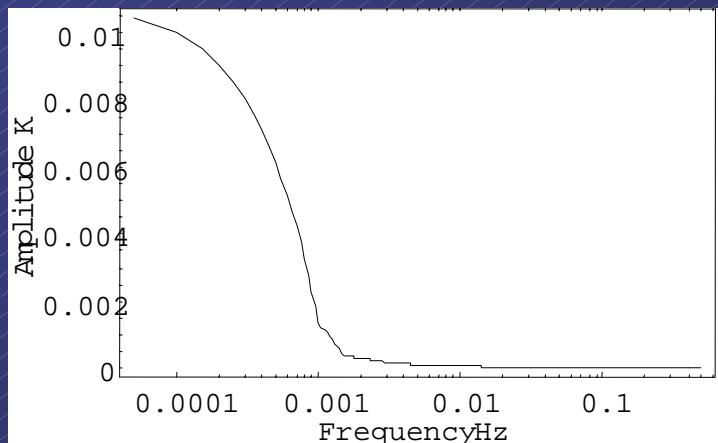
- Sorption cooler



4K Reference Load



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# Summary and Conclusions



- Relevant thermal effects identification
- Propagate effects to detectors
- Evaluation of the effects upon measurement
- Reduce the effects if needed