An update on Archeops

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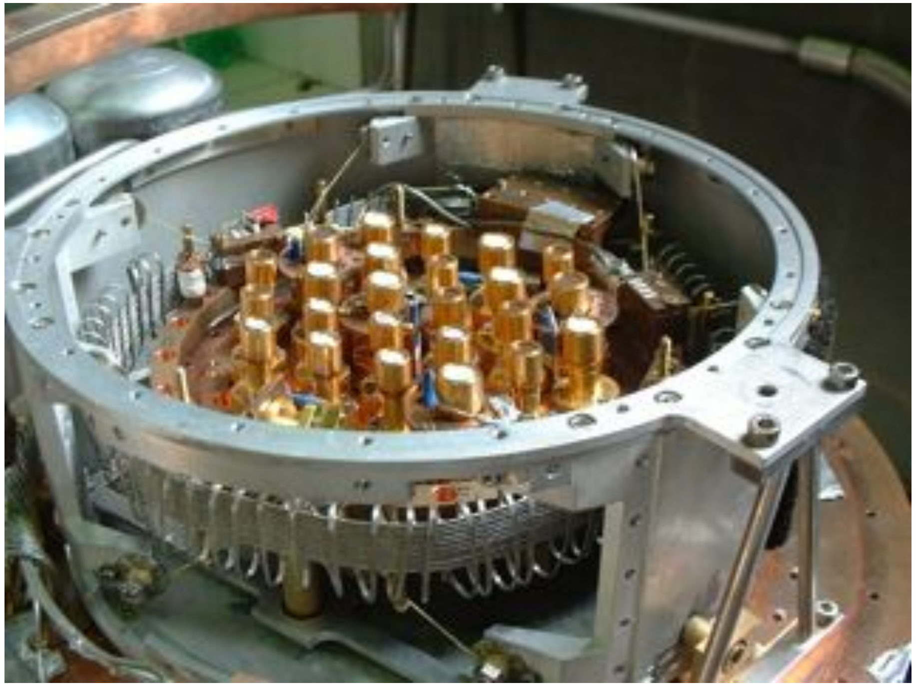
on behalf of

the Archeops Collaboration

JENAM, September 5th, 2002 Porto (Portugal)

Archeops



An updat

The Archeops collaboration

- **France**
  CESR, CRTBT, CSNSM, IAP, IAS,
  ISN, LAL, LAOG, PCC/CdF, OMP, SPP/CEA
- **Italy**
  Univ. La Sapienza (Rome), IROE CNR
- **Russia**
  Landau Ins. of Theoretical Physics
- **U.K.**
  QMW
- **U.S.A.**
  CALTECH, JPL, Univ. Of Minnesota

http://www.archeops.org

Outline

- The Archeops concept
- The instrument
- Archeops flights
- Data and processing pipelines
- Science with Archeops data

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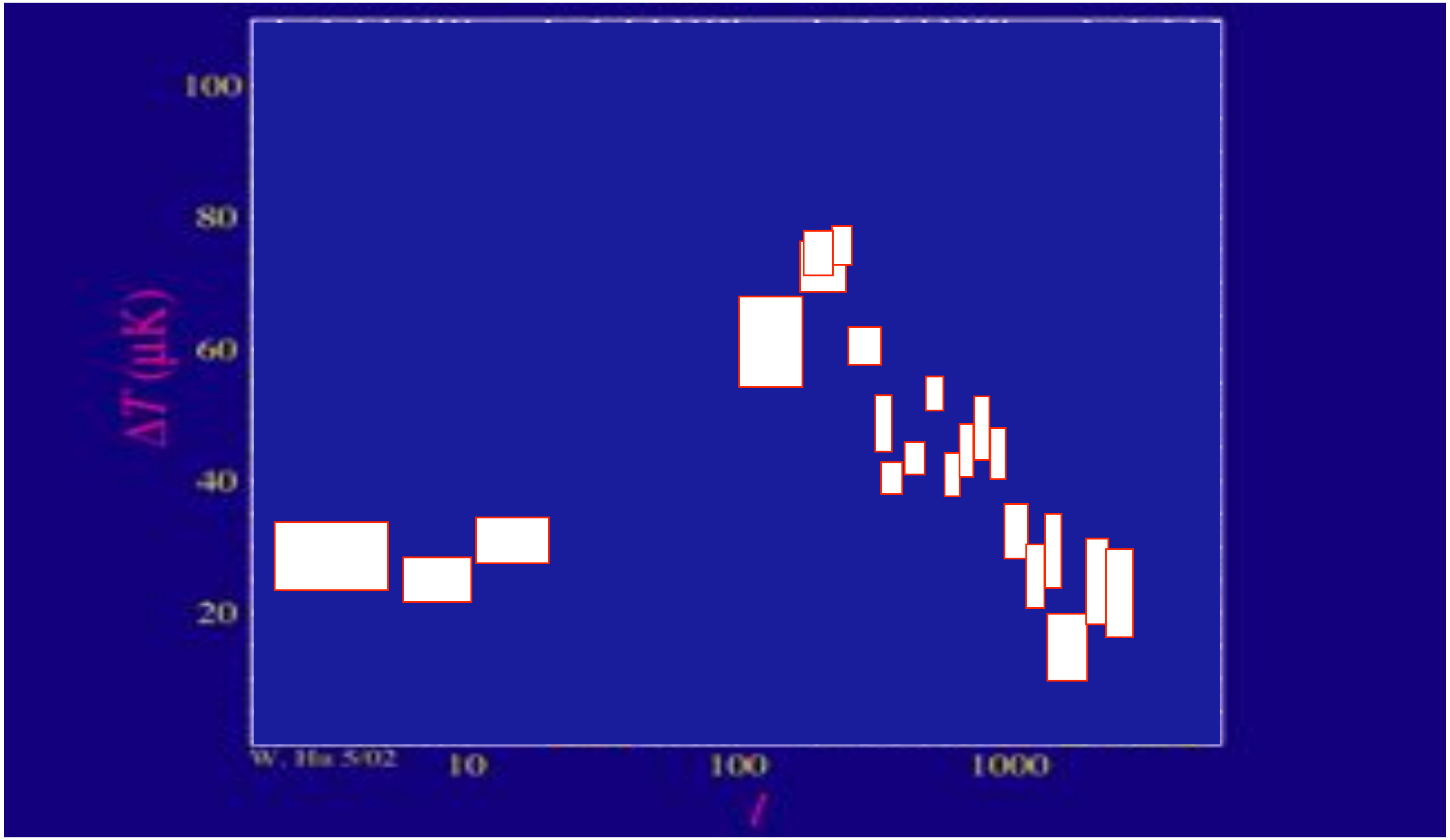
Published CMB spectrum data



The Archeops concept

- Concept similar to Planck HFI
  - Dilution cryostat cooling bolometers to 100 mK
  - Spider web bolometers
  - Off-axis Gregorian telescope
  - Scanning the sky along large circles

→ Testbed for Planck

- High angular resolution : ~ 8-12 arcmin

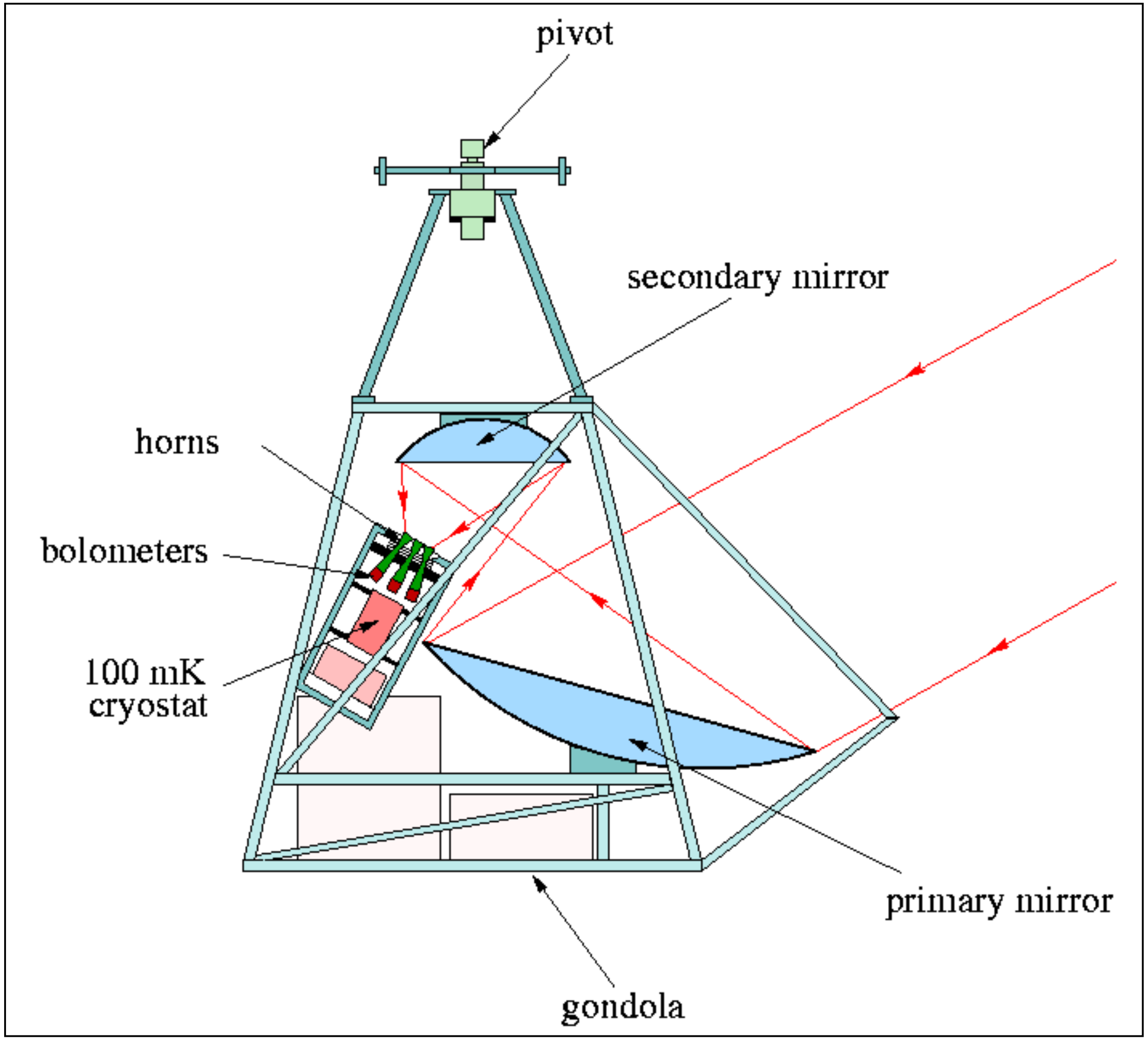
→ Constraints on high ℓ (<800)

- Large sky coverage : 20-30%

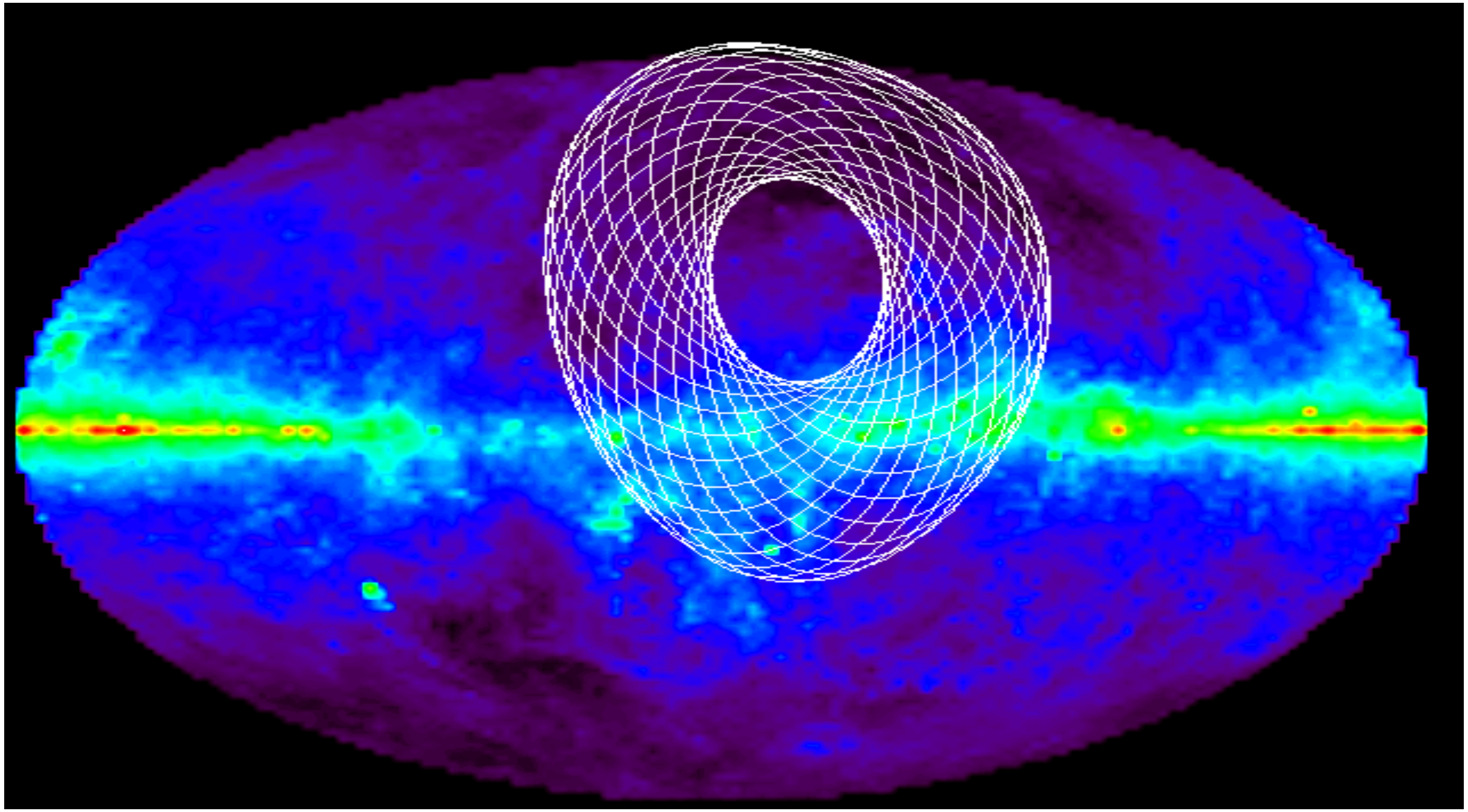
→ Constraints on low ℓ (>10)

The Archeops gondola

- 1.5 meter primary
- Altitude : 30-40 km
- Elevation : 41°
- Rotation speed : 2 rpm



Scan strategy

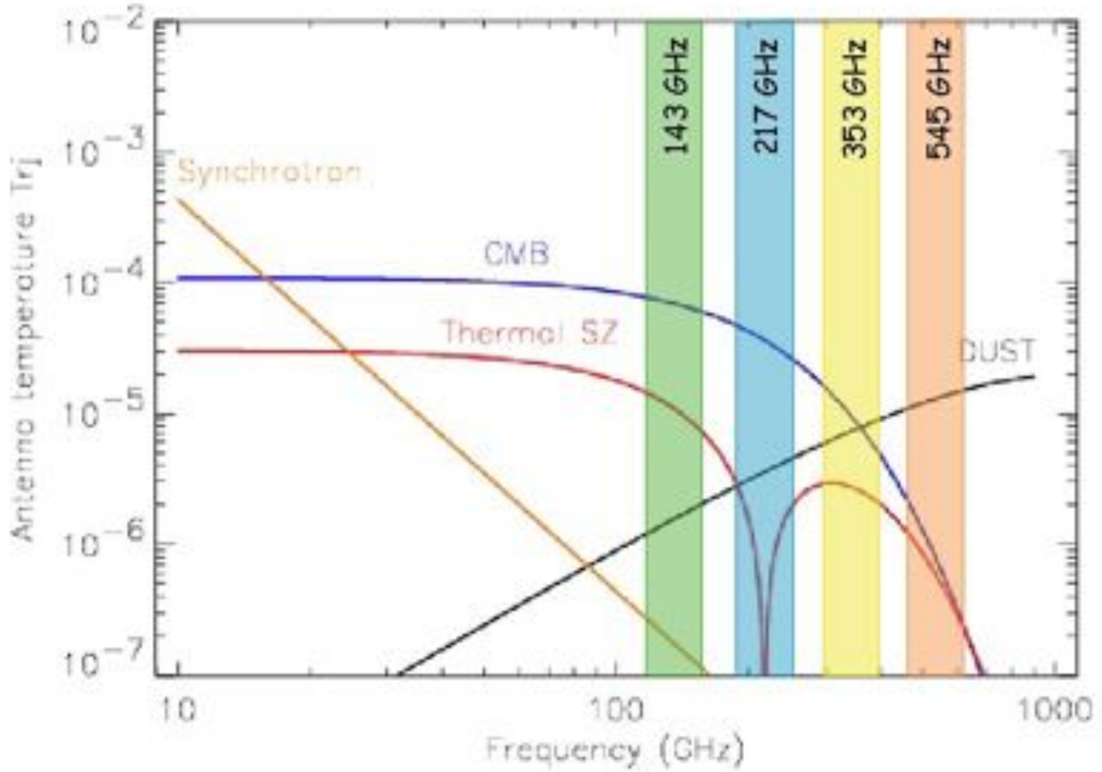


Objective : a 24-hour flight during the arctic night

The Archeops concept (cont'd)

- Multiband photometer
  - 22 bolometers
  - 4 frequency bands : 143, 217, 353, 545 GHz

Good redundancy foreground sep.



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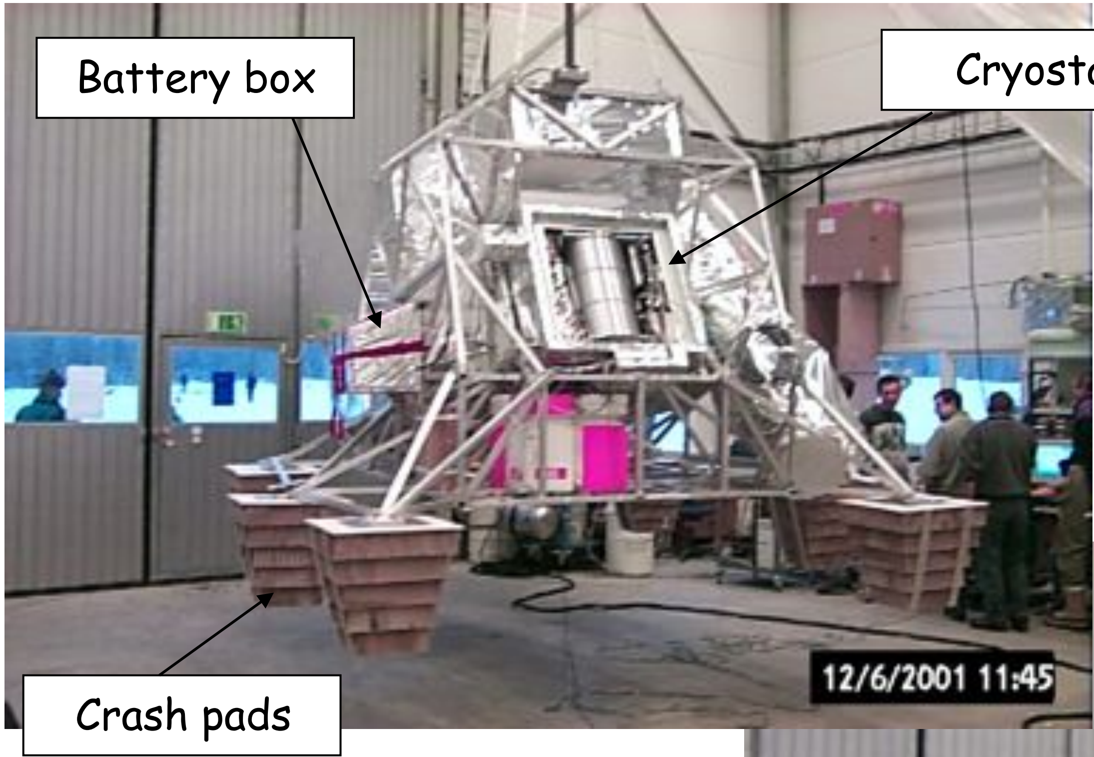
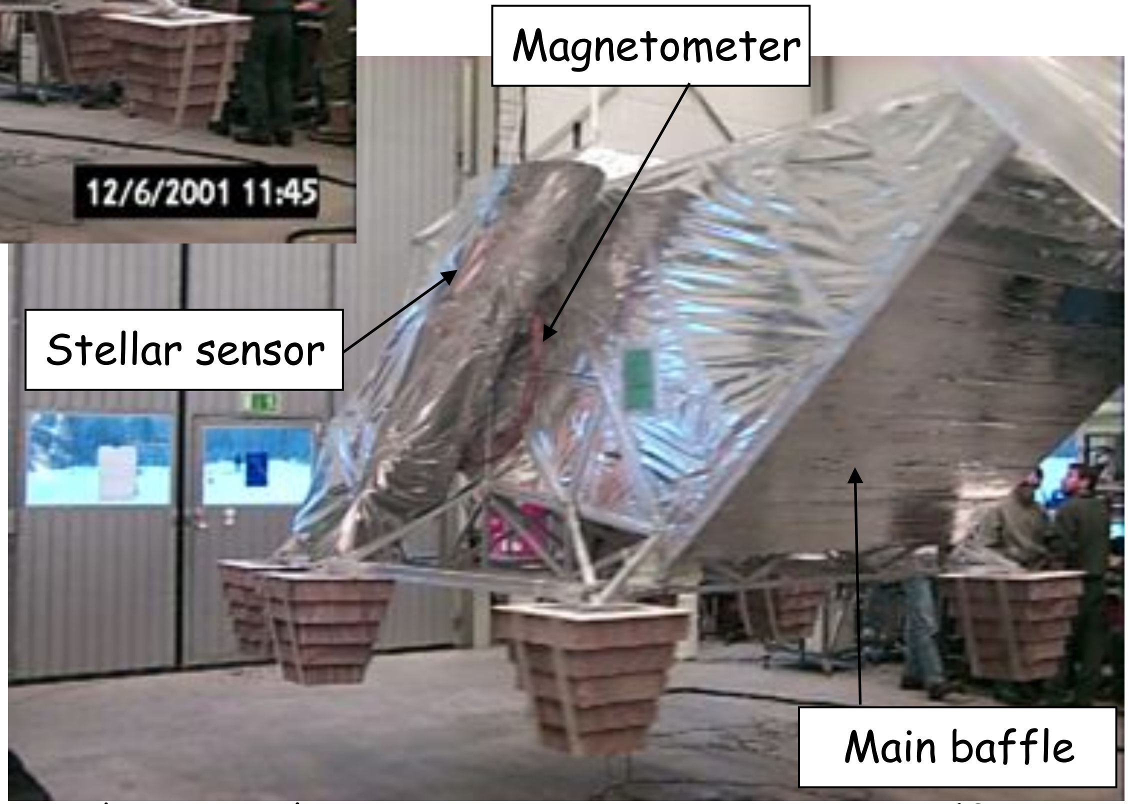
Archeops
(ready to fly)

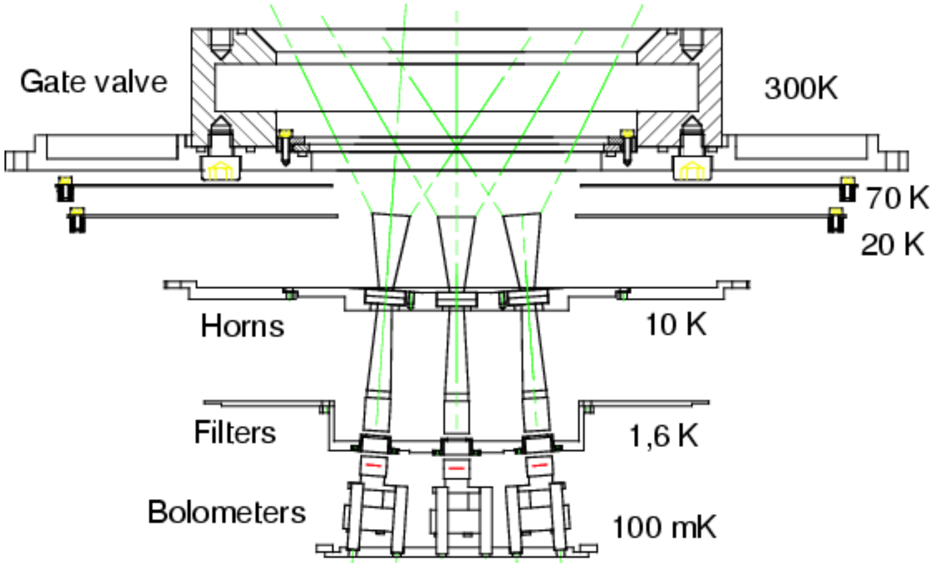


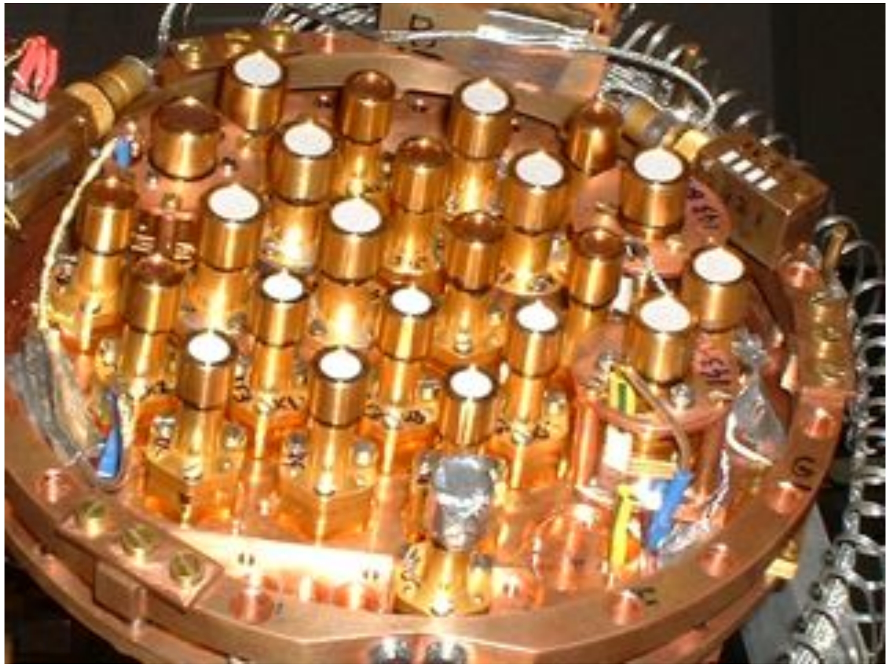


The ARCHEOPS cooling system

- Helium tank at T= 4.2K
- Open circuit dilution fridge
  - Similar to that built for Planck
  - 3He et 4He tanks
  - Mixture pumped with a charcoal pump
  - Temperature reached : **75 mK**
- Big input window (Ø 160mm)
  - First stage cooled to about 10K with4He vapour (7.5K during flight)
  - Flexible polypropylene window
  - Protection valve opening only at low outside pressure

The focal plane





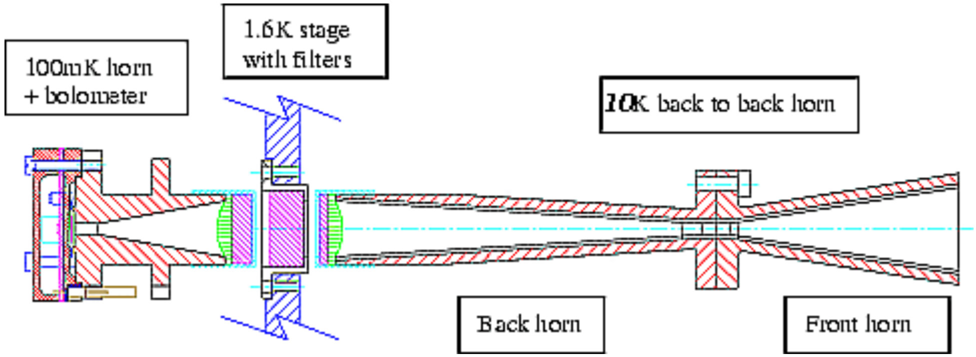
Bolometers

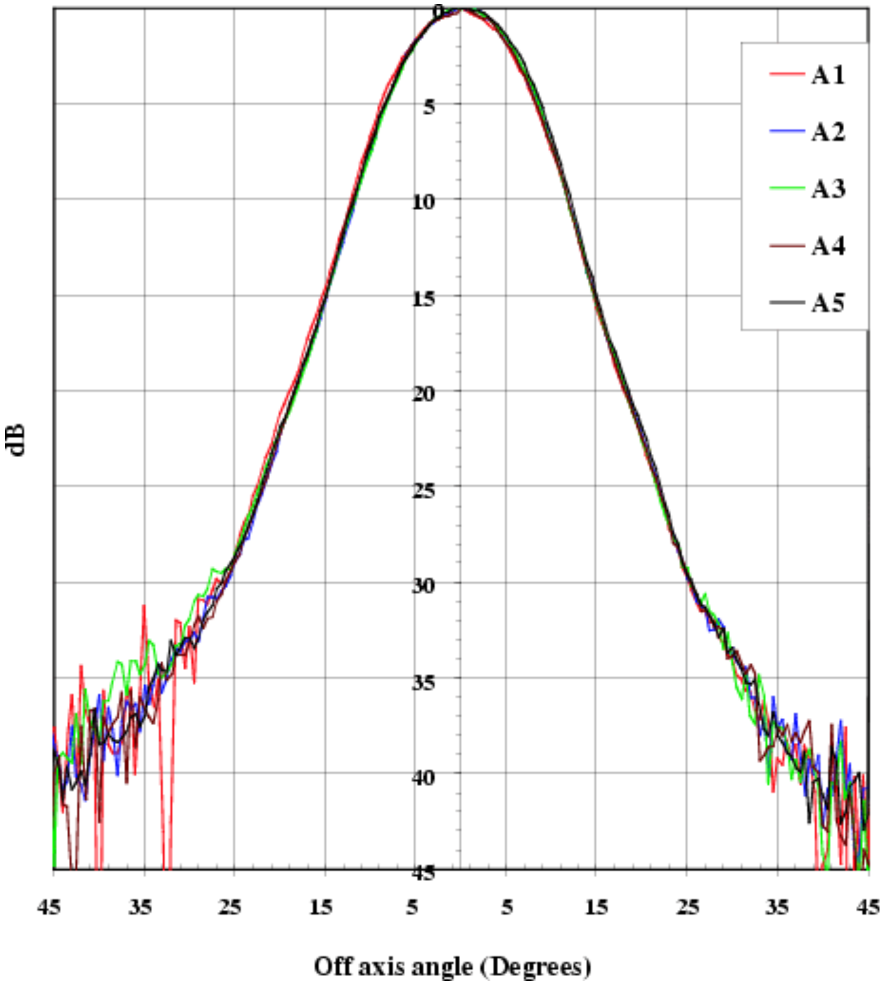
- Spider Web bolometers
  - •Low heat capacity
  - •Large photon collecting area
  - •Little sensitivity to cosmic rays

(Mauskopf et al.Appl. Opt., **36**, 1997)

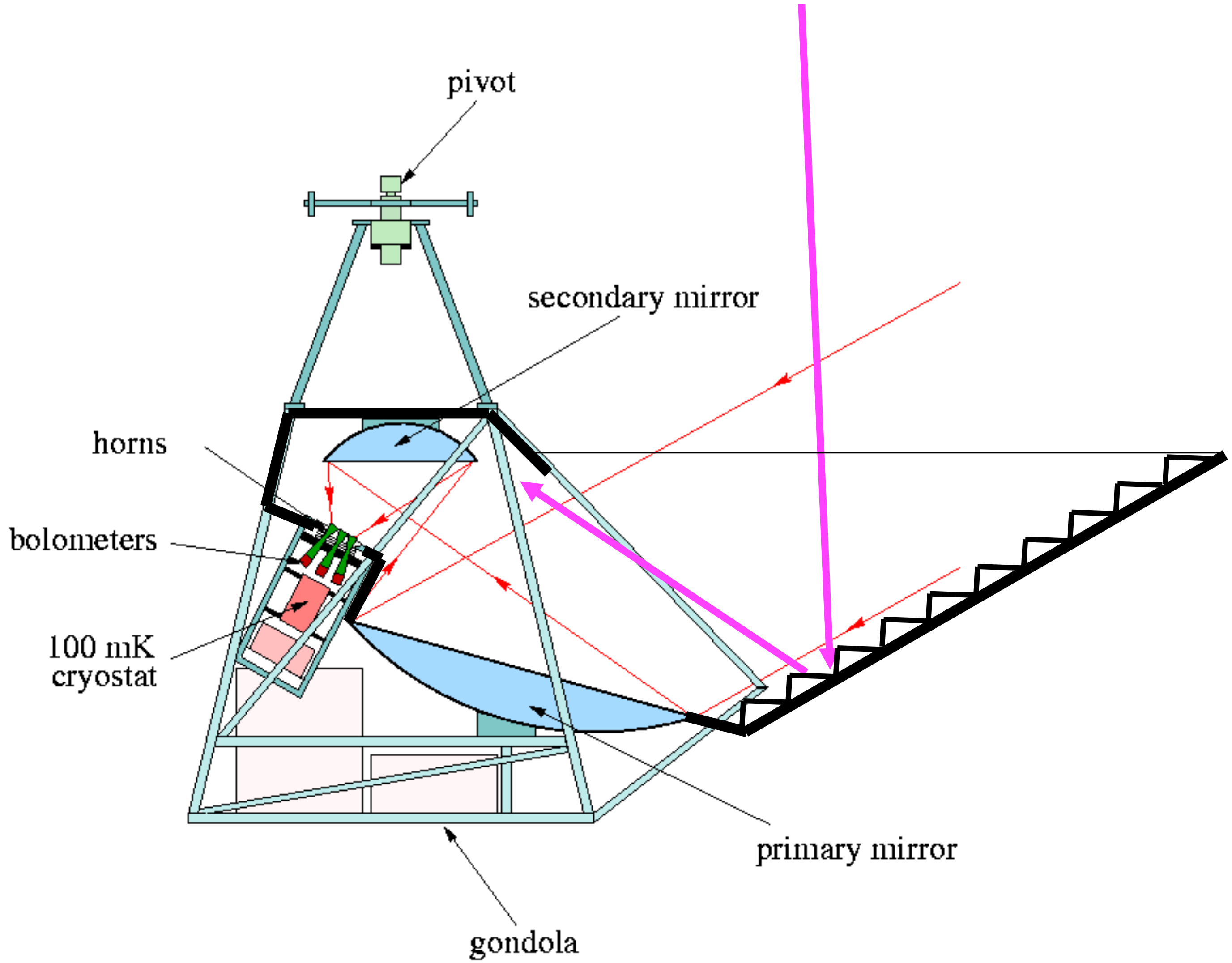
Archeops horns

- Back to Back corrugated horns (QMW) on the 10 K stage



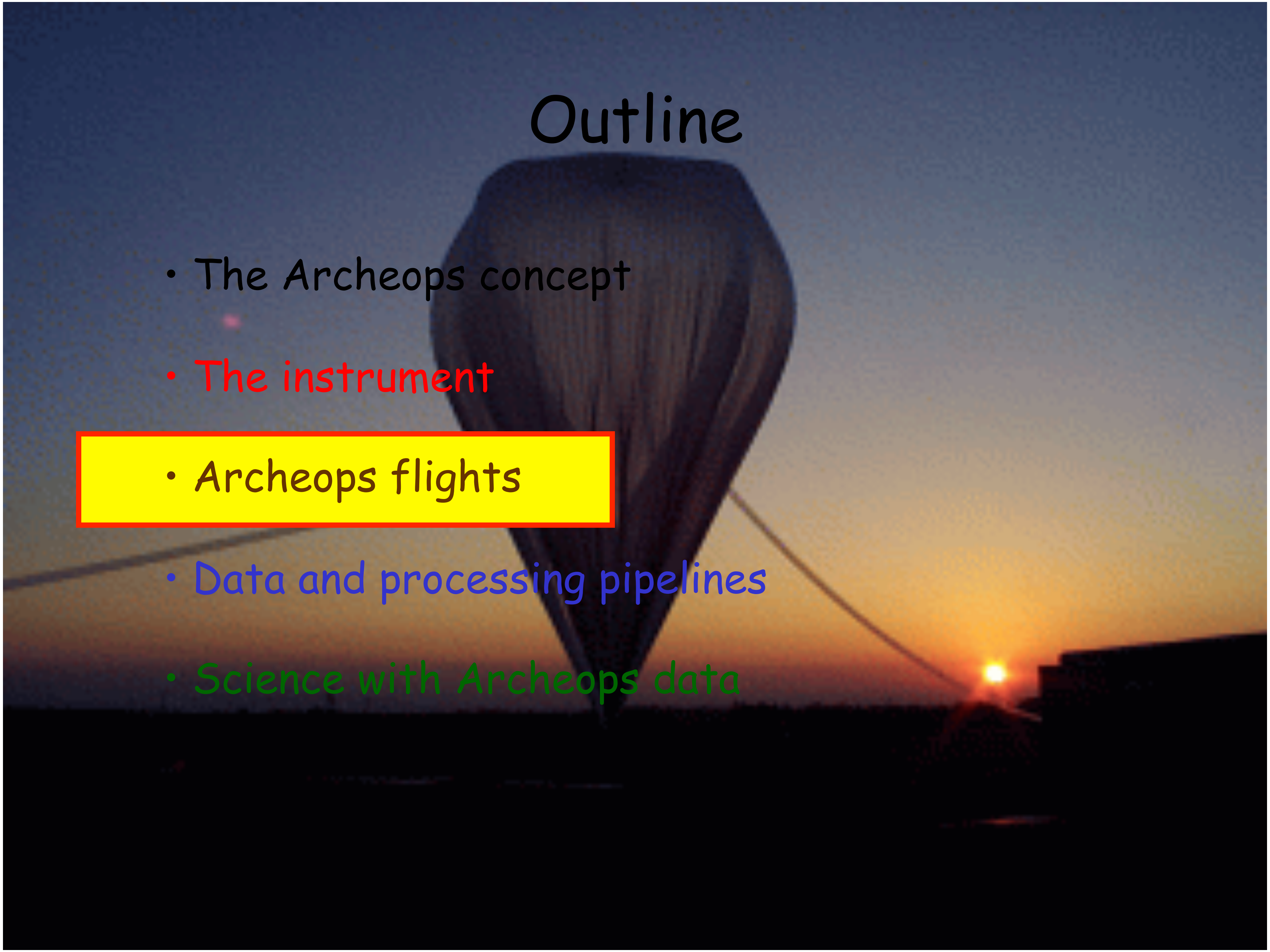


Archeops baffling system



Pointing and attitude monitoring

- Stellar sensor
  - ' Small ' (40cm) optical telescope with a photodiode array (Italy)
  - Stars identified a posteriori with a dedicated matching software (LAL)
- Additional information: GPS, gyroscopes, magnetometer
  - The GPS gives balloon position (longitude, latitude, altitude)
  - The gyroscopes give the rotation speed and pendulation
  - The magnetometer gives phase information (magnetic north)



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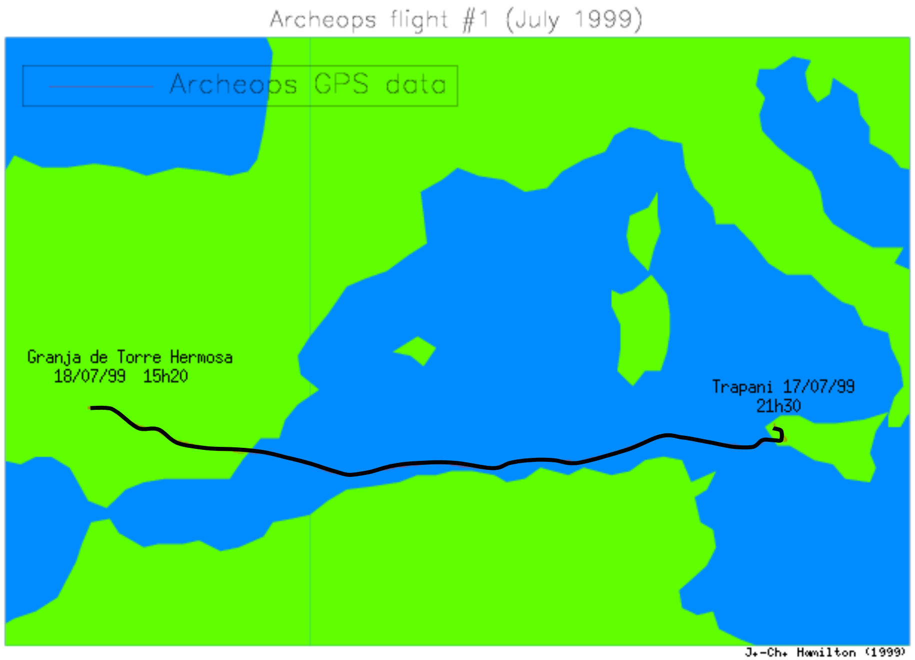
Trapani Test flight

From Trapani (Sicily) to Granada (Spain)

6 bolometers in the focal plane

Test flight from Trapani
July 1999

- 4 hours of night-time data
- 4 bolometers worked well (143, 217, 353 GHz)



- Cryostat OK
- Stellar sensor OK
- On board recorder OK

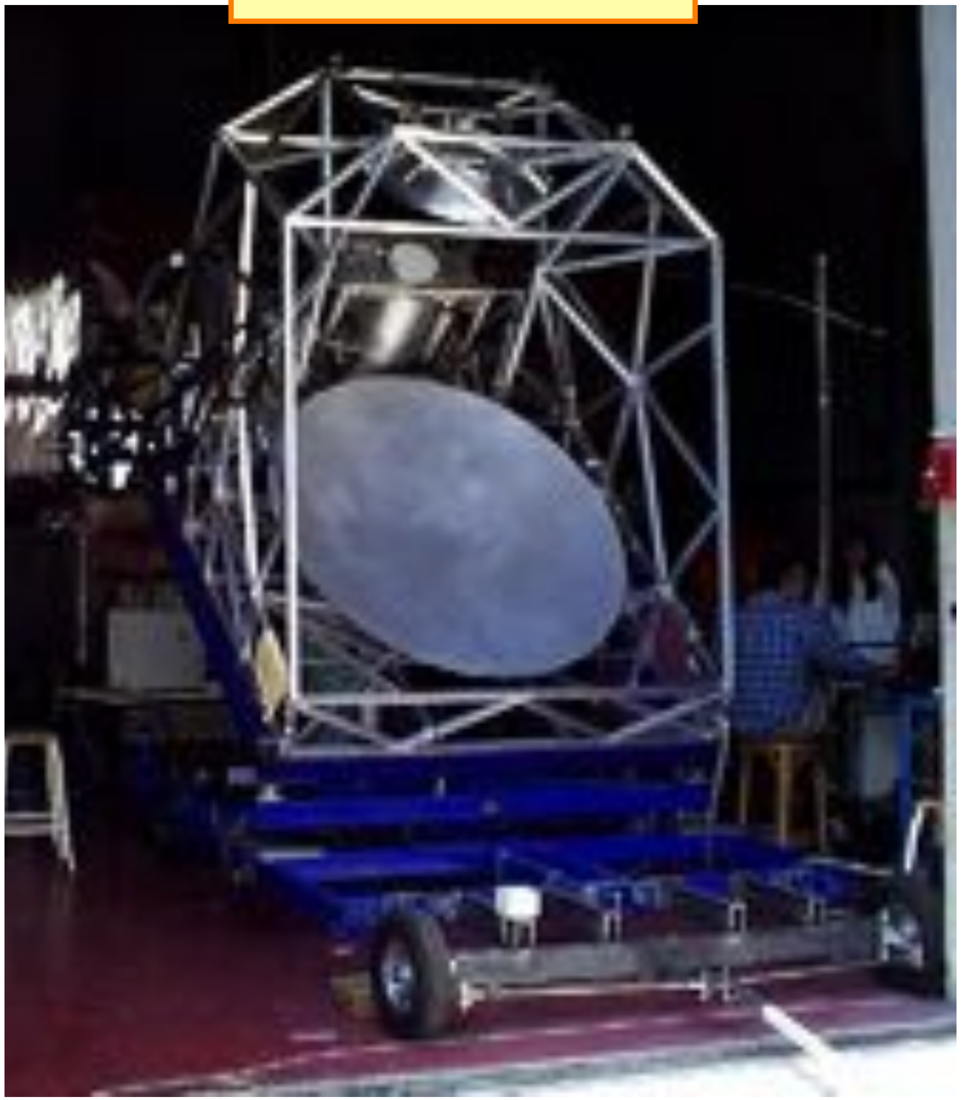
Scientific flights

- Two campains
  - december 2000 - january 2001
  - december 2001 - january 2002
- **From** ESRANGE (SSC, CNES) base near Kiruna (Sweden)
- **To** somewhere in Northern Russia...
- During Arctic night ➡ Long duration

Getting ready : ARCHEOPS ground calibration

Sensitivity measurements

Mirror alignment



Launch with auxiliary balloons

Gondola supported by auxiliary balloons
(and held by the Archeops team !)

Filling the main balloon

Launch !!!

Archeops flights from Kiruna

- Requirements to fly :
  - Not too much wind on ground (< 2 m/s)
  - Not too much snowing (avoid filling the mirror with snow !)
  - Stratospheric winds towards east and not too strong
  - Moon, Sun to be avoided, Jupiter to be seen
  - Agreements and contracts with Russians signed...
- Four flights from Kiruna :

Date	Flight duration at ceiling	
12 january 2001	//	Problem with a flow-meter
29 january 2001	7h	low altitude because of excessive winds
19 january 2002	2h	Balloon valve blocked
7 february 2002	19h	12.5 h of excellent night-time data

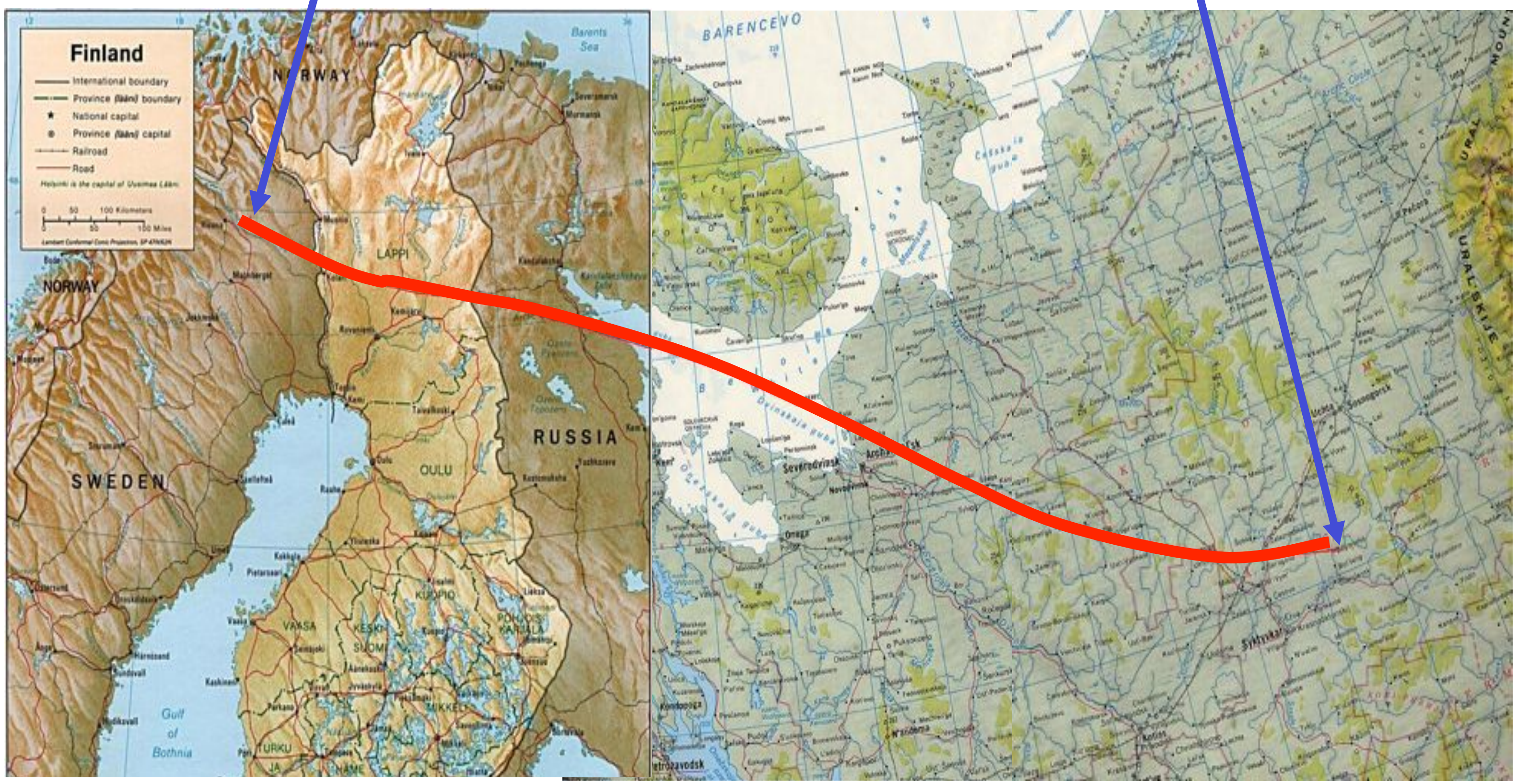
First Flight january 12th 2001

- Early failure of a flow rate meter
- Quick landing in Finland

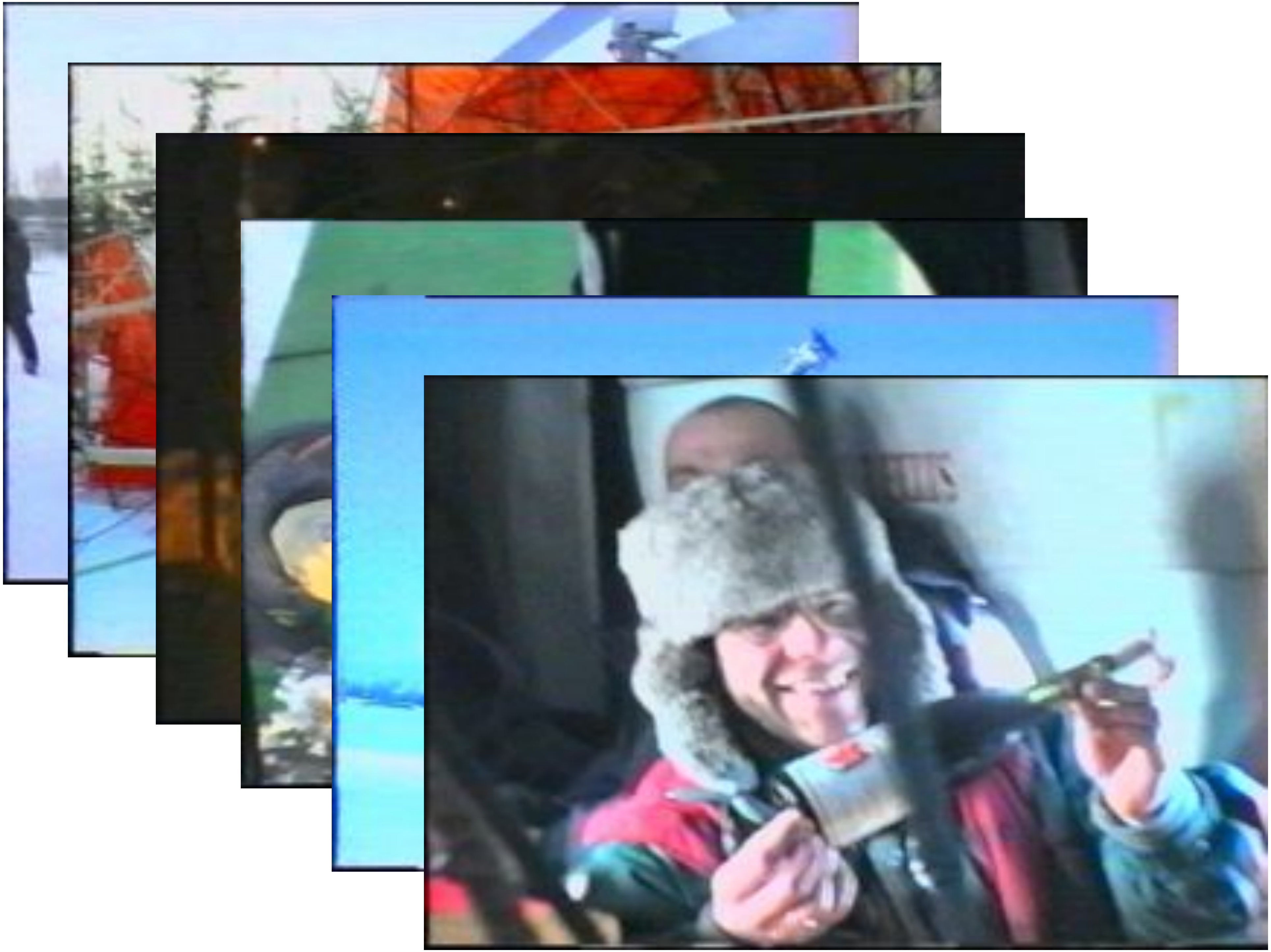
Fast recovery ...

First Scientific Flight (KS1)

- from the ESRANGE base (SSC, CNES) in Kiruna (Sweden)
- to Syktyvkar (Russia)

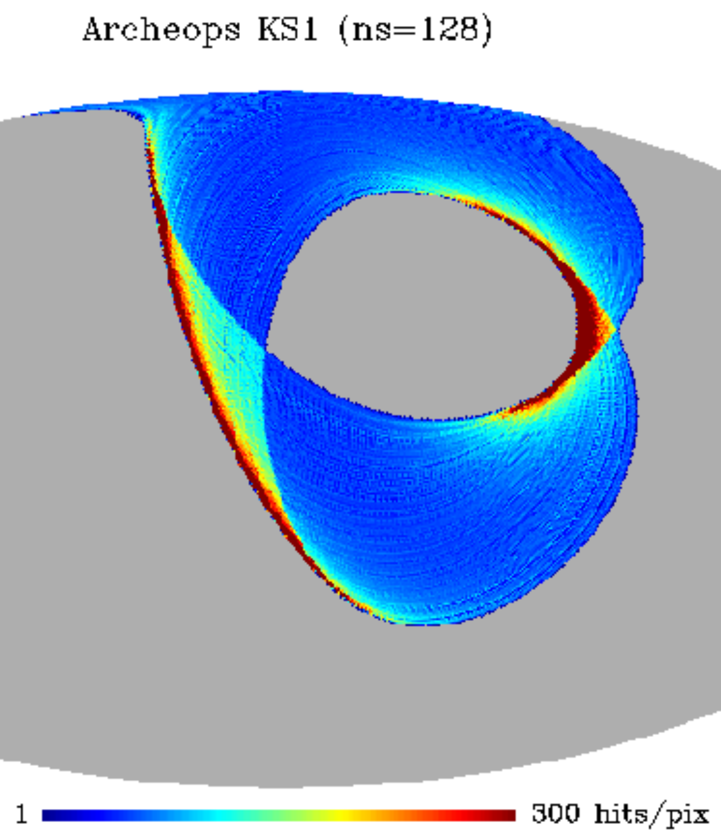


Ceiling altitude : 31.5 km



Archeops coverage (KS1 flight)

- 22 bolometers on board:
  8 143 GHz
  6 217 GHz
  6 353 GHz
  2 545 GHz



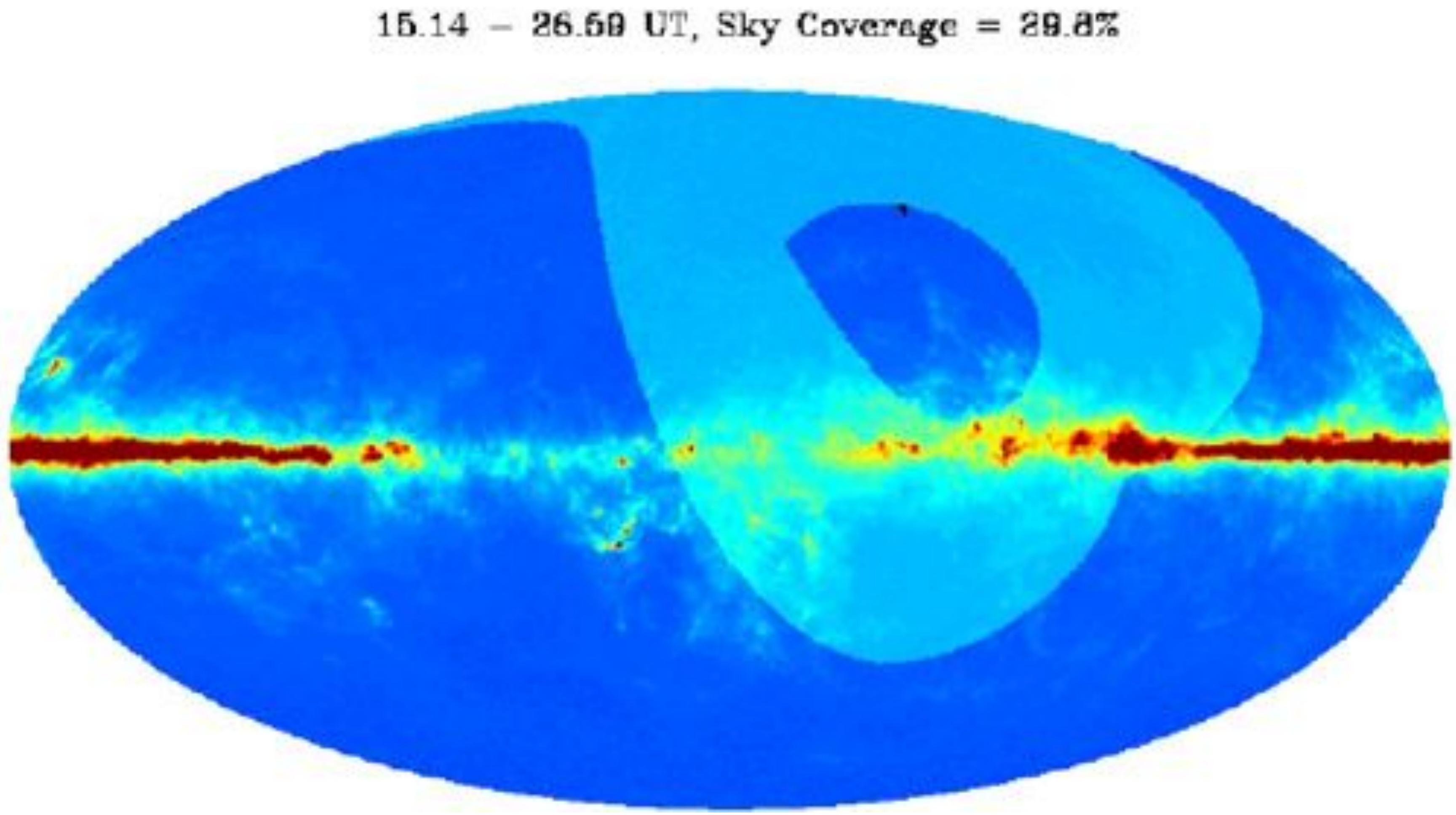
temperature always < 100 mK during the 7.5 hours of scientific data

Third Scientific Flight (KS3)

- Balloon launched at 12h44 UT February 7th
- Balloon landed at 10h20 UT February 8th
- Ceiling altitude: 34 km

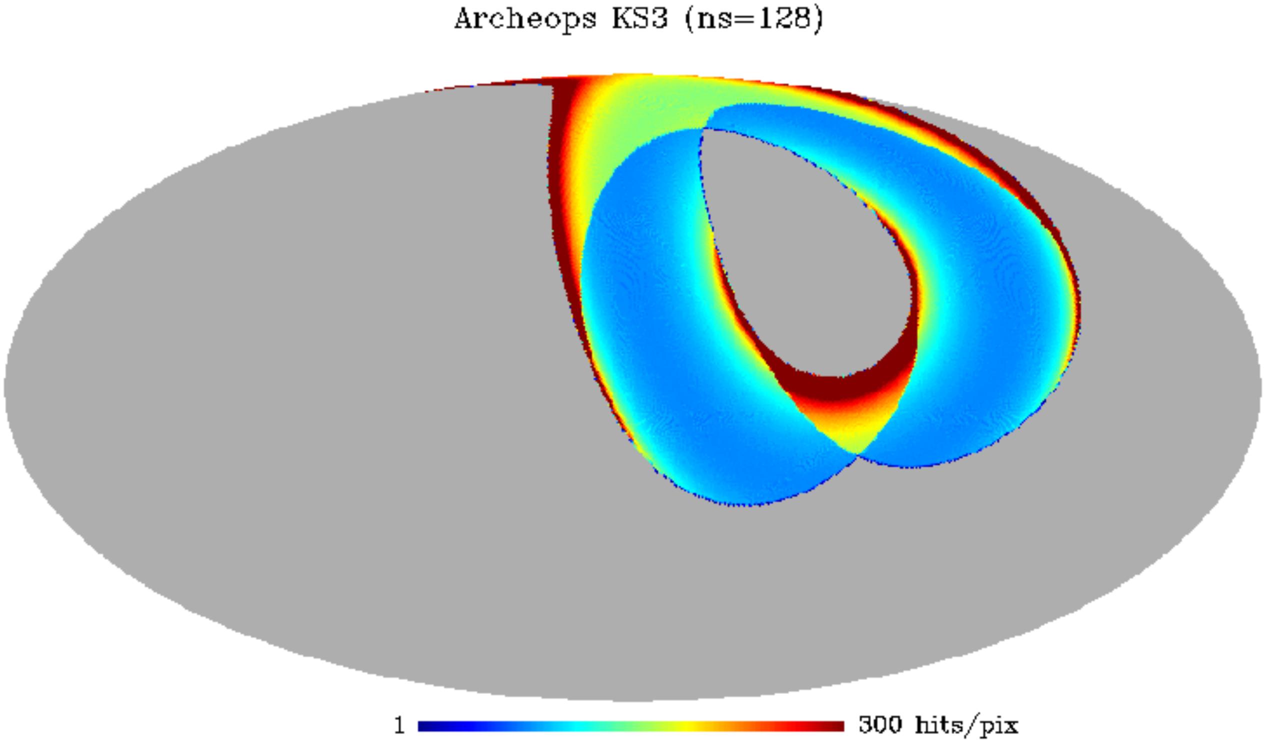
Landing close to Noril'sk (Siberia)

February 2002 flight : sky coverage



Archeops coverage (Kiruna, 7 february 2002)

- 21 bolometers on board:
  8 @ 143 GHz
  6 @ 217 GHz
  6 @ 353 GHz
  1 @ 545 GHz



12.5 hours of night data at ceiling
+ 6.5 hours during the day

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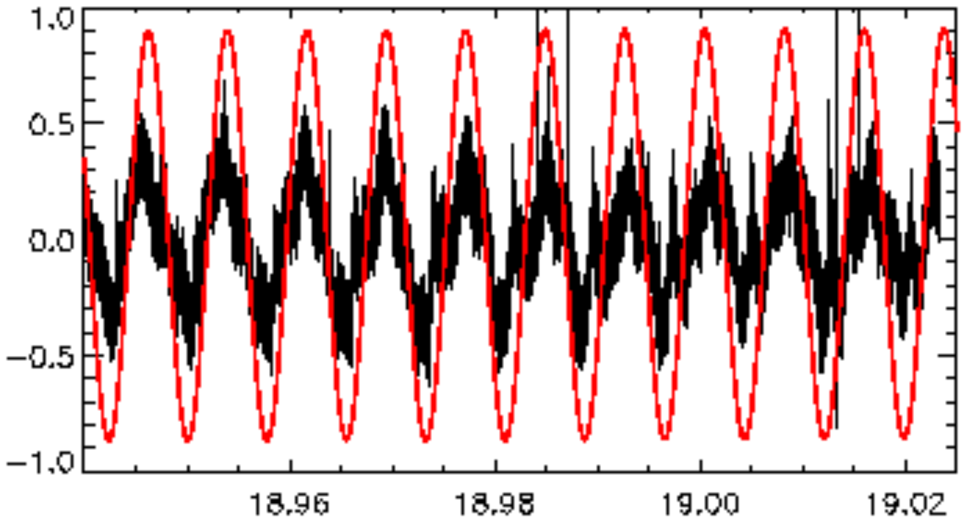
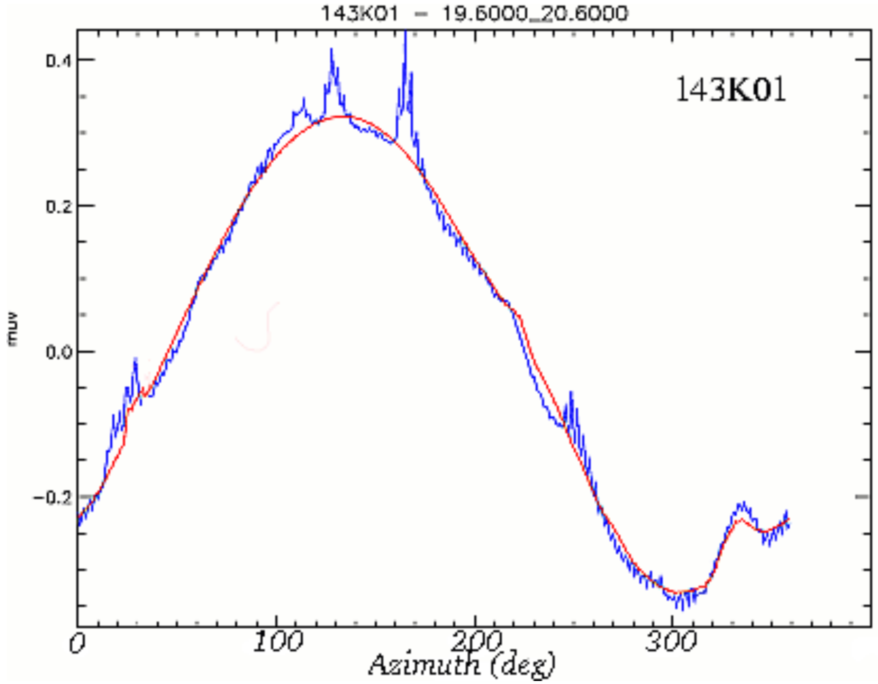
Data processing pipeline

- Cleaning the data
- Pointing reconstruction
- Calibration
- Map-making
- Component separation
- C_l spectrum estimation

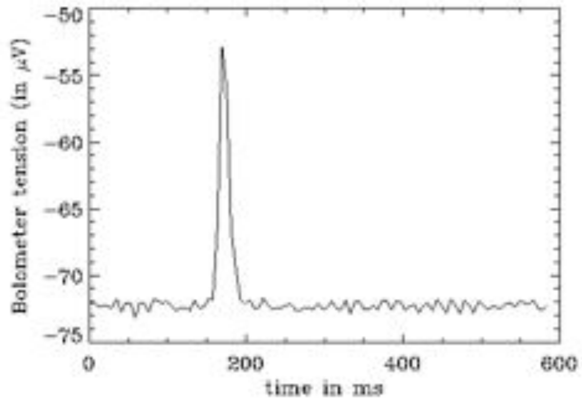
A look at Archeops timelines



5 minutes



Archeops signal
Dipole signal



Independent calibration on the dipole, on Galaxy crossings, and on Jupiter

Data cleaning

Macias-Perez, Madet, Filliatre, Renault, Désert et al.

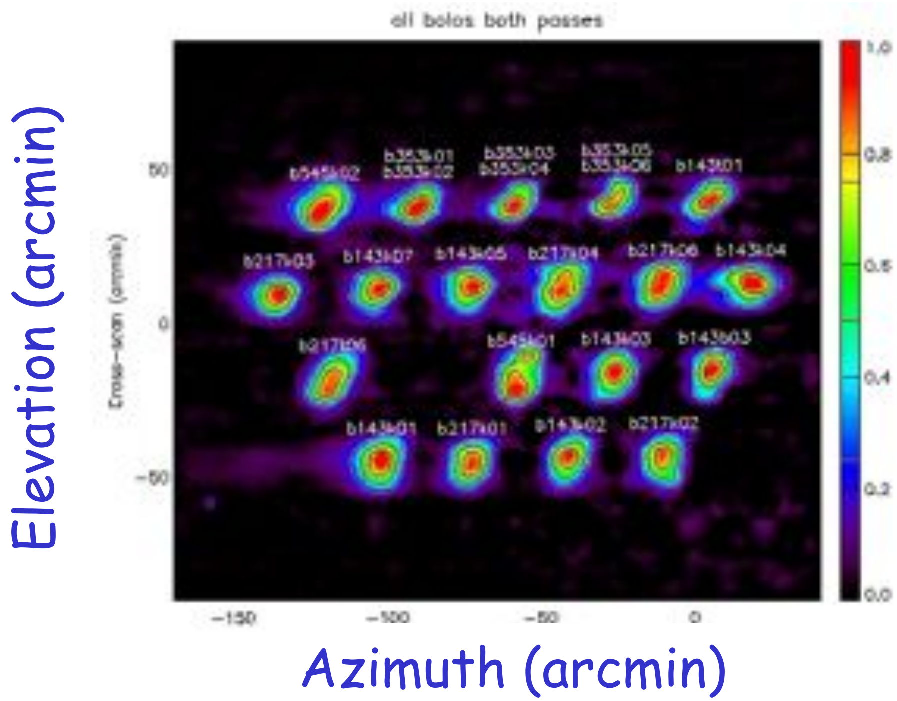
- Very low frequencies (1 minute to 1 hour)
  - Correct for slow gain drifts
  - Decorrelate slow signals proportional to airmass (altitude , elevation)
  - Decorrelate 0.1K, 1.6K 10K temperature fluctuations
- High frequency (1 - 100 Hz)
  - Remove cosmic-ray hits (glitches)
  - Remove correlated EM noise
  - Remove microphonic bursts
  - Remove noise synchronous with acquisition frequency
- A spinning frequency (30 sec)
  - separate ozone cloud emission using multi-band data
- Flag all bad data

Pointing

Couchot, Bourrachot et al.,
Hamilton, Versillé, et al.

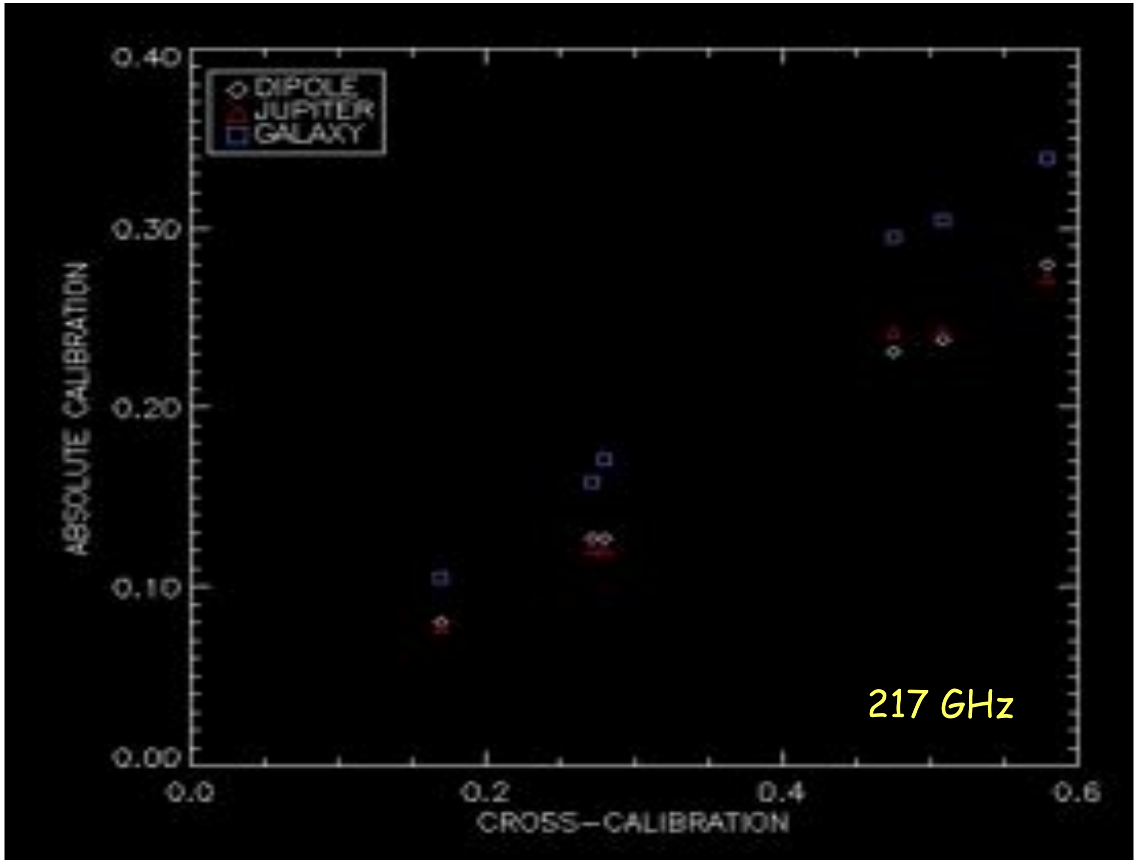
Position from GPS, attitude reconstruction using stellar sensor data (matched with a catalog of known stars)

Beam shape and focal plane geometry reconstructed using Jupiter crossings



Calibration

Lagache et al., Désert et al., Benoit et al.



About 20% systematic discrepancy between methods still being investigated

Final absolute calibration error expected to be better than ~ 5%

Map making

Yvon, Mayet et al.,
Teyssier, Prunet, Doré, Vibert et al.

MAIN ISSUE

Residual low frequency drifts below ~1 Hz + insufficient scan crossings lead to significant striping

SOLUTIONS

Method 1 : strong filtering followed by weighted co-addition

Method 2 (MAPCUMBA) : multi-resolution implementation of optimal map making

Method 3 (MIRAGE) : a combination of filtering and optimal map making

Power spectrum extraction

THREE METHODS

- MASTER method (Hivon et al.) :
  - Use sub-optimal maps obtained by filtering and co-addition
  - Use maps only from the best tree bolometers (1-143 & 2-217)
  - Make a stringent galactic cut (use only b>30°)
  - Correct for filtering effects on C_l by Monte-Carlo methods

Current baseline...

Amblard et al.

- Optimal Map method :
  - Make optimal maps with e.g. MAPCUMBA
  - C_l estimation on maps with, e.g. SPICE (Szapudi et al.)

In progress

Vibert, Doré,Prunet et al.

- Blind spectral matching method

NEW !

Patanchon et al.

Blind spectral matching method

Cardoso et al.

LINEAR MODEL : each detector's map is a linear superposition of a number of components (sources)

$$y_d(k) = A_{dc}.\ s_c(k) + n_d(k)$$

maps (a_{lm}) for detectors d

unknown mixing matrix

unknown maps of components c

Unknown noise maps

Blind spectral matching method (cont 'd)

The data autocorrelation can be written as

$$\langle y y^{\dagger} \rangle = A \langle s s^{\dagger} \rangle A^{\dagger} + \langle n n^{\dagger} \rangle$$

$$Y = ASA^{\dagger} + N$$

- Find by minimising the mismatch between Y and $ASA^{\dagger} + N$

- the mixing matrix A
- a band-power parameterised model of S
- a white noise model of N

Component separation

Patanchon et al.

Knowing A, S and N, the best estimated component maps are obtained by Wiener filtering :

$$\hat{s} = [A^{\dagger}N^{-1}A + S^{-1}]^{-1} A^{\dagger}N^{-1} y$$

Bouchet et al.

This can be done using estimated values of A, S and N obtained by spectral matching (blind component separation)

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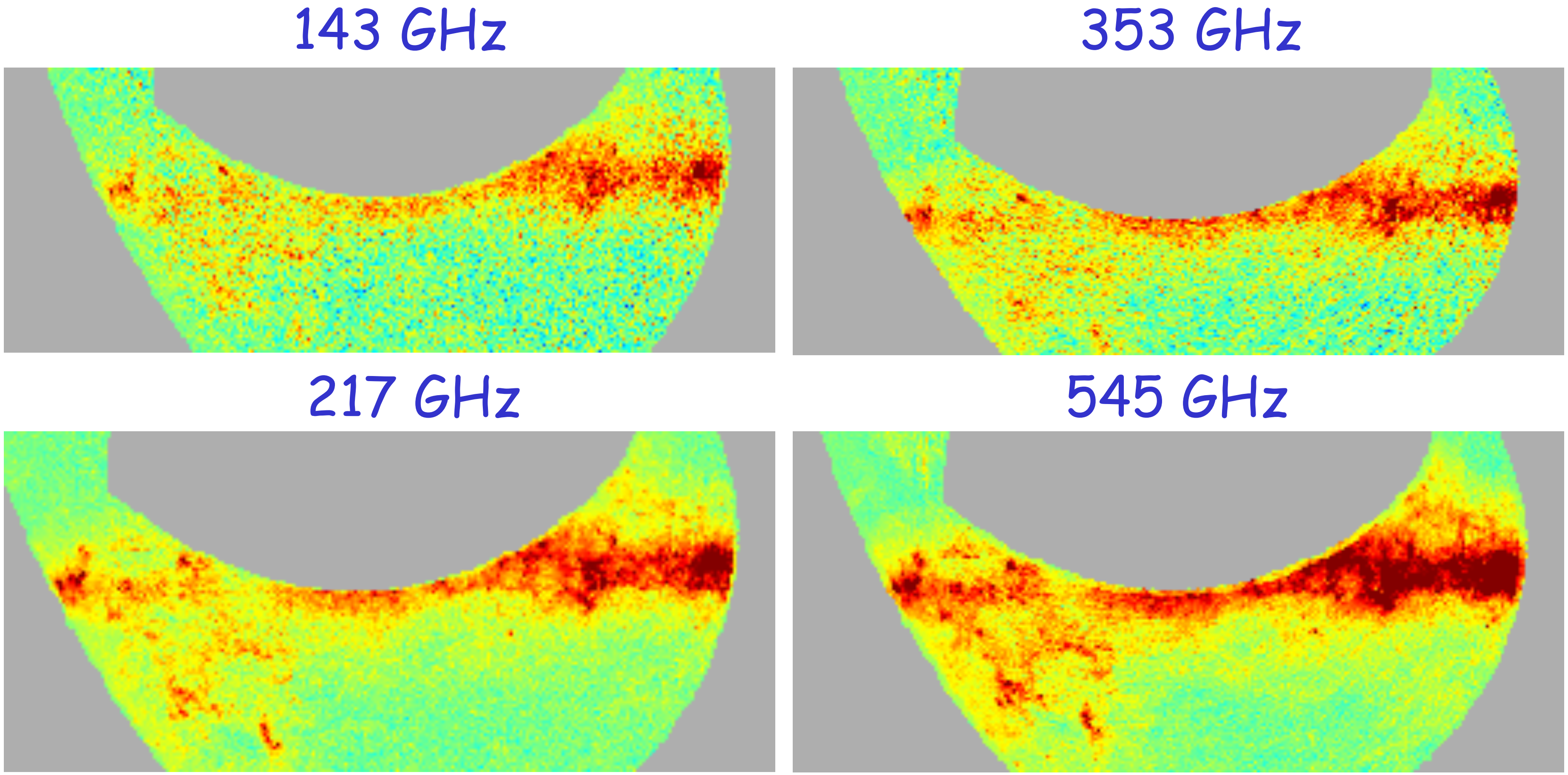
Half of the galactic plane mapped at 143, 217, 353 and 545 GHz

Constraints on foreground polarisation at 353 GHz

CMB fluctuations detected !

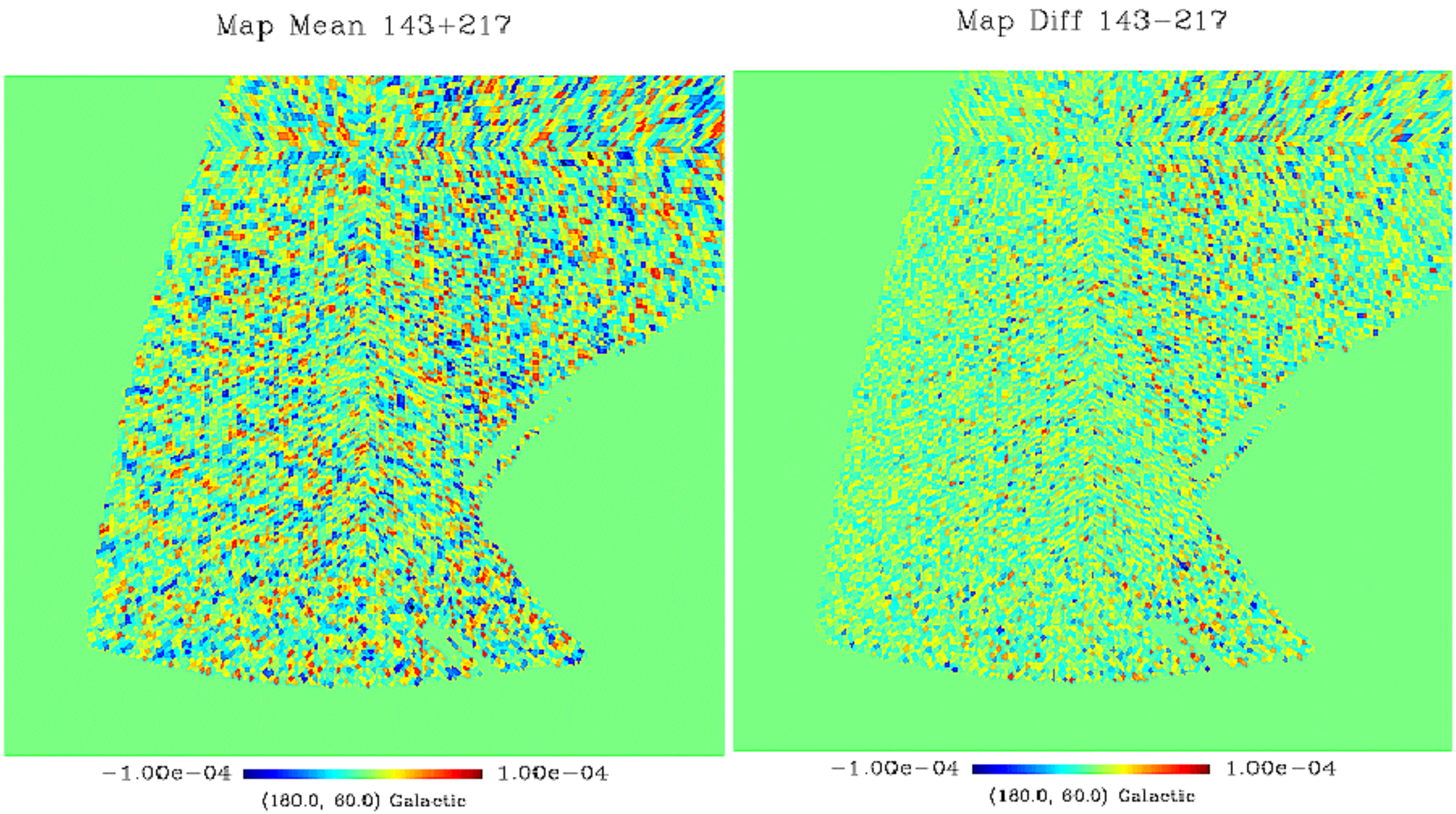
Good measurement of the CMB power spectrum in the l=10-800 range

First-order KS3 maps around Galactic plane

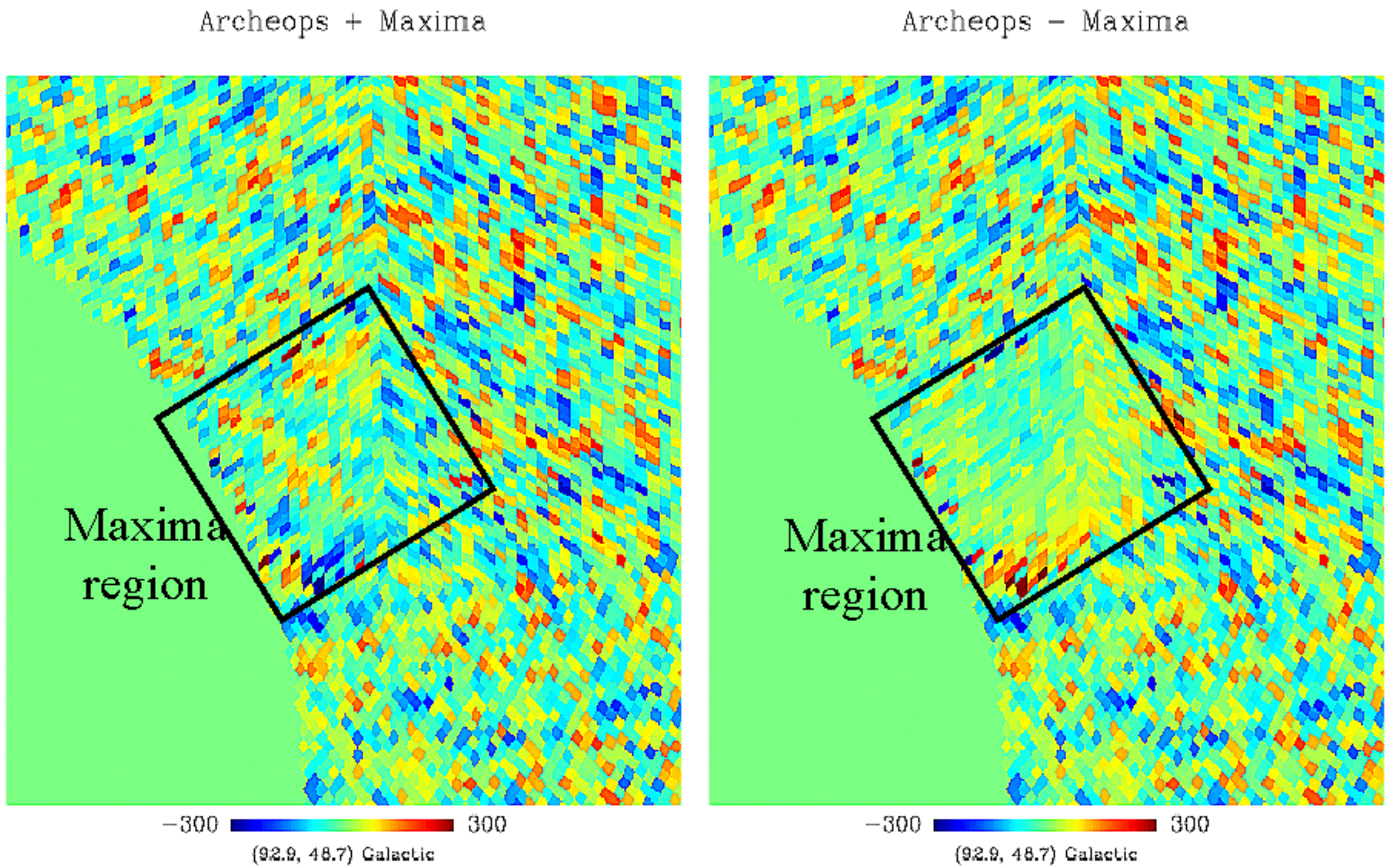


Maps covers 1/3 of the galactic plane

Comparison 143-217 GHz (best detectors)



NB :
- Non-optimal version of the pipeline
- No Wiener filtering


Archeops + Maxima
Maxima region
−300
300
(92.9, 48.7) Galactic
Archeops − Maxima
Maxima region
−300
300
(92.9, 48.7) Galactic

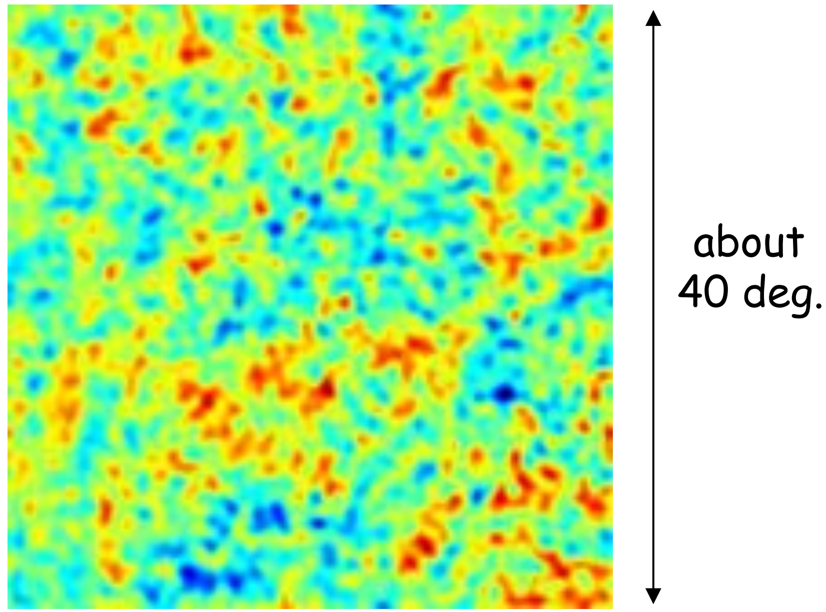
Preliminary blind separation results
far from galactic plane, high-redundancy region

Two-component separation using 18 maps (143-353 GHz)

- One of the recovered components is compatible with CMB (frequency channel dependence flat in units of δK_{CMB}, power spectrum displaying a clear peak at l~200)

- The other component is correlated detector noise (essentially low-level residual stripes)

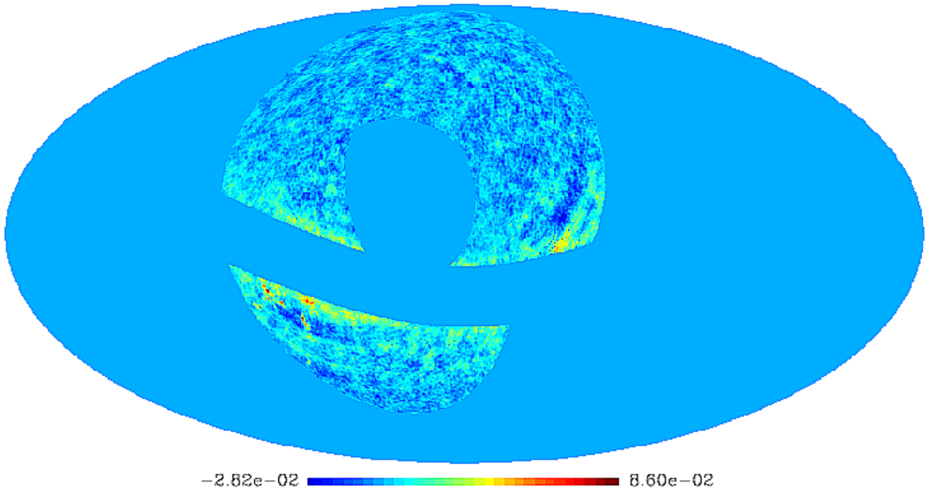
- No detectable galactic foreground contamination in this region at this stage



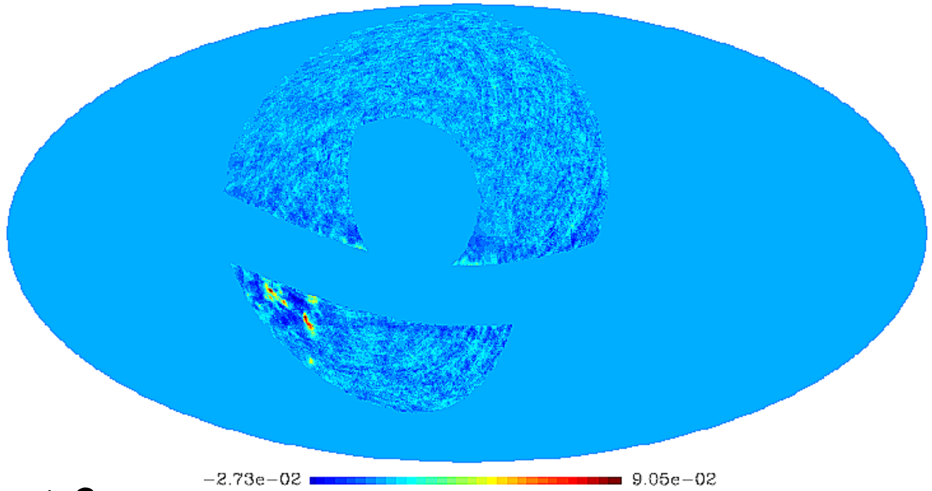
Wiener filtered recovered component map

Preliminary KS3 component maps
obtained by blind separation with Wiener filtering

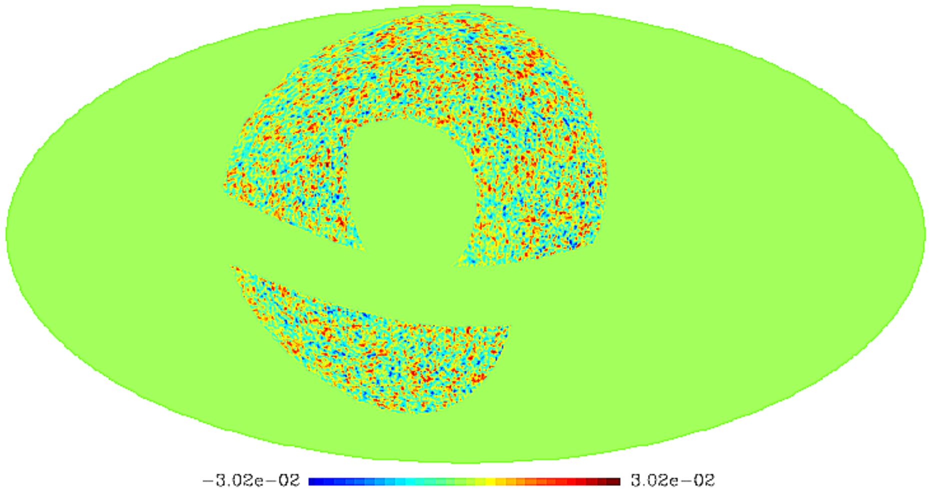
Component 1



Component 2

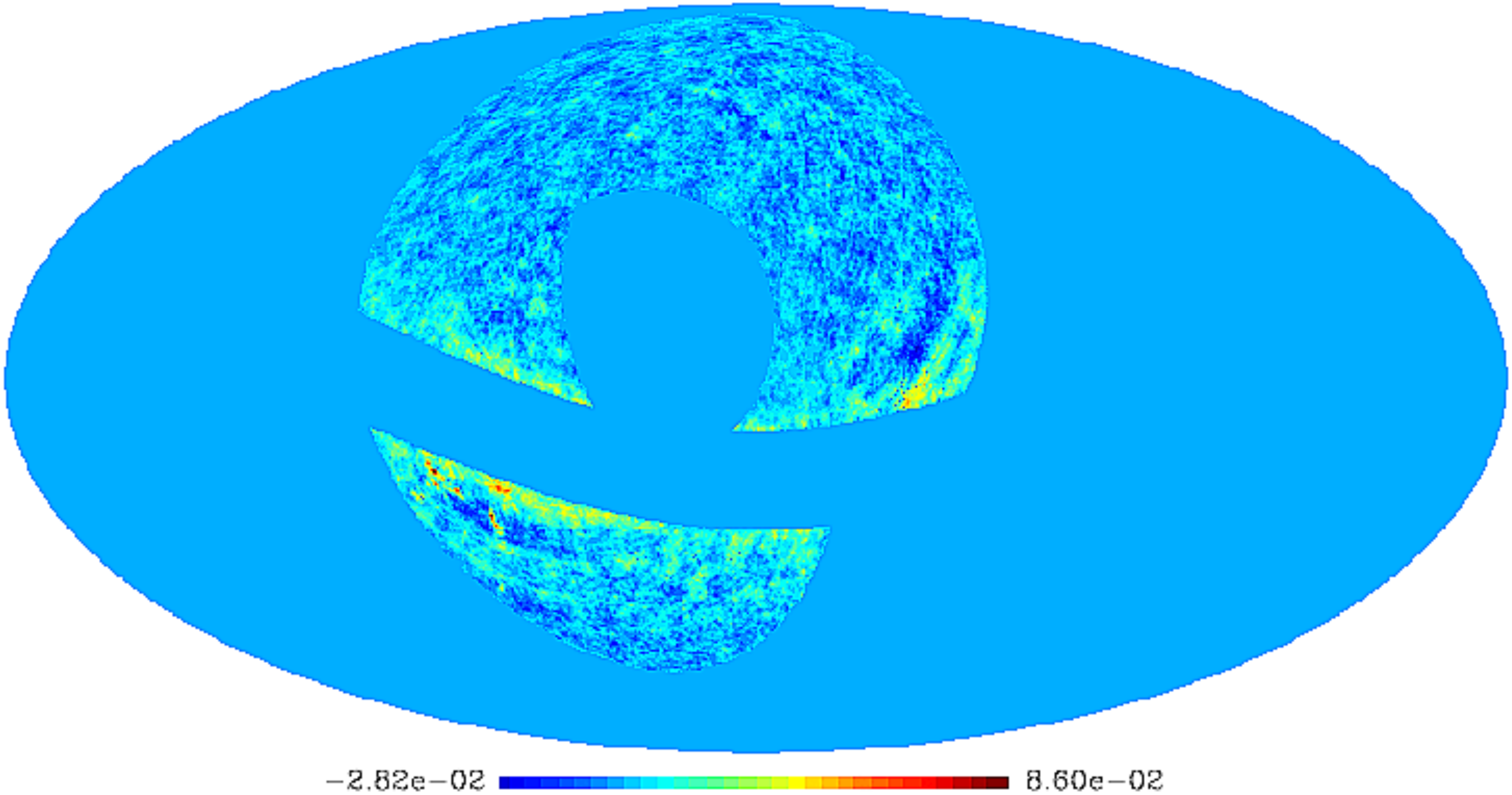


Component 3

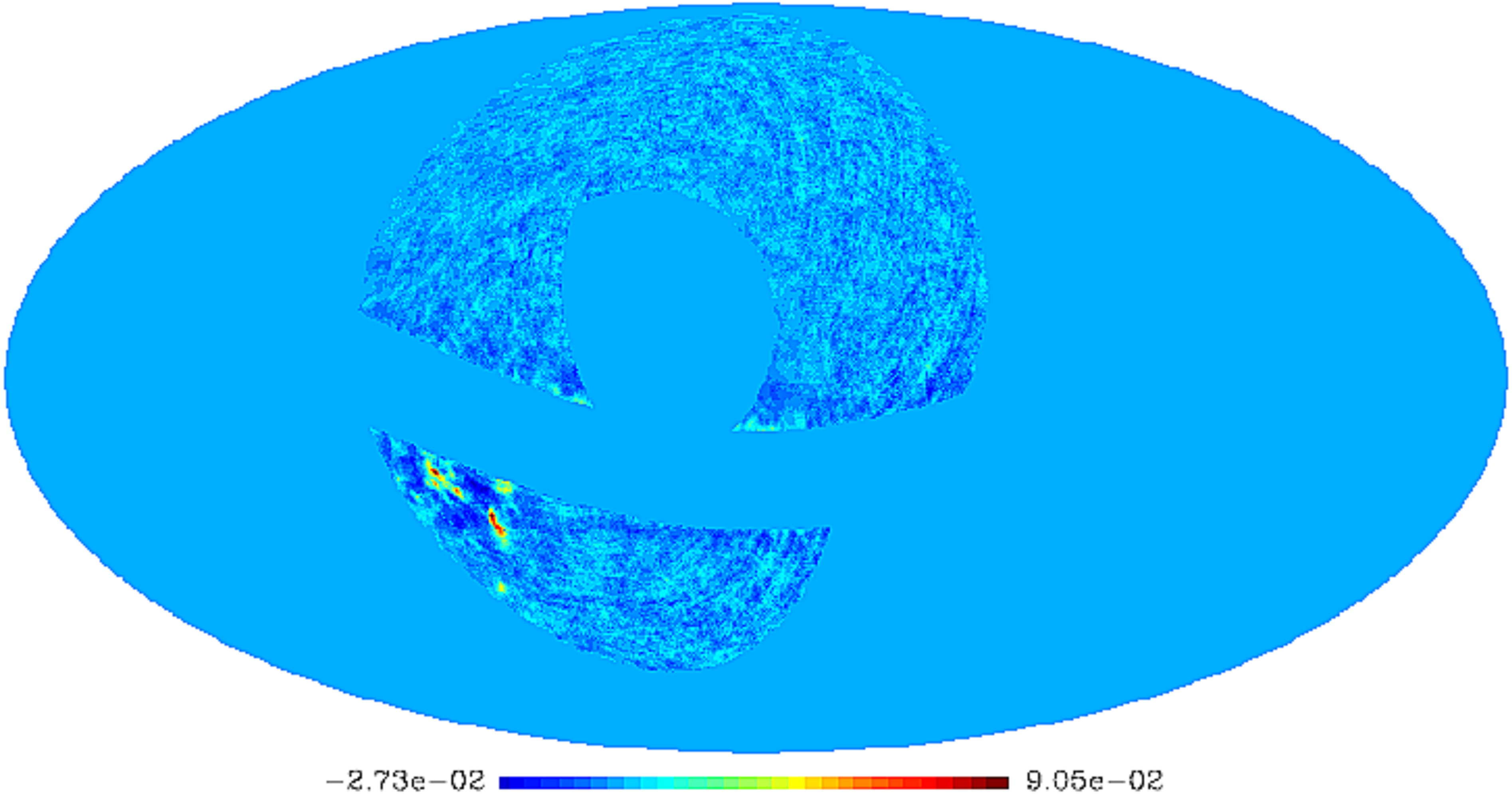


Patanchon et al.

Component 1



Component 2



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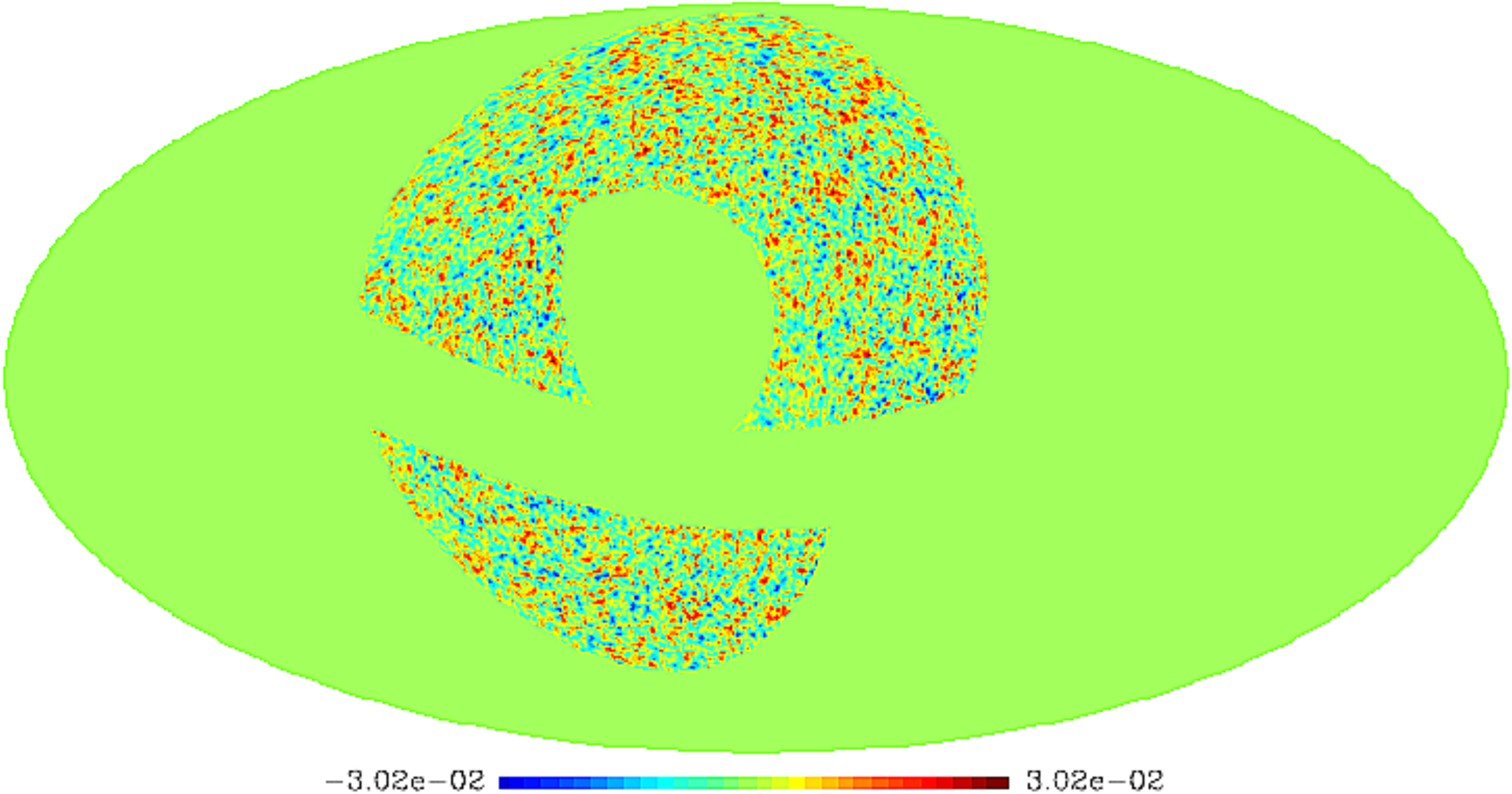

Estimated C_l sensitivity