Performances of Herschel/PACS Bolometer Arrays and future developments at CEA

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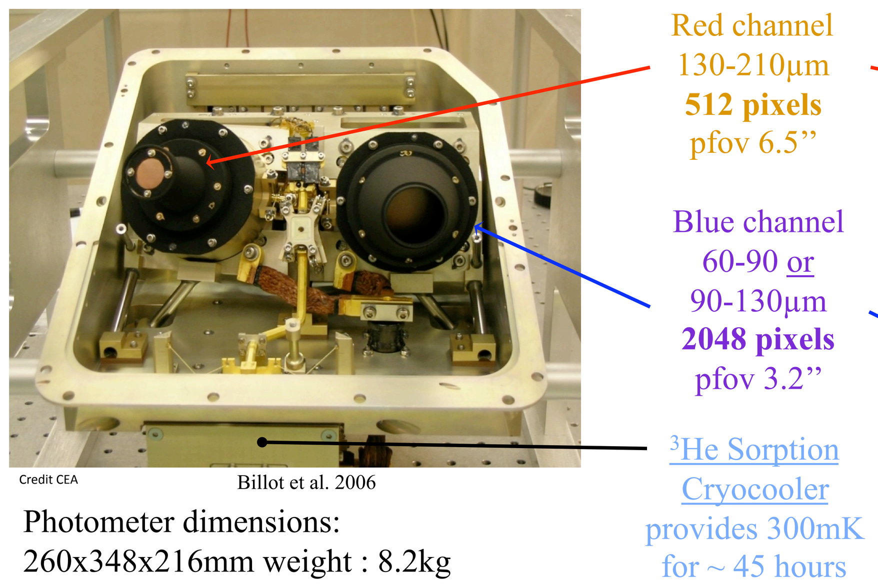
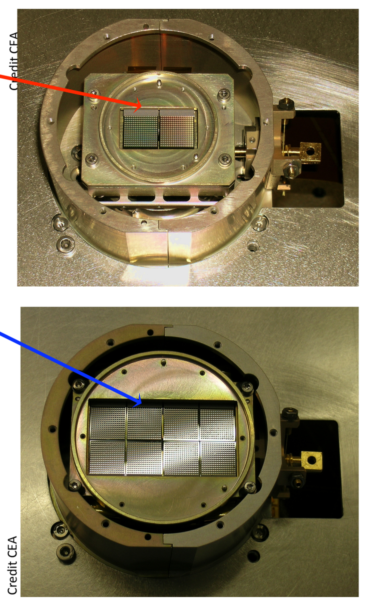
Introduction

The PACS Photometer of the Herschel Space Observatory is equipped with filled bolometer arrays developed by CEA/LETI and CEA/SAp. These innovative detectors allow to dispense with bulky light concentrators and to instantaneously sample the field of view without altering the optical coupling of the detectors to the telescope beam. CEA/LETI opted for an all-silicon design to allow for the collective manufacturing of 16x16 bolometer arrays. Being 3-side buttable these arrays are now the building blocks for making large focal planes necessary for the next generation of wide-field sub-mm cameras.

We present the unique architecture of CEA filled bolometer arrays and we report on the latest performance measurements of the Herschel/PACS Photometer. We also present current and future developments at CEA for ground-based, balloon borne and space telescopes.

PACS Photometer



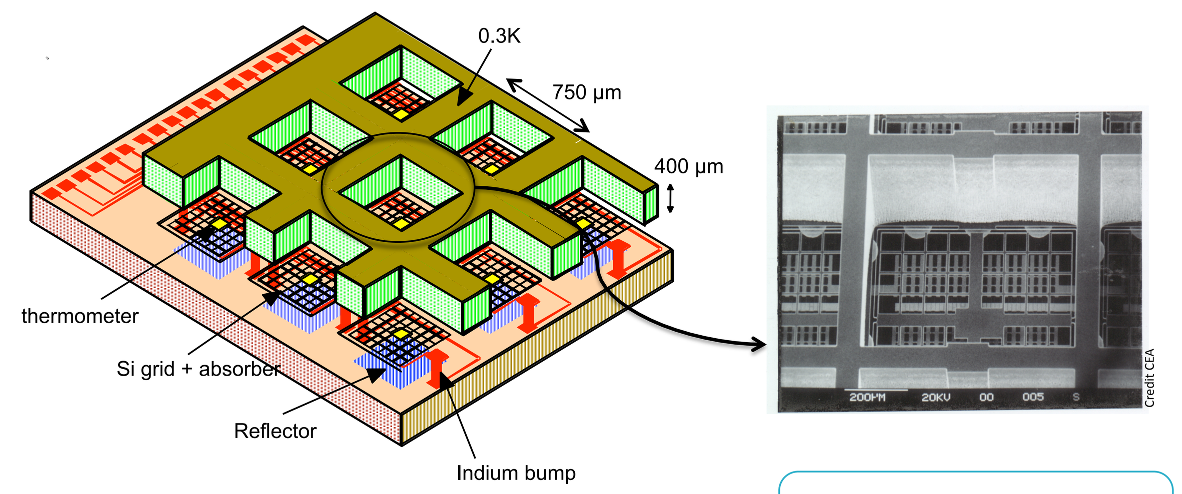


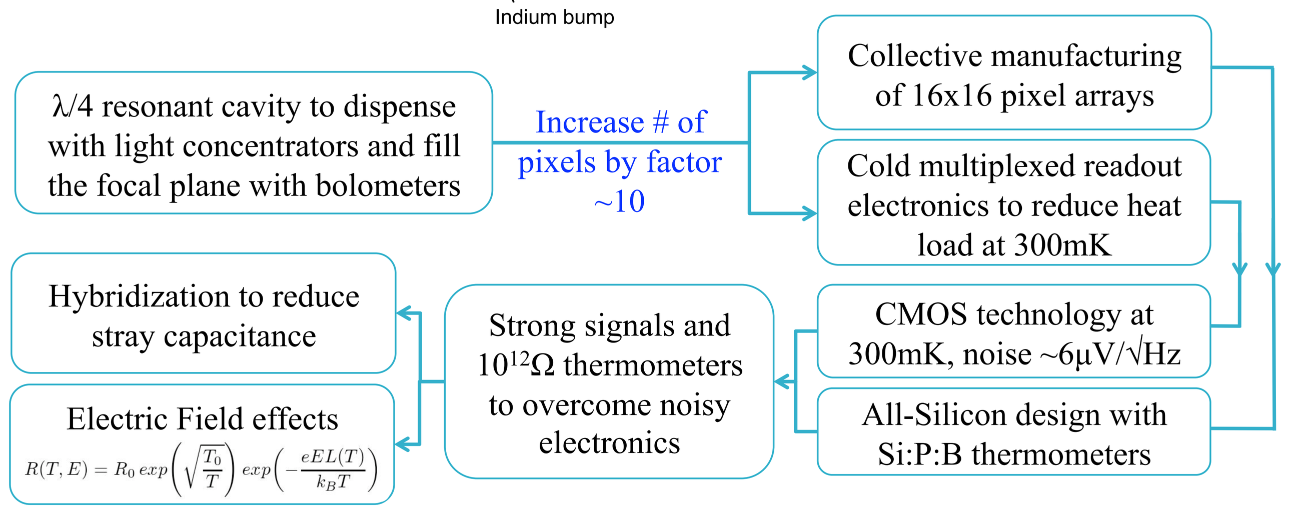
Photometer dimensions:
260x348x216mm weight : 8.2kg

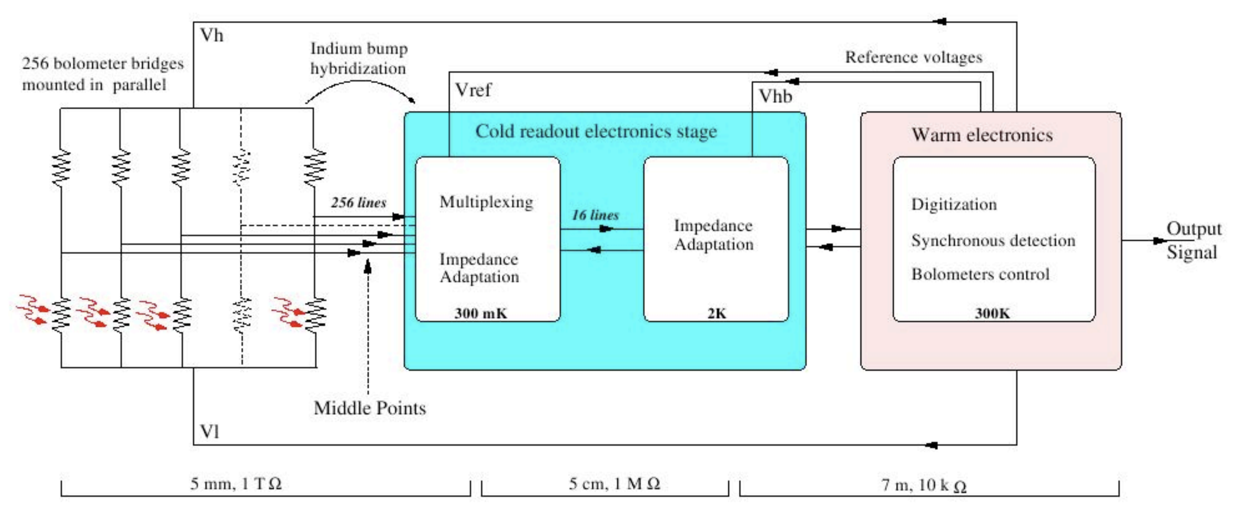
The PACS Photometer Focal Plan Unit in a nutshell:

Dual band imaging, cold dichroïc to split radiation between Blue and Red channels, focal plane based on a mosaic of filled bolometer arrays (16x16 pixels each), fully sampled field of view of 1.75'x3.5' for both channels, ~5µW dissipation at 300mK.

Detectors Architecture



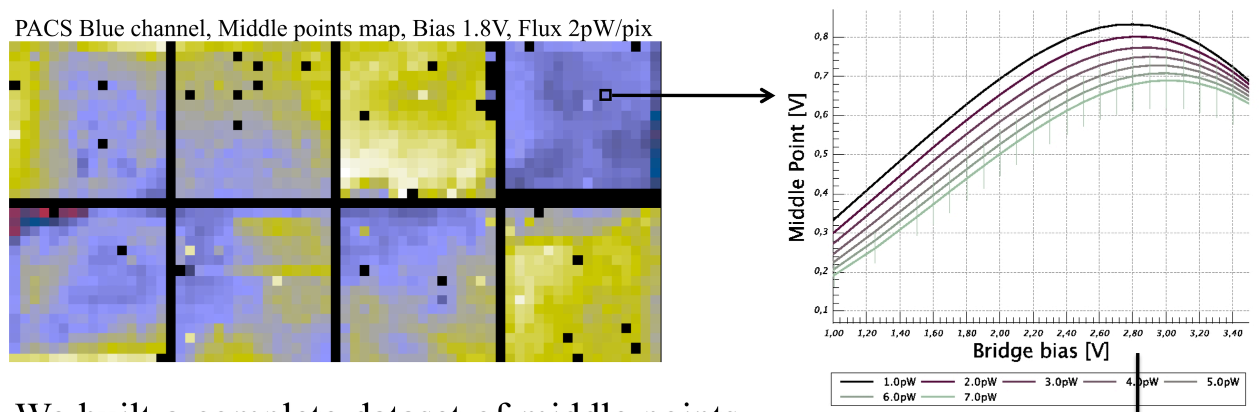




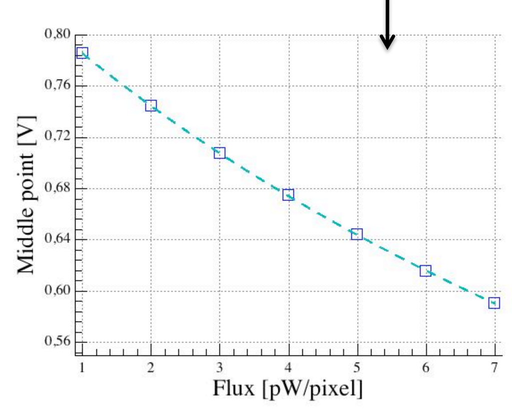
Calibration and Performances

Most bolometers are calibrated by measuring the current flowing through thermistors as a function of the voltage applied across them, and by fitting these load curves with an analytical model of the detectors to extract their physical parameters. However, in the case of CEA bolometer arrays, this standard method is inapplicable to individual pixels since we cannot access the current flowing through individual bolometers (reference resistors cannot be considered as known current sources as their impedance depends on the optical load through electric field effects).

We developed a pragmatic calibration procedure based on the retrieval of bolometric bridge middle points. These quantities are independent of the readout electronics and represent the electrical state of each bolometric bridge. To access middle points and correct for the various offsets of the readout electronics, we measure the transfer function of the whole electronics chain by injecting known reference voltages at different stages of the readout electronics.



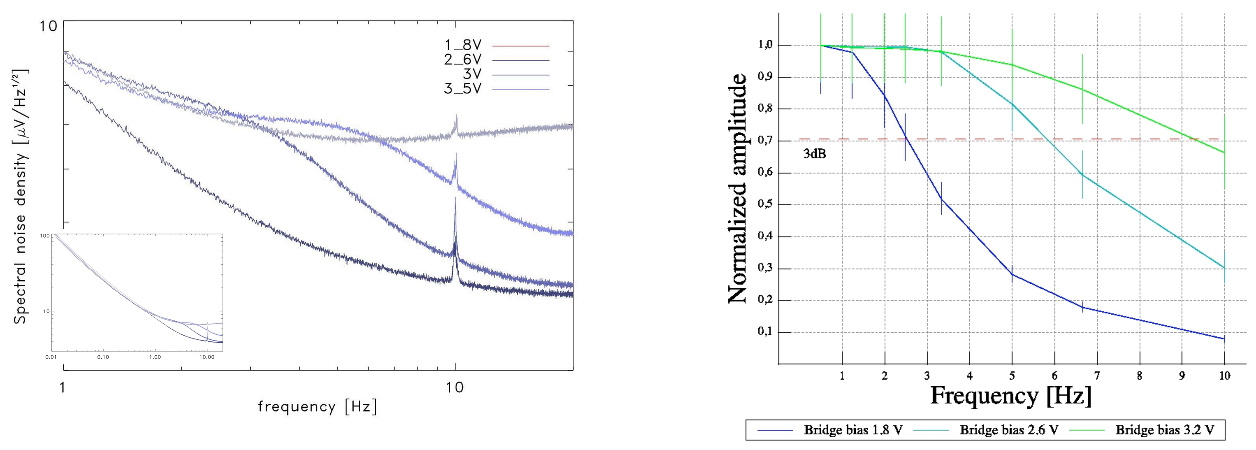
We built a complete dataset of middle points for each pixels to predict their behavior for any given bridge bias and optical load. This information is used to automate the fine tuning of the readout electronics offsets. We successfully applied our procedure during the PACS calibration campaign to test thousands of configurations of the system while minimizing saturation.



We measured the bolometers response time in time- and Fourier-domain.

- We use two warm black bodies and a chopper to measure the signal amplitude as a function of the modulation frequency. The low-pass cutoff frequency is the frequency at which the amplitude is attenuated by 3dB.
- The spectral noise density contains the imprint of the low-pass filter. We extract the cutoff frequency by fitting the spectrum with a simple model.

Both methods yield time constants of the order 20-40 ms depending on the bias voltage applied across the bolometric bridges.



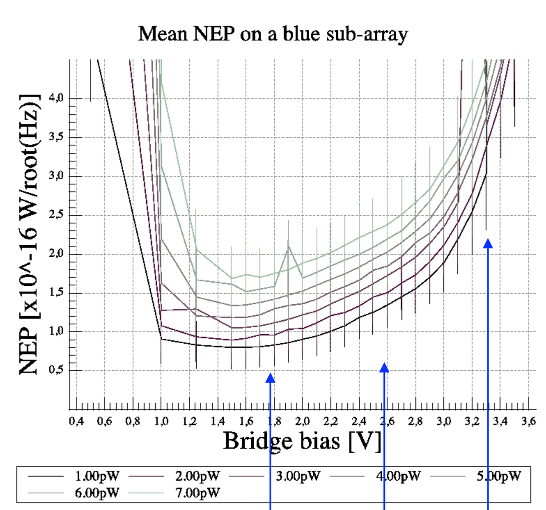
The detectors sensitivity, or Noise Equivalent Power, depends on the bias voltage and the optical load.

NEP = Noise/Responsivity [W/√Hz]

Noise ~ 6µV/√Hz

Responsivity ~ 3×10^{10}V/W

The setting of PACS bolometer arrays is a trade-off between sensitivity and rapidity.



Scientific requirement is 5mJy (5σ, 1hr)

Photometer Channel [µm]	70	110	170
Sensitivity [mJy (5σ, 1hr)]	1.53	1.78	3.22

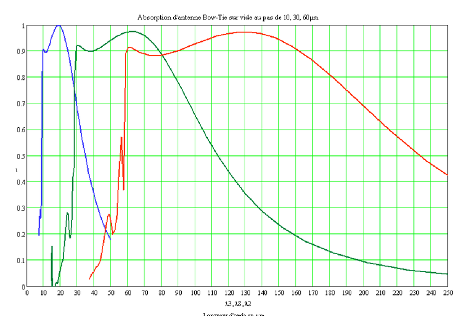
Uncertainties remain on PACS sensitivity computation (telescope temperature, susceptibility to EM perturbations, etc)

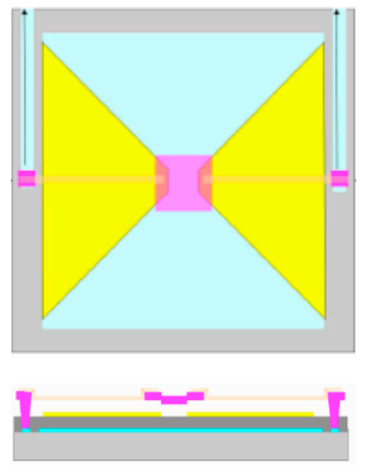
Future Developments

Space Instrument : SPICA / SAFARI

CEA is proposing a new detector design to meet sensitivity requirements of the SPICA / SAFARI instrument

- •Bow tie antenna located λ/4 above reflector to absorb EM radiation.
- •Capacitive coupling between antenna and suspended load resistor.
- •Reduce heat capacity by reducing suspended mass (no silicon grid, no metal absorber) and operating the detectors at lower temperatures.
- •Increase thermal resistance by thinning suspending rods to 20-100nm and by operating the detectors at 50-100mK.
- •High electro-thermal response using Si:P:B thermometers at 50-100mK.
- •Time Domain Multiplexing based on CMOS or Quantum-Point-Contact HEMT operating at 50-100mK.





Absorption calculations for bow tie antennae with "air gap" cavity on reflector. Different curves correspond to different sizes of cavity and antenna.

Ground-based : ArTéMiS

P.I. Philippe André, CEA

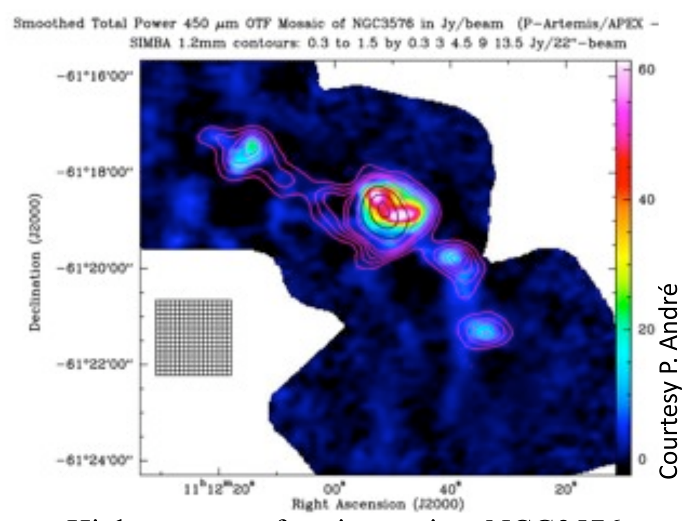
Wide-field sub-mm camera for the APEX telescope (2010)

Simultaneous imaging at 200, 350 and 450µm

Total of 5560 bolometers (20 arrays of 16x18 pixels)

Autonomous cooling system (pulsed tube + ^{3}He-^{4}He cryocooler)

The prototype instrument, P_ArTéMiS, which is equipped with a modified PACS bolometer array optimized to absorb radiation in the 450µm window, has already been tested on KOSMA and APEX telescopes. These test runs demonstrated the relevance of the CEA bolometer arrays concept.



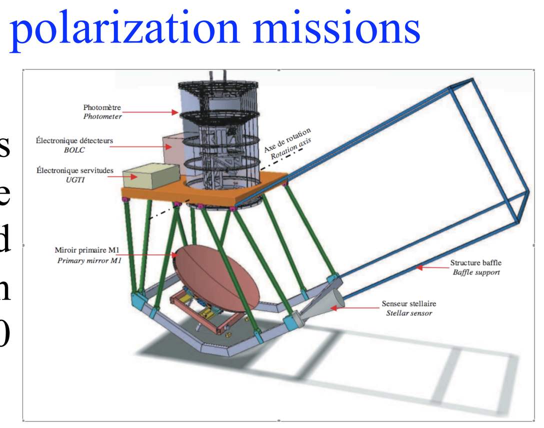
High-mass star forming region, NCG3576 , observed at 450 µm with P_ArTéMiS on APEX

Balloon borne : PILOT

P.I. Jean-Philippe Bernard, CESR

Polarization measurements of the ISM at 240 and 550µm to prepare for future CMB polarization missions

8 modified PACS Bolometer Arrays
83 cm telescope
700 kg payload
600 000 m³ balloon
First flight scheduled for 2010



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