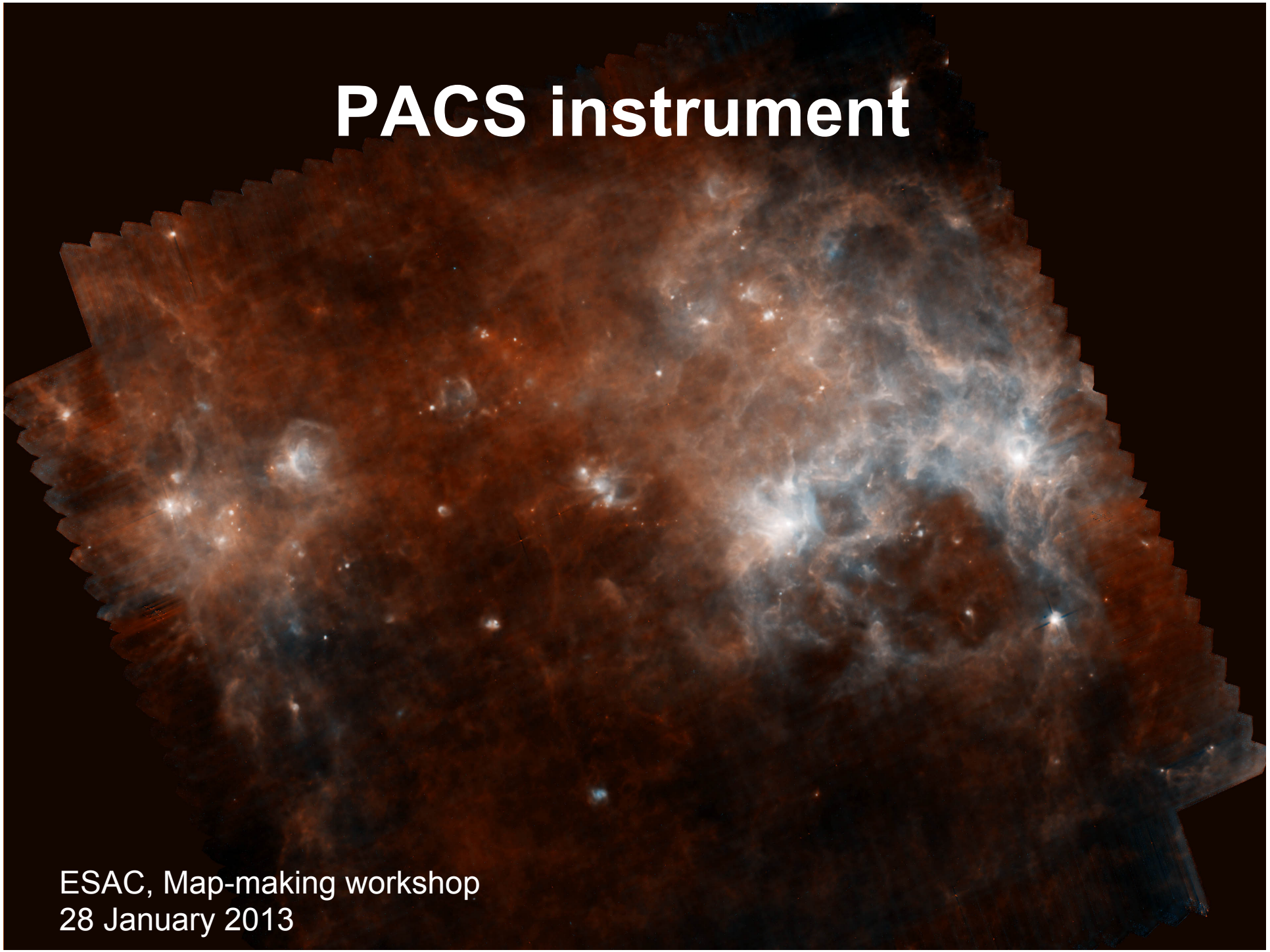
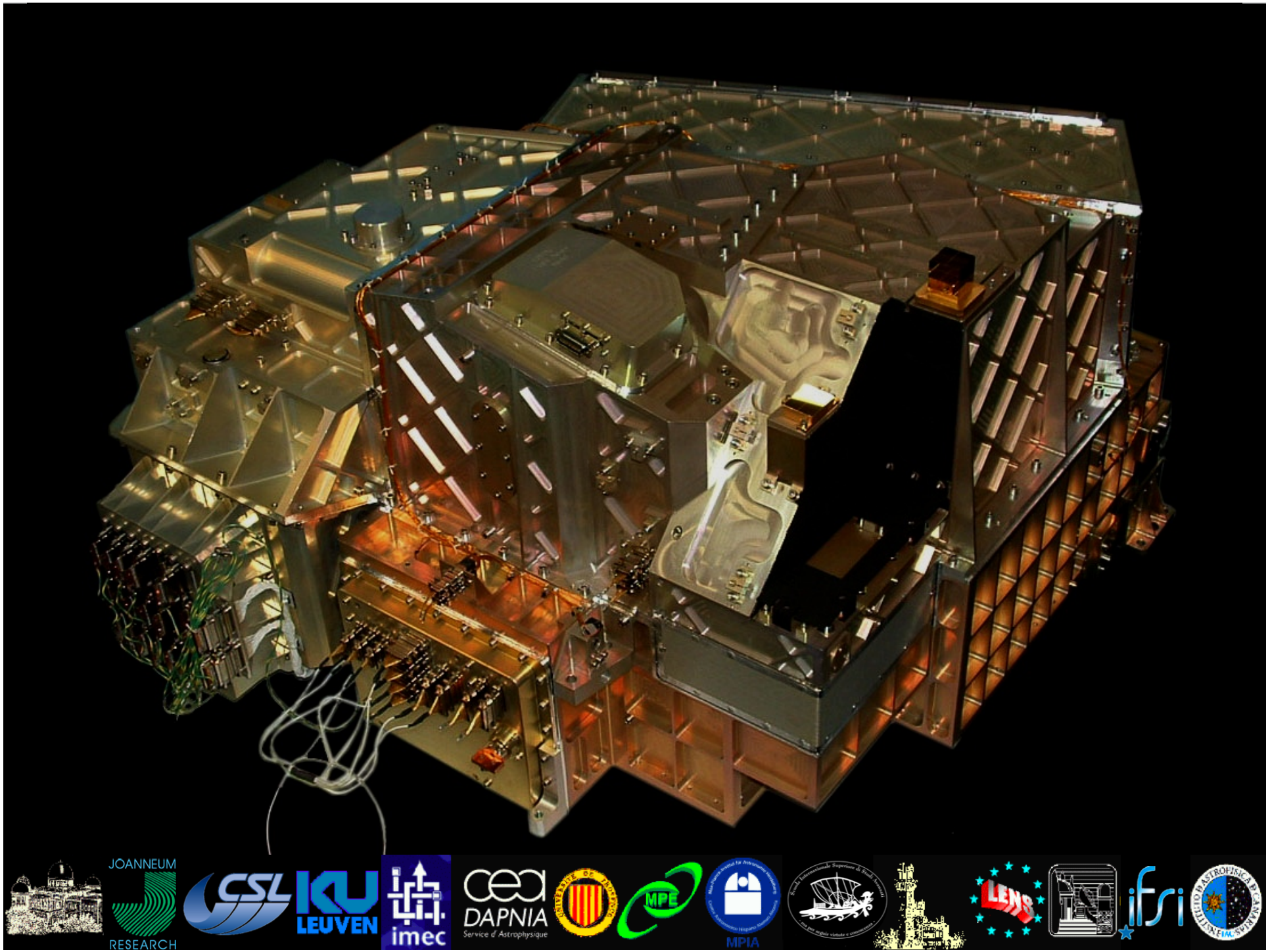
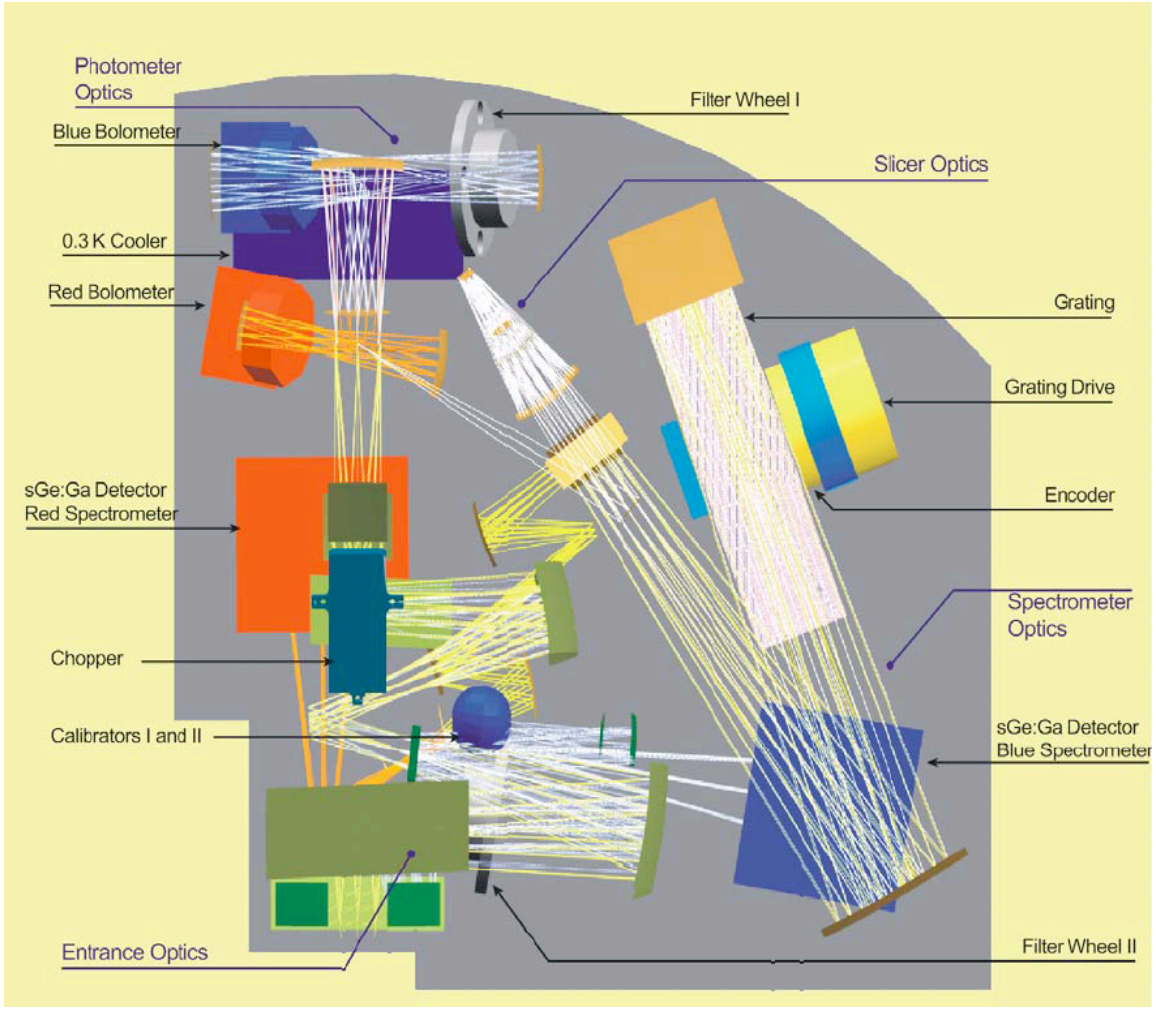


PACS instrument

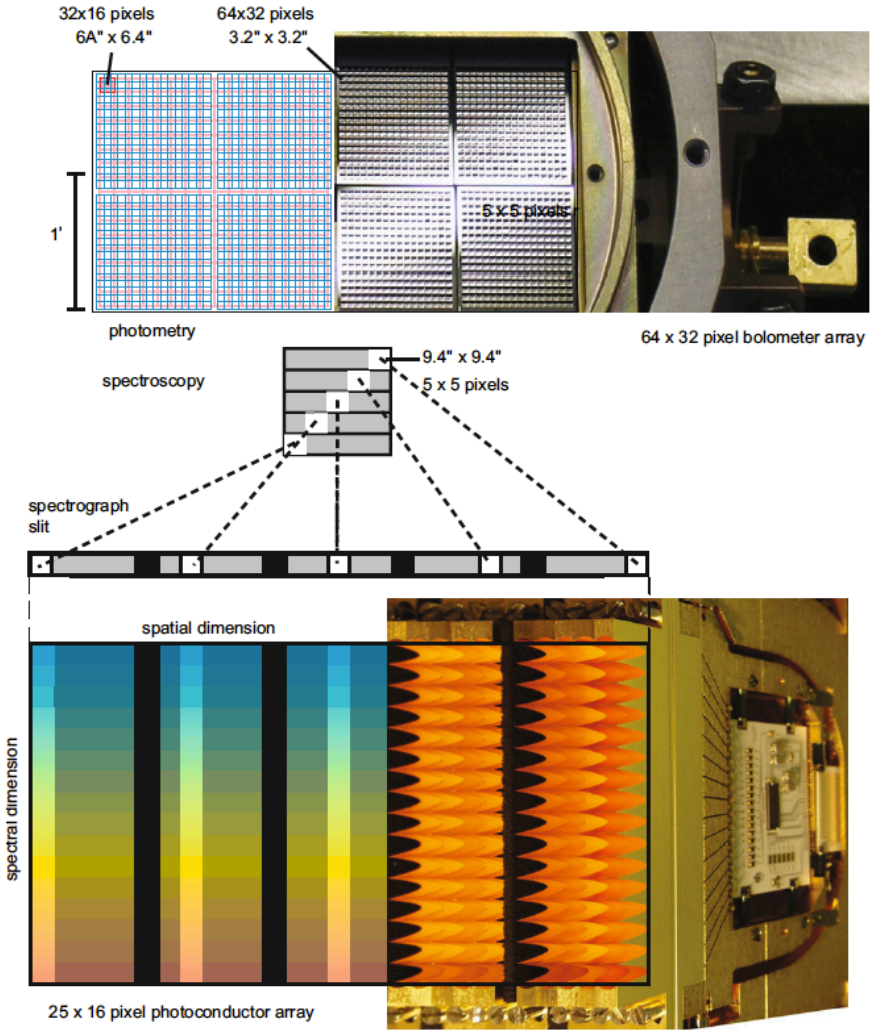
ESAC, Map-making workshop
28 January 2013


JOANNEUM
RESEARCH
CSL
KU
LEUVEN
imec
cea
DAPNIA
Service d'Astrophysique
MPE
MPIA
LENS
ifsi

Optical layout



Two instruments in one

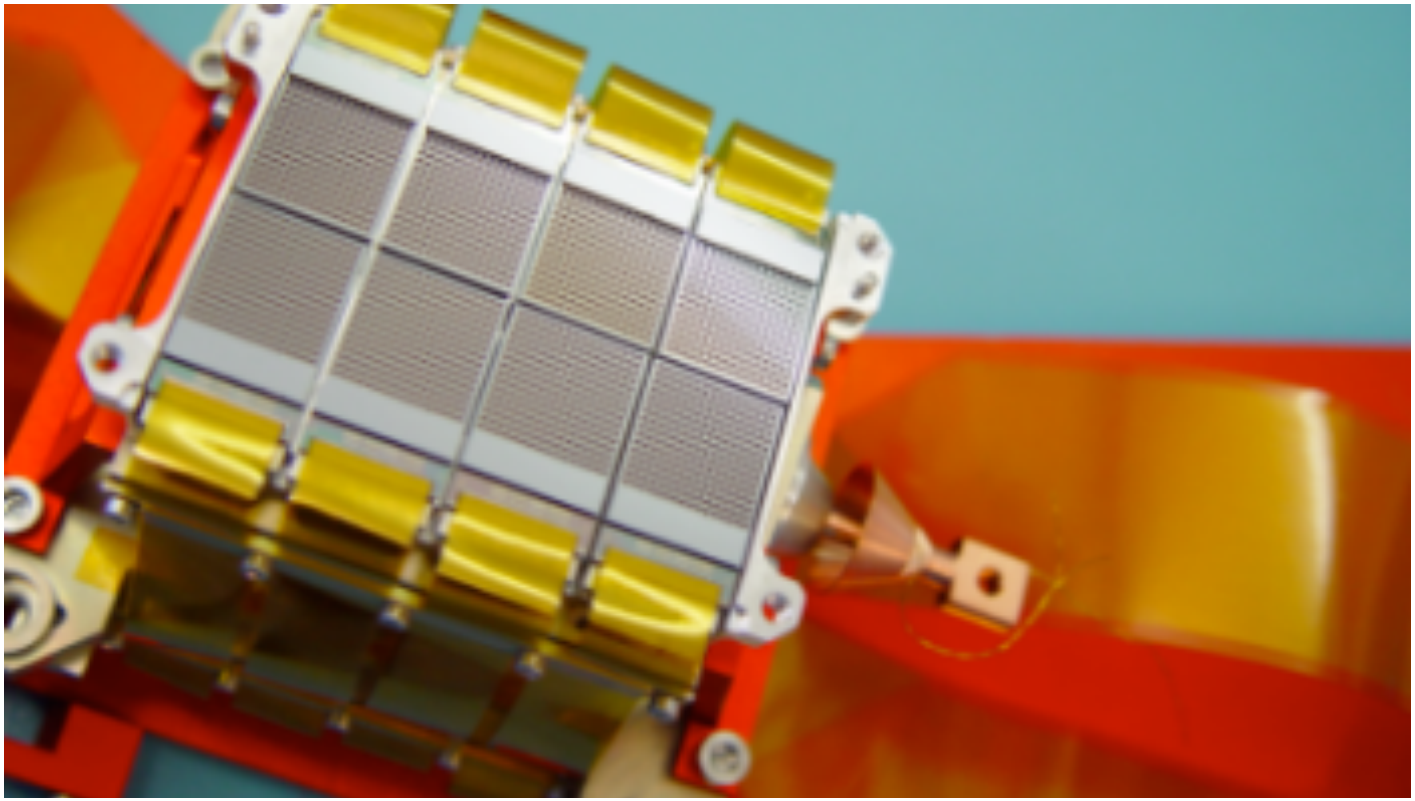


Photometer
- two field silicon bolometers

Spectrometer
- Ge:Ga photoconductors arrays
- Integral field spectroscopy
- 55-210 micron

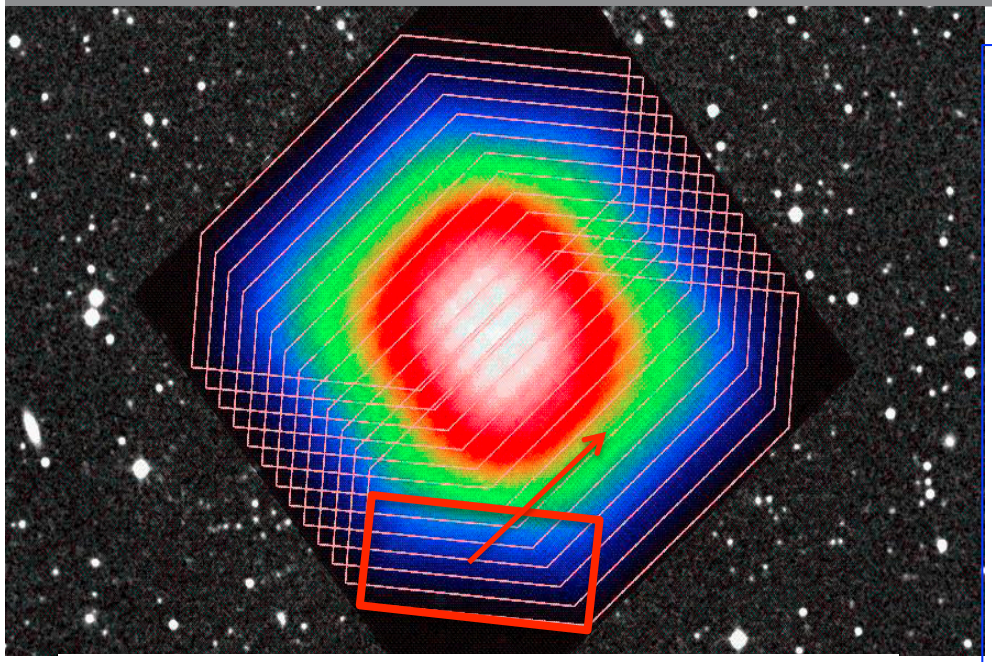
Poglitsch+2010 A&A, 518, L2

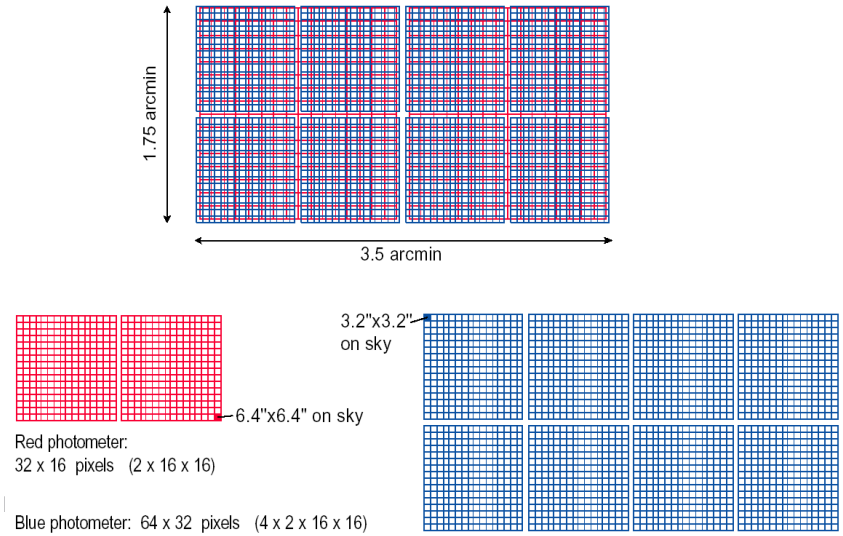
Filled silicon arrays



Fully sampled image, no feedhorn

PACS photometer: dual band imaging





- **Two filled bolometer arrays** in dual band imaging:
  - 64x32 pixels at 70 & 100μm
  - 32x16 pixels at 160μm
- Field-of-view: 1.7'x3.5'
- Build-up of maps by scanning in a *boustrophedon* fashion.

- PSF FWHM: 5.5", 6.7" and 11.5"

- 40Hz readout frequency
- on-board co-adding, to stay within allocated 130kb/s rate downloaded frequency : 10Hz (prime) and 5 Hz in parallel in the blue channel)

Two observing modes

Two spatial modulation techniques to extract faint sources from the high telescope background:

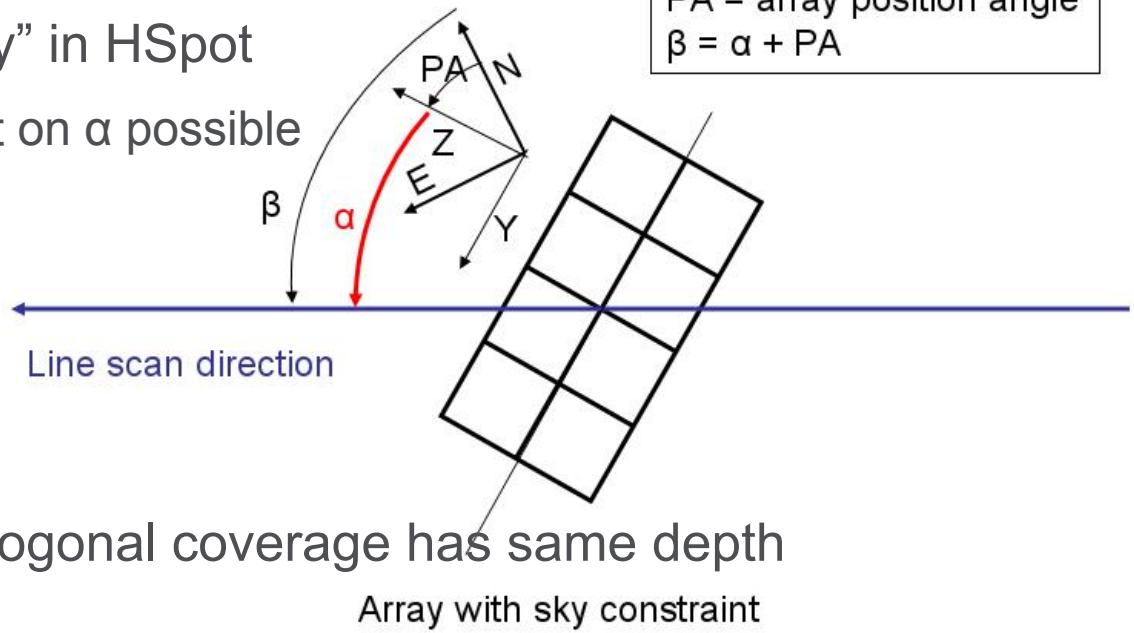
1. **Chopping/nodding**, to move the source by about one blue channel matrix at 1.25Hz and nodding in the perpendicular direction
    - degraded sensitivity compared to pre-flight predictions
    - Not used for science but kept for calibration (photometry & pointing monitoring)
2. **Scan mapping**
    - Allows to relatively small (mini-scan maps) to very large areas (fast scan, e.g. parallel mode)

Scan mapping principle

1. In reference frame “array” in HSpot
    a. α fixed, constraint on β is possible
    b. Selection of homogeneous coverage offered in HSpot.

α = array-to-map angle
β = map orientation angle
PA = array position angle
β = α + PA

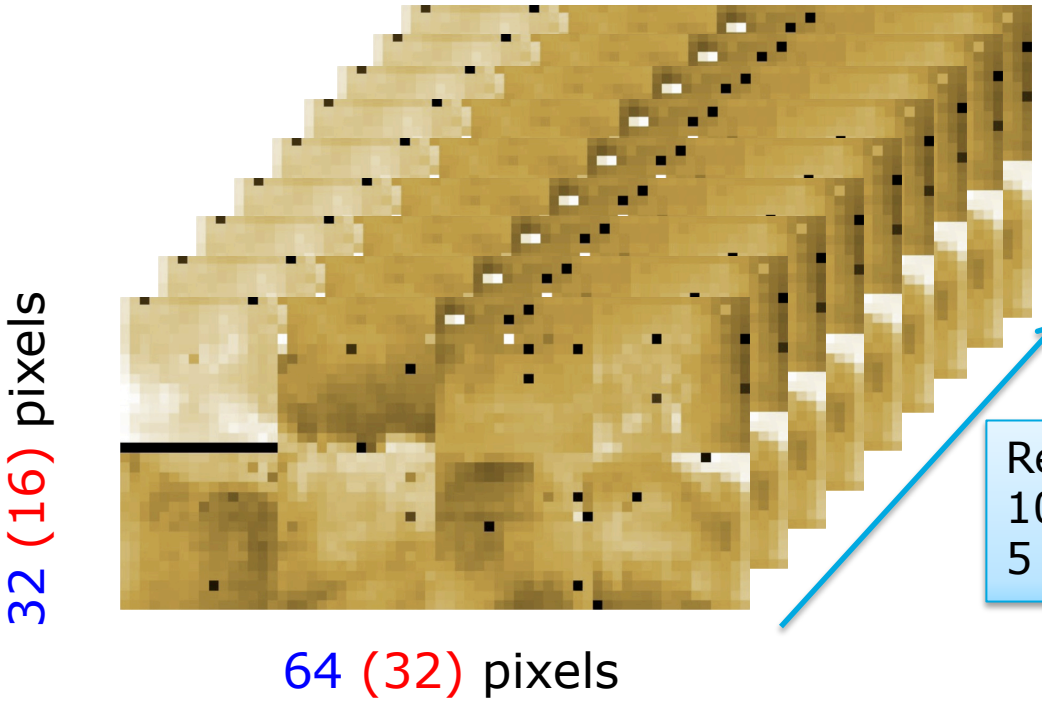
2. Oriented in the sky, “sky” in HSpot
    a. β fixed, constraint on α possible



3. Note: If α=45° then orthogonal coverage has same depth

Array with sky constraint

Data cubes

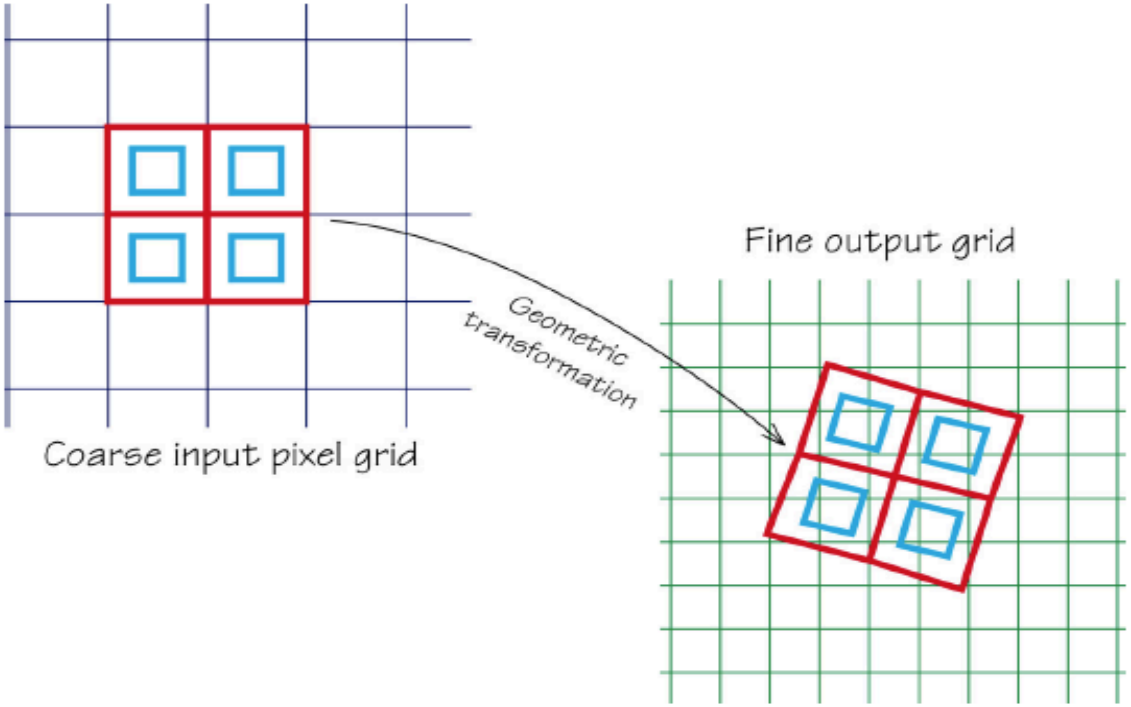


Readout sequence
10 Hz – PACS Prime
5 Hz – Pacs PMode

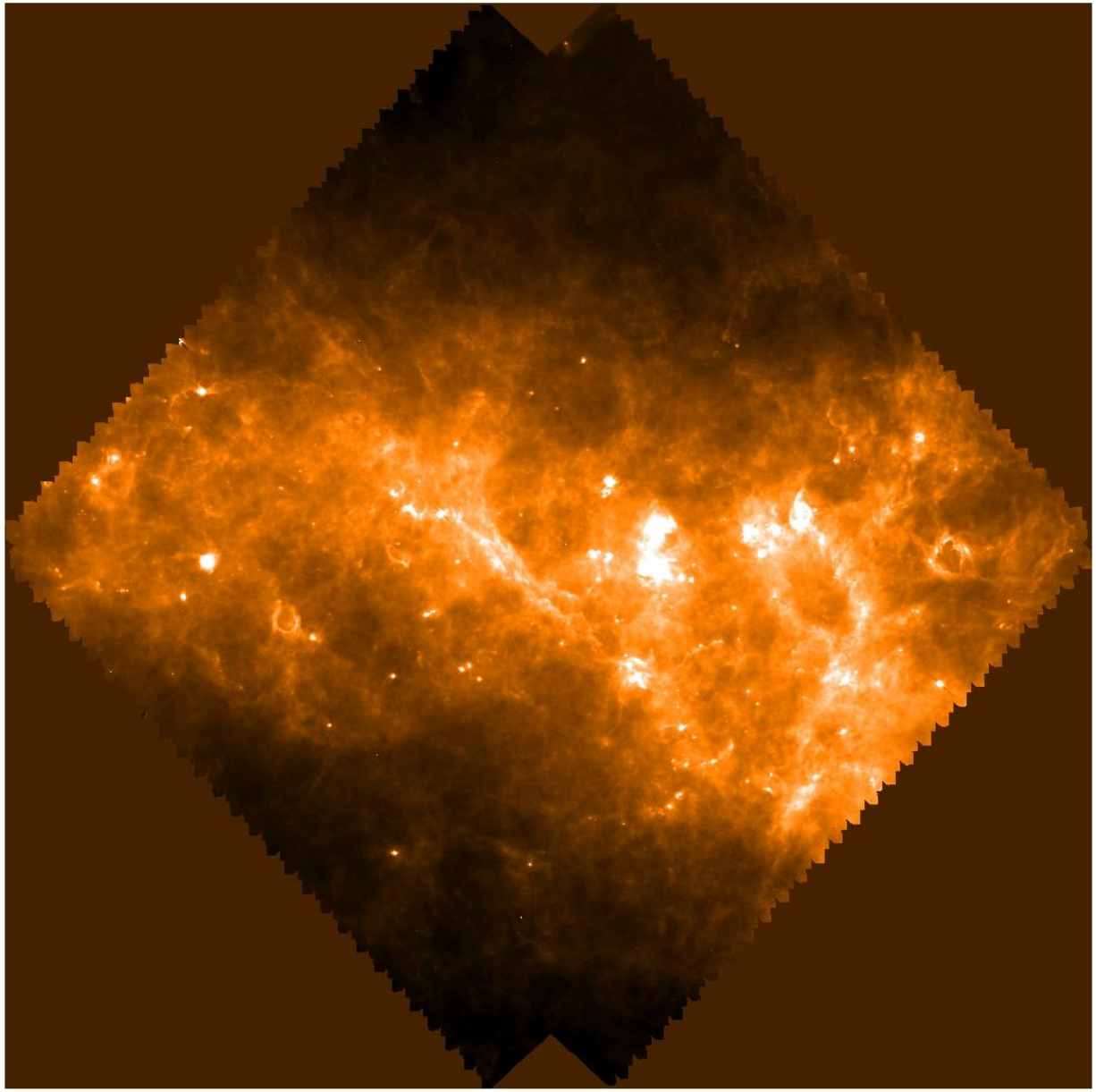
Most sources will not be visible on single frames due to intrinsic offset dispersion.
Signal dispersion ~ 30000 ADU

Drizzling technique to project map

- 1/f noise filtering
- Projection (pixel size and drop size)



Somewhere on the galactic plane



HiGAL OT KP
(S. Molinari)
160um
2x2 degrees

CALIBRATION PHILOSOPHY

Flux calibration (responsivity & EEF (Encircled Energy Function) relies on stellar photosphere models of standard stars.
Point-source photometry accuracy of 5% in the 3 bands

Table 8: Observed and calibrated ("FM, 6") monochromatic flux densities at 70, 100, 160 μm divided by the corresponding model predictions for all 5 fiducial stars.

Target	blue obs/model				green obs/model				red obs/model			
name	no.	median	mean	stddev	no.	median	mean	stddev	no.	median	mean	stddev
β And	2	—	**1.011**	0.015	2	—	**1.013**	0.010	2	—	**0.993**	0.018
α Cet	3	—	**1.011**	0.008	3	—	**1.007**	0.005	3	—	**0.999**	0.020
α Tau	4	—	**0.987**	0.011	4	—	**0.979**	0.009	5	—	**0.978**	0.011
α Boo	3	—	**1.000**	0.012	3	—	**1.000**	0.009	3	—	**1.007**	0.012
γ Dra	23	**0.985**	0.983	0.009	8	**1.000**	0.991	0.016	28	**1.010**	1.016	0.039
mean/stddev		**0.999±0.013**				**1.000±0.013**				**0.997±0.013**		

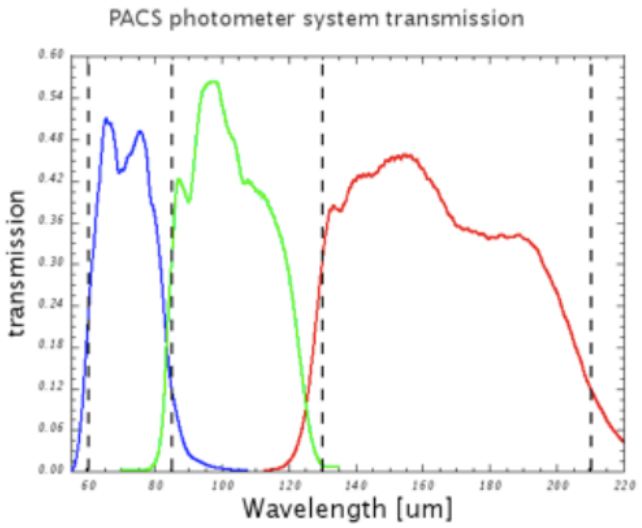
But (point-source) photometry depends very much on exact data processing if one targets the few % level

- **high-pass filter width (if photProject is used), pixel size and drop size (drizzling)**
- **size of masking area(s)**
- **aperture radius**

CALIBRATION PHILOSOPHY

The estimated **absolute flux accuracy for point sources** is better than 5% in the 3 bands

Spectral convention: νf_ν = *Constant*



BB temp.	CC_70	CC_100	CC_160
BB (10 000 K)	1.02	1.03	1.07
BB (5000 K)	1.02	1.03	1.07
BB (1000 K)	1.01	1.03	1.07
BB (500 K)	1.01	1.03	1.07
BB (250 K)	1.01	1.02	1.06
BB (100 K)	0.99	1.01	1.04
BB (50 K)	0.98	0.99	1.01
BB (20 K)*	1.22	1.04	0.96
BB (15 K)*	1.61	1.16	0.99
BB (10 K)*	3.65	1.71	1.18
Power law (ν^β)	CC_70	CC_100	CC_160
$\beta = -3.0$	1.04	1.04	1.06
$\beta = -2.0$	1.02	1.01	1.02
$\beta = -1.0$	1.00	1.00	1.00
$\beta = 0.0$	1.00	1.00	1.00
$\beta = 1.0$	1.00	1.01	1.03
$\beta = 2.0$	1.02	1.03	1.08
$\beta = 3.0$	1.04	1.07	1.14

http://www.herschel.be/twiki/pub/Public/PacsCalibrationWeb/PhotMiniScan_ReleaseNote_20101112.pdf

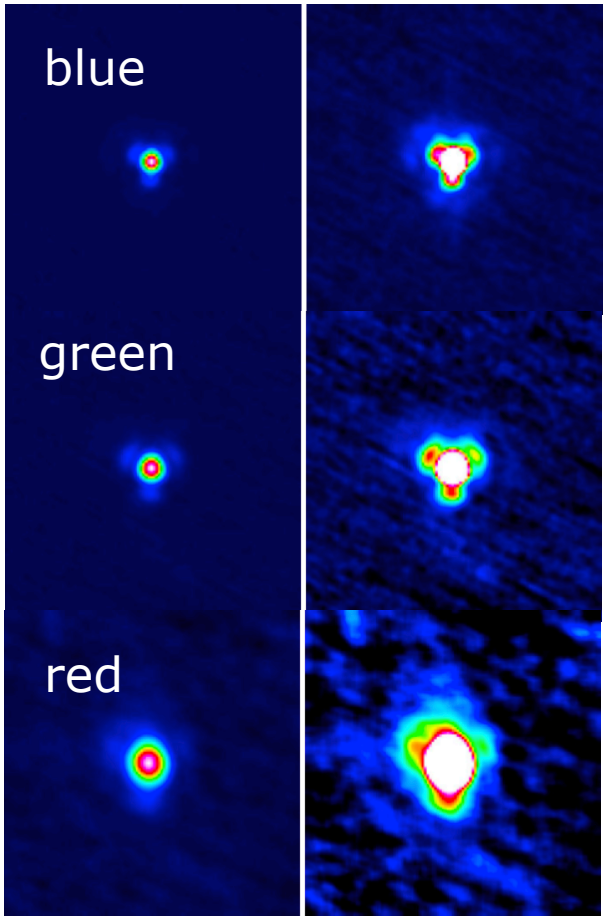
v2.0, 12 November 2010, T. Müller et al.

PACS PSF

➢ The core of the PSF is in line with expectations: it is diffraction limited
  • core gaussian

➢ The outer structure is due to deformation of primary mirror from its support

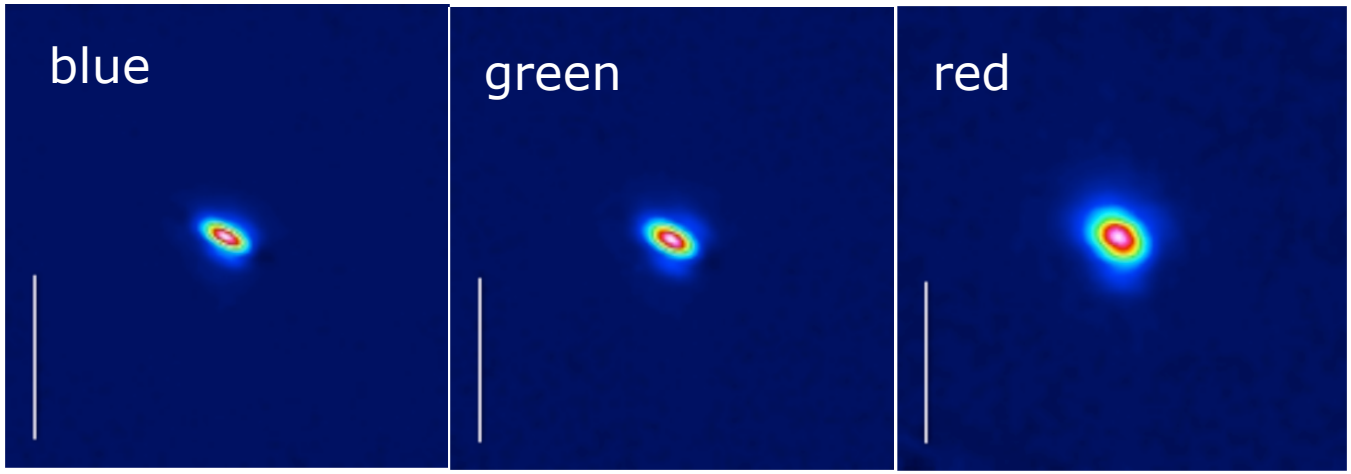
Important note: there is not a unique standard PSF, as it depends on :
- scan angle
- scan speed
- data processing: type of projection, high-pass filter width …



Lutz, 2012 (PICC-ME-TN-033)

PACS PSF

The PSF is distorted at high scan speeds



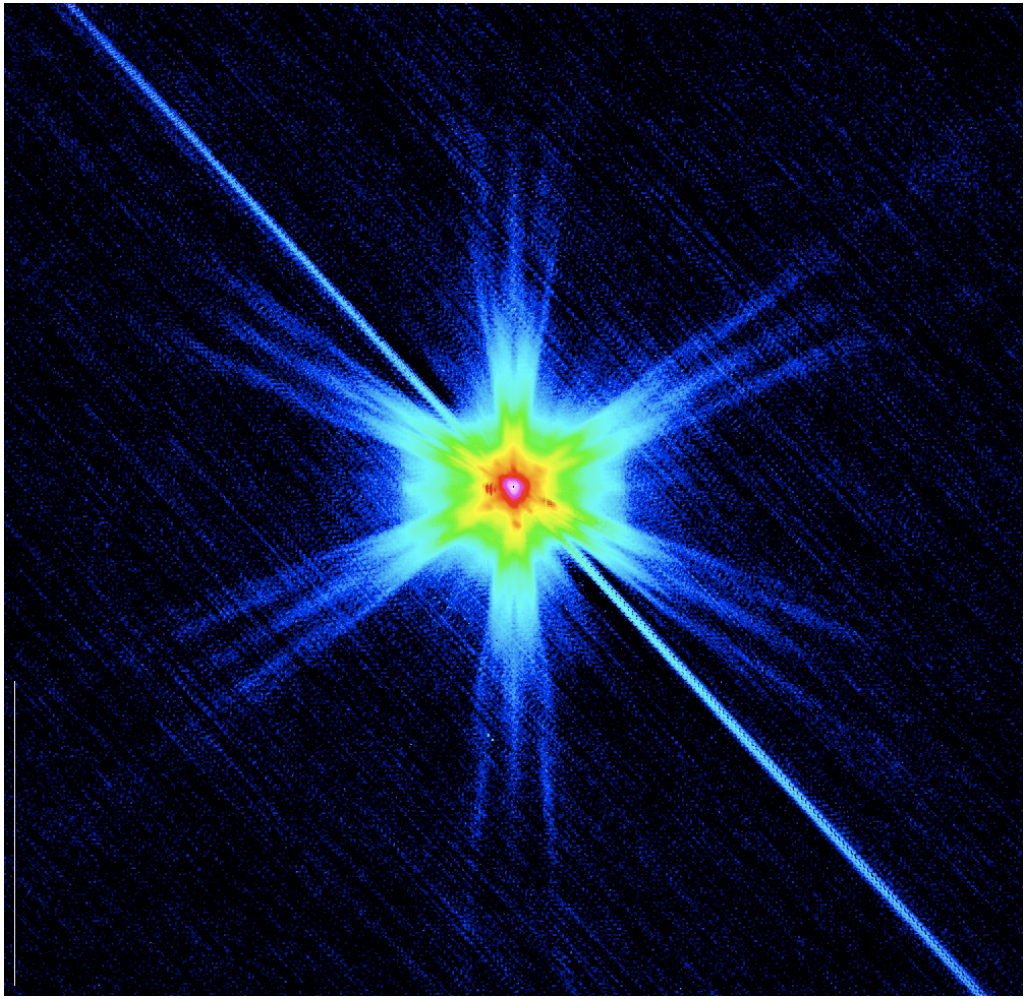
Scan speed 60 "/sec
Compression = 8 frames

Including multiple scan directions, this could lead to single, double, triple or quadruple tailed PSFs

Lutz, 2012 (PICC-ME-TN-033)

PACS PSF

PSF wings

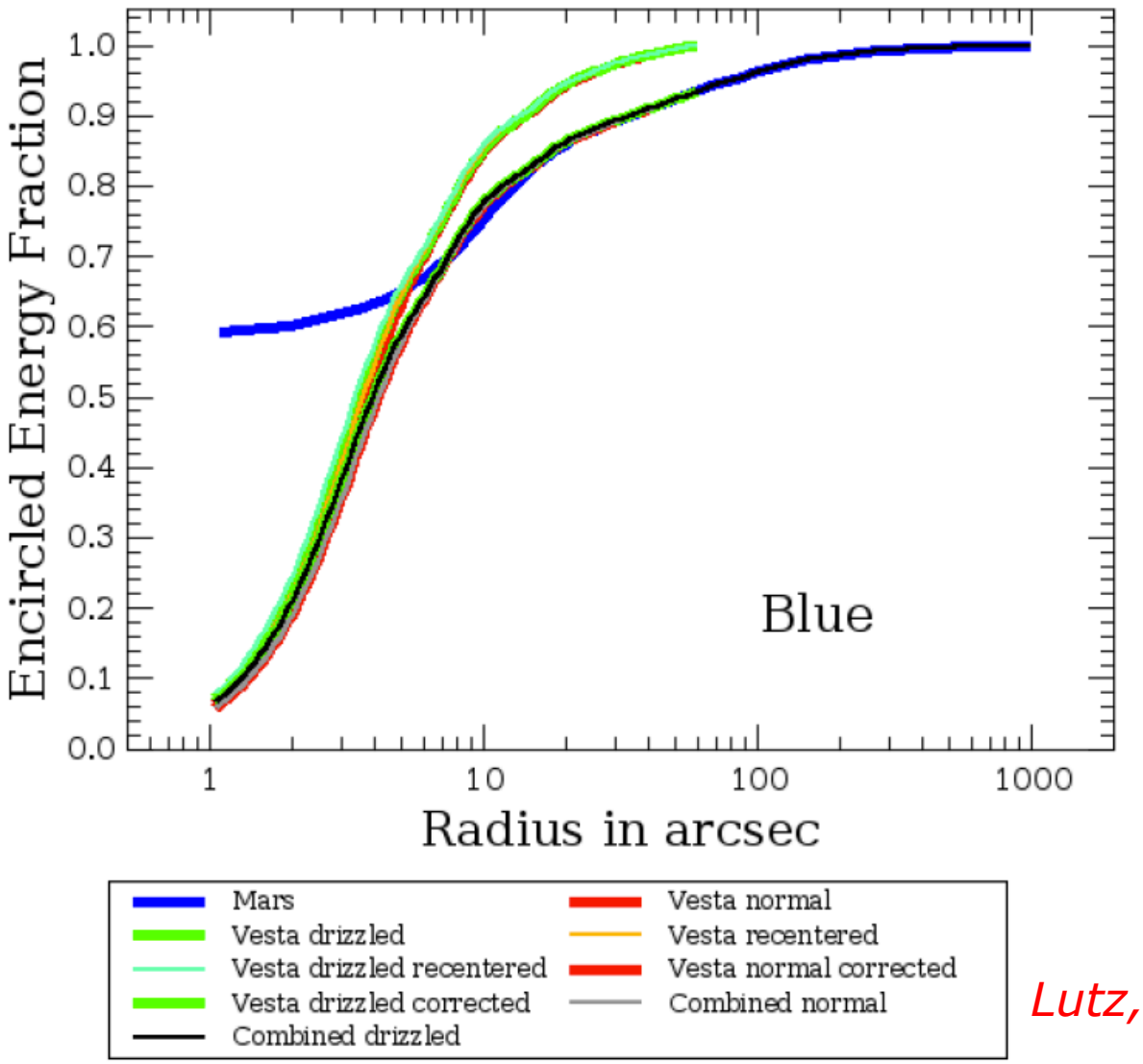


- Extremely bright point sources show structure several arcminutes away

- Up to **10%** of the flux in PSF wings beyond 1 arcmin (strikes)

Mars PSF

Aperture corrections



- Flux calibration based on an hybrid (asteroid +Mars) PSF normalized at 16.7 arcmin

- This affects extended emission normalization/ calibration.

Lutz, 2012 (PICC-ME-TN-033)

Conclusions

1. Absolute photometry accuracy of **5%** for **point sources**
   - Limited by photosphere models and absolute K-band ground-based photometry
2. Absolute photometry accuracy of **10%** for **extended emission**
   - from additional beam/PSF characterization
   - Very conservative, so it seems an upper limit.
3. PSF/EEF based on high-pass filtered maps, hence the derived responsivity (Jy/pixel) while other mapper might have slightly different PSF at a few % level.
4. Open Issue
   - ✓ Pointing reconstruction
   - ✓ Focal Plane Geometry (time dependence ?)

❑ Missing : a reference paper for the PACS photometer calibration
   - ✓ Several TNs so far on HSC PACS web page
   - ✓ Official statement on extended emission photometric accuracy.

Which map-maker to use for extended emission ?

1. MADmap
2. Scanamorphos
3. JPScanam
4. Unimap
5. Tamasis
6. Sanepic
7. *Supreme (for PACS ?)* – hipe plug-in already

- **Hopefully the answer in this workshop !**

- **Level 3 maps in HSA by SPG11 or 12:** stacking on a given field
    - HPF maps
    - MADmap