PACS Photometer Calibration Programme Overview

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on behalf of the PACS ICC and the Calibration Working Group

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PACS Photometer Calibration
General Aspects

Central reference documentation:

- PACS Calibration Document (PACS-MA-GS-001)
  detailed definition and description of all PACS calibration aspects

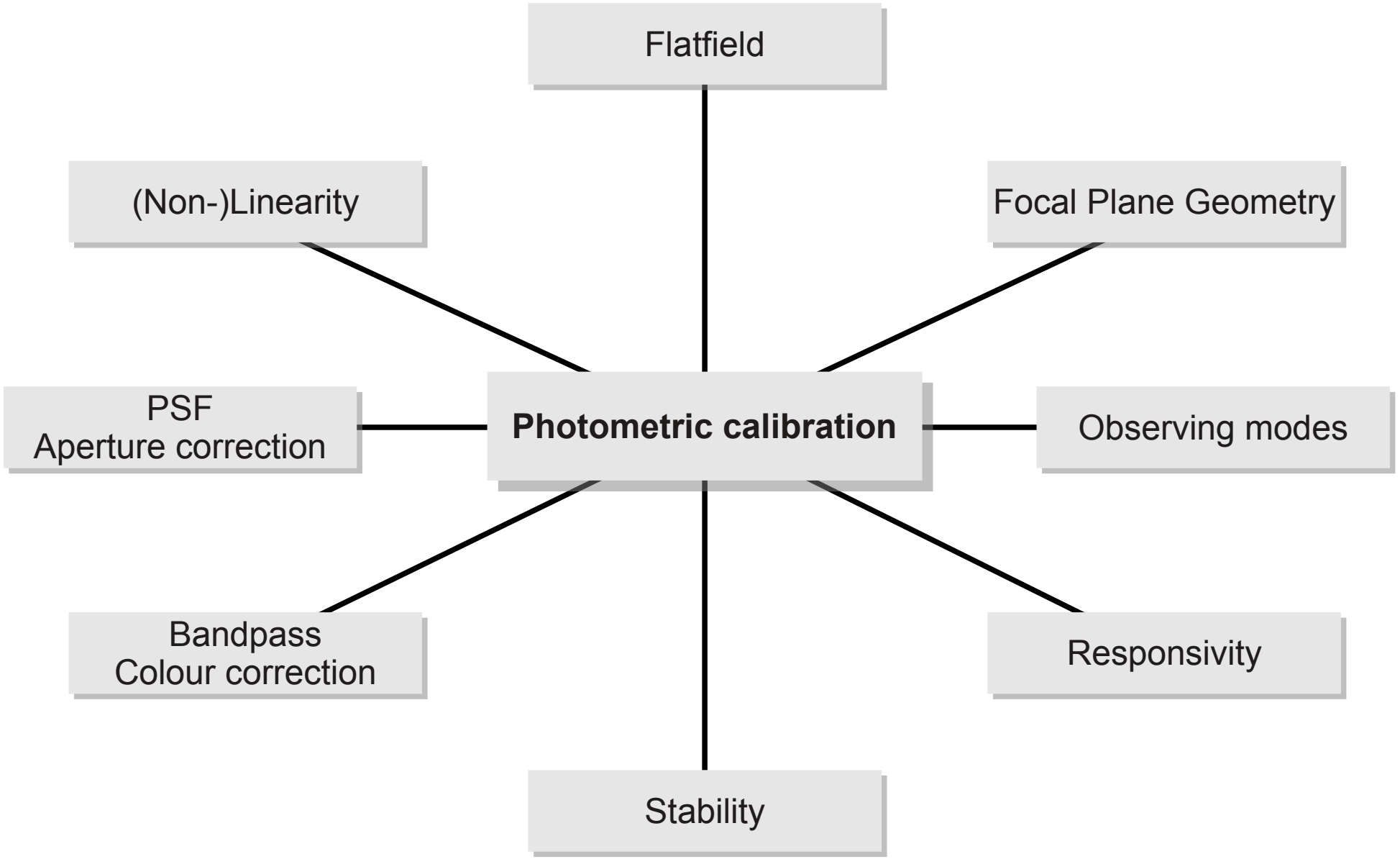
- PACS Commissioning Phase Plan Document (PACS-ME-PL-024)
  detailed implementation plan for calibration during commissioning phase

- PACS Performance Verification Phase Plan Document (PACS-MA-PL-001)
  detailed implementation plan for calibration during PV phase

- PACS Routine Phase Calibration Plan Document (PACS-MA-PL-002)
  detailed implementation plan for calibration during routine science phase

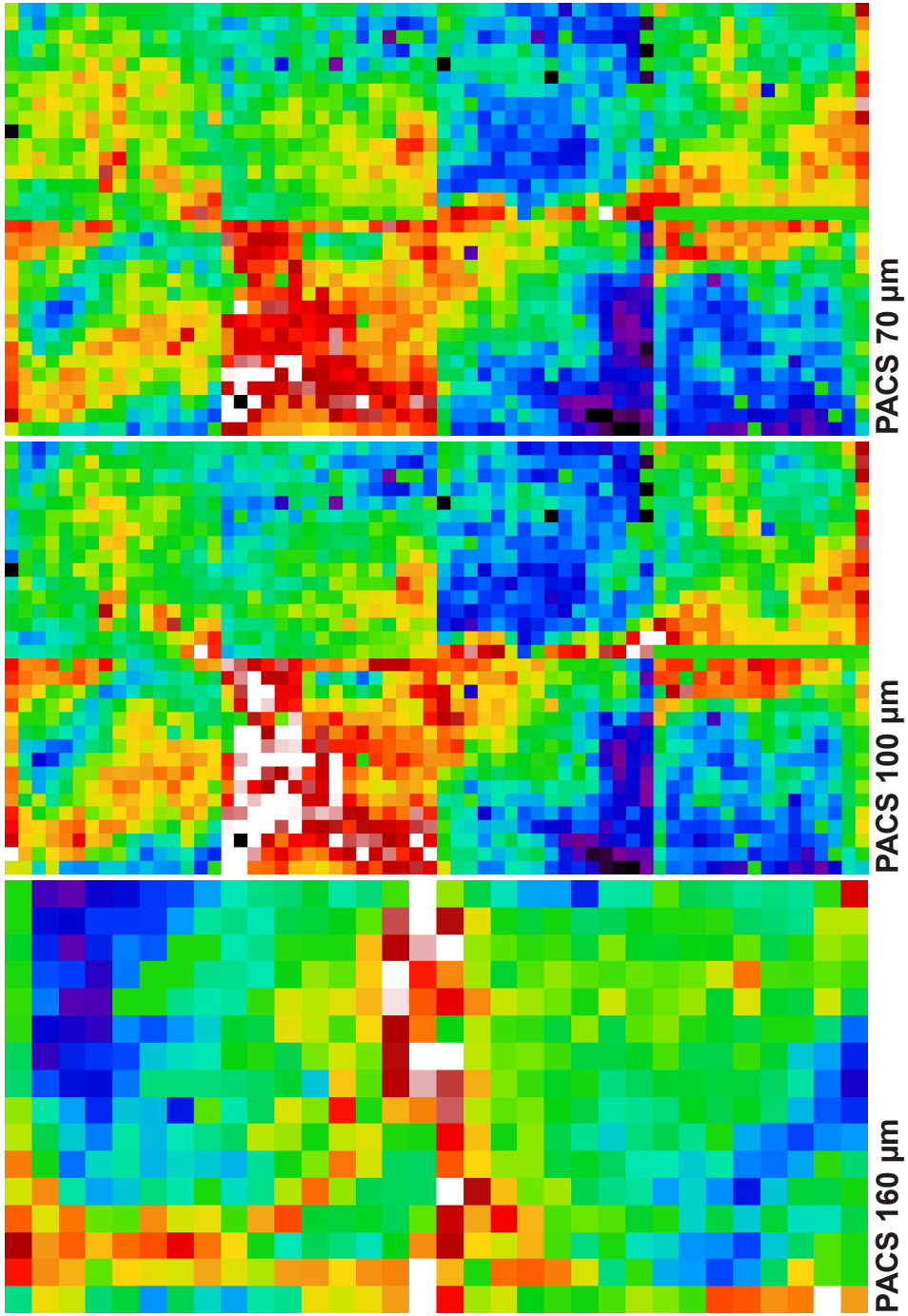
- http://herschel.esac.esa.int/twiki/bin/view/Public/PacsCalibrationWeb
  instrument calibration details

PACS Photometer Calibration Topics



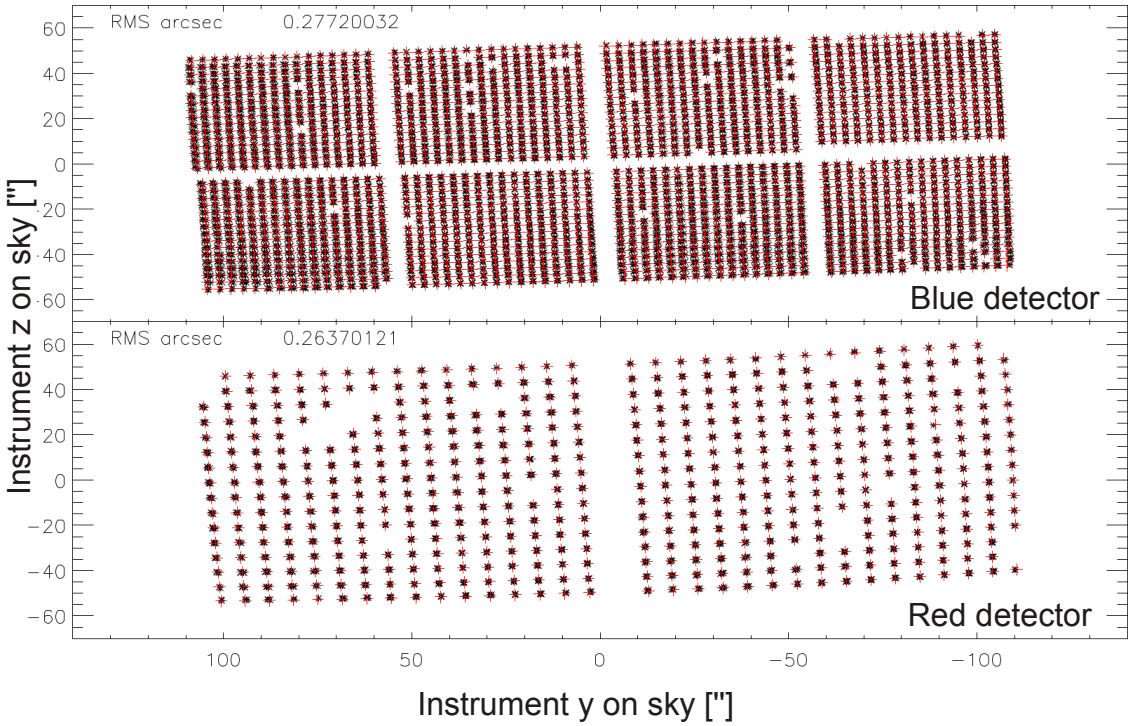
- In total: 290 h and 1460 AORs (incl. pointing and parallel mode calibration)

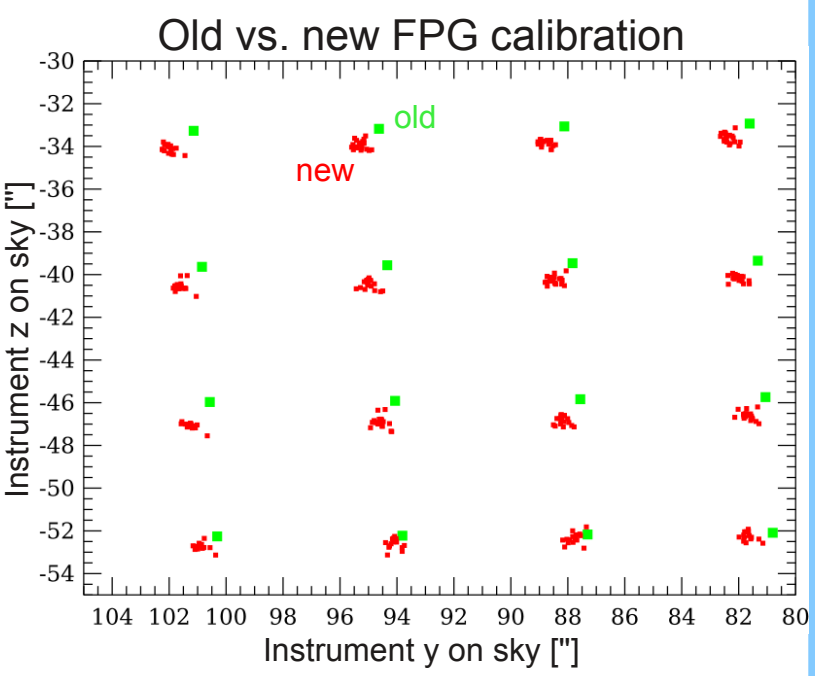
PACS Photometer Calibration
Flatfield



- Flatfield established for all three bands
- Obtained from scan maps of compact sources along detector rows
- Individual sub-matrices visible
- Variation in time to be investigated

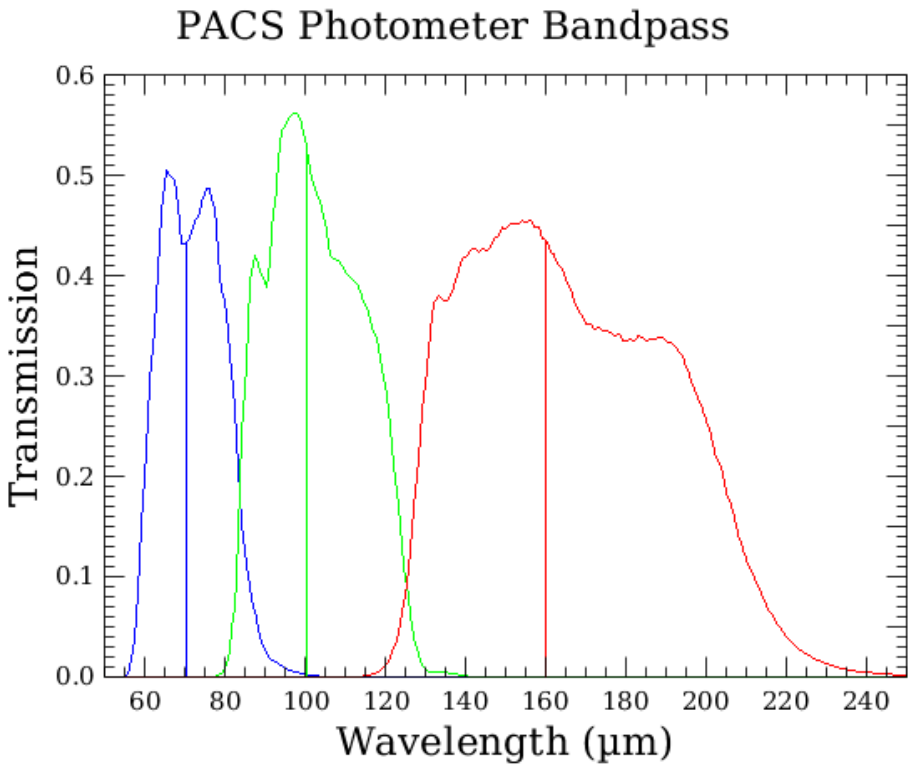
PACS Photometer Calibration
Focal plane geometry / Field distortion





- Current FPG calibration based on on-ground measurements
- Small rotation and distortion
- Update based on in-flight measurements expected in forthcoming version
- Will scale FPG by 1% + local variations
- Will have an impact on PSF/EEF and on flux calibration

PACS Photometer Calibration
Bandpass / Colour correction



- Conversion from in-band flux to mono-chromatic flux via colour correction factors
- Convention: $\nu f_{\nu,s} = \text{const.}$
- Reference wavelength λ_0 chosen to keep corrections small
- Colour corrections large only for very “cold” SEDs

$$P_{\text{band}}[\text{W}] = T\, A \int_{\lambda_1}^{\lambda_2} \frac{c}{\lambda^2} f_{\nu,s}(\lambda) S(\lambda)\, d\lambda$$

reflective losses — effective mirror area — source SED — system response

	70 µm	100 µm	160 µm
Stars (T > 3000 K)	1.016	1.033	1.074
Asteroids	1.00	1.02	1.07
Vesta	1.00	1.03	1.07
Planets	0.98	0.99	1.01

$$K_{\text{CC}} = \frac{\lambda_0}{f_{\nu,s}(\lambda_0)} \frac{\int_{\lambda_1}^{\lambda_2} \frac{c}{\lambda^2} f_{\nu,s}(\lambda) S(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} \frac{1}{\lambda} S(\lambda)\, d\lambda}$$

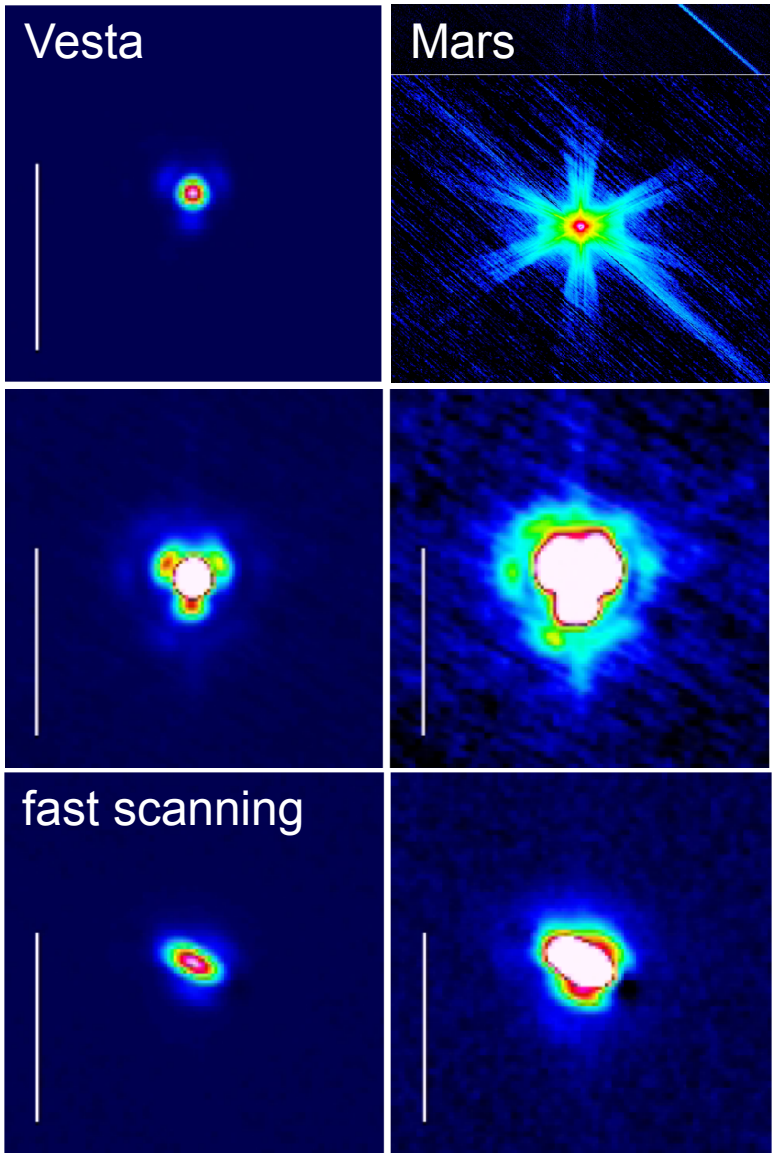
PACS Photometer Calibration
PSF / Encircled Energy Fraction

- derived from scan map observations
- PSF core: (nearly) point sources Vesta and α Tau
- PSF wings: unsaturated areas of Mars

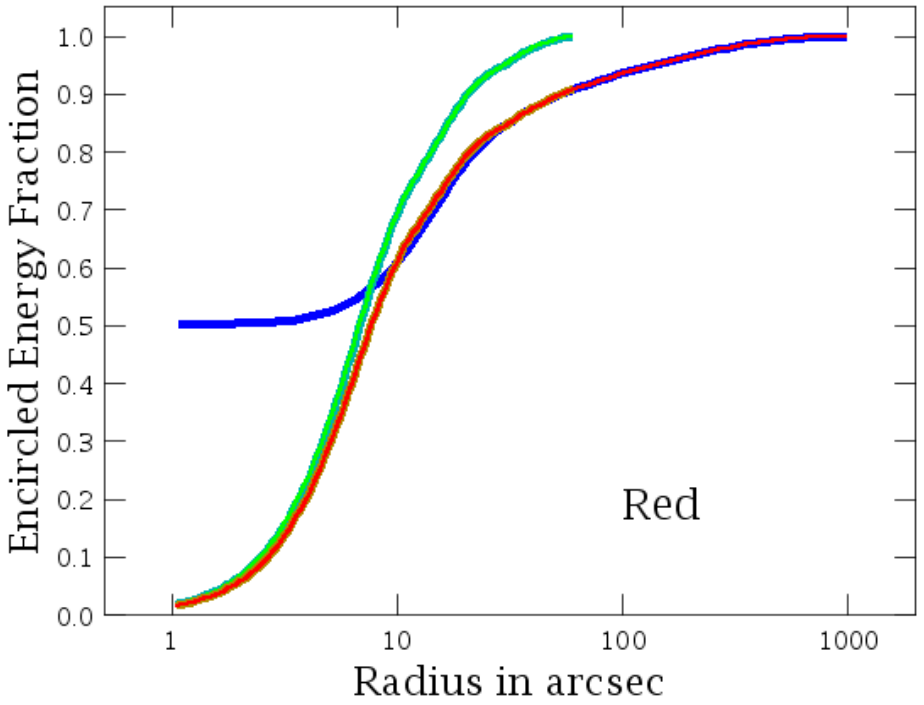
WARNING! There is no single general PSF!

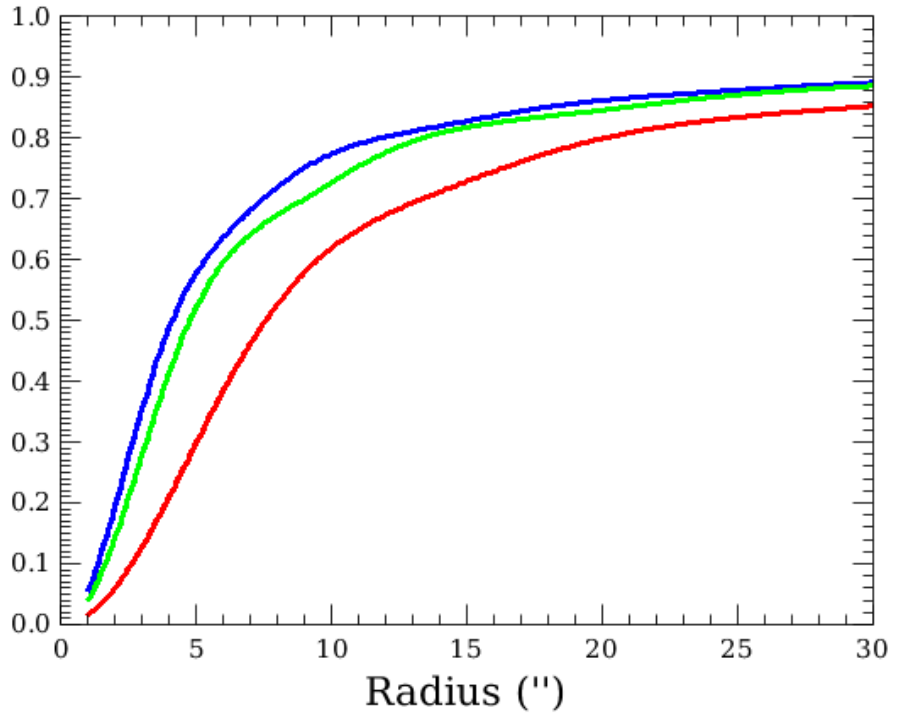
A PSF is influenced by:

- fast scan PSF smearing
- reduction methods:
  highpass filtering, map pixel size, drizzling
- source SED
- straylight and ghost effects
- pointing quality



PACS Photometer Calibration
PSF / Encircled Energy Fraction





- Initial EEF measured from Vesta (used in previous calibration versions)
- Sky background was set to zero at r = 60"

- Current EEF is a combination of Vesta and Mars (PSF core saturated)
- Adds ~10% flux at large radii and at all bands

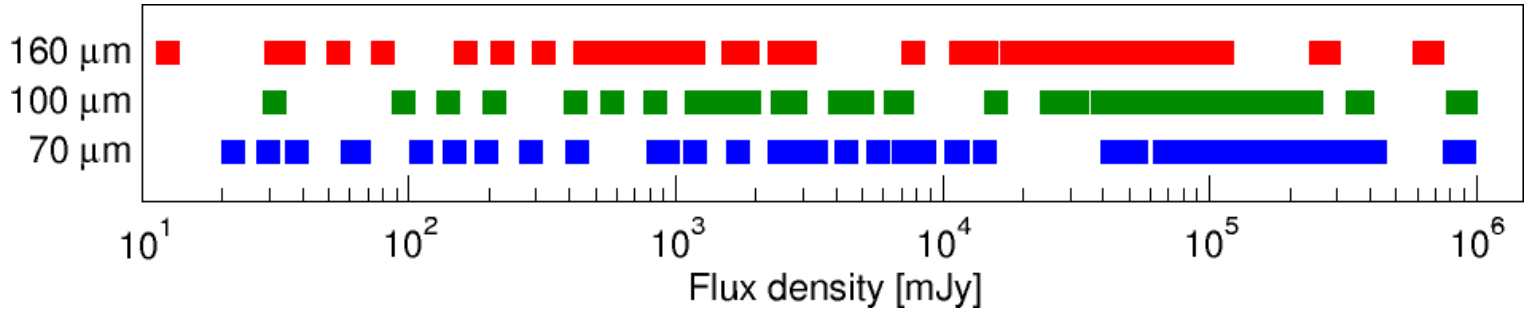
PACS Photometer Flux Calibration
Target selection

Important note:

- Zero point calibration not feasible (high telescope background of ~400 Jy/pix @ 70 µm)
- Consistency checks of extended emission with other observatories (talk by R. Paladini)

General guide lines:

- Wide and dense flux coverage (from a few mJy to several hundred Jy)



- Wide temperature range (a few hundred to several thousand K)
- Well established model predictions across the entire spectral range (PACS, SPIRE)
- Good database of reference measurements (ground based, IRAS, ISO, SPITZER)
- No (random) intrinsic variability
- Low background confusion
- Good visibility

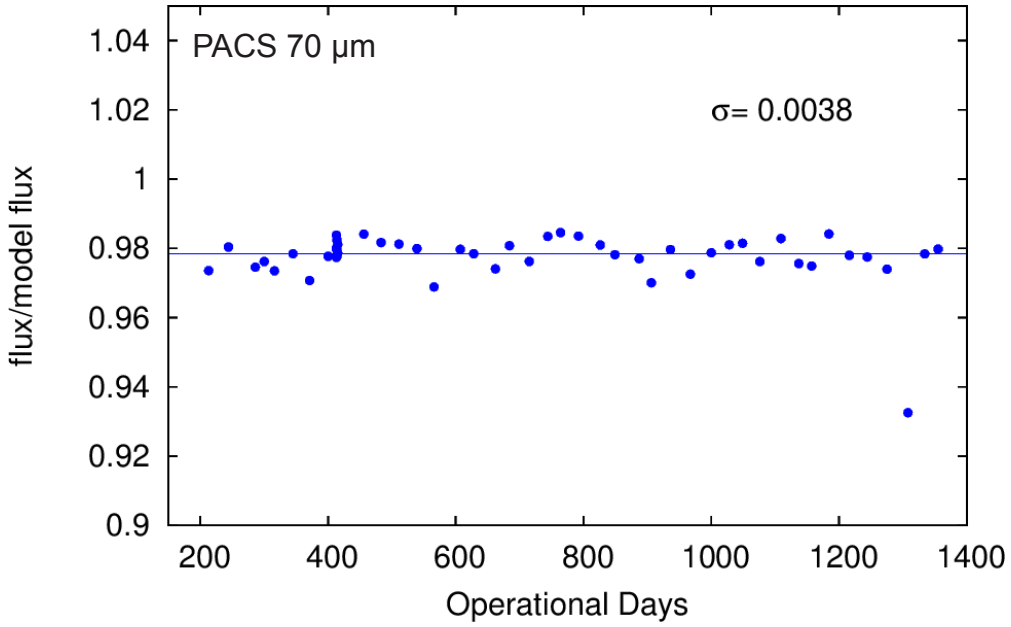
PACS Photometer Flux Calibration
Target selection

4 classes:

prime standard stars	secondary standard stars	asteroids	planets
• α Boo, α Cet, α Tau, β And, γ Dra • based on models • hot source SEDs • highest confidence see talk by J. Blommaert	• less reliable stars for which models exist: α CMa, β Peg, β UMi • Additional sources based on archival data - ISO GBPP - Gordon MIPS calibration - IRAS • converted to PACS bands • extends flux range to faintest levels • less confidence	• based on models • warm source SEDs • time dependent (models) • provides fine adjustment of flux grid coverage • closes gap between stars and planets • partly non-linear flux regime • confidence varies between high and low see talk by T. Müller	• Uranus, Neptune • based on models • warm source SEDs • time dependent (models) • non-linear flux regime • high confidence see talks by R. Moreno, G. Orton

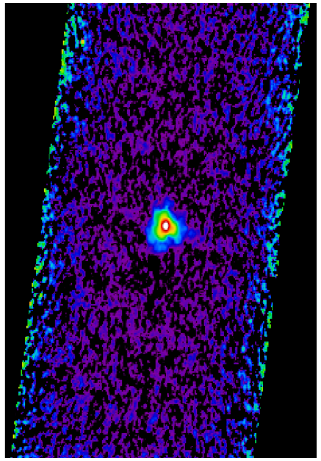
PACS Photometer Flux Calibration
Programme design

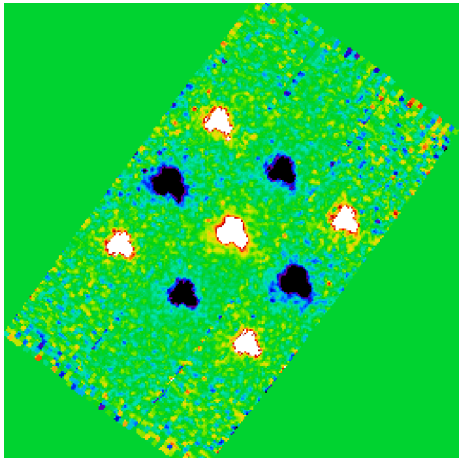
- Flux calibration based on the five prime stellar standards
- Mini scan map mode (medium scan speed, i.e. 20”/s)
- Chopped observations used for verification
- High S/N to optimise photometric accuracy
- Secondary and SSO targets used for verification
- Coordination of SSO observations with other ICCs and Planck to allow for cross calibration
- Stability monitoring on γ Dra (always visible), once per month

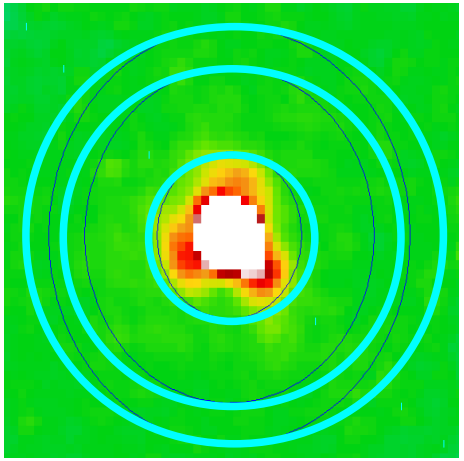


PACS Photometer Flux Calibration
Analysis procedure

- For the processing details, see talk by Z. Balog
- Non-linearity correction applied
- Sky background subtracted aperture photometry with aperture correction (EEF)


PACS scan map

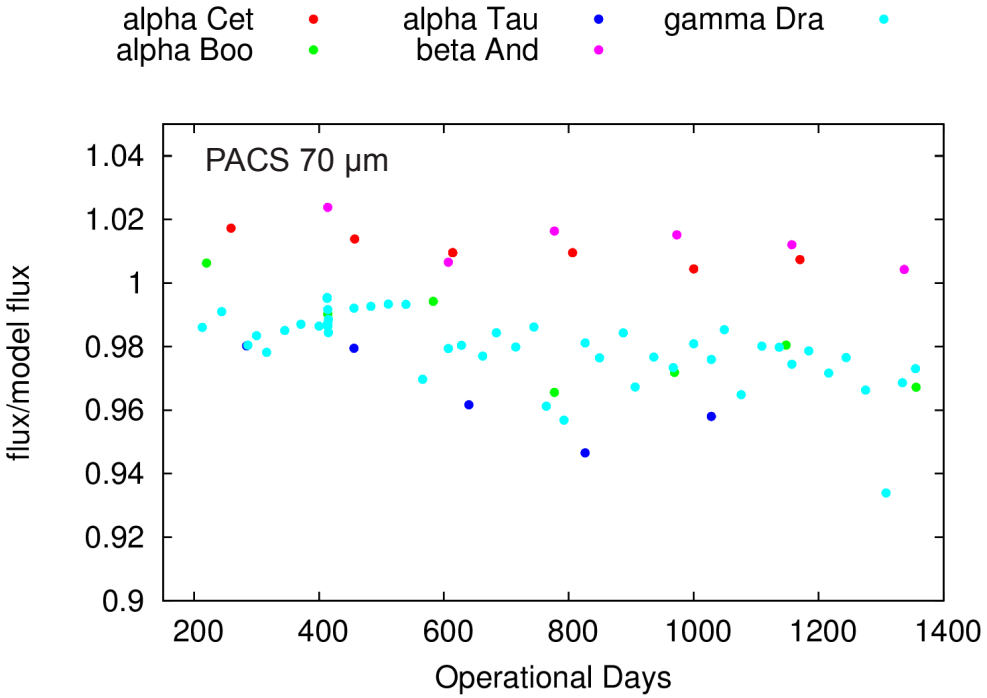

PACS chop-nodded map

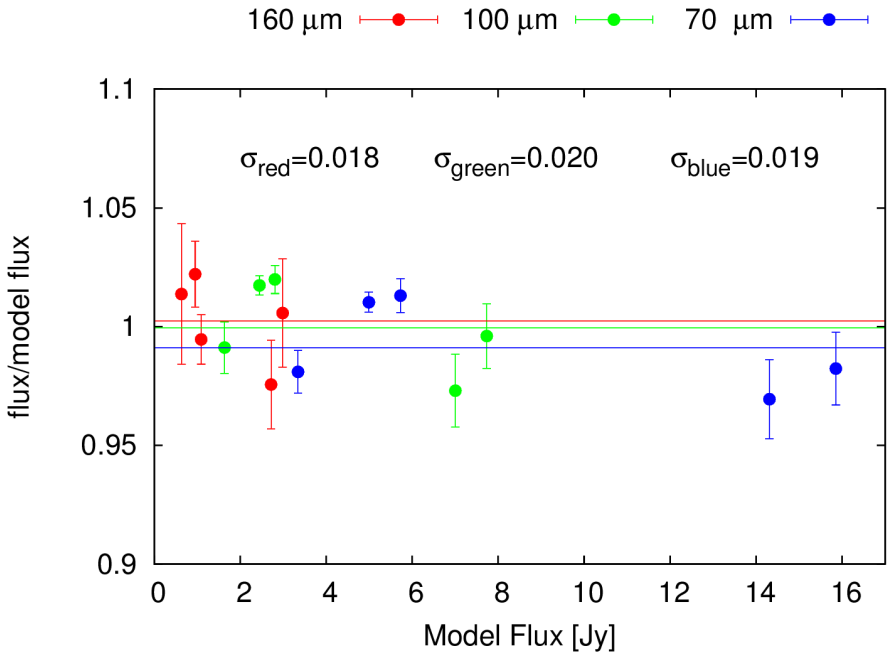

PACS point source with aperture

- Extract interesting observing and HK parameters for investigating possible correlations
- Calculate measured to model flux ratios
- Stellar models as shown by J. Blommaert
- Asteroid models as shown by T. Müller
- Planet models as shown by R. Moreno and G. Orton

PACS Photometer Flux Calibration
Result summary

- Details given in Z. Balog's talk
- Current situation already very good
- Calibration uncertainties are dominated by systematic model uncertainty (~ 5%)
- Measurement uncertainty 2% for combination of 5 prime standards in all bands

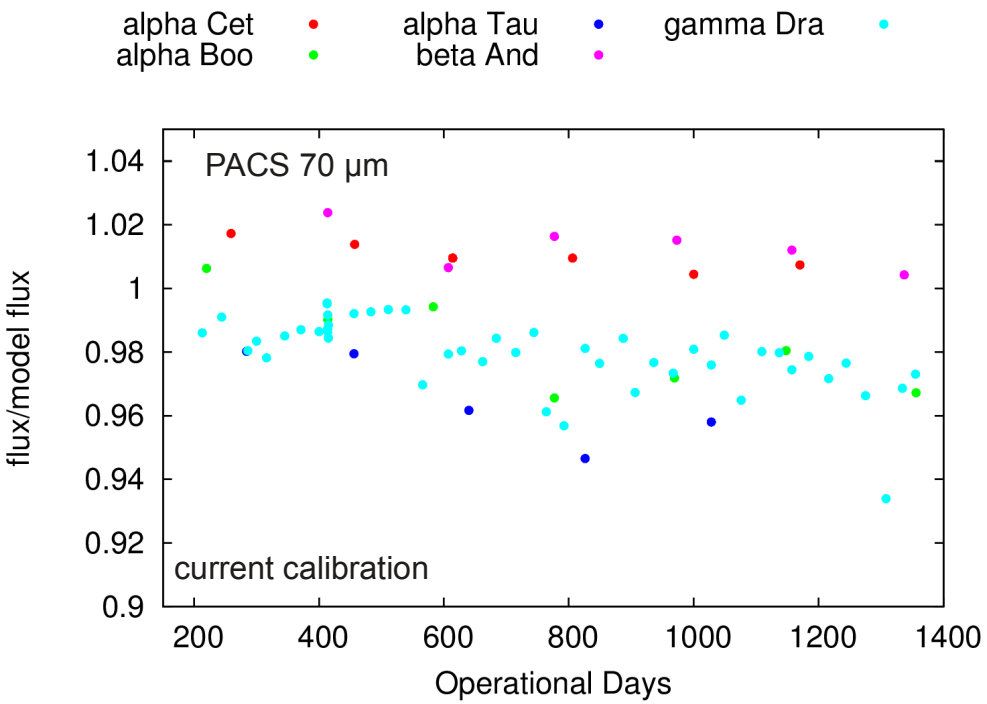


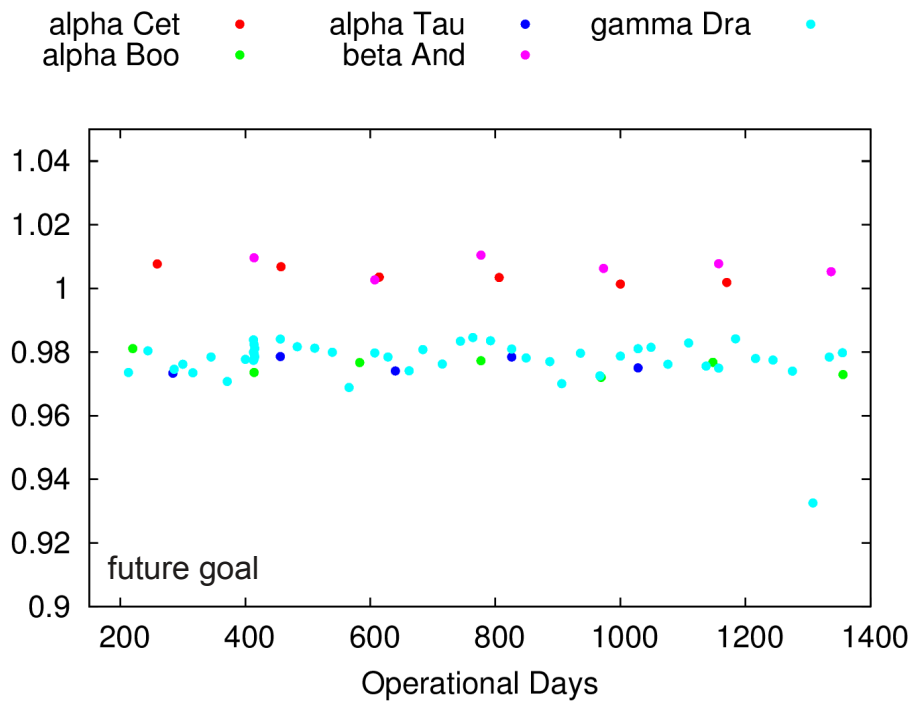


- High reproducibility of source flux (even without using internal calibration sources)
- Agreement with all (secondary) targets across the entire flux range → no NIR filter leak
- Non-linear range only important for PS fluxes beyond 100 Jy → okay for asteroids/planets
- PS fluxes derived from scan maps and chopped observations differ by ~ 8%

PACS Photometer Flux Calibration
Future developments

- Internal calibration data used for long trend analysis (see poster by A. Móor)
- Correlations found with evaporator temperature and main mirror flux
- To be converted into correction algorithms
- Model fluxes to be corrected for updated stellar diameters
- Initial results very promising





- Clear distinction between K and M giants → stellar models
- Measurement uncertainty for combination of five prime calibrators ~ 1.5%
- Repeatability for given object at ~ 0.5%