Herschel Photodetector Array Camera & Spectrometer

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FPU Mounting
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Herschel PACS Instrument
Overview

- Instrument concept
  - Design
  - Operation
- Flight Model test results
  - Subunits
  - Instrument/System level tests/verification
  - Ground calibration
- Predicted in-orbit performance
- Observing with PACS
Instrument Concept

- **Imaging photometry**
  - two bands simultaneously (60-85 or 85-125 µm and 125-210 µm) with dichroic beam splitter
  - two filled bolometer arrays (32x16 and 64x32 pixels, full beam sampling)
  - point source detection limit \(~4\) mJy (5 \(\mu\), 1h)

- **Integral field line spectroscopy**
  - range 57 - 210 µm with 5x5 pixels, image slicer, and long-slit grating spectrograph (R \(\sim\) 1500)
  - two 16x25 Ge:Ga photoconductor arrays (stressed/unstressed)
  - point source detection limit \(3...20 \times 10^{-18}\) W/m² (5 \(\mu\), 1h)
Observing Modes Concept

• Combinations of instrument modes and satellite pointing modes

• Instrument modes:
  – photometry (dual-band)
  – line spectroscopy
  – observation of individual lines
  – range spectroscopy
  – observation of extended wavelength ranges

• Pointing modes:
  – stare/raster/line scan
  – with/without nodding/off-position

• Internal chopper
  – background subtraction
  – calibration

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Photoconductor Arrays (Spectrometer)

- Two 25x16 pixel filled arrays
- Extrinsic photoconductors (Ge:Ga, stressed/unstressed)
- Integrated cryogenic readout electronics (CRE)
- Near-background-noise limited performance expected
Detector Performance: System NEP

- System NEP of red array as expected
- System NEP of blue array better than at module level

Median detector NEP:
- Red: $8.9 \times 10^{-18}$ W Hz$^{-1/2}$
- Blue: $2.1 \times 10^{-17}$ W Hz$^{-1/2}$
Detector Performance: Transient Response

Response of blue detector to transient signal of 1/3 of typical background flux

- Fast modulation is possible at expected background with small penalty in terms of sensitivity
- But detailed calibration required
Detector Performance: Transient Response

- Flux-step dependent photometric correction necessary

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Detector Operation/Performance under p+ Irradiation

• Responsivity Jumps:
  – Must be filtered out
  – Different for LS & HS
  – Force short chopper plateaus
Bolometer Arrays (Photometer)

- Two filled arrays: 64x32 pixels (blue) and 32x16 pixels (red)
- Bolometers and multiplexing readout electronics operating at 0.3K
- Detector/readout noise comparable to background-noise (FM)
- Cooler hold time \( \sim 48h \)
FM Bolometer Performance

- Pixel yield ~98%
- NEP ~1.7...5 x BLIP
  - Trade-off NEP --> speed
  - 1/f noise
  - Narrow frequency window for signal modulation (scanning, chopping)
Bolometer Bandwidth <-> NEP Optimization

- Simulations show acceptable PSF at close-to-minimum NEP
- Re-optimization for actual background in orbit necessary

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Mechanisms: Dynamics and Precision

- Chopper reaches duty-cycle >90% for 1/4s plateaus
- Grating achieves required 30ms settling time for small steps (normal scanning)

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Filter Performance

Spectrometer filter bands (grating order sorters)

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Photometer PSF

- Source: ~ diffraction PSF size hole mask in front of external blackbody, contrast ~1% of background
- Slightly wider core / excess at 1-3 gaussian sigmas
No indication for unexpected large scale wings
- Slight astigmatism
Photometer Focal Plane Geometry/Distortions

- Positions/distortions determined with \(~1/20\) pixel accuracy
- All these precise results refer to the test optics (XY stage)!
- Ongoing modeling to transfer to sky
Spectrometer PSF

- No significant deviations from predicted performance

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Spectrometer Focal Plane Geometry/Distortions

- Some displacement between slices in IFU
- Chopper-angle dependent field rotation (as in photometer)
- No dependency on grating position
Spectrometer Resolution

- Spectral line profiles determined with FIR gas laser
- Derived spectral resolution in good agreement with calculated values

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Spectrometer Spectral Calibration

- FIR laser, H2O + CO (absorption cell)
- Requirement “peak position to within 10-20% of a spectral resolution element” fulfilled (Littrow + pixel correction terms)
Predicted Spectrometer Sensitivity

- Proposal sensitivity partly achieved

...but cosmic rays!

![Graphs showing spectral line and continuum sensitivity]

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Predicted Photometer Sensitivity

- Point source sensitivity equivalent to mapping speed of \( \sim 10' \times 10' \) in 1 day

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Spectrometer Observing Modes

- **Line Spectroscopy**: observation of individual line(s)
  - Chop/nod or wavelength switching
  - Staring or mapping
  - $R \sim 1500$

- **Range Spectroscopy**: observation of extended range(s)
  - Chop/nod or off position
  - Staring or mapping
  - SED mode

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Spectrometer Line Scan Schemes

“Bright Line” Mode

“Faint Line” Mode

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Photometer Observing Modes

4 AOTs in photometry channel

Point source photometry:
- 4-positions
- 2 chop/nod cycles
Repeat basic cycle to gain more sensitivity

Dual Band: 70+160 μm
or 100+160 μm

Extended source Mapping:
- Options are Scan (shown) or chopped Raster
- Maximum size 4-deg
- 3 scan speeds or fixed chopping

Small source photometry:
- Small 2x2 raster
- 200”x100” FOV
- Dither to cover inter-matrix gaps
Remarks on Scan Map

Cross-scan distance

Scan leg length

βουστροφηδόν
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Sneak preview (SPIE 2010) ...

1.4°x1.4° XMM COSMOS (Hasinger et al.)

~100 Mpc spatial scale
~$10^{14}$ $M_{\text{sun}}$ mass scale

~200h for full 2sq.deg field to 11mJy

Simulated deep PACS sub-field survey