# Herschel Photodetector Array Camera & Spectrometer

Albrecht Poglitsch, MPE Garching

Christoffel Waelkens, Katholieke Universiteit Leuven

Otto H. Bauer, Max-Planck-Institut für extraterrestrische Physik

Jordi Cepa, Instituto de Astrofísica de Canarias

Helmut Feuchtgruber, Max-Planck-Institut für extraterrestrische Physik

Thomas Henning, Max-Planck-Institut für Astronomie

Chris van Hoof, Interuniversity Microelectronics Center Leuven

Franz Kerschbaum, Institut für Astronomie der Universität Wien

Oliver Krause, Max-Planck-Institut für Astronomie

Etienne Renotte, Centre Spatial de Liège

Louis Rodriguez, Commissariat a l'Energie Atomique, Saclay

Paolo Saraceno, Istituto di Fisica dello Spazio Interplanetario

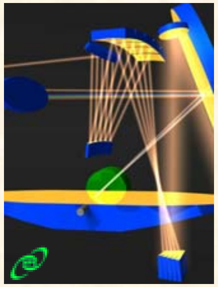
Bart Vandenbussche, Katholieke Universiteit Leuven

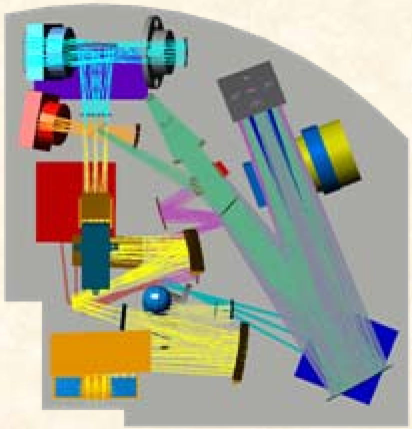
# FPU Mounting

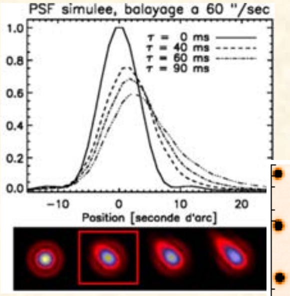
## 9 July 2007

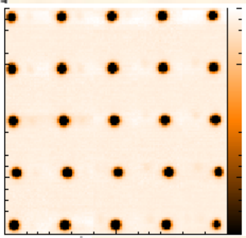
# Overview

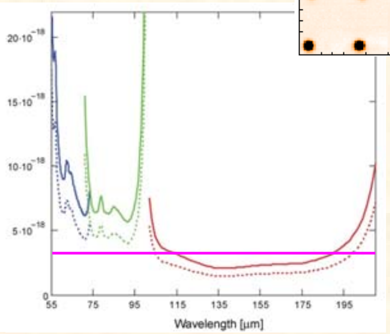
- Instrument concept
  - Design
  - Operation
- Flight Model test results
  - Subunits
  - Instrument/System level tests/verification
  - Ground calibration
- Predicted in-orbit performance
- Observing with PACS

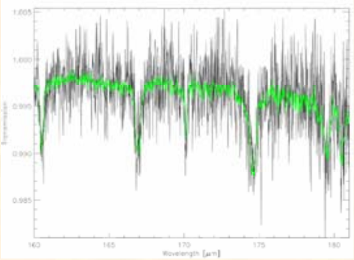


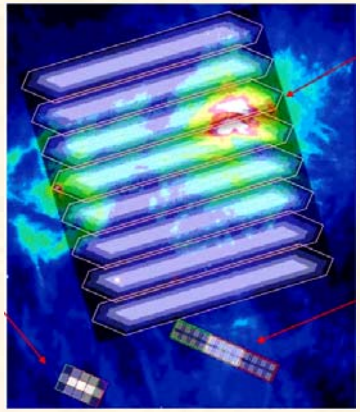






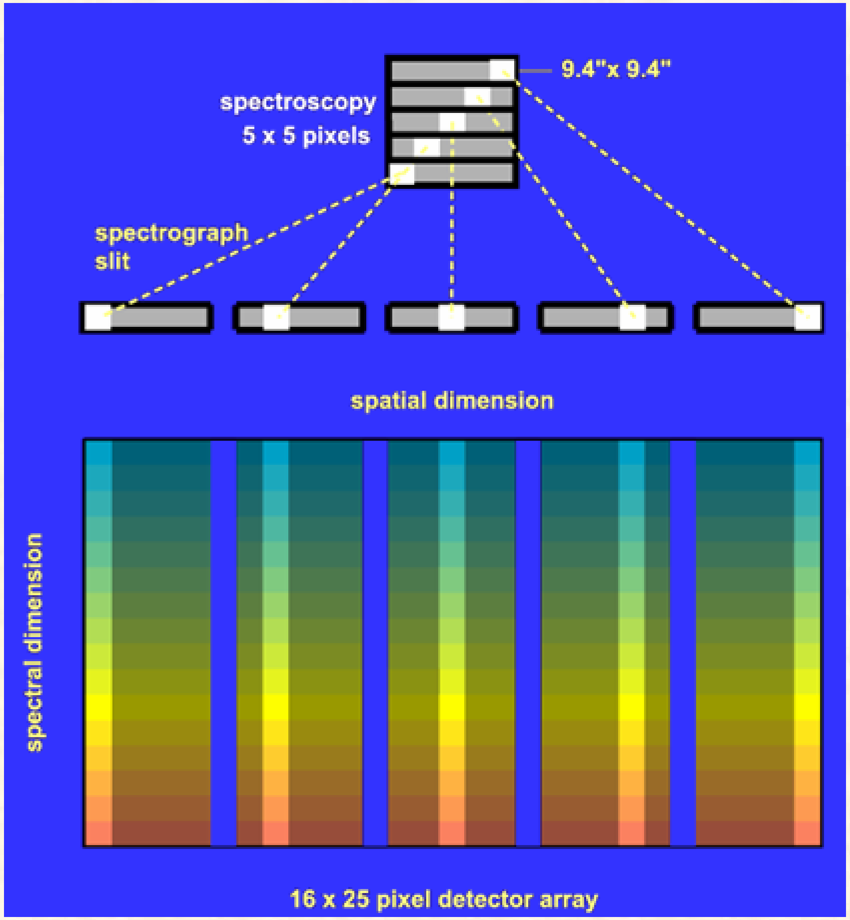





# Instrument Concept

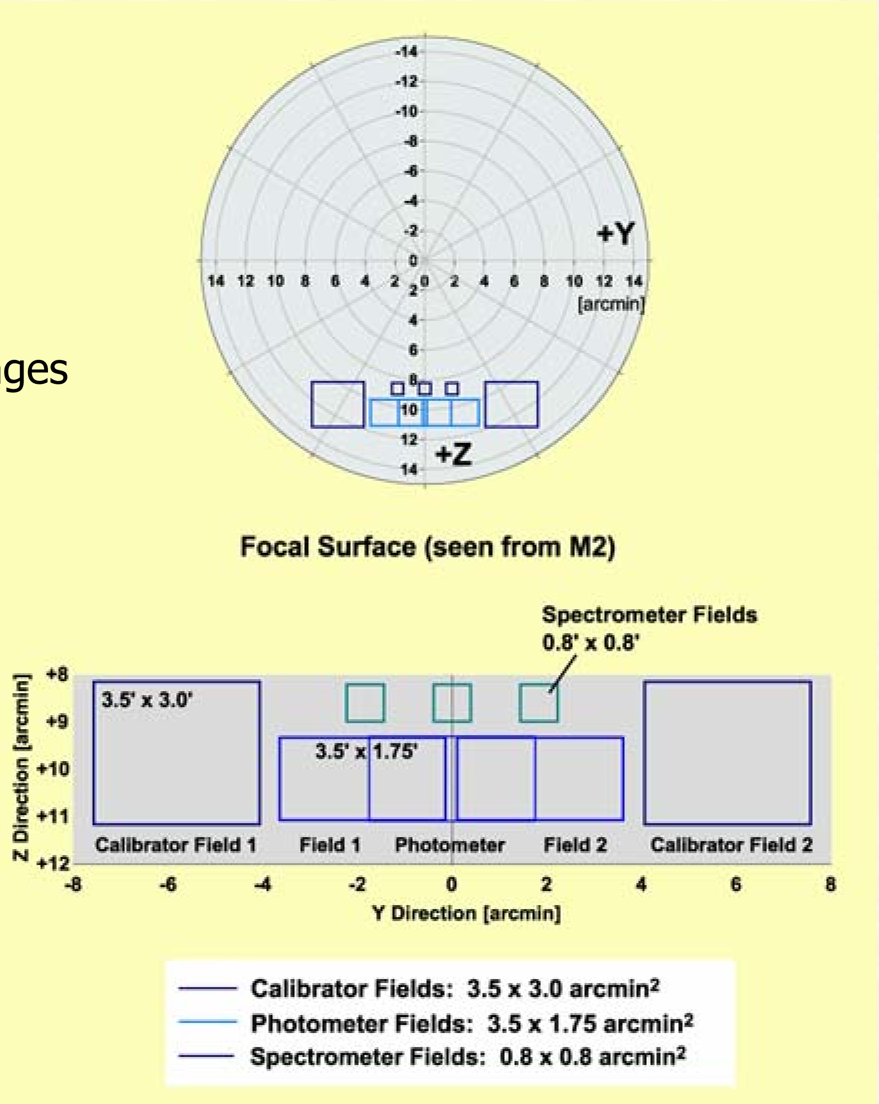
- **Imaging photometry**
  - two bands simultaneously (60-85 or 85-125 μm and 125-210 μm) with dichroic beam splitter
  - two filled bolometer arrays (32x16 and 64x32 pixels, full beam sampling)
  - point source detection limit ~4 mJy (5 ʃ, 1h)
- **Integral field line spectroscopy**
  - range 57 - 210 μm with 5x5 pixels, image slicer, and long-slit grating spectrograph (R ~ 1500)
  - two 16x25 Ge:Ga photoconductor arrays (stressed/unstressed)
  - point source detection limit 3…20 x$10^{-18}$ W/$m^2$ (5 ʃ, 1h)

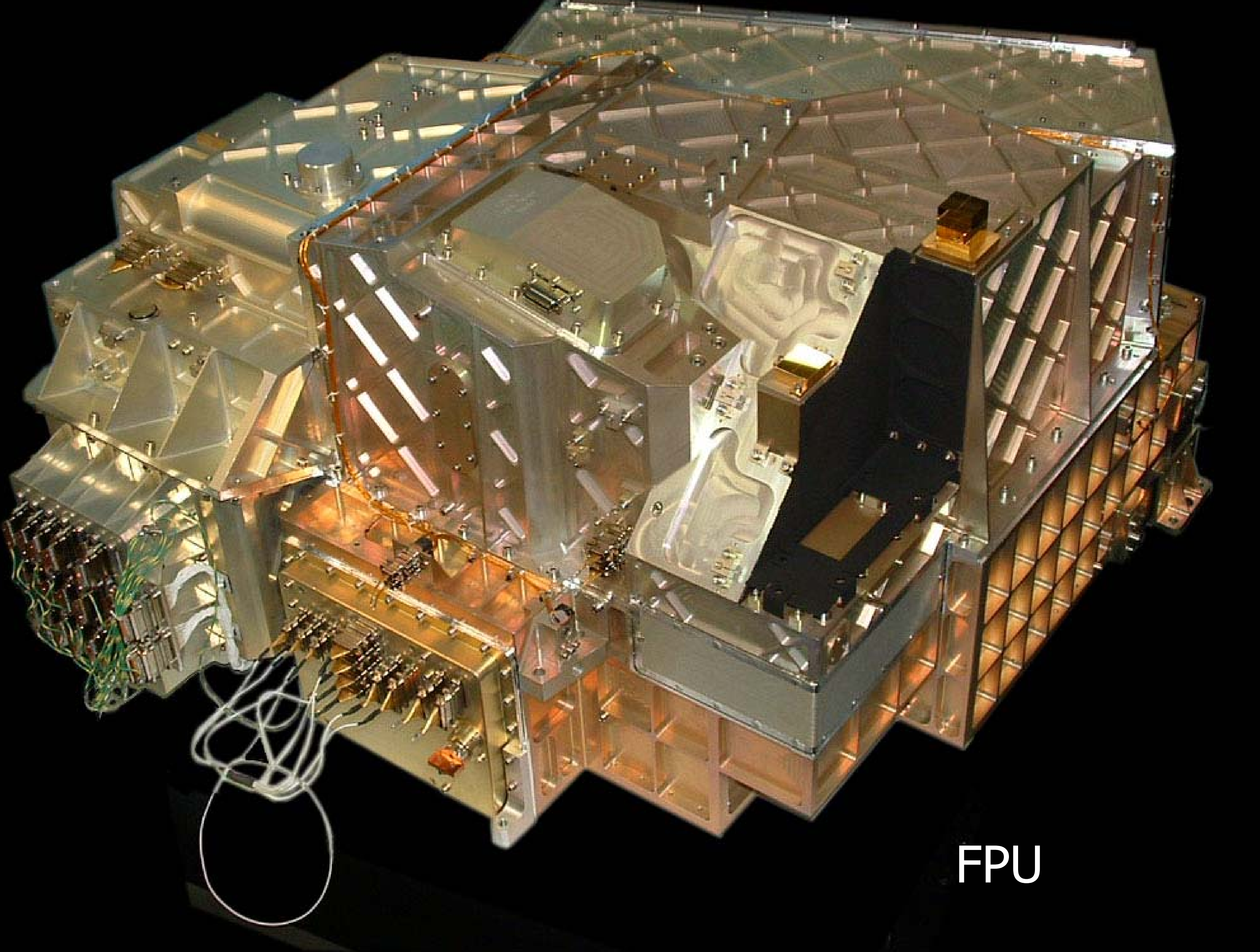
Focal Plane Footprint



# 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

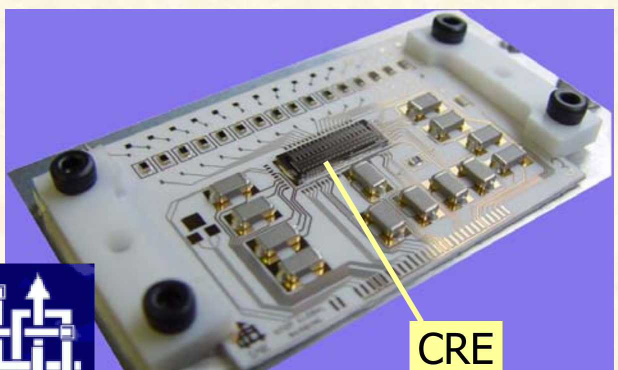


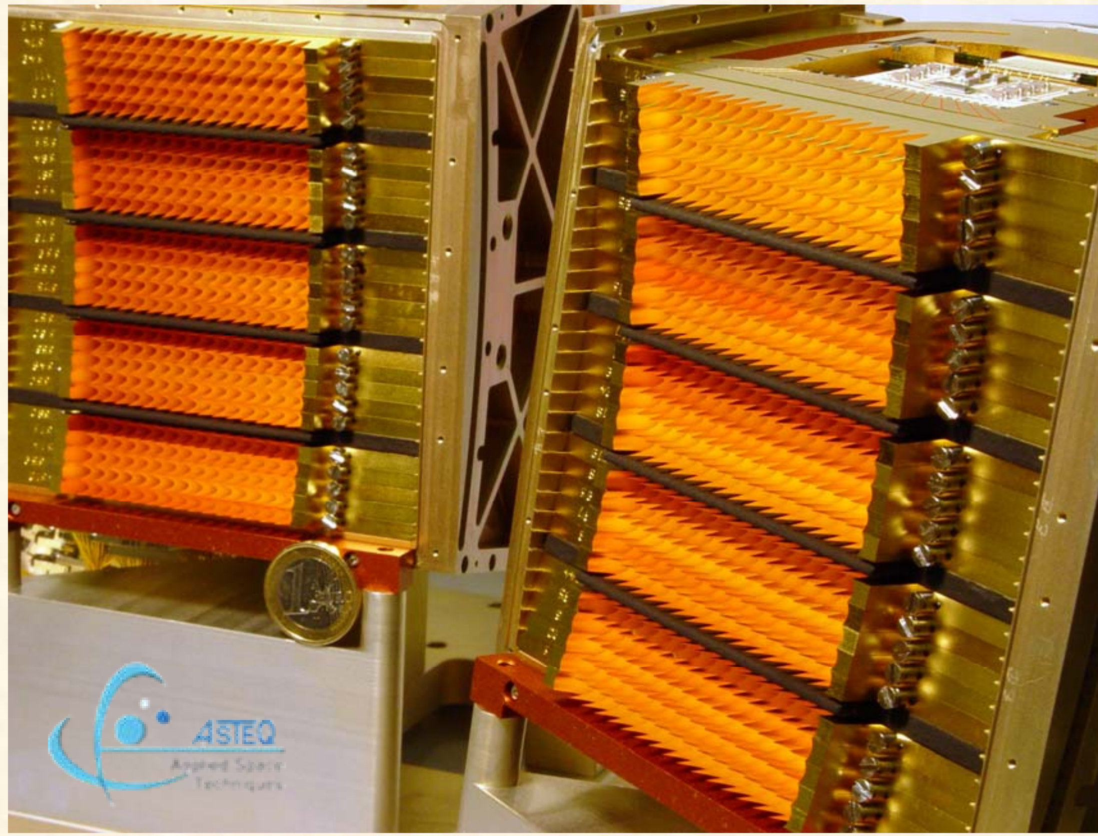


FPU

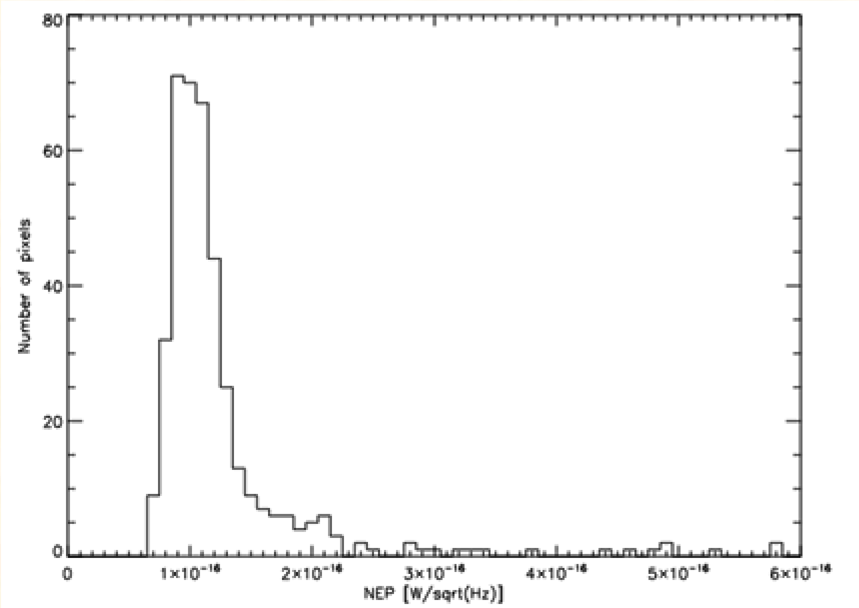
# Photoconductor Arrays (Spectrometer)

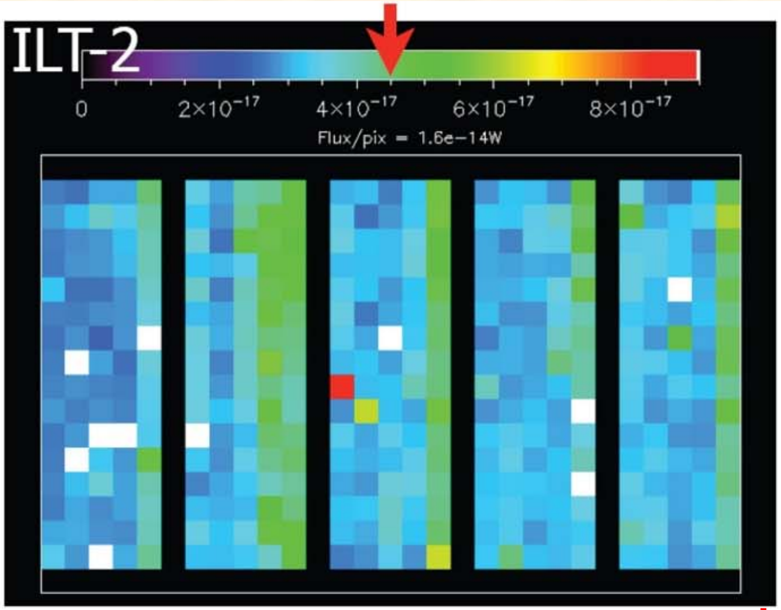
- Two 25x16 pixel filled arrays
- Extrinsic photoconductors (Ge:Ga, stressed/unstressed)
- Integrated cryogenic readout electronics (CRE)
- Near-background-noise limited performance expected



# Detector Performance: System NEP




Blue

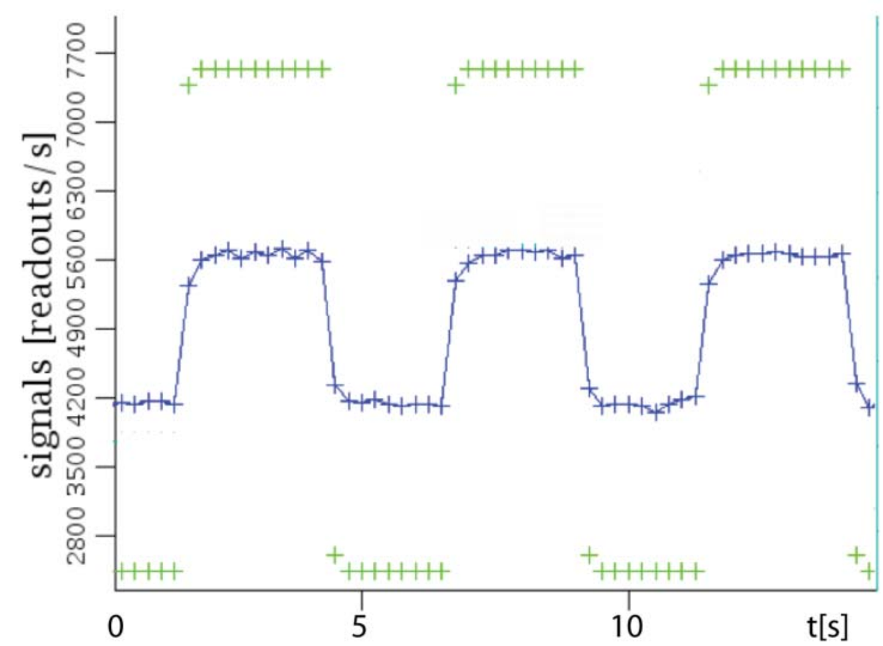
Median detector NEP:
$2.1\times10^{-17}$ W Hz$^{-1/2}$

Red

Median detector NEP:
$8.9\times10^{-18}$ W Hz$^{-1/2}$

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

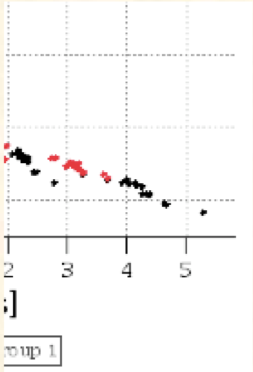
# Detector Performance: Transient Response



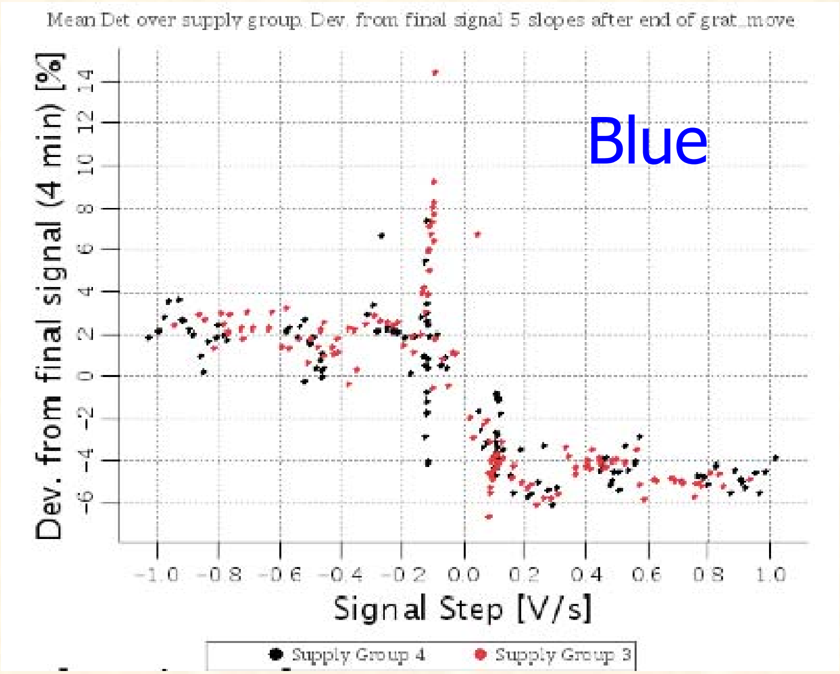

Response of blue detector to transient signal of 1/3 of typical background flux

- Fast modulation is possible at expected background with small penalty in terms of sensitivity
- But detailed calibration required

# Detector Performance: Transient Response

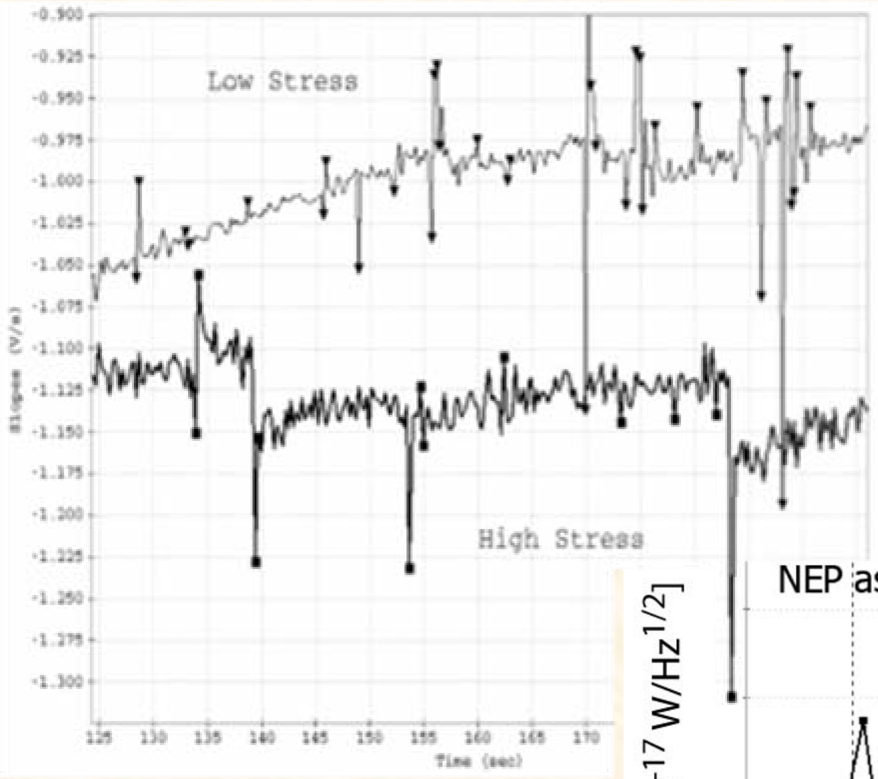



Red

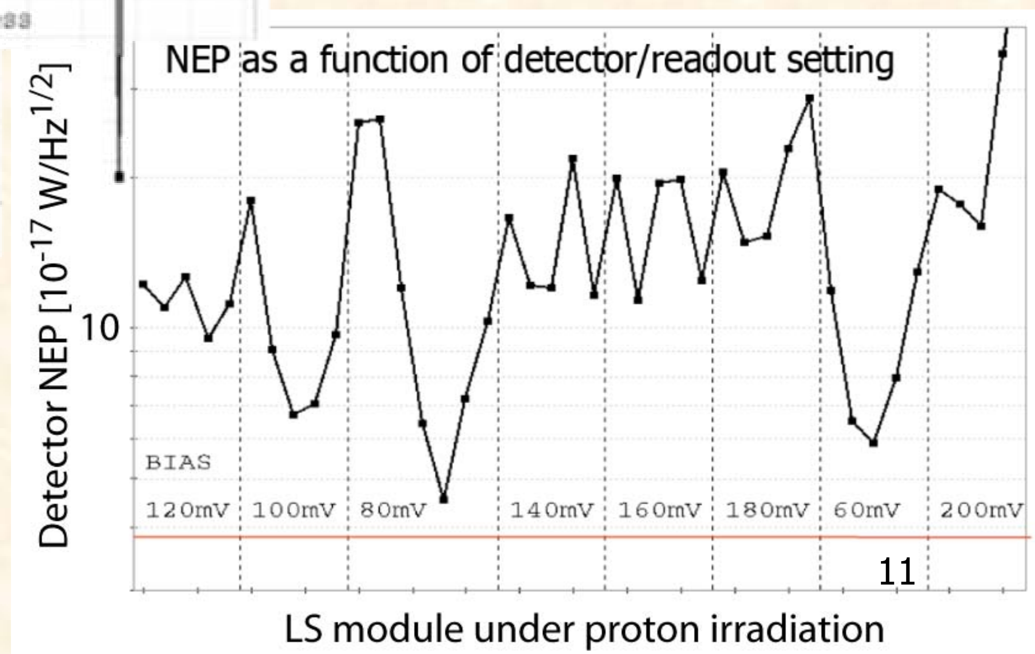



- Flux-step dependent photometric correction necessary

# Detector Operation/Performance under p+ Irradiation



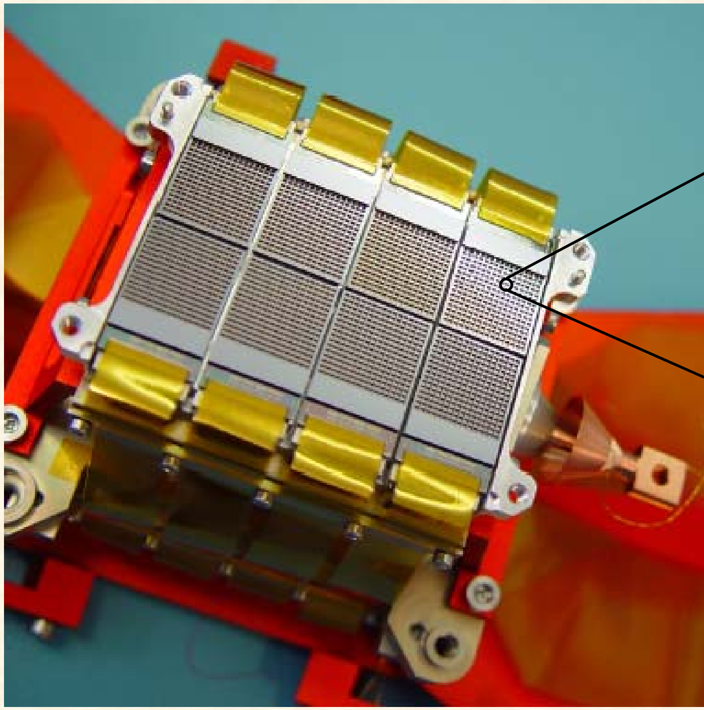

- Responsivity Jumps:
  - Must be filtered out
  - Different for LS & HS
  - Force short chopper plateaus

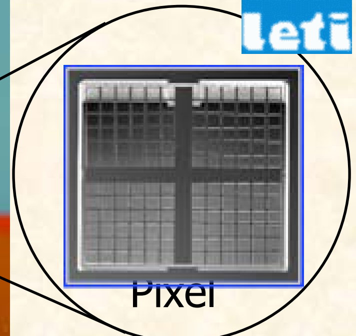


# Bolometer Arrays (Photometer)

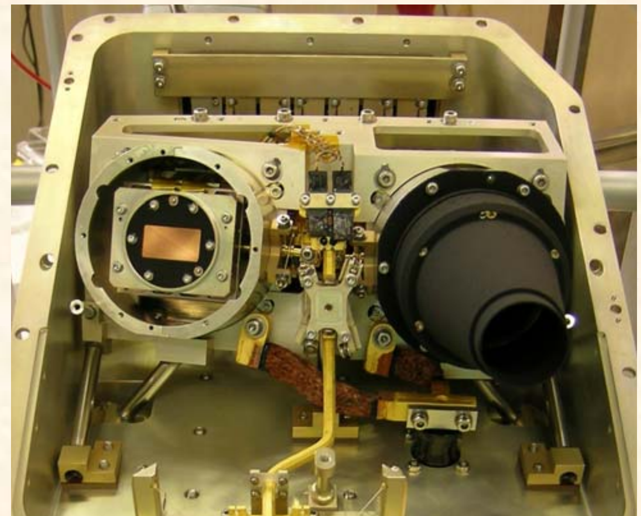
- Two filled arrays: 64x32 pixels (blue) and 32x16 pixels (red)
- Bolometers and multiplexing readout electronics operating at 0.3K
- Detector/readout noise comparable to background-noise (FM)
- Cooler hold time ~48h

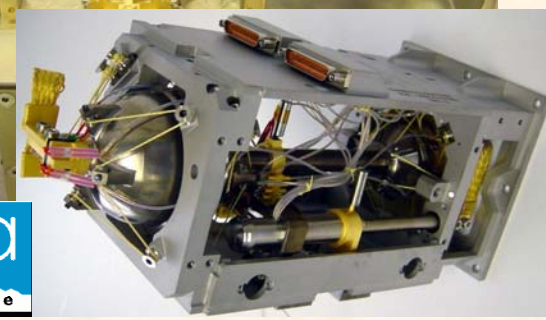
Blue focal plane






Herschel PACS Instrument

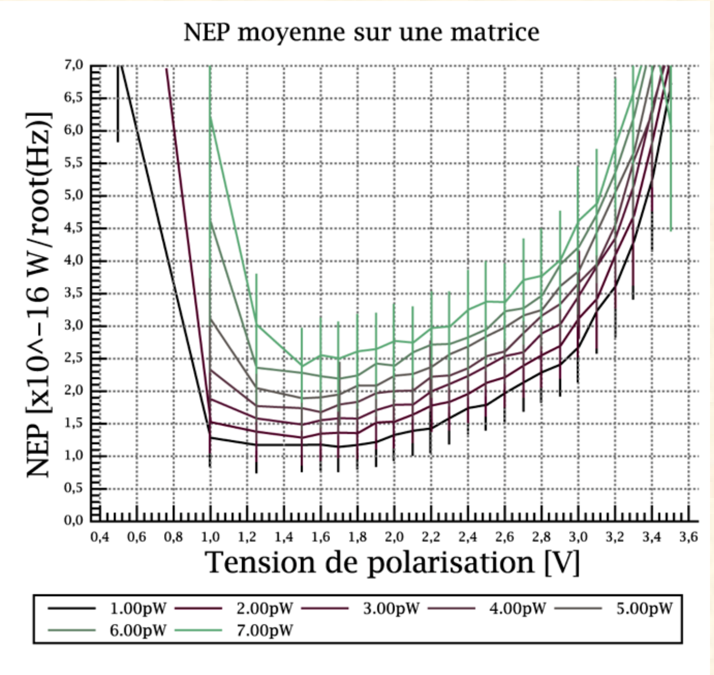


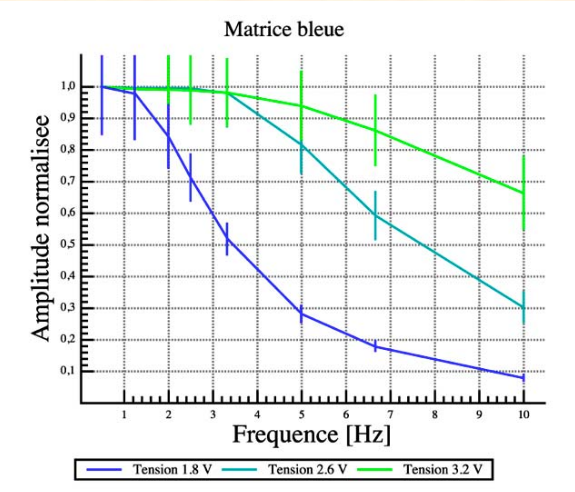


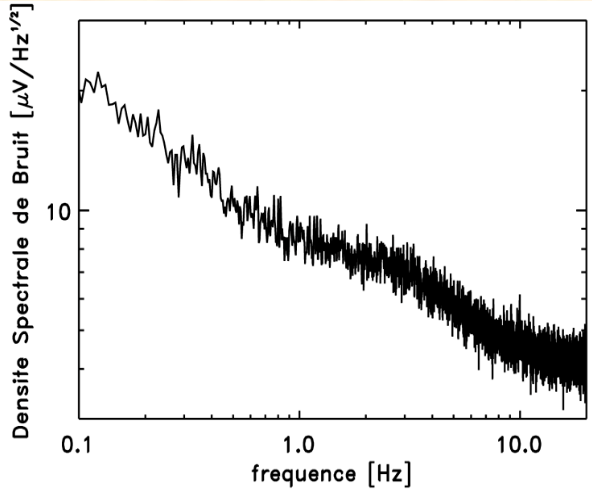
Photometer unit with blue + red focal planes and $^3He$ cooler

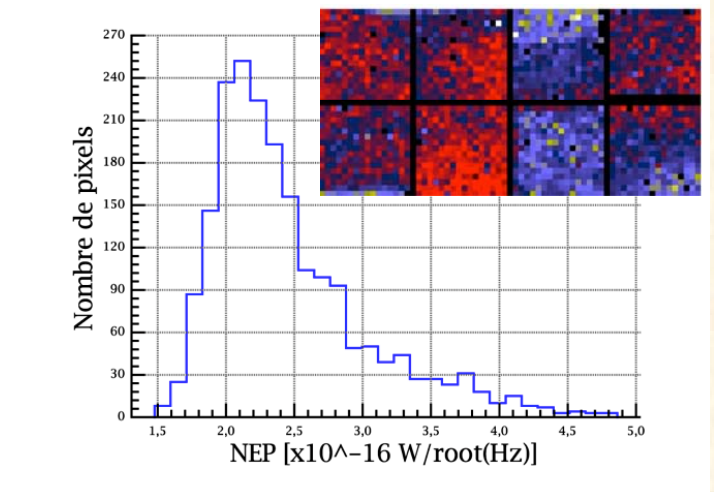
# FM Bolometer Performance

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

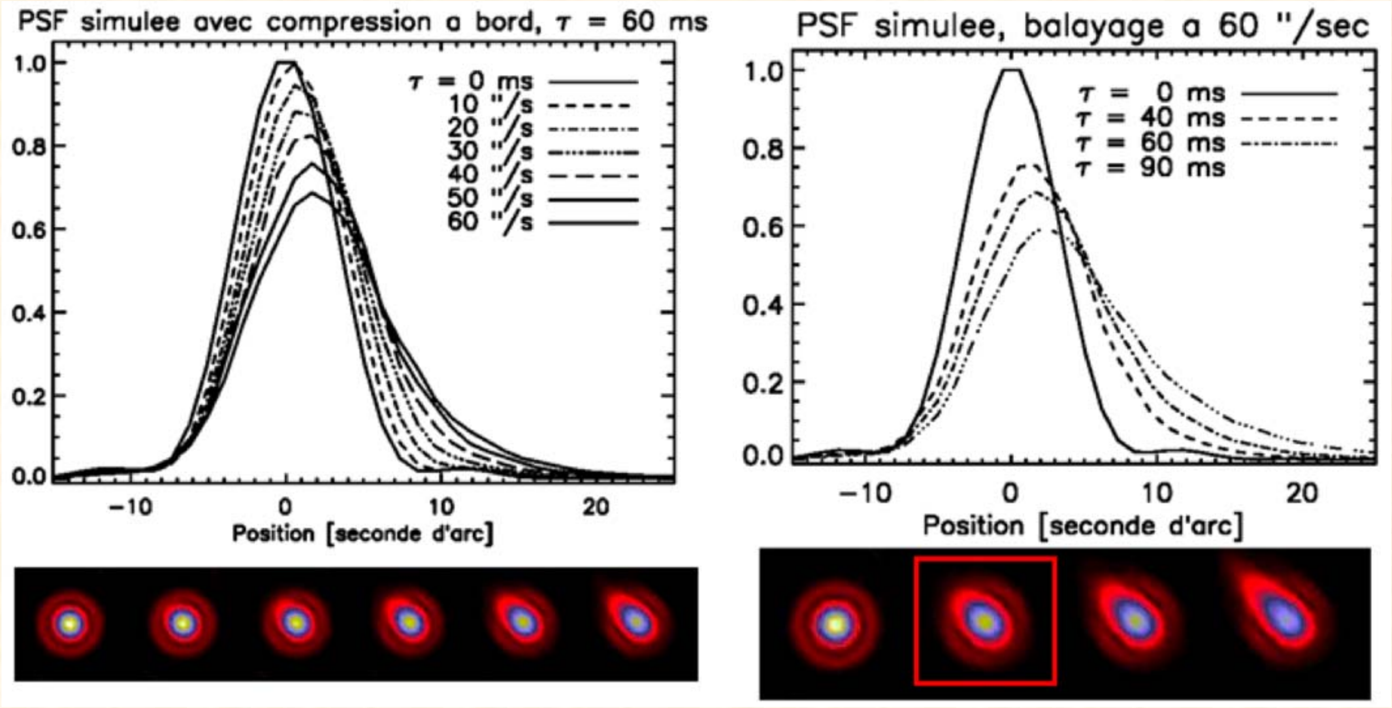


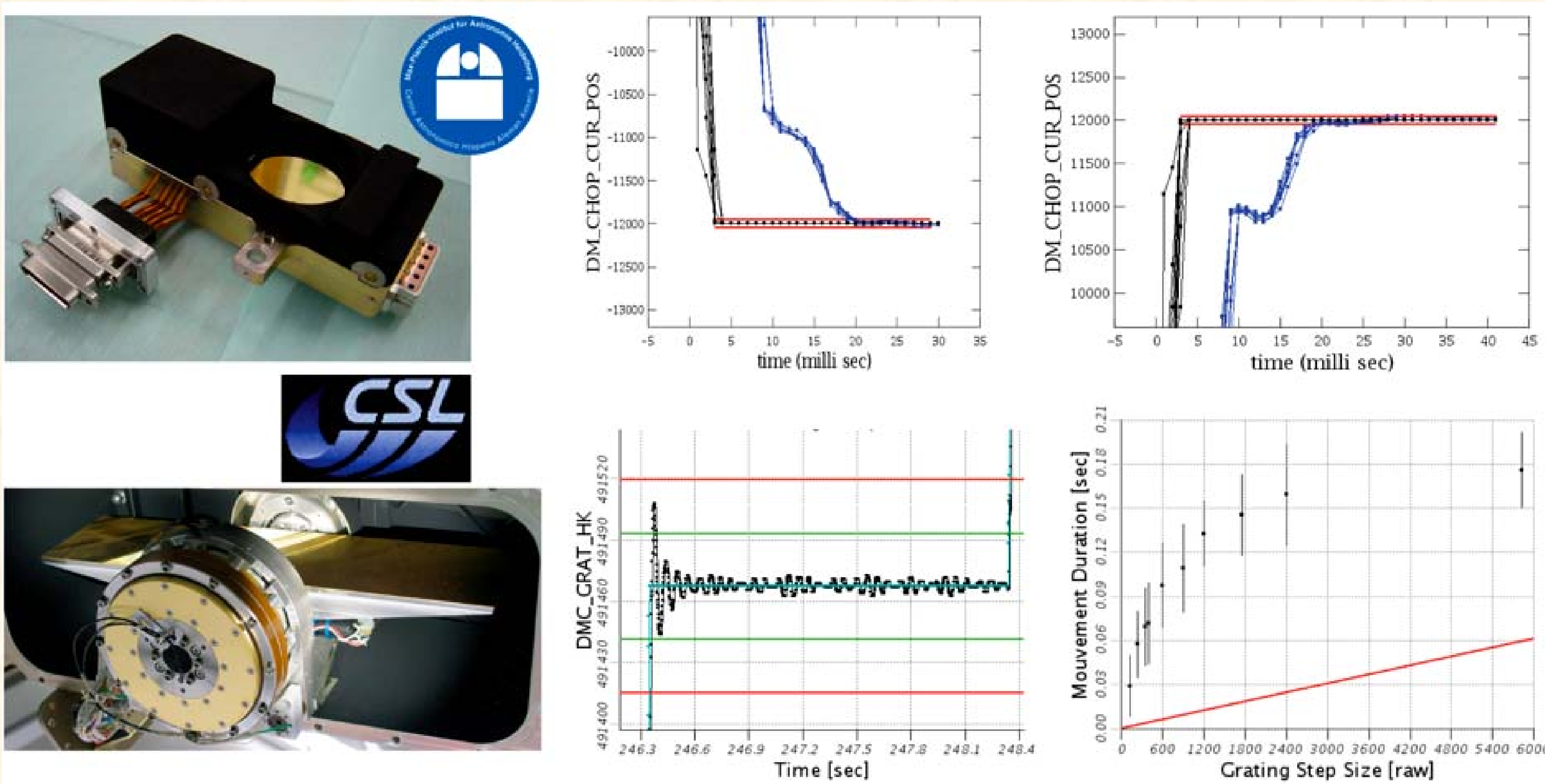



# Bolometer Bandwidth <--> NEP Optimization



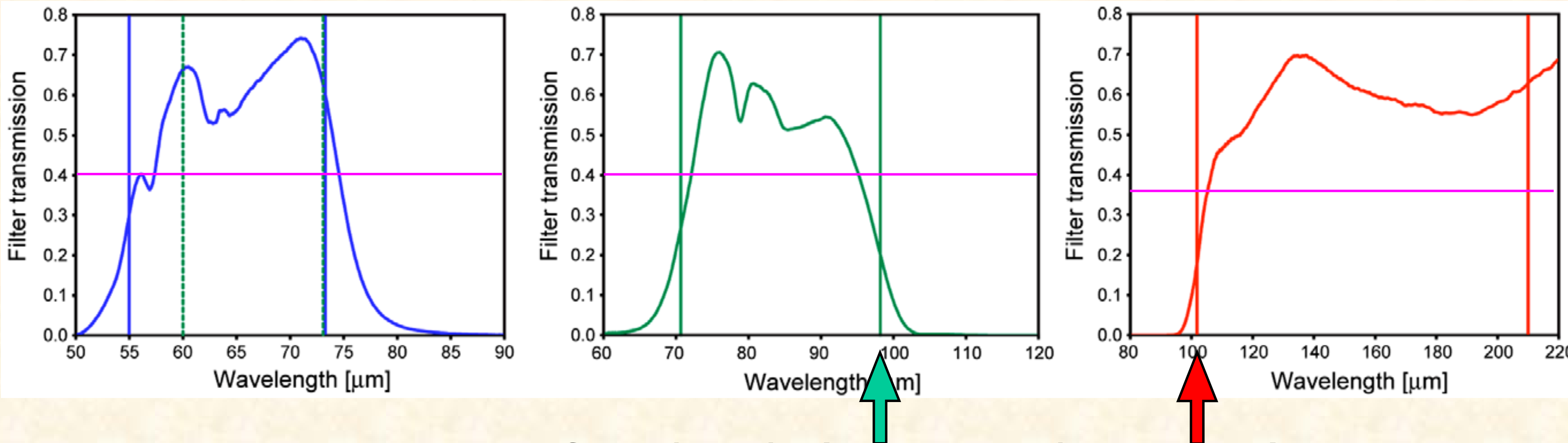

- Simulations show acceptable PSF at close-to-minimum NEP
- Re-optimization for actual background in orbit necessary

# Mechanisms: Dynamics and Precision




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

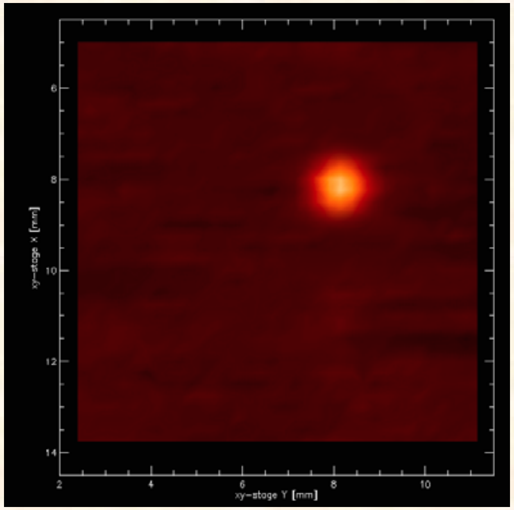
# Filter Performance

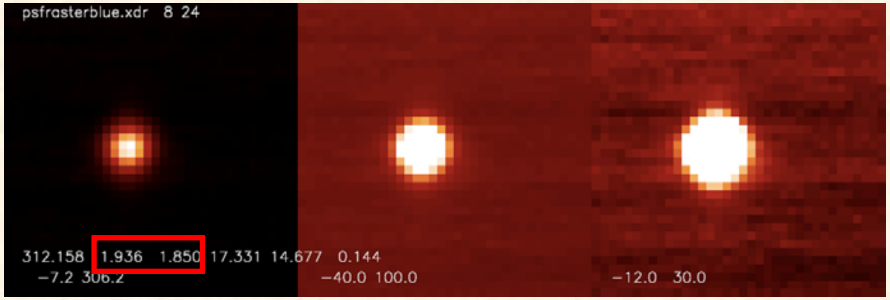



Spectrometer filter bands (grating order sorters)

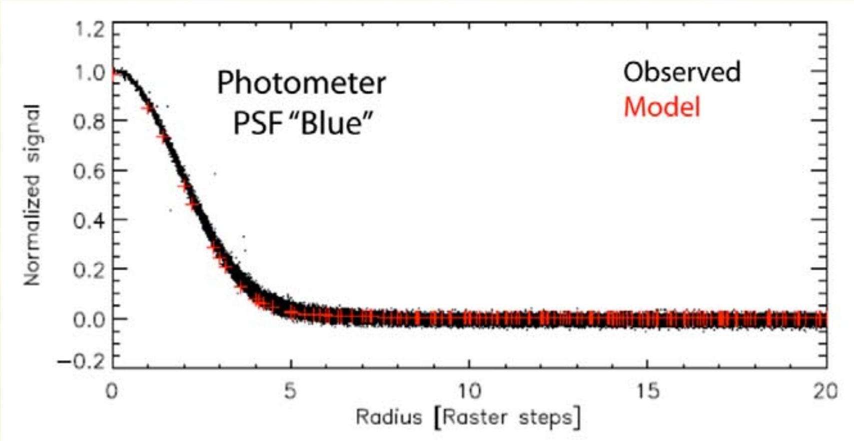
# Photometer PSF

- Source: ~ diffraction PSF size hole mask in front of external blackbody, contrast ~1% of background
- Slightly wider core / excess at 1-3 gaussian sigmasNo indication for unexpected large scale wings
- Slight astigmatism

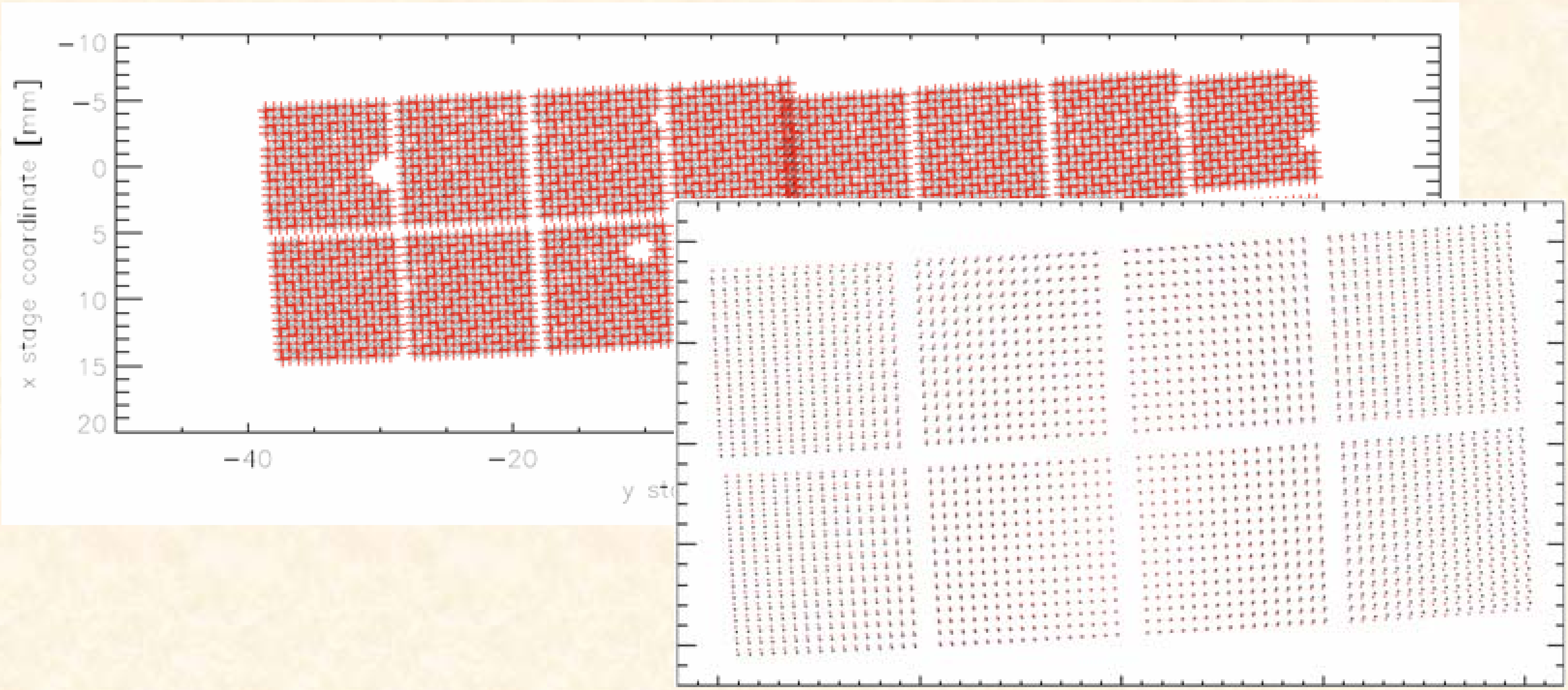



gain up →

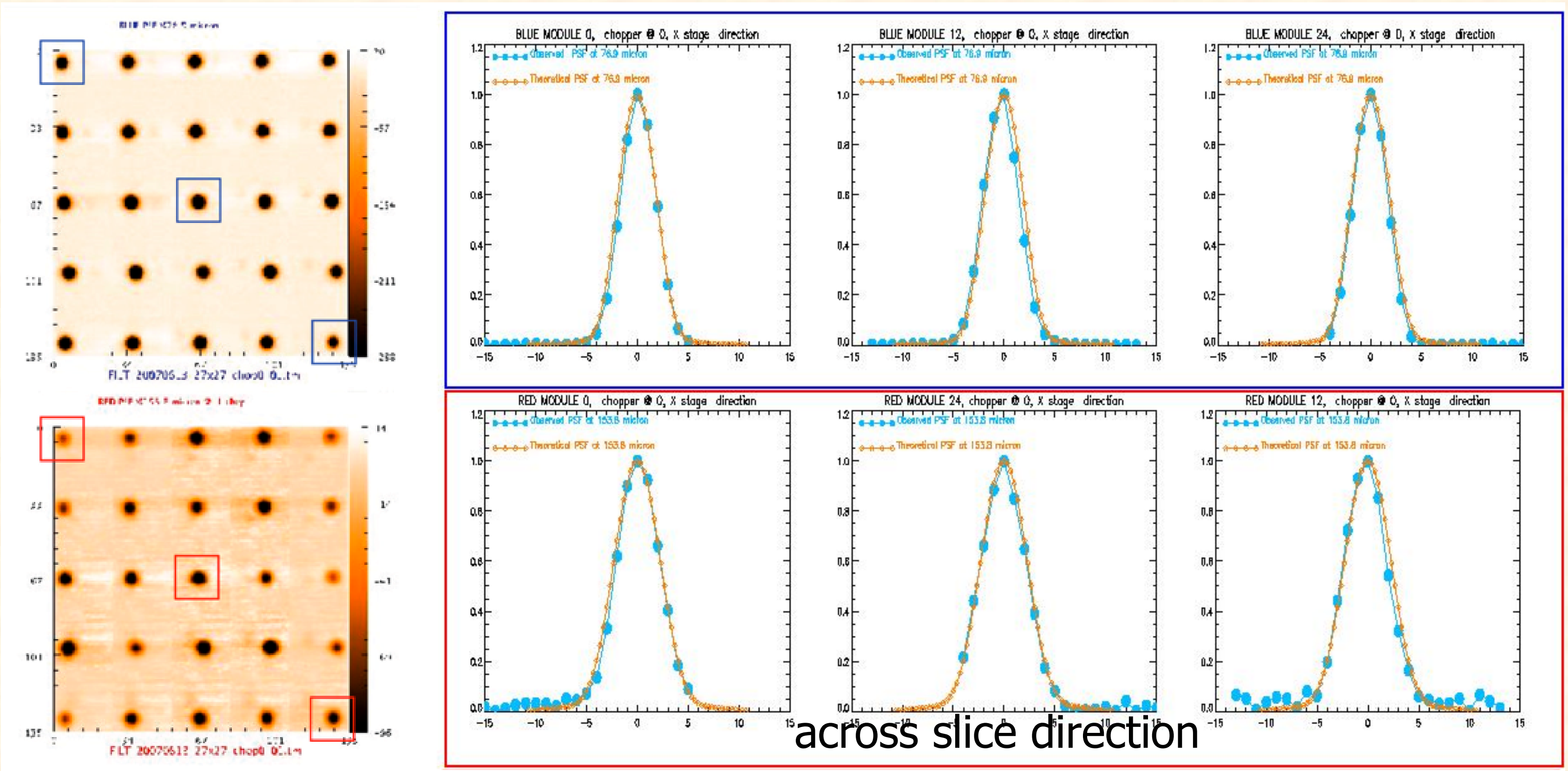


# Photometer Focal Plane Geometry/Distortions



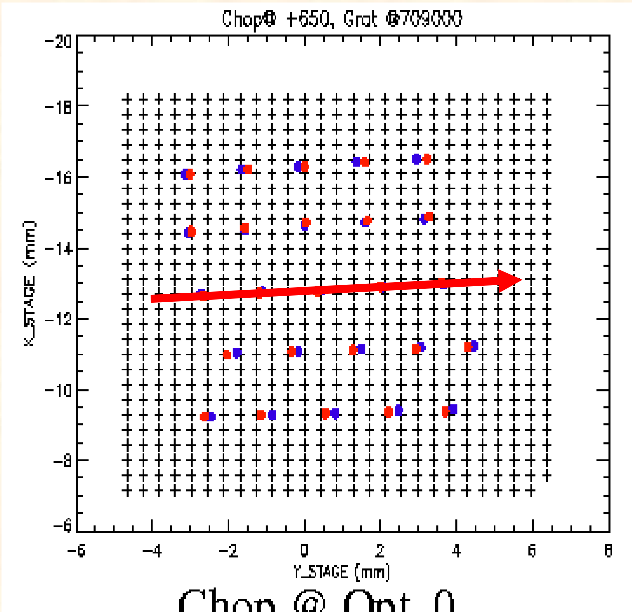

- Positions/distortions determined with ~1/20 pixel accuracy
- All these precise results refer to the test optics (XY stage)!
- Ongoing modeling to transfer to sky

# Spectrometer PSF

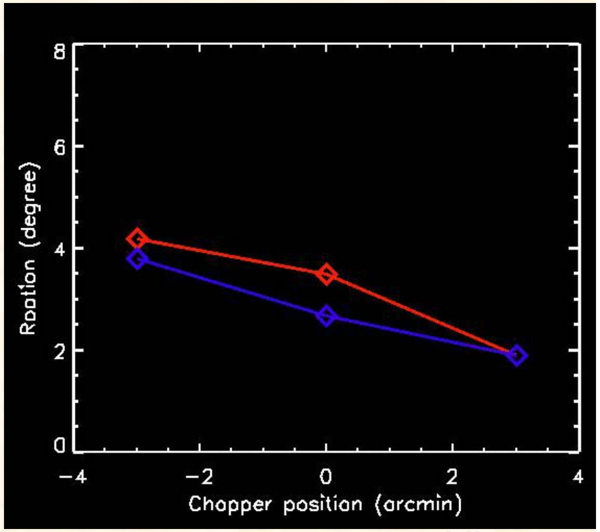



- No significant deviations from predicted performance

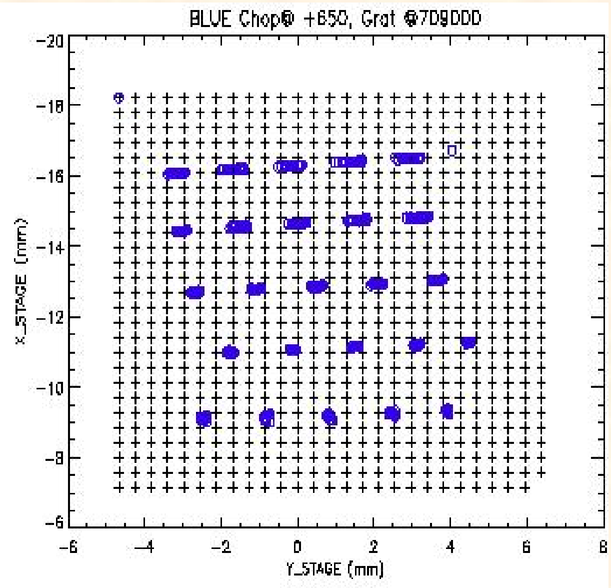
# Spectrometer Focal Plane Geometry/Distortions




Spatial pixel positions red/blue (spectral pixels averaged)



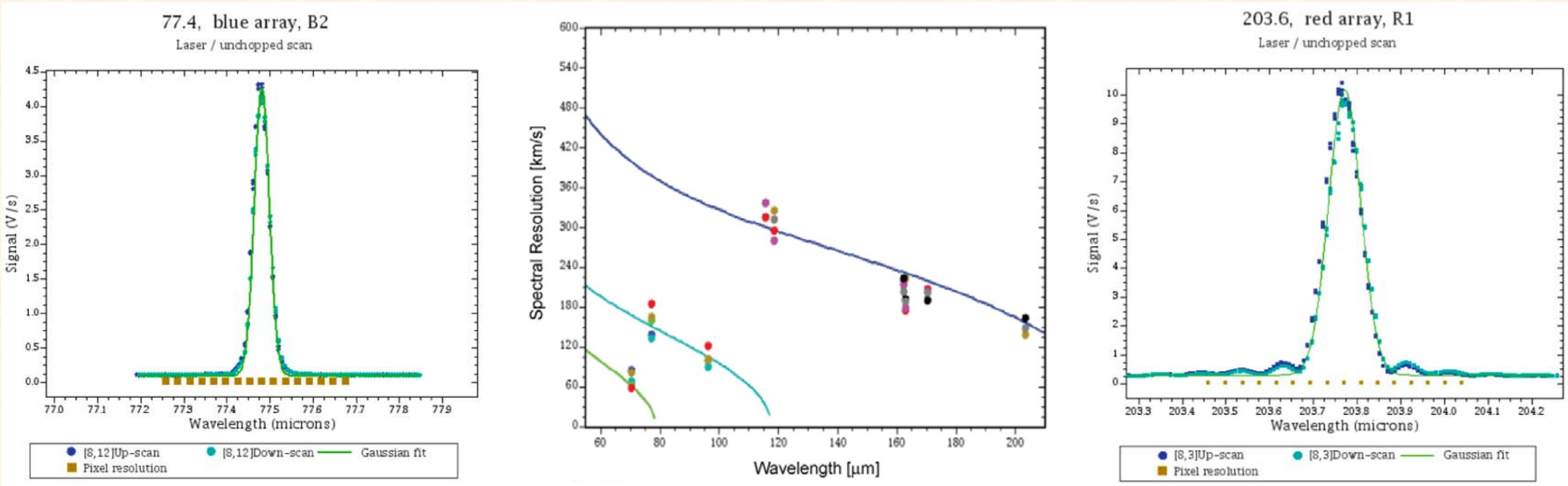

Center positions red/blue vs. chopper angle




Spatial positions of all spectral pixels (blue)

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

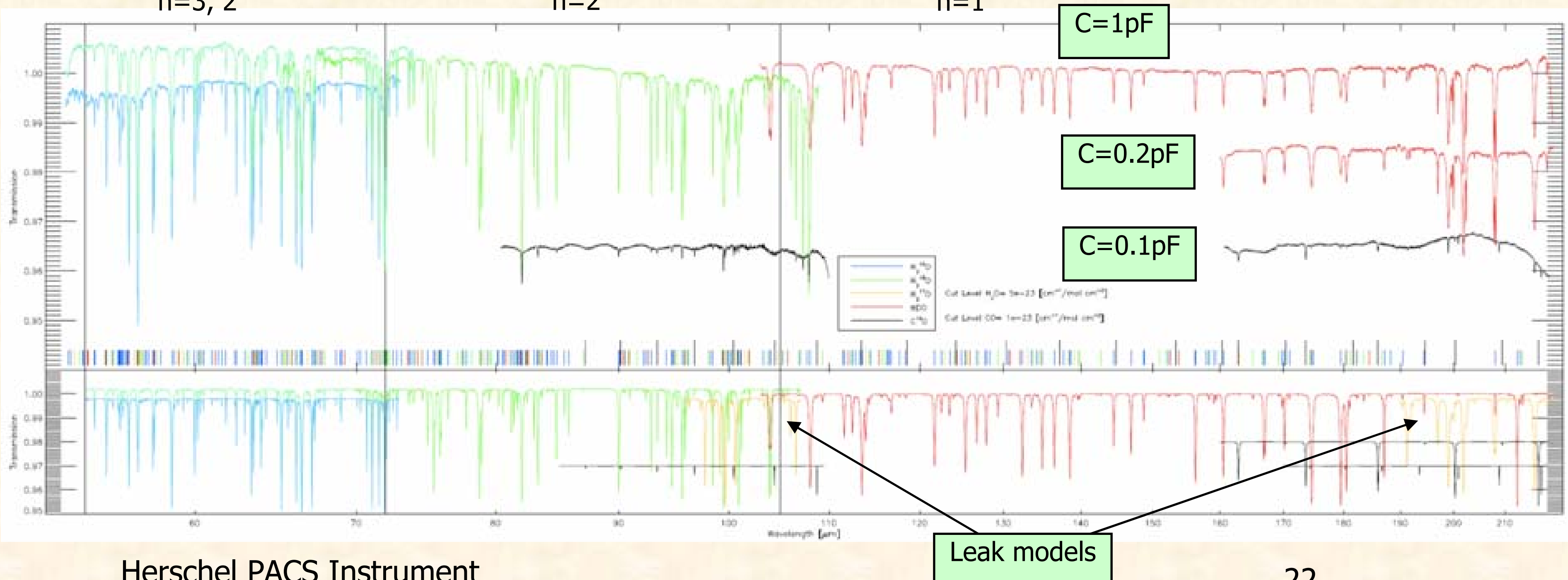
# Spectrometer Resolution




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

# Spectrometer Spectral Calibration

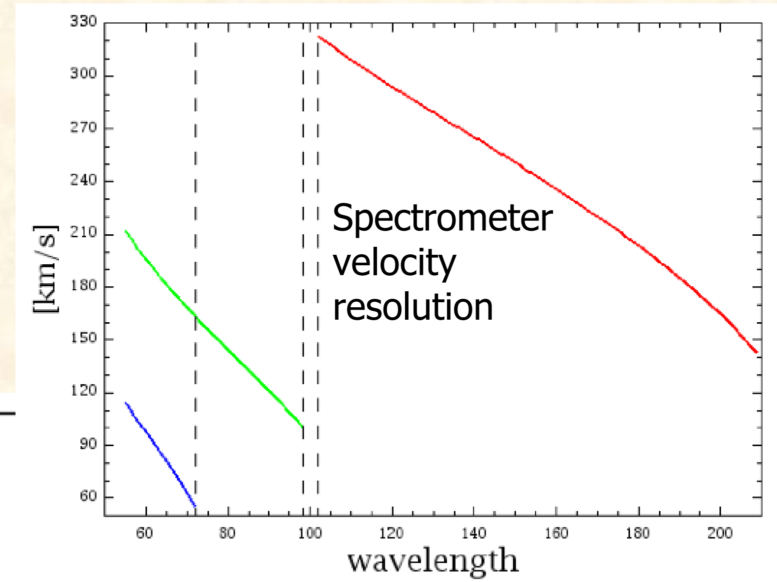

- FIR laser, H20 + CO (absorption cell)
- Requirement “peak position to within 10-20% of a spectral resolution element” fulfilled (Littrow + pixel correction terms)

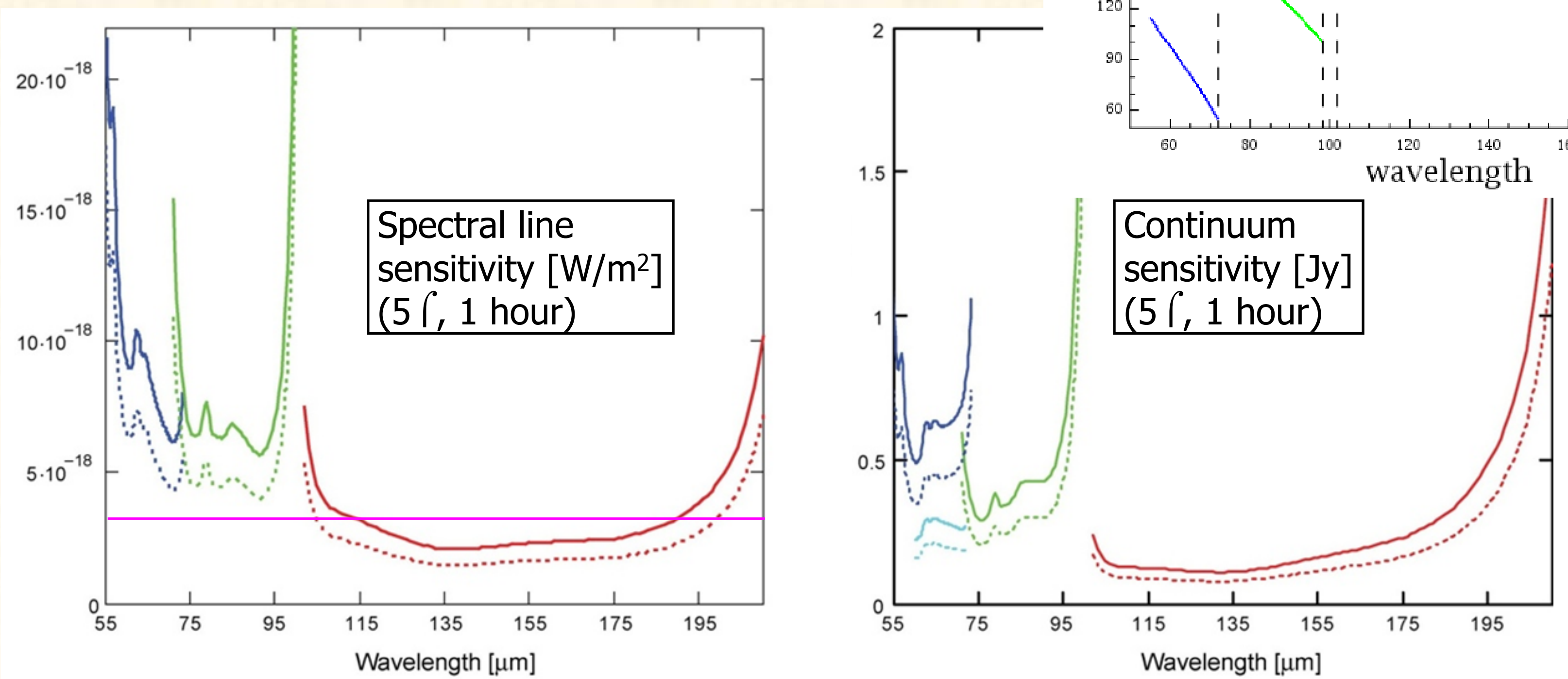


# Predicted Spectrometer Sensitivity

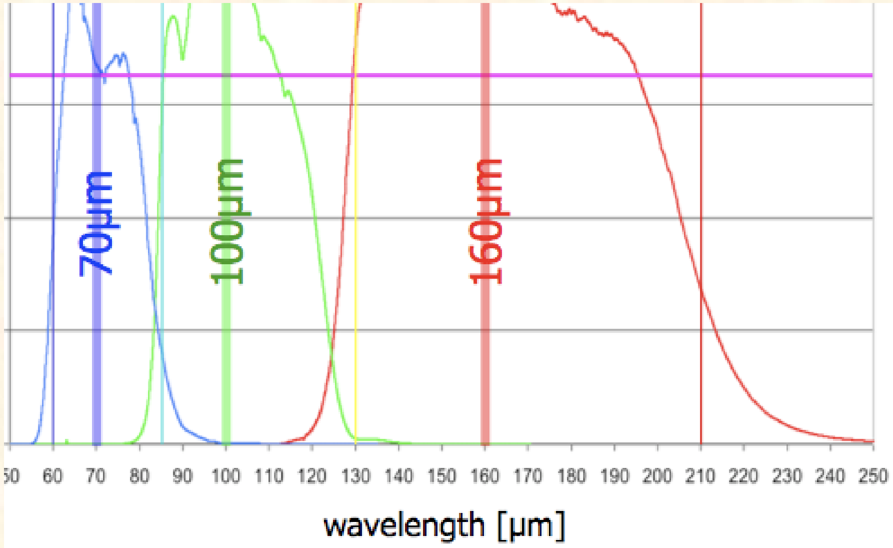
- Proposal sensitivity partly achieved

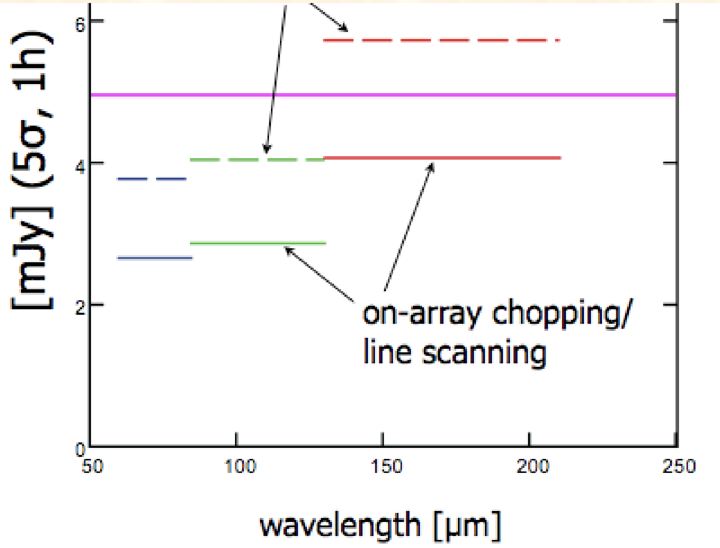
...but cosmic rays!



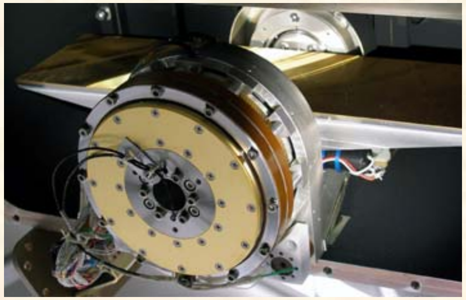
# Predicted Photometer Sensitivity

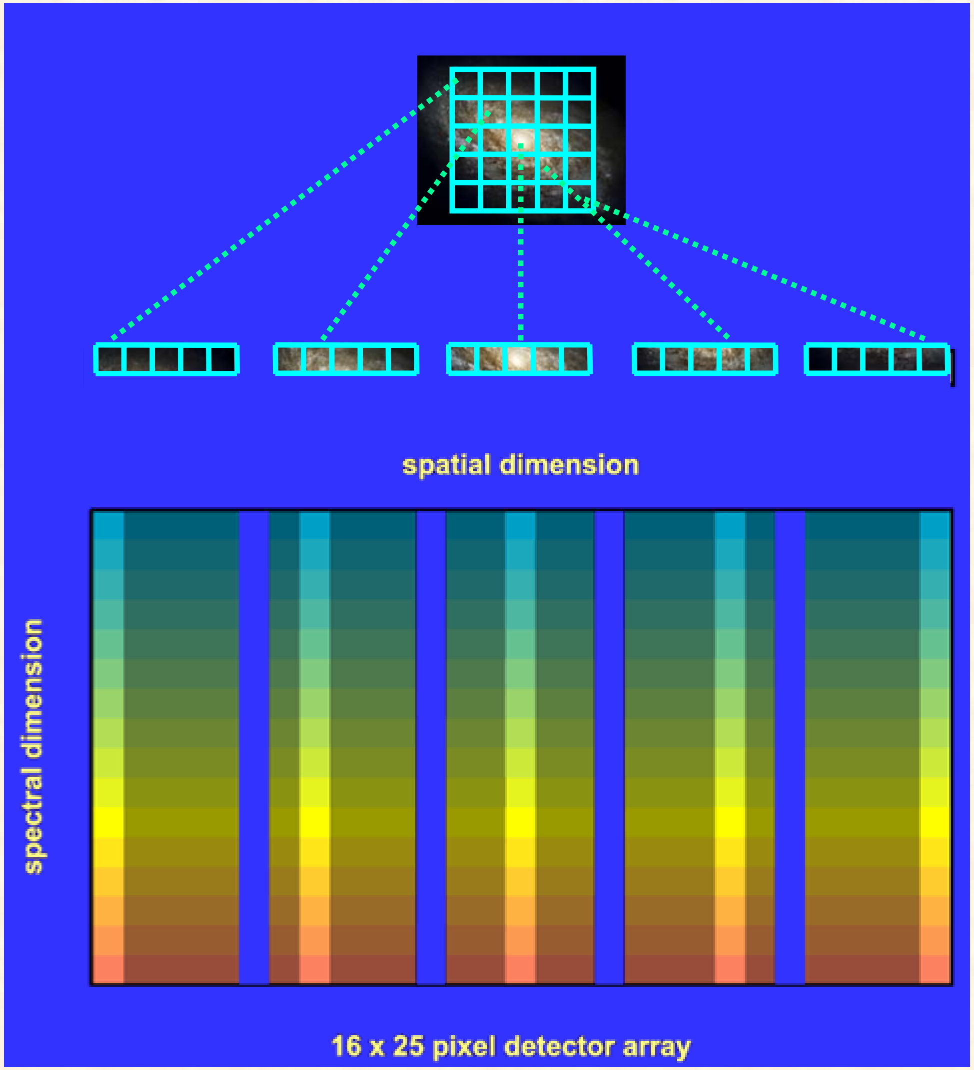



- Point source sensitivity equivalent to mapping speed of ~10′ x 10′ in 1 day

# Spectrometer Observing Modes



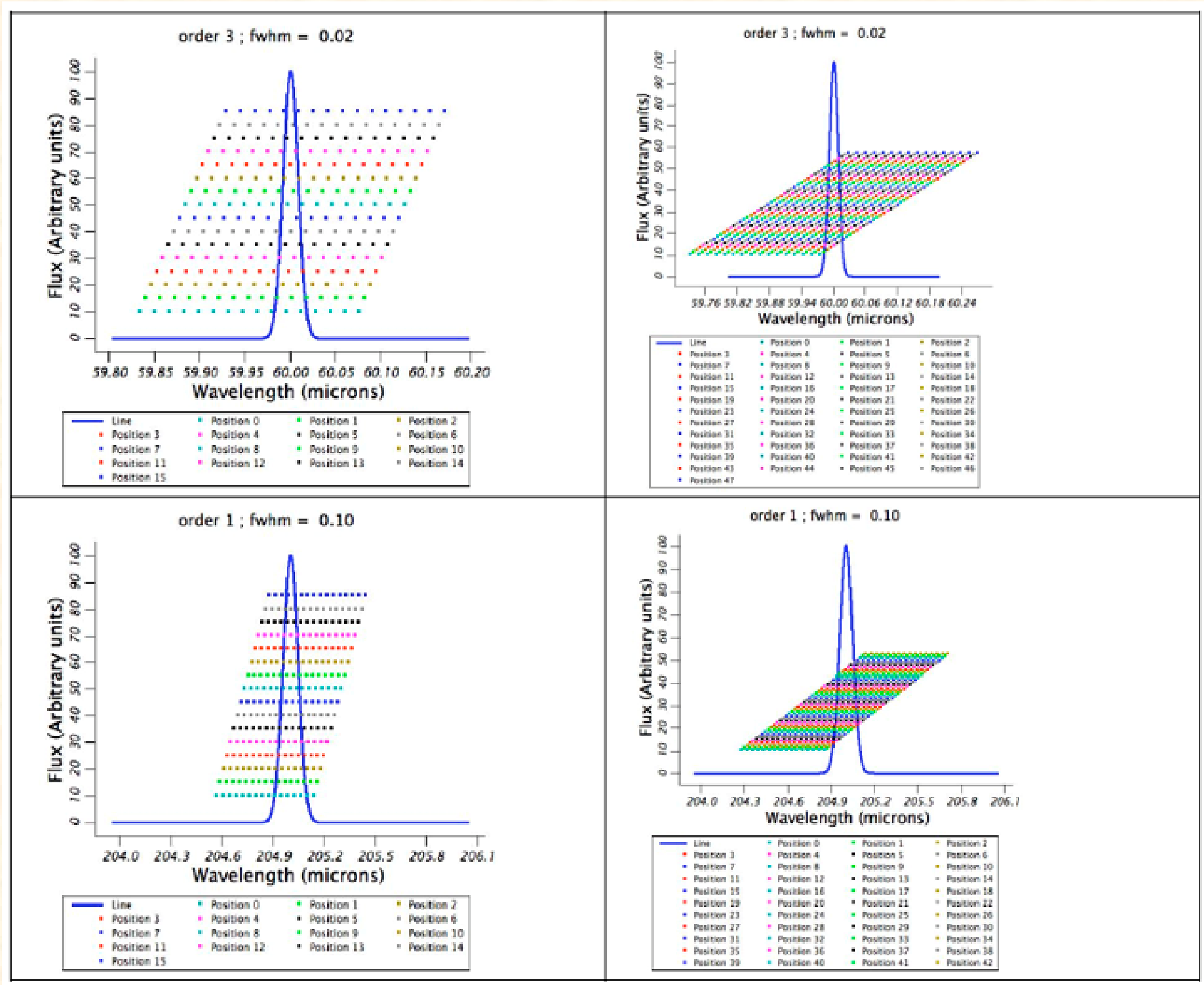



- **Line Spectroscopy: observation of individual line(s)**
  - Chop/nod or wavelength switching
  - Staring or mapping
  - R ~ 1500

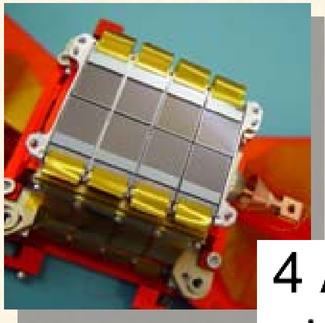
- **Range Spectroscopy: observation of extended range(s)**
  - Chop/nod or off position
  - Staring or mapping
  - SED mode

# Spectrometer Line Scan Schemes

"Bright Line" Mode

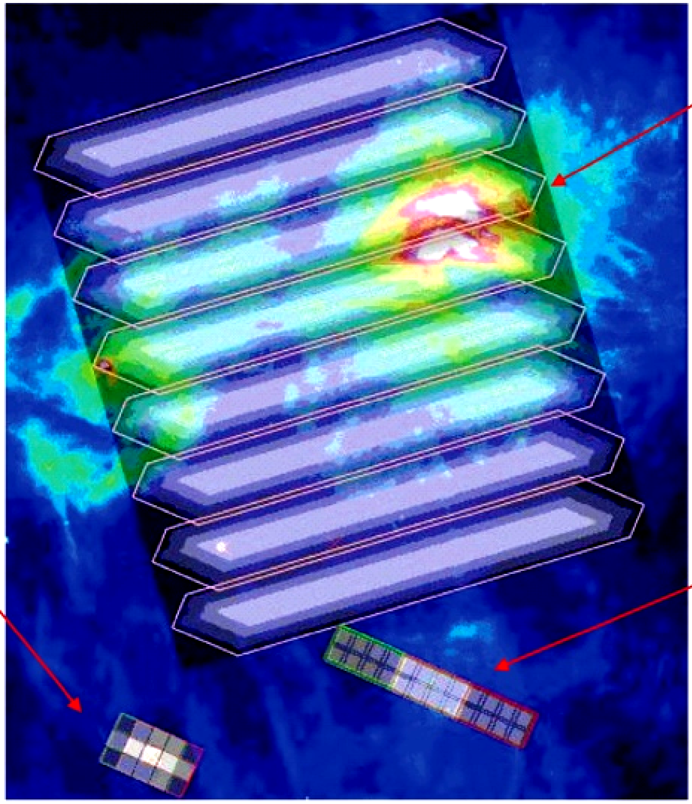



"Faint Line" Mode



# Photometer Observing Modes

4 AOTs in photometry channel



**Extended source Mapping:**

Options are Scan (shown) or chopped Raster

Maximum size 4-deg

3 scan speeds or fixed chopping

**Point source photometry:**

4-positions

2 chop/nod cycles

Repeat basic cycle to gain more sensitivity

**Small source photometry:**

Small 2x2 raster

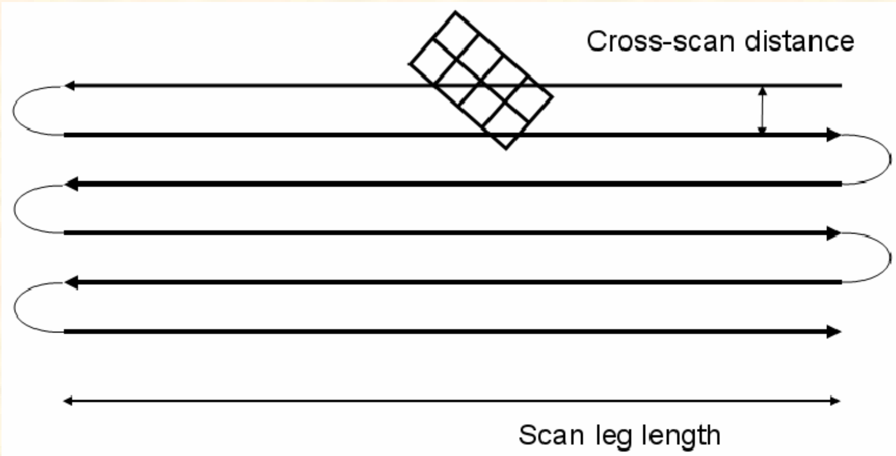
200"x100" FOV

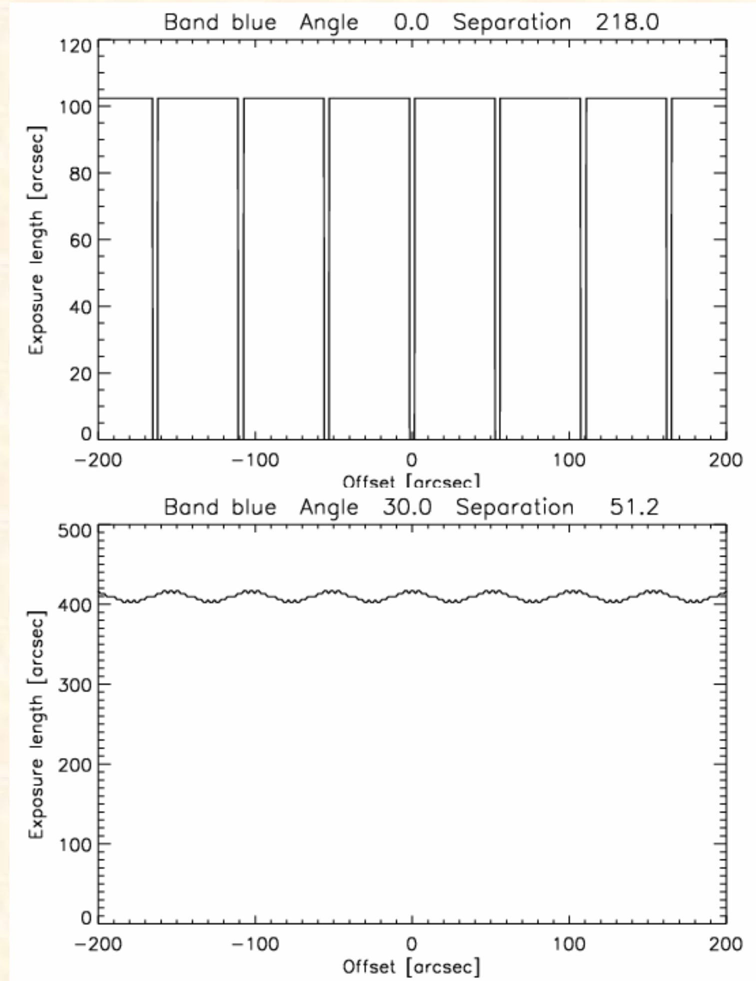
Dither to cover inter-matrix gaps

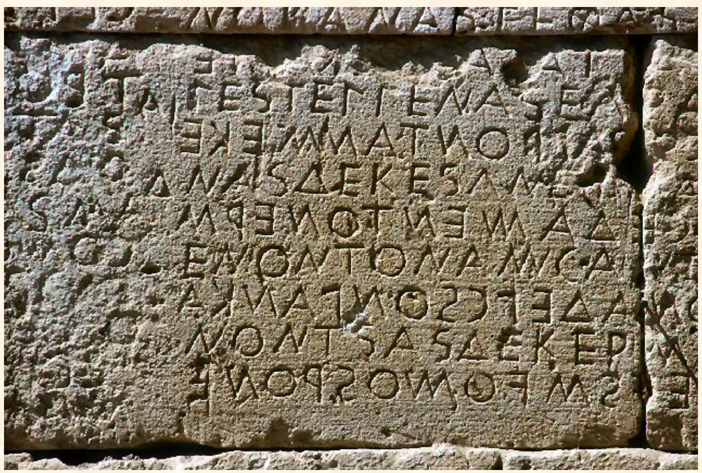
**Dual Band:** 70+160 µm

**or** 100+160 µm

# Remarks on Scan Map



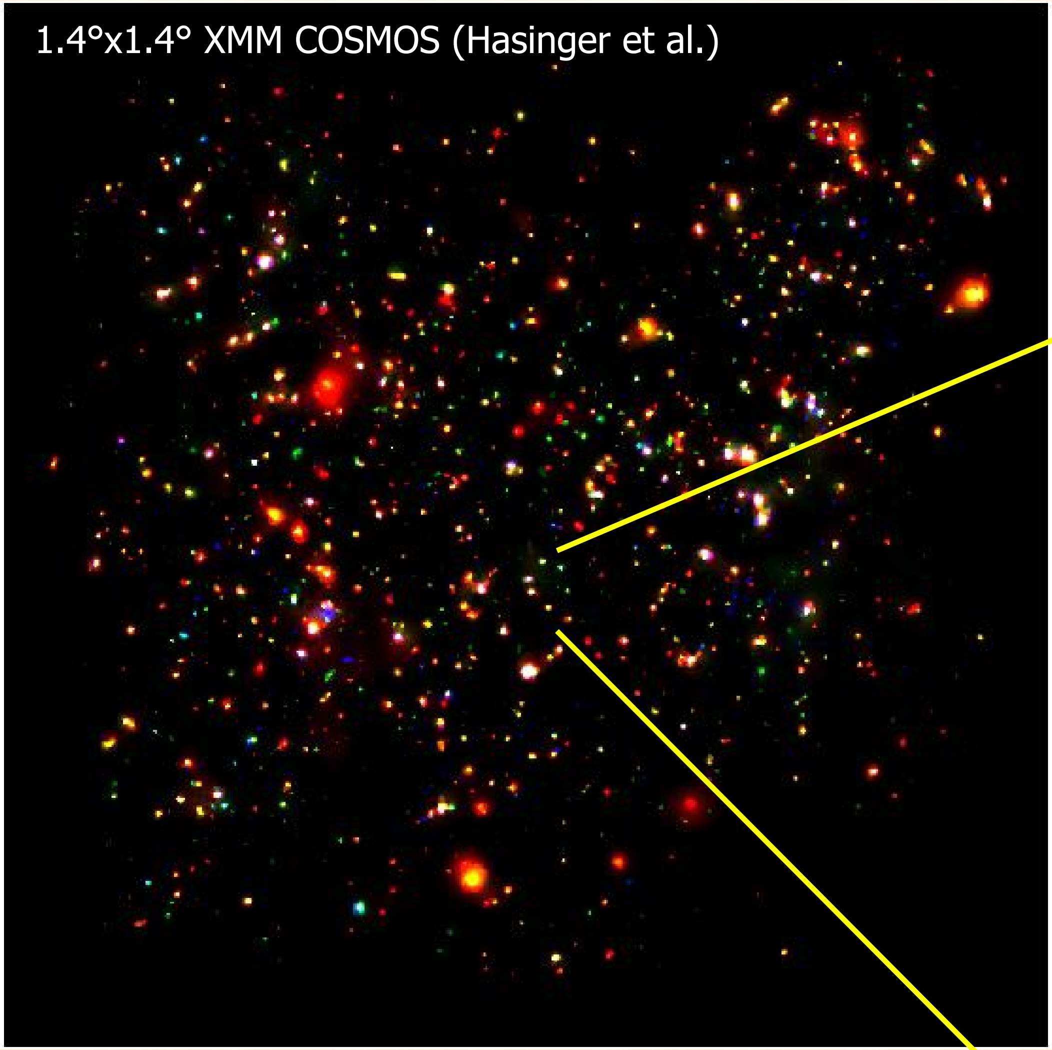
βουστροφηδόν

Herschel PACS Instrument

# Sneak preview (SPIE 2010) …

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

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




Herschel PACS Instrument

Simulated deep PACS sub-field survey