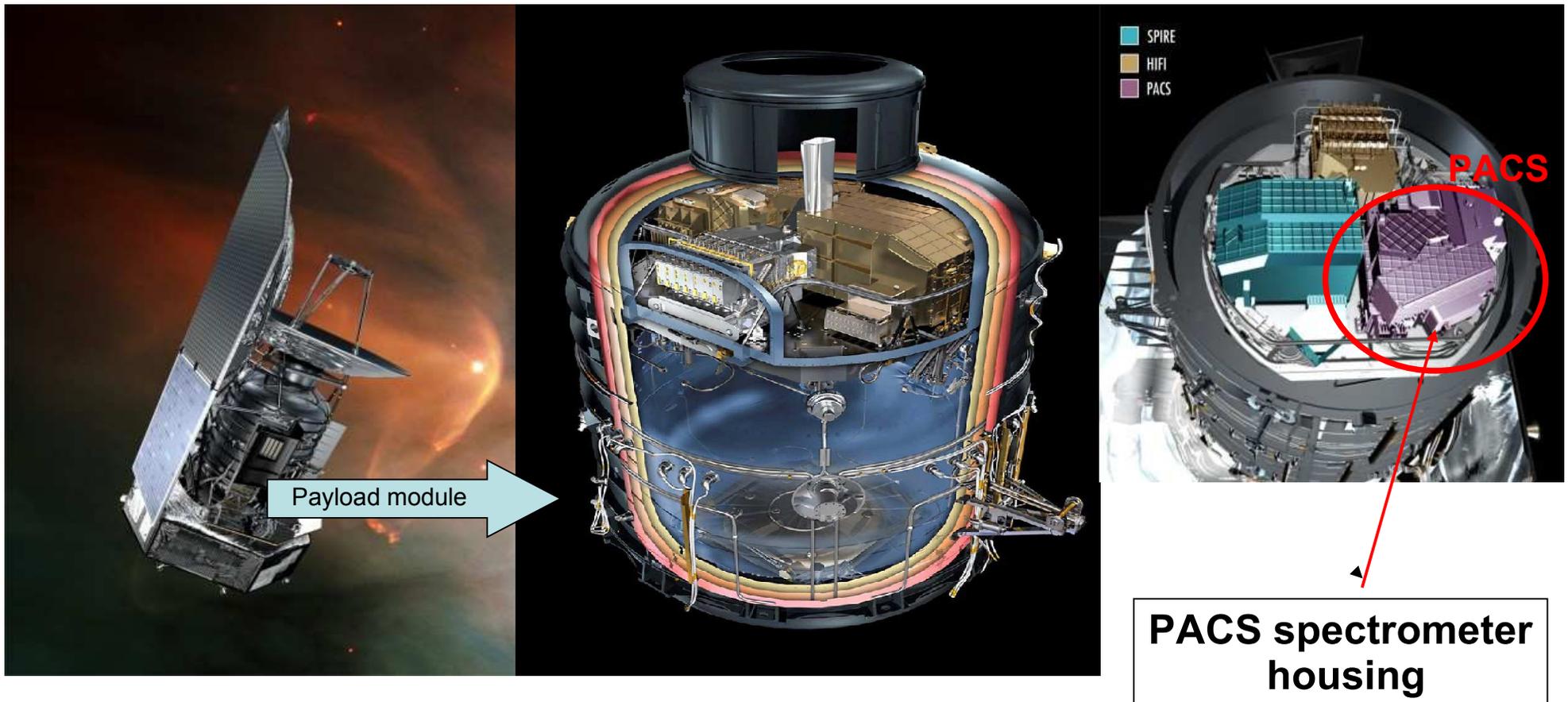


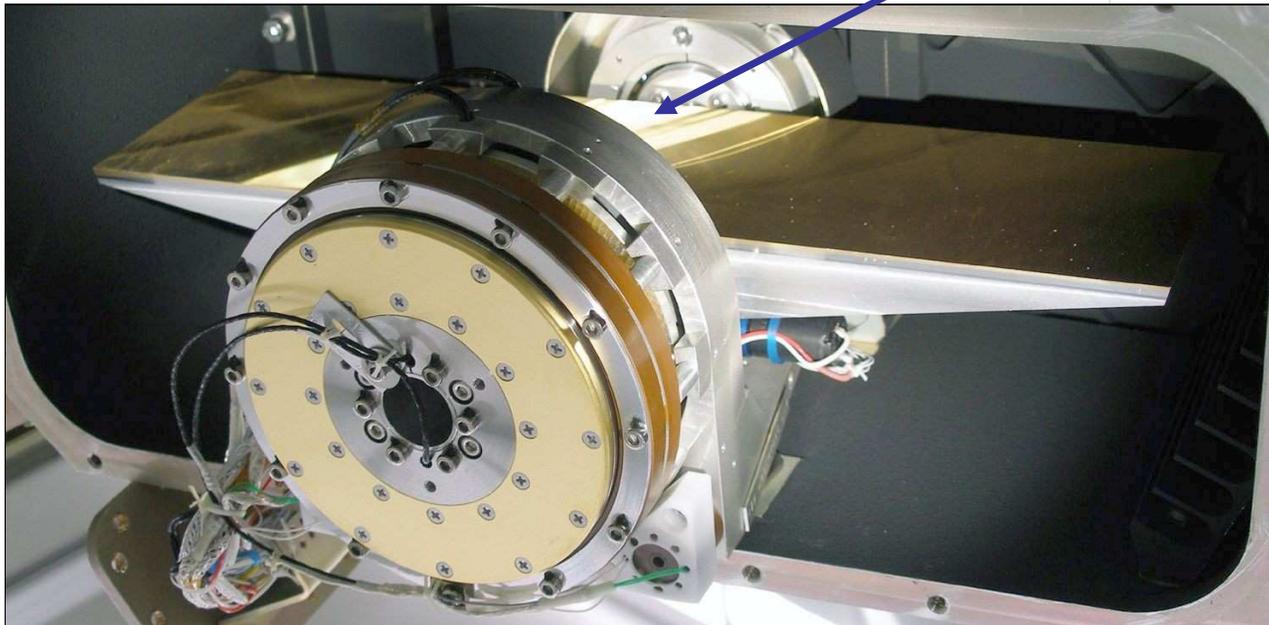
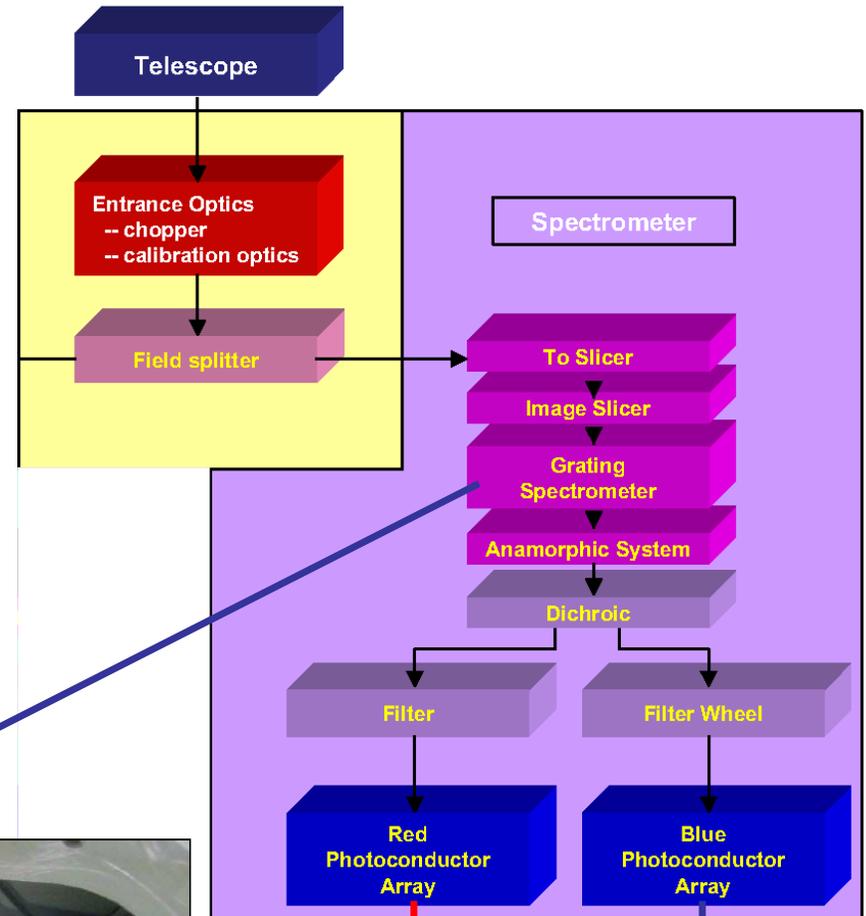
# *PACS Spectrometer*



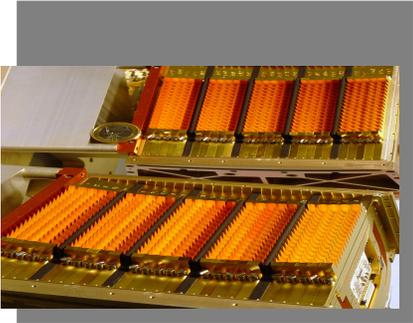
Instrument, AOTs, Observing Modes  
R. Vavrek and the PACS ICC

# Diffraction grating spectrometer with high- and low-stressed Ge:Ga detector arrays

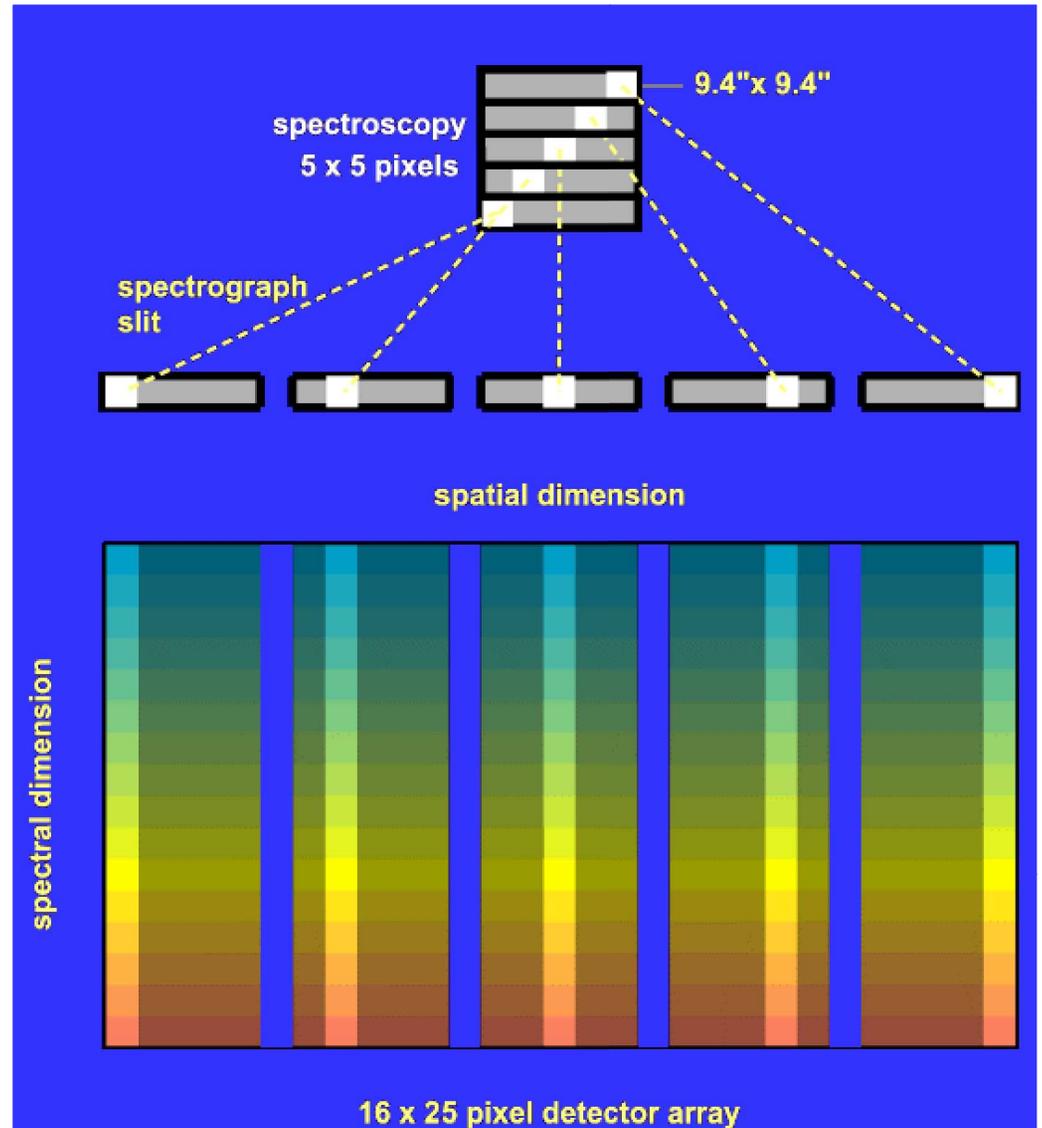
Grating: diffraction element used in 3 orders



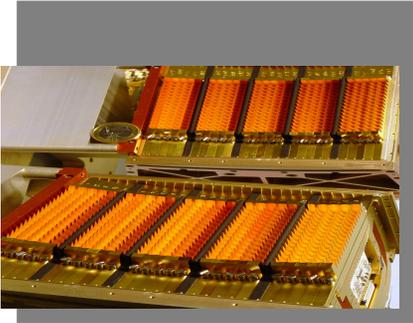
# *Integral-field concept*



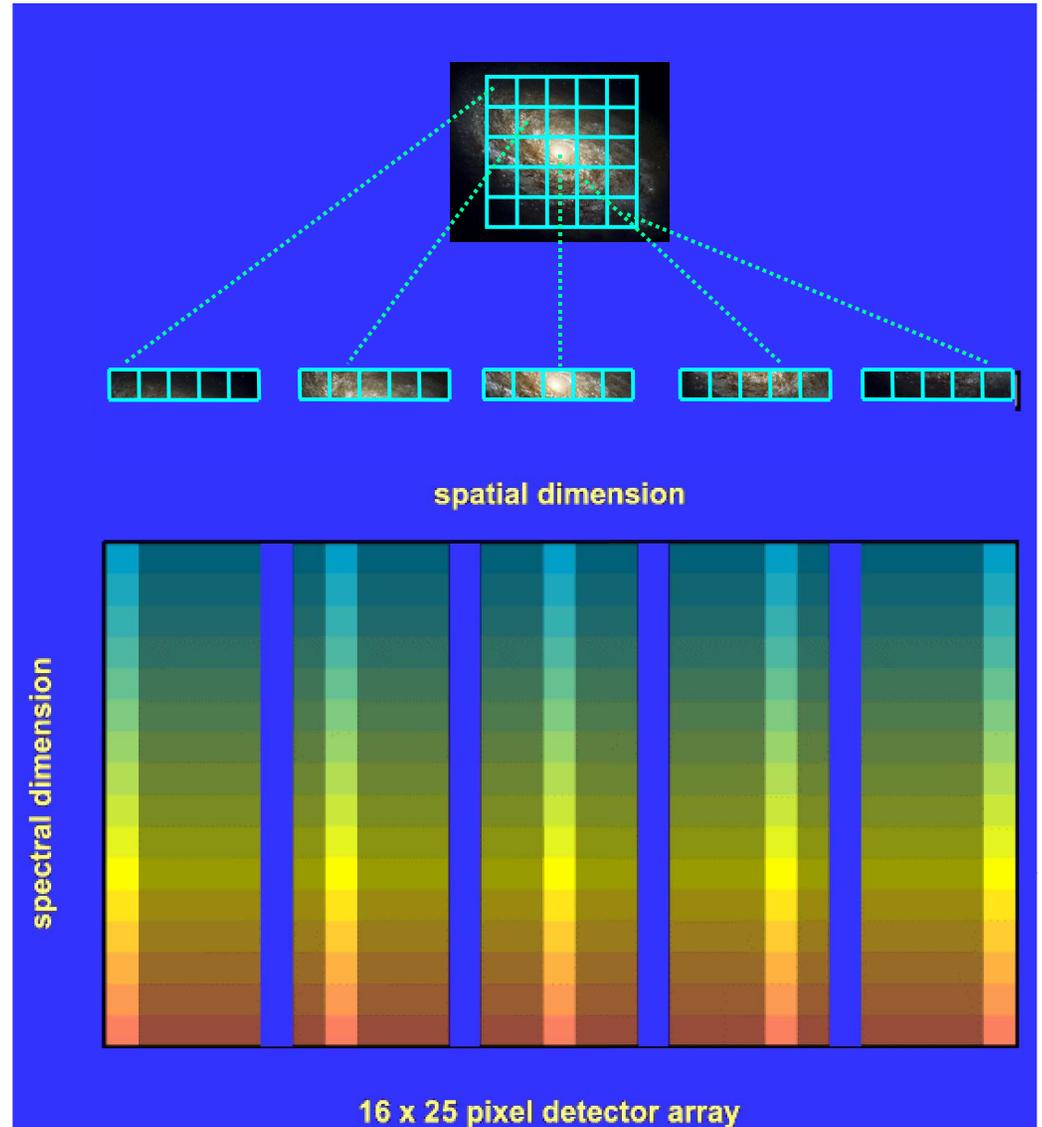
**47"x47" (5x5 pixels) FOV  
rearranged via an image  
slicer on two 16x25  
detector arrays**



# *Integral-field concept*



- ☀ **Simultaneous 55-98 & 102-210  $\mu\text{m}$  spectroscopy**
- ☀ **Performance:**
  - $\lambda/\Delta\lambda \sim 1500$
  - **Sensitivity:**  $\sim 5 \times 10^{-18}$  W/m<sup>2</sup> ( $5\sigma$ , 1h)

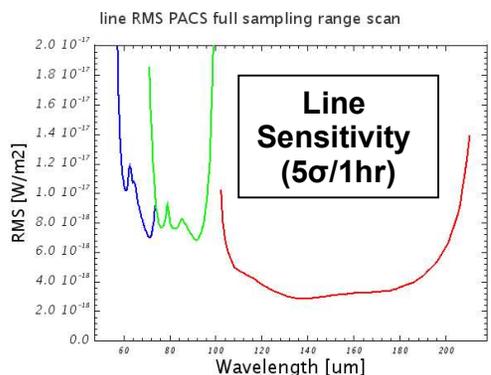
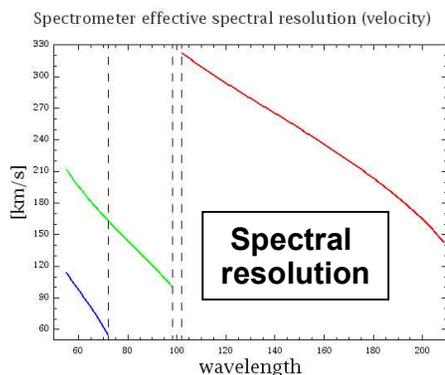
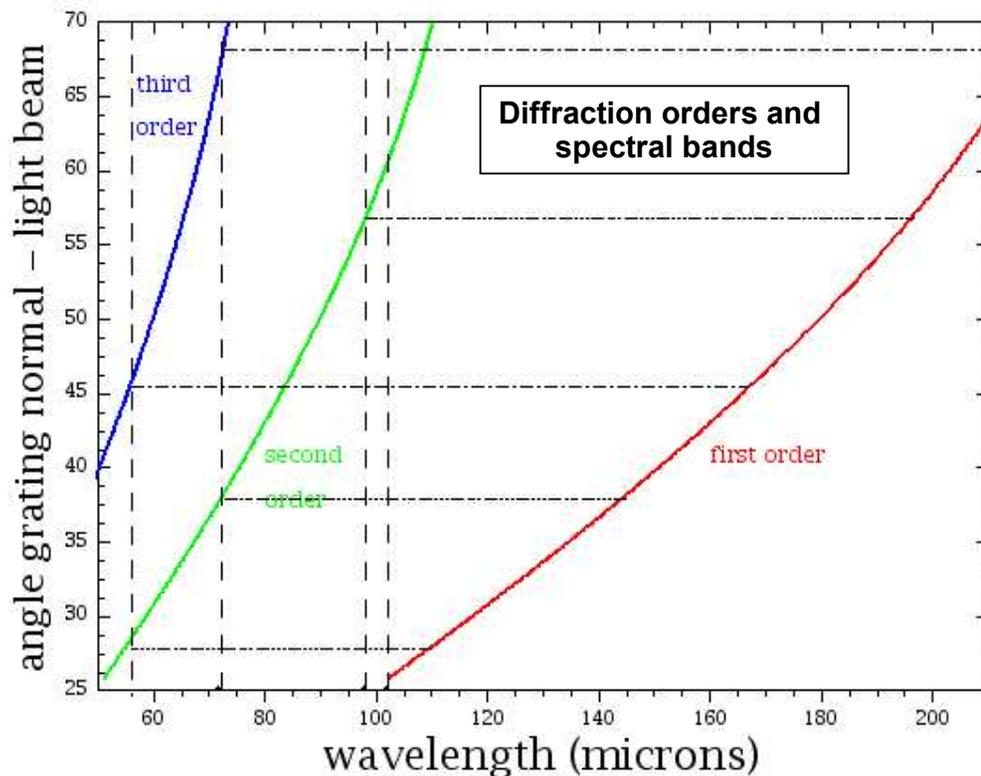


# ***PACS presents: Death of Photon***



# PACS spectral bands

Grating angle – wavelength relation in Littrow configuration

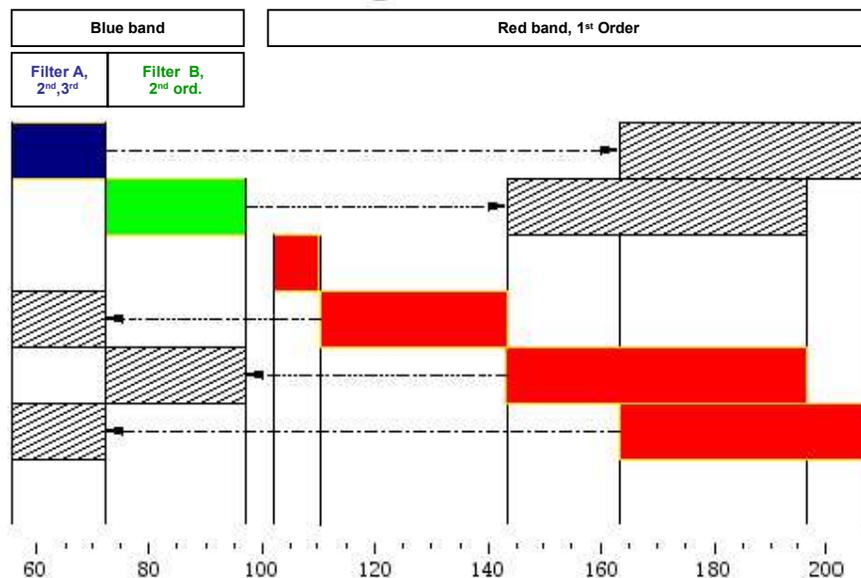
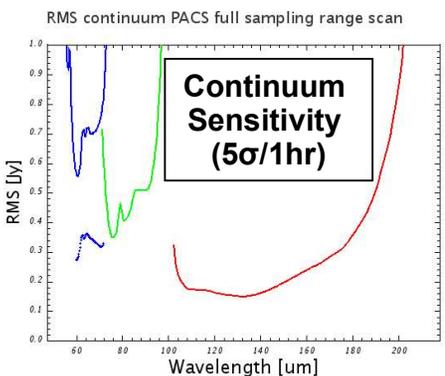


**Nominal bands and parallel data**

**In Littrow grating configuration:**

$$m\lambda = \text{const.}$$

**for a given grating angle, m=1,2,3 (orders)**



# Spectrometer Astronomical Observing Templates (AOTs)

## ☀ Line Spectroscopy AOT: observation of individual narrow lines:

Signal modulation  
Techniques

### Chopping/nodding

- Pointed, dithered and mapping modes
- For isolated sources and rasters  $\leq 6$  arcmin
- Variable grating sampling for faint and bright lines

### - Wavelength switching

- For mapping observations of crowded fields
- Mandatory off-position

## ☀ Range Spectroscopy AOT: observation of extended ranges, broad lines or continuum

Range  
definition

- **Range scan** (same concept as Line Spectroscopy) *for broad lines*
- **SED mode** (1<sup>st</sup> and 2<sup>nd</sup> orders [71-98, 102-210  $\mu\text{m}$ ] or 3<sup>rd</sup> order [55-73  $\mu\text{m}$ ]) *for continuum*
- **SED blue sensitive mode** (extended 2<sup>nd</sup> order [60-73  $\mu\text{m}$ ]) *for continuum*
- **Nyquist sampling** same as SED mode for restricted ranges *for continuum and bright lines*

### - Chopping/nodding

- Pointed, dithered and mapping modes
- For isolated sources and rasters  $\leq 6$  arcmin
- For broad lines, multiple line coverage or continuum studies

Signal modulation  
Techniques

### - Off-position

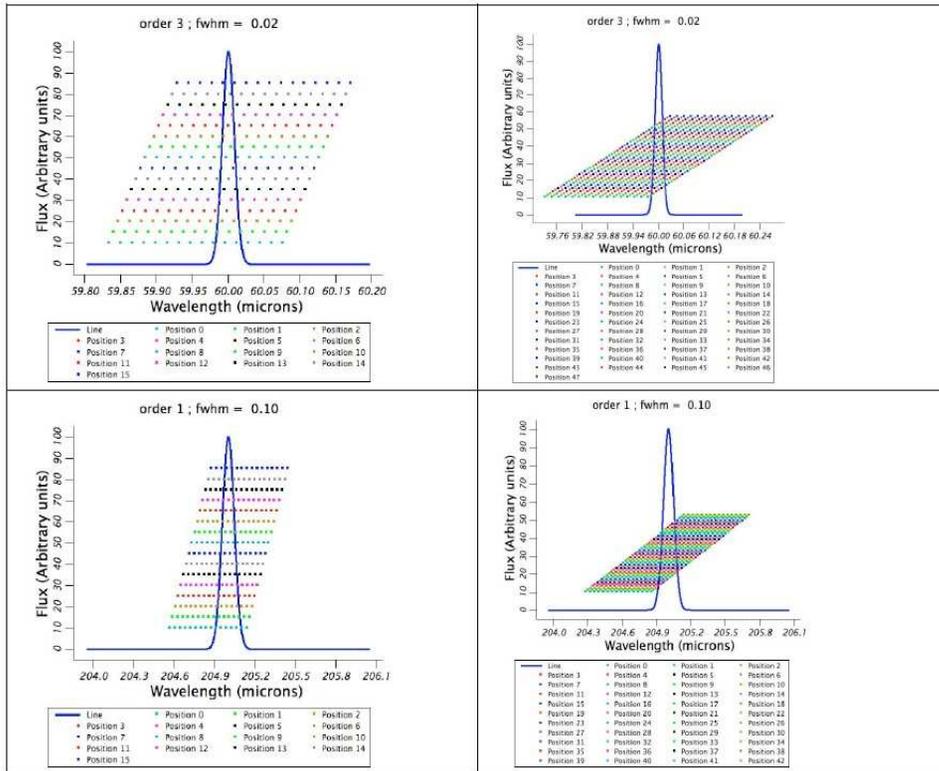
- For mapping observations of crowded fields

# Observing modes

## Spectroscopy AOT concept

☀ Signal modulation is required to compensate for transient effects due to instantaneous response changes (IRCs) of glitch affected detectors and measure differential signal on **high telescope background**

### Chopping/nodding



### Chopping/nodding

- Diffraction order dependent parameters (grating step size and number of steps)
- Bright lines option applies the same grating step size but fewer steps

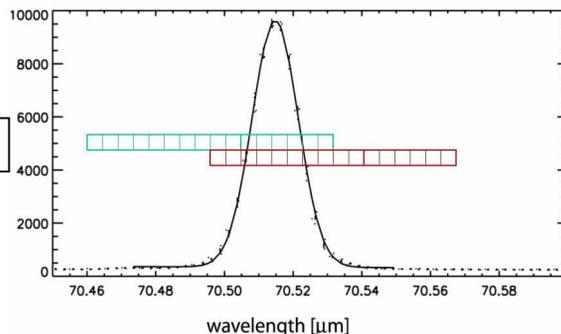
### Wavelength switching

- Applicable only for narrow lines when the full line profile is always on-array
- Off-position is required to compensate for detector memory effects

### Off-position

- Not a very well defined mode, timescales are significantly longer (*option only for range scan mapping*)

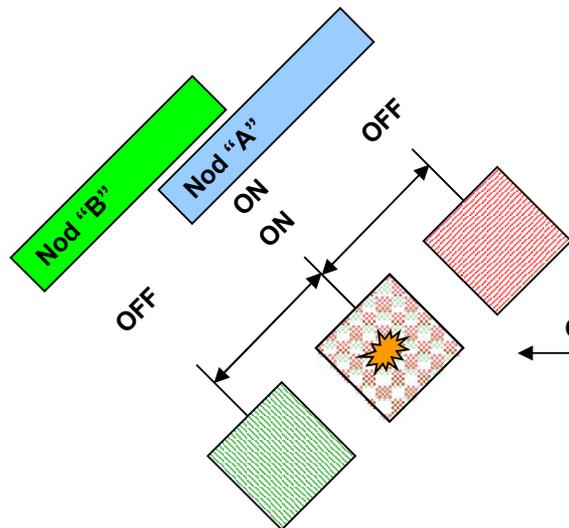
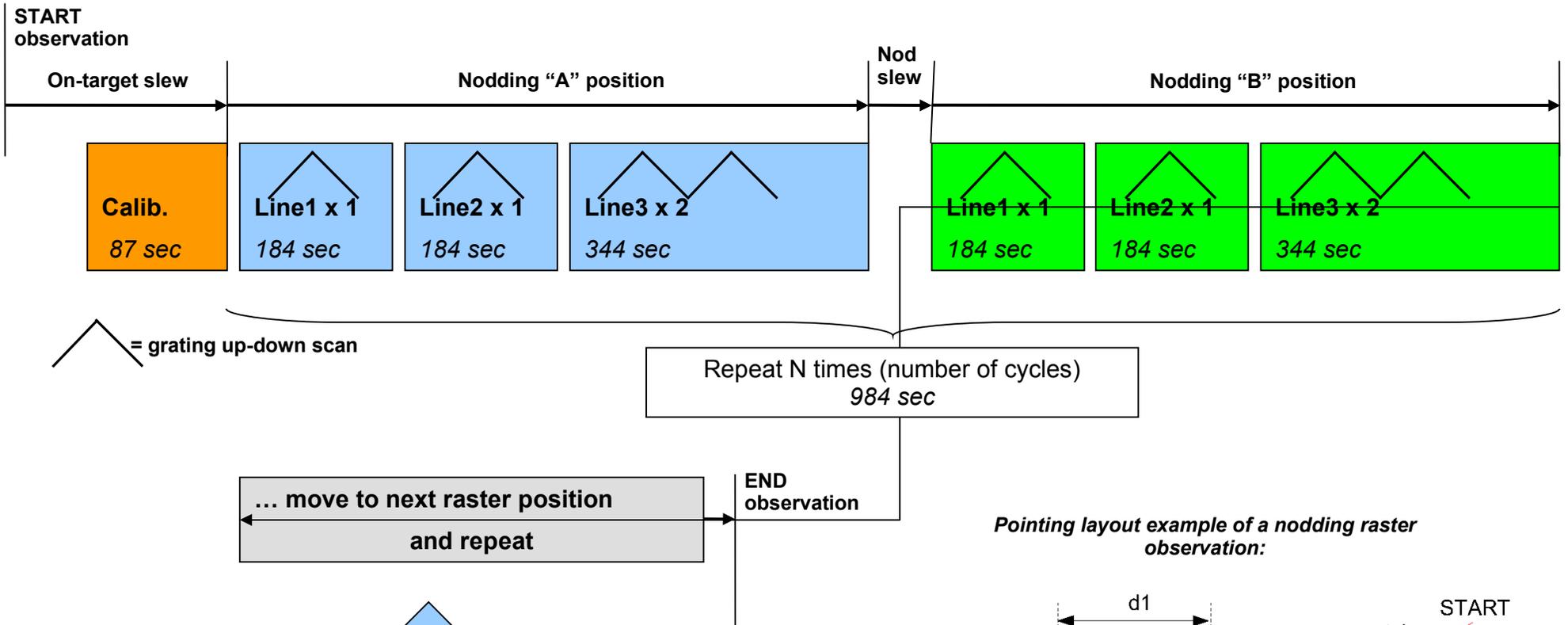
### Wavelength switching



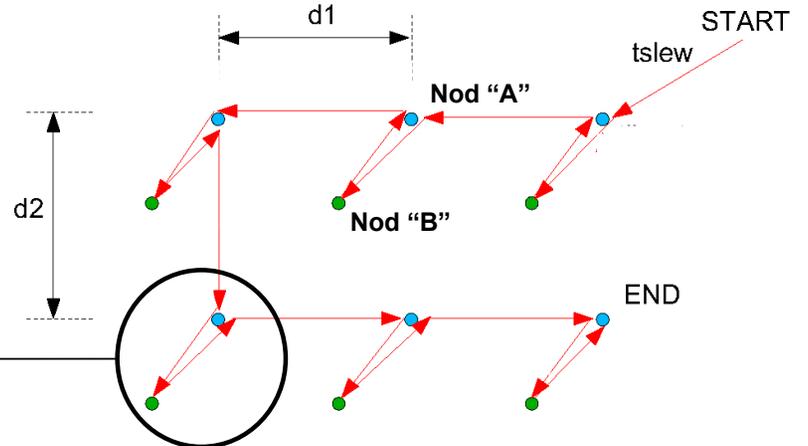
☀ Range scan is an extension of the Line Spec. concept

- The high sampling density mode applies the same grating sampling as the Line Spectroscopy AOT (*Nyquist sampling of a resolution element*)
- SED mode and Nyquist sampling apply the same sampling density (*Nyquist sampling with the 16 pixels instantaneous coverage*)

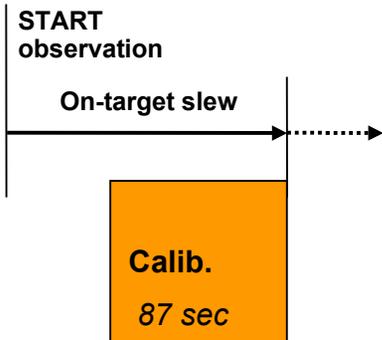
# AOT blocks



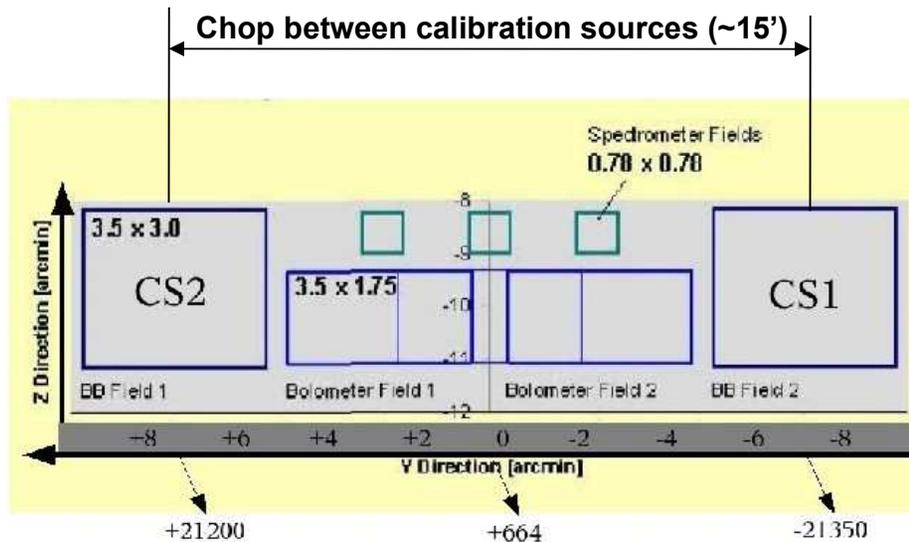
*Pointing layout example of a nodding raster observation:*



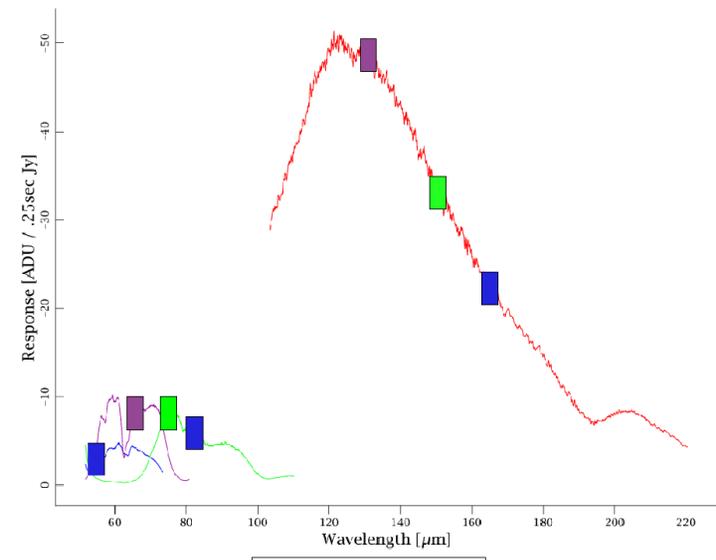
# AOT calibration block



- \* On-target slew calibration block(s) on key wavelengths
- \* Calibrate the response on one point of the RSRF, we believe the RSRF does not change (a lot) over the mission lifetime
- \* Chopping between the calibration sources and grating up/down scans
- \* Homogeneous dataset over the entire mission lifetime
- \* One key wavelength per diffraction order:
  - flat part of the RSRF
  - close to the most frequently used lines



Key wavelengths on the Relative Spectral Response Function (RSRF)



CS1 and CS2= Internal Calibration Sources 1 and 2

# ... and how blocks are defined in HSpot

Instrument blocks

Pointing blocks

PACS Line Editor

Target: NGC7027 Type: Fixed Single  
Position: 21h07m01.59s,+42d14m10.2s

Number of visible stars for the target: 23  
Star tracker target: RA: 136.757 degrees Dec: -42.236 degrees

Wavelength Settings  
Selection of wavelength ranges  
Wavelength ranges [73-98] and [103-210] microns (2nd + 1st orders)

Line Id	Wavelength (µm)	Redshifted Wav.	Line Flux	Line Flux Unit	Continuum Flux	Line Width	Line Width Unit	Line Repetition
Line 1	97.000	97.00	0.00	10 <sup>-18</sup> W/m <sup>2</sup> /0.00	0.00	km/s		1
Line 2	80.000	80.00	0.00	10 <sup>-18</sup> W/m <sup>2</sup> /0.00	0.00	km/s		1
Line 3	158.000	158.00	0.00	10 <sup>-18</sup> W/m <sup>2</sup> /0.00	0.00	km/s		2

Observing Mode Settings  
Nodding/wavelength switching cycles  
Number of cycles 2  
To control the absolute sensitivity consider to adjust the number of integration cycles

Observing Mode Settings  
Choose one of the modes below:

Observing mode selection  
 Chopping/nodding  
 Chopping/nodding (bright lines)  
 Wavelength switching

Observing mode parameters  
 Chopper throw:  Small  Medium  Large  
 Chopper avoidance angle: Angle from degrees 0.00, Angle to degrees 0.00  
 Off position:  By effect  By position  
 Raster Map:  Raster point step (arcsec) 20.0,  Raster line step (arcsec) 20.0  
 Orientation angle (degrees): 0.0, KA offset (arcmin): 0.0000  
 Number of raster points per line: 3, RA degrees: 0.0000  
 Number of raster lines: 2, Dec degrees: 0.0000

Herschel Observation Planning Tool - KP OT version

Observations: ISSA- 25 µm, ngc7027

Target: ngc7027 Type: Fixed Single  
Total Duration (hrs): 2.47  
Proposal: --No File-- Total AOBs: 2 / Active: 2

PACS Range Editor

Target: ngc7027 Type: Fixed Single  
Position: 21h07m01.70s,+42d14m11.0s

Number of visible stars for the target: 23  
Star tracker target: RA: 136.757 degrees Dec: -42.236 degrees

Wavelength Settings  
Range scan or SED mode  
Range mode Range scan in [55-73] and [102-210] microns (3rd + 1st orders)

Range ID	Blue Edge (µm)	Red Edge (µm)	Reference wav.	Line Flux	Line Flux Unit	Continuum Fl.	Line Width	Line Width Unit	Range Repet.
Range 1	55.00	73.00	55.00	0.00	10 <sup>-18</sup> W...	0.00	0.00	km/s	2
Range 2	102.00	210.00	210.00	0.00	10 <sup>-18</sup> W...	0.00	0.00	km/s	1

Observing Mode Settings  
Nodding or map repetition cycles  
Repetition 1  
To control the absolute sensitivity consider to adjust the number of integration cycles

Depth of the observation is set via repetition factors:

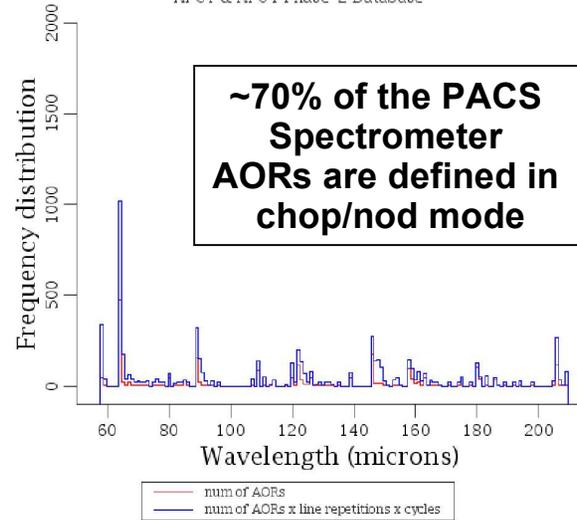
- Line/Range repetition for relative Line/Range strength, total number of repetitions is  $\leq 10$  to limit the maximum block duration
- Single repetition in SED mode block
- Nodding/switching/mapping cycles define how many times a block has to be repeated
- Overlap between pointing blocks (d1, d2 step size < 47")

# Spectroscopy observing modes

## Key Programs statistics

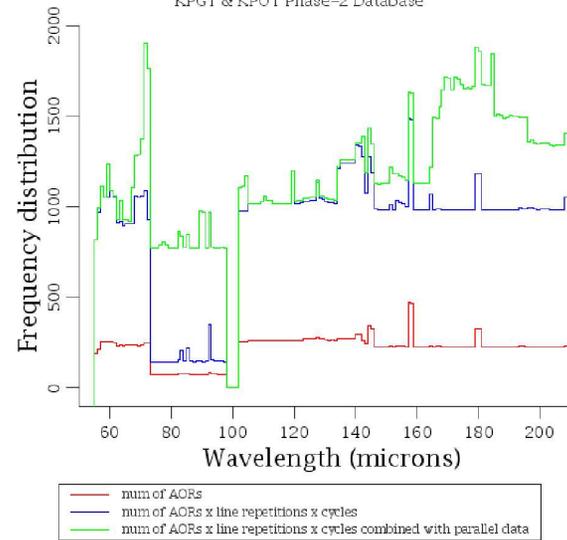
PacsLineSpec: Chop/Nod

KPGT & KPOT Phase-2 Database



PacsRangeSpec: Range+SED modes

KPGT & KPOT Phase-2 Database



PacsLineSpec: Wavelength switching

KPGT & KPOT Phase-2 Database

