PACS Calibration Strategy

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Herschel Space Observatory Calibration Workshop
Models & Observations of Astronomical Calibration Sources

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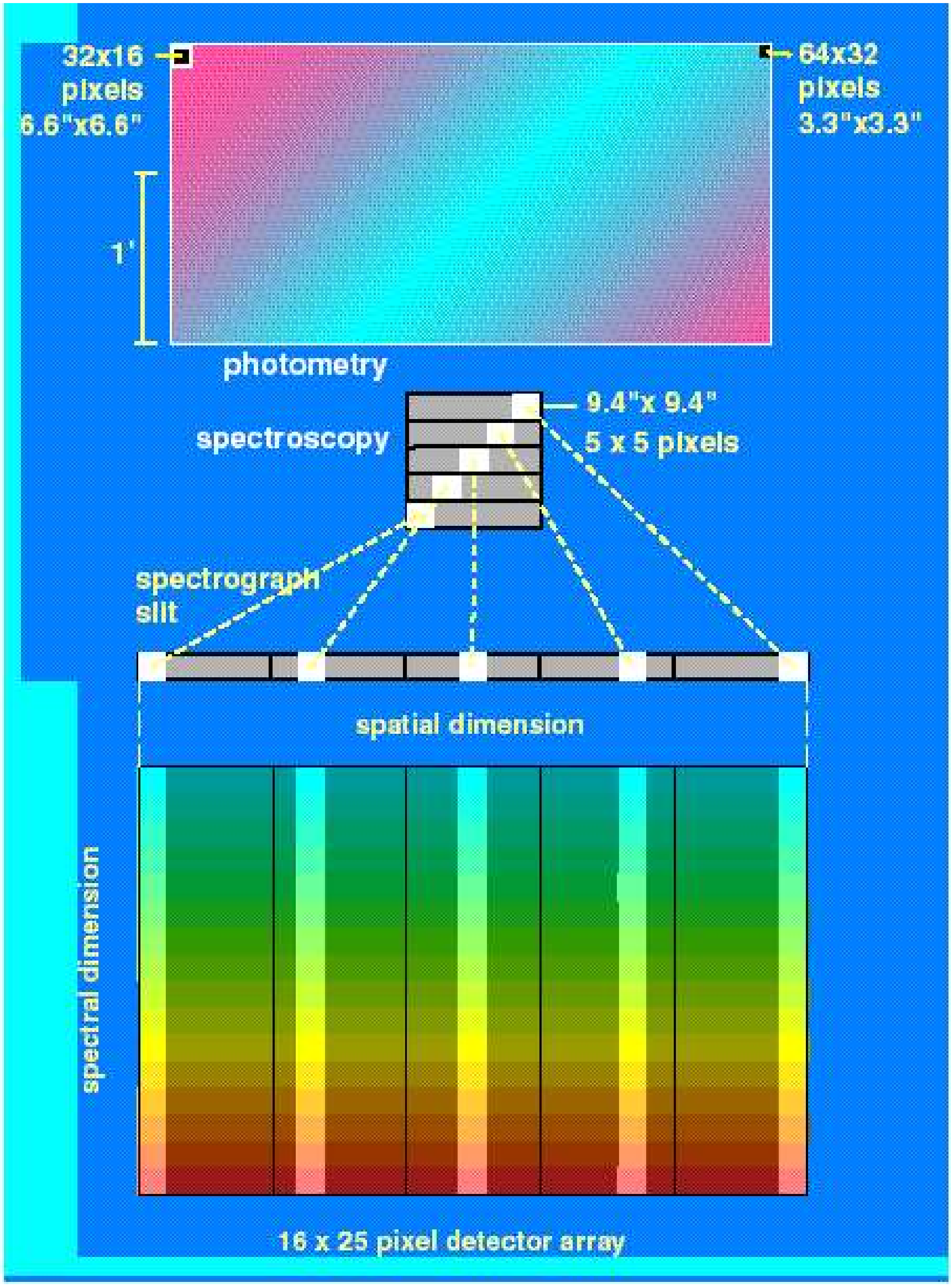
PACS =

Photodetector Array Camera & Spectrometer

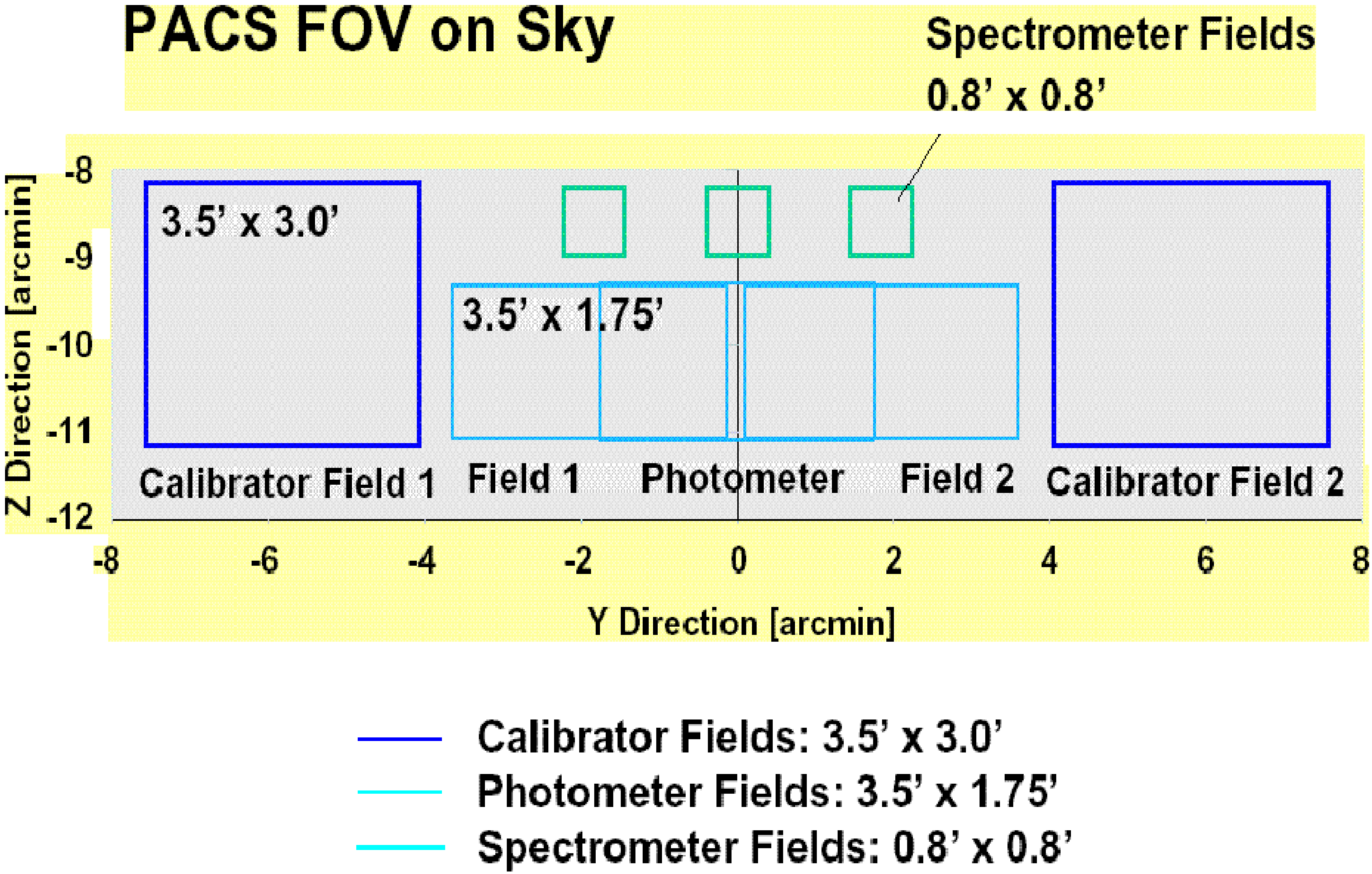
- **Large FIR arrays:**
  32 × 64 pixels (blue) & 16 × 32 pixels (red) Si bolometer arrays

- **FIR Integral-Field Spectrometer**
  5 × 5 spatial pixels onto 16 × 25 pixels Ge:Ga photoconductor arrays

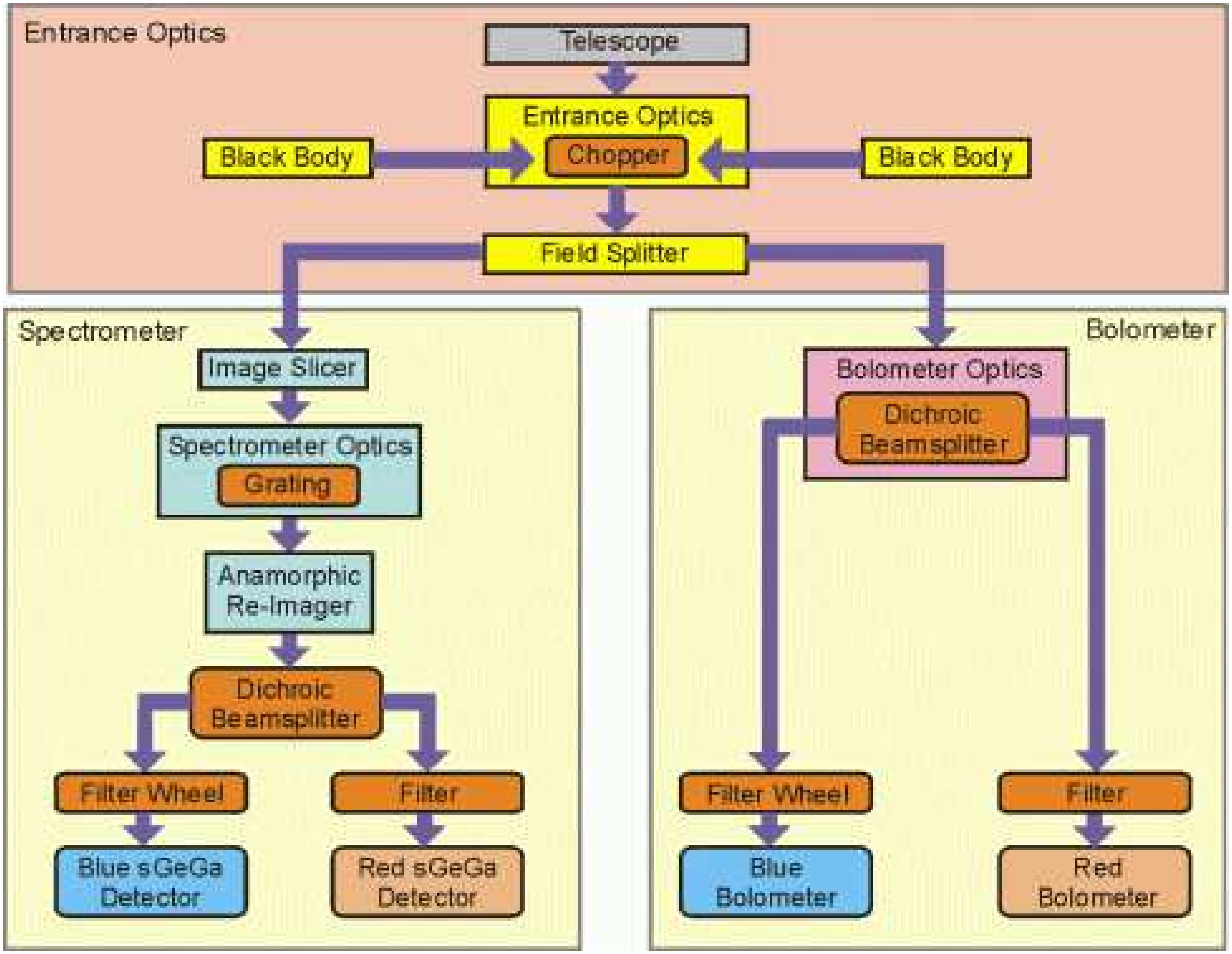
- **Spatial resolution at least a factor of 4 better than all past and current FIR facilities**



32x16
pixels
6.6"x6.6"
64x32
pixels
3.3"x3.3"
1'
photometry
spectroscopy
9.4"x 9.4"
5 x 5 pixels
spectrograph
slit
spatial dimension
spectral dimension
16 x 25 pixel detector array



PACS FOV on Sky
Spectrometer Fields
0.8' x 0.8'
3.5' x 3.0'
3.5' x 1.75'
Calibrator Field 1
Field 1
Photometer
Field 2
Calibrator Field 2
Z Direction [arcmin]
-8
-9
-10
-11
-12
-8
-6
-4
-2
0
2
4
6
8
Y Direction [arcmin]
Calibrator Fields: 3.5' x 3.0'
Photometer Fields: 3.5' x 1.75'
Spectrometer Fields: 0.8' x 0.8'


Entrance Optics
Telescope
Entrance Optics
Chopper
Black Body
Black Body
Field Splitter
Spectrometer
Image Slicer
Spectrometer Optics
Grating
Anamorphic Re-Imager
Dichroic Beamsplitter
Filter Wheel
Filter
Blue sGeGa Detector
Red sGeGa Detector
Bolometer
Bolometer Optics
Dichroic Beamsplitter
Filter Wheel
Filter
Blue Bolometer
Red Bolometer

Photometric Calibration Strategies

Calibration of faint fluxes

- **Unprecedented sensitivity: $2 - 5\,\mathrm{mJy}$, $5\,\sigma$ in 1 h**

- **Passively cooled telescope produces background corresponding to $\approx 1000\,\mathrm{Jy} \Rightarrow$ source-to-background contrast 10^{-6}**
  i.e. dynamic range in flux small (usually factor 2)
  but high linearity of signal or characterization of non-linearity needed.

- **Differential measurements: $2 - 3$ position chopping + telescope nodding**
  $\Rightarrow$ need to assess chopper offset + offset by confusion

need of calibration standards with fluxes down to sensitivity limit
need of faint calibration standards in cosmological fields to verify impact of confusion noise

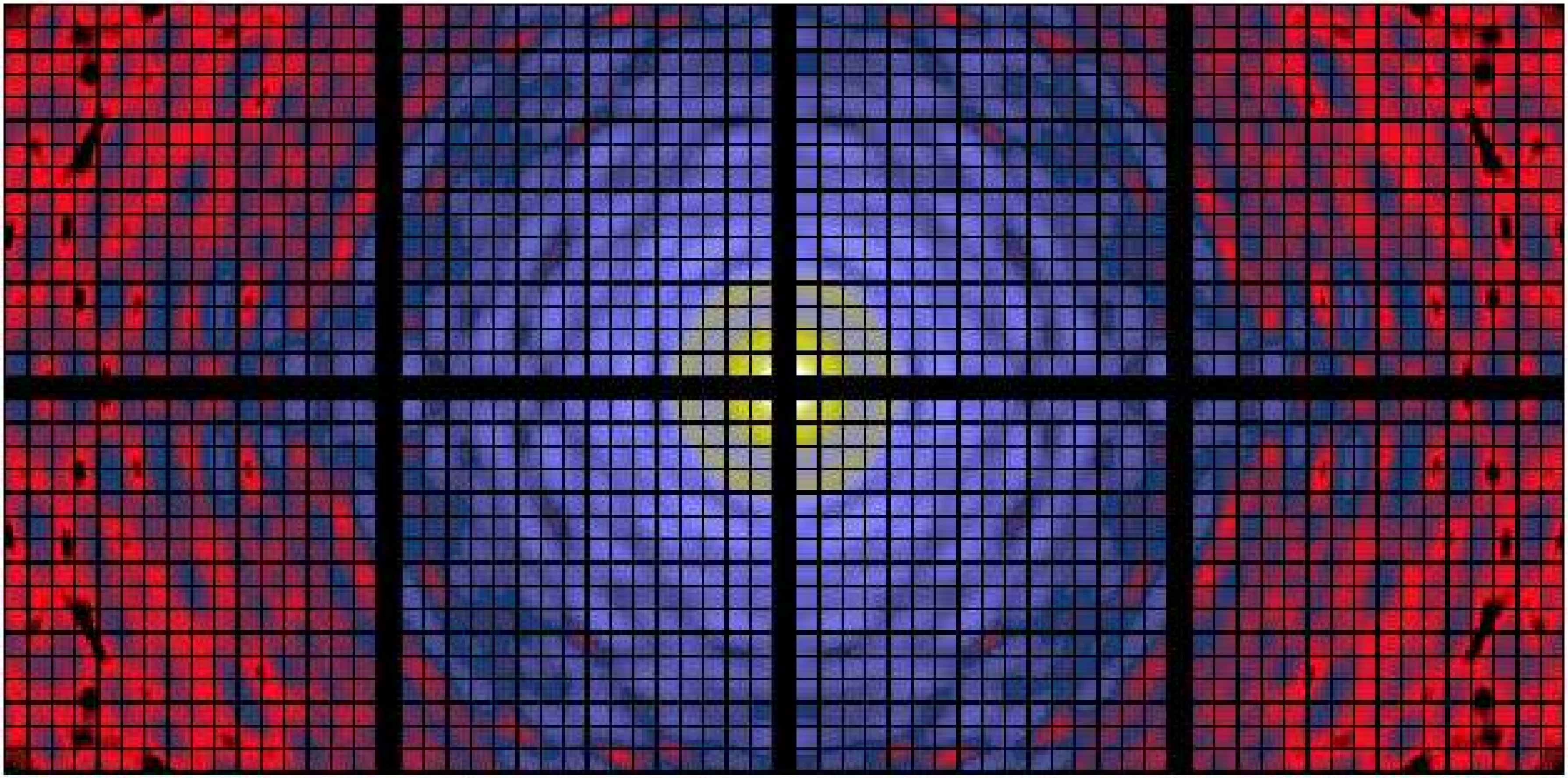
Linearity assessment

Uranus, Neptune:	**brightest flux standards**
asteroids:	**500 Jy – 1 Jy**
stars:	**10 Jy – few mJy**

PSF calibration

- **Arrays have filling factors of 73%**
- **PSF size is $\approx$ 2 pixels**
- **Arrays are made of subarrays (blue: 8, red: 2) with 1 pixel wide gap inbetween**
  $\Rightarrow$ Position point source in the centre of one subarray
  $\Rightarrow$ Perform dithering pattern for extended sources to minimize flux losses

Establish PSF with reasonable bright unresolved sources
10 Jy source gives S/N $\approx$ 1500 in $1 - 2$ min (one pointing centered)



Astrometric calibration

- **PACS is located $\approx$ 10' off the telescope axis**

- **Need to assess distortion in FOV**
  $\Rightarrow$ need multiple sources with well defined angular distances and orientation
  $\Rightarrow$ can also be used for angular calibration of chopper

currently best suited candidates: **- bright binaries selected in K** **- galaxy pairs**

Monitoring of detector stability

- **Double differential measurement:**
  sky pixel output related to blind pixel output & reference voltage

- **Responsivity frequently monitored against chopped measurements between internal calibration sources simulating the telescope background $+\Delta$**

Spectrometric Calibration Strategies

Spectrophotometry

- **Spectral resolution: 1000 – 4000**

- **Wavelength range is covered by three grating orders (2 for blue detector, 1 for red detector)**

- **Differential measurement technique for line detection grating up and down scans or frequency switching**

Spectrophotometric standards: down to 500 mJy (@100 μm)
For relative spectral response function consider sources with >10 Jy (@100 μm) yielding S/N $\approx$ 100 in 1 h
Consider line standards?

Wavelength calibration

- **PACS spectral resolution $\approx$ 10 times better than LWS**

- **LWS λ-calibrators – PN & HII regions – provide coverage of PACS spectrometer range (incl. [NII]205 μm line) but not enough lines per grating order (only 1 in 2nd order)**

Consider stars with rich water emission line spectrum
but lines should be mainly unblended

Monitoring of detector stability

- **Responsivity frequently monitored against chopped measurements between internal calibration sources simulating the telescope background $+\Delta$**

- **Consider regular thermal curing (flash curing?)**

Ground calibration

- **Characterize instrument and its components from module to full system level**

- **Ground calibration plan developed for CQM model large set of measurement procedures executed during tests analysis procedures & first set of calibration files under development**

- **Have dedicated ground calibration sources**
  - **- internal (cold) and external (hot) BBs**
  - **- moveable point source simulators**
  - **- water vapour cells for λ-calibration**
  - **- tunable laser sources for monochromatic measurements**
  - **- proton cyclotron for radiation and curing tests**

6.1 Optical and mechanical set-up

An overview of the optical and mechanical set-up of OGSE 3 is given in figure 9. A cryogenic test optics and Herschel telescope simulator is aligned to the PACS FPU and both are operated at nominal LHe temperature levels provided by a big specific test cryostat. The cryogenic test optics comprises a Herschel telescope simulator providing the expected telescope background. Internal and external calibration sources can be used. Internal sources are available by mirror/filter wheel selection through a baffled cryogenic optics system. External sources could be feed-in by two cryostat windows after internal mechanism pre-selection.

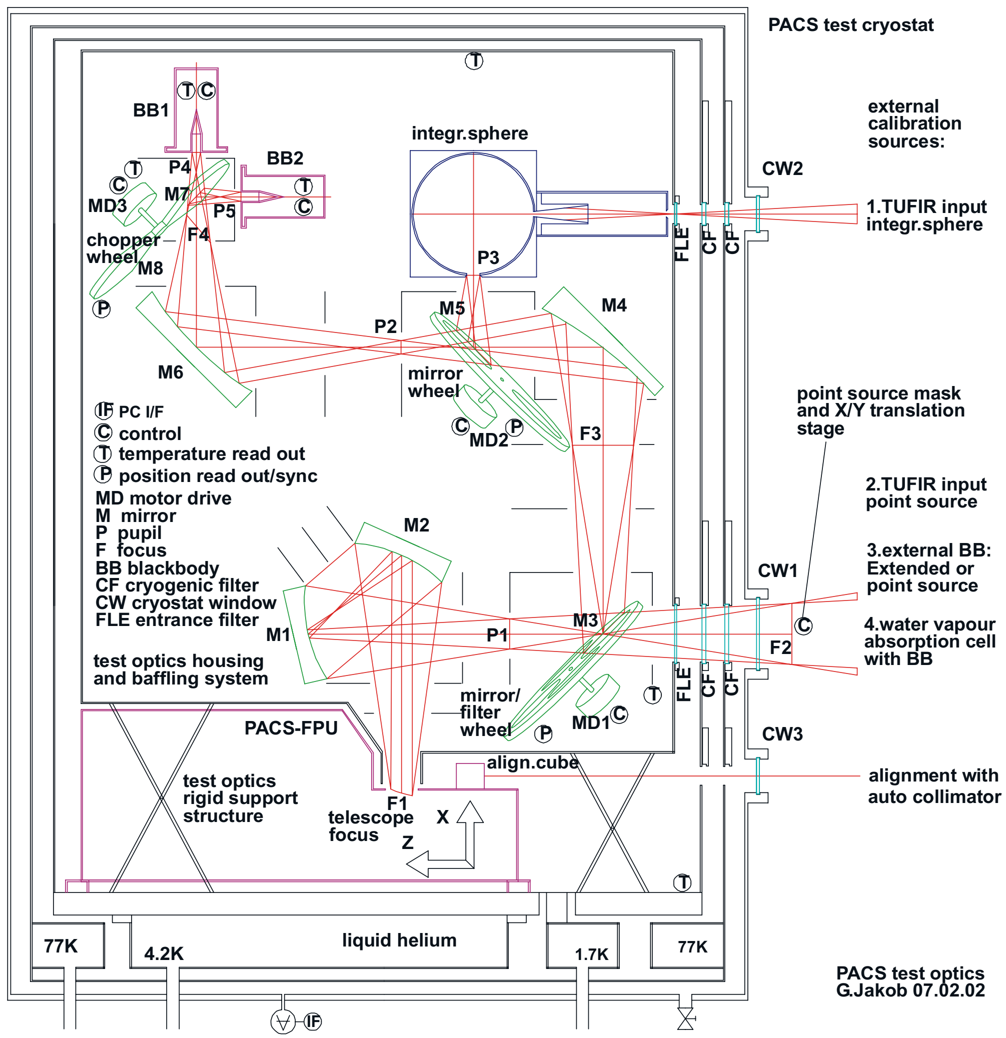
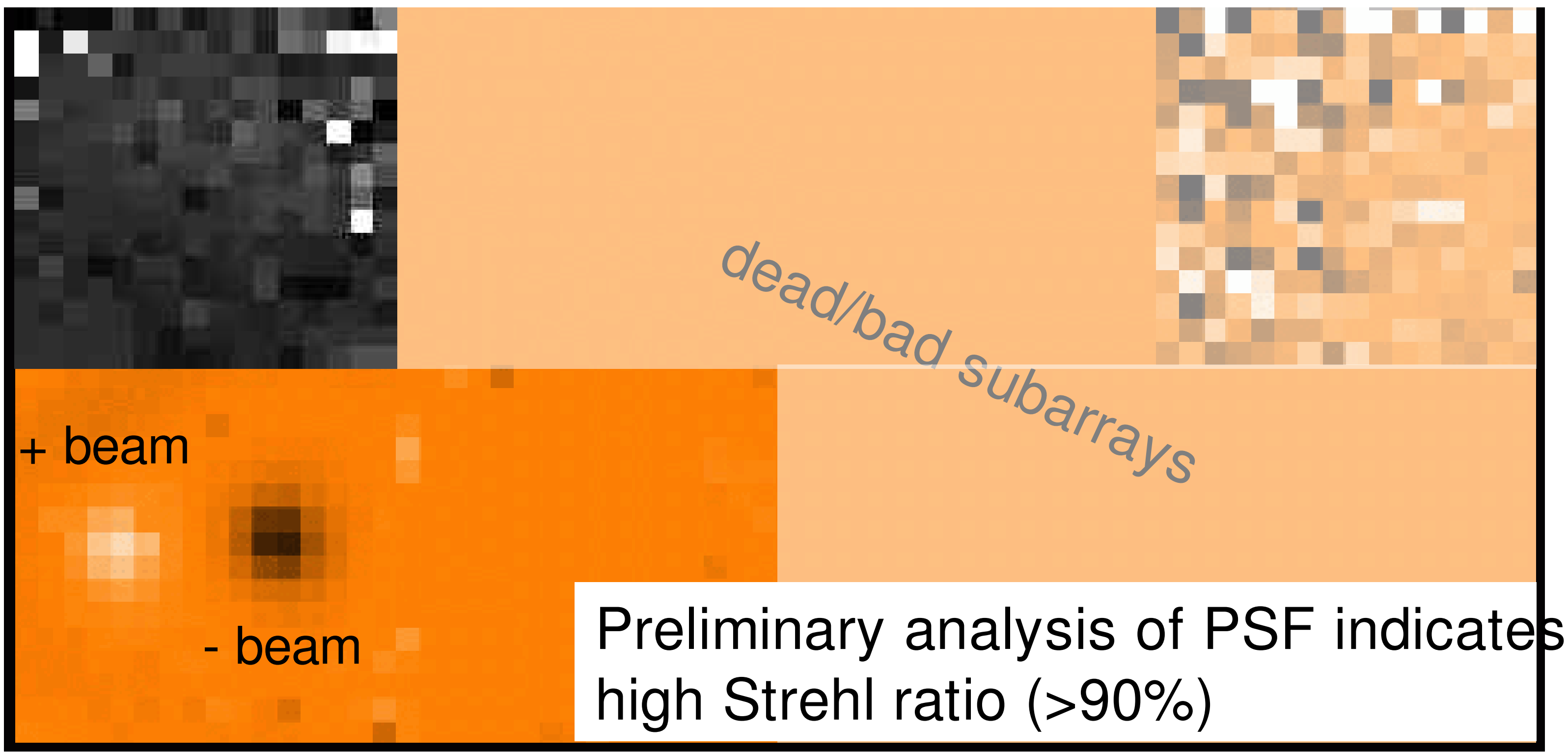


Fig. 10 PACS test optics and Herschel telescope simulator schematic

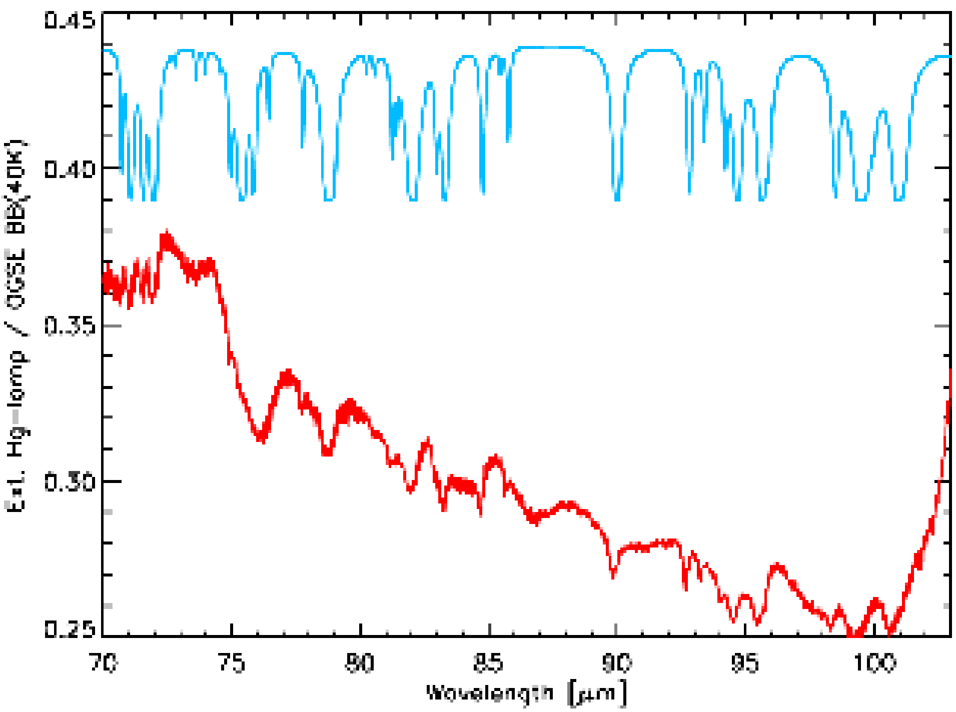
Example 5 - First Point Source Image (Blue Photometer)

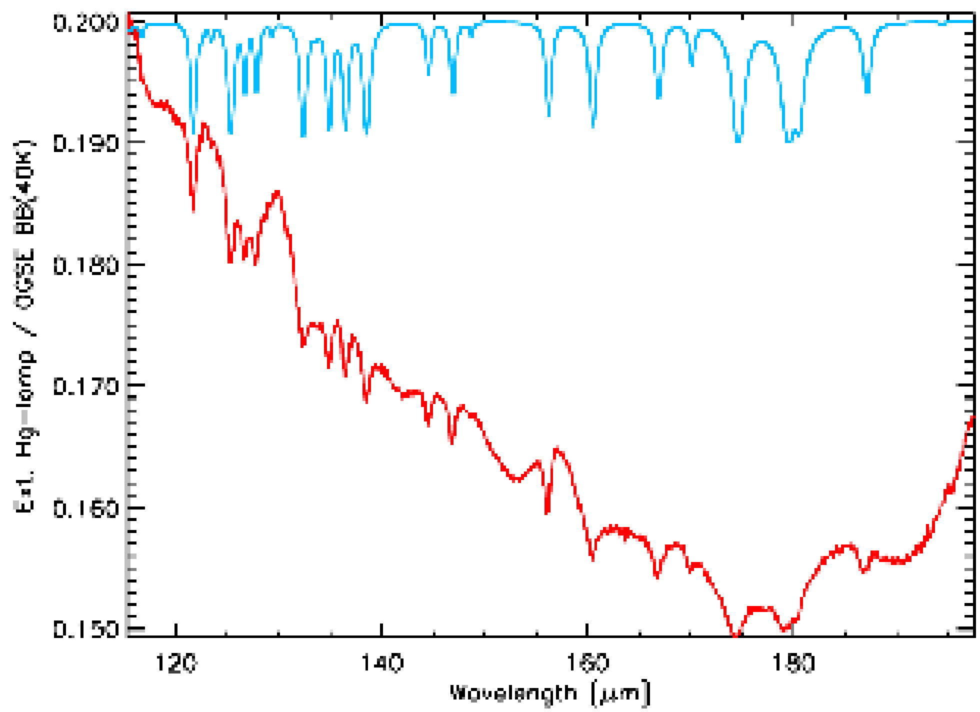
- “Point source”: hole with equiv. diam. 7” (~2 pixels) in front of external blackbody, on-array chopping+nodding
- Same source, “line scanning” mode, unprocessed data



Example 9 - First (Water) Spectra (Spectrometer)

- Look out of the cryostat window toward Hg arc lamp through lab air
- Internal blackbody for reference





Simulator

- **Simulate the behaviour of all instrument components, the telescope (e.g. PSF) & the sky source (SED, structure)**

- **Supports optimization of observing modes**

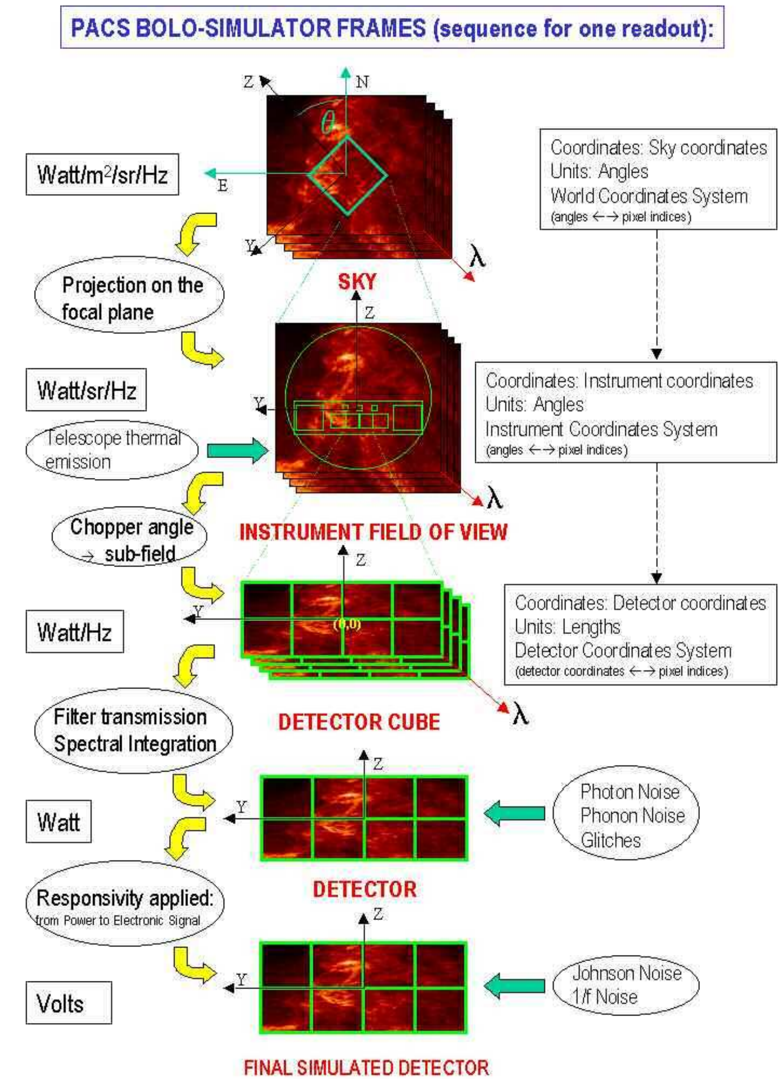


Figure 1

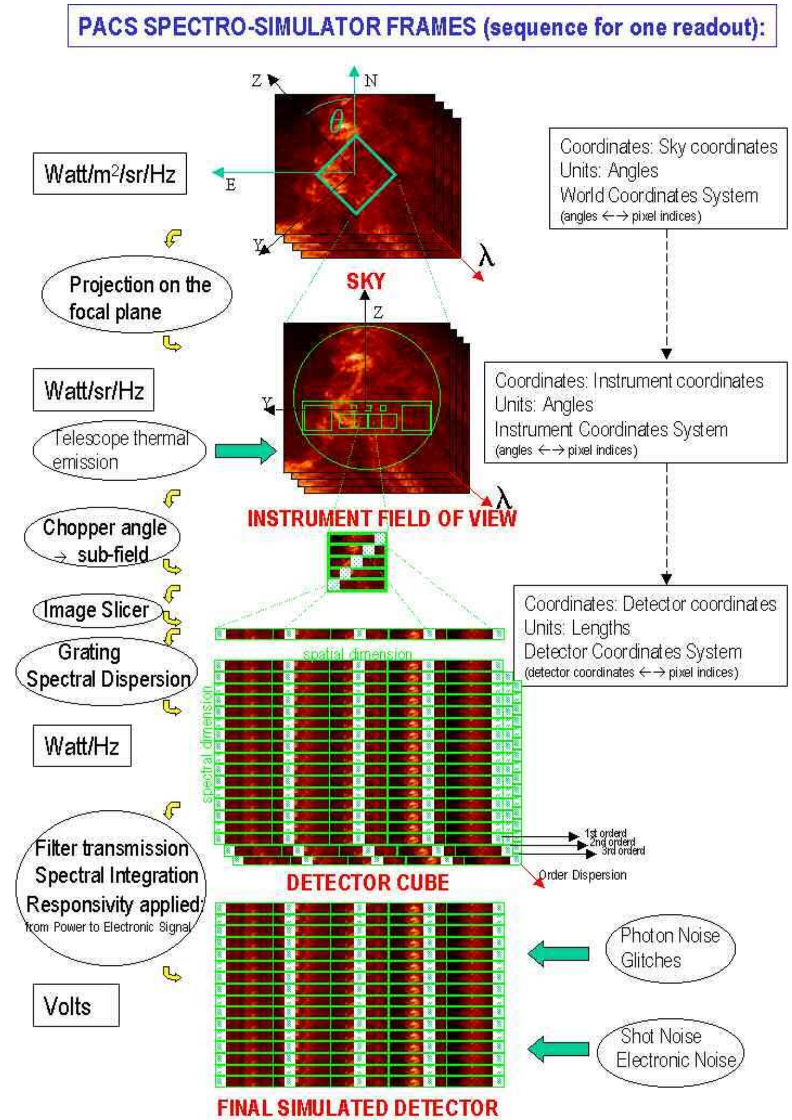


Figure 2