X-RAY IMAGING PRACTICUM

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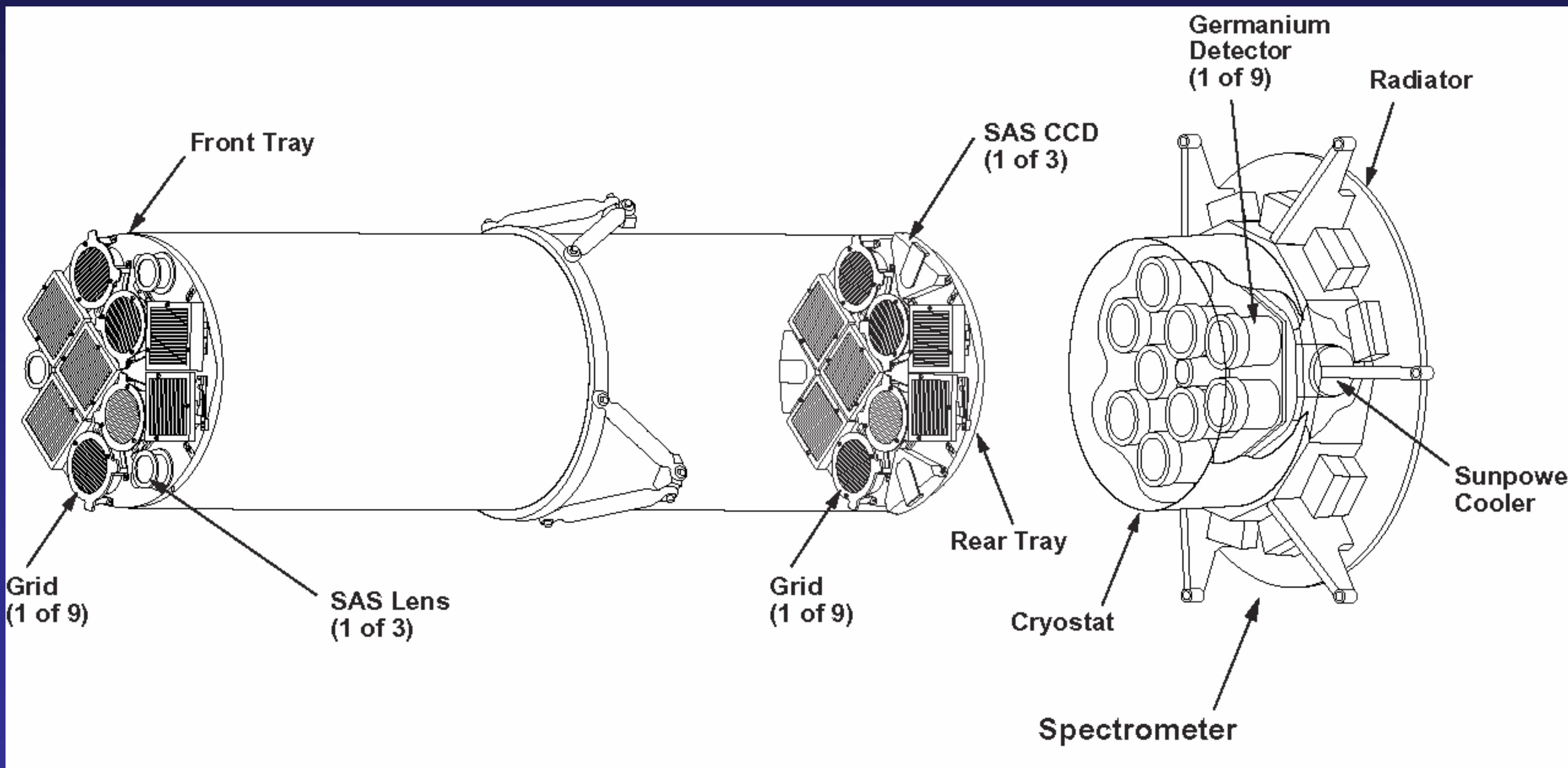
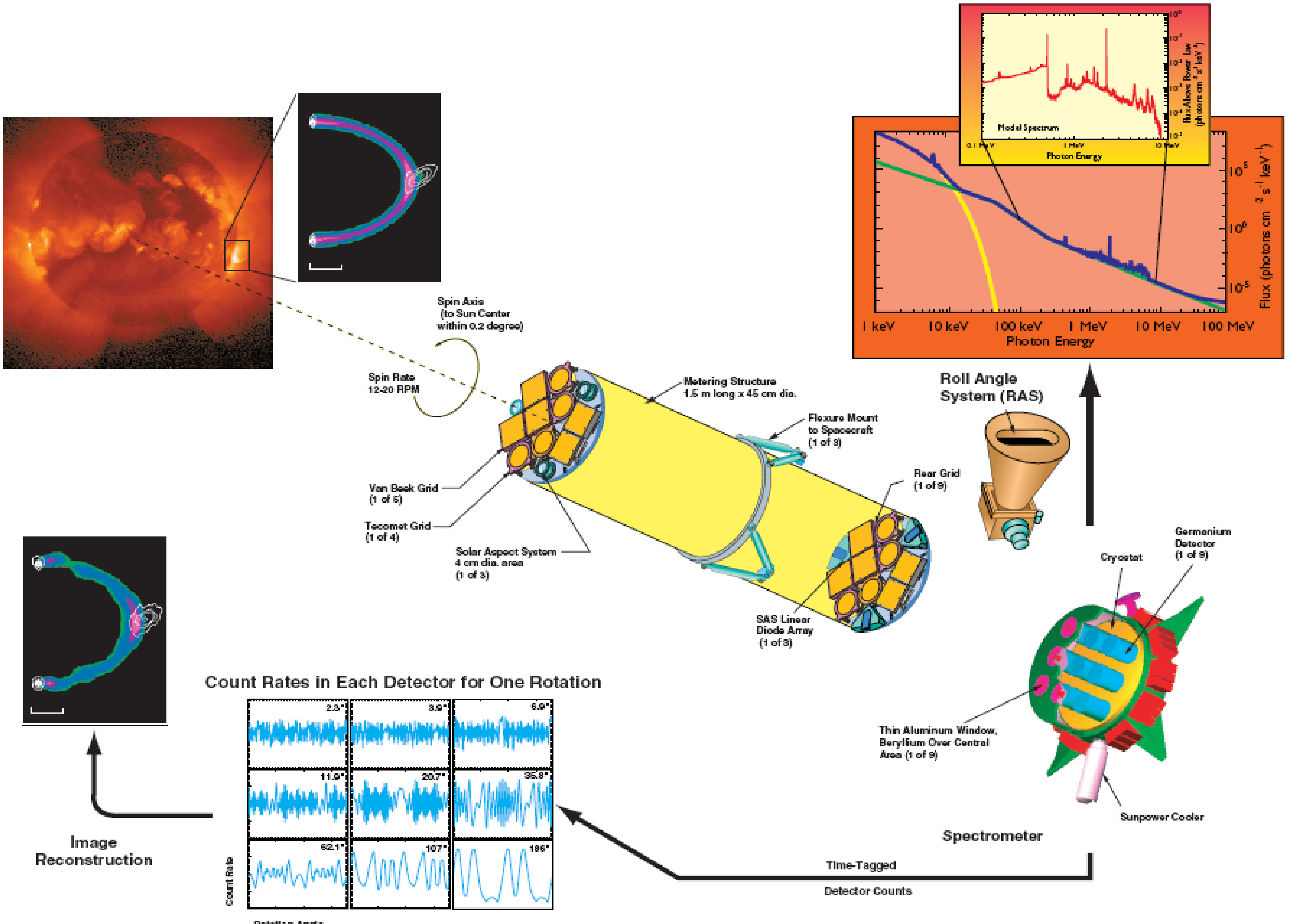
X-RAY IMAGING PRACTICUM

- Objectives
- Intuitive perspective on RMC imaging
- Introduction to some real-world hardware and design considerations
- Introduction to how visibilities are related to modulation patterns and how they can be used

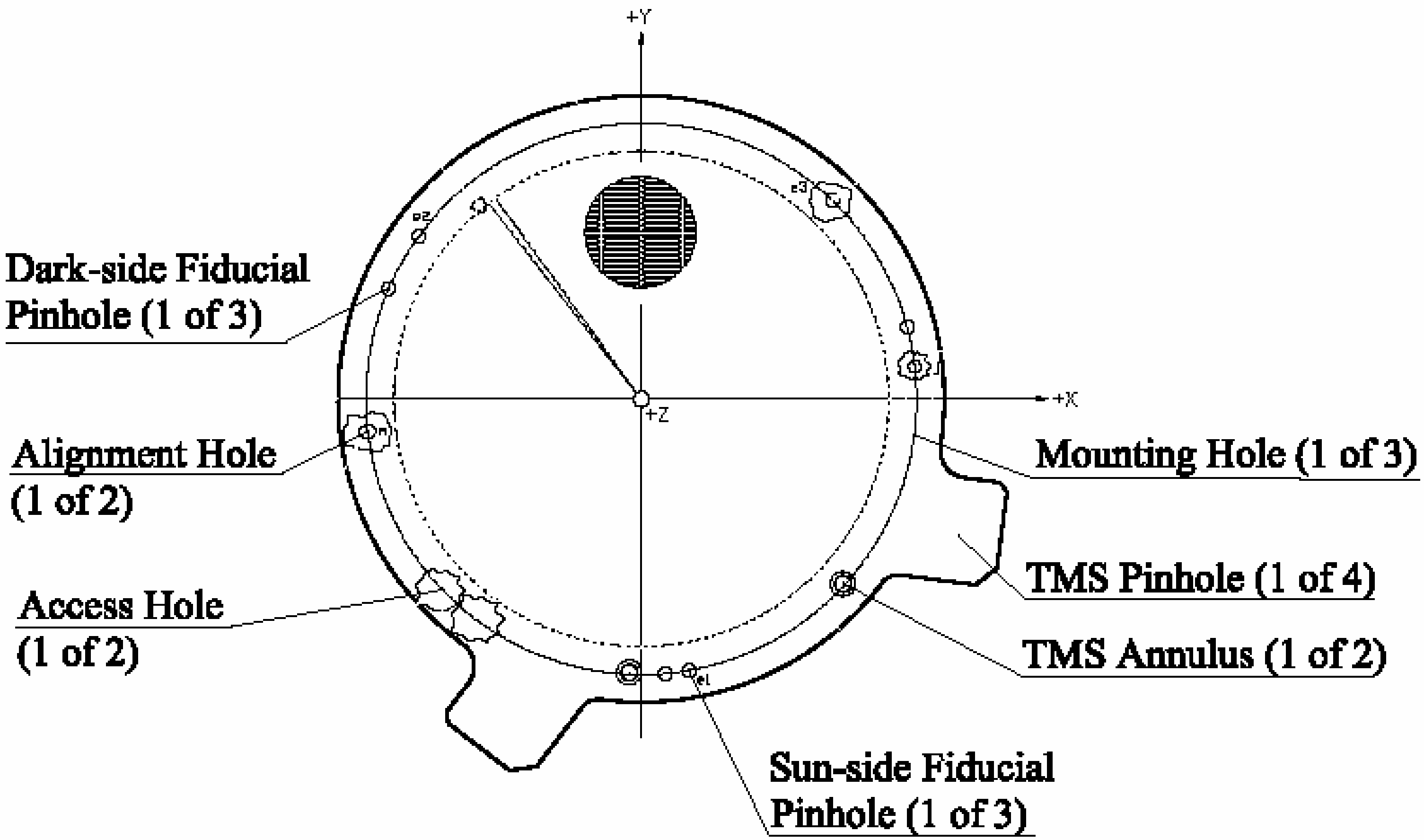

Germanium
Detector
(1 of 9)
Radiator
Front Tray
SAS CCD
(1 of 3)
Sunpower
Cooler
Rear Tray
Grid
(1 of 9)
SAS Lens
(1 of 3)
Grid
(1 of 9)
Cryostat
Spectrometer

HESSI Imaging Spectroscopy



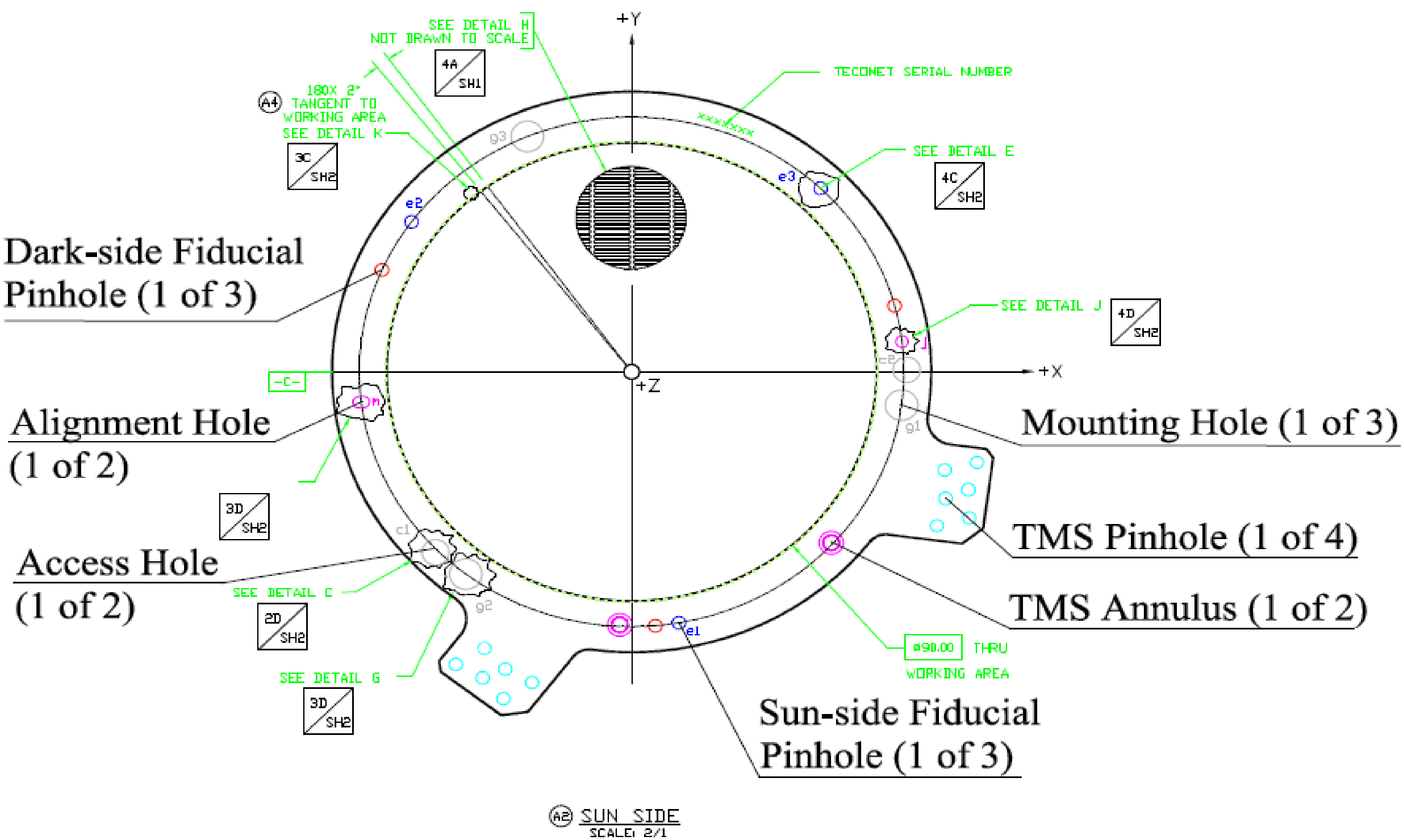
Tecomet Grid #3

Sun-side View

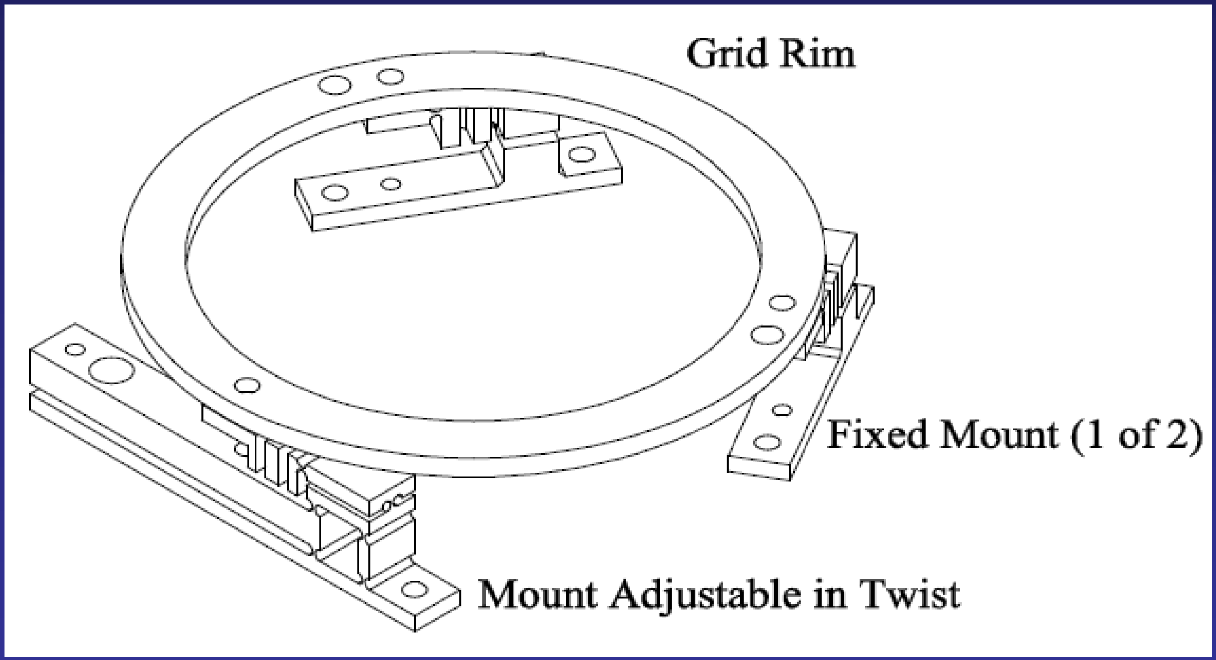


Tecomet Grid #3

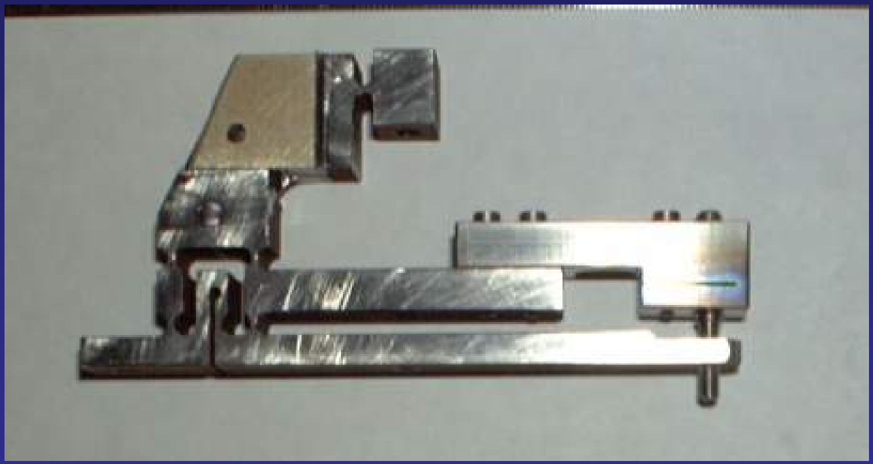
Sun-side View

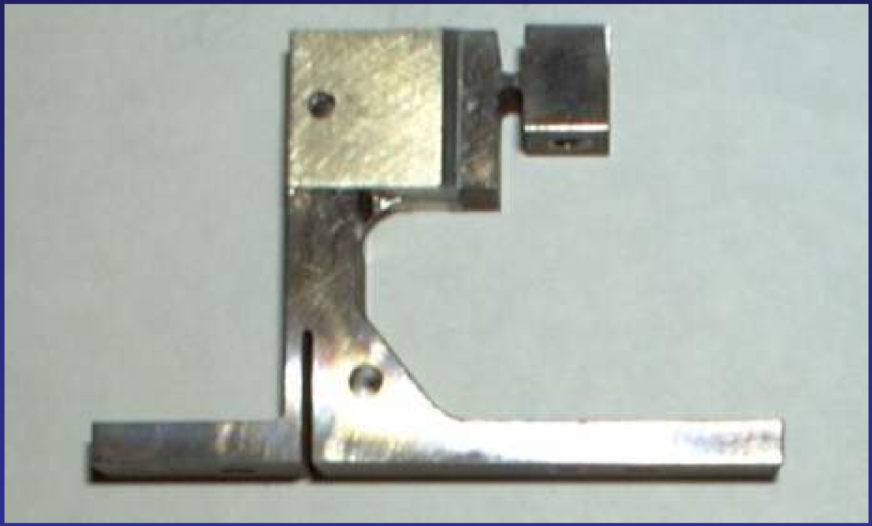


Mounts for Grids 1 - 4



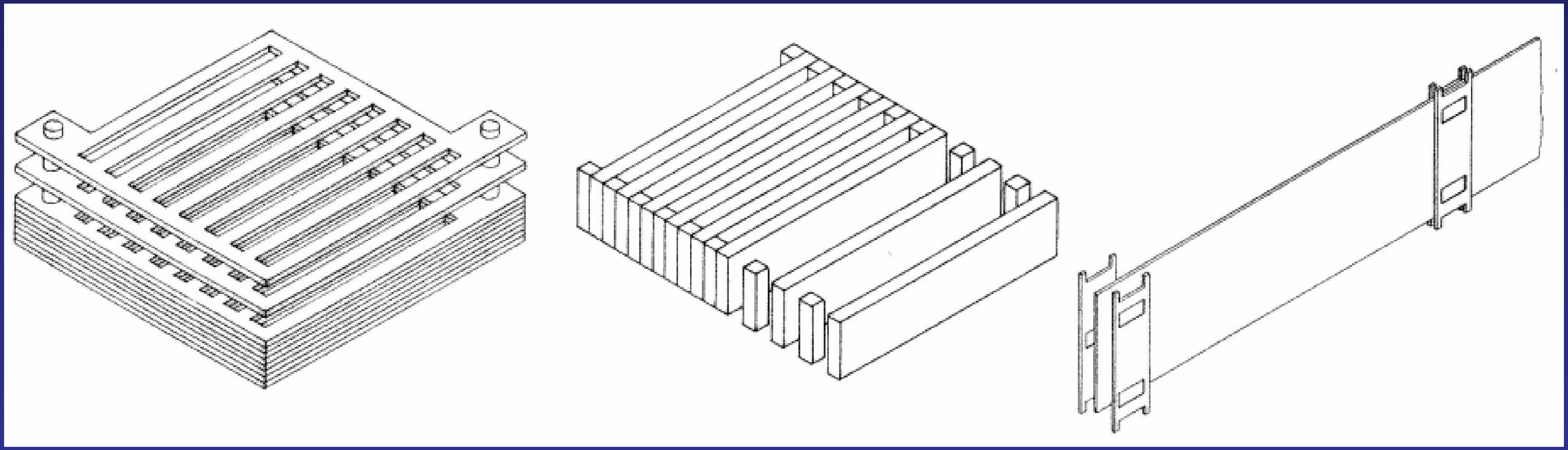
Grid #4 Kinematic Mounts



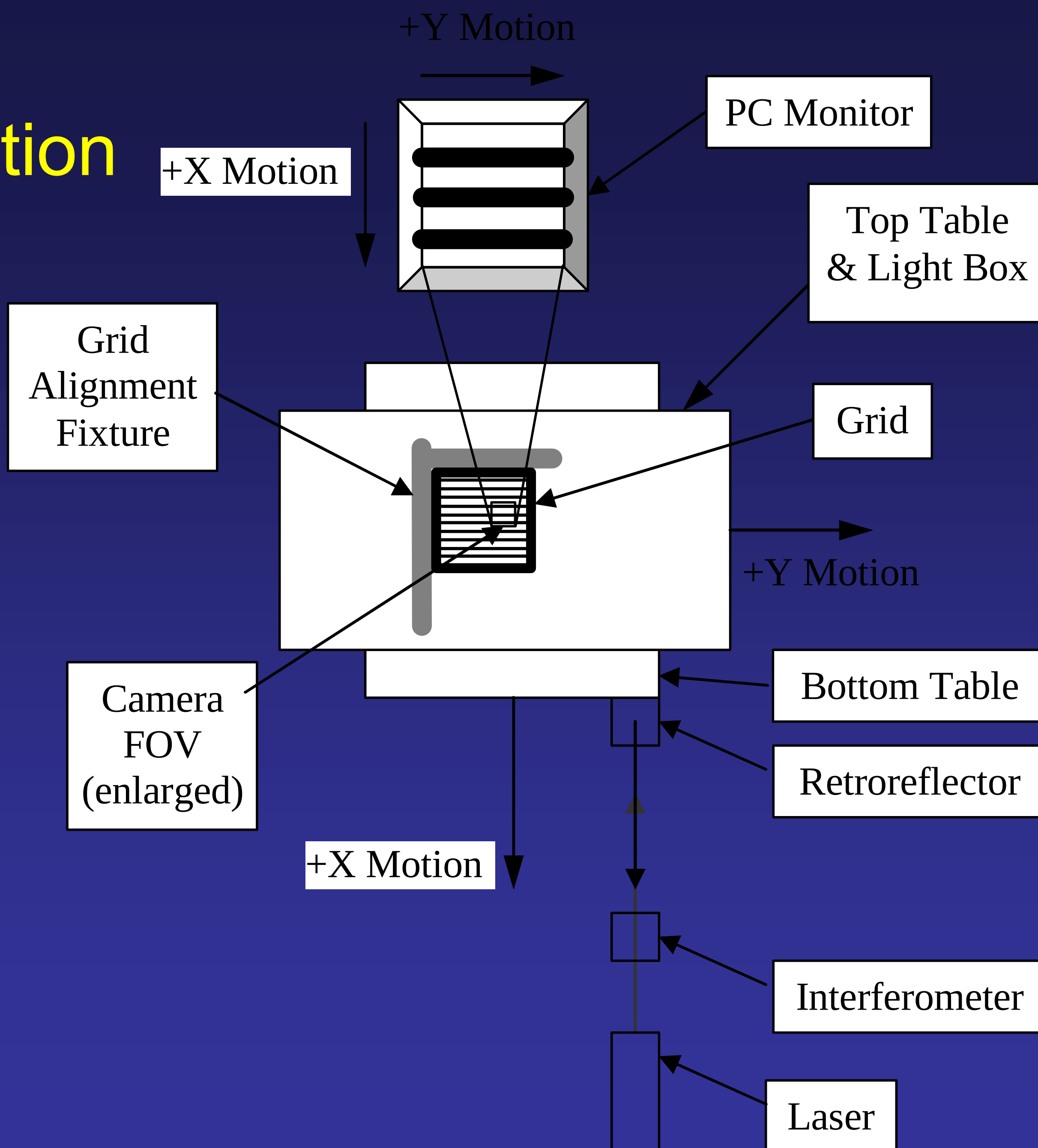


Coarse Grids #5 - 9

Stacking Coarser Grids

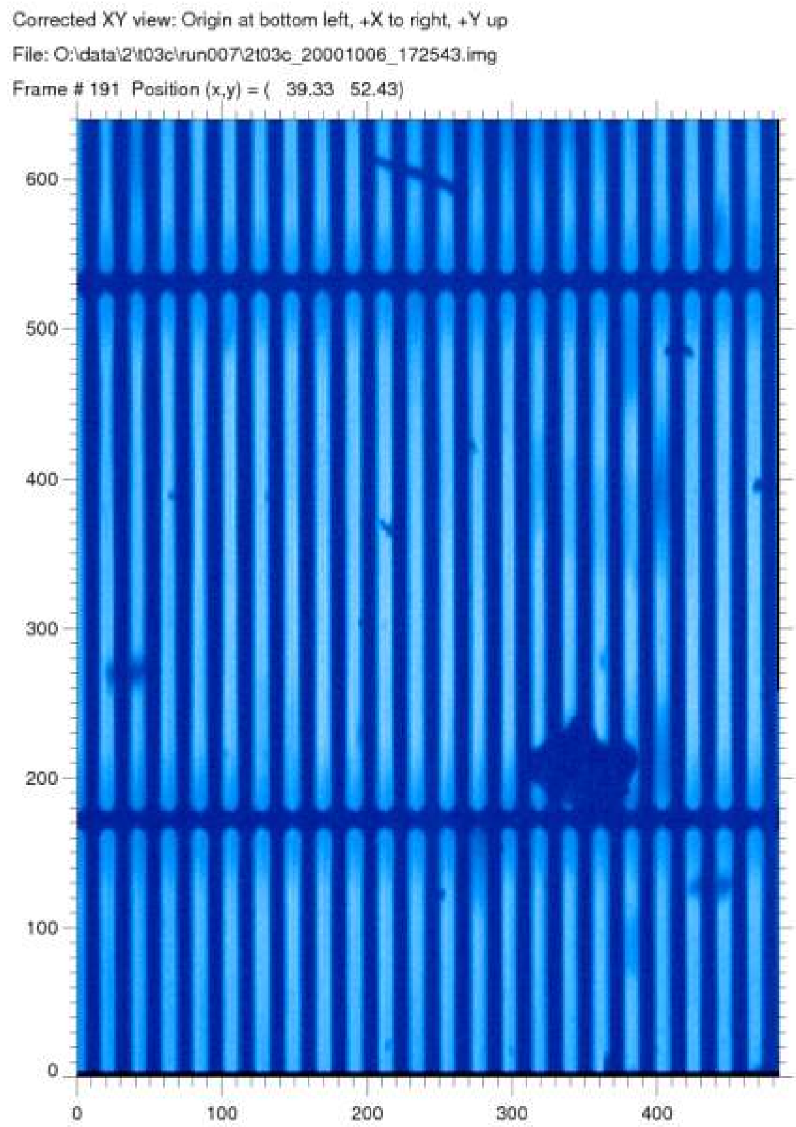


Optical Characterization Facility

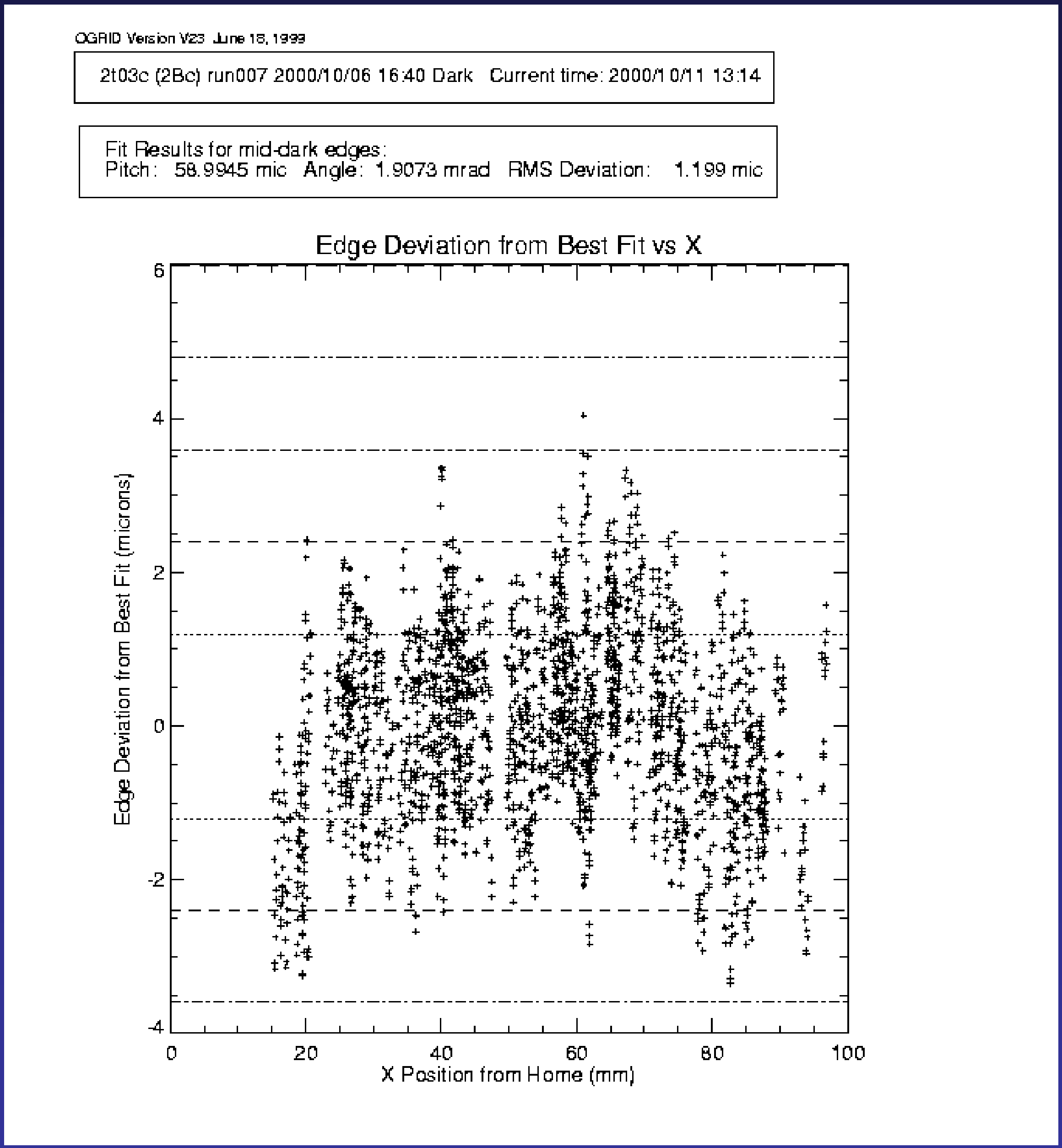


Grid #2

Pitch 59 **m**m
Slit width 41 **m**m
Thickness 2.04 mm
Material Tungsten



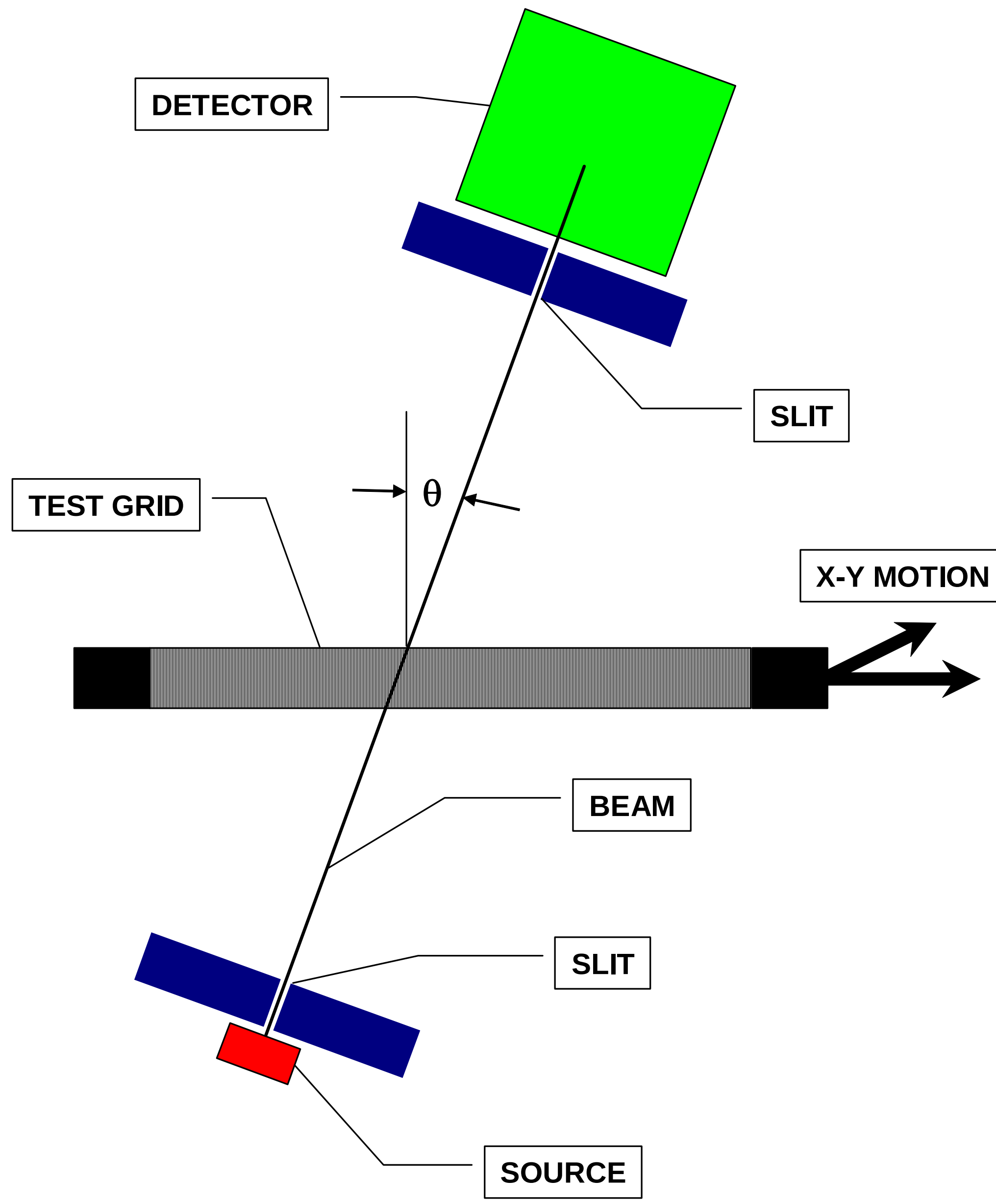
OGCF Results



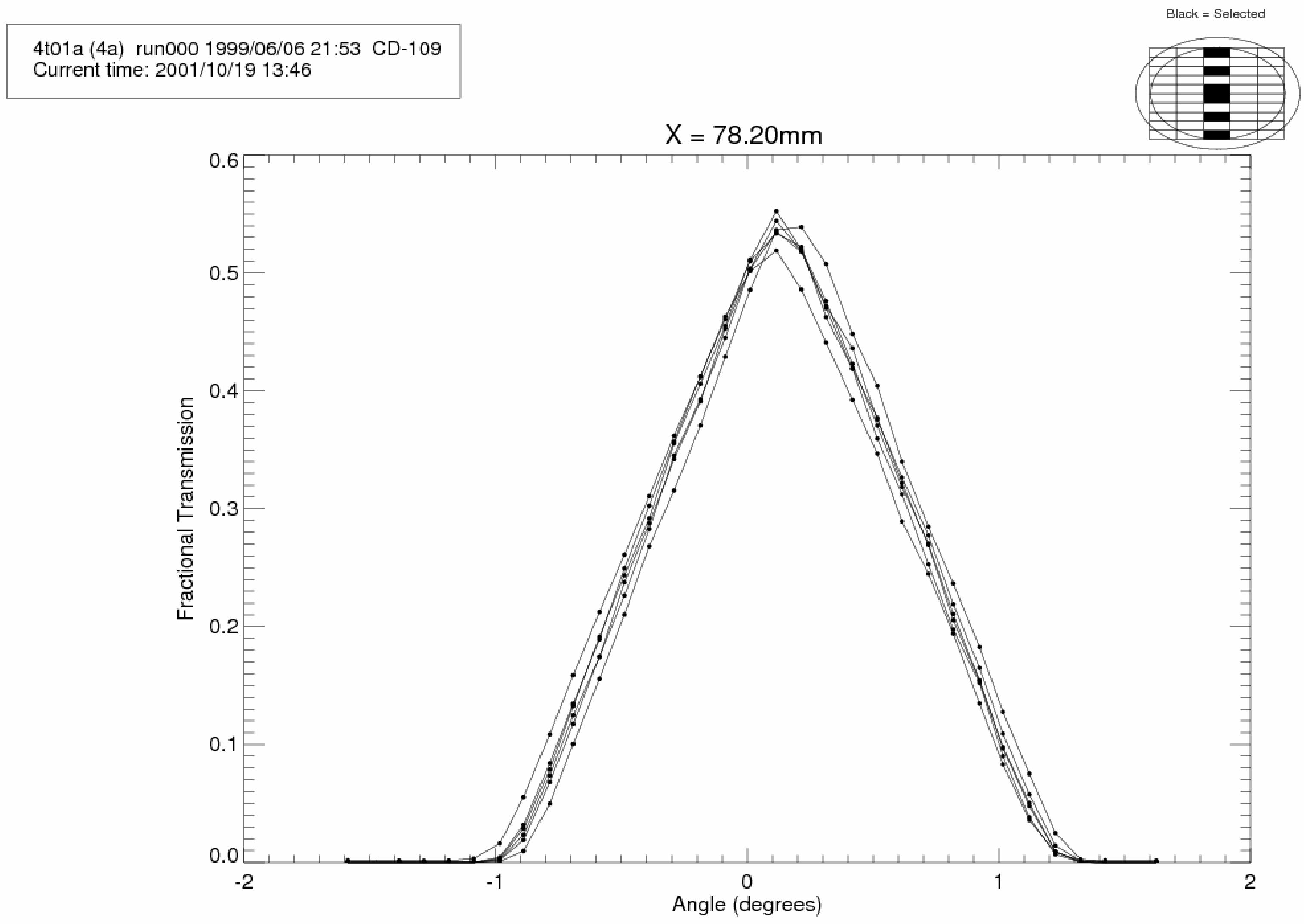
X-Ray Grid Characterization Facility

Radioactive Sources Used

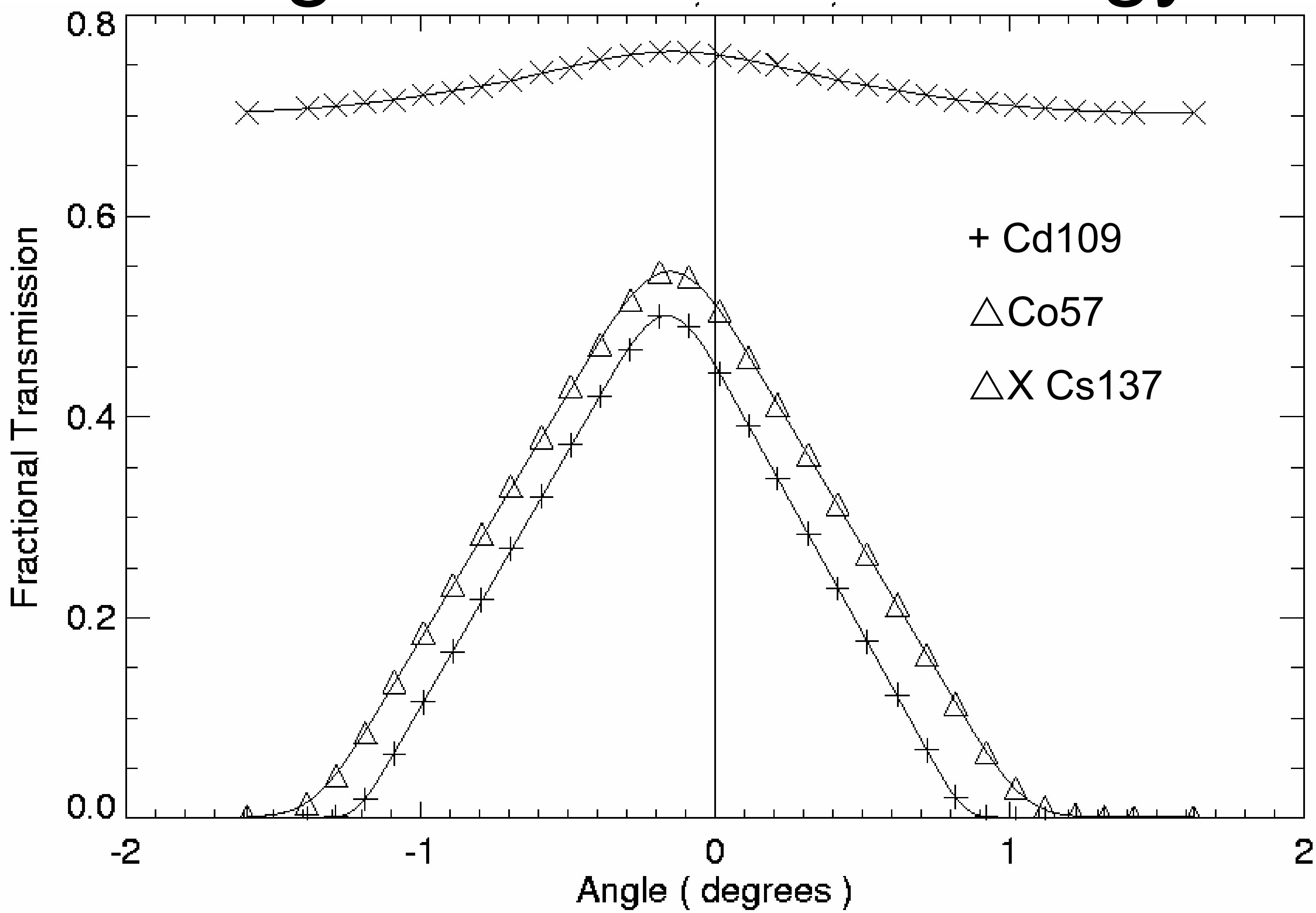
Source	Energy (keV)	Strength on 5/19/1998 (mCi)
Cd^{109}	22	50
Co^{57}	122 129	40
Cs^{137}	662	40



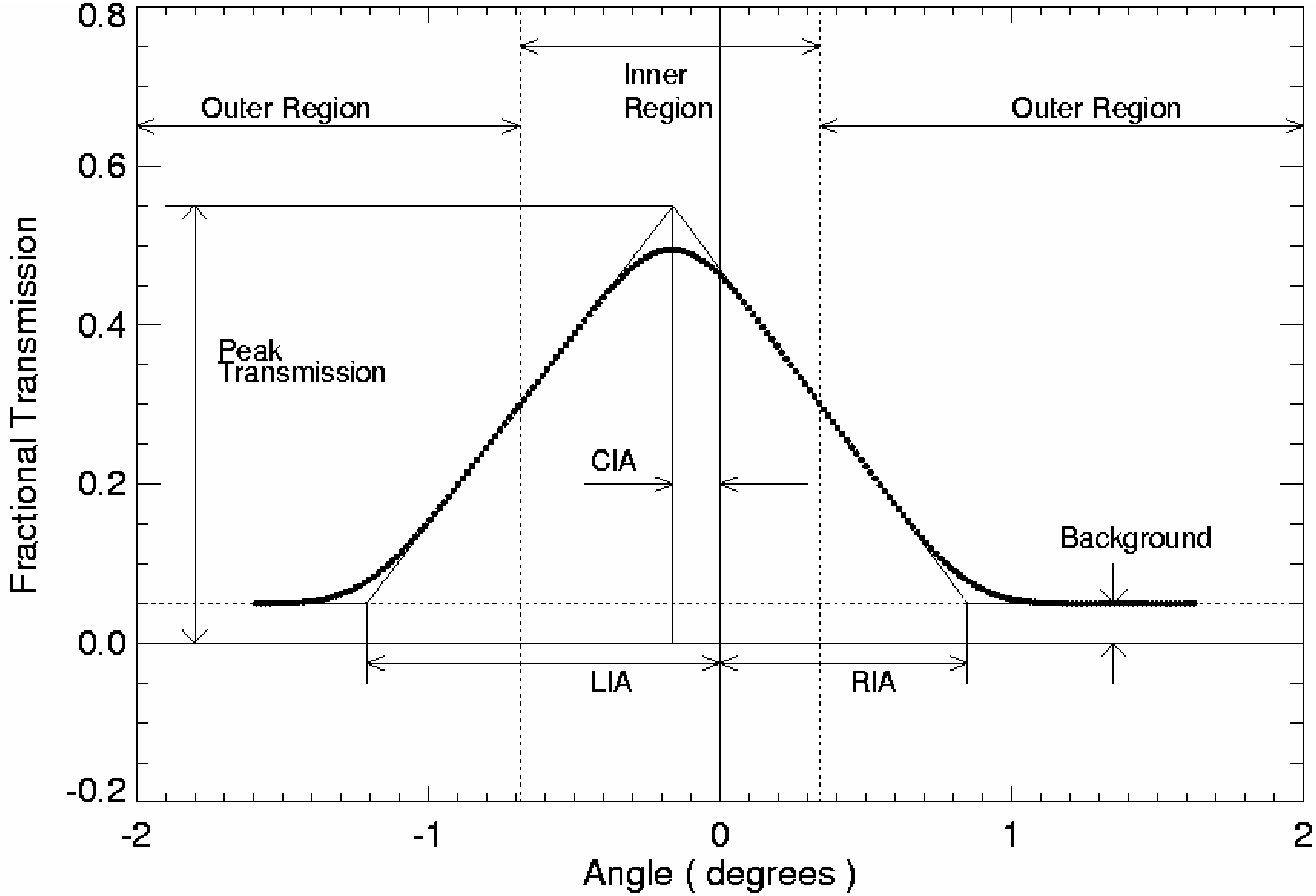
Grid #4 X-ray Angular Response



Grid #4 transmission as a function of angle to normal & energy.



Definition of model fit parameters used to characterize the angular dependence of the grid transmission.



Factors that degrade modulation

Grid transparency

Difference in grid pitch

Relative twist

Aspect errors

Random errors in slit / slat locations

Diffraction

Need to limit effective sum of errors to achieve satisfactory modulation efficiency

Combining errors

- Key to RHESSI error budget was that each error source was equivalent to ‘smearing’ the source in a distinctive way
- Fixed source + aspect error = perfect aspect + moving source
- Fixed source + twisted grids = perfect grids + distributed source
- Use ‘gaussian model’ of smeared source to calculate loss of modulation

Numerical example

- Grid 1: 35 microns, 1.55m, 7cm diameter
- Twist of 35microns/7cm smears source over 1 modulation cycle → zero modulation.
- Compare twist tolerance to angular resolution!

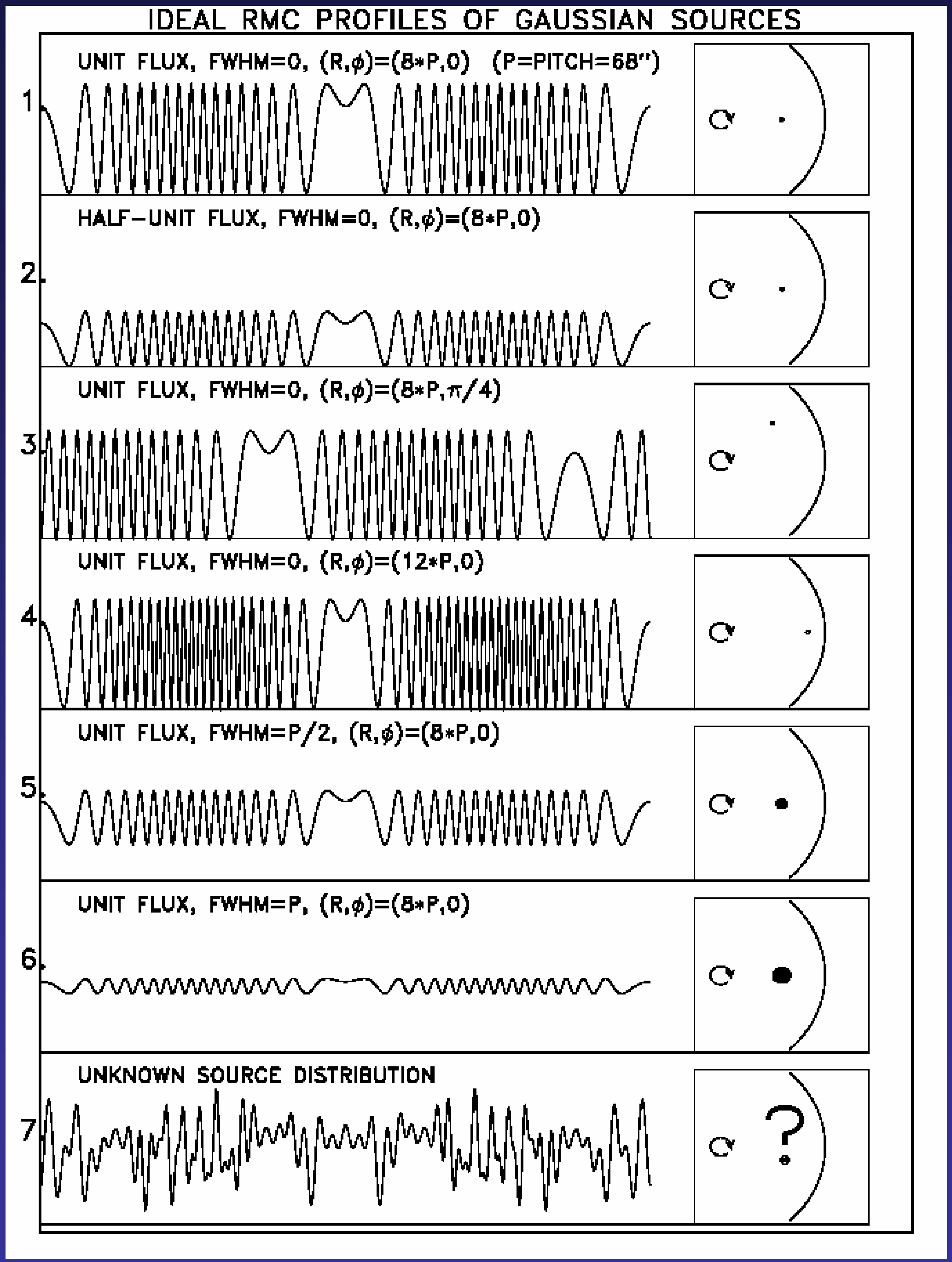
Exercise 1

- Consider RHESSI grid 1:
  - 34 micron pitch
  - 25 micron apertures
  - 1 mm thick
  - separated by 1.55m
  - Grids 9 cm in diameter
  - Detector 6 cm in diameter

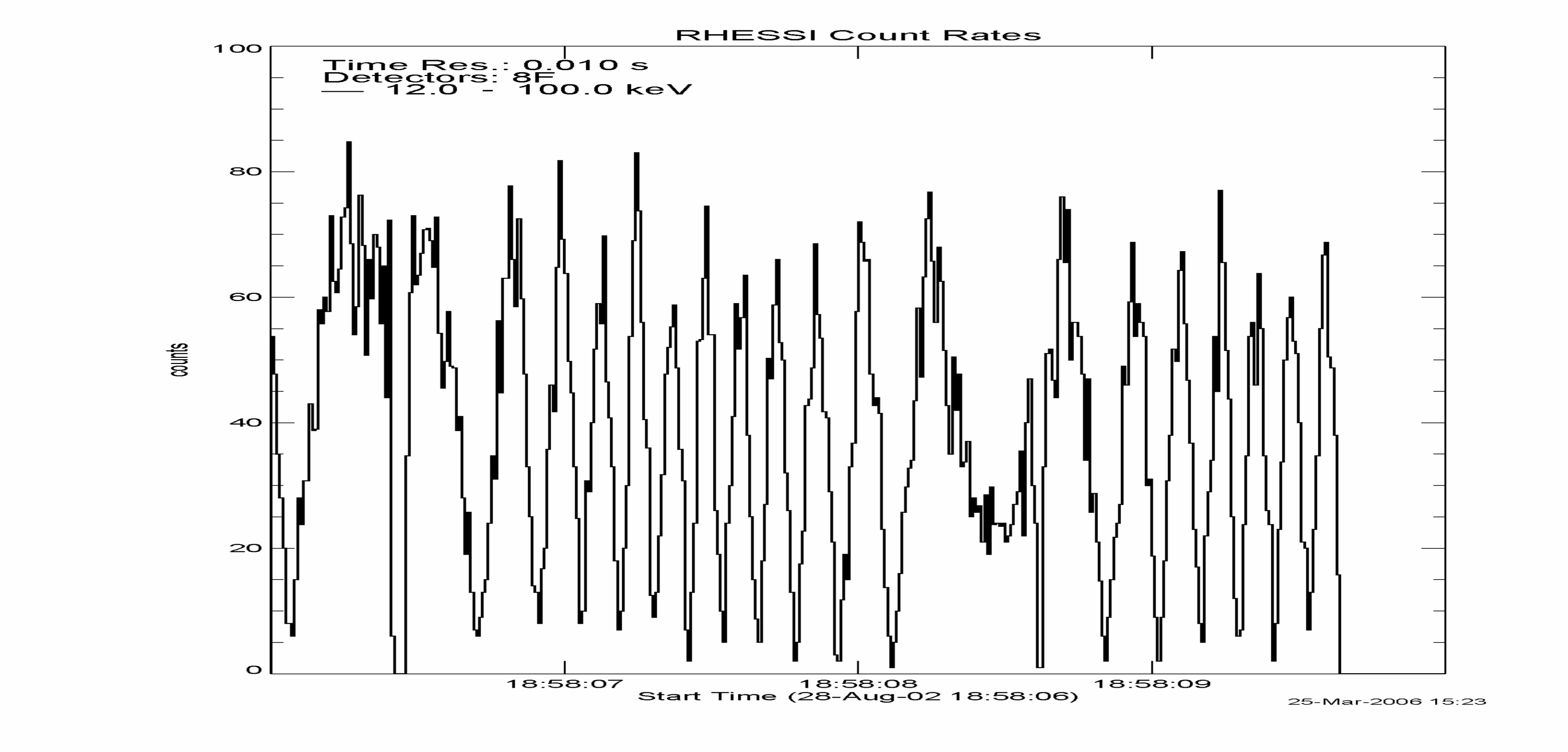
1. What is the FWHM resolution of RMC1 (assume 1st harmonic only) ?

2. How much relative twist is required to totally destroy the modulation?

3. What would be the qualitative and quantitative effect of a relative twist of ½ of this amount ?

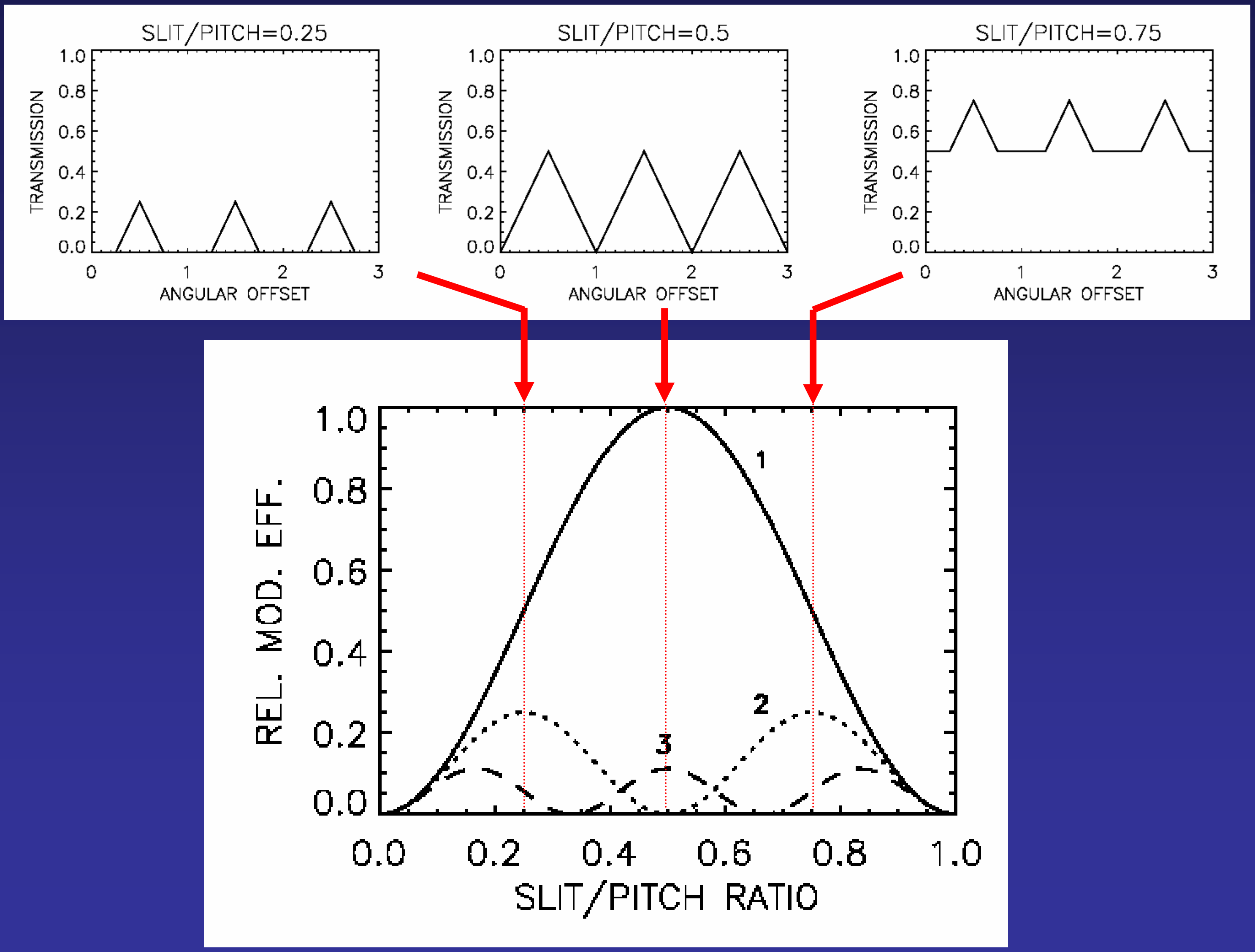

IDEAL RMC PROFILES OF GAUSSIAN SOURCES
1
UNIT FLUX, FWHM=0, (R,φ)=(8*P,0) (P=PITCH=68")
2
HALF-UNIT FLUX, FWHM=0, (R,φ)=(8*P,0)
3
UNIT FLUX, FWHM=0, (R,φ)=(8*P,π/4)
4
UNIT FLUX, FWHM=0, (R,φ)=(12*P,0)
5
UNIT FLUX, FWHM=P/2, (R,φ)=(8*P,0)
6
UNIT FLUX, FWHM=P, (R,φ)=(8*P,0)
7
UNKNOWN SOURCE DISTRIBUTION
?

Exercise 2



Spin axis at [246,-73]
Grid 8 slits were pointed at solar north at 18:58:08.5 UT and rotating at 15 rpm (clockwise looking at rear of collimator)
What is the source location?
Bonus questions: What is effect of a 1 arcminute error in the pointing?
a 1 arcminute error in the aspect solution?
a 1 acminute error in the roll aspect?
Do a back projection image grid 8, 28-aug-2002 185750-185850 and compare to your estimate. Alternatively, use his_vis_fwdfit on the visibilities.

Slit/Pitch Ratio & Modulation Efficiency



What are Visibilities?

A visibility is the calibrated measurement of a single Fourier component of the source image.

$$V(u,v) = \iint I(x,y)\, e^{-2\pi i(ux+vy)}\, dx\, dy$$

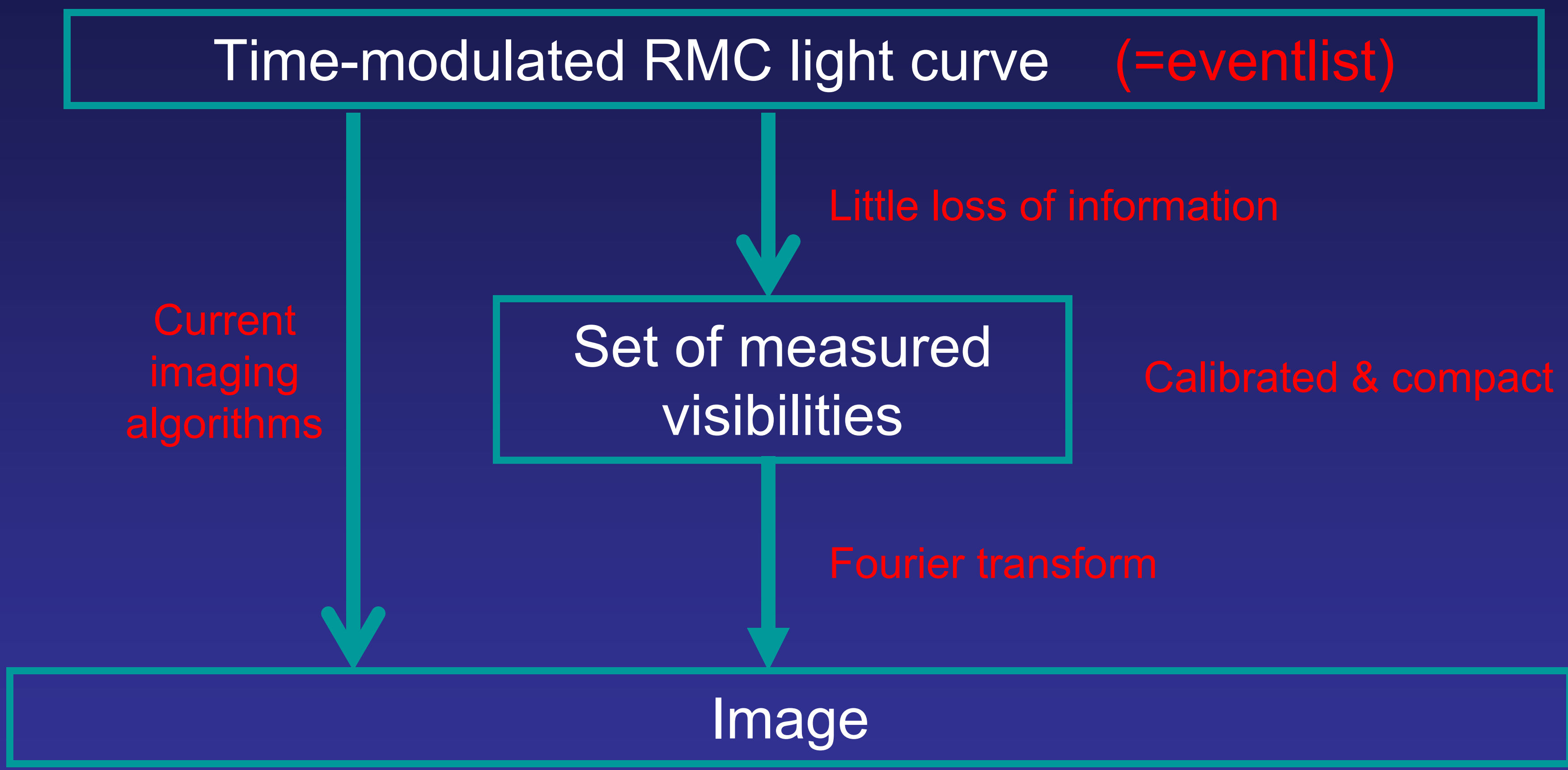
V – visibility

u, v – inverse period in x, y

period = 2 x FWHM

I – count rate (count s^{-1})

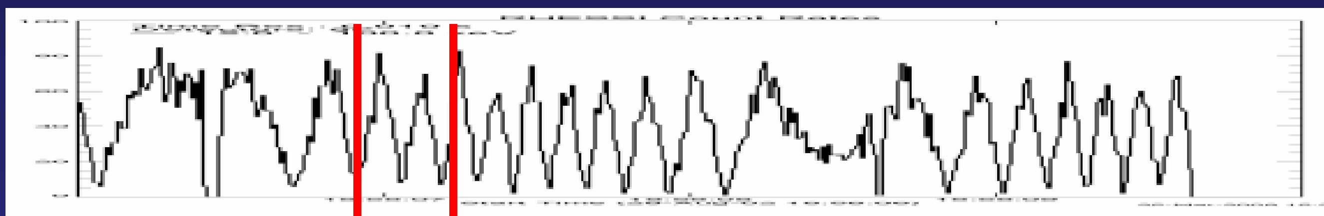
Role of Visibilities



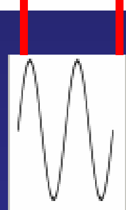
- Visibilities represent an intermediate step between modulated signal and image.

Single Visibility Measurement

A visibility measures one Fourier component of source image.



Typical modulated light curve



Visibility for one RMC at one orientation is determined by calibrated amplitude (A) and phase (Φ) of modulation

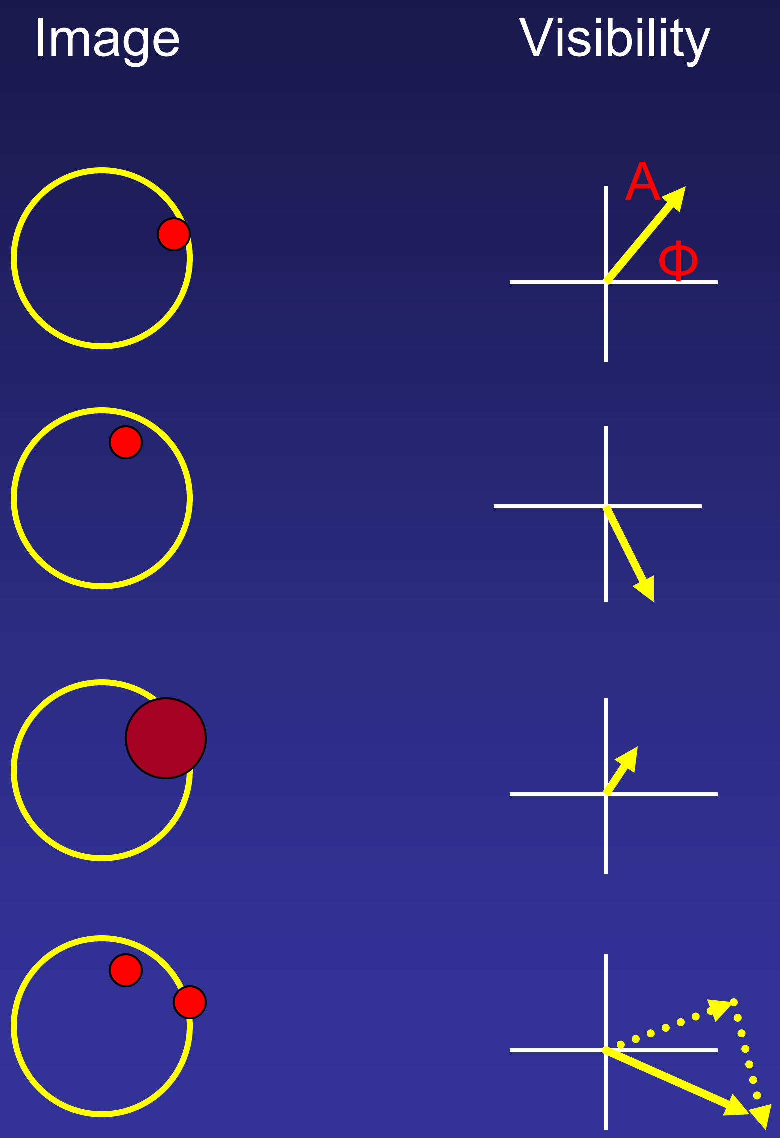
$$V(u,v) = A\, e^{i\Phi}$$

u, v define spatial frequency at which the visibility is measured

$\sqrt{u^2 + v^2} = 0.5 / (\text{FWHM resolution})$ $\text{TAN (orientation)} = v / u$

USEFUL PROPERTY: Unmodulated background is ignored.

Single Visibility Properties



For single sources:

- Amplitude depends on flux and size
- Phase depends on position

For multicomponent sources:

•Visibilities add vectorally

Image ⟷ Visibilities

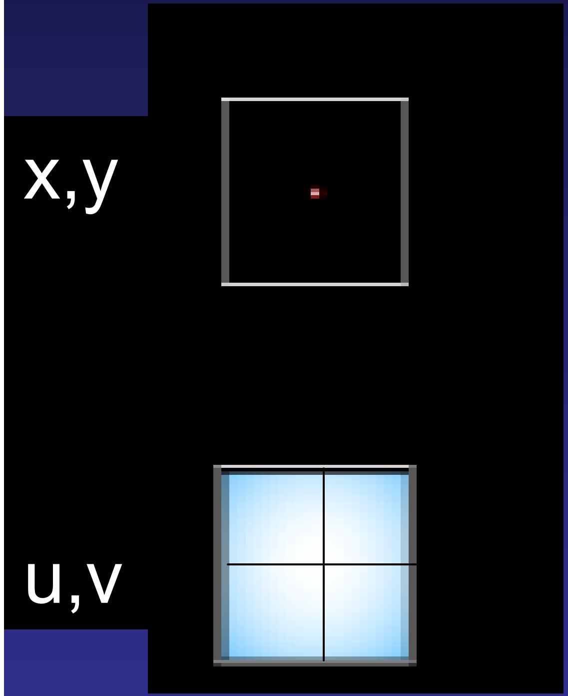


Image ⟷ Visibilities

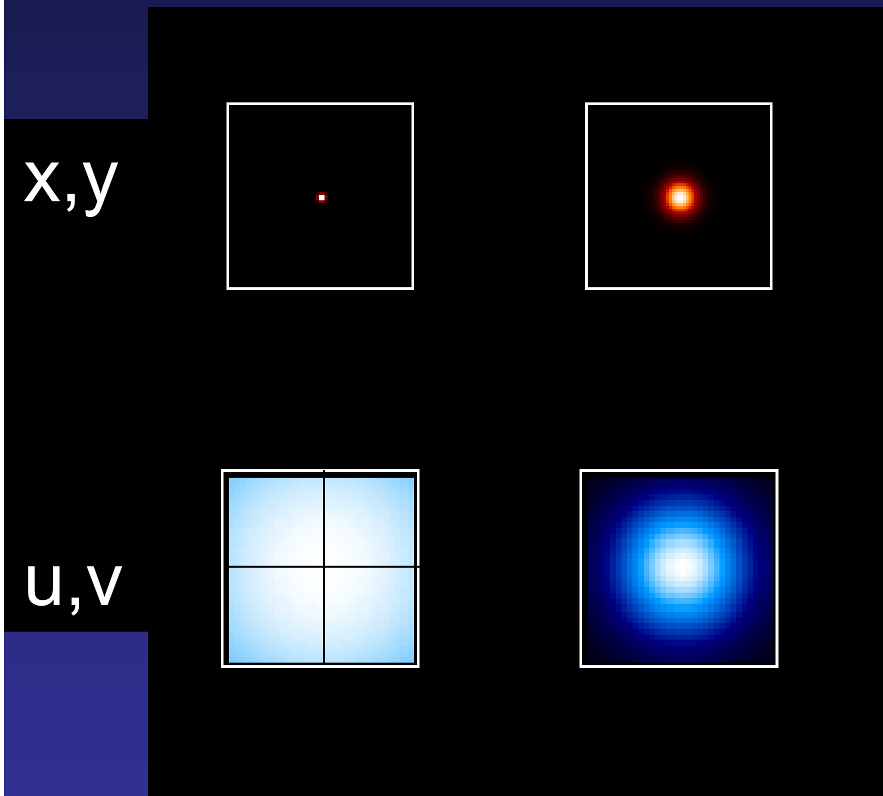


Image ⟷ Visibilities

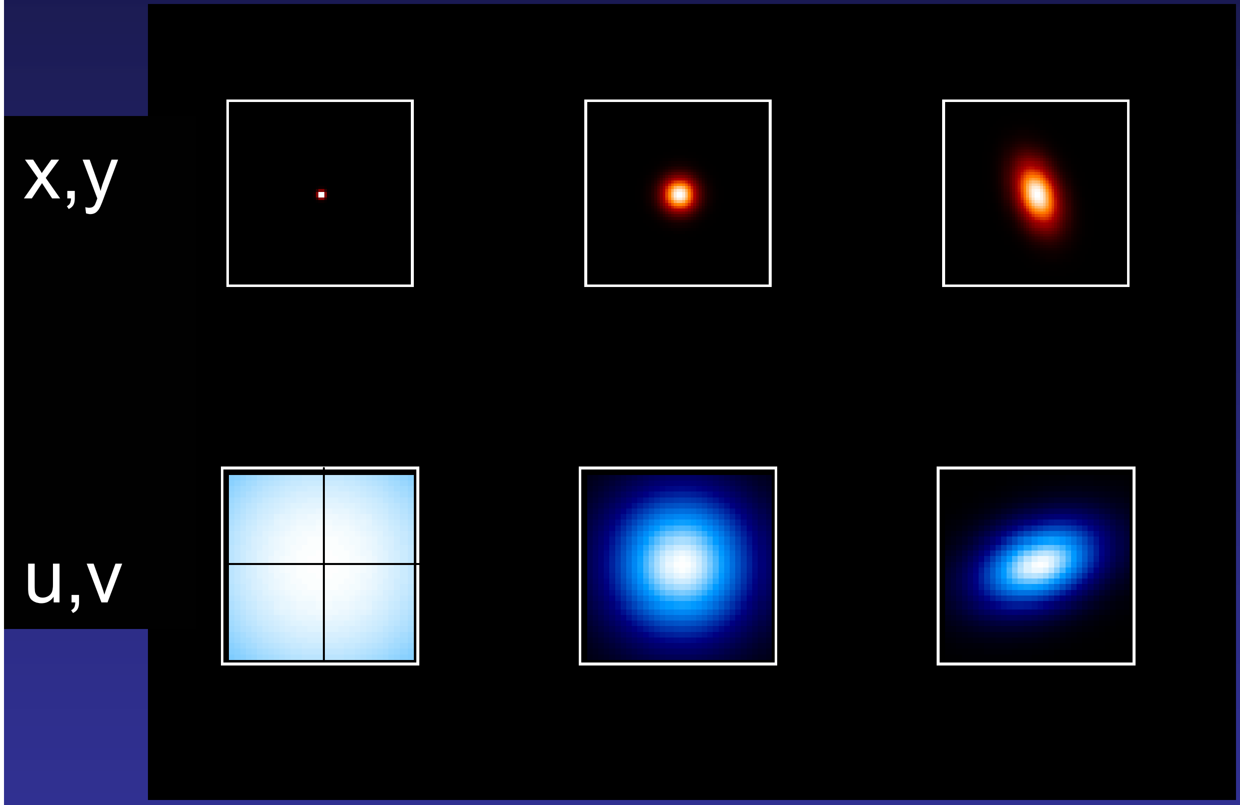


Image ⟷ Visibilities

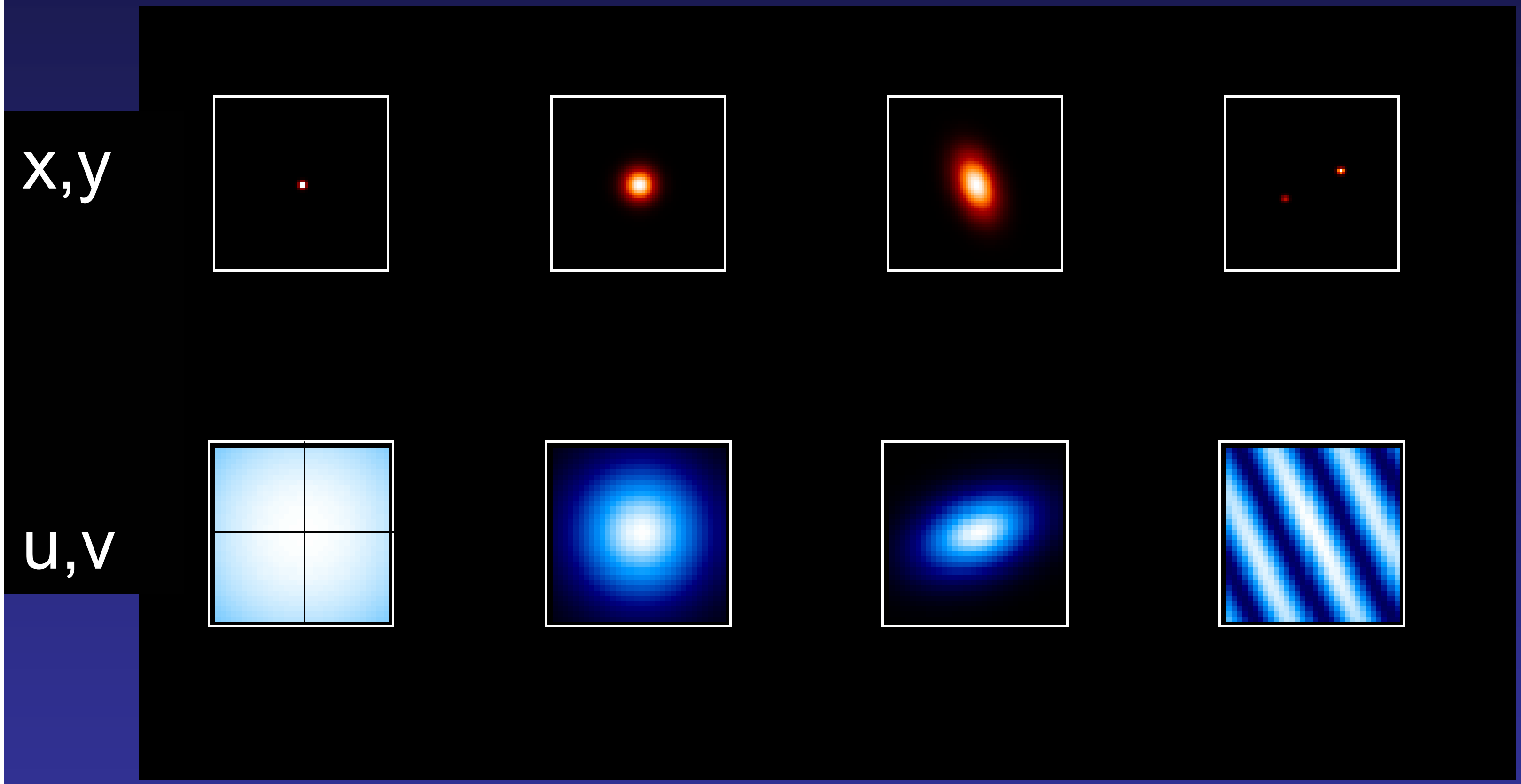


Image ⟷ Visibilities

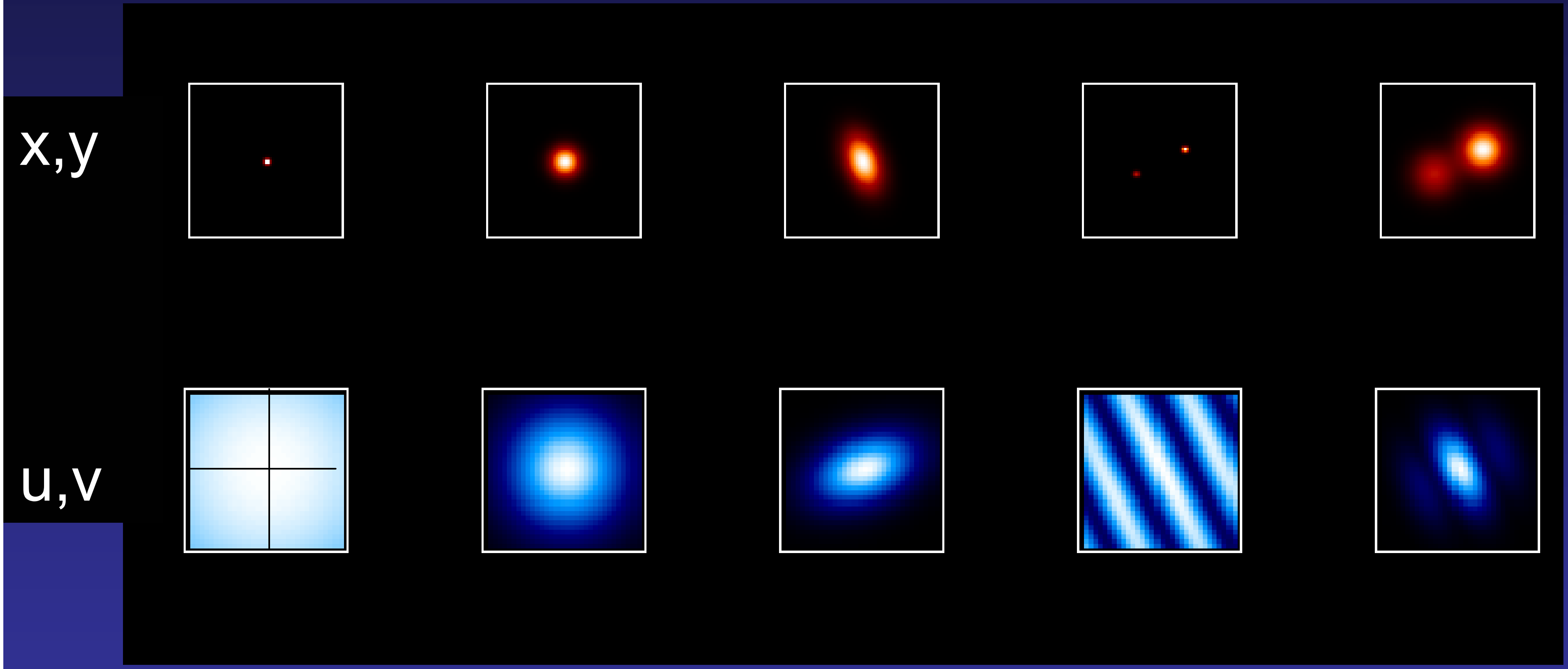
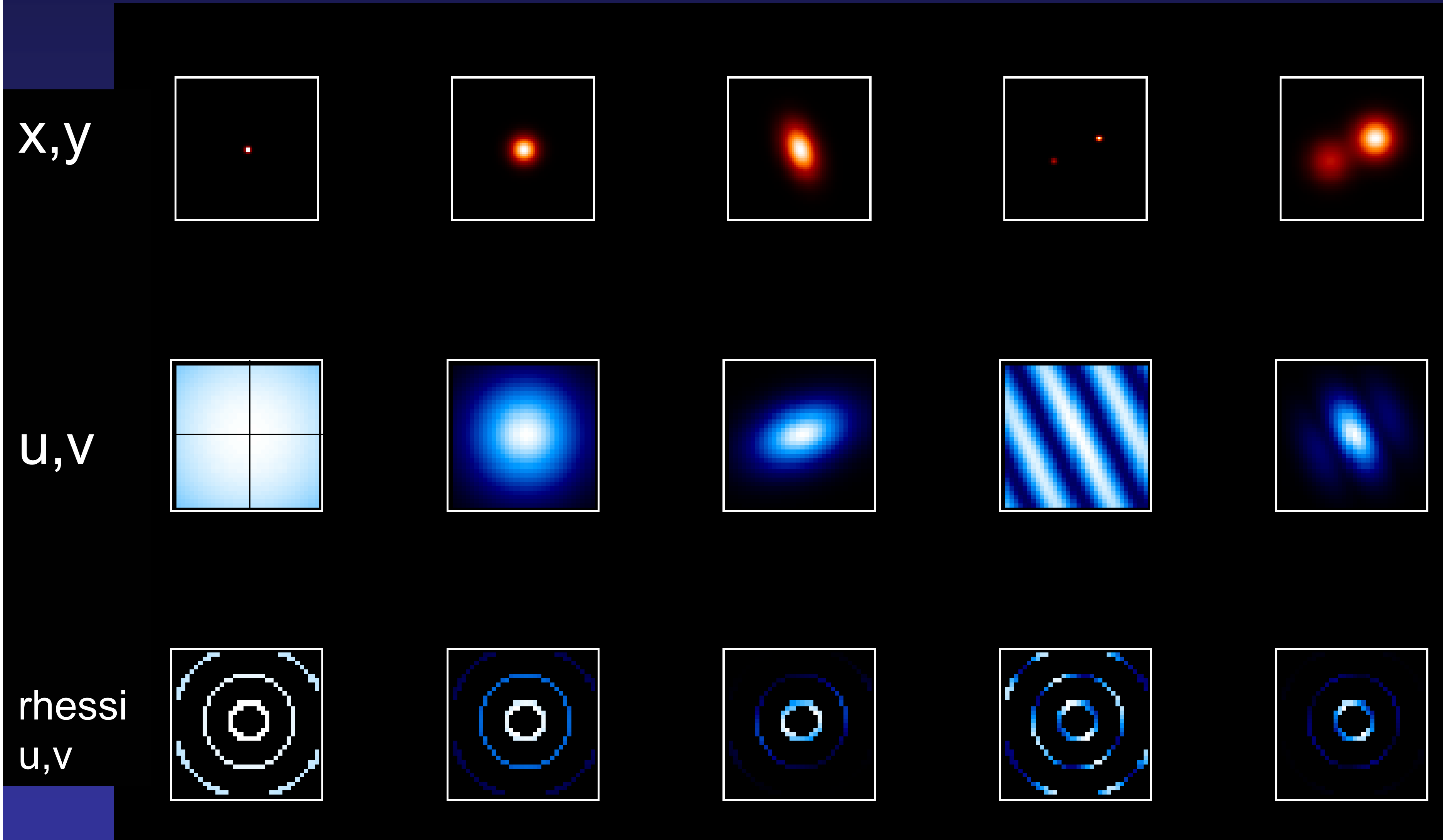


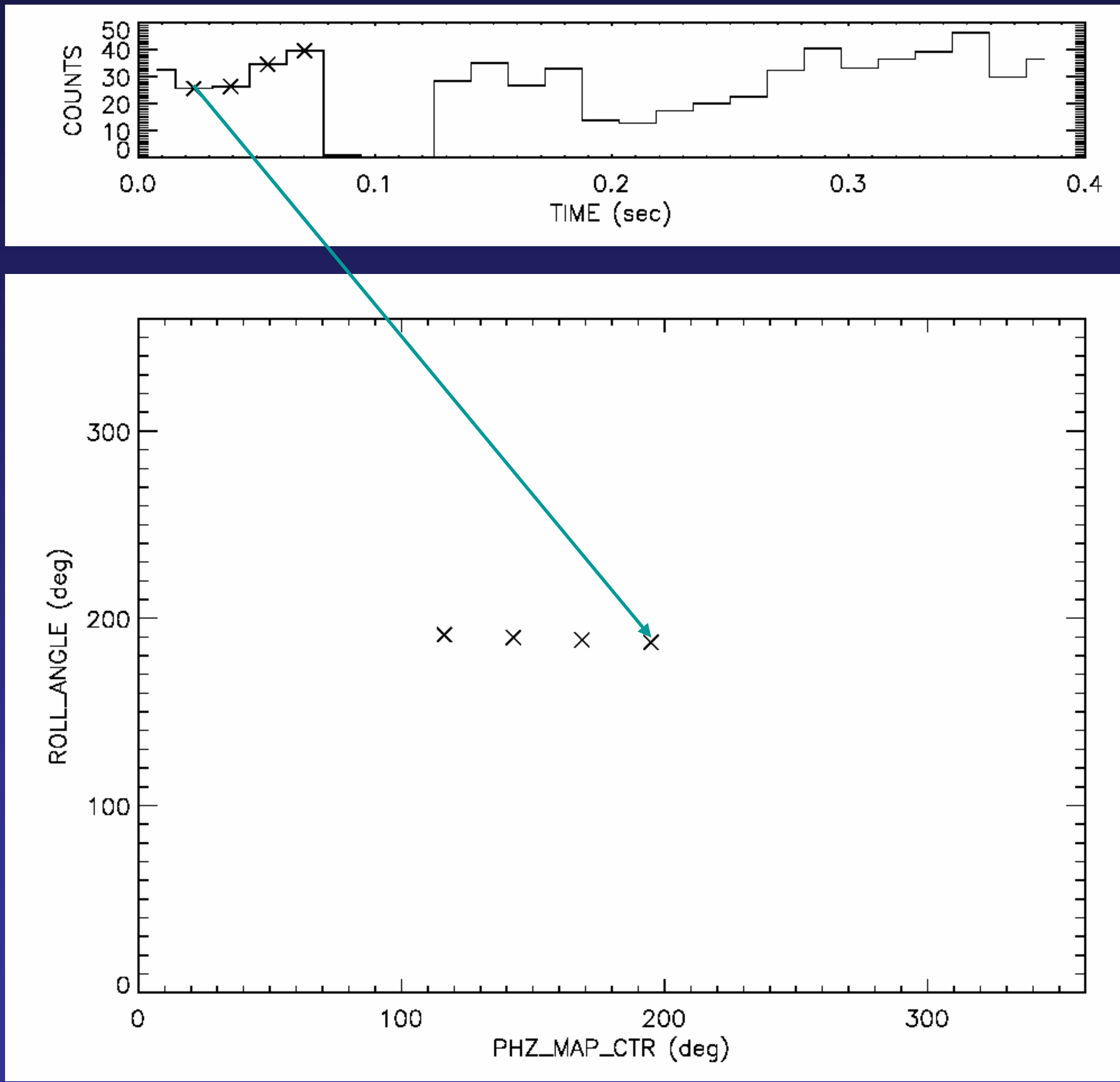
Image ⟷ Visibilities



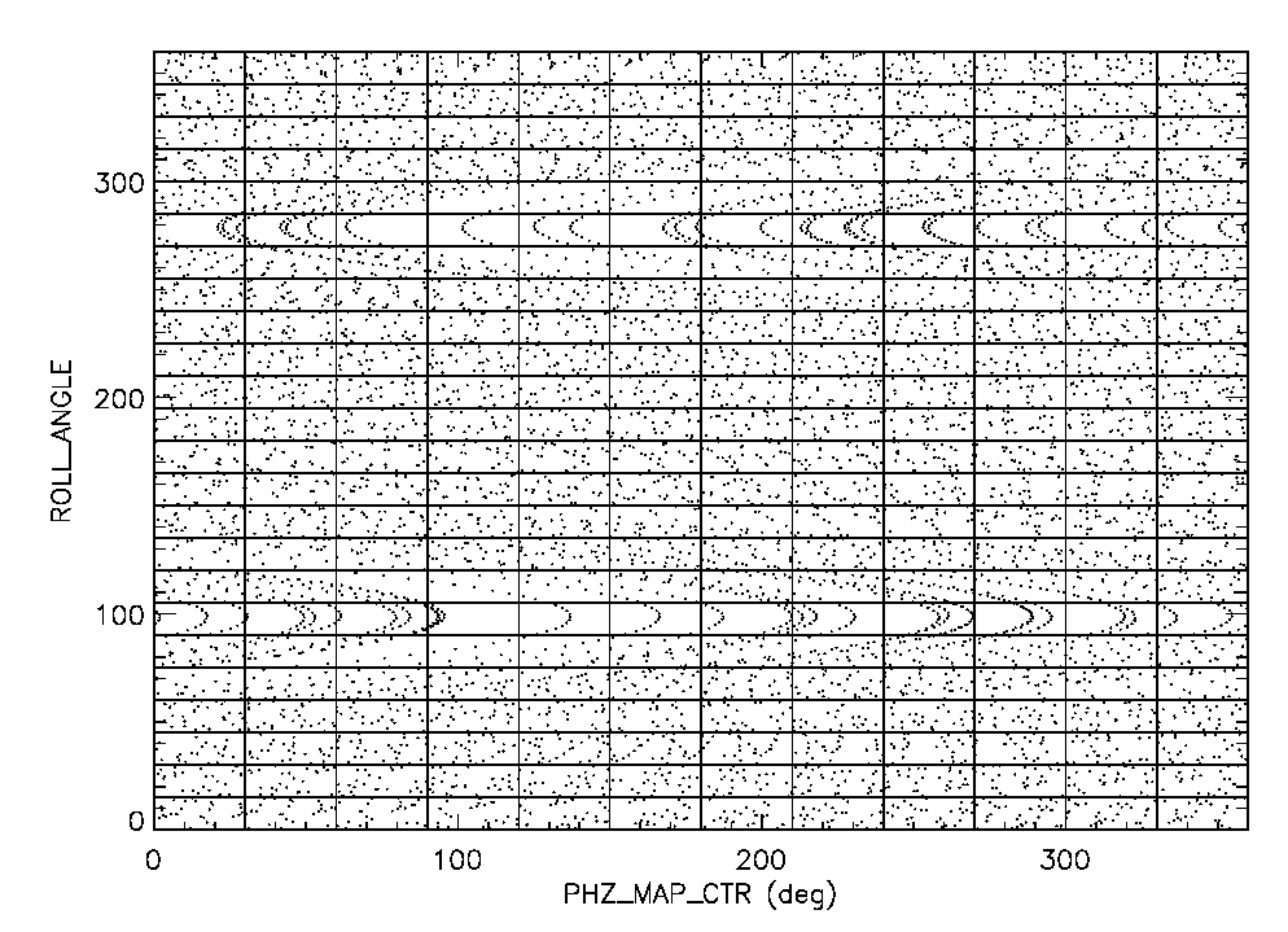
Measuring Visibilities with RHESSI

1. Map calibrated eventlist to roll/phase bins with stacker.
   (This is the only time-consuming step.)
2. For each roll bin, fit count rate vs. phase.
3. Save measured visibilities as a “bag of visibilities”.
4. Optionally display / edit / combine visibilities.
5. Use visibilities in your application.

Mapping Time Bins to Roll/Phase Bins

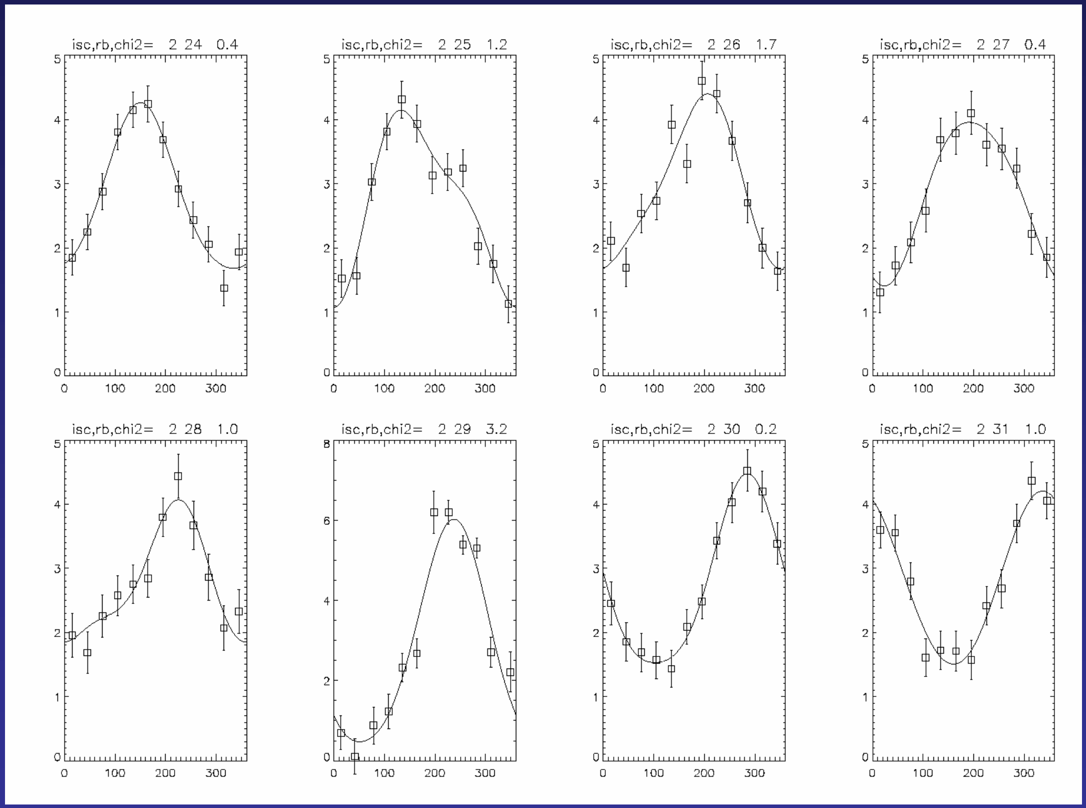


Roll and Phase Bins



Rate vs. Phase Bin Fits

Typical plots of rate vs. phase bin at 8 roll orientations.



5 parameter fits of amplitude and phase at fundamental and 2^{nd} harmonic

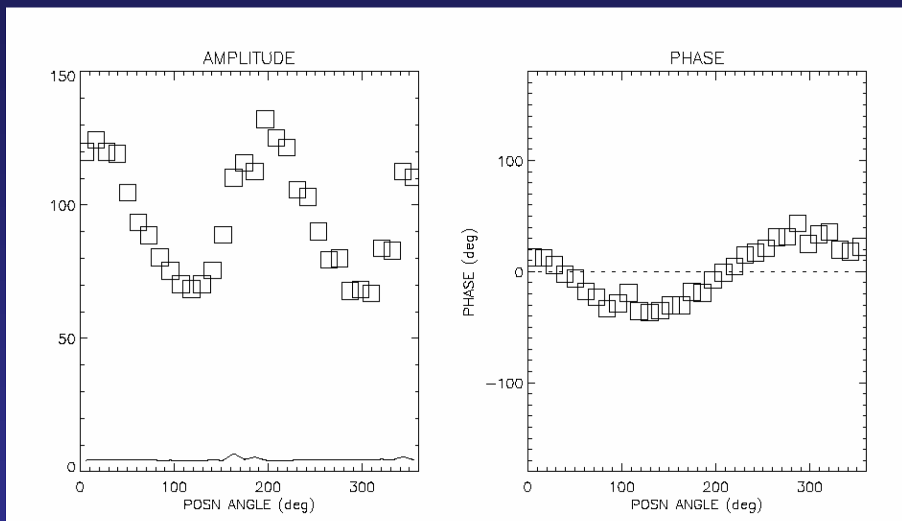
USEFUL PROPERTY:

Evaluates statistical errors in visibilities.

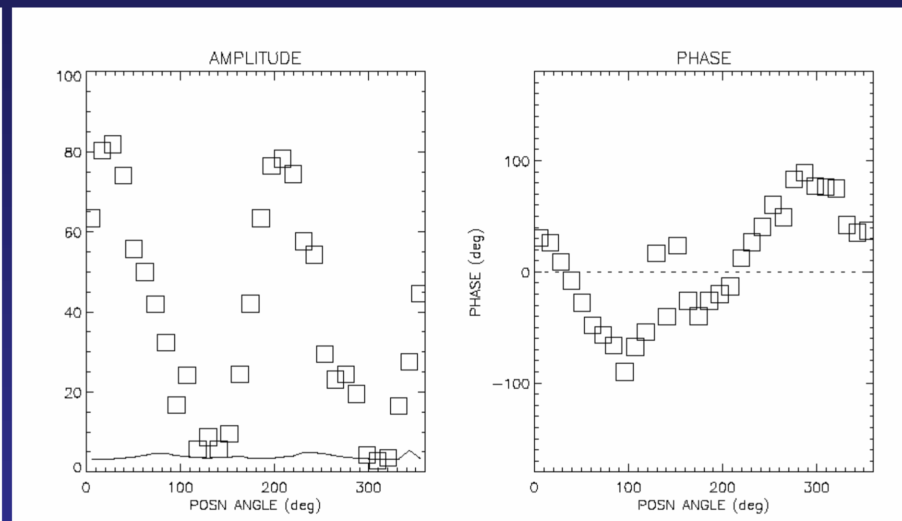
Displaying Visibilities

Amplitude and phase vs. position angle

RMC 7



RMC 6



USEFUL PROPERTIES:

Amplitudes and phases are fully calibrated (ph/cm2/s).

Phase coherence is a reliable indicator of ‘detection’.

Conjugate visibilities can be averaged.

Visibility Applications

- hsi_vis_fwdfit determines the best fit parameters for simple sources
    - ➔Flux, size, orientation, location vs. time, energy
    - ➔Ability to fit albedo
- mem_njit = a new, visibility-based maximum entropy algorithm
- Insight into imaging performance and limitations
- Improved grid calibration
- Harmonics
- Can be used as input to radio astronomy imaging packages
- Imaging in photon energies, not detected energies
- High time resolution studies
- Long time integrations
- Weighting (t, E) may enhance sensitivity for weak sources
- Source fine structure

hsi_vis_fwdfit

- Visibility-based imaging algorithm that determines best-fit parameters for simple source geometries
- Currently supported shapes
    - Elliptical gaussian (default)
    - Circular gaussian
    - Loop (= curved elliptical gaussian)
    - Two circular gaussians
    - An optional, combined albedo component
    - User selects shape and approximate location
- Determines statistical errors in fitted parameters

ASSUMES selected shape is a good representation of real source !!!

Visibility Software

Example:

To make a set of visibilities,

```
vis = his_vis_usershell (time='2005-jul-30 '+['06:29', '06:36'], $
            energy=[25,50], xyoffset=[-810,140],   $
                phz_radius=30)
```

optional

To display visibilities:

```
hsi_vis_display, vis, /ps
```

To make a forward fit map (assuming a curved elliptical gaussian)

```
his_vis_fwdfit, vis, /loop, /showmap
```

For details:
sprg.ssl.berkeley.edu/~ghurford/VisibilityGuide.pdf

Preliminary version of visibility software is on ssw

Demo of hsi_fwd_fit
and exercise with Aug 28 event