Indian X-ray Polarimeter (POLIX)
Onboard X-ray Polarimetry Satellite (XPoSat)

- X-ray polarization measurement methods and POLIX
- Some of the Key science issues to be addressed with POLIX
- POLIX in the context of other missions

Biswajit Paul
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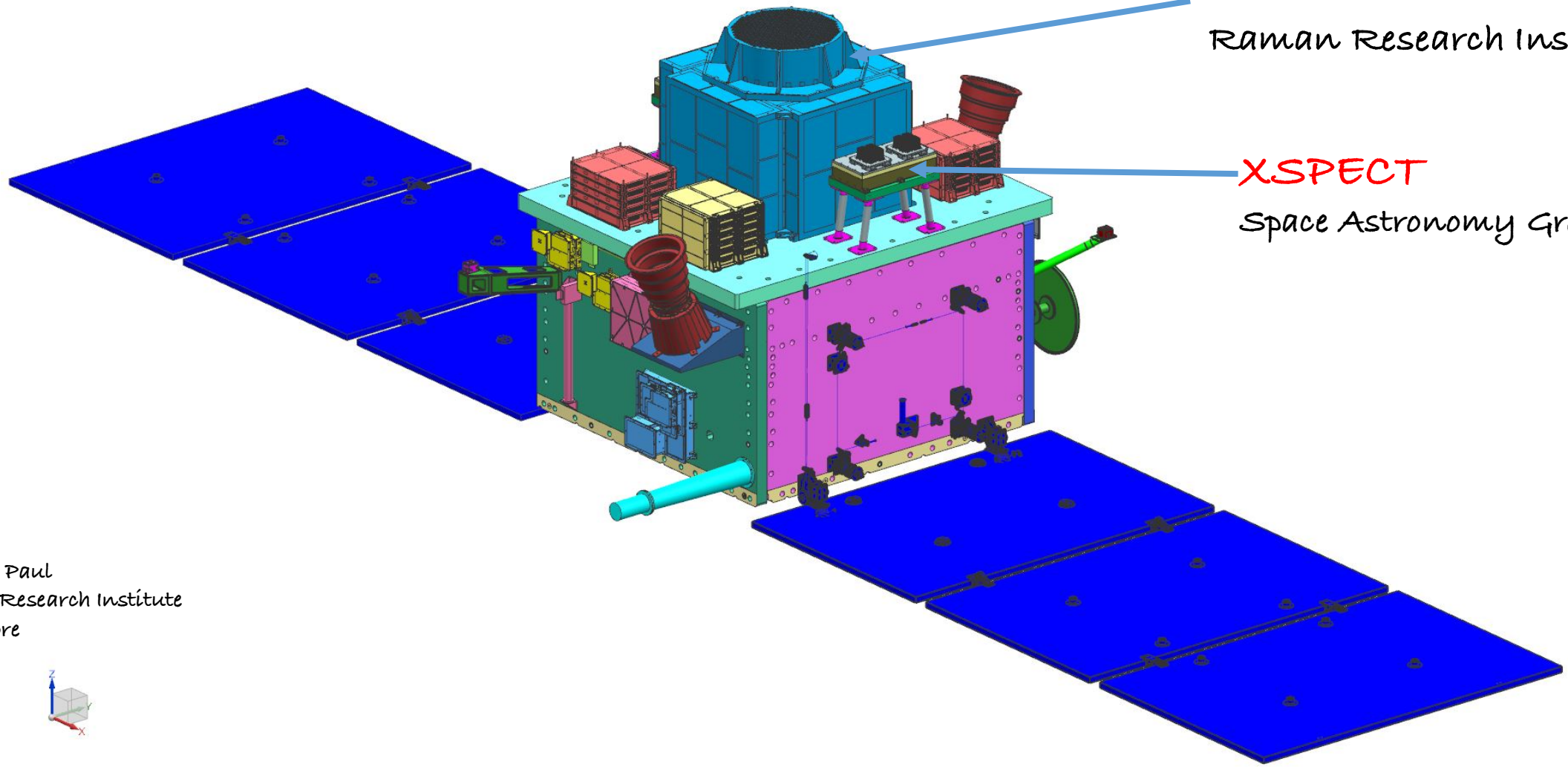
Bangalore

X-ray Polarimetry Satellite



POLIX

Raman Research Institute

XSPECT

Space Astronomy Group - URSC

Biswajit Paul
Raman Research Institute
Bangalore

X-ray Polarisation

Polarisation is relatively unexplored in High Energy Astrophysics

X-ray emission from the following processes should be polarised

- Emission, transmission through magnetic field
- Emission, scattering from non-spherical plasma
- Synchrotron, Cyclotron , Non-Thermal Bremsstrahlung

These objects should produce polarised X-ray radiation

- Accretion powered pulsars
- Rotation powered pulsars
- Magnetars
- Pulsar wind nebulae
- Non-thermal supernova remnants
- Black holes, micro-quasars and active galactic nuclei
- Low Mass X-ray Binaries
- Solar X-rays
- Gamma Ray Bursts

Crab nebula is the only source for which high S/N X-ray polarisation Measurement exists.
This was made in 1976 & recently with Astrosat and PolarLight

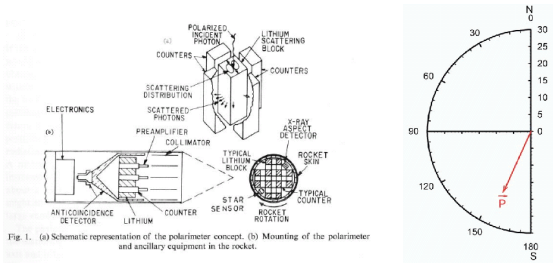
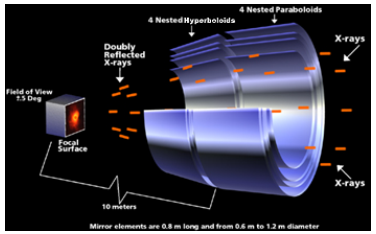
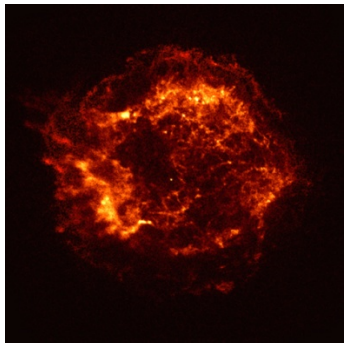


Fig. 1. (a) Schematic representation of the polarimeter concept. (b) Mounting of the polarimeter and ancillary equipment in the rocket.

Chandra X-ray Observatory





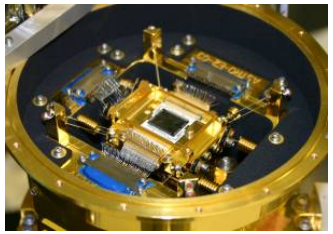
Imaging

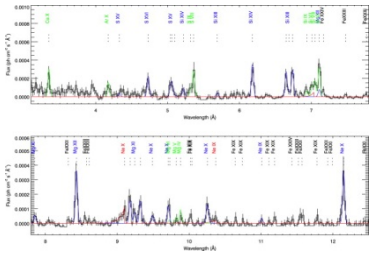
Polarisation

Astronomy

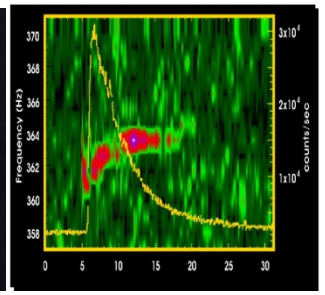
Timing

Spectroscopy



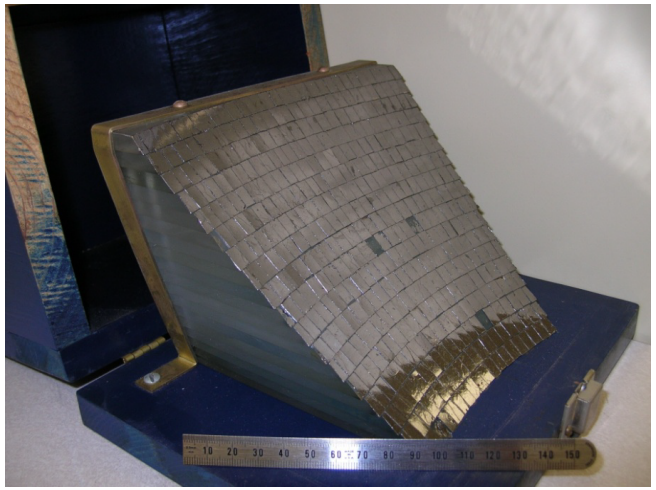


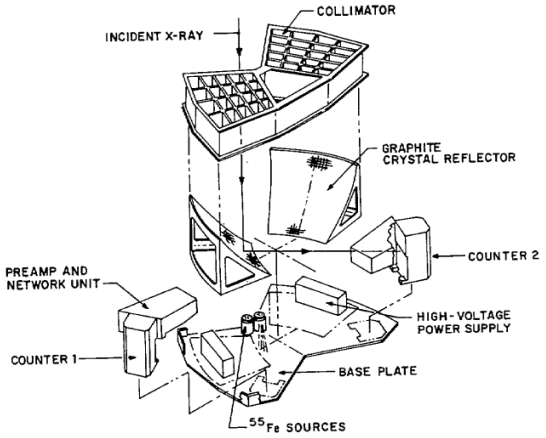
Hitomi



RXTE / Astrosat

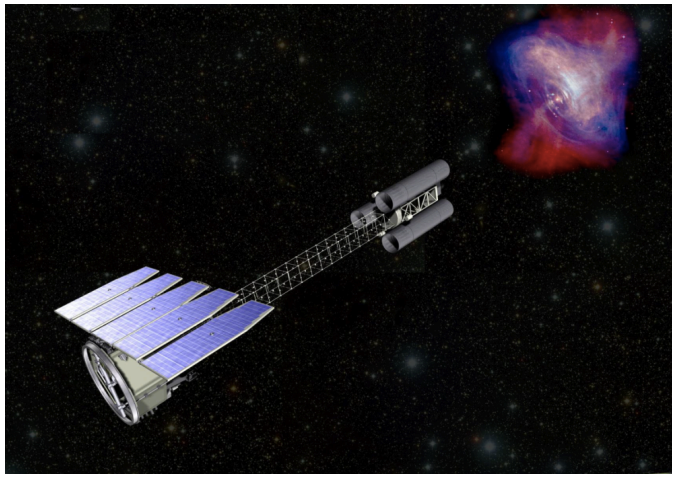
X-ray Polarimetry: Past, Present, and near Future



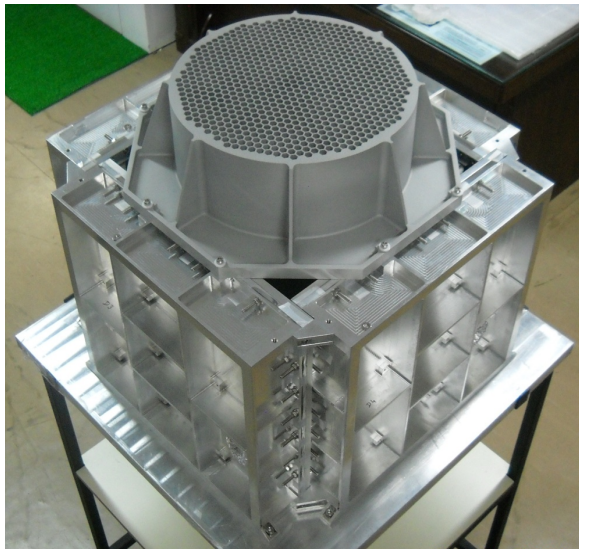


OSO – 8 / Bragg Reflection

ASTROSAT – CZTI
Compton Scattering



IXPE / Photoelectron Polarimeter



POLIX – XPoSat
Thomson Scattering

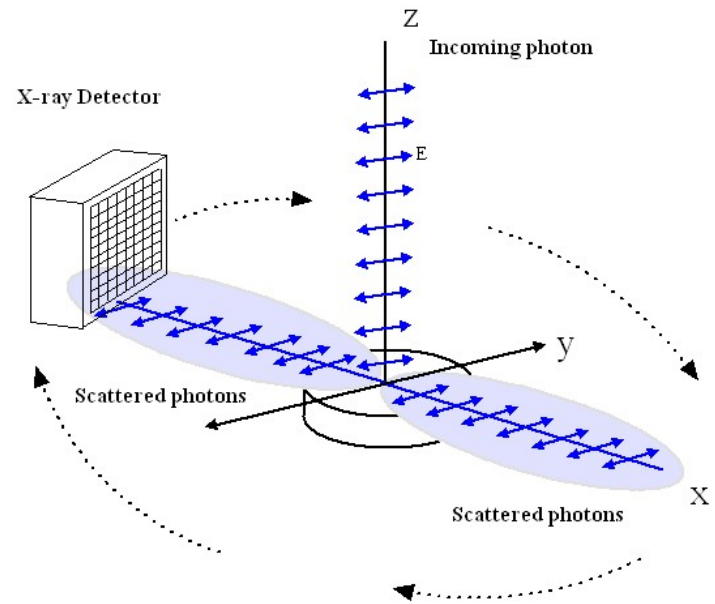
X-ray Polarimetry: Techniques

- Bragg reflection: < 3 keV
- Photo-electron track: 2-8 keV
- Thomson scattering: 5-30 keV
- Compton scattering: > 30 KeV
- MeV-GeV-Tev band polarimetry being explored

- Pointed : for known X-ray sources
- Wide field: for GRBs

Thomson X-ray Polarimeter

- Photoelectron/Bragg: < 8 keV
- Thomson: 5-30 keV
- Compton :> 30 KeV



Instrument Configuration

Satellite Requirement

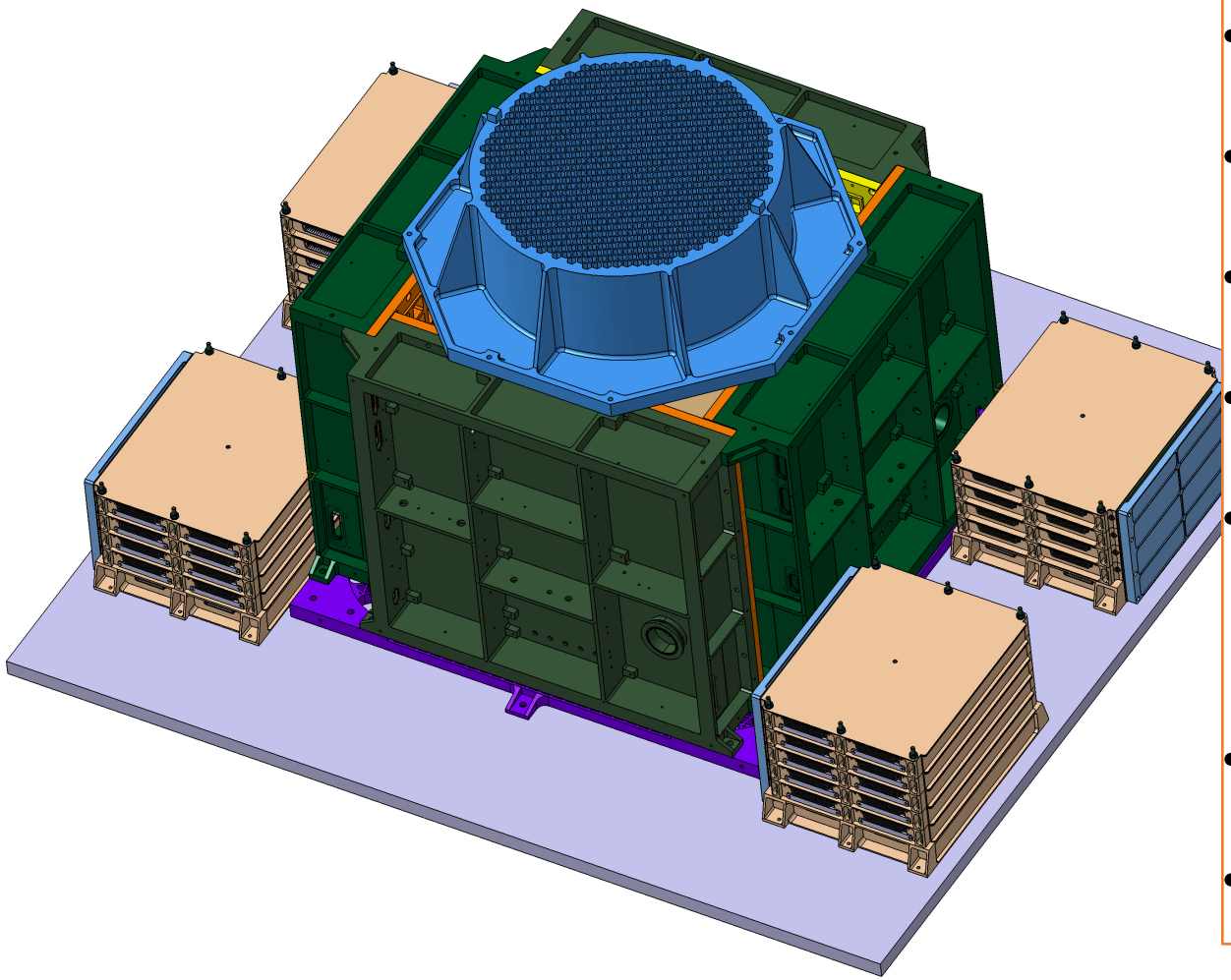
Absolute Pointing Accuracy: < 0.1 degree

Spin around viewing axis: 0.2 rpm

Long Observations: 1-4 weeks on one source

Maximum possible duty cycle

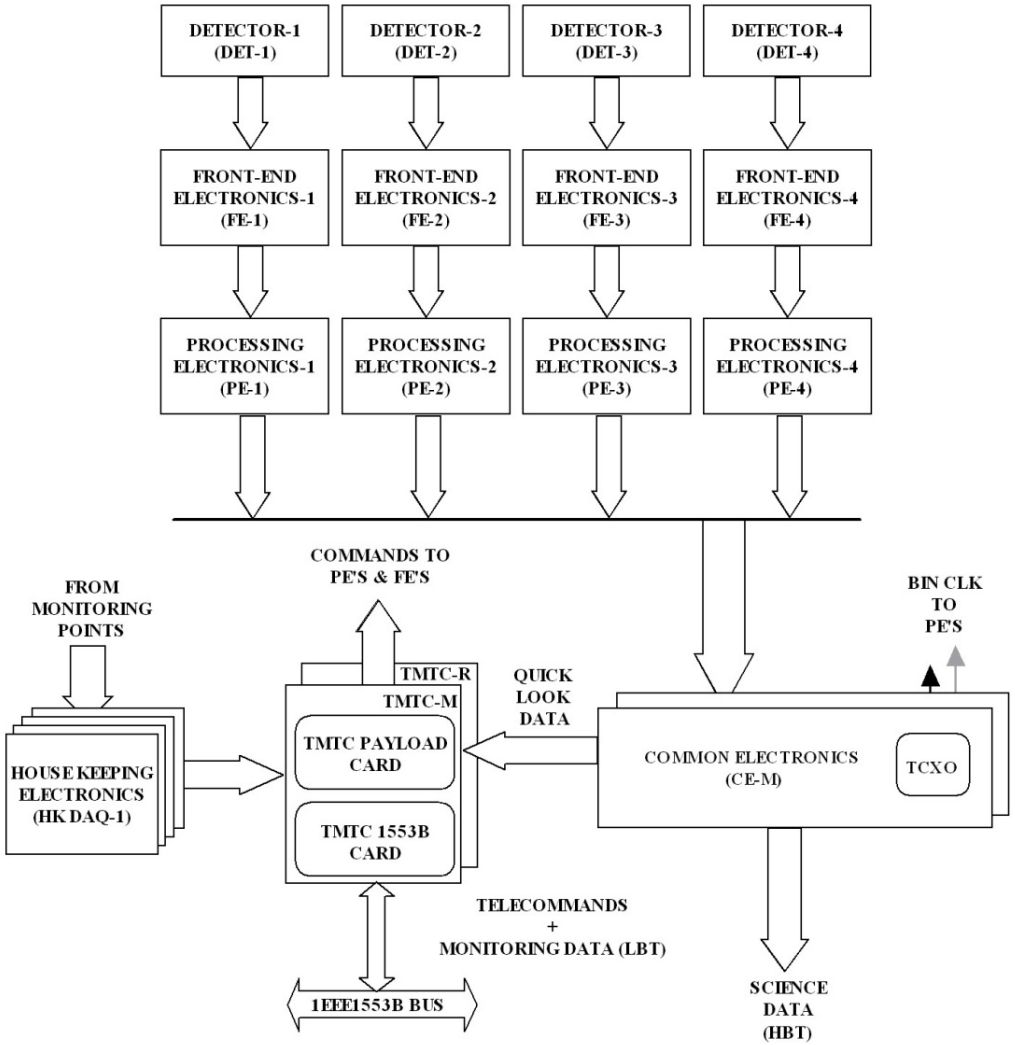
POLIX



- Collimator
- Scatterer
- Detectors
- Detecotr drive electronics
- Signal processing electronics

- Low Scattering Efficiency
- Large Background

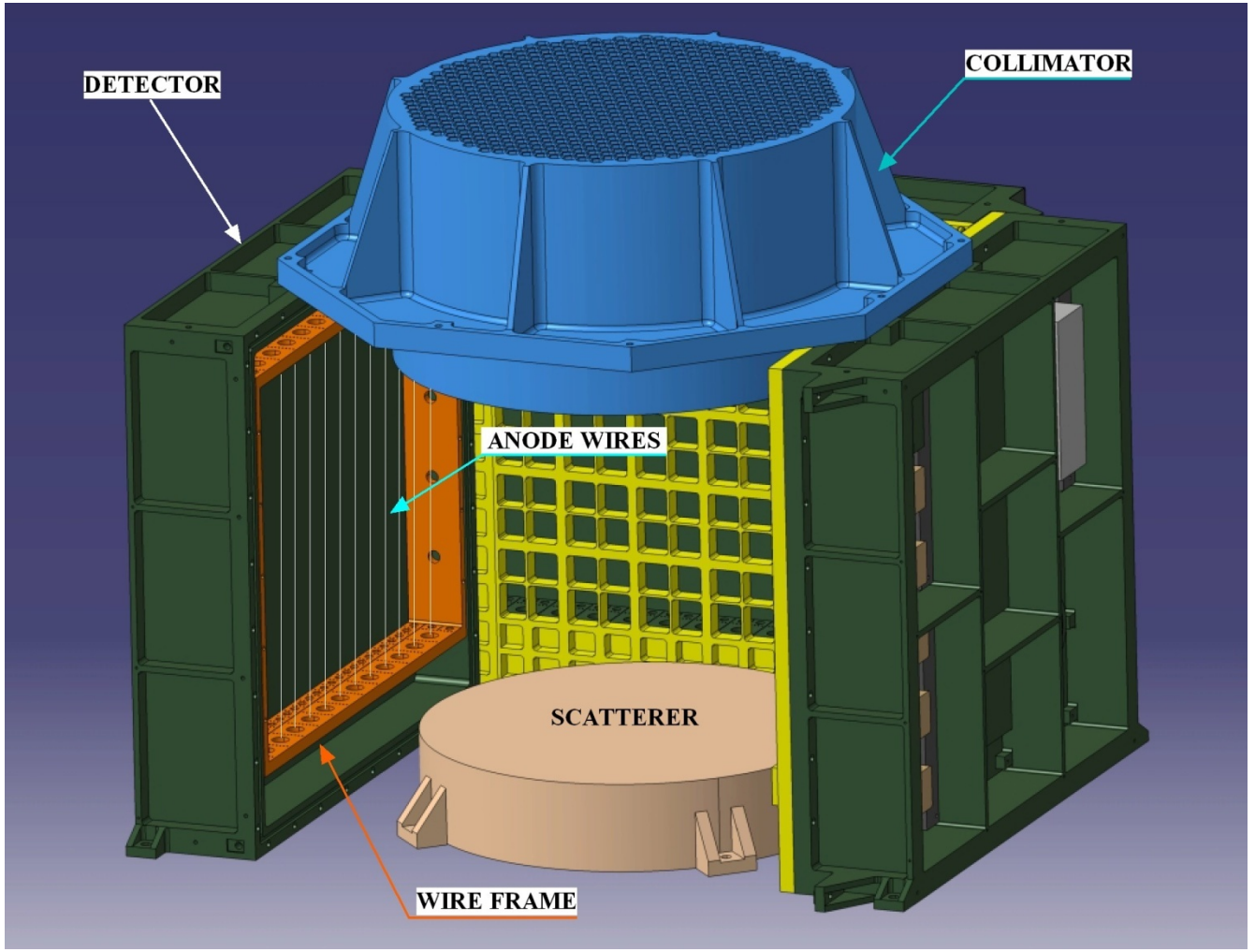
Electronics



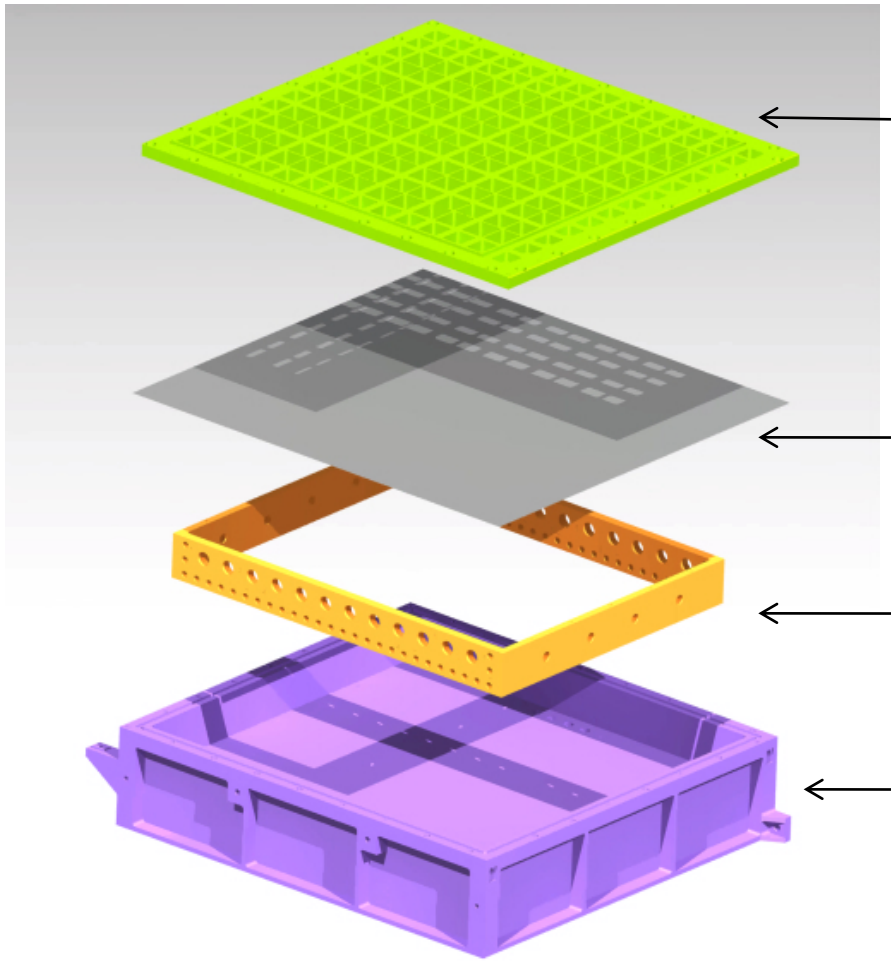
POLIX Specifications

Parameter	Value
Photon Collection Area	640 cm^2
Field of View	3 degree x 3 degree
Energy Range	8-30 keV
Detectors	Proportional Counters
Scatterer	Beryllium
Dimension	650 mm x 650 mm x 600 mm
Mass	125 kg
Power	87 Watt
Data Rate	6.5 Gb per day
Modulation factor	40-44%

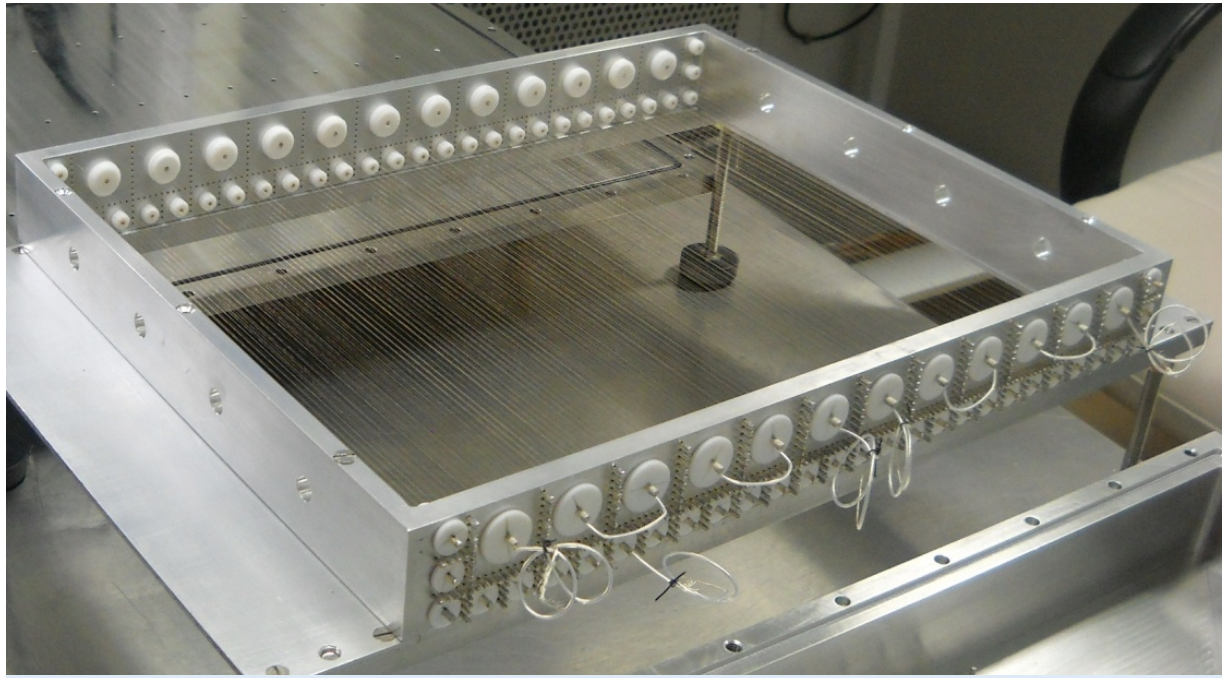
Mechanical configuration.....



Detector


Top plate or
Window support plate
Mylar window
Wire frame
Detector housing

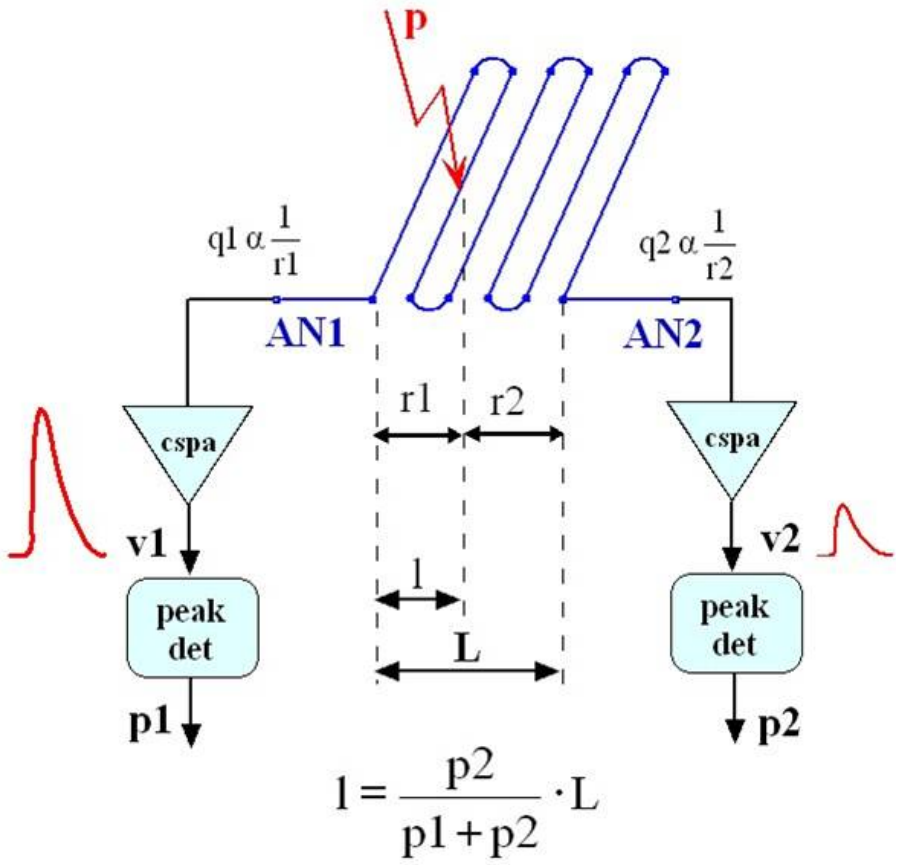
Wireframe



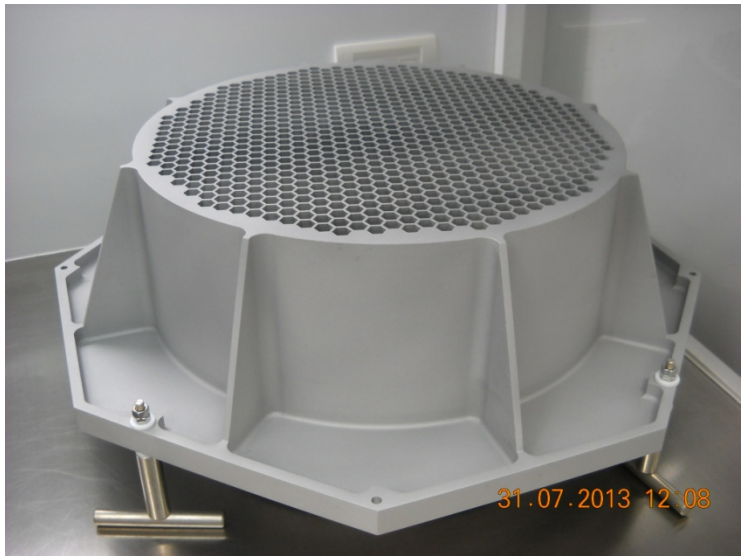
A fully wired wireframe

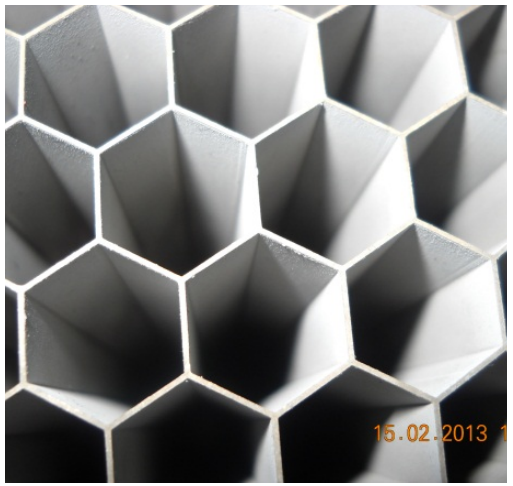
Principle of charge division

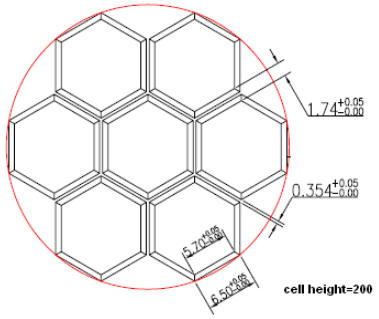
- Principle of Charge Division.
- Resistive Nichrome wires
- Wires looped together at the ends

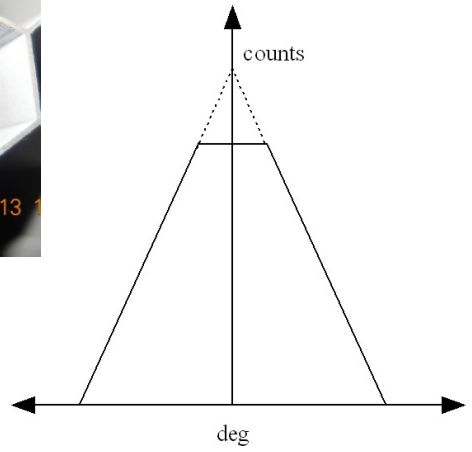


Collimator



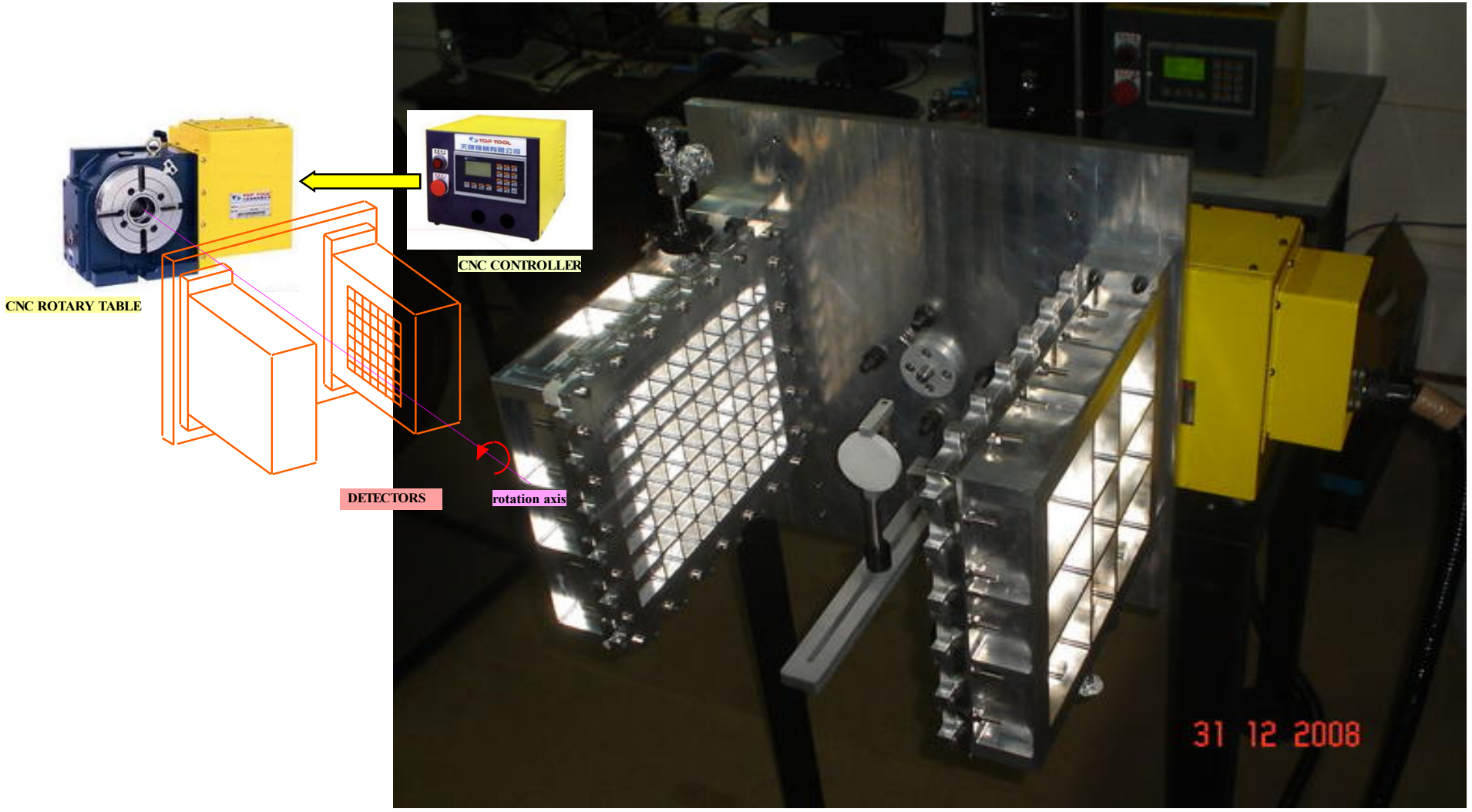




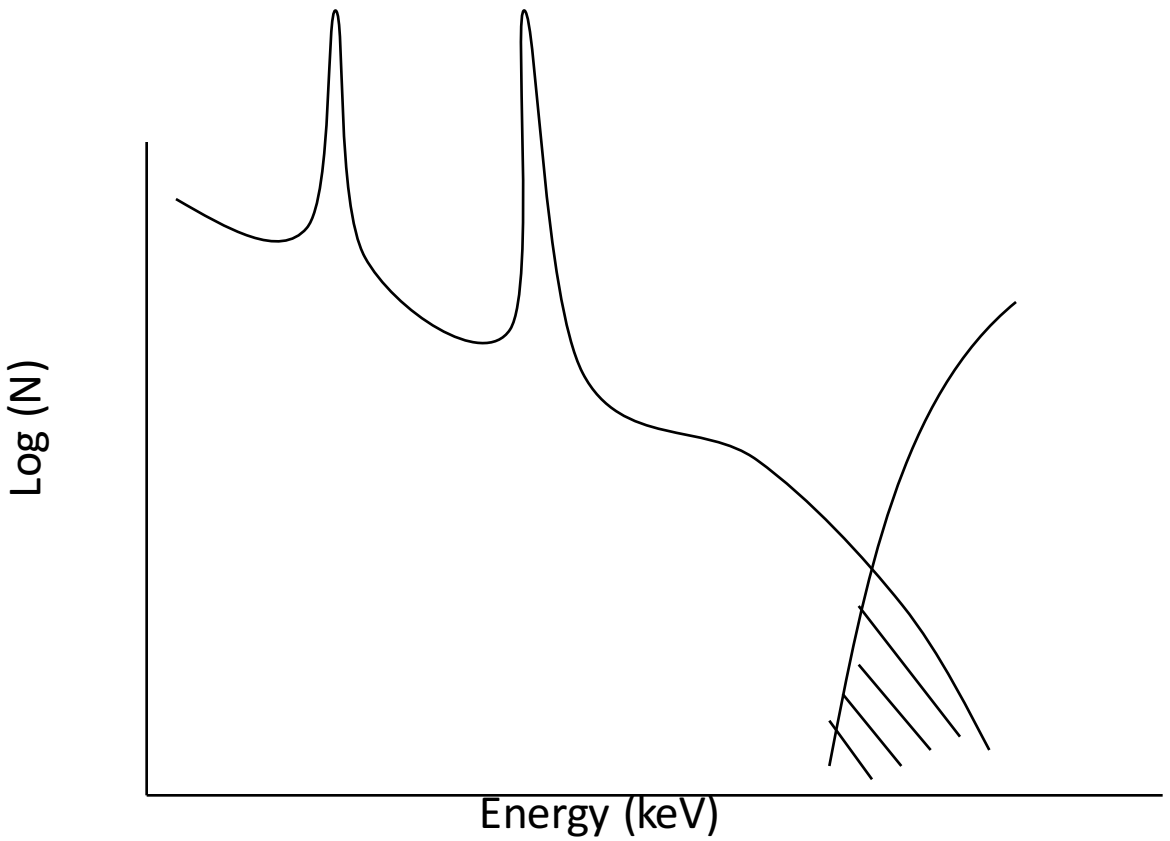


- Restricts the field of view to 3 deg x 3 deg
- Hexagonal tapered holes
- Flat top response (±0.2 deg) – to mitigate pointing offset

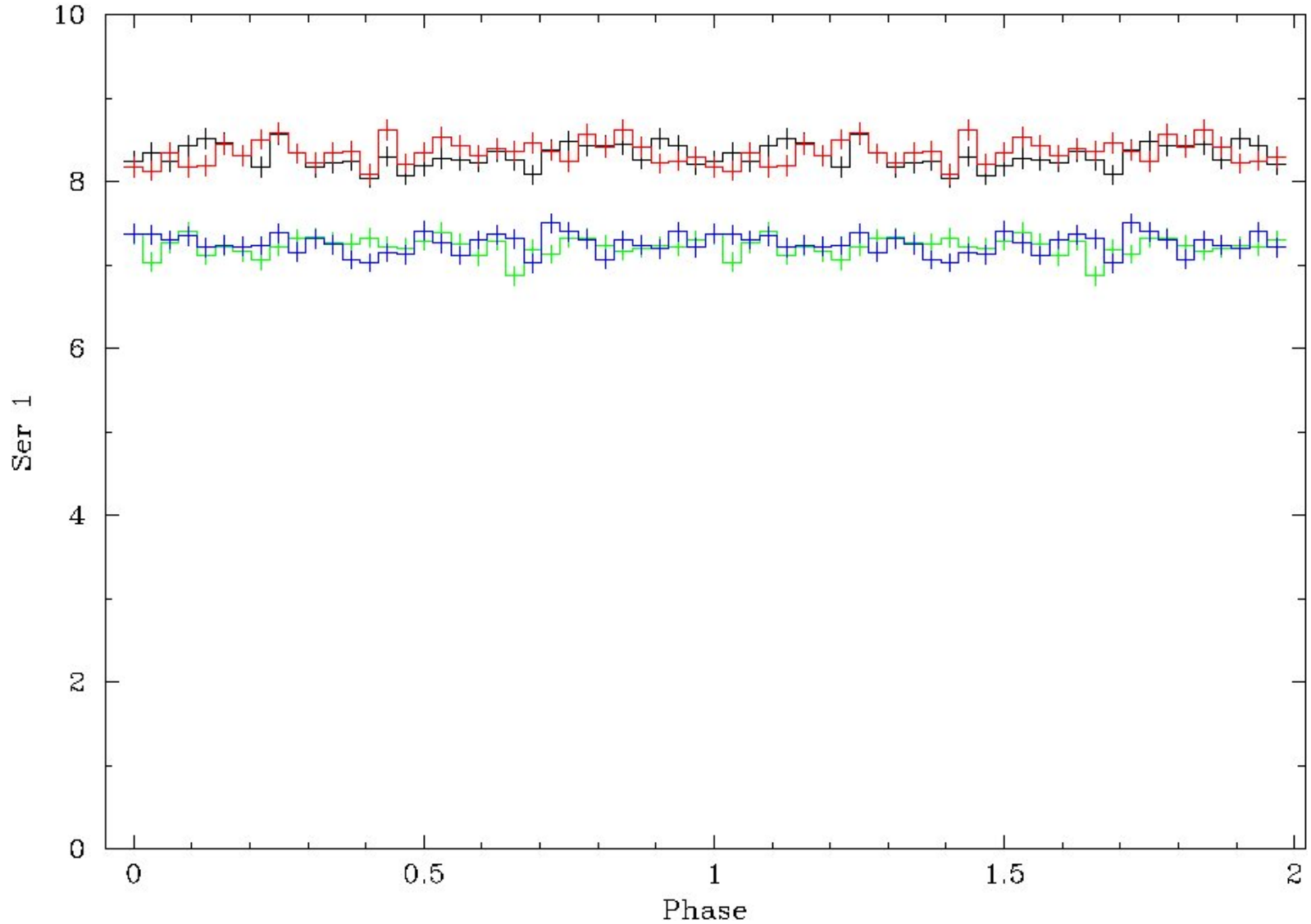
Laboratory Unit



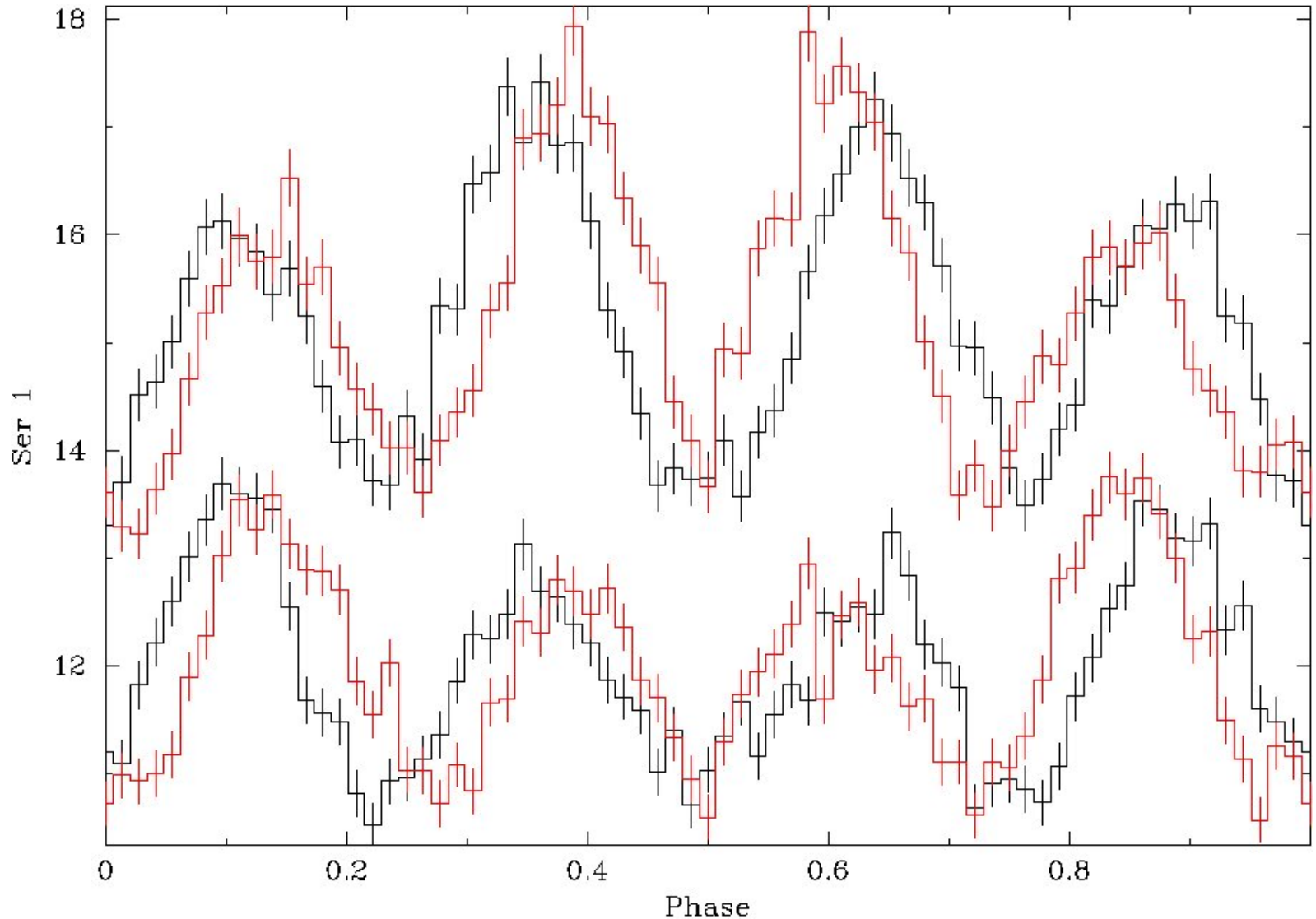
Polarised X-ray Source



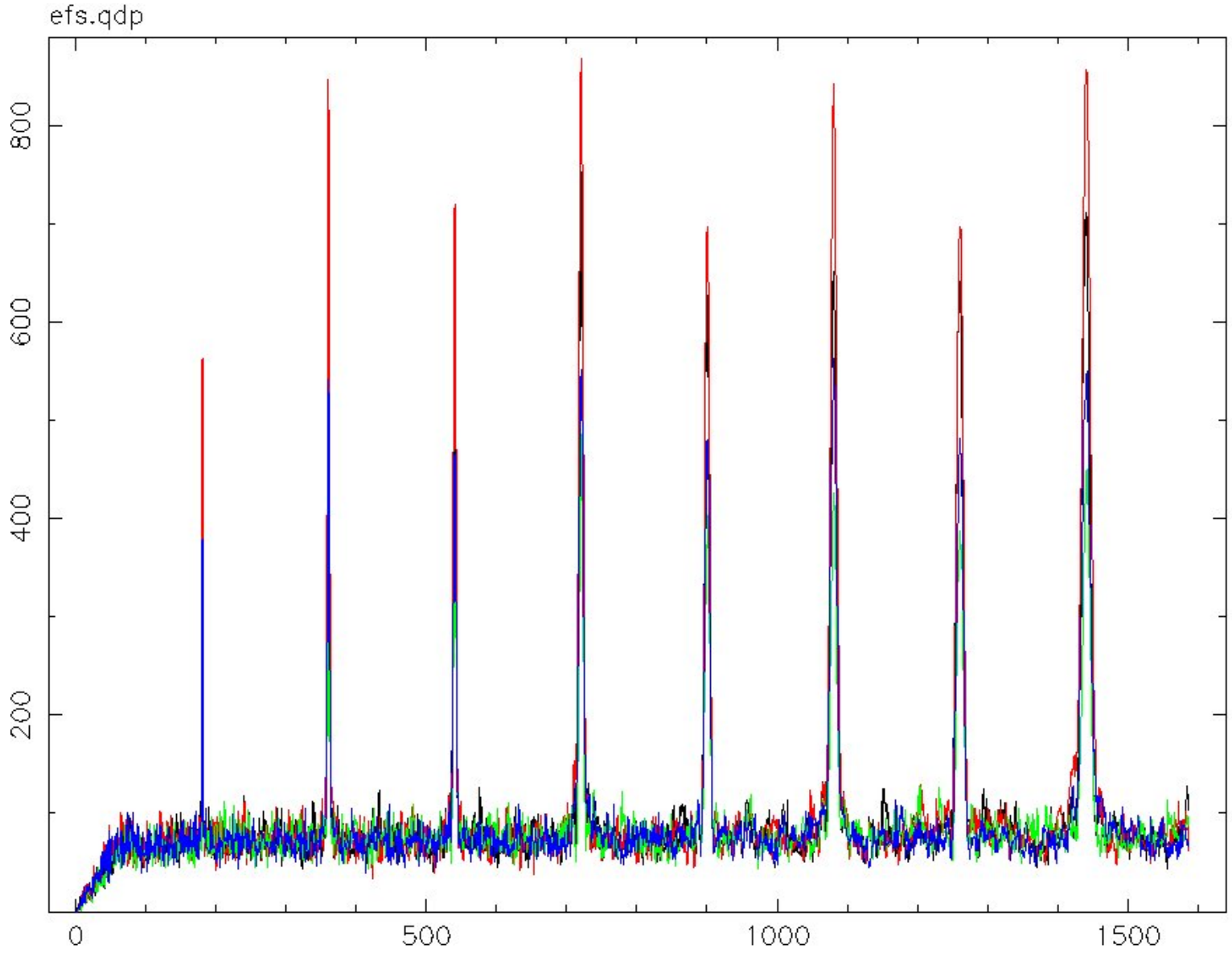
Test Results



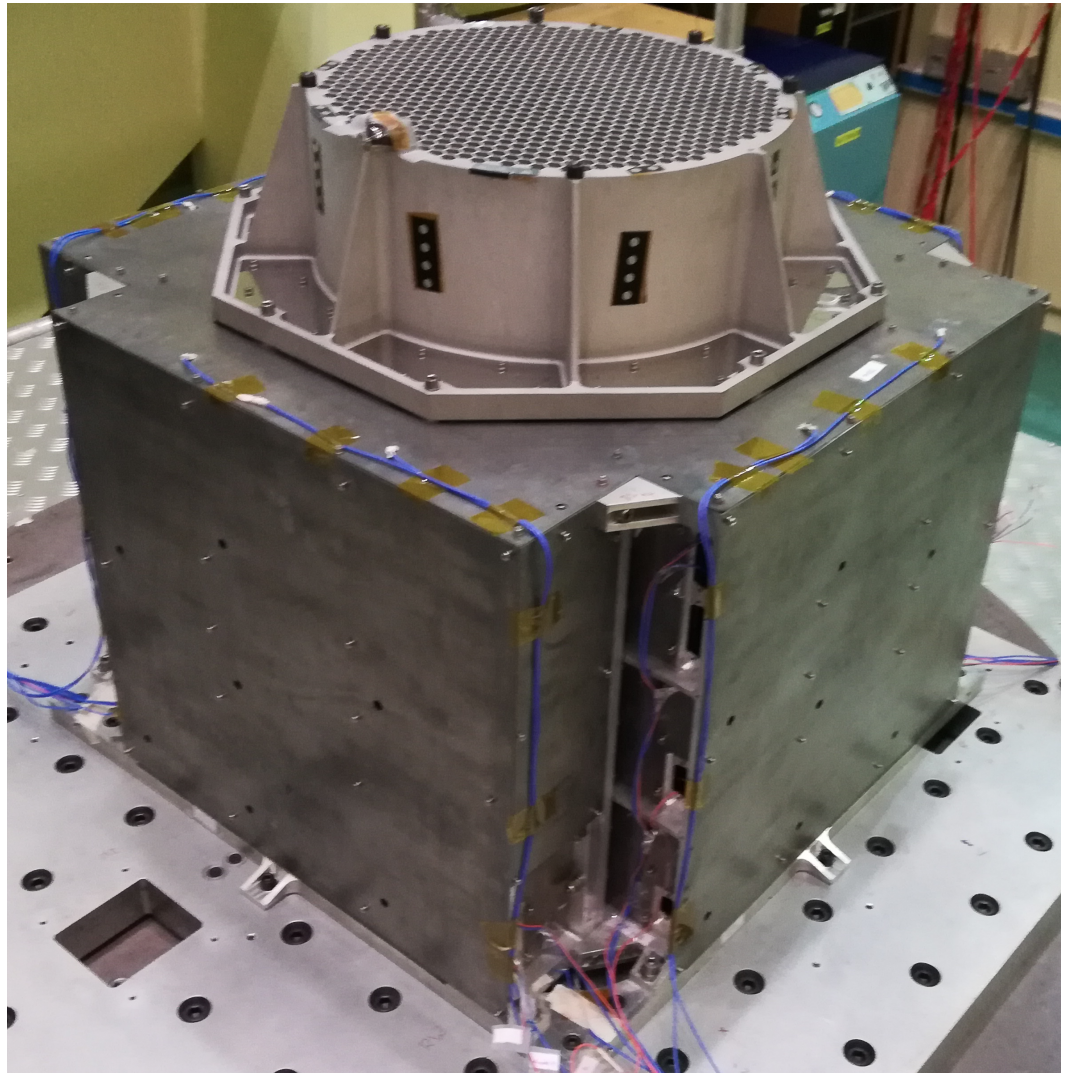
Test Results

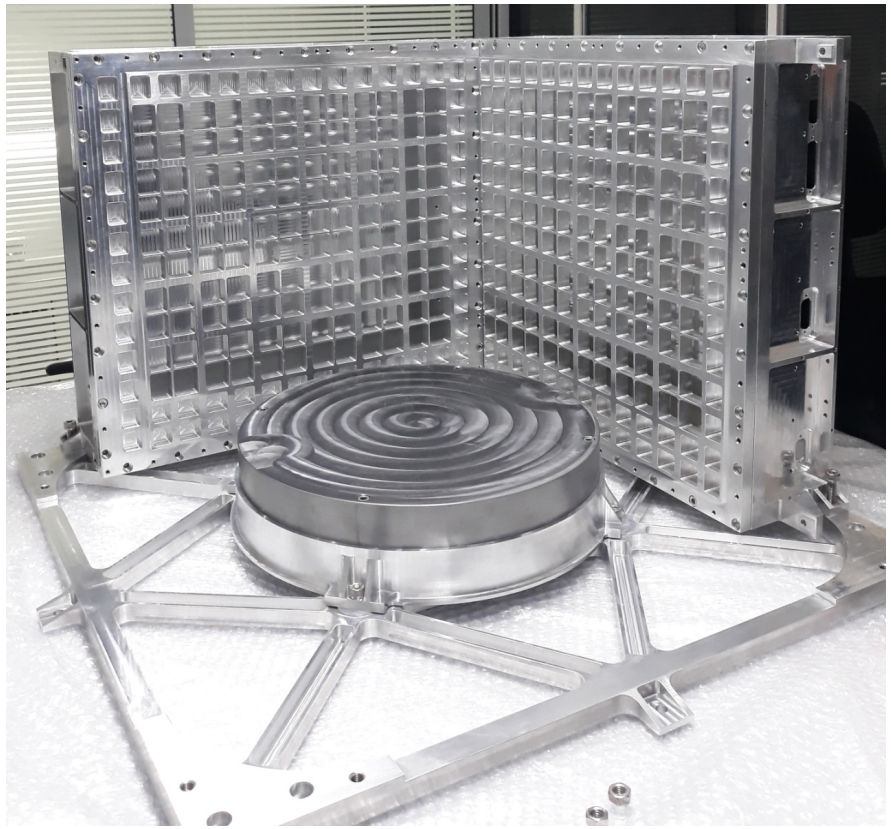


Test Results

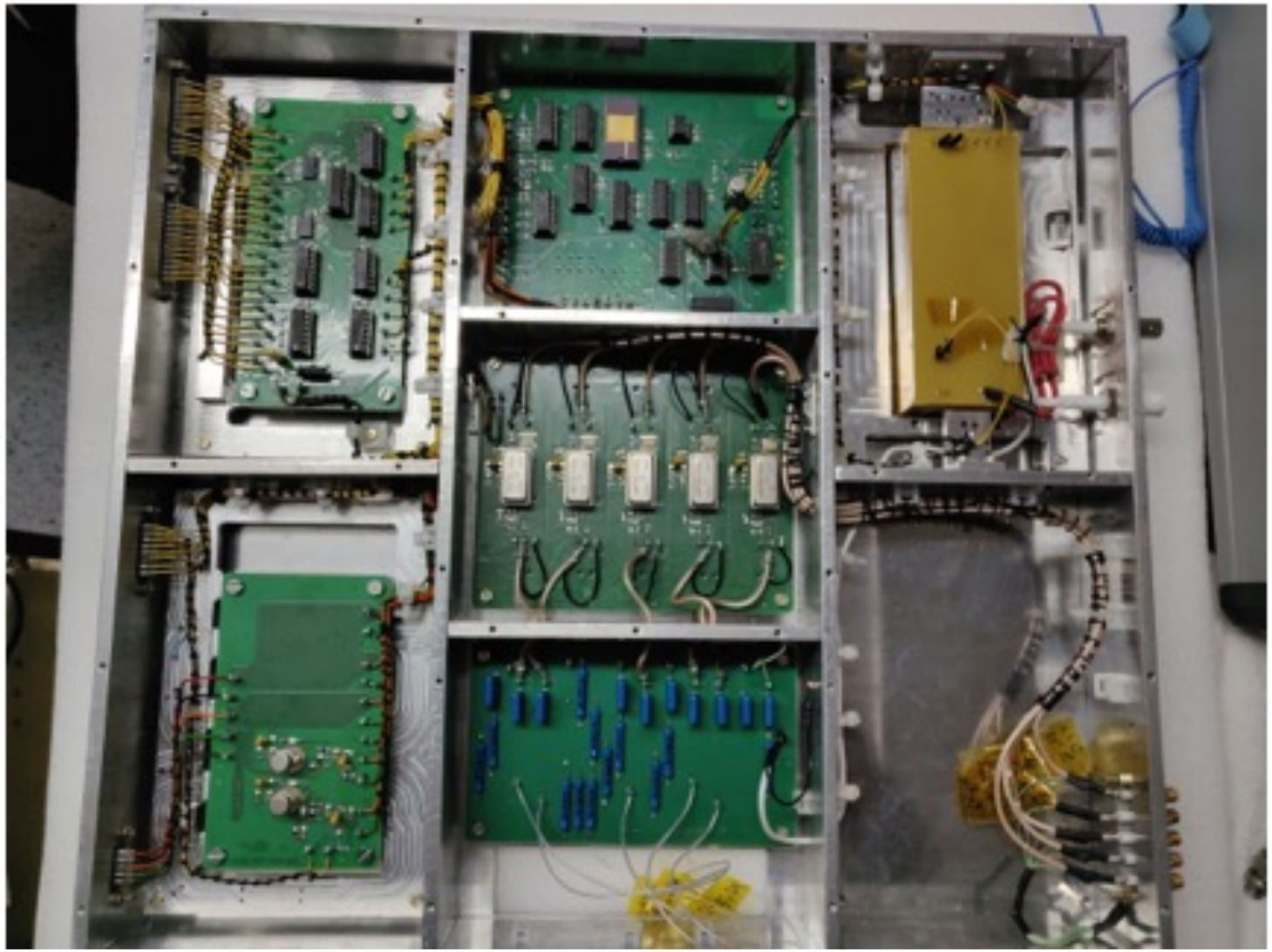


POLIX detector system





Front-end electronics



Processing Electronics

PE-analog card

PE-digital card

HK card

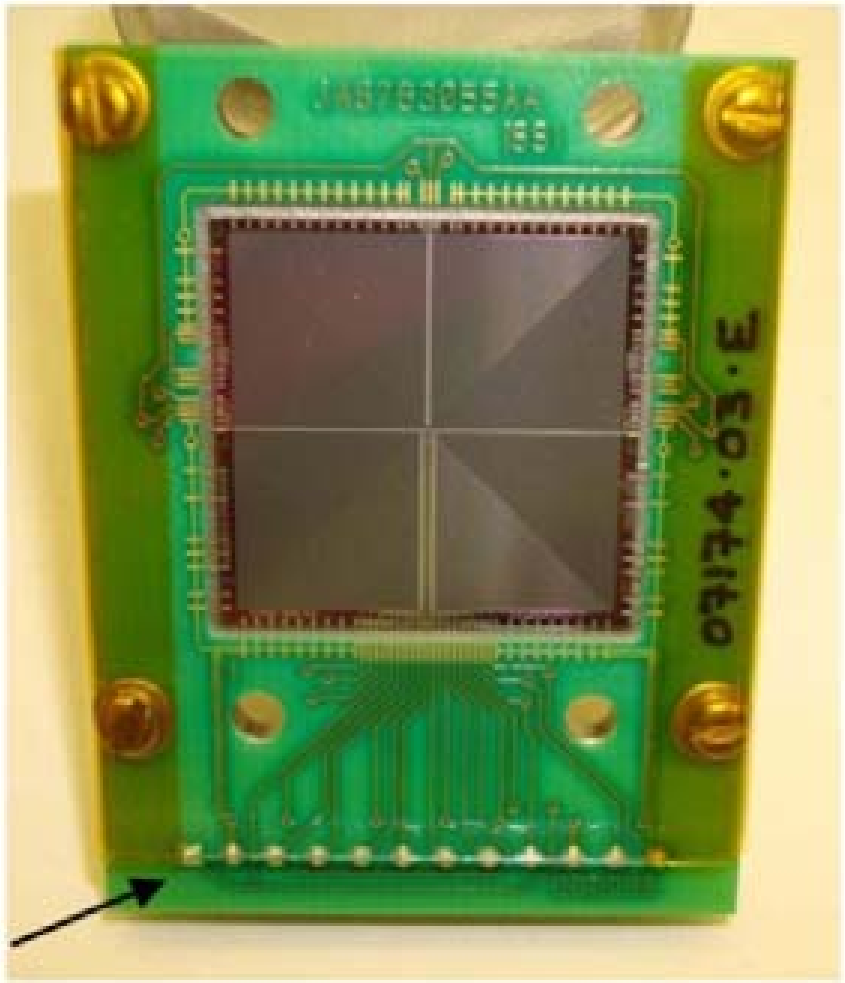
TMTC-PLD card

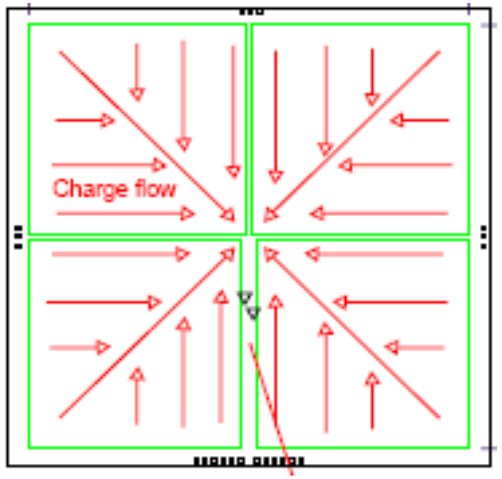
TMTC-RT card

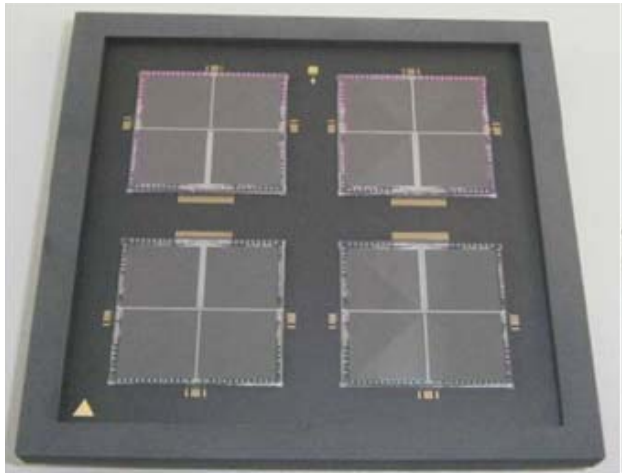
BE-power card

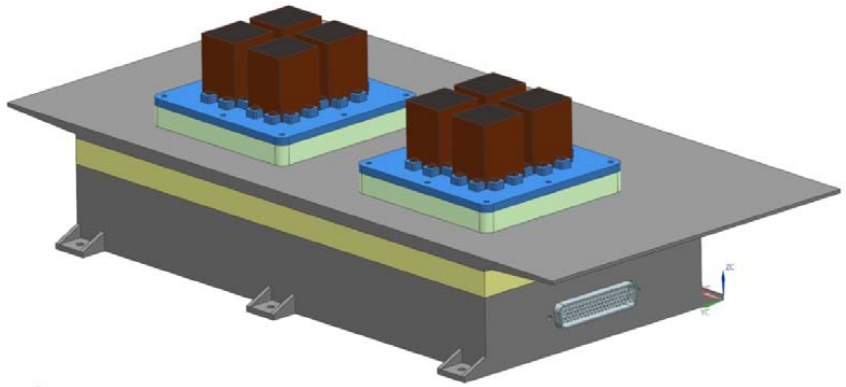
CE card

X-ray SPECtroscopy and Timing (XSPECT) Payload









X-ray CCD – Swept Charge Device

0.8-15.0 keV

64 cm^2

200 eV resolution at 6 keV

POLIX: Minimum Detectable Polarisation

$$\mathrm{MDP} = \frac{4.29}{\mu r}\sqrt{\frac{r+b}{T}} = \frac{4.29}{\mu}\frac{1}{\sqrt{N}}\sqrt{1+\frac{b}{r}},$$

- 5 % MDP for 100 mCrab

POLIX effective area

Photoelectric absorption

–

Forward scattering

–

Side scattering

–

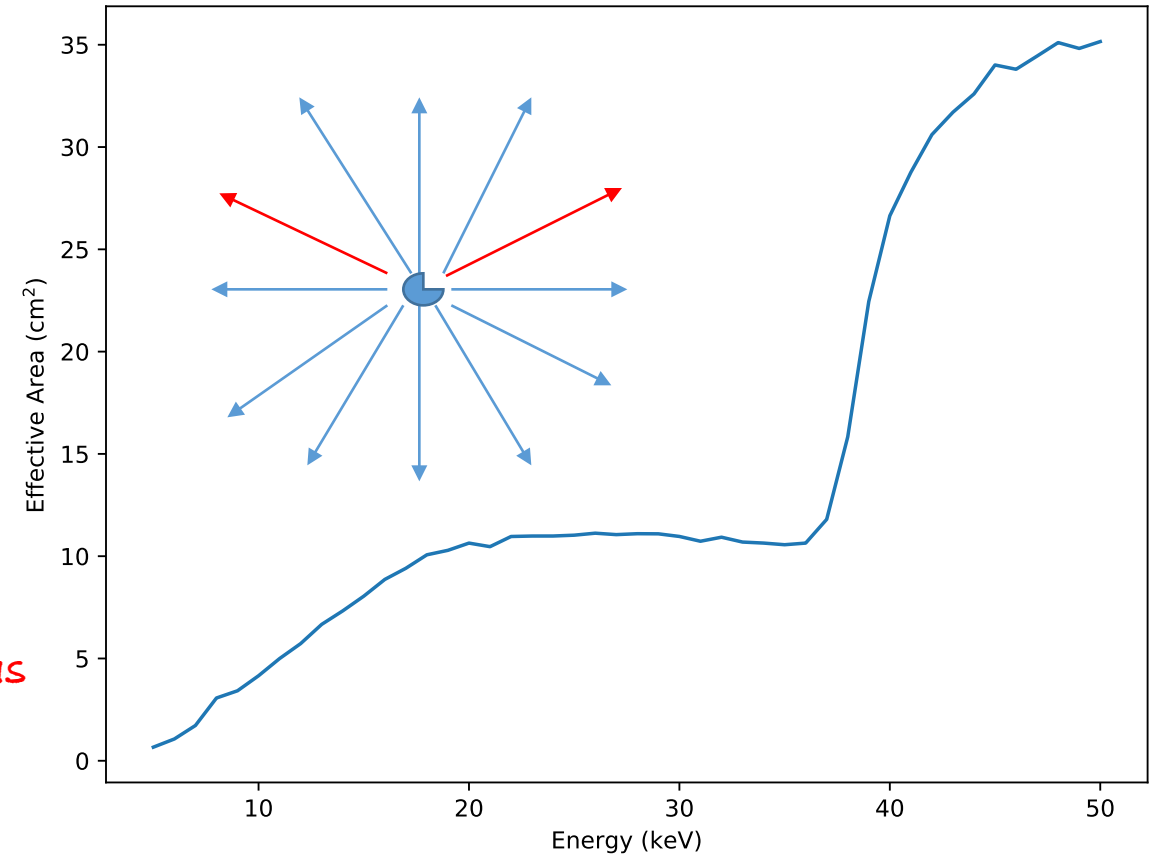
Back scattering

–

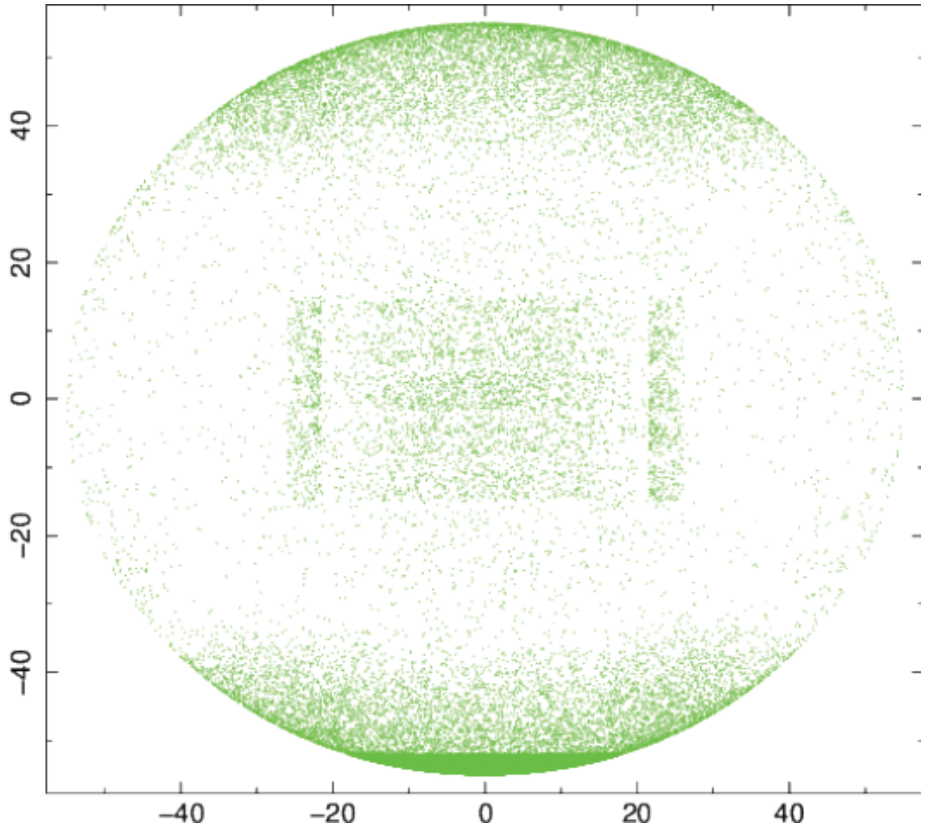
Blocked by window support structure

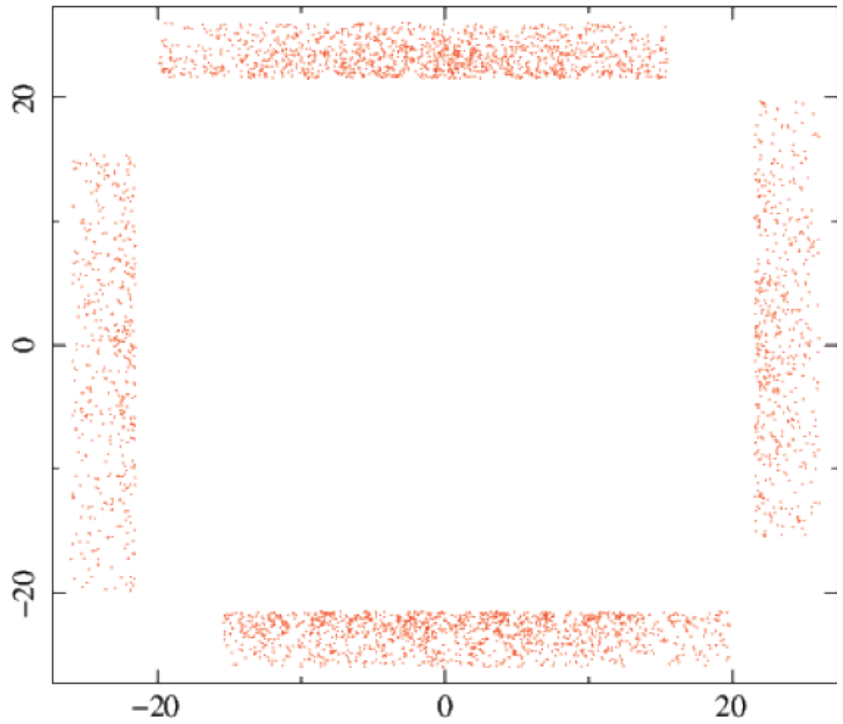
–

Quantum efficiency of Gas

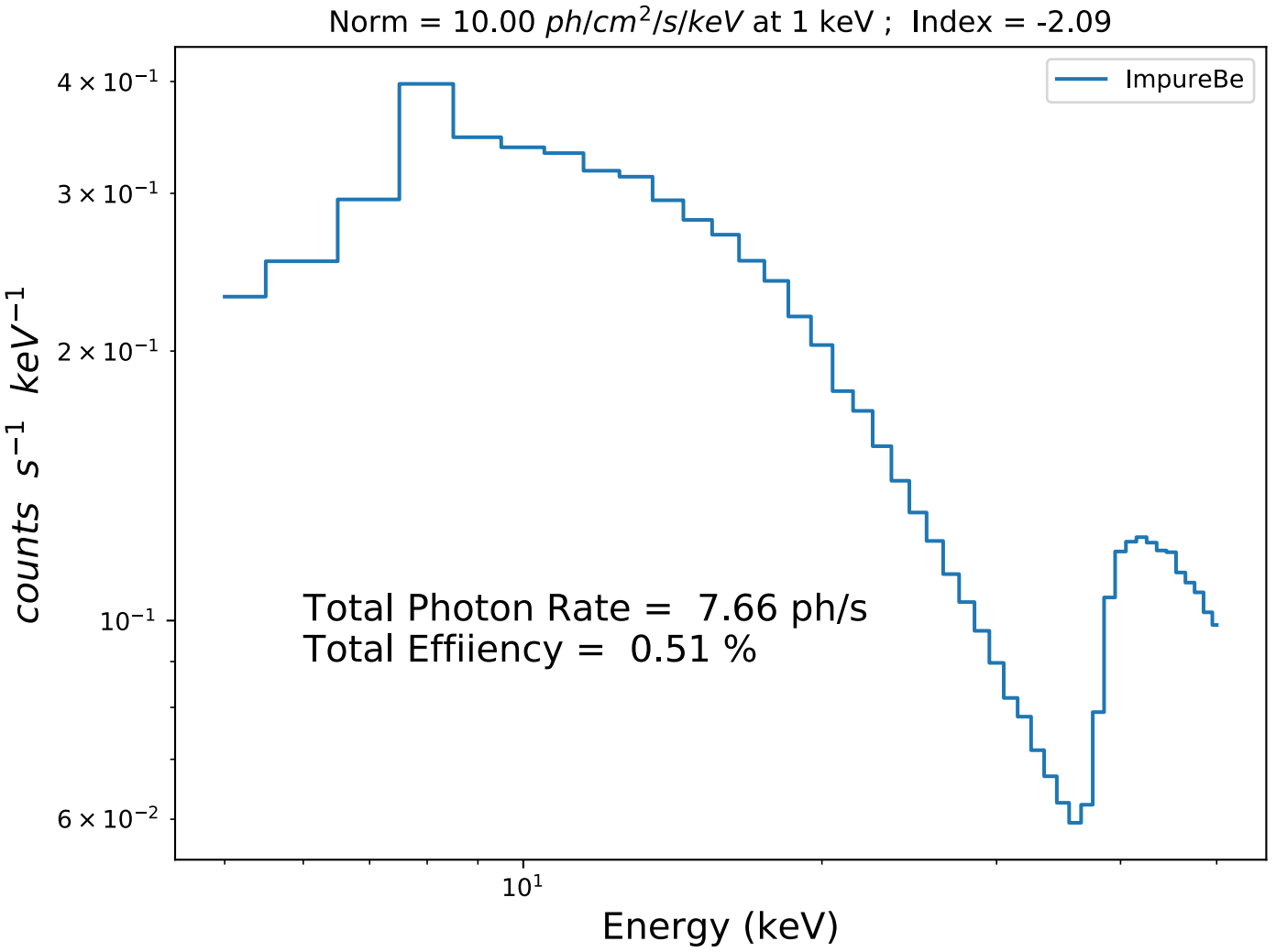


POLIX: Sensitivity

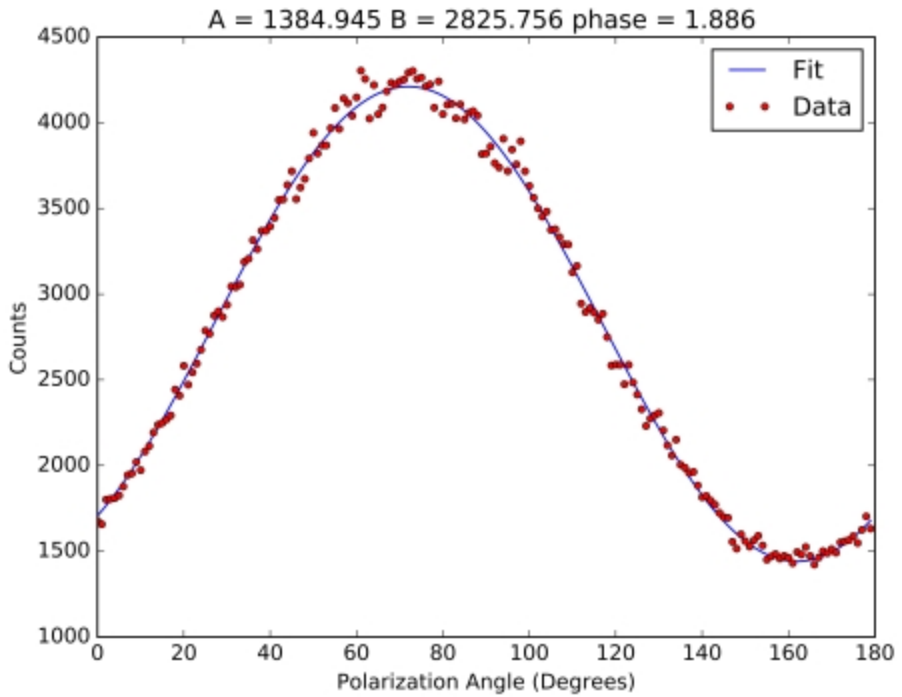




Simulated Crab Spectrum



POLIX: Simulation results



POLIX MDP for Accretion Powered Pulsars

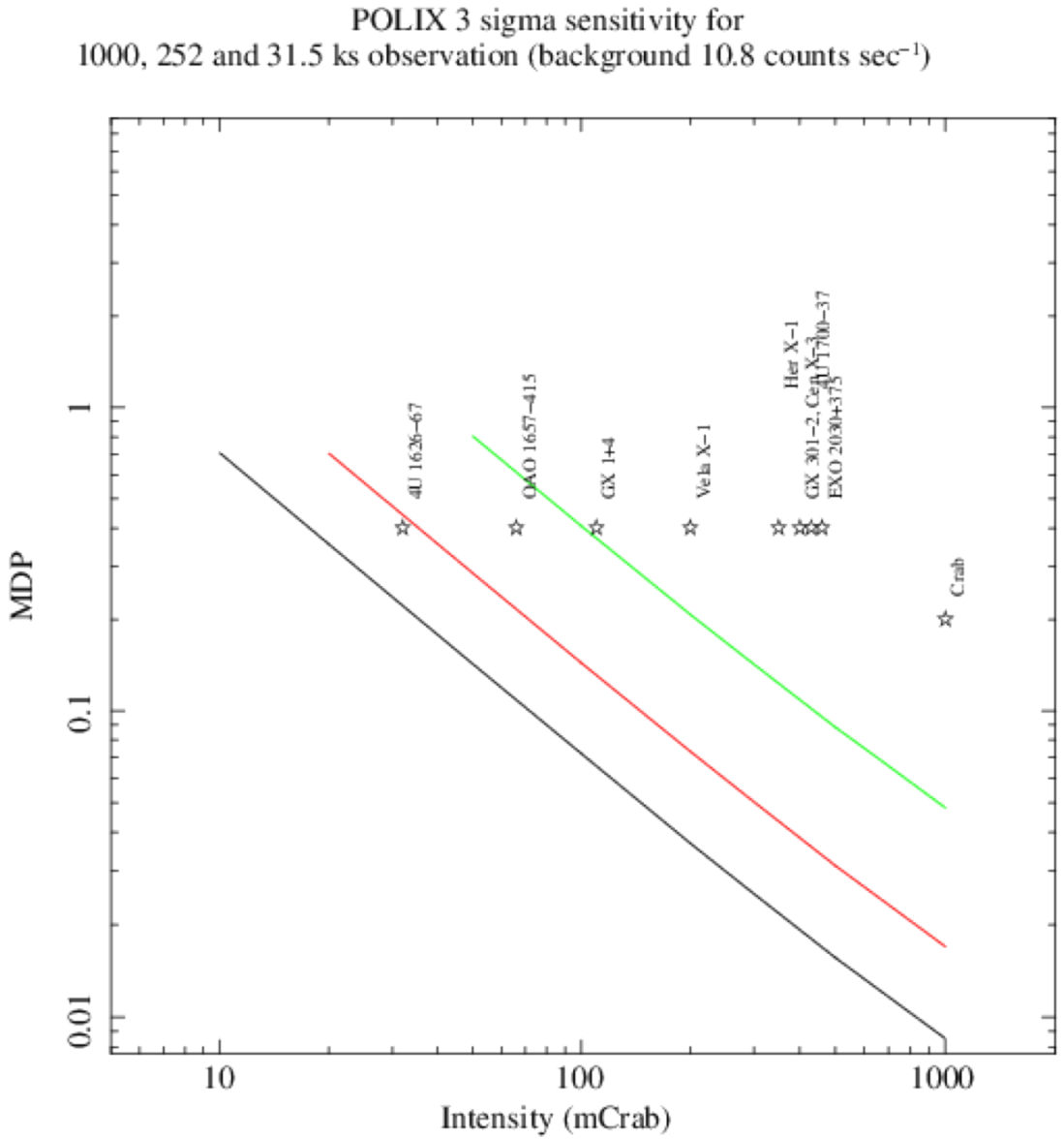
18 ks per day
x 14 days
= 252 ks

Spectral parameters taken
From Suzaku observations
of these sources.

Intensity uncertain by a
factor of 1-4

Degree of Polarisation
Uncertain by a factor of
~2

Planned observations will
give 3-20 sigma polarisation
Measurements in accretion
Powered pulsars



Accreting X-ray Pulsars

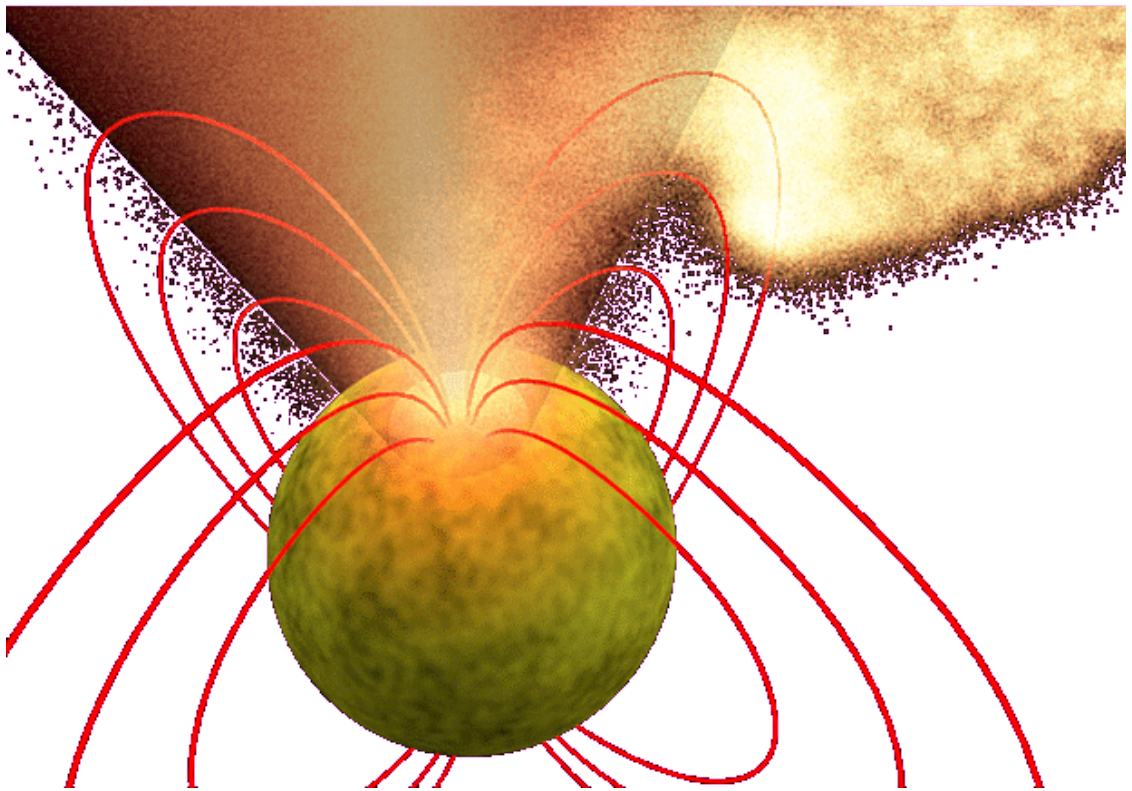
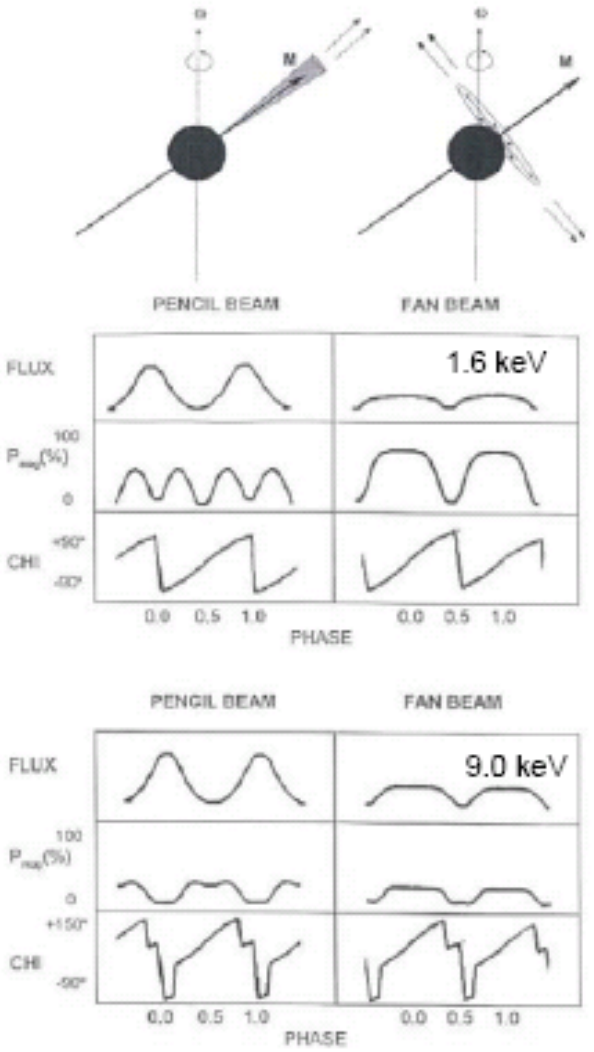
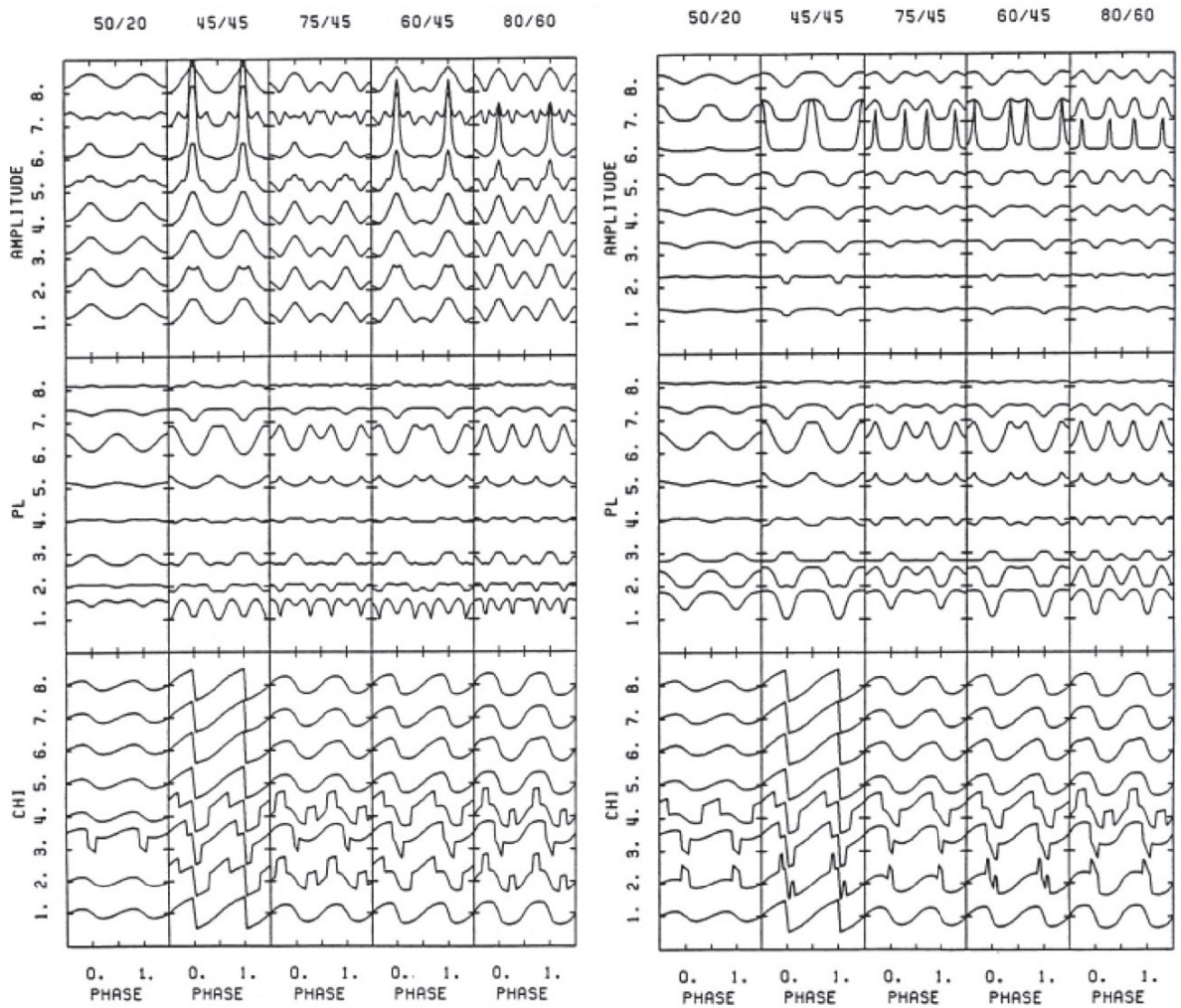


Image: NASA



Meszaros et al. 1988



Meszaros et al. 1988

Detection of X-ray Polarisation in Accretion Powered Pulsars

Key signature of strong Magnetic field in Accretion Powered pulsars

Pulse phase dependence of X-ray Polarisation in Accretion Powered Pulsars

Determination of beaming pattern in Accretion powered pulsars

Energy dependence of X-ray Polarisation in
Accretion Powered Pulsars

Enhanced polarisation near cyclotron line energy

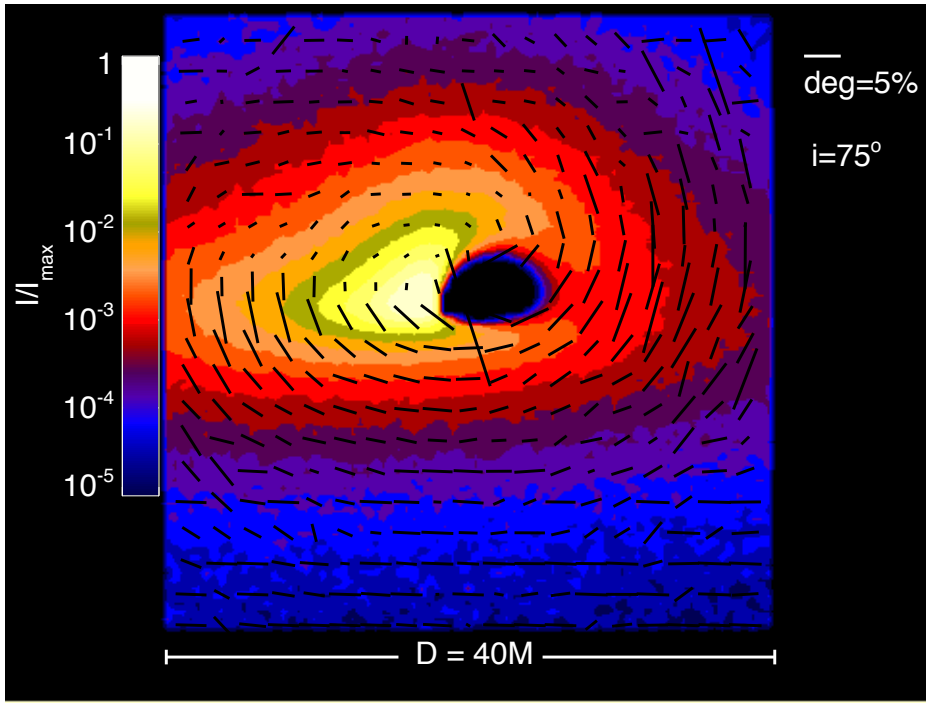
Luminosity dependence of X-ray Polarisation in
Accretion Powered Pulsars

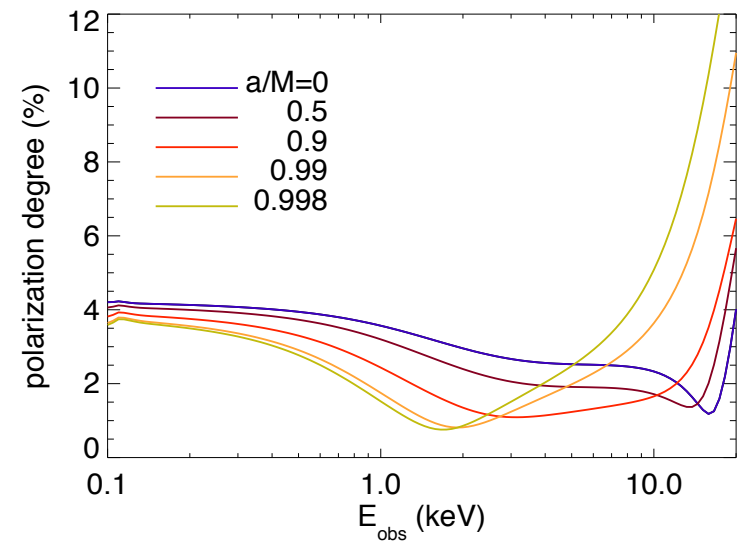
Change of accretion column structure

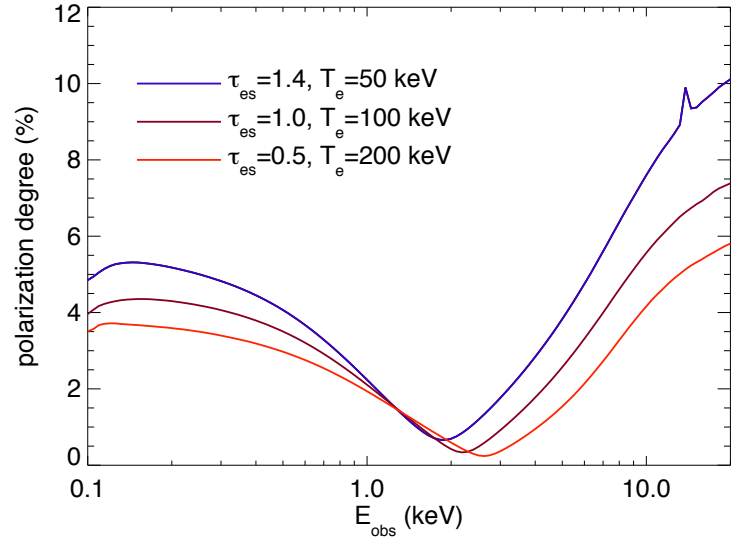
Luminosity dependence of
Pulse phase dependence of
X-ray polarisation

Change of beaming pattern

Black Holes in Binaries

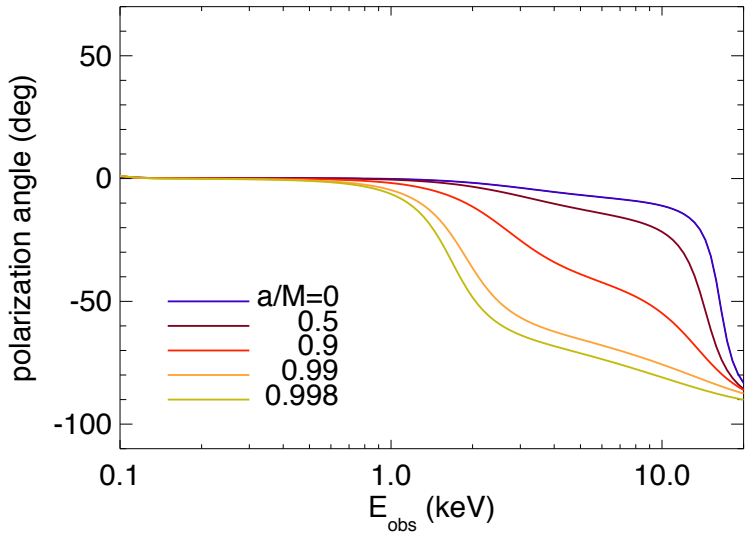


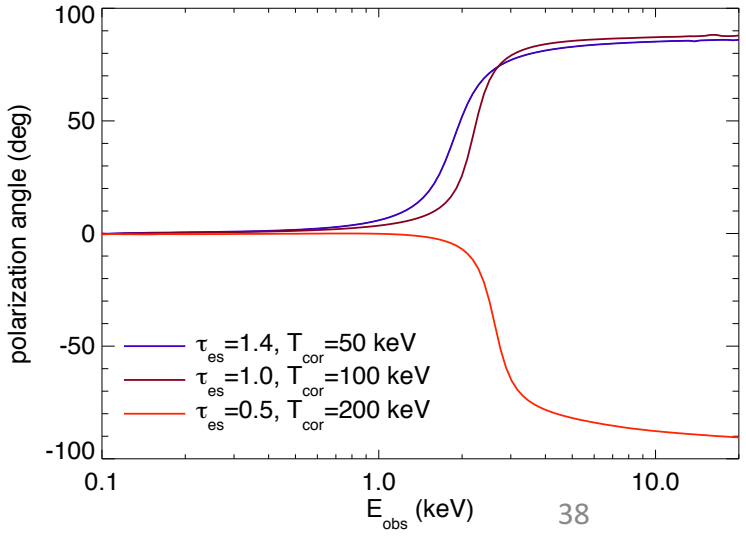




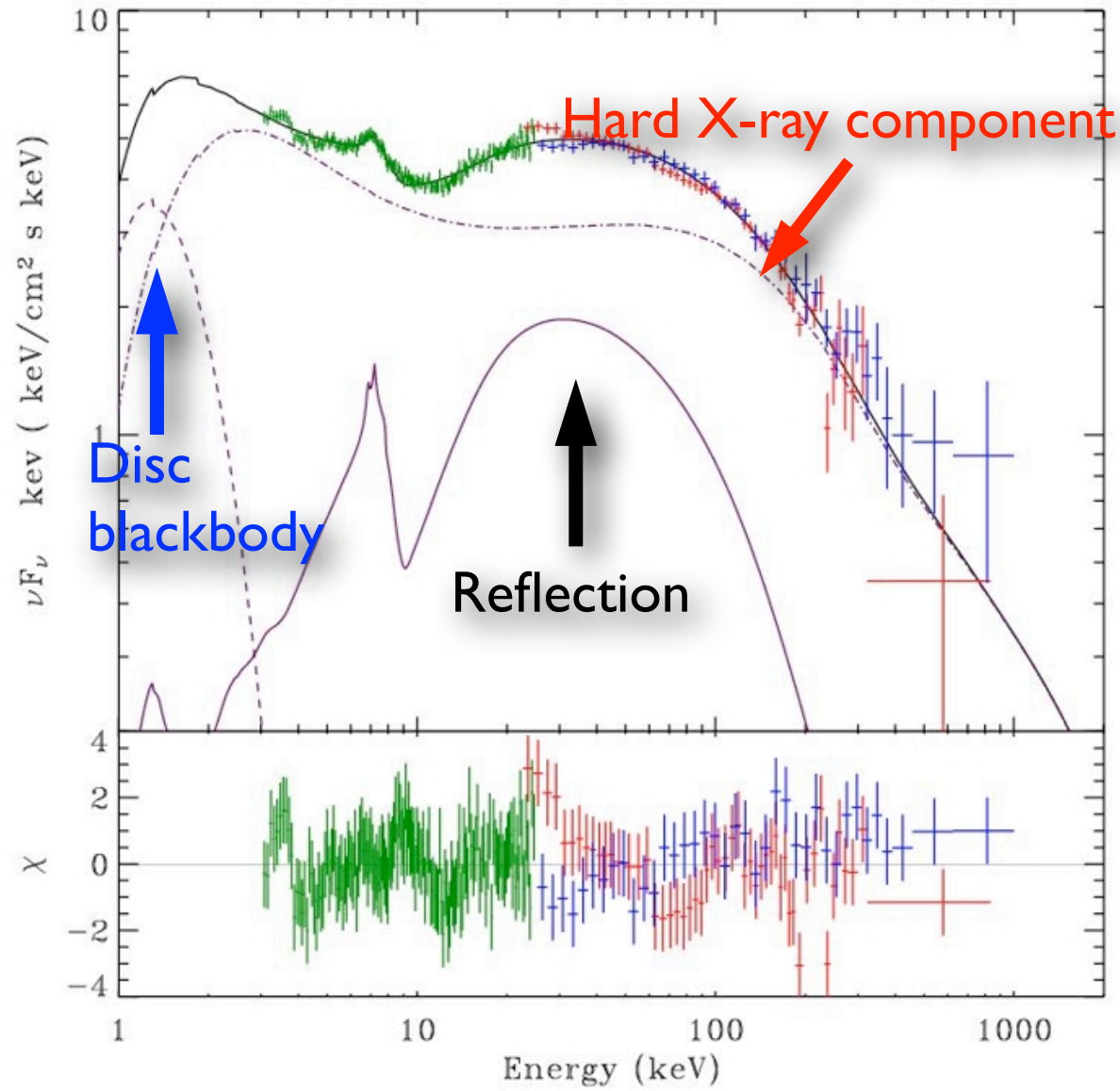
Soft State

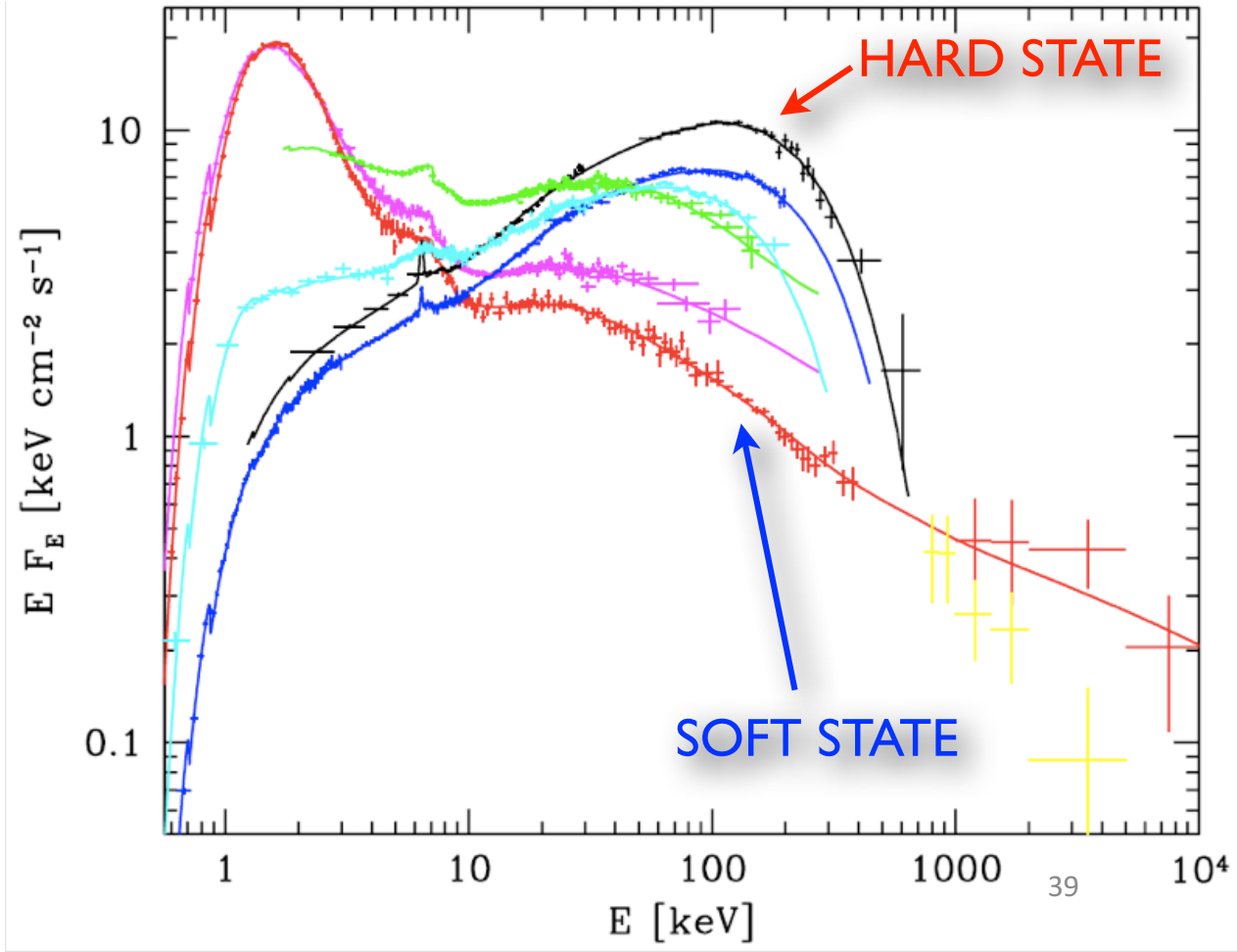
Hard State



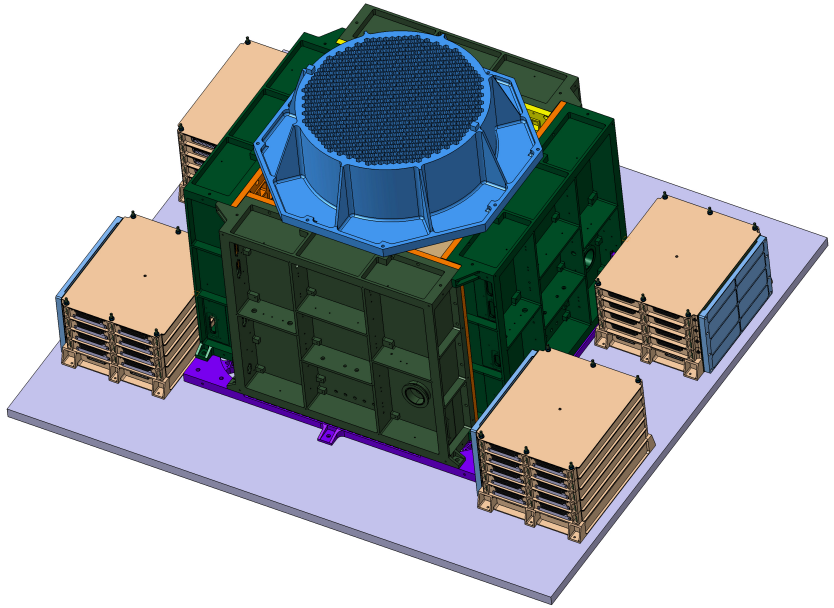


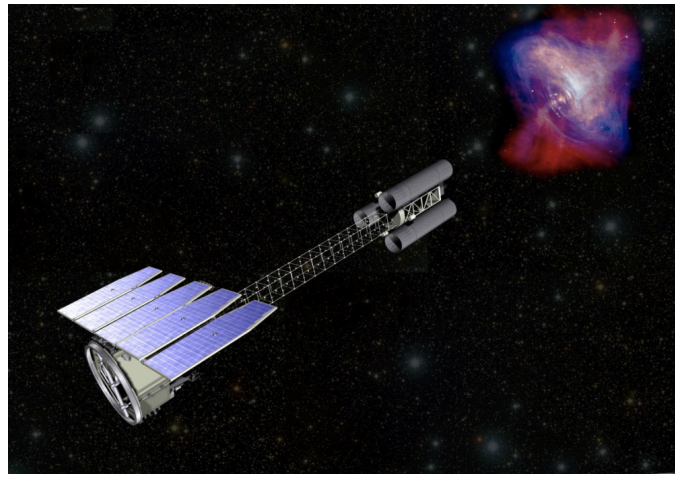
Spectral States of X-ray Binaries





POLIX (ISRO) and IXPE (NASA)





8-30 keV

2-8 keV

Complementary Energy Bands