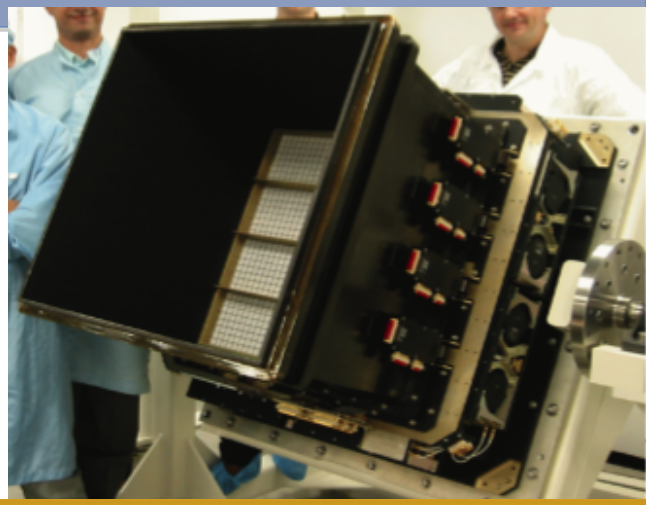
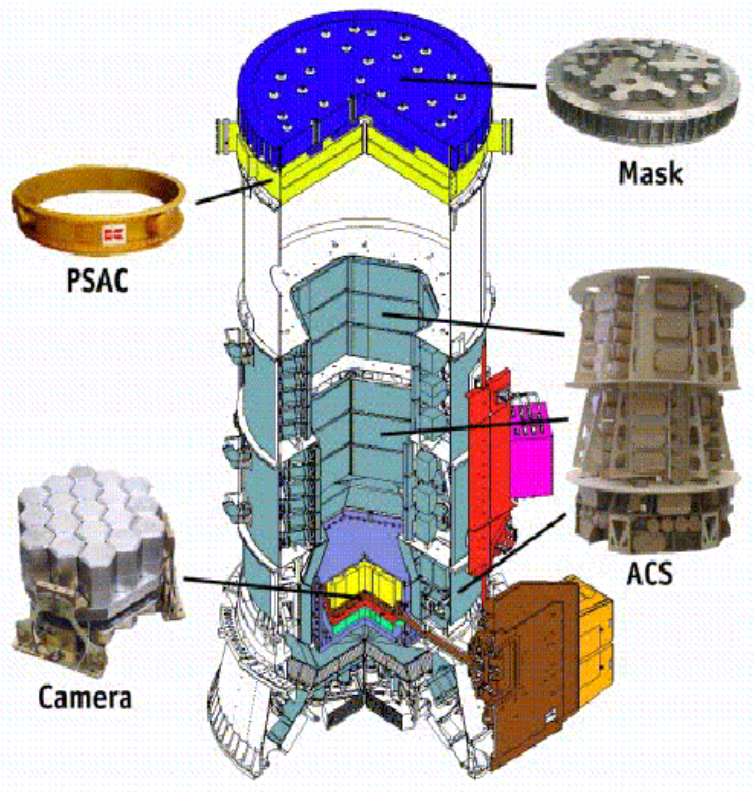
INTEGRAL Instruments

Nicolas Produit ISDC





Spectroscopy, Imaging, Timing, Polarization

For every photon: time of arrival, direction of arrival, energy, polarization

Photo effect, Compton effect, pair production → transfer of energy to charged particle

Charged particle loose energy very rapidly (2 MeV cm^2/g)

Spectroscopy need big crystals (containment of Compton, Maximize photoeffect => heavy nucleous)

Imaging need fine pixels

Not possible with just one instrument

Photon lists, image, ligthcurve, spectrum, phase

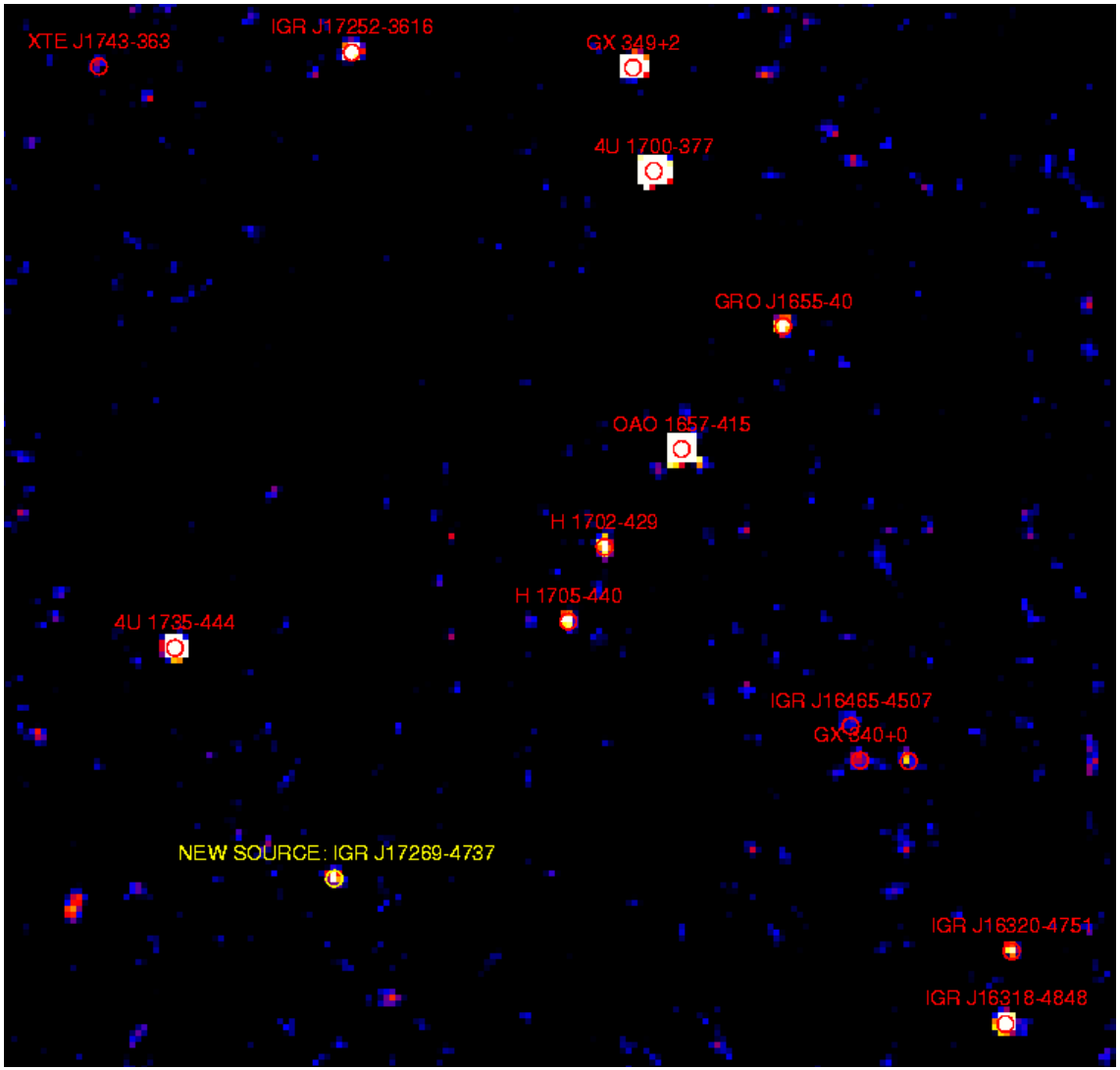
Photon list

TIME	RA	DEC	E	Pol
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx

For every photon the list of relevant information

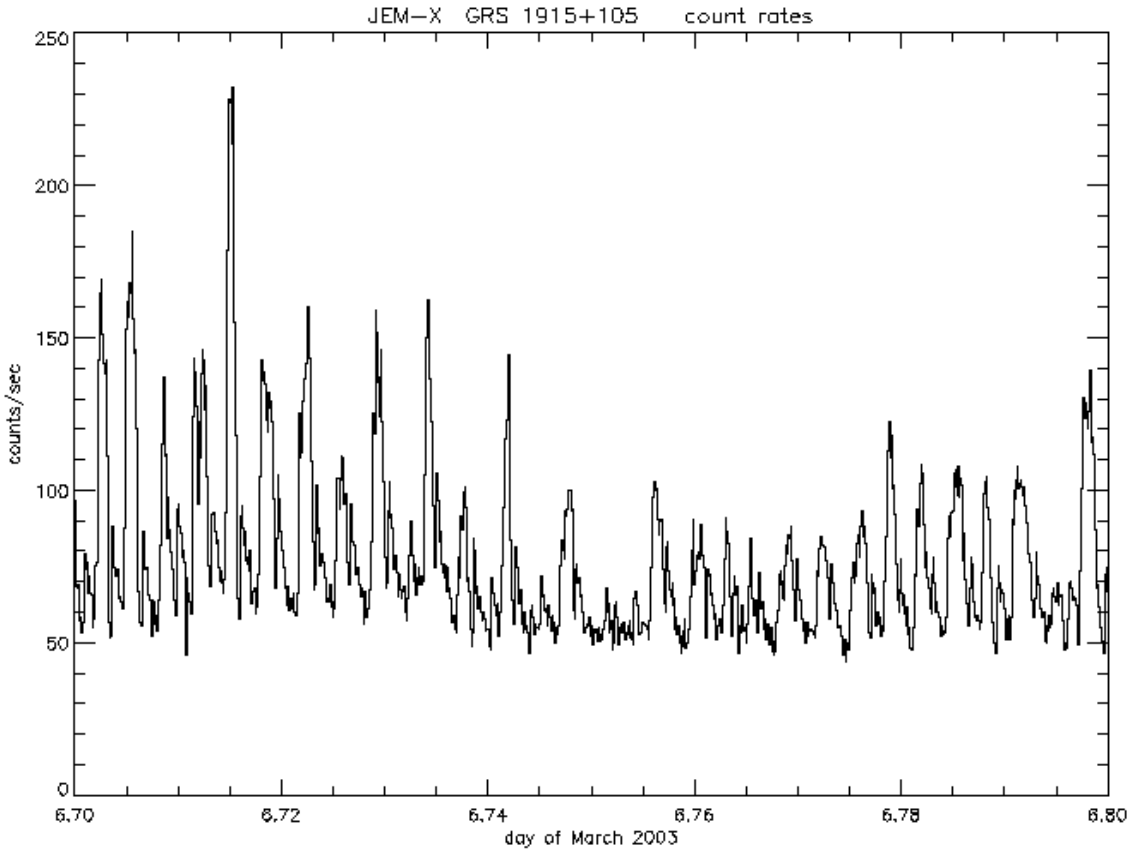
Photon lists, image, ligthcurve, spectrum, phase

Image:
flux versus RA,DEC
(cut in energy...)



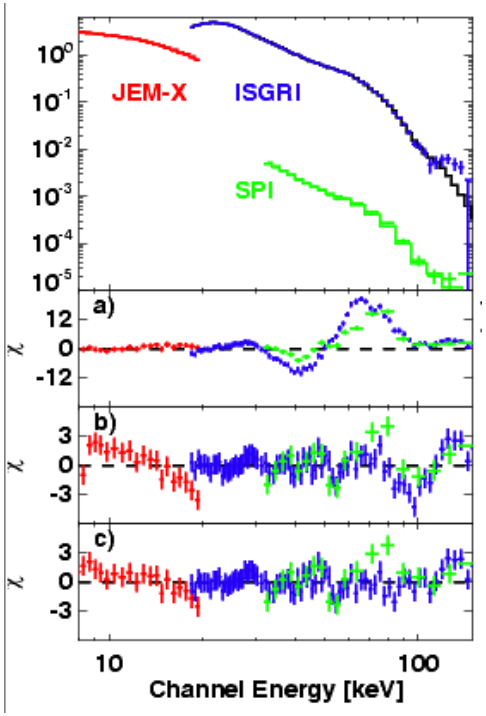
Photon lists, image, ligthcurve, spectrum, phase

Lightcurve: flux versus time (cut in RA, DEC, Energy)



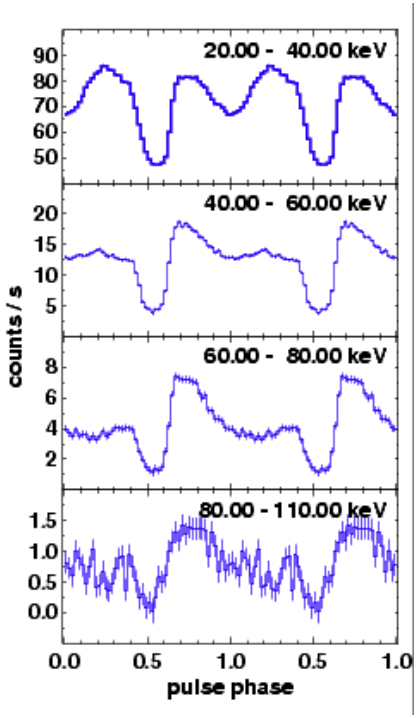
Photon lists, image, ligthcurve, spectrum, phase

Spectrum: flux versus energy
(cut in RA,DEC,Energy)
Standard deconvolution tool: XSPEC



Photon lists, image, ligthcurve, spectrum, phase

Phase diagram: flux versus phase
For periodic signal. Direction (for barycentrization)
(cut in RA, DEC, Energy)



Multiple instruments

Imaging: low energy ISGRI, high energy PICsIT, both: IBIS

Spectroscopy: SPI

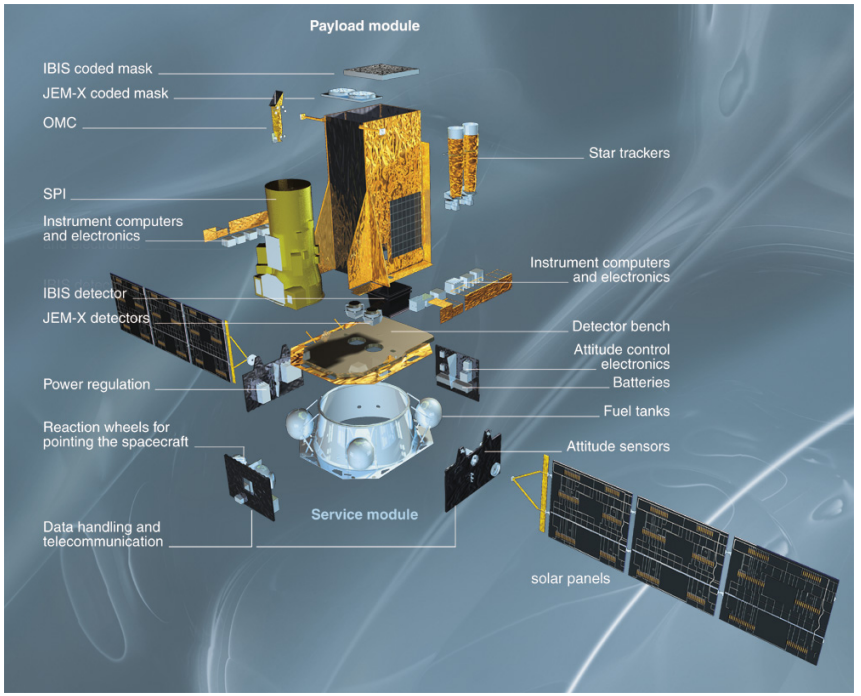
Polarimetry: 2 coincidence SPI or 2 planes IBIS

X rays: 2 JEMX

Visible: OMC (V, only predefined stars, GRB)

Alignment: star tracker

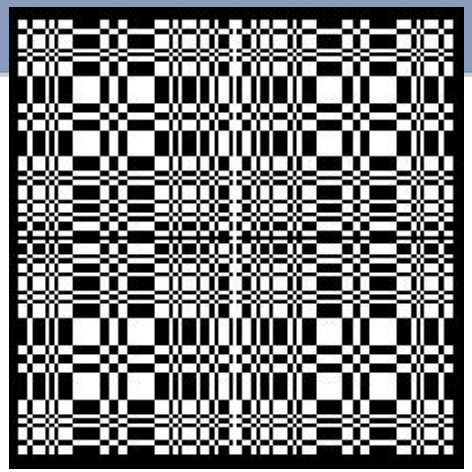
Radiation: IREM (electrons, protons, heavy ions)



Exploded view of INTEGRAL

Coded mask

IBIS mask



Cannot (yet) focalize gamma rays

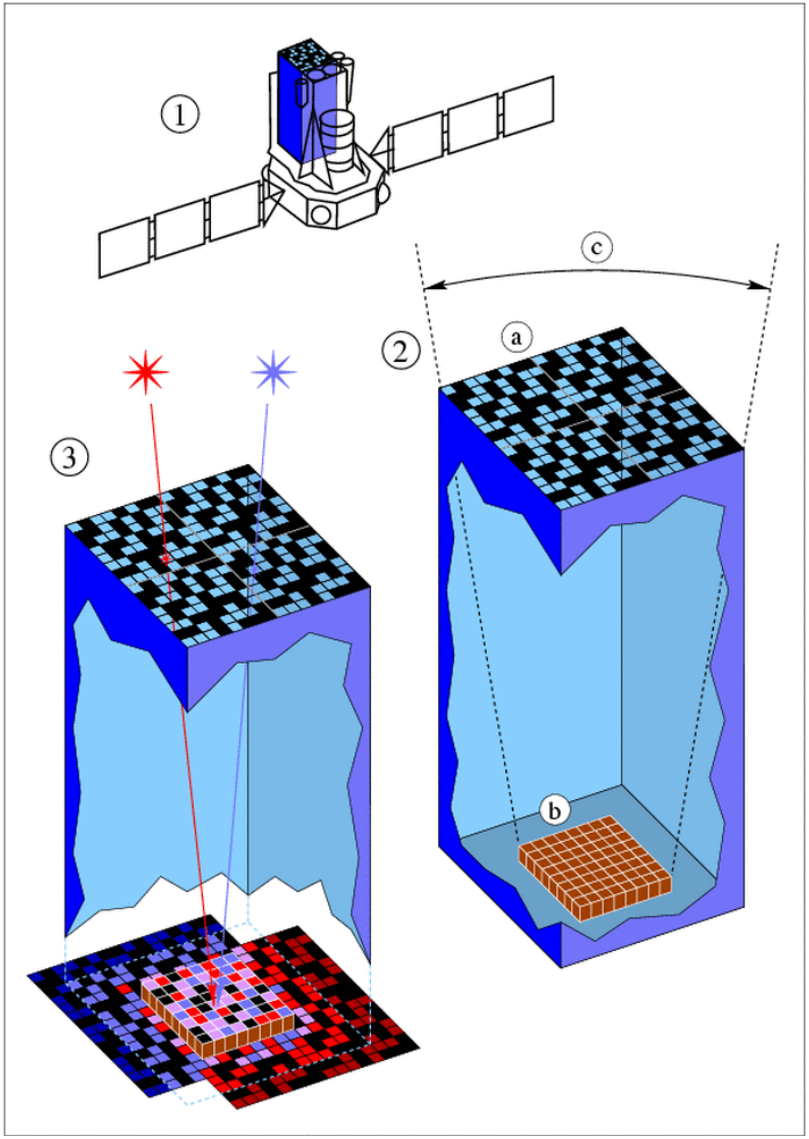
Very large background (radioactivity, induced radioactivity, belts, solar flares)

Signal over noise very small (<<1).

Signal measured (S+N)-N difference of two large numbers

Must measure background as well (or better then) signal

Coded mask



Principle of coded mask:

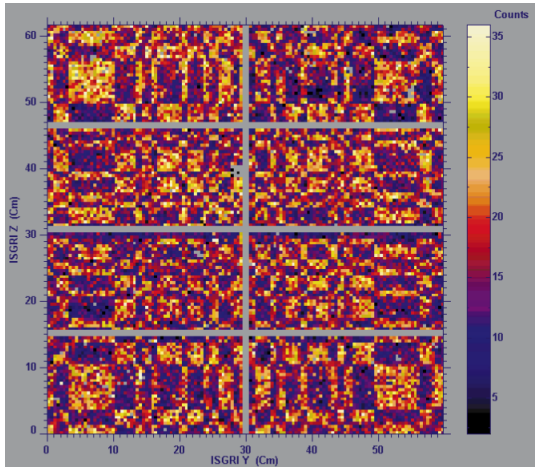
Block of heavy material block the view of single sources
In a recognizable pattern

Multiple source can be deconvoluted from the multiple shadows

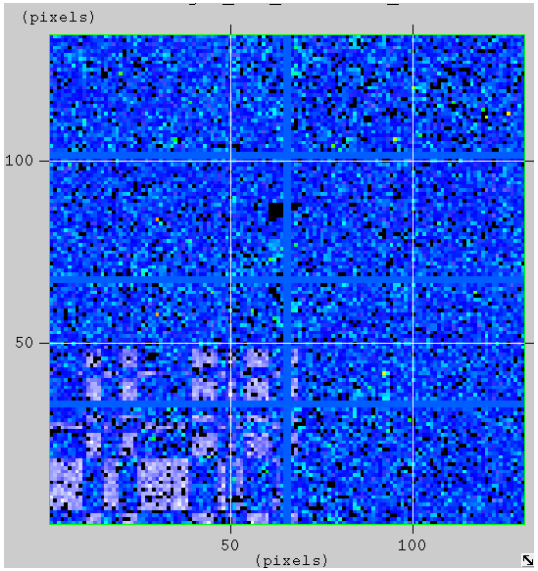
This is a linear process

Coded mask

Pattern chosen for ease of computability (M^{-1}=2M-1)
Autocorrelation: delta function+ const
Other possibility: Random mask (Swift)
Ghosts due to symetry
FOV, FCFOV, PCFOV



Shadowgram
with a source in FCFOV



Shadowgram
with a source in PCFOV

Photon lists, image, ligthcurve, spectrum, phase

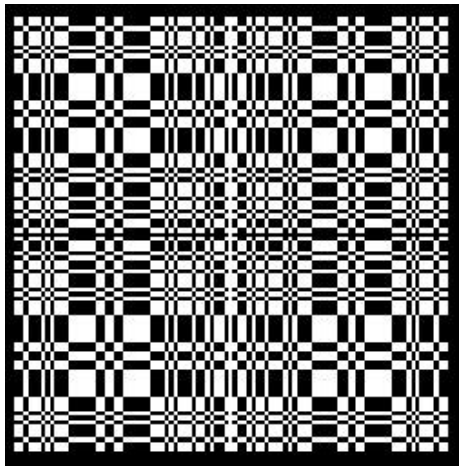
Photon list in the form we can provide them

PIF=Pixel illumination fraction

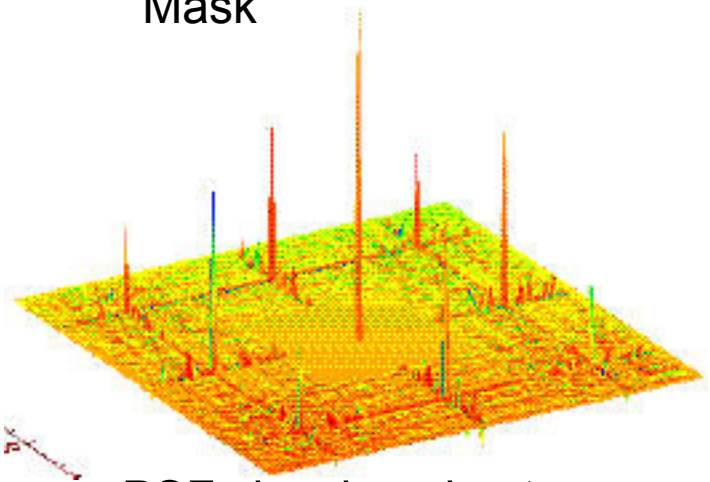
TIME	Source 1 PIF	TIME bary source1	Source 2 PIF...	E
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx

E is a measured energy, real energy
Can be very different (Compton effect)
Not Gaussian, non invertible relation!

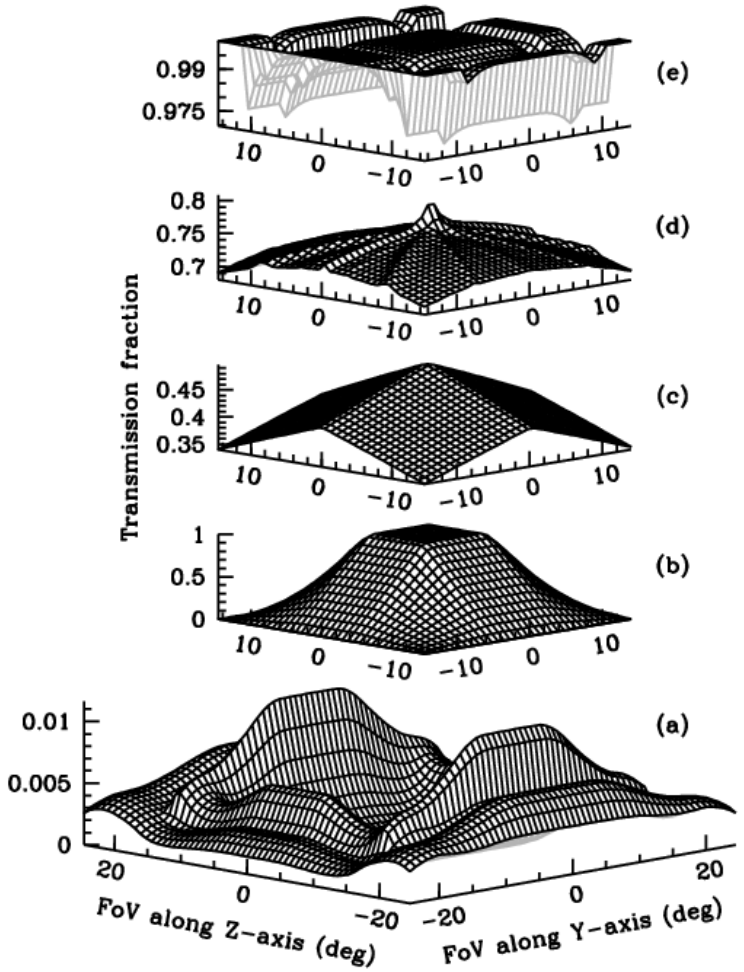
Coded mask further effects



Mask

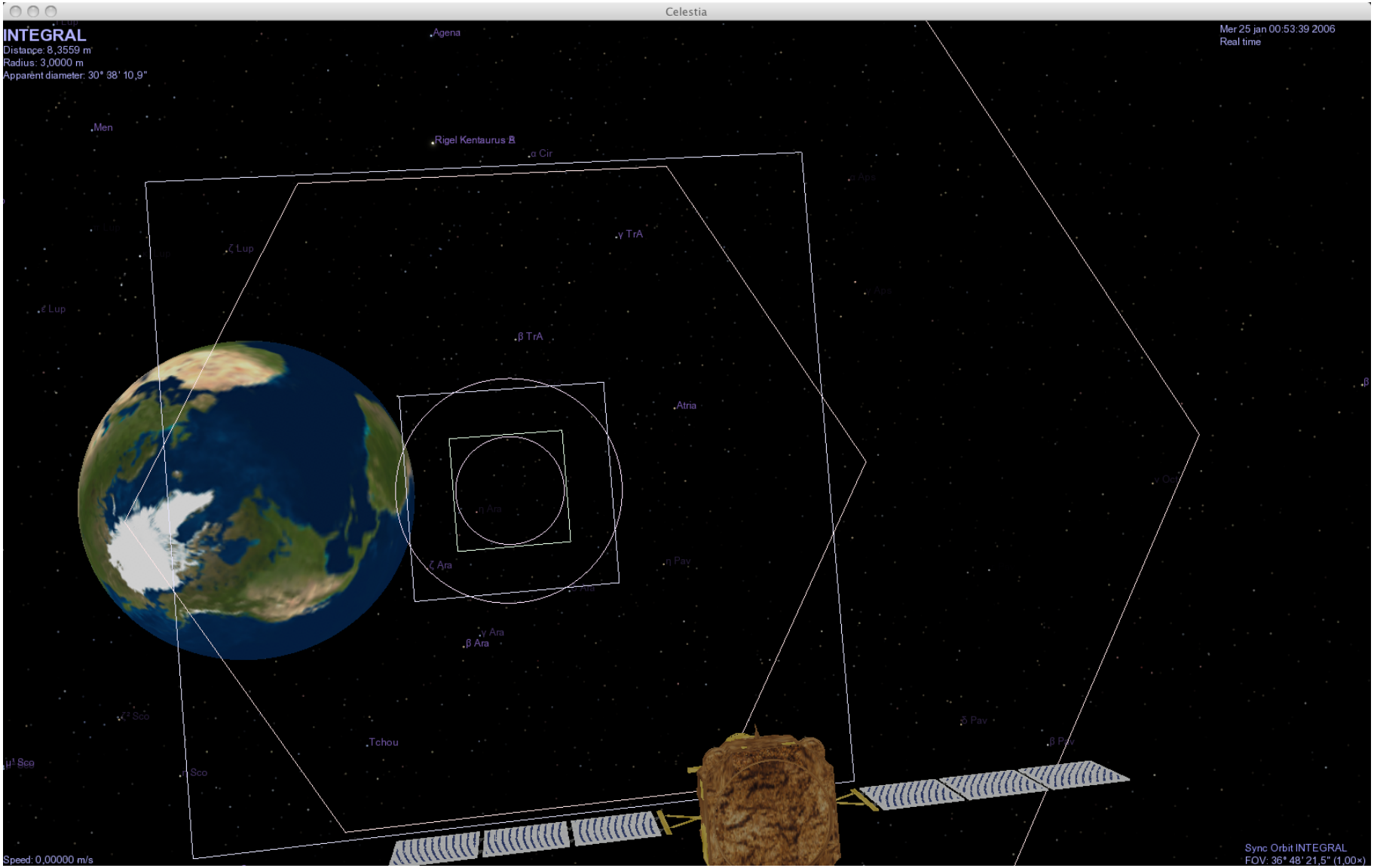


PSF showing ghosts



Different efficiencies vs angle

FOV

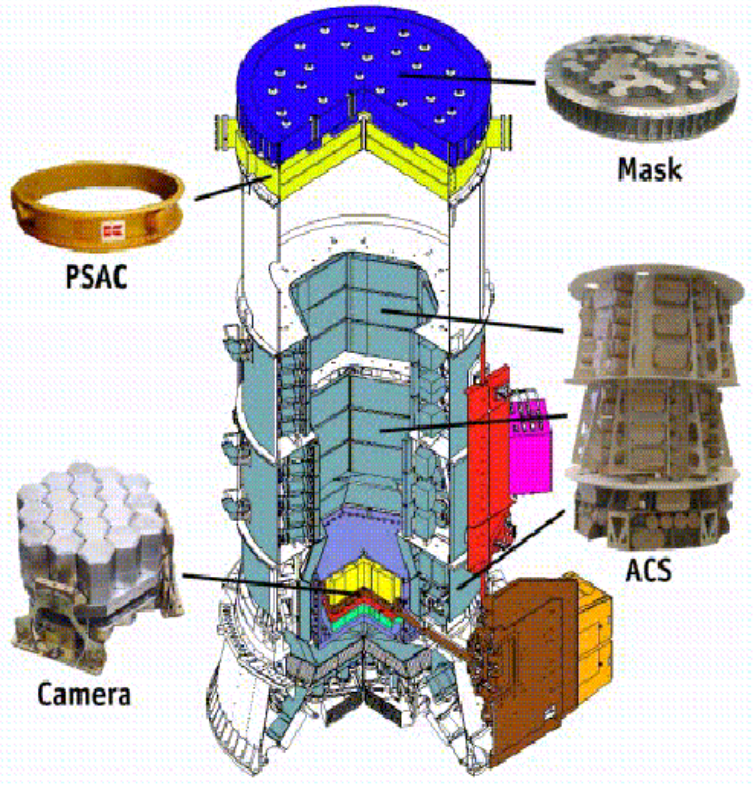

Celestia
INTEGRAL
Distance: 8,3559 m
Radius: 3,0000 m
Apparent diameter: 30° 38' 10,9"
Mer 25 jan 00:53:39 2006
Real time
Agena
Men
Rigel Kentaurus B
α Cir
γ TrA
ζ Lup
ε Lup
β TrA
Atria
η Ara
ζ Ara
γ Ara
β Ara
Tchou
Sco
Speed: 0,00000 m/s
Sync Orbit INTEGRAL
FOV: 36° 48' 21,5" (1,00×)

Spectrometer SPI

19 big Germanium detectors
Actively cooled
Periodic annealing
3 broken
Resolution:
- Time: 100 µsec (pulsar, GRB)
- Energy: $dE/E=10^{-3}$
- Angle: 2degree dithering → 30'

Spectral stability of background!

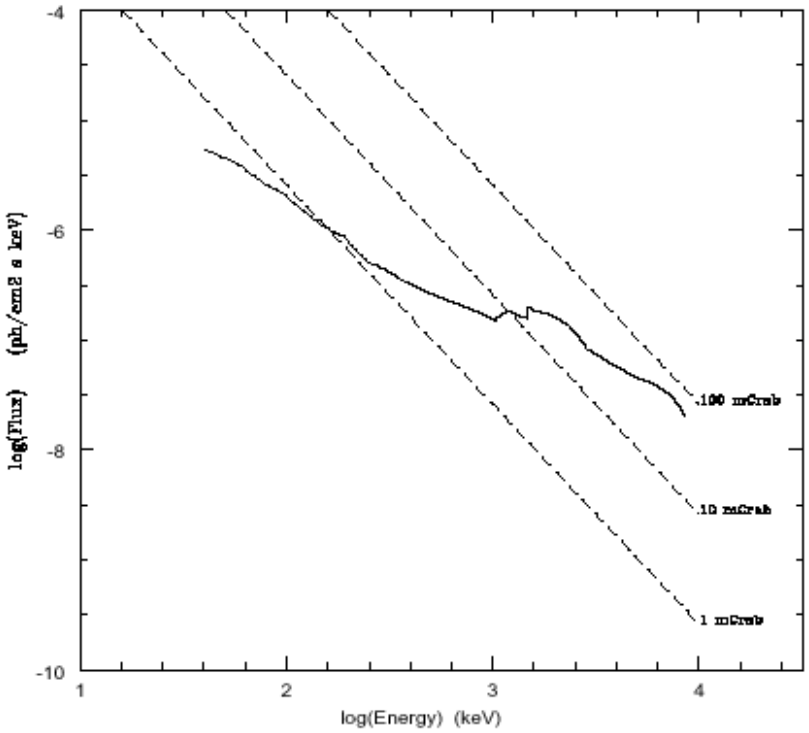
ACS_ biggest Gamma detector in space



Exploded view of SPI

Spectrometer SPI sensitivity

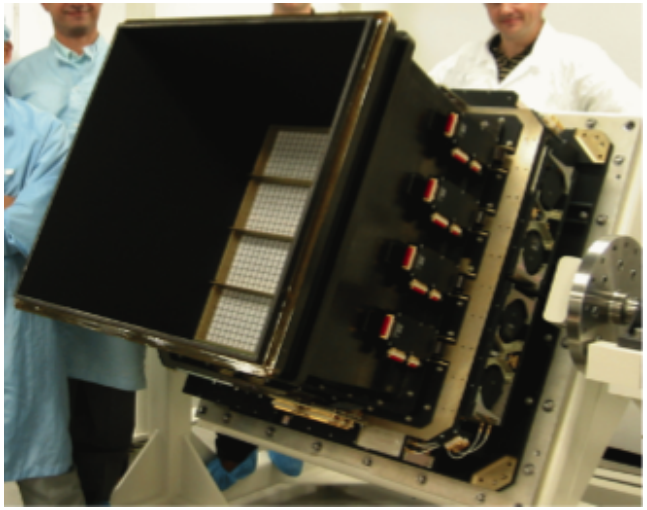
Crab in 1 sec at 100 keV
1mCrab in 1 Msec at 100 keV
10 mCrab in 1 Msec at 1 MeV
Continuum sensitivity <> line sensitivity



Continuum sensitivity of SPI

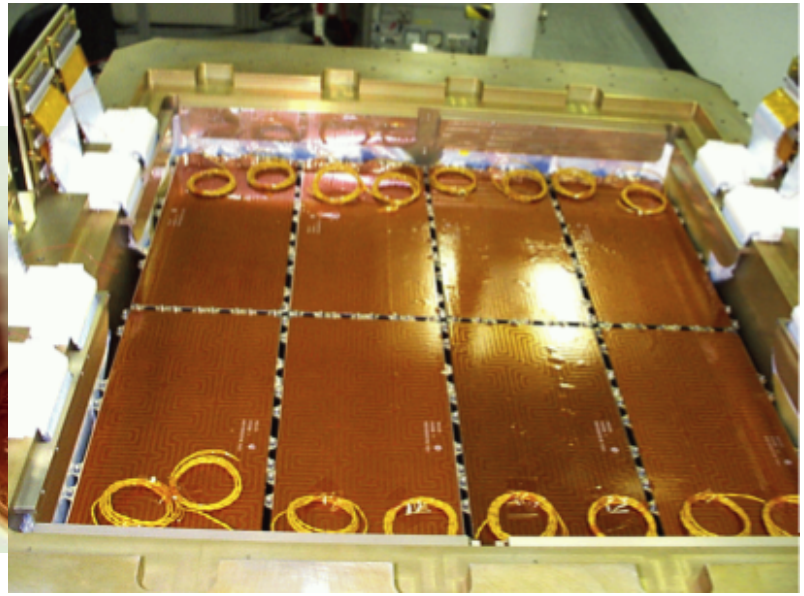
Imager IBIS

2 planes:
ISGRI: 65536 CdTe, semi conductor
PICsIT: 16384 CsI, scintillator, photo diode.
Using the two planes for polarization



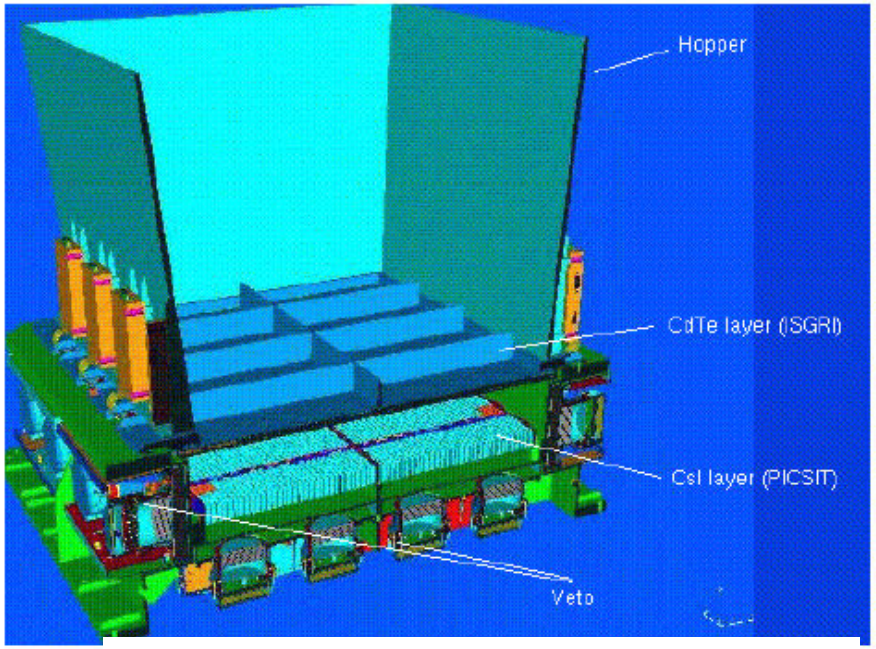
MASK

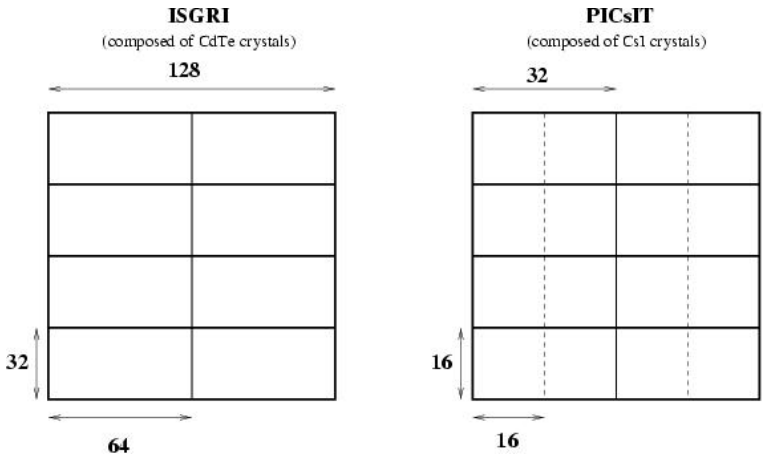
ISGRI PIXELS

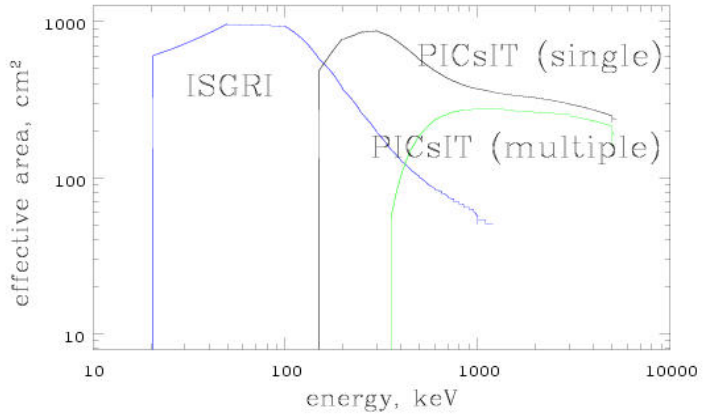


Imager IBIS

General view of IBIS
The two planes
Hopper
Support structure
Veto







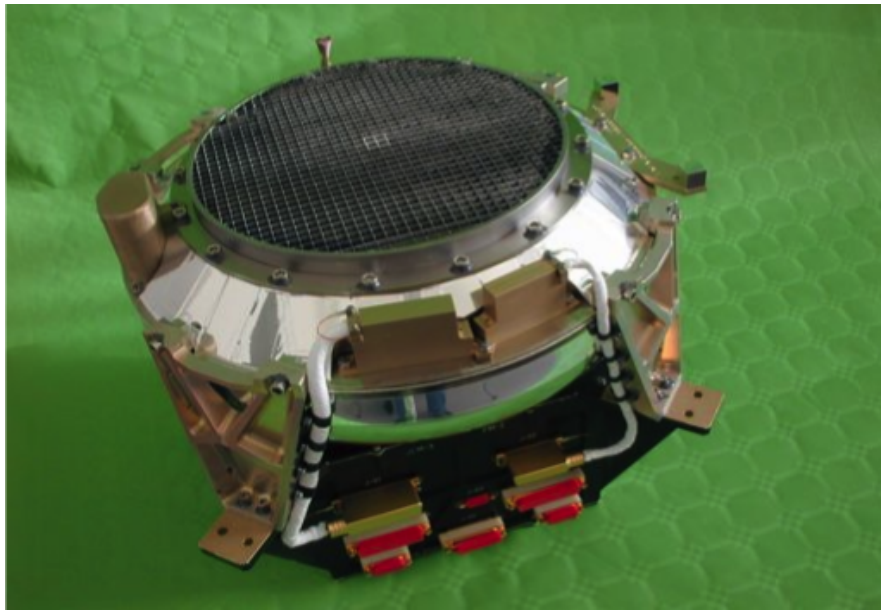
ISGRI

Performances:
Time: relative and absolute <50 µsec in barycentric coordinates
Energy: 10%.
Energy range: > 18 keV. After 200keV run out of sensitivity.
Position: PSF: 12', stacking down to 0.5' (see Crab morphology paper)
Dead time 25%

Features:
Run out of telemetry during strong GRB
Noisy pixels. Energy calibration. Aging.
All taken into account in standard software

JEMX

2 of them (JEMX1 JEMX2)
most of the time just one running (telemetry)
Gas drift chamber

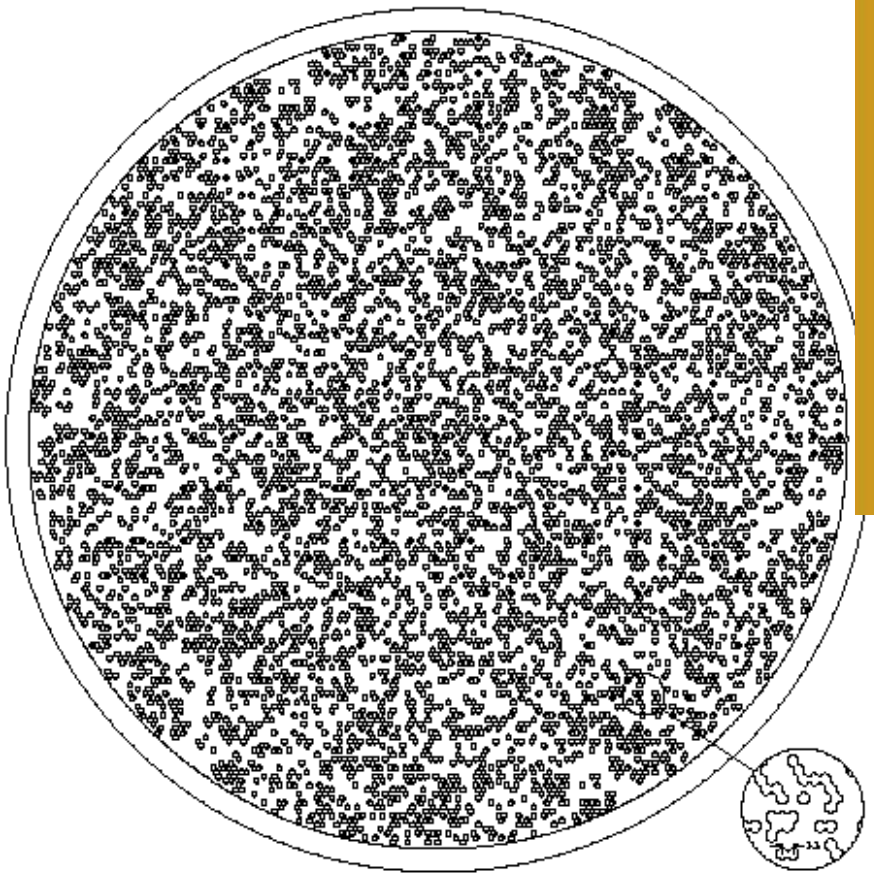


JEMX instrument

Performances:
Time: 122 µsec
Energy: 15%. Very time varying.
Energy range: 3-35 keV
Position: PSF: 3'
Dead time: grey filter

Features:
Dying anodes
Changing calibration
Small effective area and small FOV (dithering pattern)
Unfair competition from XMM, Chandra, Swift (coded mask versus concentrators), but larger E coverage and FOV, can look at very bright sources

JEMX MASK



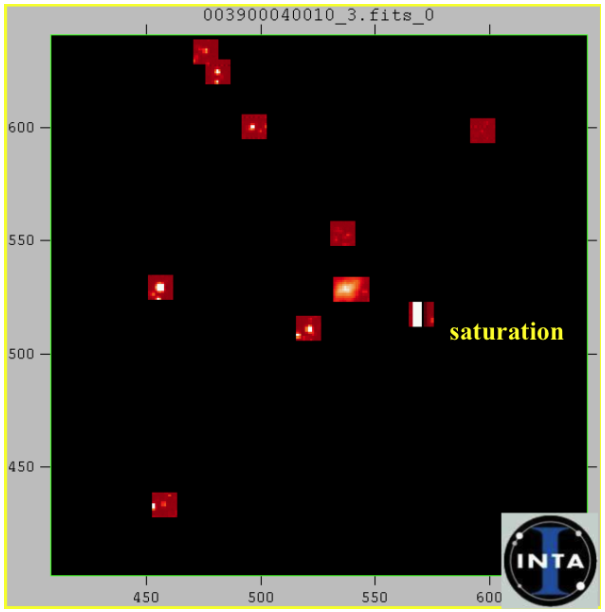
Mask hexagonal pattern, 30% open
70% closed

Mask support structure

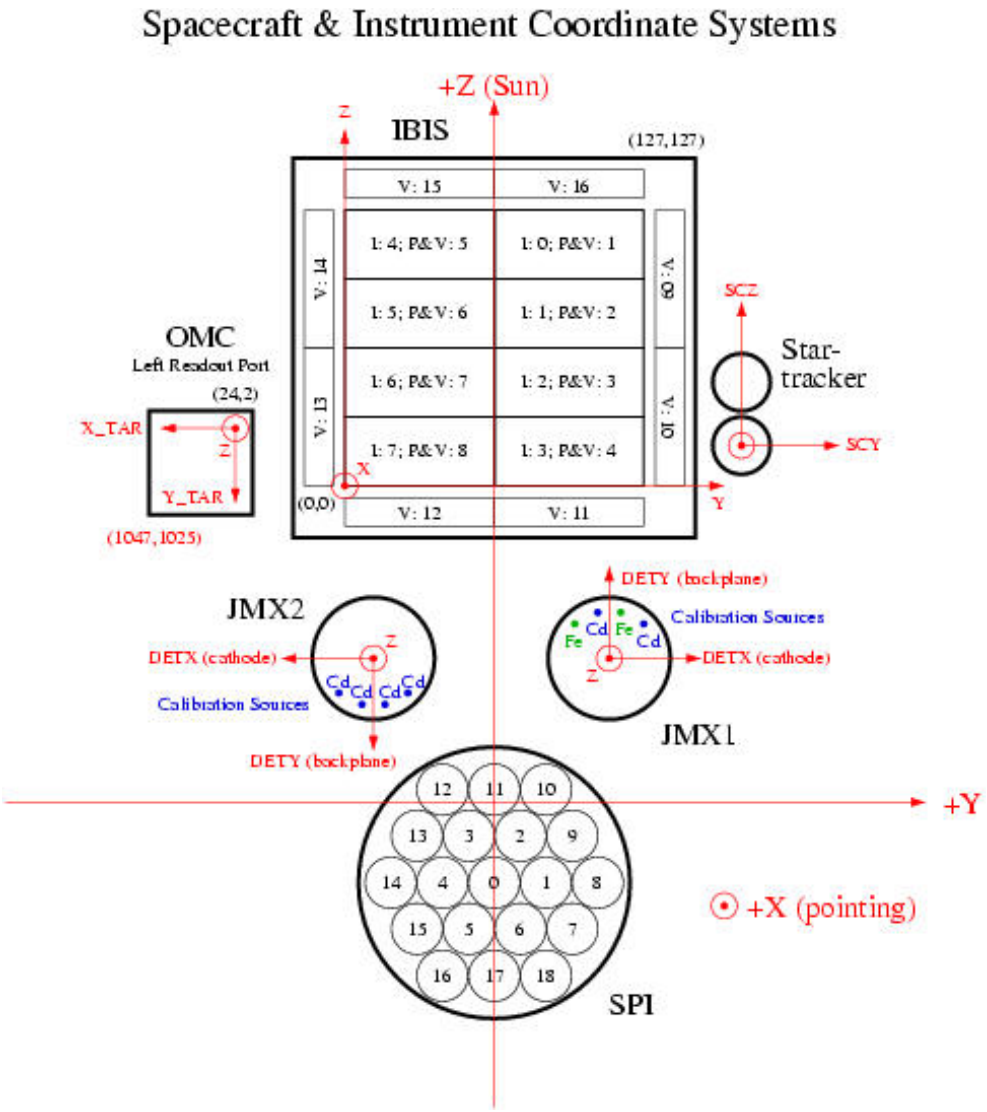
OMC

Vband
CCD (2048x1024)
FOV: 5^0X5^0
18.2 mag in 1000 s
Only predefined stars
GRB commending

OMC typical image



Disposition



Overall performances summary

instrument	Energy range	Energy resolution	PSF	FOV	PCFOV	Sensitivity	Sources (no GRB)
SPI	20 keV to 8 MeV	1.6 keV @ 1 MeV	2^0	15^0	31^0	3 10^{-13}erg/cm^2/keV/s @ 100 keV in 1 Ms	175
ISGRI	15 keV to 1 MeV	<10%	12'	10^0	30^0	10^{-13}erg/cm^2/keV/s @ 100 keV in 1 Ms	845
PICsIT	170 keV to 10 MeV	10%	12'	10^0	30^0	10^{-12}erg/cm^2/keV/s @ 300 keV In 1 Ms	9
JEMX	3 to 35 keV	2 keV	3'	4.8^0	10^0	3 10^{-11} erg/cm^2/s/keV 2-10 keV in 2000 s	149 (published, sources)
OMC	V	Vband	17arc sec	5^0	X	18.2 mag in 1000 s	catalog

References

Reference:

INTEGRAL, IBIS, ISGRI,
PICsIT, SPI, OMC, IREM

All can be found in

Special Issue A&A Nov. 2003

See all of them on:

http://www.isdc.unige.ch/integral/science/publications