INTEGRAL spectra of Galactic Bulge sources

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INTEGRAL: International Gamma-Ray Astrophysics Laboratory

- The payload
- The mission
- The project

INTEGRAL payload

· IBIS (Imager on-Board the Integral Satellite)

⇒ high resolution images of celestial objects of all classes.

⇒ 15keV – 10MeV. ISGRI // PICsIT

⇒ FOV ~ 8º x 8º

· JEM-X (Join European Monitor for X-rays)

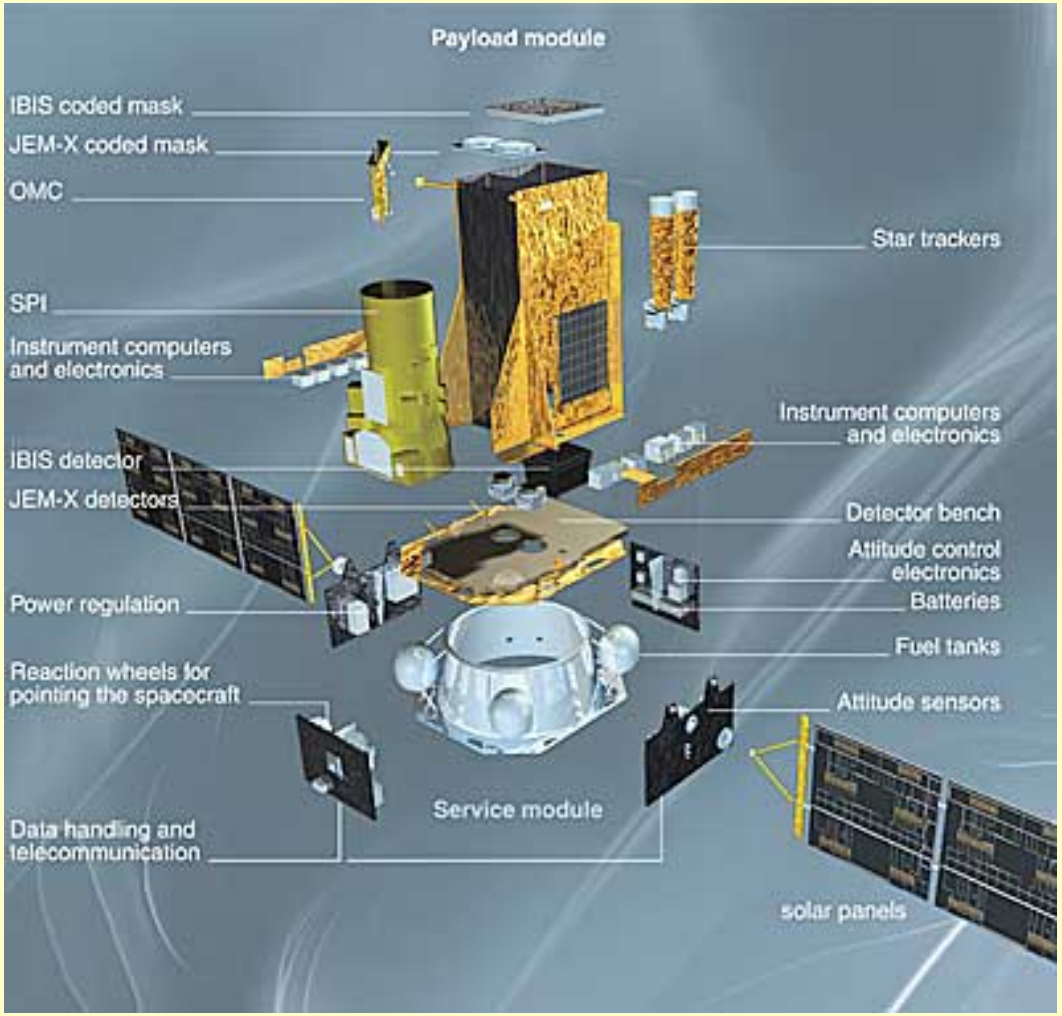
⇒ 3 – 35 keV

⇒ Images

⇒ FOV: 5º radius circle

· SPI (Spectrometer on Integral)

· OMC (Optical Monitoring Camera)



INTEGRAL

Observation of various gamma-ray phenomena by combining fine spectroscopy with imaging and accurate positioning of celestial sources of gamma-ray emission.

Science objectives:

⇒ Compact objects *(White Dwarfs, Neutron Stars, Black Hole Candidates, High Energy Transients and Gamma-Ray Bursts)*

⇒ Extragalactic astronomy *(Galaxies, Clusters, AGN, Seyferts, Blazars, Cosmic Diffuse Background)*

⇒ Stellar nucleosynthesis *(Hydrostatic Nucleosynthesis (AGB, WR Stars), Explosive Nucleosynthesis (Supernovae, Novae))*

⇒ Galactic plane and centre structure *(Cloud Complex Regions, Mapping of continuum and line emission, ISM, CR distribution)*

⇒ Particle processes acceleration *(Transrelativistic Pair Plasmas, Beams, Jets)*

⇒ Identification of high energy sources *(Unidentified Gamma-Ray Objects as a Class)*

The INTEGRAL Galactic Bulge monitoring program

Observe the region frequently and regularly

$\Rightarrow$ investigate the source variability and transient activity on time scales of days to weeks and months

$\Rightarrow$ relatively soft and hard energies

Get the data of IBIS/ISGRI and JEM-X

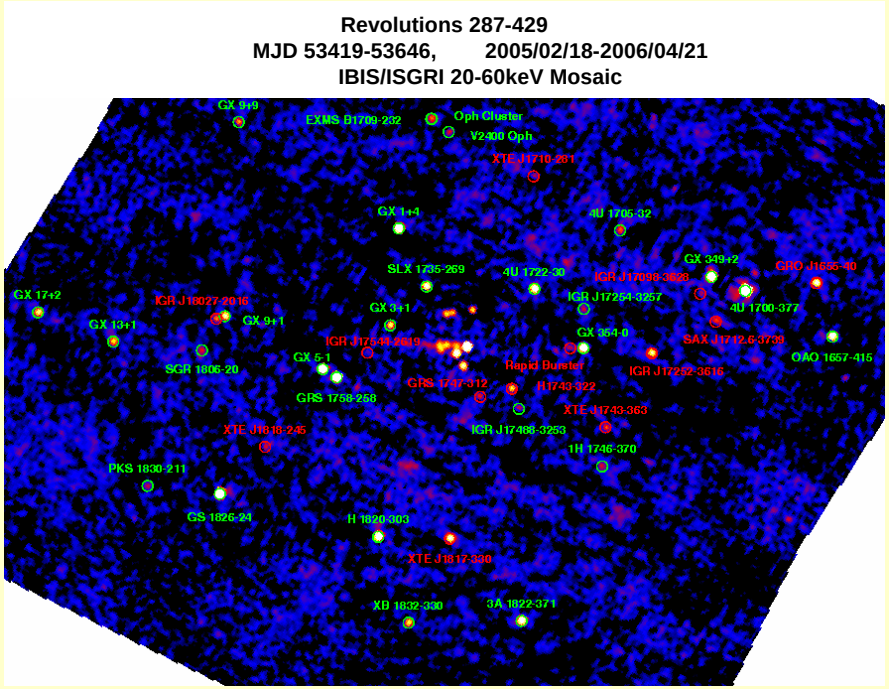
fit to standard models: powerlaw & cutoffpowerlaw

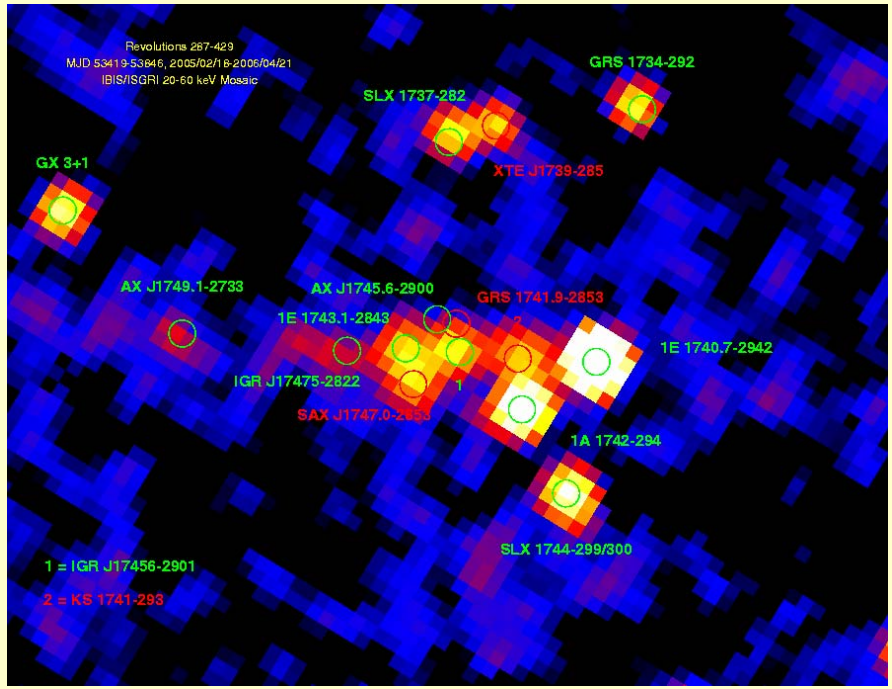
-Have we missed something?

plot the parameters with time (revolutions)

- Global properties of the sources
- Are there spectral changes?

Why IBIS/ISGRI & JEM-X?





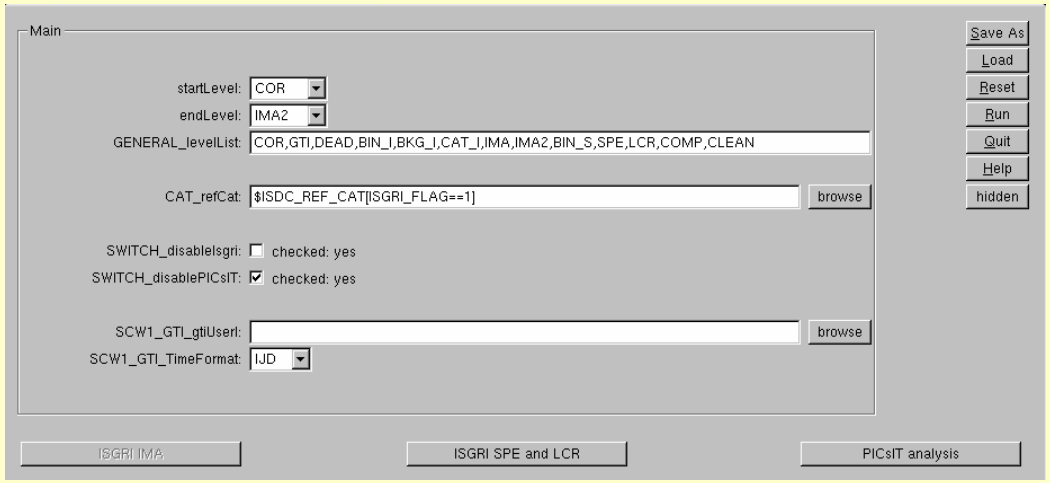
All the sources

Galactic center

⇒ SPI: bad resolution (2.5º) (IBIS: Angular resolution: 12arcmin)

⇒ OMC: too many stars (optical !!)

Obtaining the data



IBIS/ISGRI

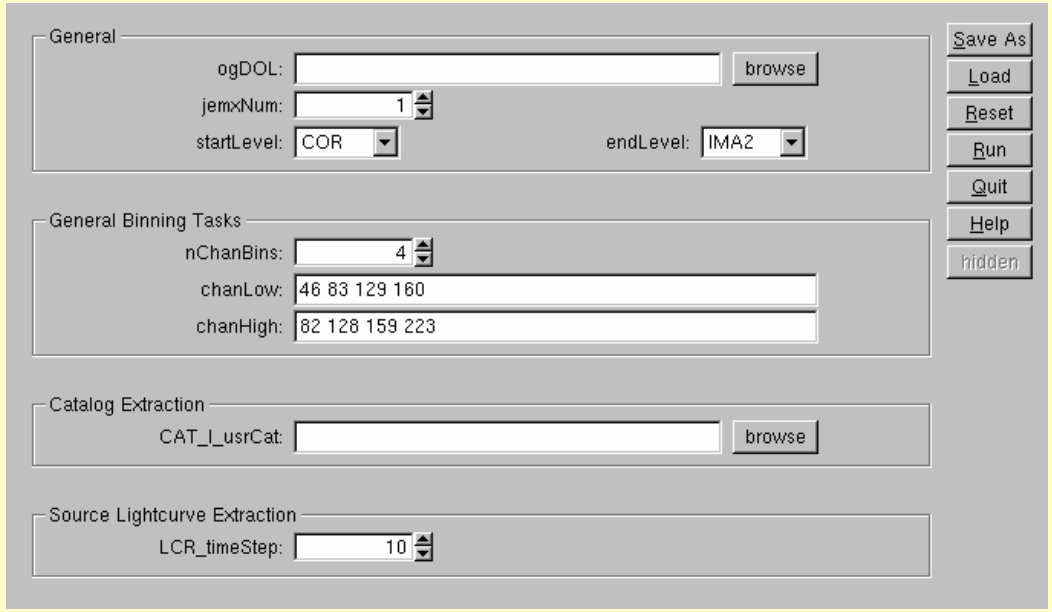
81 sources

10 hours

JEM-X

12 more significant sources

1 hour



Data treatment

fv: Binary Table of isgri_srcl_res.fits[1] in /home/lbarragan/integral/ibis_data_rep/obs/0287-good/

File Edit Tools

Select All Invert

	NEW_SOURCE 1I	SOURCE_ID 16A	DAY_ID 1D d	NAME 20A	CLASS 1I	RA_OBJ 1E deg	DEC_OBJ 1E deg	ERR_RAD 1E deg	RELDIST 1E
64	0	J180839.3-202440	0.000000000000E+00	SGR 1806-20	1730	2.721638E+02	-2.041097E+01	1.400000E-04	0.000000E+00
65	0	J173816.0-270016	0.000000000000E+00	SLX 1735-269	1420	2.645667E+02	-2.700444E+01	2.800000E-04	0.000000E+00
66	0	J174057.0-281836	0.000000000000E+00	SLX 1737-282	1400	2.652375E+02	-2.831000E+01	2.800000E-04	0.000000E+00
67	0	J174725.9-295958	0.000000000000E+00	SLX 1744-299	1400	2.668579E+02	-2.999944E+01	2.800000E-04	0.000000E+00
68	0	J174950.6-331155	0.000000000000E+00	SLX 1746-331	1400	2.674608E+02	-3.319861E+01	9.720000E-03	0.000000E+00
69	0	J185502.2-310948	0.000000000000E+00	V1223 Sgr	1500	2.837593E+02	-3.116347E+01	3.000000E-05	0.000000E+00
70	0	J171236.5-241445	0.000000000000E+00	V2400 Oph	1600	2.581519E+02	-2.424572E+01	3.000000E-05	0.000000E+00
71	0	J183544.0-325855	0.000000000000E+00	XB 1832-330	1520	2.789333E+02	-3.298195E+01	2.800000E-04	0.000000E+00
72	0	J171012.3-280754	0.000000000000E+00	XTE J1710-281	1420	2.575512E+02	-2.813167E+01	2.800000E-04	0.000000E+00
73	0	J171954.0-314500	0.000000000000E+00	XTE J1720-318	1434	2.599750E+02	-3.175000E+01	3.333000E-02	0.000000E+00
74	0	J173954.2-282944	0.000000000000E+00	XTE J1739-285	32768	2.649758E+02	-2.849556E+01	1.660000E-03	0.000000E+00
75	0	J174300.0-362041	0.000000000000E+00	XTE J1743-363	1000	2.657500E+02	-3.634472E+01	3.000000E-05	0.000000E+00
76	0	J174805.1-282826	0.000000000000E+00	XTE J1748-288	1400	2.670211E+02	-2.847383E+01	1.700000E-04	0.000000E+00
77	0	J180659.8-292430	0.000000000000E+00	XTE J1807-294	1000	2.717492E+02	-2.940833E+01	2.800000E-04	0.000000E+00
78	0	J181743.5-330107	0.000000000000E+00	XTE J1817-330	32768	2.744314E+02	-3.301874E+01	5.500000E-05	0.000000E+00
79	0	J181800.0-245000	0.000000000000E+00	XTE J1818-245	32768	2.746050E+02	-2.454200E+01	1.660000E-02	0.000000E+00
80	0	J175404.0-225215	0.000000000000E+00	IGR J17541-2252	32768	2.685170E+02	-2.287100E+01	7.000000E-02	0.000000E+00
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83	1	NEW_2	NULL	NEW_2	NULL	NULL	NULL	NULL	NULL
84	1	NEW_3	NULL	NEW_3	NULL	NULL	NULL	NULL	NULL

➡ Cleaning for IBIS/ISGRI

· Collecting the sources ⇨ get images, spectra & light curves

· Binning for JEM-X

· Fitting with XSPEC: (PROGRAM)

⇒ Fitting IBIS/ISGRI & JEM-X independently

⇒ Fitting IBIS/ISGRI & JEM-X together ⇨ Parameters in each revolution

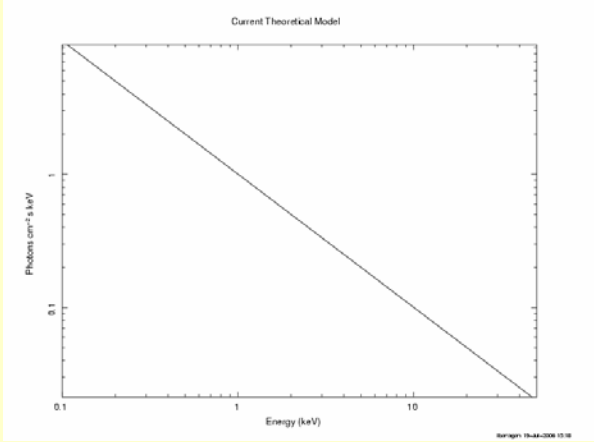
The models:

Powerlaw:

$$A(E) = N \cdot E^{-\Gamma}$$

par1 = Γ photon index of power law (dimensionless)

norm= N photons $keV^{-1}cm^{-2}s^{-1}$ at 1 keV



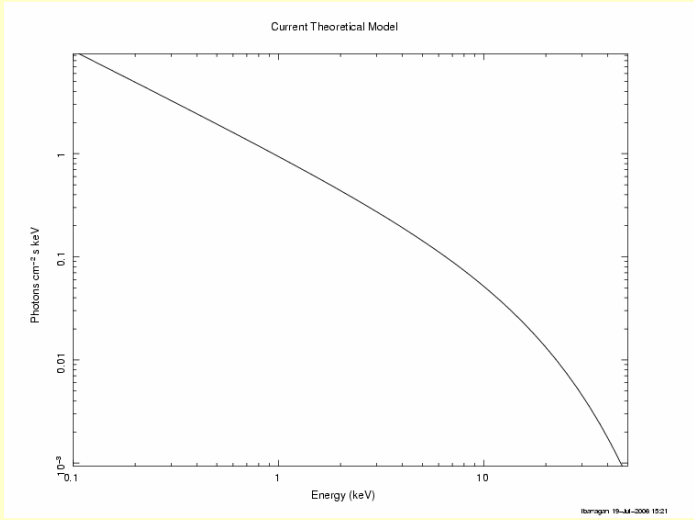
Cutoffpl: power law, high energy exponential cutoff

par1 = Γ power law photon index

par2 = β e-folding energy of exponential rolloff (in keV)

norm = *N* Photons $keV^{-1}cm^{-2}s^{-1}$ at 1 keV

$$A(E) = N \cdot E^{-\Gamma}\left(\frac{-E}{\beta}\right)$$



The fitting:

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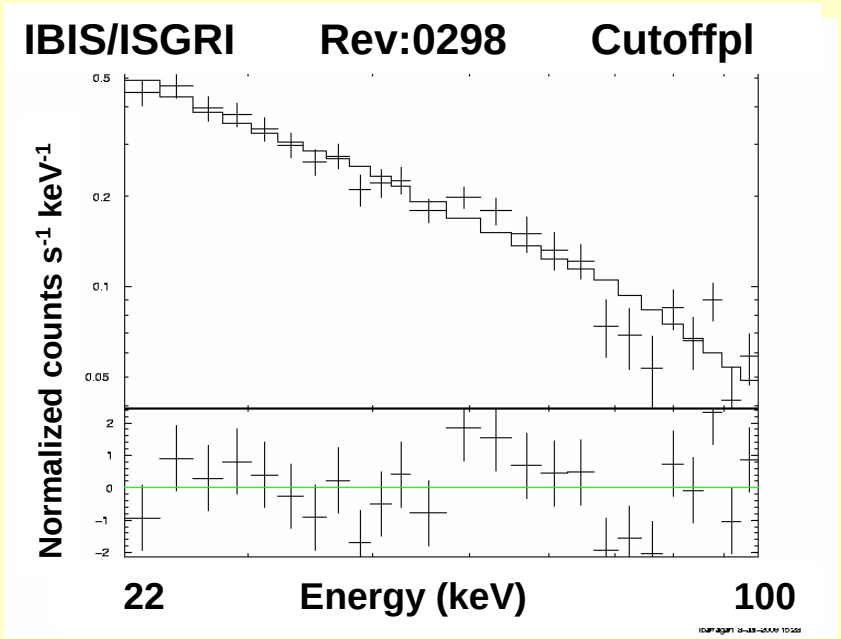
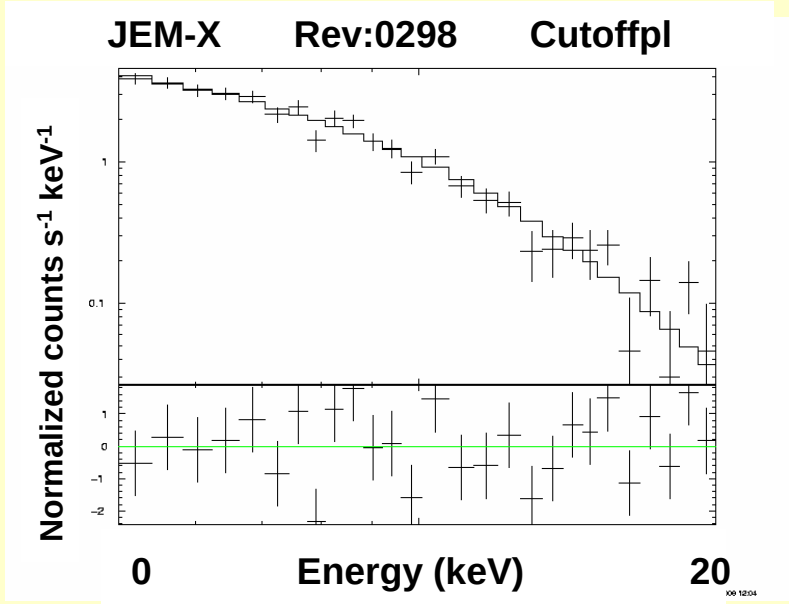
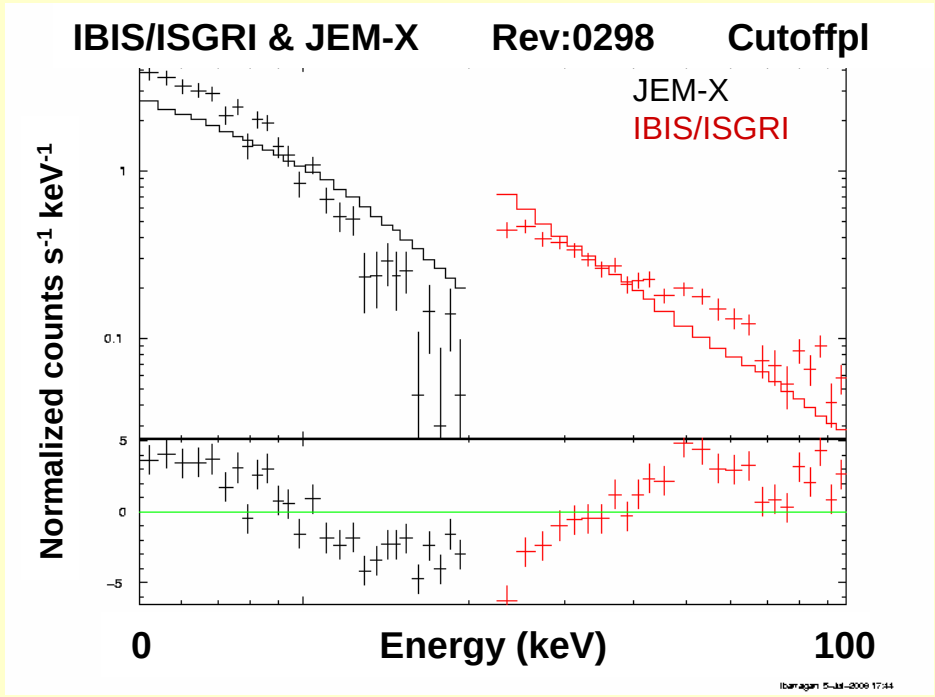
Strong source







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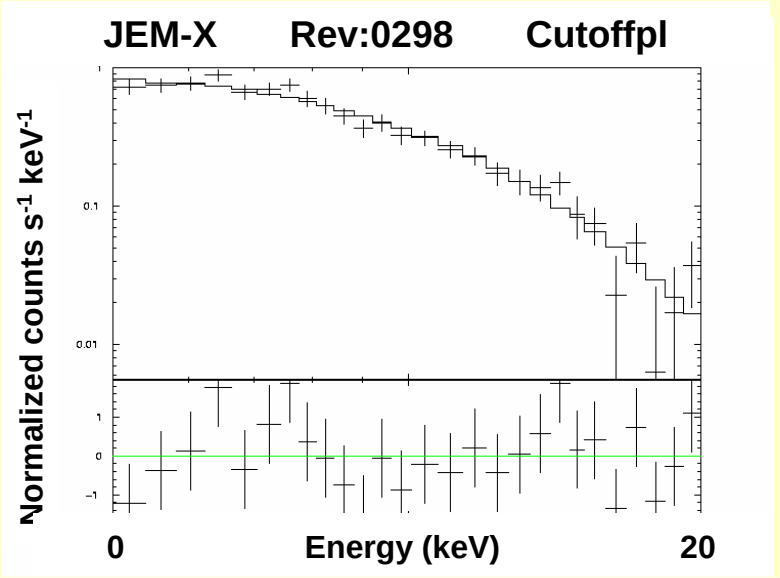
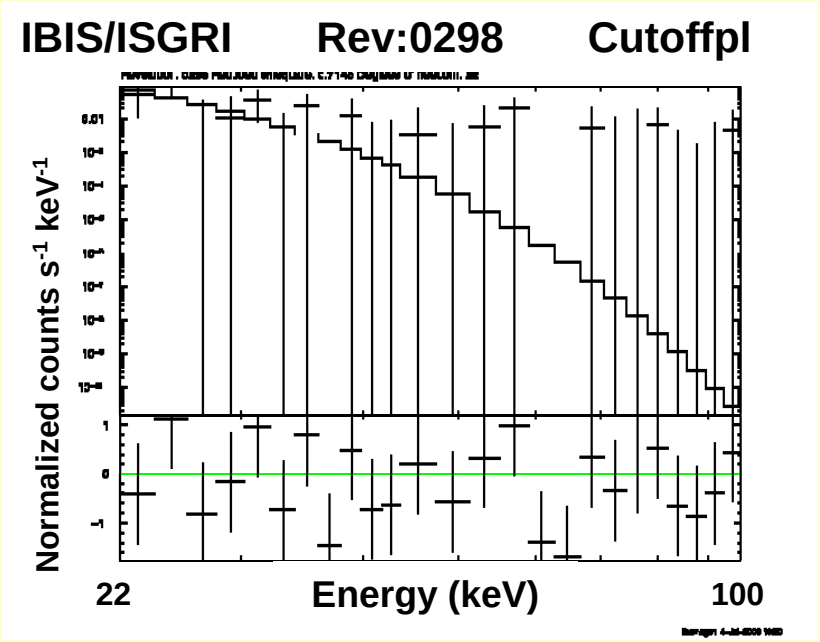
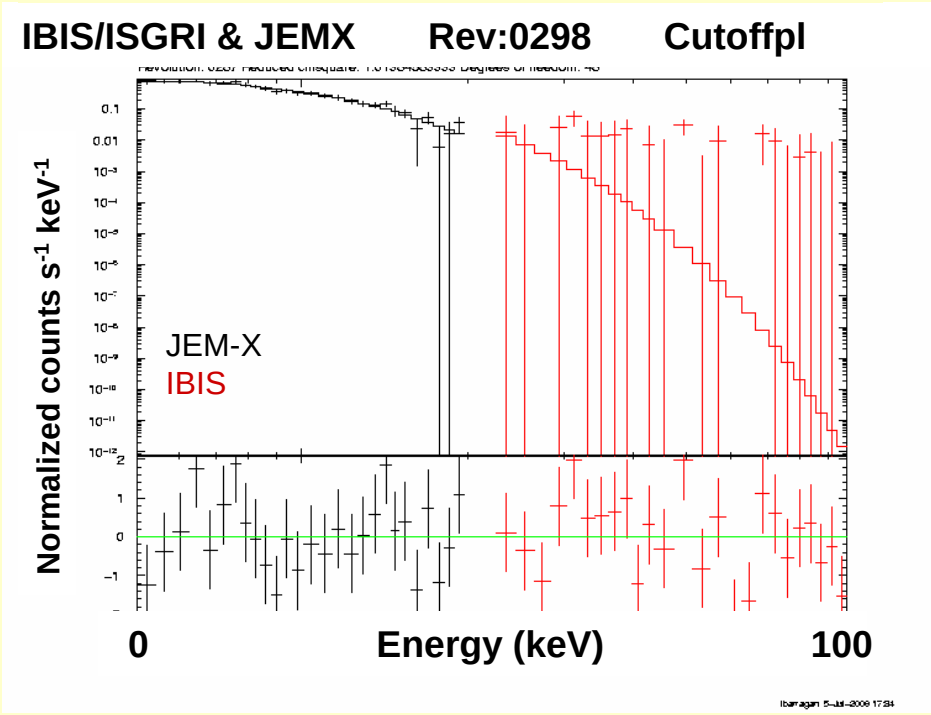
weaker source







What the program does:

⇒ Ignores the bad energies: compromise

⇒ Fits the models (adding a constant when we have both detectors)

⇒ Asks for the detection significance

⇒ Plots the fitted spectra and saves them

⇒ Saves the fittings

⇒ Saves the parameters and errors for each source and model

Do tables per source or per revolution

Tables

1A1742-294	0287_	ibis=>1.893674						
		jemx=>6.366455						
			cutoffpl	1.01384583333	48			
						HighECut	3.04827	2.46647	3.76889
						PhoIndex	0.339208	-1.03229	0.202403
						norm	0.0440495	0.0204574	0.0848622
						factor	177.163	0	665.753
			powerlaw	1.6486877551	49			
						PhoIndex	2.60637	2.52898	2.68574
						norm	1.30568	1.10451	1.54277
						factor	45.9245	0	94.7367
4U1722-30	0287_	ibis=>11.94899						
		jemx=>5.31						
			cutoffpl	0.855120833333	48			
						HighECut	497.52	0.0103426	500
						PhoIndex	1.99015	1.60583	2.2178
						norm	0.0957875	0.0432066	0.159581
						factor	1106.95	802.575	1337.23
			powerlaw	0.835812244898	49			
						PhoIndex	2.08794	1.88883	2.30079
						norm	0.116182	0.0720688	0.189047
						factor	1194.37	865.344	1681.61

⇒ Easy access to the data ➡ COMPARISON

⇒ Combine the data in order to plot the parameters

FIRST SCIENTIFIC RESULTS

Plotting the parameters (function of time)

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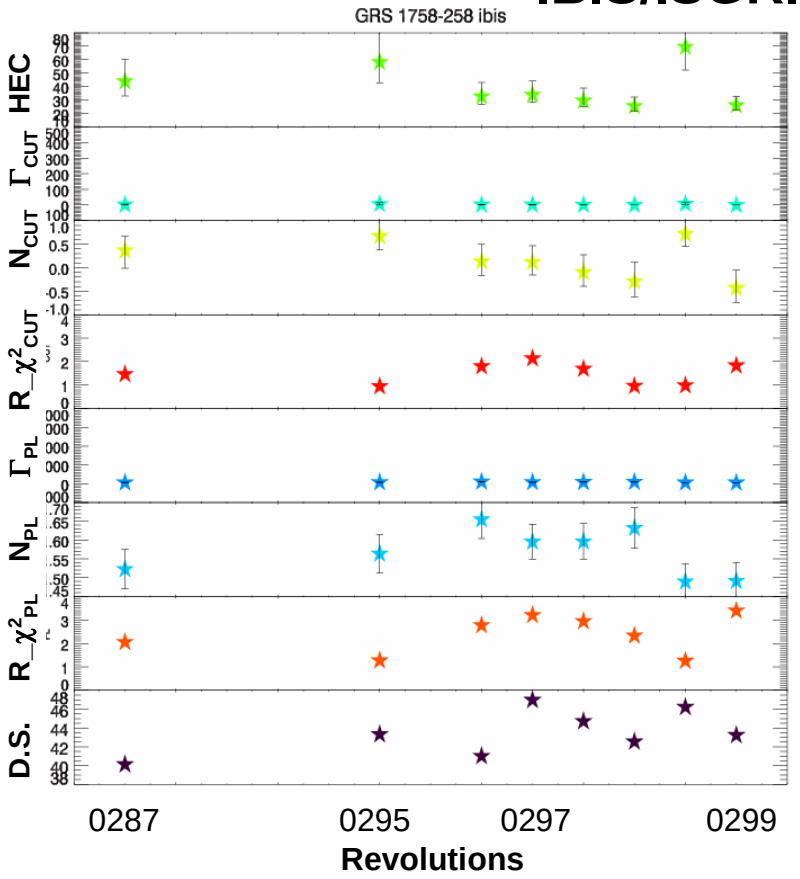
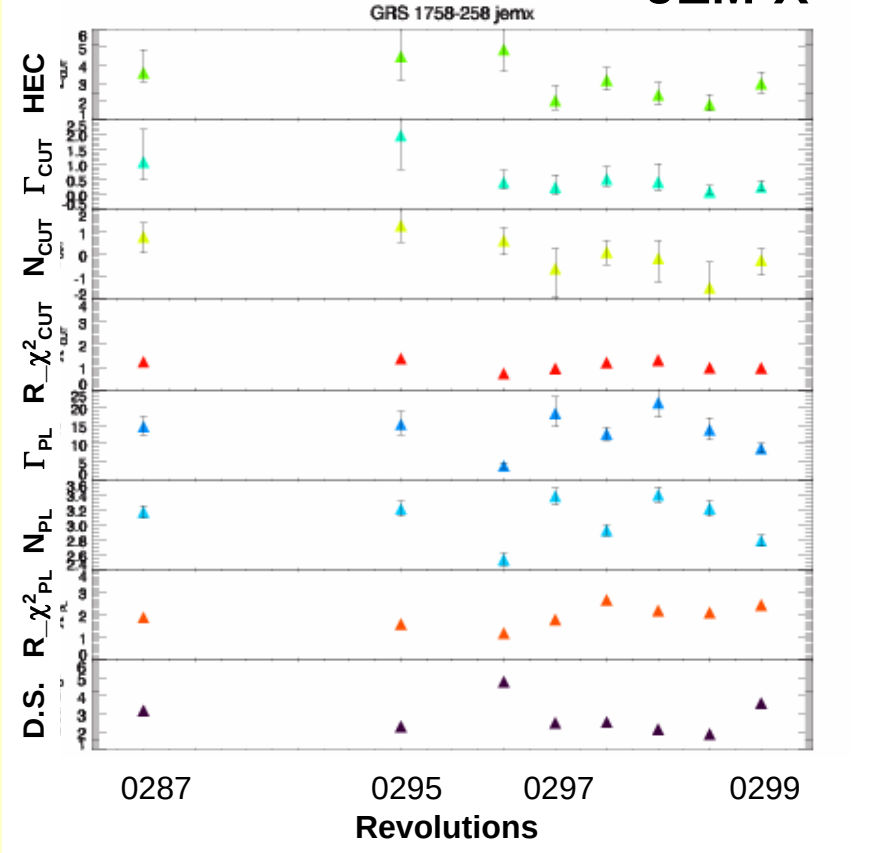
IBIS/ISGRI



JEM-X



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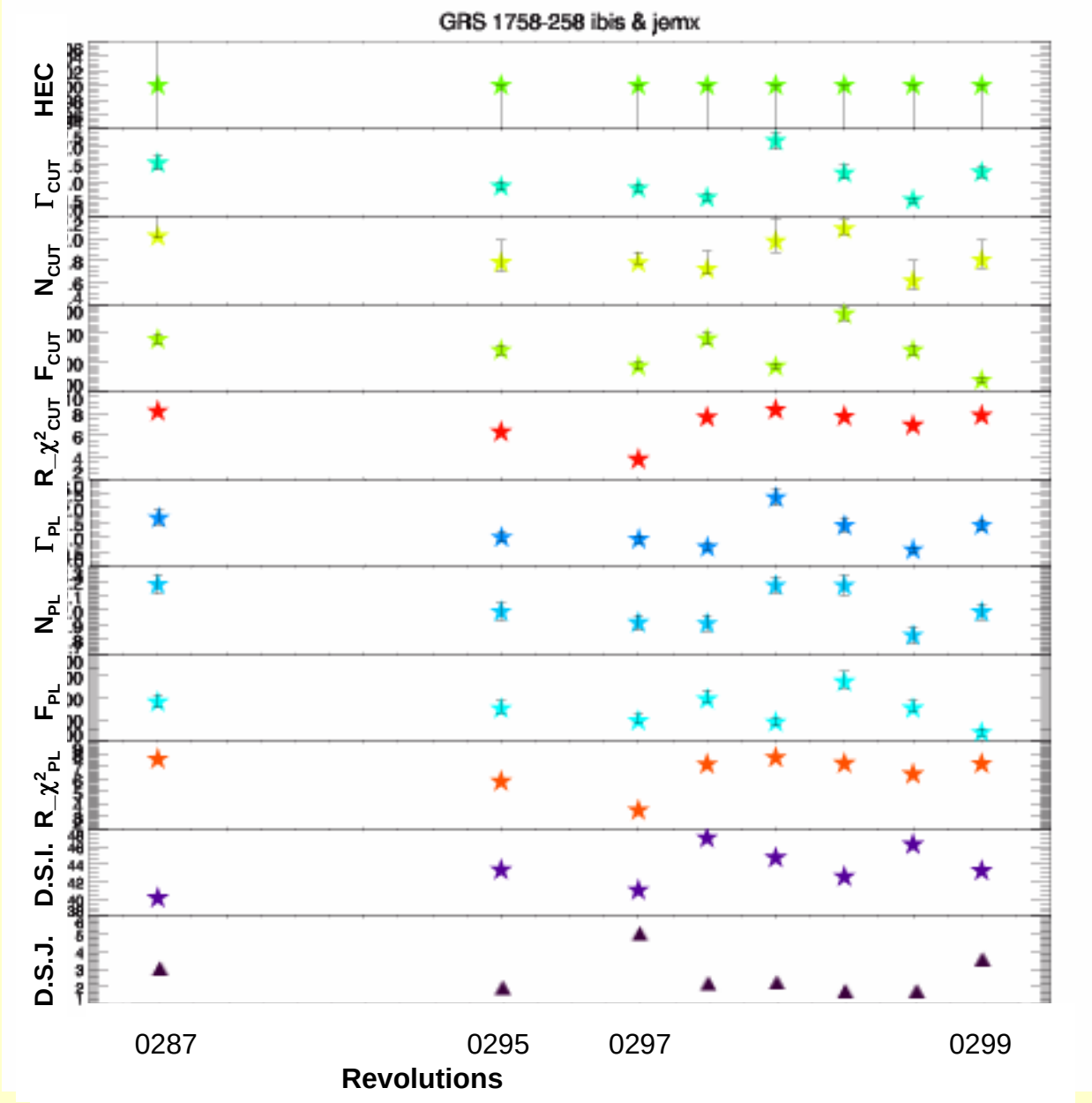
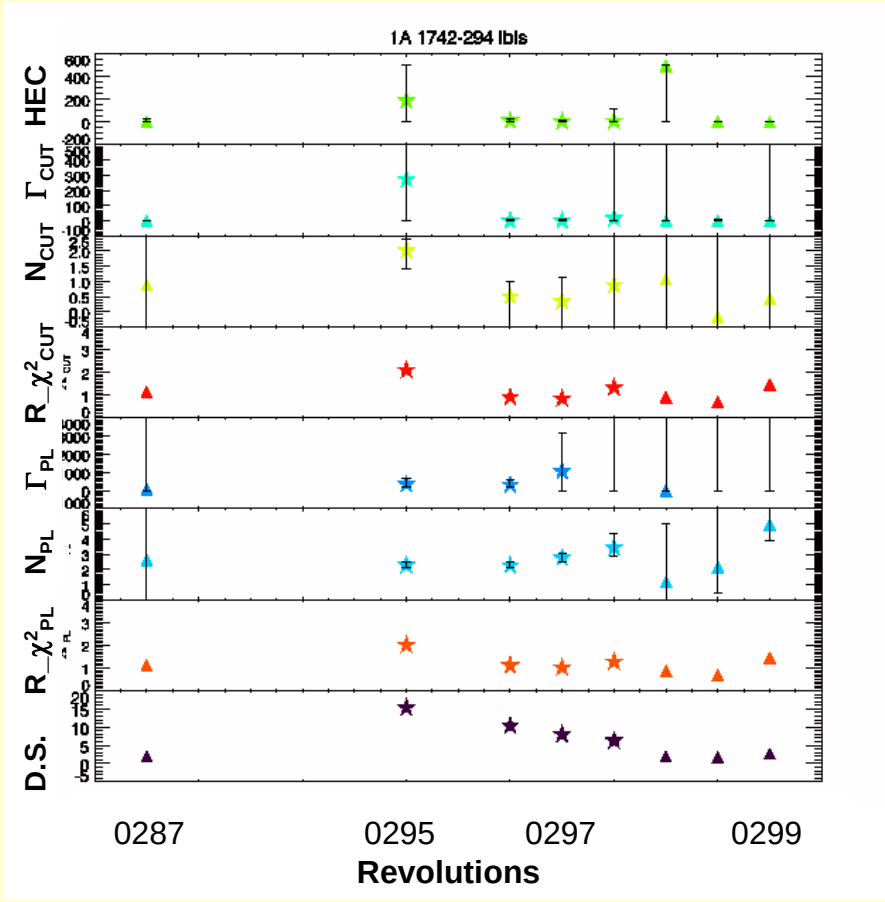
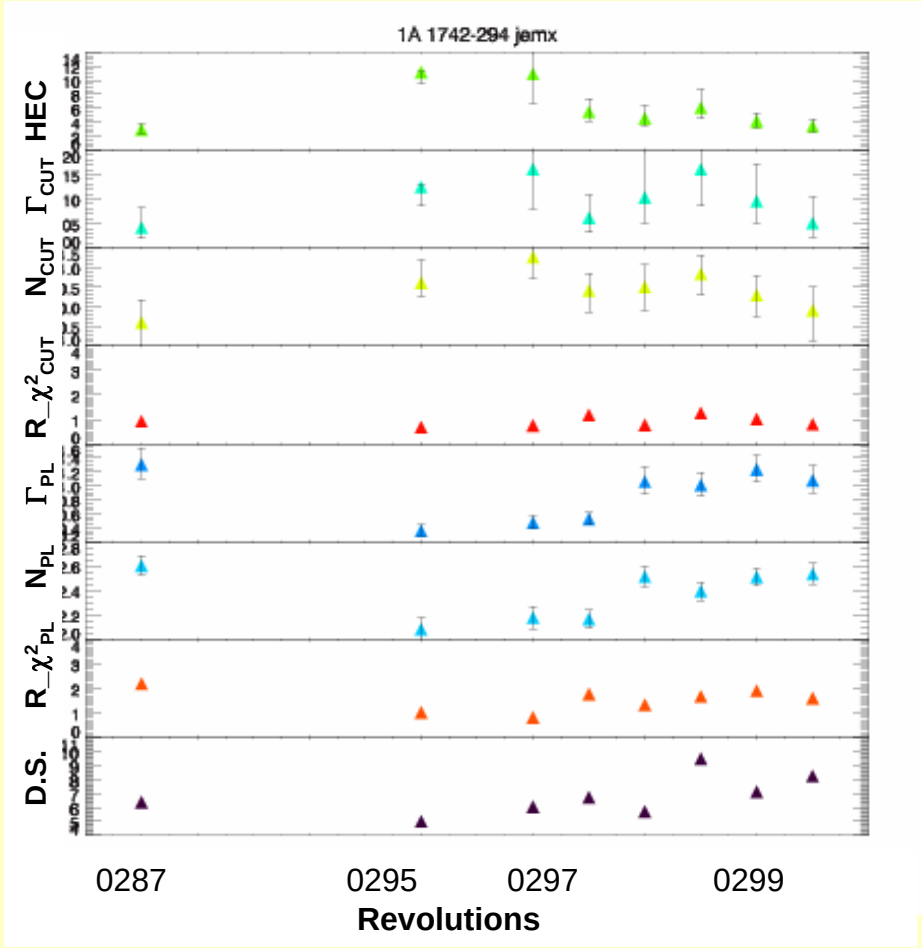
Both IBIS/ISGRI & JEM-X



1A 1742-294



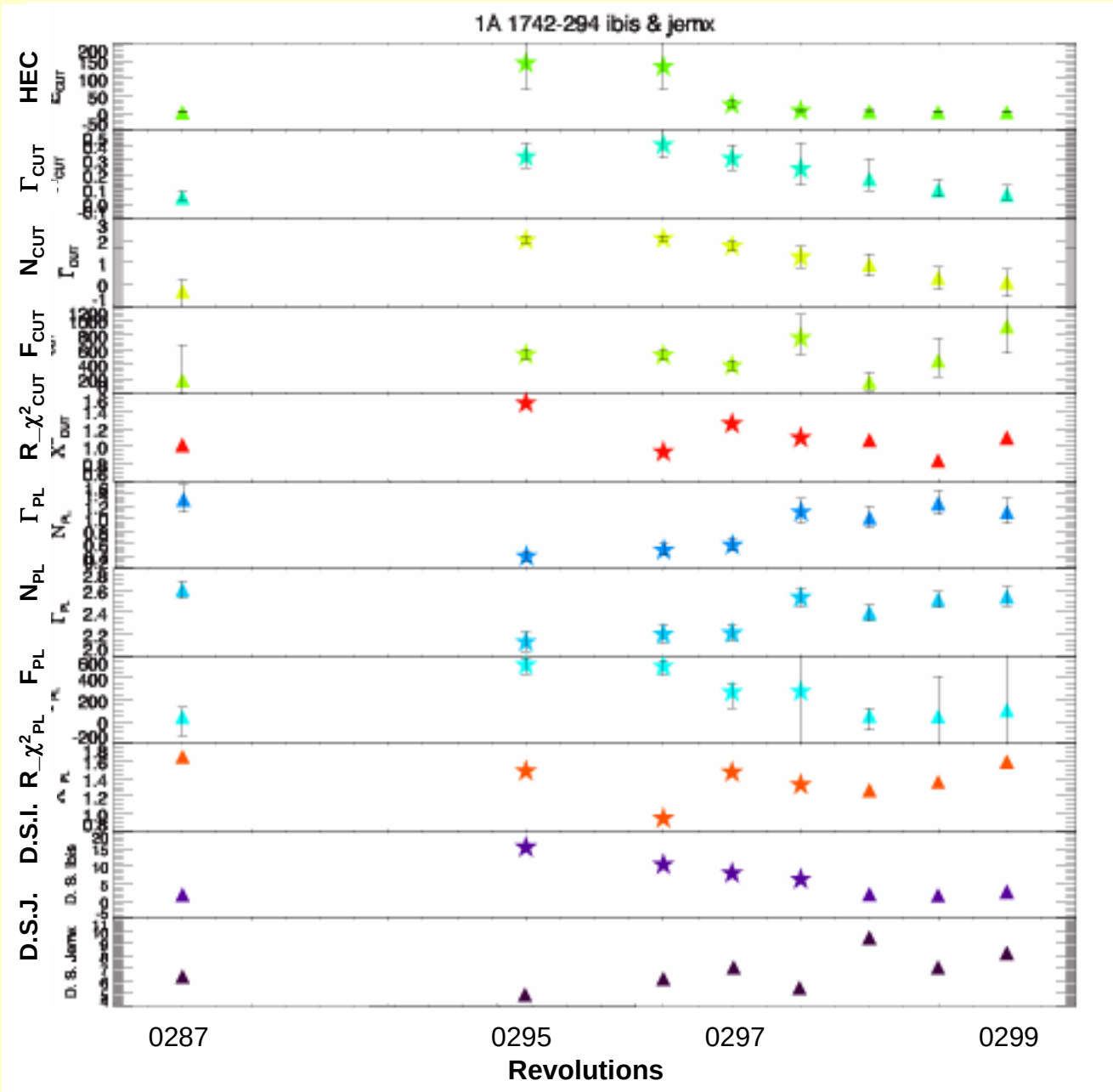
IBIS/ISGRI



JEM-X

1A 1742-294

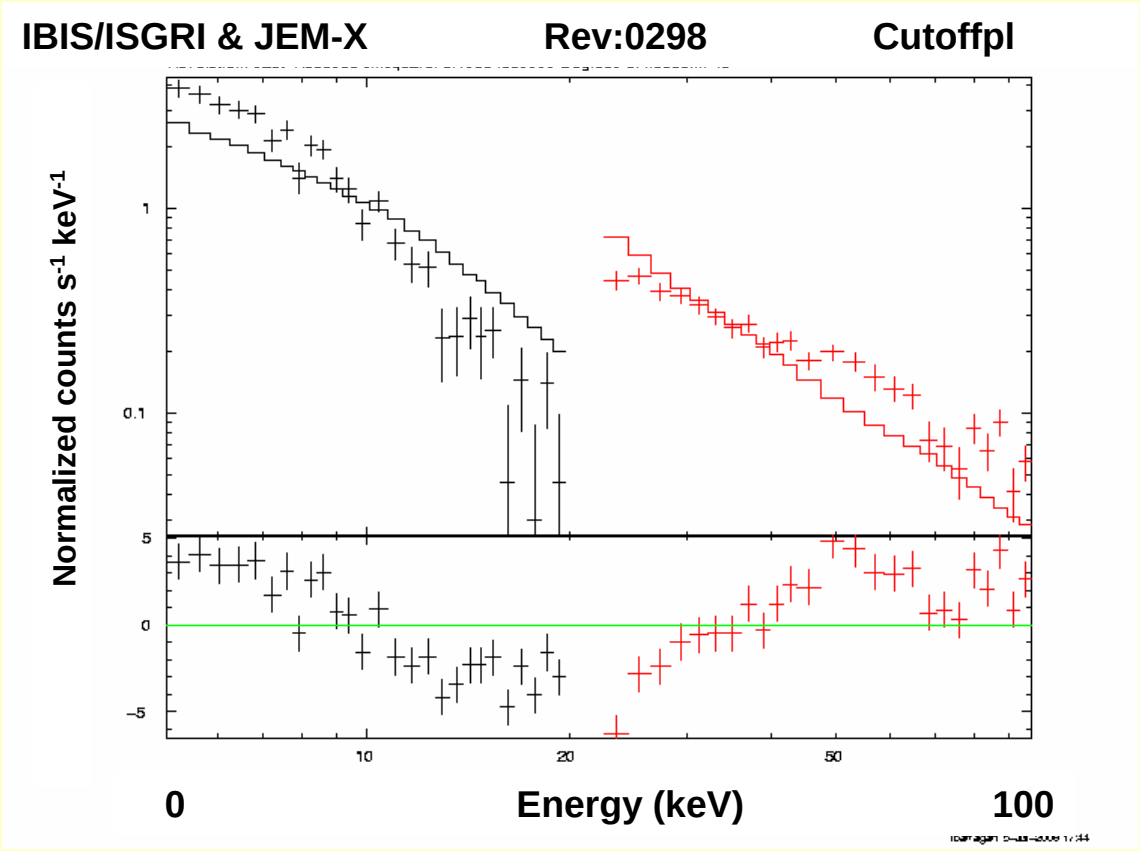
Both IBIS/ISGRI & JEM-X



Future work:

- ✓ Improve modeling

Ex: Red χ^2_{CUT} ~ 6



Future work:

- ✓ Fit all the revolutions
- ✓ Plot the parameters we obtain
- ✓ Compare the different types of sources
  (X-ray bursters, BH-binaries, etc)

CODED MASK TECHNIQUE

EXTRA SLIDE

NO MIRRORS IN GAMMA RAYS

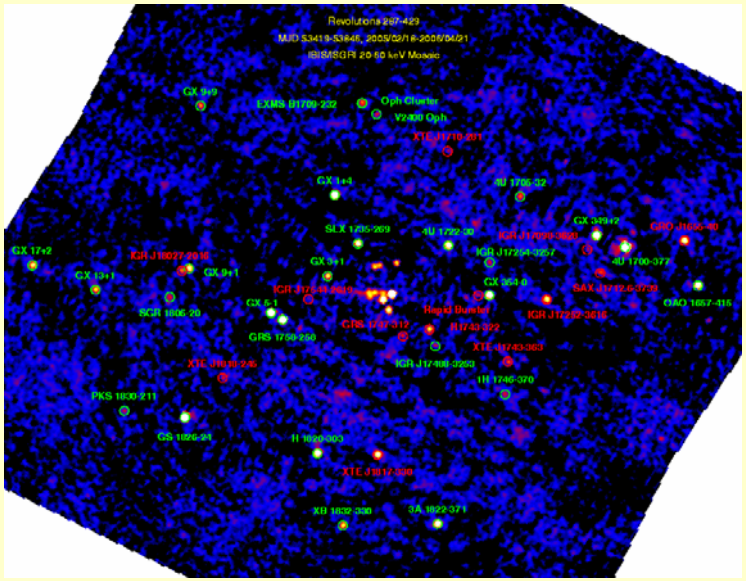
NO OPTICAL-LIKE IMAGES

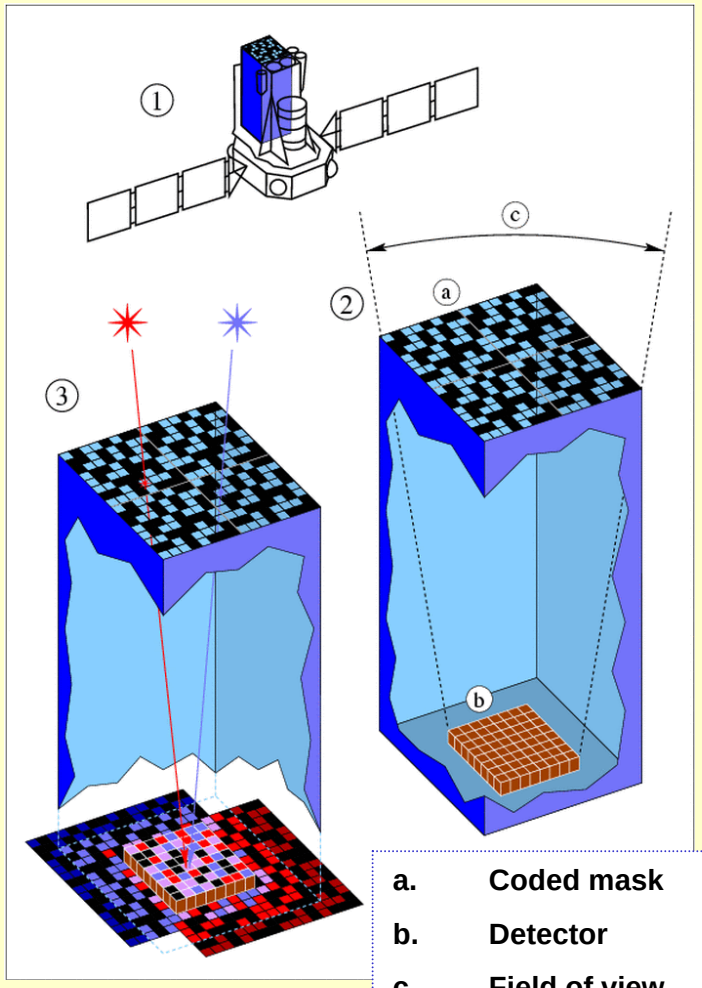
CODED MASK:

- Mask the opening of the telescope
- Measure its shadow on the detector
- orientation of the satellite & analysis of data from the detector

determine position & intensity of sources

image of the observed sky:





a. Coded mask
b. Detector
c. Field of view

ANTI-COINCIDENCE SYSTEM

E X T R A S L I D E