INTEGRAL/ISGRI calibration status

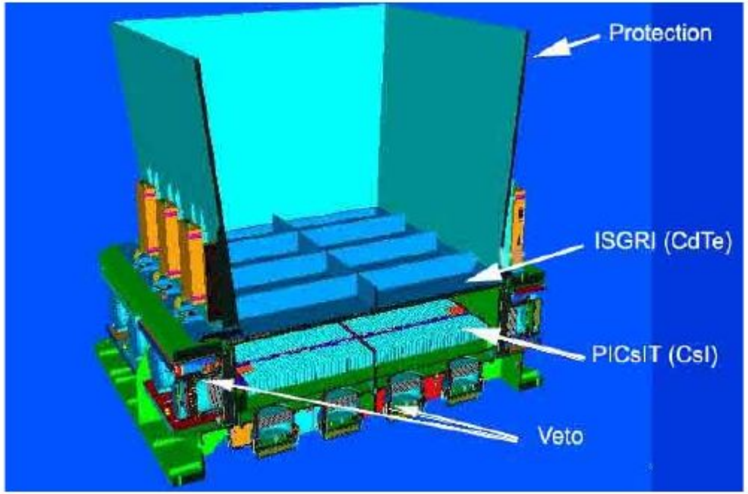
V. Savchenko

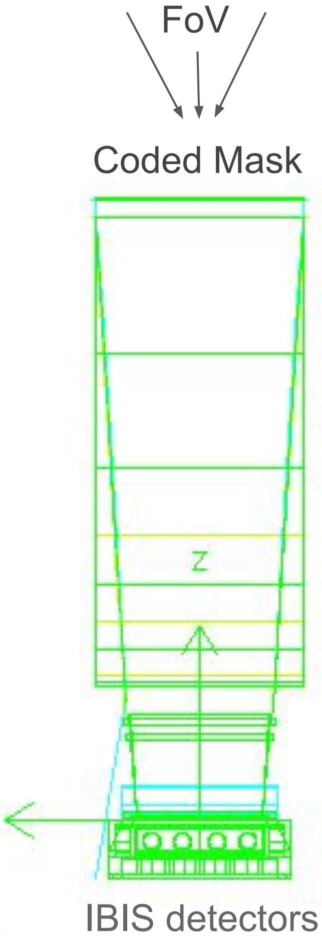
On behalf of IBIS team in Paris/Saclay and Rome

IACHEC 2018

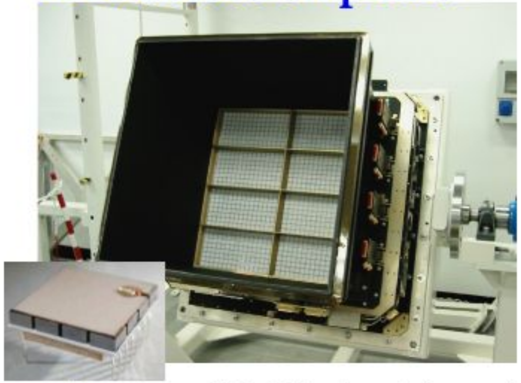
INTEGRAL imager IBIS/ISGRI

The **IBIS coded mask**, placed at 3.2m from detector. Built using 16mm thick W blocks, min.size 11.2mm

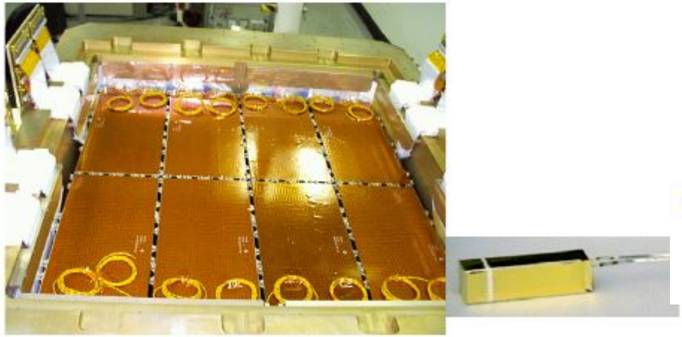




IBIS detection plane



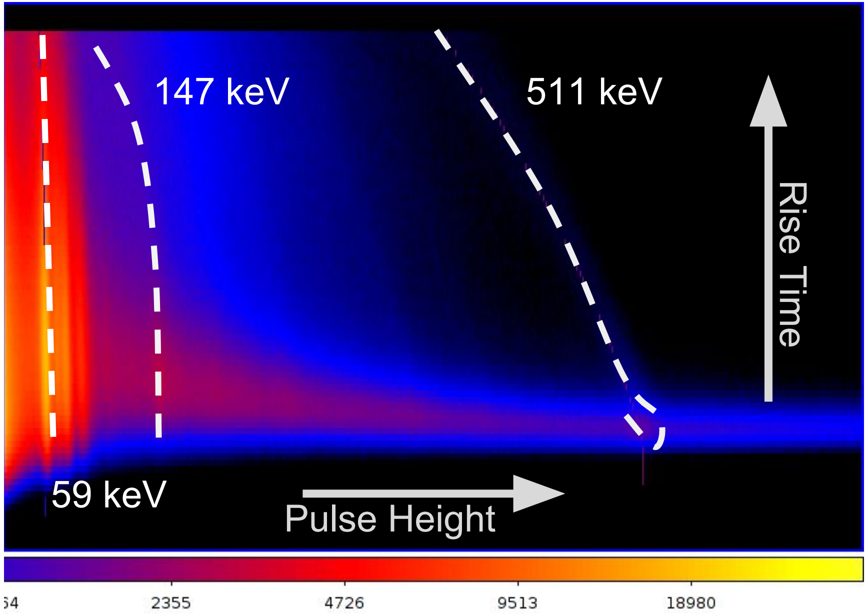
ISGRI: 2mm thick CdTe, 8 modules, total of 128x128 pixels, 4 mm resolution, energy range 15-1000 keV



PICSiT: 3cm thick CsI bars, 8 modules, total of 64x64 pixels. Energy range 0.2-10 MeV

IBIS/ISGRI spectral response calibration challenges

For each incident photon ISGRI measures Pulse Height (PH) and Rise Time (RT).**Single incident energy occupies 2D region in the PH-RT space**. These regions have several complex properties



Count rate in PH-RT bins

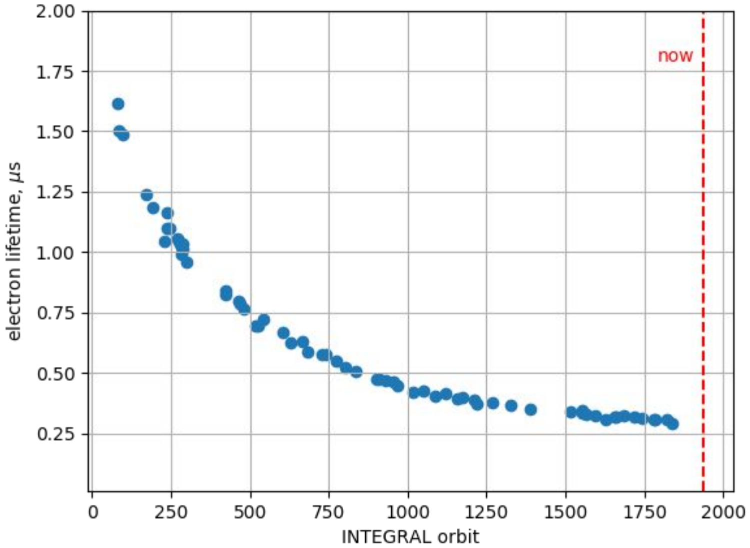
Low-energy regions converge with high-energy at high RT: source of major problems until OSA11

Effective gain is **non-linear in the whole energy range**, and getting worse with time, while the response at 20 keV must be determined from extrapolation from ~60 keV to 511 keV region.

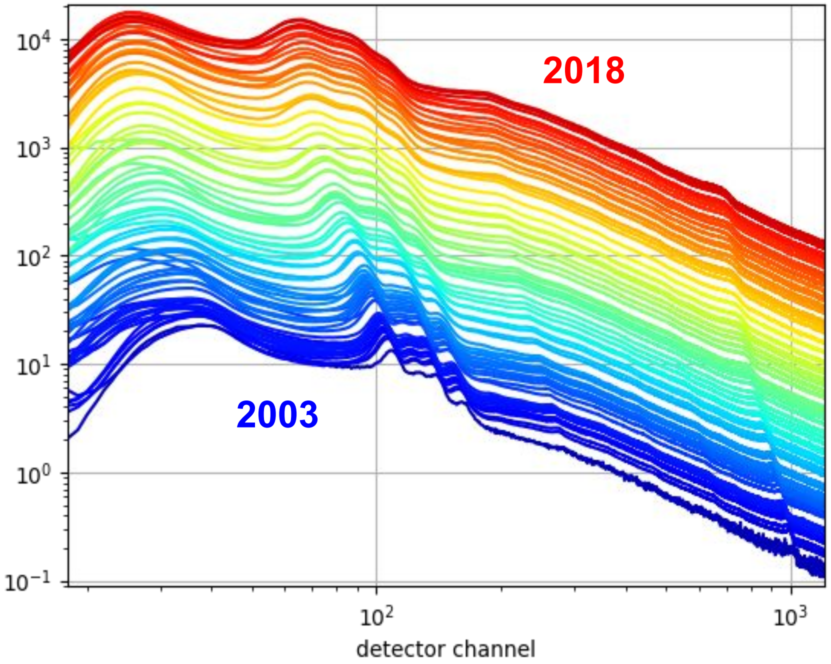
Low-energy Calibration lines are in the most non-linear region, where detector becomes transparent

Detector evolution

In more than 15 years **gain of ISGRI has decreased by factor ~2**, driven by **loss of electron lifetime in CdTe with irradiation**



Evolution of uncorrected background spectrum



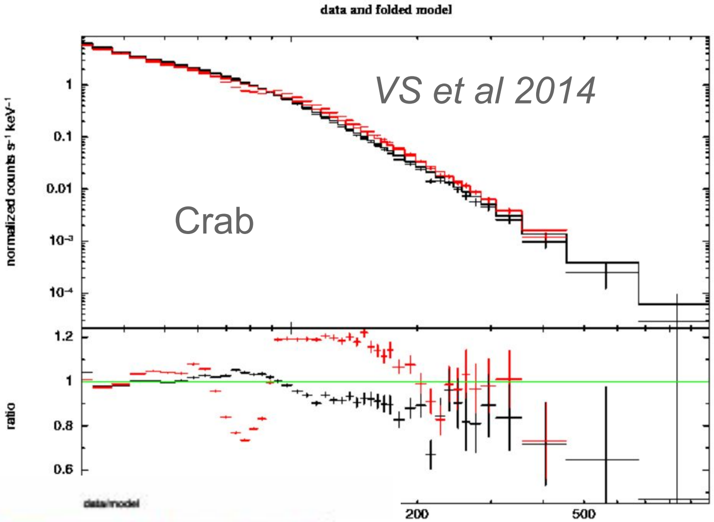
Since Low Threshold is fixed in the Pulse Height, gain drop implies **rise of the Low Threshold in keV. Resolution** in the first approximation also **degrades** just because of gain drift.

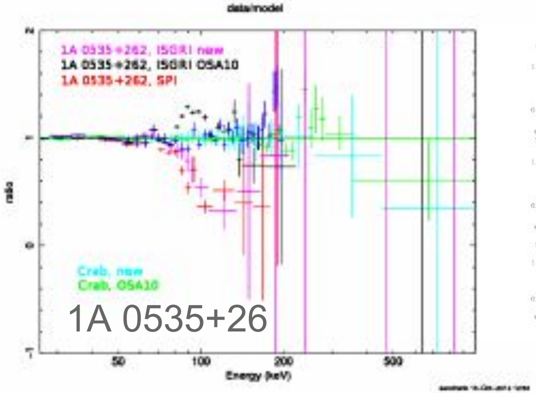
Mass model + ground calibrated electronics response

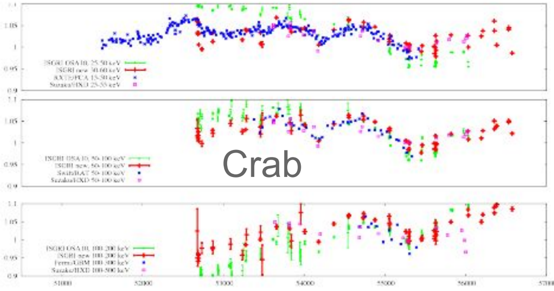
Early attempt for calibration fixed several major issues, but pure MC model did not quite fit the data.

Several factors were identified that contribute to the discrepancy:

- Underestimated energy resolution
- Not sufficiently accurate mask support NOMEX absorption model
- Dependency of the response on incident angle
- Inhomogeneous and unstable polarization of the detector
- Complex evolution of the multiple event trigger efficiency







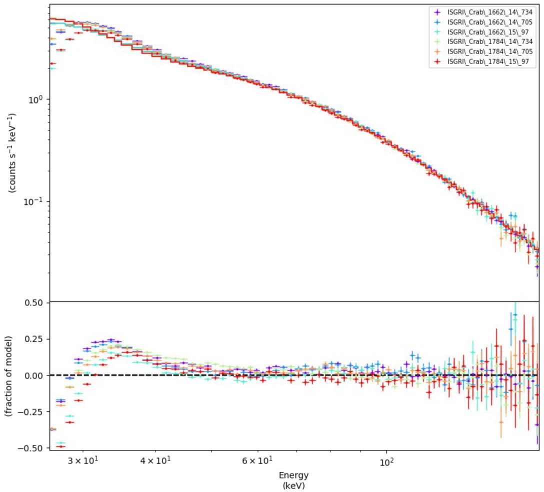
The Response Model

Finally, it was decided to use phenomenological model that captures effects which are **understood in principle, but hard to model exactly**. Whenever possible fit is done with several very bright sources of different spectral shape, using INTEGRAL/SPI as a reference.

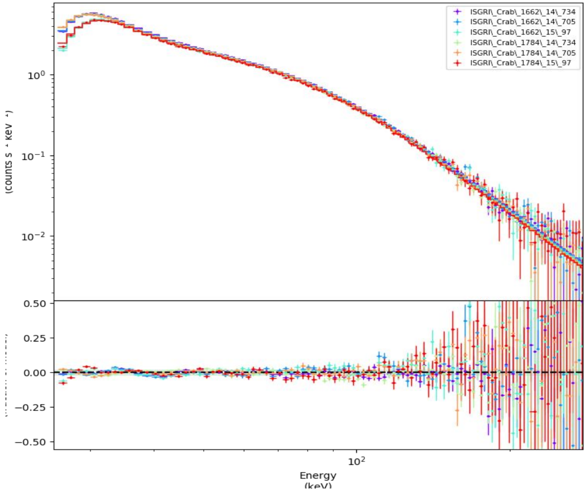
Two principal aspects are fitted: **low-energy efficiency and low-energy resolution**

Focus on **minimal number of parameters** over long term: 5 + 1 in each pixel subset parameters in 3 years.

Crab 2016-2017



Extrapolation from Ground calibration

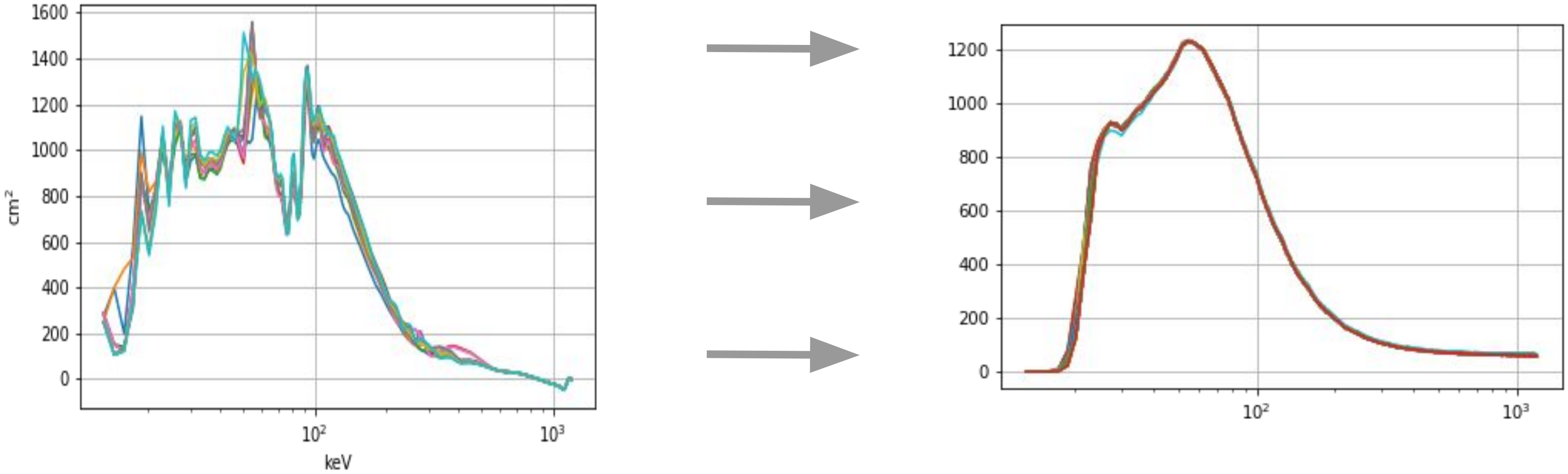


Best fit response model

The modelling was done done The Multi-Mission Maximum Likelihood framework (**3ML**), Vianello et al 2015, python framework to fit (locally or globally) astrophysical models to arbitrary data, perform bayesian inference, etc.

The Response Model

Since model focuses on reproducing known response properties it results in a “good-looking” ARF.



There are 8 **pixel settings, adjusted every orbit,** and need to be extrapolated between calibration observations.

In principle since there are more pixels in each group than sources It is possible to non-degeneratively fit efficiency in each revolution, but this requires very different user software.

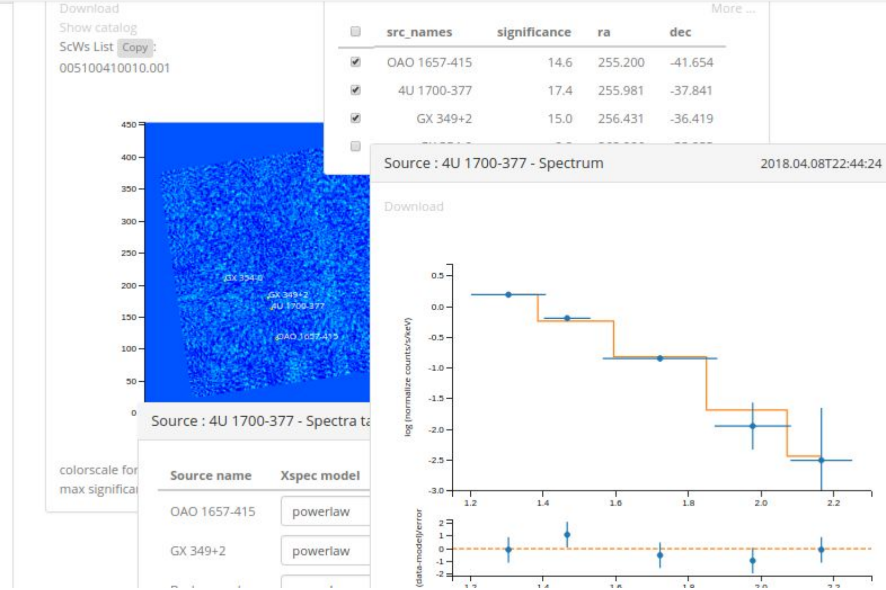
The result is remaining **uncertainty in the threshold region (15 keV in 2003, ~25 keV now)**

Software

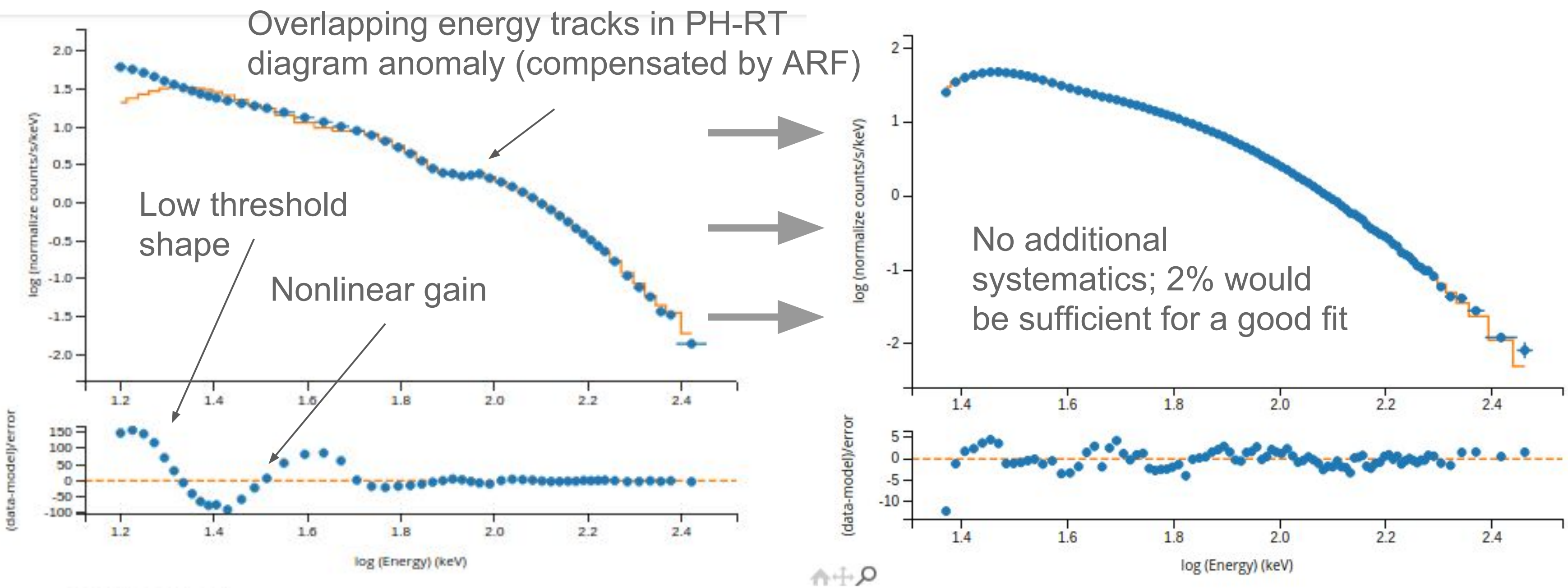
- Regular performance updates couple with long-term response model are expressed in Instrument Characteristics (IC), generated in a calibration pipeline.

- Aiming towards final software release and eventual transitioning in legacy phase, special effort is made to handle the **software, including calibration workflow, in a reproducible and maintainable way.** Both source code and live containers are being provided.

- Finally, as a part of a larger project, ISDC integrated this analysis workflow in CDCI **online analysis interface**.



Case: MAXI J1820+070: currently active 4xCrab



Exposure 22787.486328 (s)
Fit report for model cutoffpl

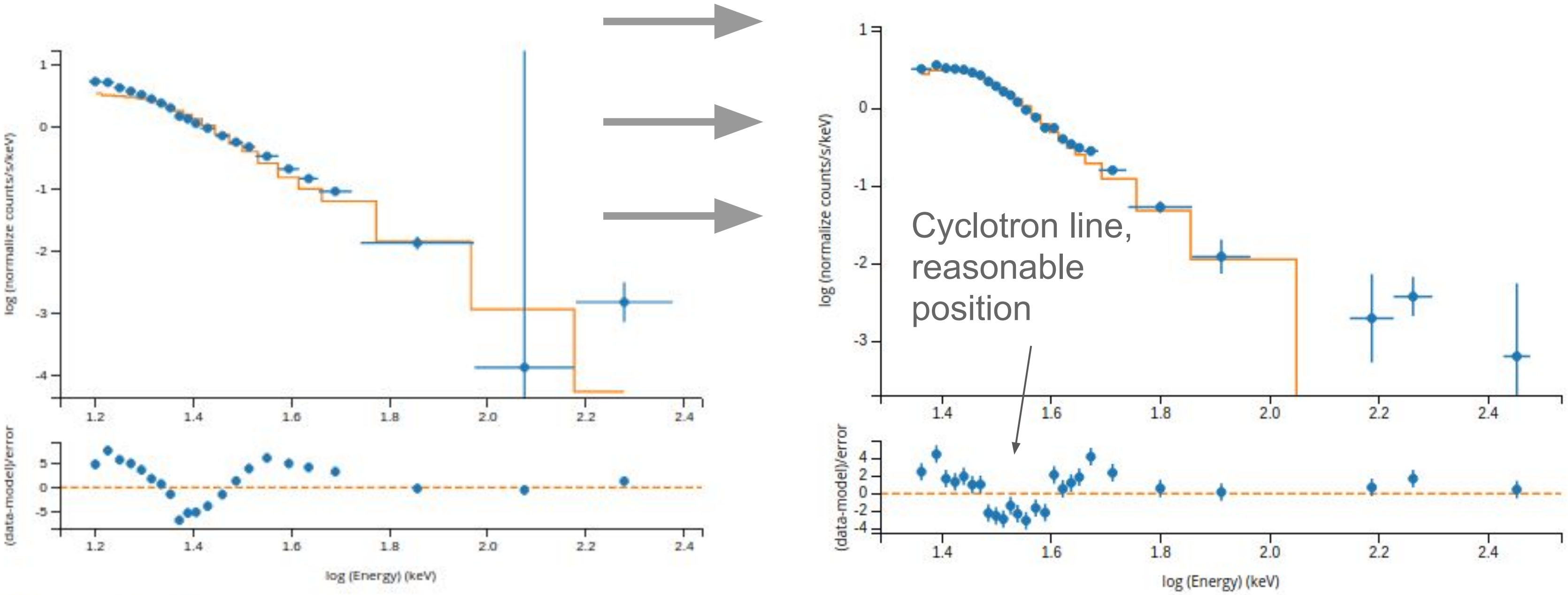
Component	Par name	Value	Units	Error
cutoffpl	PhoIndex	1.62591		0.00358
cutoffpl	HighECut	148.50624	keV	1.46792
cutoffpl	norm	6.80286		0.06990

Exposure 22787.216797 (s)
Fit report for model cutoffpl

Component	Par name	Value	Units	Error
cutoffpl	PhoIndex	1.21164		0.00507
cutoffpl	HighECut	74.85780	keV	0.52323
cutoffpl	norm	4.57126		0.06773

Her X-1: end of 2017

(recent 2018 observation under investigation)



Exposure 28036.449219 (s)

Exposure 28036.408203 (s)

Summary and Further steps

- *Increase of role of the non-diagonal response components, the calibration must be done in combination of energy calibration and response, i.e. not trivilar to separate tasks. But a lot of help from Rome team and SPI for establishing calibration cases, and of course this work started from ISGRI team in Paris.*
- Due to the extent of the validation required and shear amount of computing time, release schedule is decided to be in stages. First part, 2016-2018, most critical for the most recent, most challenging, observations, has been just approved, and will be released in May, when the packaging and documentation is completed. The calibration database will be updated progressively as soon as possible but likely till the end of the year.
- This release should not affect imaging performance in any substantially way. Some of the obvious improvements are not straightforward in current user software design, revised tools, also available in the online analysis, are being considered.