The soft gamma-ray sky observed with INTEGRAL's IBIS-PICsIT detector

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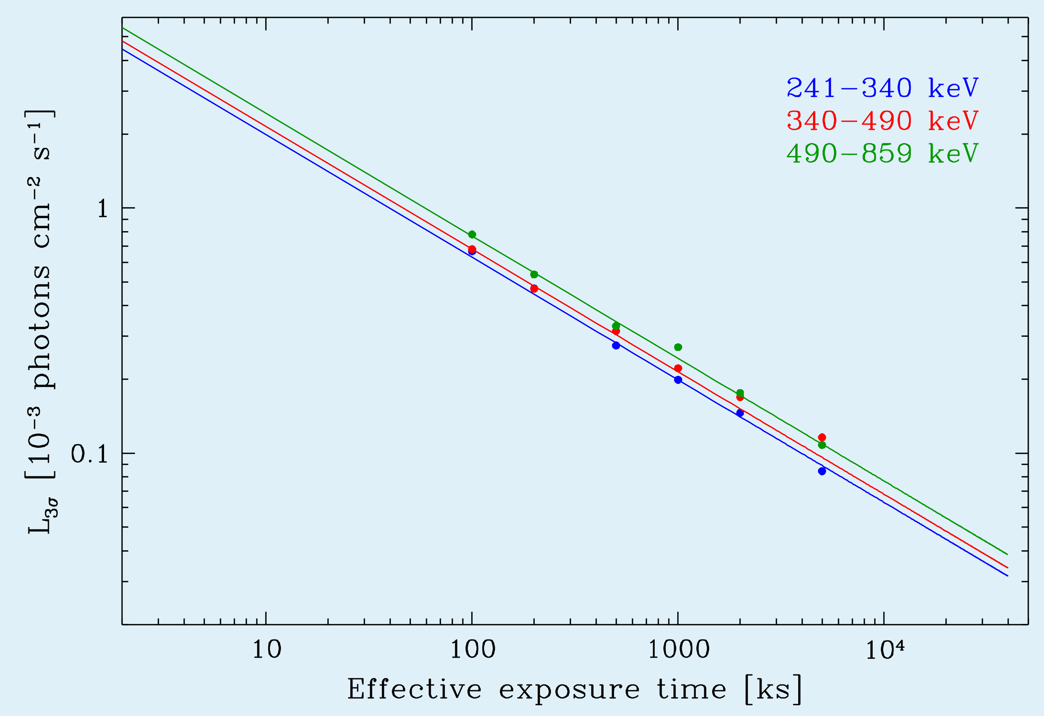
PICsIT detector

Since multi-messenger astronomy entered a new phase after the detection of gravitational waves and fast radio bursts, observations over the whole electromagnetic domain become more and more important. In particular, detailed spectral information in the soft γ-ray band (100 keV - 10 MeV) is essential to study the processes responsible for the non-thermal emission, e.g., the jet physics or antimatter annihilation.
The INTEGRAL satellite [1] hosts two soft γ-ray instruments, the SPI [2] and IBIS [3] coded-mask telescopes. The IBIS has two layers: upper is the ISGRI detector [4] operating in the 15 keV – 1 MeV band and bottom is the PICsIT detector [5] operating in the 175 keV – 10 MeV band. PICsIT has sensitivity similar to that of SPI above 200 keV and offers an unprecedented angular resolution of 12'. Despite the high instrumental background a fully-Bayesian data analysis with a careful modelling of the noise level [6] allowed us to detect 17 sources, providing unique results in the 240–1000 keV range.

Detection limits

A very high instrumental background is the main issue limiting sensitivity of the space detectors operating in the soft γ-ray band. Background emission varies in a complex way, depending on activation of the detector and surrounding material by a cosmic radiation. In the case of the PICsIT detector the background count rate is several orders of magnitude higher than the Crab count rate. Therefore, a precise determination of the background level is crucial for a detection of any source.
Since the background fluctuates on various time scales, detection for longer exposure times must be verified with a dedicated noise level study. In our study we used for this observations of the sky regions without detectable sources, determining a false detection probability for several energy bands. The results for the 3-σ noise limit shown below for exposure times T between 100 ks and 5 Ms can be approximated by a dependence $L_{3\sigma} = C/\sqrt{T}$ (T given in ks), with C = 6.3, 6.8 and 7.7 $\times 10^{-3}$ photons cm^{-2} s^{-1} for the 241–340, 340–490 and 490–859 keV bands, respectively.

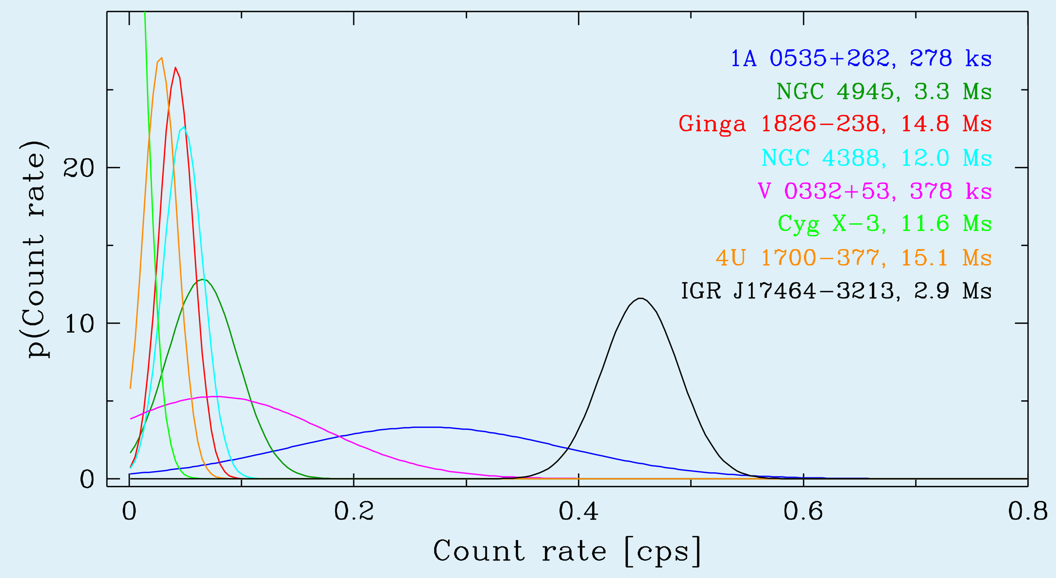


Detected sources

Low energy limit of the PICsIT operation band is 175 keV but its detection efficiency becomes significant above ≈240 keV. Since there is a quite limited number of strong celestial sources emitting above that energy, the PICsIT sample is moderate and consists of 17 objects detected up to now. The sample is dominated by the black hole binaries characterized by relatively hard spectra. Among more than hundred potential detections selected according to the 100–200 keV count rate found with ISGRI we have analyzed closer several dozens of sources. Examples of the probability density distributions found for the count rate in the 241–340 keV band for not detected objects are compared with the distribution obtained for IGR J17464-3213, with a 4-σ detection. Many bright BH and NS systems, persistent or transient, are not detected due to too soft spectra. On the other hand, the hard spectra' AGN are too weak emitters, despite a considerable exposure time. We expect more detections after a careful state-wise selection of data, the catalog will be published in 2020.

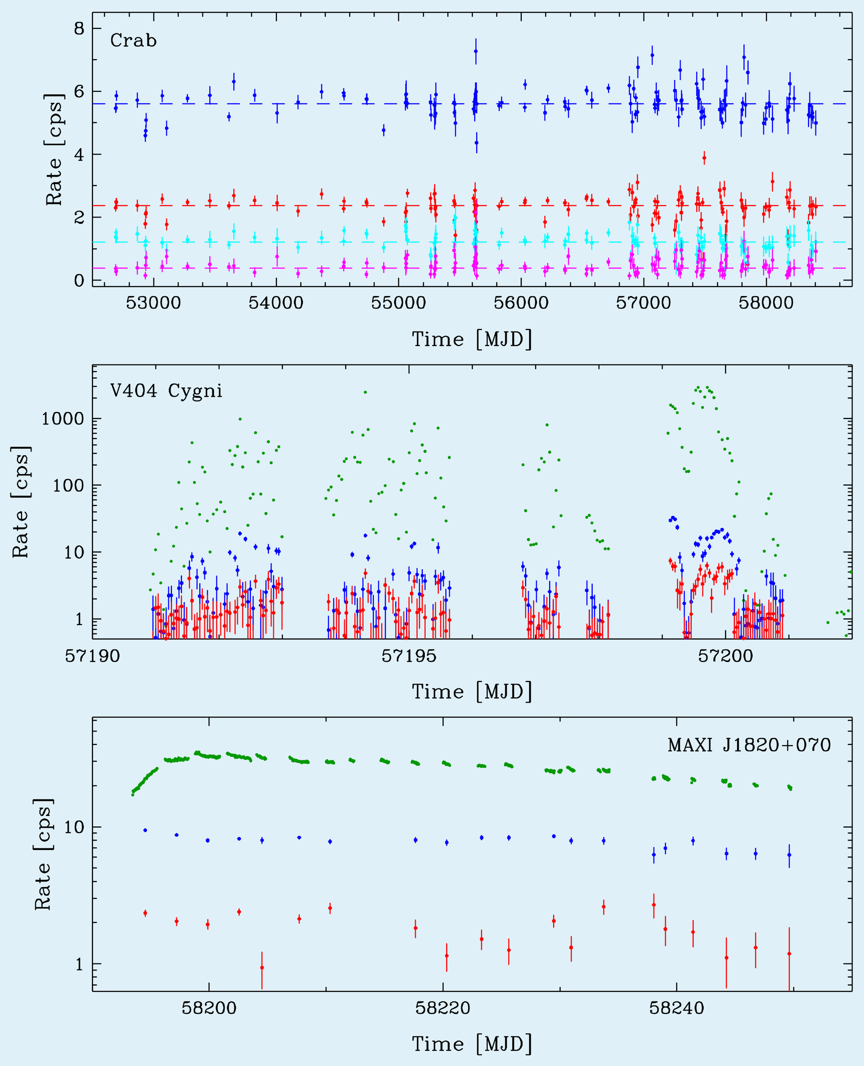
Objects detected with PICsIT

Persistent		Transient	
Crab	NS	XTE J1550-564	BH
Cyg X-1	BH	GX 339-4	BH
Cen A	AGN	IGR J17497-2821	BH
PSR B1509-58	NS	IGR J17464-3213	BH
GRS 1915+105	BH	GRO J1719-24	BHC
1E 1740.7-2942	BH	V404 Cygni	BH
GRS 1758-258	BH	MAXI J1535-571	BHC
3C 273	AGN	MAXI J1820+070	BHC
		SWIFT J1753.5-0127	BH



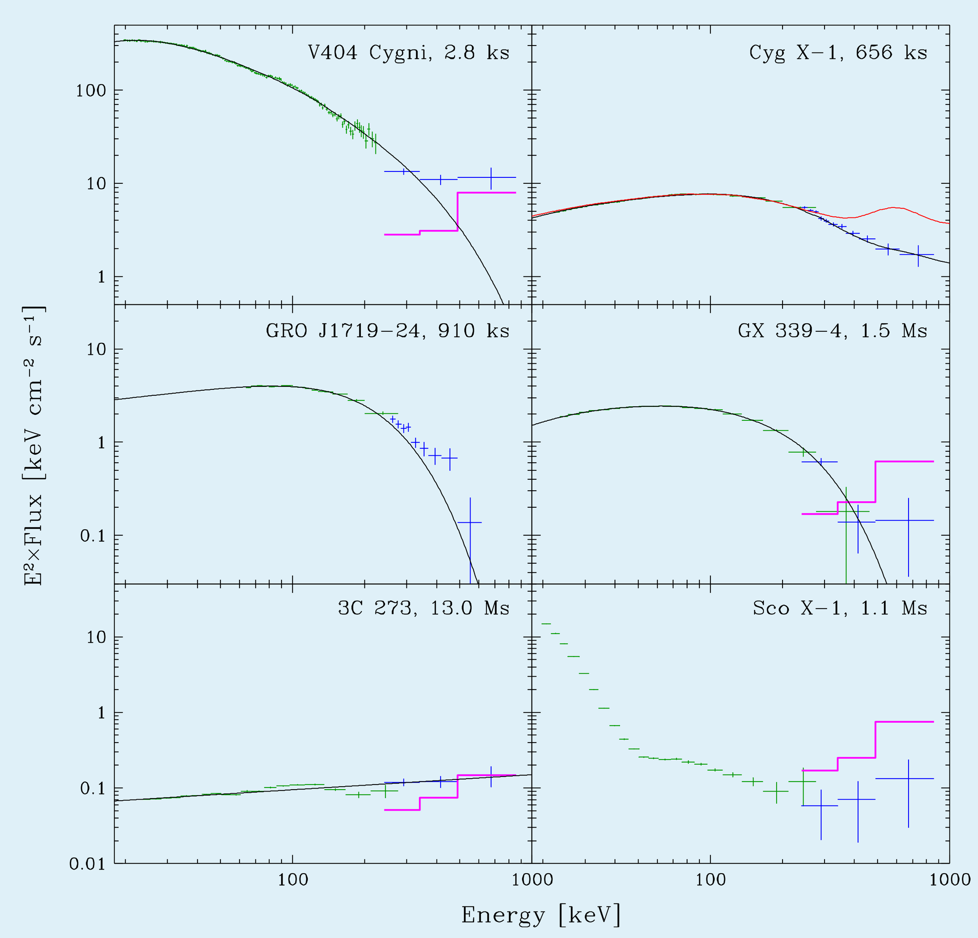
Light curves

The PICsIT light curves can be extracted for sufficiently bright sources. Here we show three examples of the light curves. For Crab we show that the count rates in several energy bands are stable over the mission period: 241–340 keV (blue), 340–490 keV (red), 490–859 keV (cyan) and 859–1995 keV (magenta).
PICsIT raw spectral data are integrated on-board and a minimal time bin is duration of a single INTEGRAL pointing, typically 0.5–2.0 hours. Example of such short-term light curve is shown for the 2015 outburst of V404 Cygni: 100–200 keV band of ISGRI (green) and 241–340 (blue) and 340–490 keV (red) bands of PICsIT. The same color coding is used for the light curve of much longer outburst of MAXI 1820+070 in 2018, except for ISGRI data (40–100 keV, scaled by a factor of 0.1).



Spectra

Six examples of joint IBIS' ISGRI (green) and PICsIT (blue) spectra are presented with the fitted model (black). For wider PICsIT bands we show also the 3-σ detection limits (magenta). The brightest spectra ever registered by INTEGRAL are those from the V404 Cygni outburst. The spectral model fitted to the ISGRI spectrum only is consistent with a thermal Comptonization, however, the PICsIT spectrum indicates a strong high-energy tail. An opposite effect is shown for the hardest state of Cyg X-1, where adding the PICsIT spectrum changed the spectral fit, limiting strongly the non-thermal emission when compared to the model fitted to the ISGRI spectrum only (red). The last example illustrates a lack of detection of Sco X-1 for so-called flaring branch with a hard tail [7].



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Summary

- INTEGRAL's PICsIT detector provides unique data in the 240–1000 keV band.
- These data allow to constrain the spectral models of accreting systems.
- We encourage users to check with the provided detection limits if their sources can be detected and contact us for PICsIT data.

Acknowledgements

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