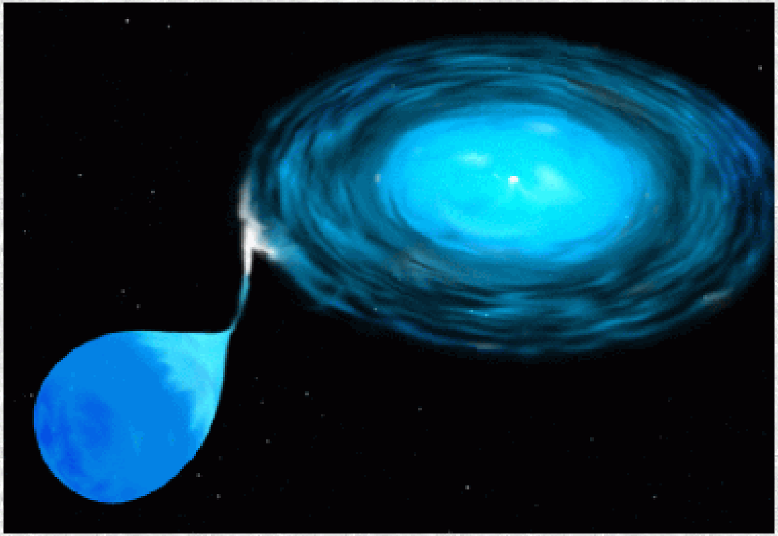
# INTEGRAL observation of GX 1+4



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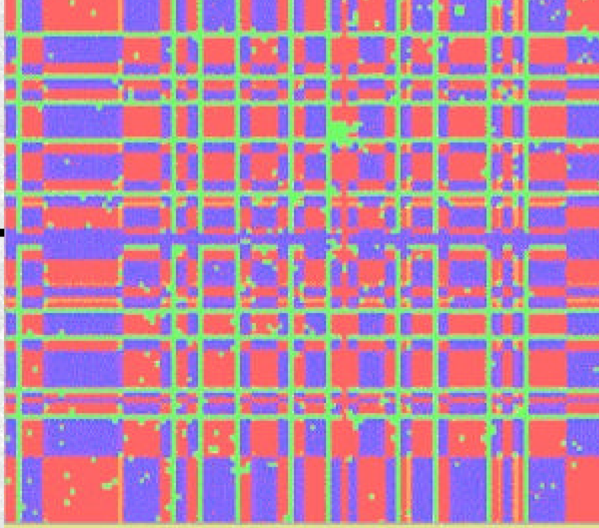
# Summary

- ***Method to extract spectra, lightcurves and pulse profiles for ISGRI***
- ***Calibration and response matrix issues***
- ***Pulse profile and spin period evolution***
- ***Spectral dependence on luminosity state***

# IF based Extraction Method





Compute Photo Illumination Fraction (PIF) for each pixel and each source (OSA tool by N. Produit)

Filter out noisy pixels

For each source select 2 sets of pixels based on their PIF values, e.g. pixels with PIF>0.75 (ON) and PIF<0.25 (OFF)

- For the ON and OFF pixel datasets accumulate light curves, spectra and pulse profiles
- Normalize to number of pixels and subtract OFF from ON
- Sum spectra and pulse profiles; collect light curves for each scw

# PIF based Extraction Method /2

## source decontamination

Background is not perfectly uniform on detector but, due to large number of pixels and mask construction, it contributes almost equally to on ON and OFF

The mask imaging PSF is not an ideal delta, so a small degree of contamination among the sources in the FOV is expected (few %)

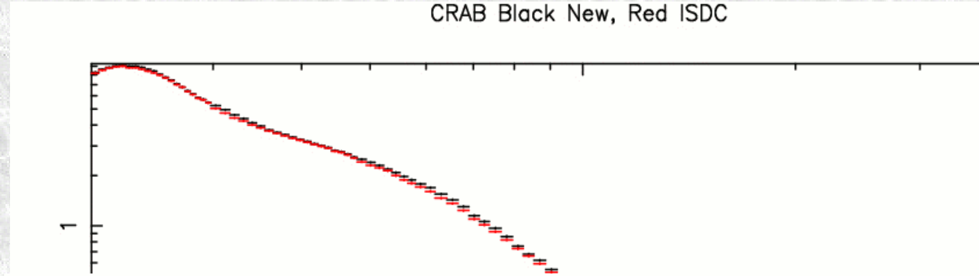
Contamination depends on source positions respect to detector axes. Dithering further reduces it by

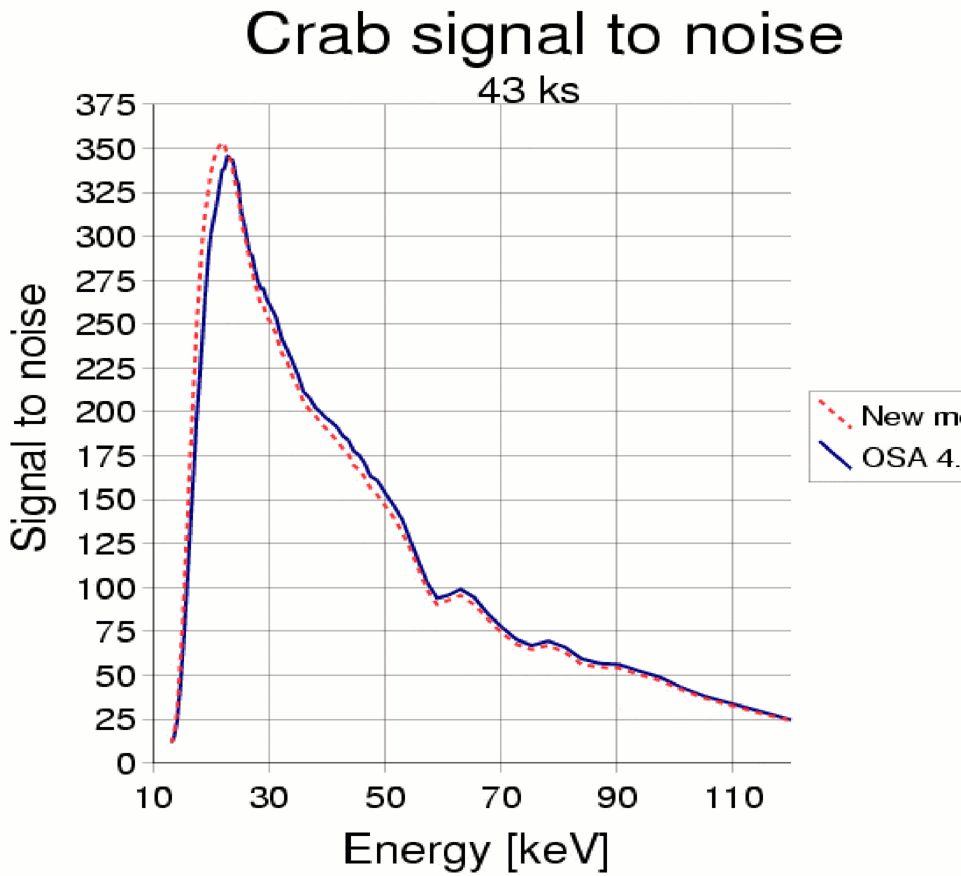
- ? Using the PIF information it is possible to decontaminate the spectrum of each source from the other contributions in the FOV using algebraic operations.
- ? In the case of GX 1+4, althou there are other 5 luminous sources, their contamination, computed from PIF, is negligible, less than 1%.

# Comparison with OSA spectra

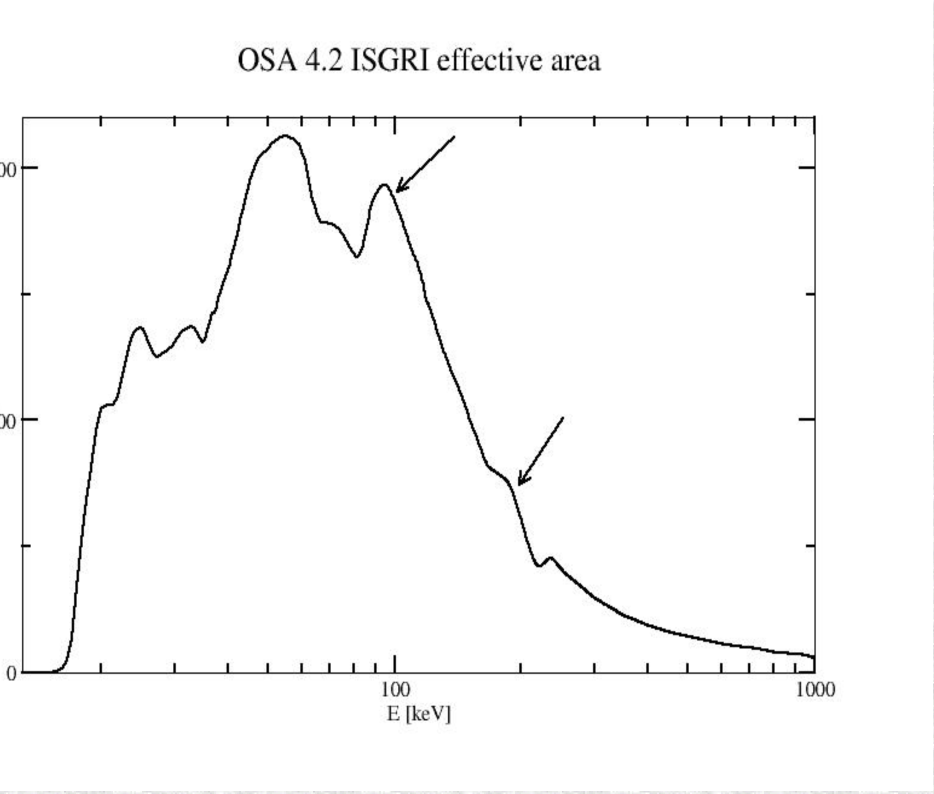
The PIF based extraction method gives results equivalent to OSA 4.2 both in S/N and spectral shape

to extract a spectrum in 132 bins on 2.8Ghz a Linux PC takes ~45m for 13 scws with OSA4.2 compared to <1min with our PIF based extraction method



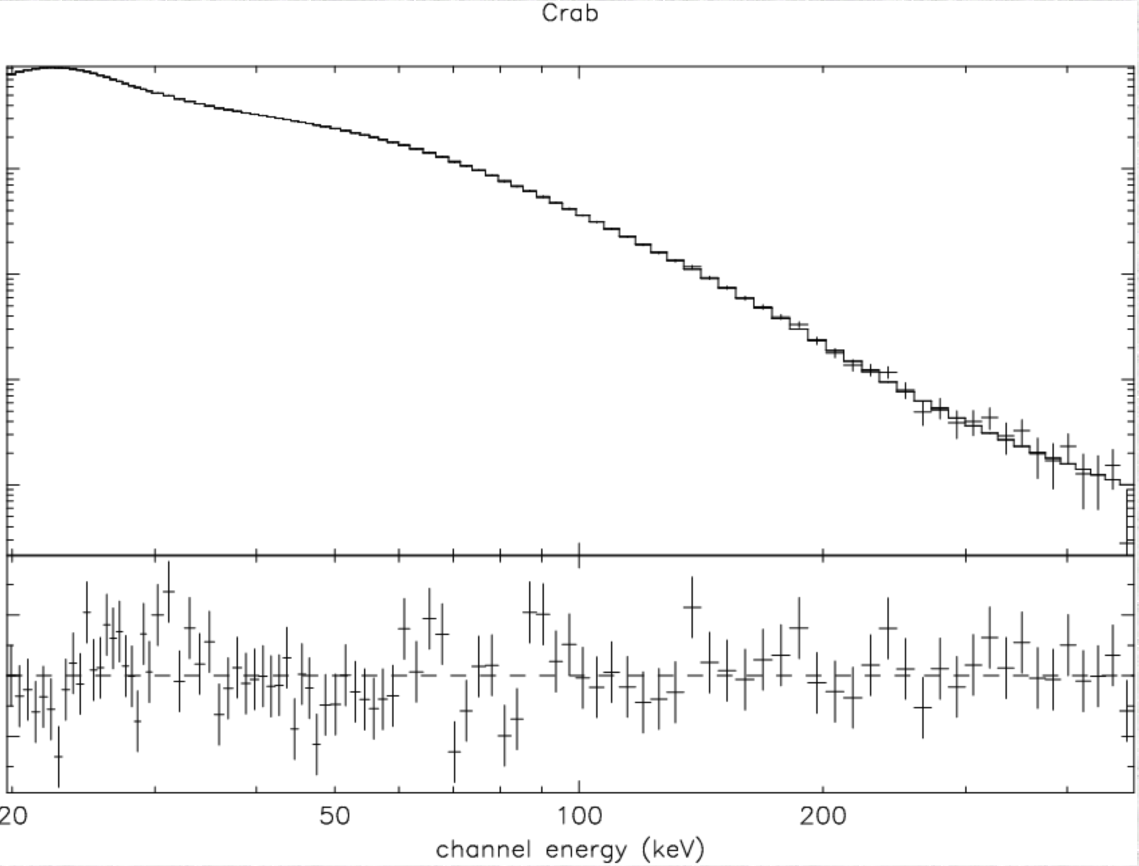
# ISGRI calibration and response matrix issues




- As said by F. Lebrun artific wiggles have been introduce in the OSA 4.* ISGRI effective area, based on the wiggles observed in the CRAB spectrum. However, since the wiggles depend o the source spectral shape, unreliable results would be obtained for other sources.

# ISGRI calibration and response matrix issues /2

- For the processing of ISGRI data we




LUT as reference. (See Segreto's talk

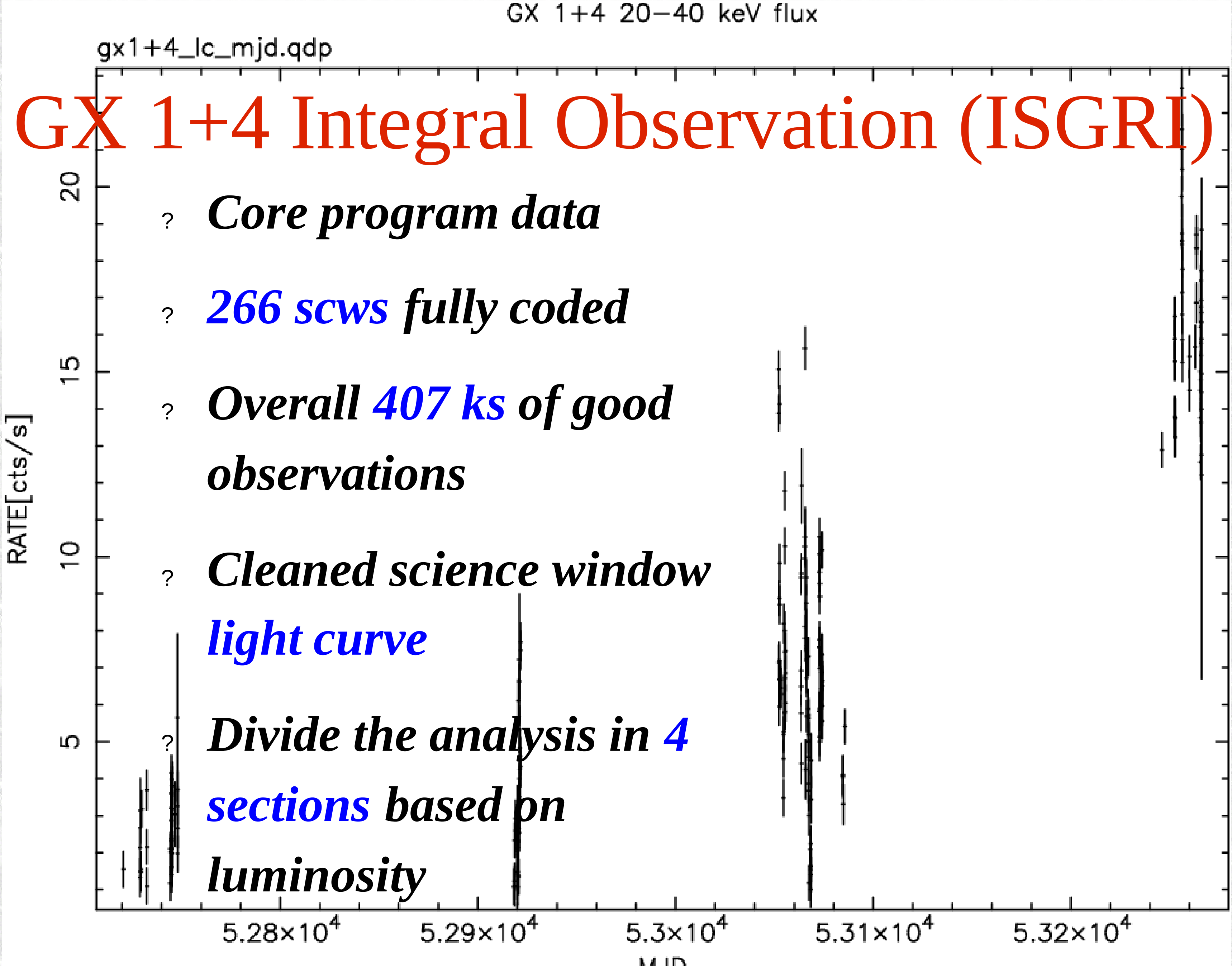
- Finally the Crab spectru does not present any artificial wiggles and ca be fitted with a power la from 20 to 300 keV wit index 2.103±0.002 and $\chi^2$/d=1.013 d=114 with adding systematic error

# What is GX 1+4?

- Long orbital period (~304 days) HMXRB (M5 III giant V2116 Oph)
- ~2 minutes spin period
- Fastest spin up in the 1970s ($6x10^{-12}$ Hz/s) with L>100 mCrab
- Spin down from 1987 and lower luminosity
- Spin reversal and emission while spinning down suggest that corotation radius ~ magnetospheric radius
- Magnetic field of $\sim10^{14}$G can be estimated. It implies cyclotron features at a fraction of MeV
- Hardest X-ray spectrum among persistent X-ray pulsars

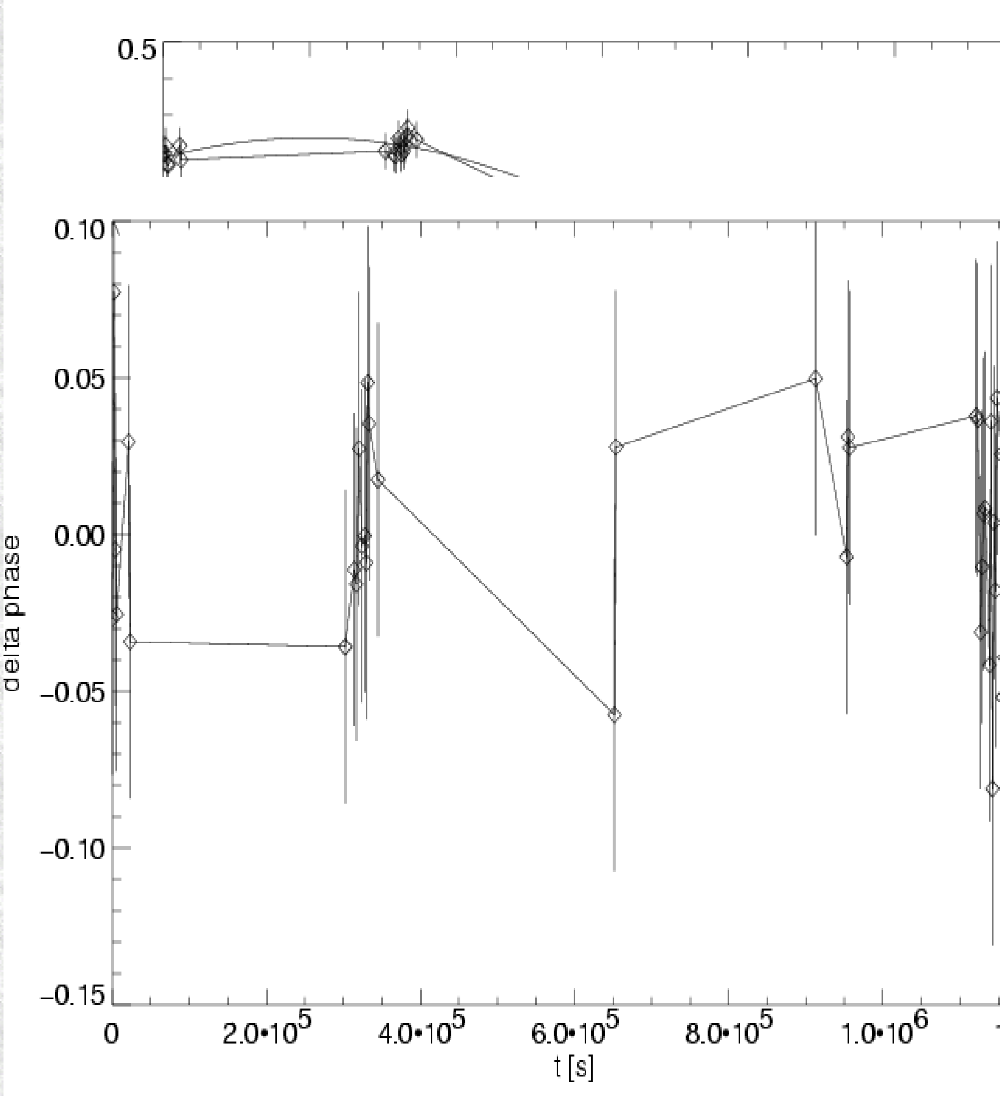
# GX 1+4 Integral Observation (ISGRI)

- ***Core program data***
- ***266 scws fully coded***
- ***Overall 407 ks of good observations***
- ***Cleaned science window light curve***
- ***Divide the analysis in 4 sections based on luminosity***



# Spin period determination

- For each scw we extracted the net pulse profile in 20-40 keV range folding with a constant period
- Fit each pulse with a sinus function and compute the phase difference
- Fit the difference and get refined spin period and derivative



# Spin period evolution

P = (139.630±0.006)s

$\dot{\nu}$ = (-7.8±1.6) $10^{-12}$ Hz/s

ref. time 5/10/2003 15.32 h

exposure 97 ks // 5.4 cts/s

P = (140.613±0.010)s

$\dot{\nu}$ = (-5.25±0.03) $10^{-12}$ Hz/s

ref. time 17/02/2004 2.23 h

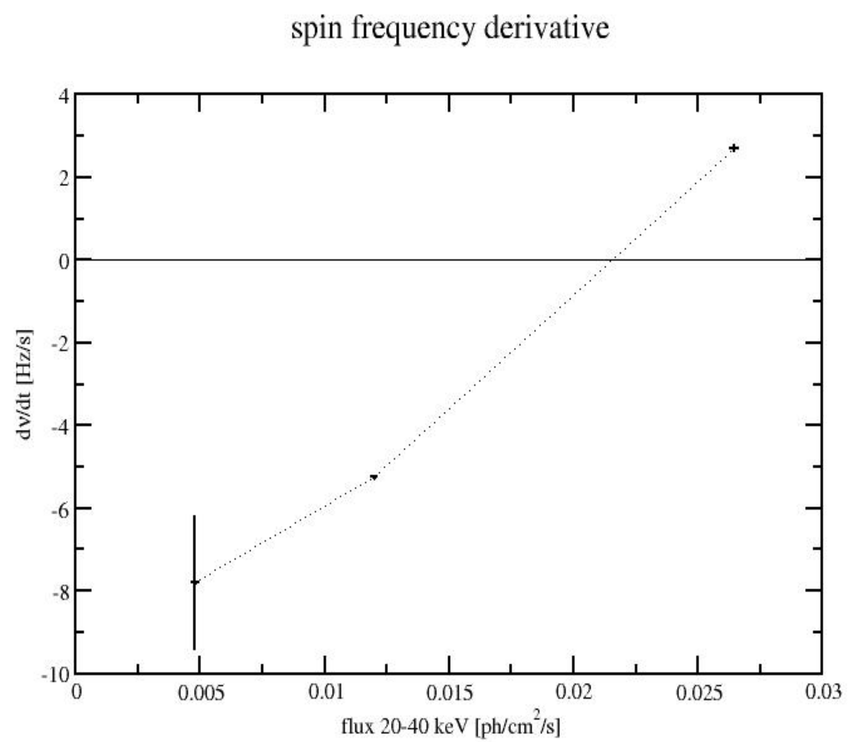
exposure 155 ks // 12.8 cts/s

P = (141.562±0.002)s

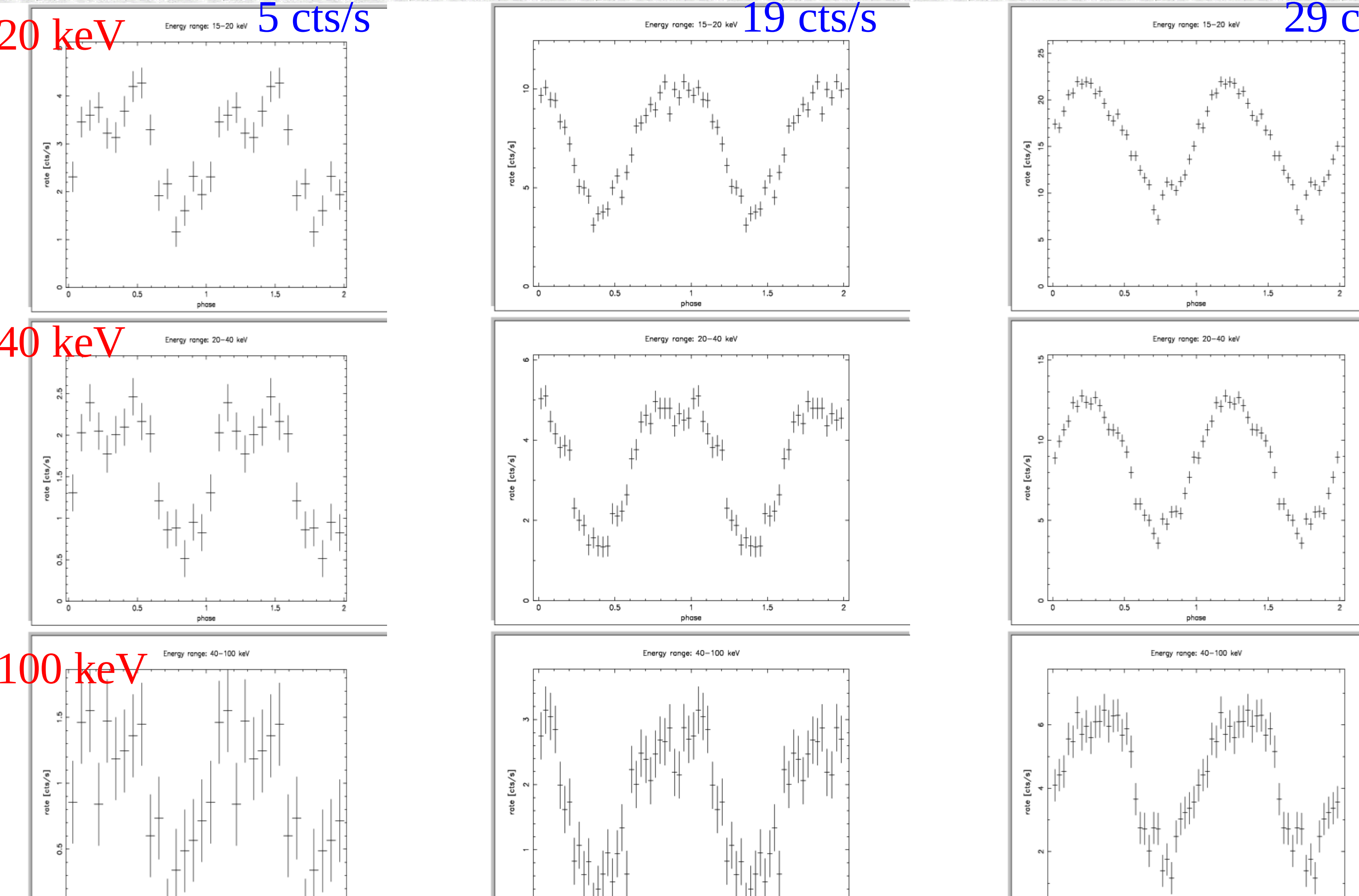
$\dot{\nu}$ = (2.70±0.07) $10^{-12}$ Hz/s

ref. time 04/09/2004 10.63 h

exposure 84 ks // 28.9 cts/s

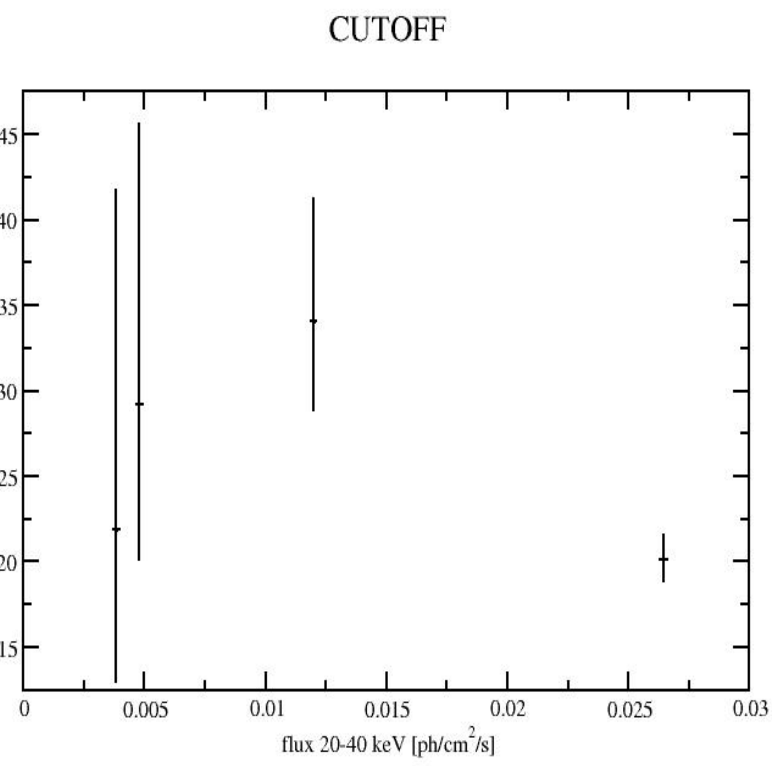


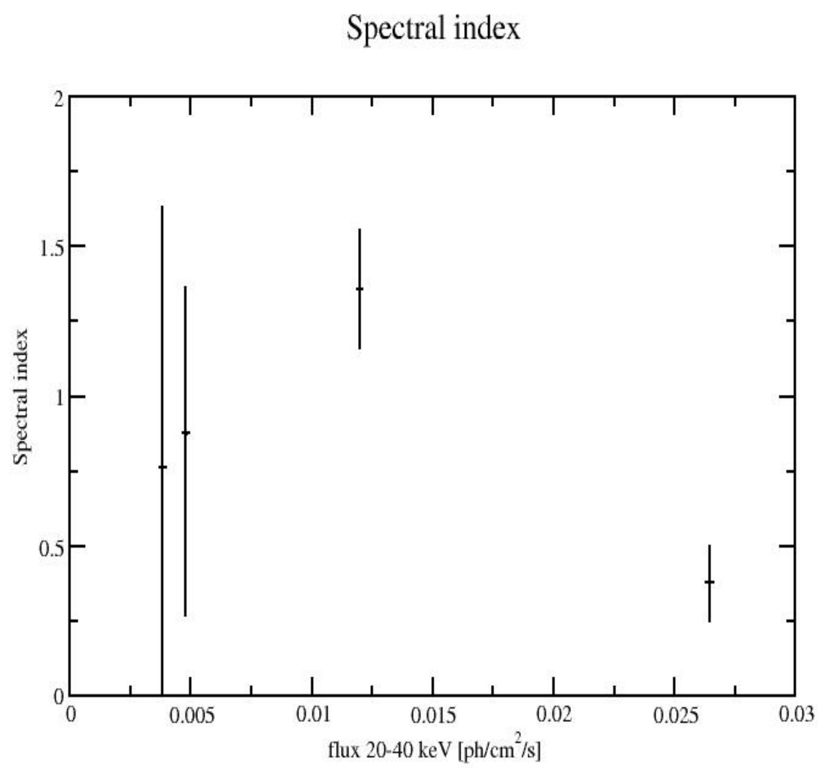
# Background subtracted pulse profiles



# Fit results /1

- Phase resolved spectroscopy shows no significant spectral variations with phase
- But there are obvious variations on the spectral shape with luminosity



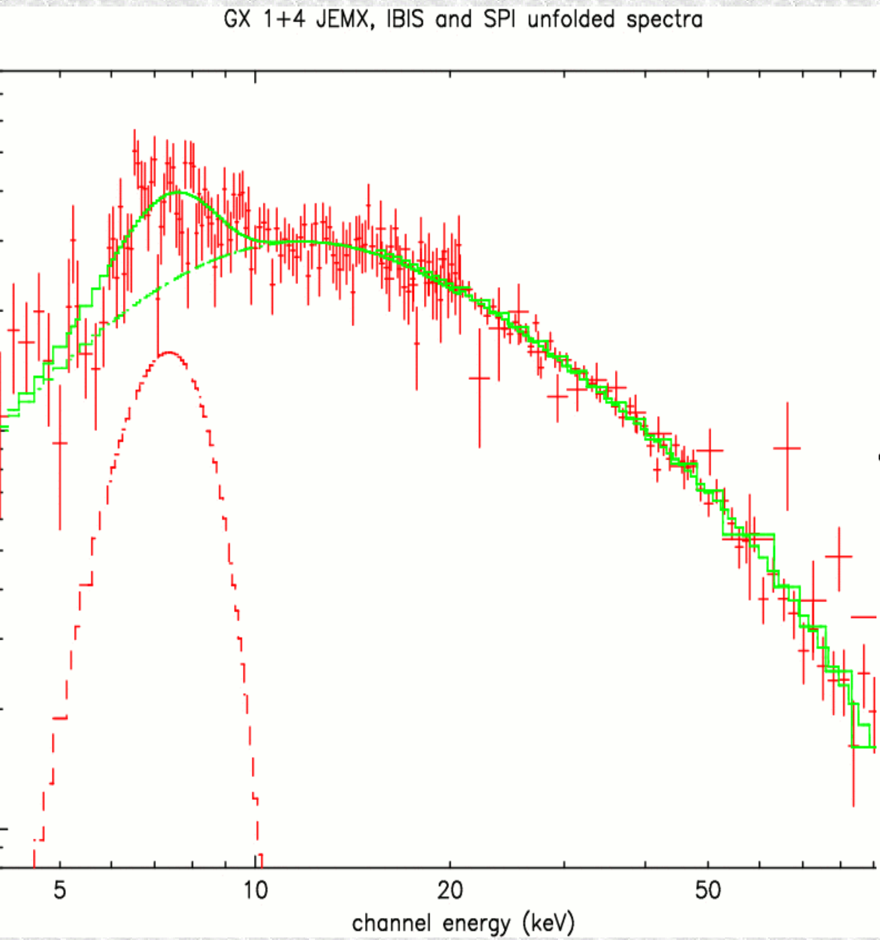



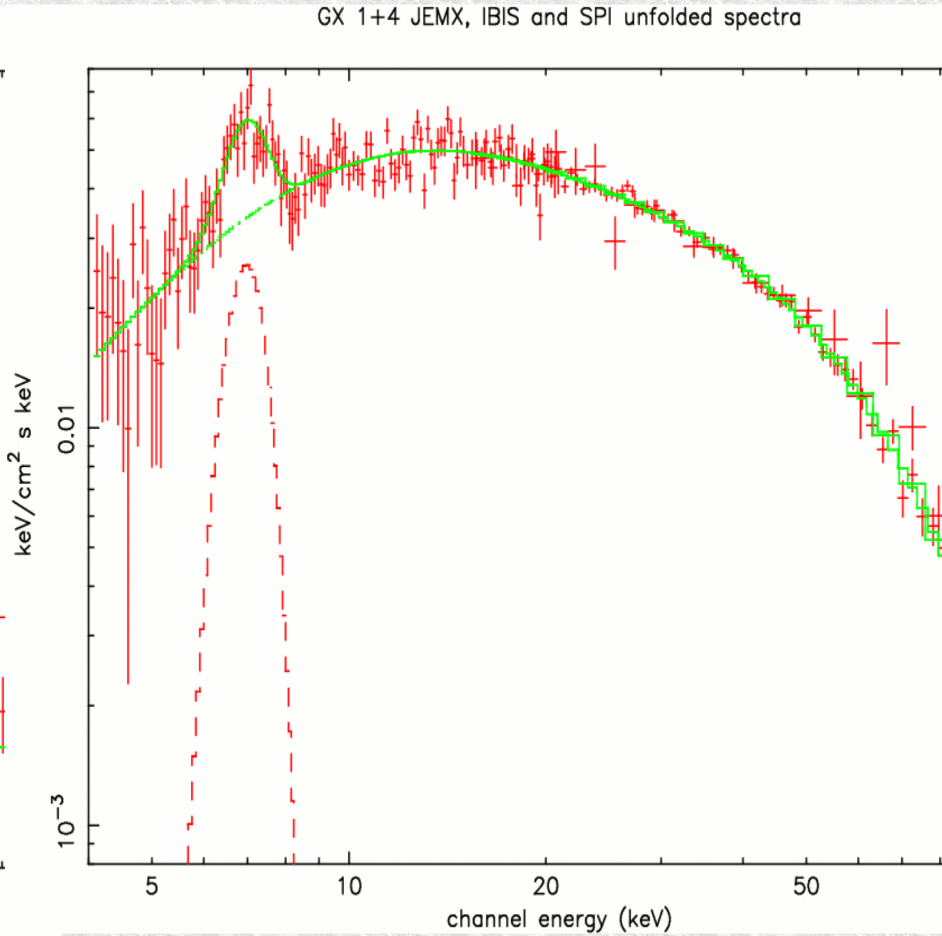
# Fit results /2

JEMX and SPI spectra available only in the brightest data sets

Overall fit with compTT plus (iron) Gaussian line.

At larger luminosity cooler and denser plasma for comptonizati



# Conclusions/1

Performed phase resolved spectroscopy of GX 1+4 using new PIF based method.

New method is compatible with OSA spectral extraction but it allow also temporal and phase analysis

To avoid artificial features in the ISGRI spectra, we have replaced the OSA LUT, with a better one and used a new response matrix generated with the CRAB

- New response is essential to investigate the presence of spectral features
- Found that the GX 1+4 can b fitted in the 20-110 keV rang with a simple cutoff powerla without evidence of spectral features

# Conclusions/2

Time analysis showed a genuine torque reversal corresponding t
the highest luminosity state.

Using JEMX and SPI together with ISGRI it is possible to investigate a physical model with comptonization of cooler photons (~2 keV) from hotter plasma (12-16 keV) with high optical depth (4-7).

The brightest dataset shows higher optical depth and lower temperature suggesting a more intense accretion flux

The spin-up episode does not correspond to the ephemerids proposed by Pereira et al (2000)