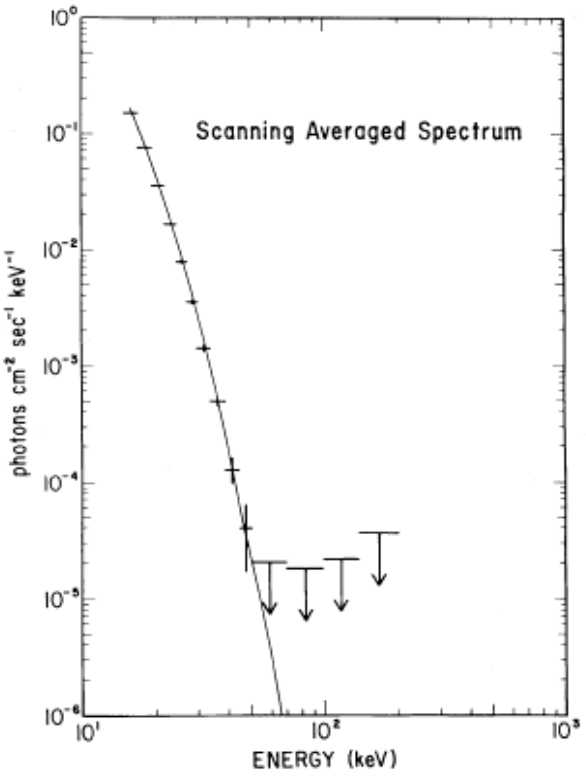
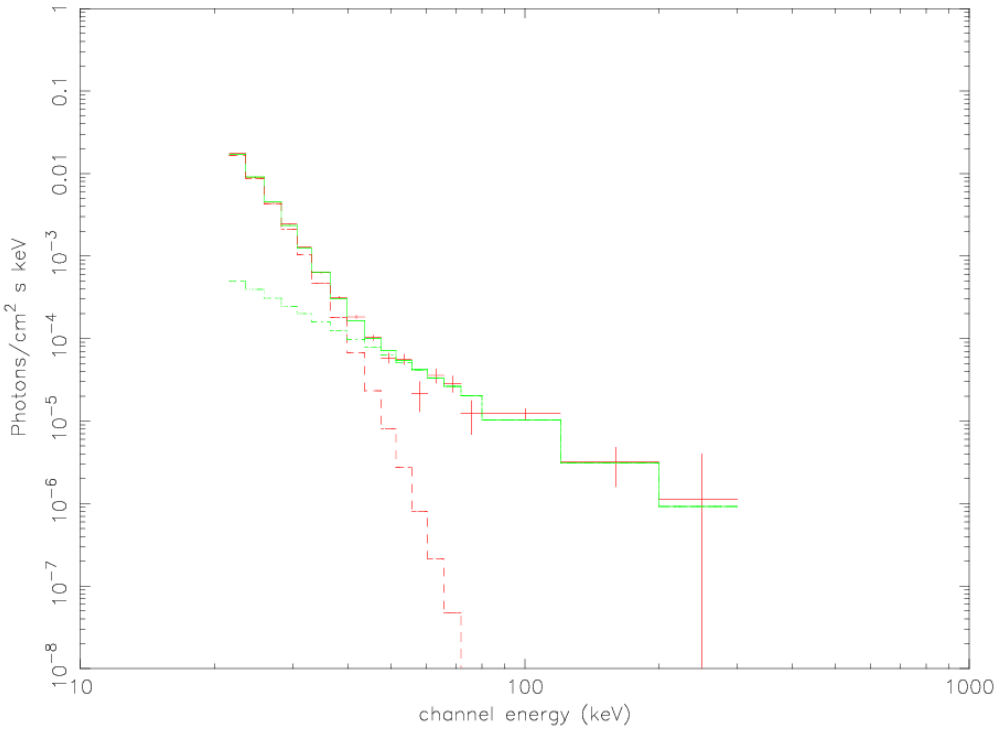
Hard X-ray Properties of Sco X-1

P. Goldoni & the LMXB group





Sco X-1 main characteristics

First extrasolar X-ray source (Giacconi et al. 1962)

Brightest soft X-ray source, thermal spectrum, kT~ 3-5 keV;
weak hard X-ray source

Optical counterpart M < 1 Msun d = 2.8 kpc, Porb = 3 hours

Soft X-ray behaviour very complex and difficult to model

Bright radio source, and recently VLBI jets at 0.45 c (Fomalont et al 2001)

Coordinates: + 23°, high on the Galactic plane…

Hard X-ray properties before INTEGRAL-I

Claims of detections of a hard X-ray component since the 1960's at levels of 10^{-4} ph cm^{-2} s^{-1} (e.g. Peterson & Jacobson 1966, Duldig et al. 1983)

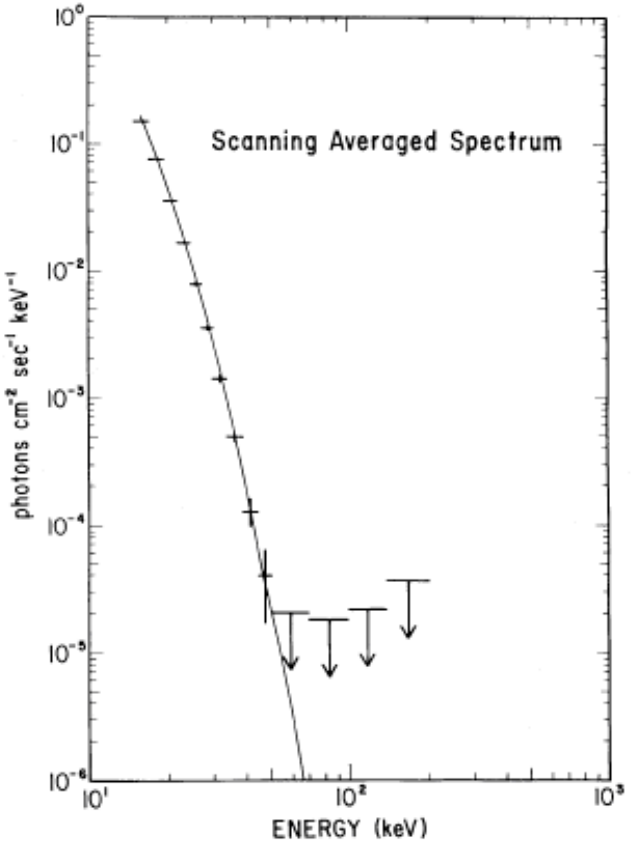
Non detections at LOWER (~10^{-5} ph cm^{-2} s^{-1}) levels often reported (e.g. Lewin, Clark & Smith 1967, Johnson et al. 1980, Soong & Rothschild 1980)

Recently two results were reported:

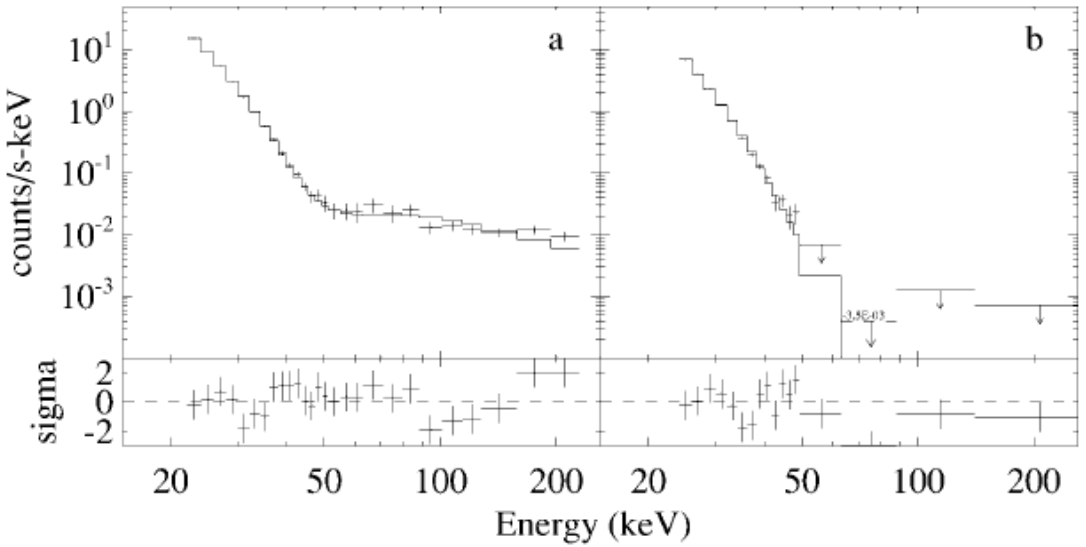
1) D'Amico et al. 2001 (RXTE) report the presence of a variable hard X-ray component $E^{-?}$ whose intensity does not depend on the source spectral state. The power law index ? goes from -0.7 to 2.4

2) Strickman & Barret (OSSE) report hard X-ray flares with a fairly constant hard component with ?~2.5

Hard X-ray properties before INTEGRAL-II



HEAO-1 (UCSD/MIT) spectrum (Soong & Rothschild 1980)
50-165 keV flux < 10^{-5}ph cm^{-2} s^{-1}
2? u.l.

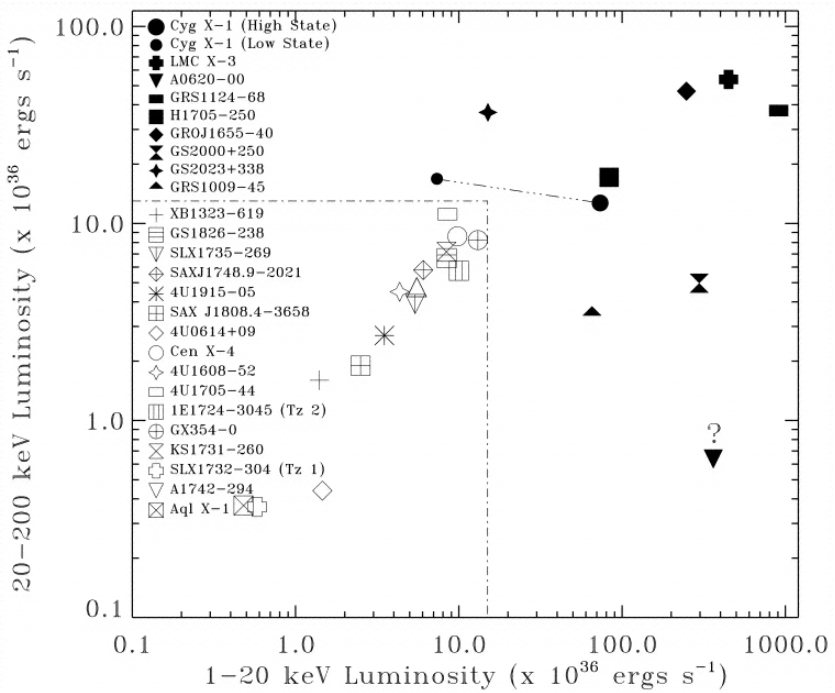


RXTE/HEXTE spectra from D'Amico et al.
Presence and absence of hard tail, no correlation hard X-ray flux ~ 10% of background. Model Bremmstrahlung kT~5 keV + powerlaw ? ~-0.17
Fl (75-220 keV)=(3.6-13.6) x 10^{-10} erg cm^{-2} s^{-1}

Hard X-ray properties of Z sources

Z sources are bright, AND luminous (d >1 kpc) LMXB, their emission is mainly thermal and for a long time it has been believed that they were not Hard X-ray emitters

NS vs. BH « Burster Box »



BeppoSax detected GX 17+2, Cyg X-2, GX 5-1, some of them, notably GX 17+2 and GX349+2 are outside the burster box.

Emission modeled with a power law, notably all these sources are radio emitters (Di Salvo et al. 2001)

INTEGRAL CP observations of Sco X-1

Galactic Coordinates: 359.1 + 23.8

ALWAYS OFF-AXIS ! Good off-axis correction needed

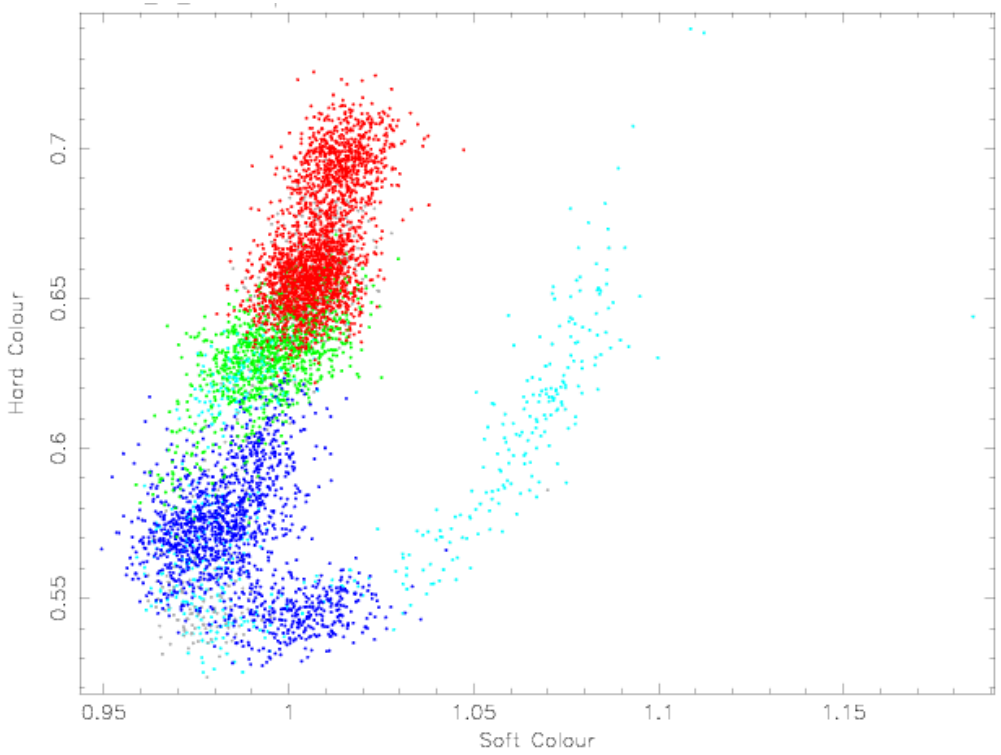
IBIS/SPI Exposure time with Sco X-1 at < 4 degrees ~ 3.7 x 10^4 sec
NO CONTAMINATING SOURCE !!

IBIS/SPI Exposure time with Sco X-1 at < 8 degrees ~ 1.57 x 10^5 sec
ONLY OTHER SOURCES GX1+4 and 4U1700-377 !!

JEM-X exposure time ~3x 10^4 sec; at < 2.5 deg. 3 scws !!!

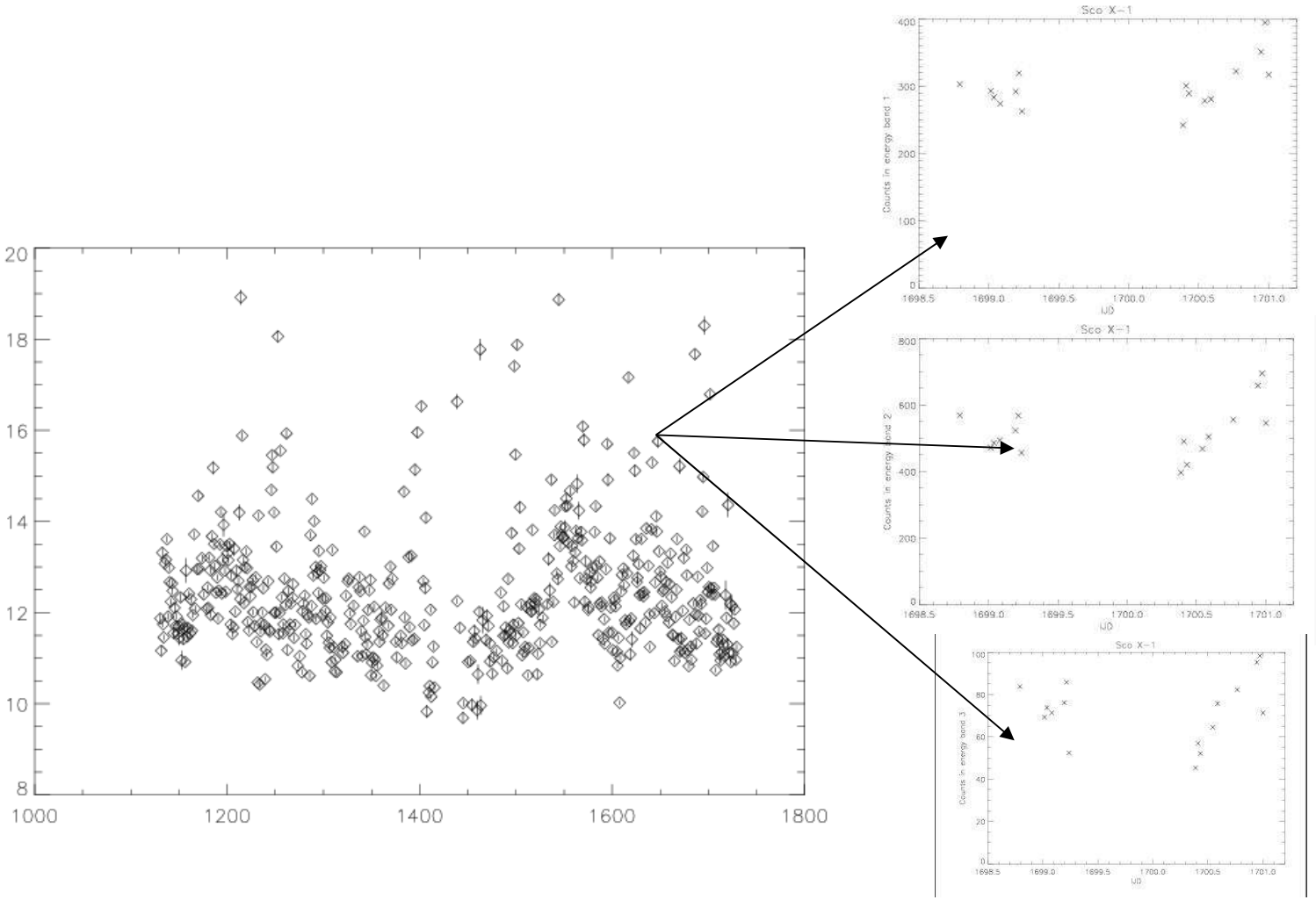
Pointed observation (September 2003)

Two revolutions on Sco X-1 (PIs Stella, van der Klis), RXTE monitoring

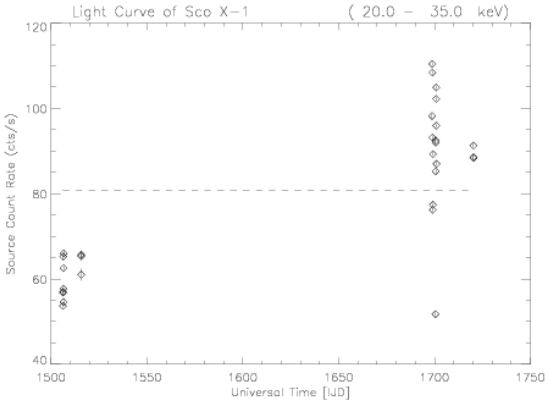


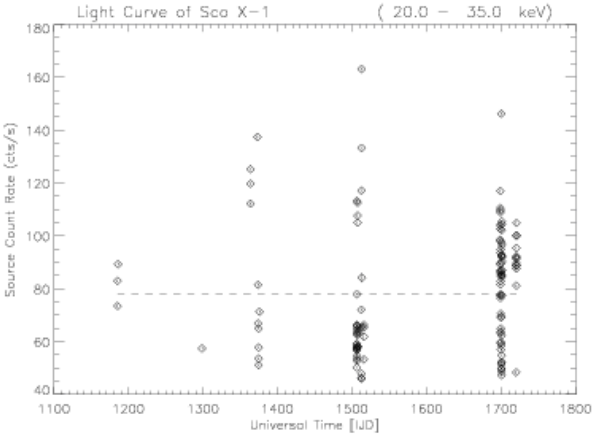
Clear detection of a hard component with ISGRI, SPI and RXTE/HEXTE (Di Salvo et al. in preparation), Spectral index ~ 2.8 +/-0.3, similar to other Z sources but pointing was a 5x5 dithering

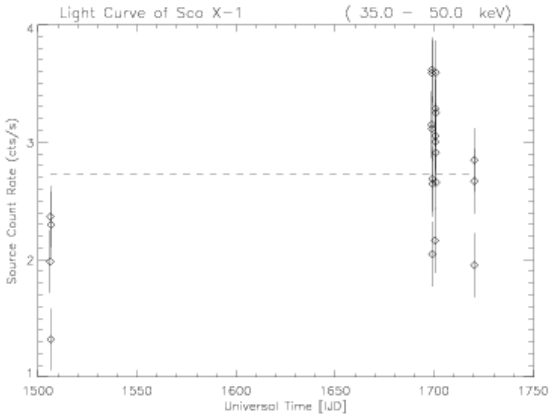
Soft X-ray lightcurves (2-12 keV)

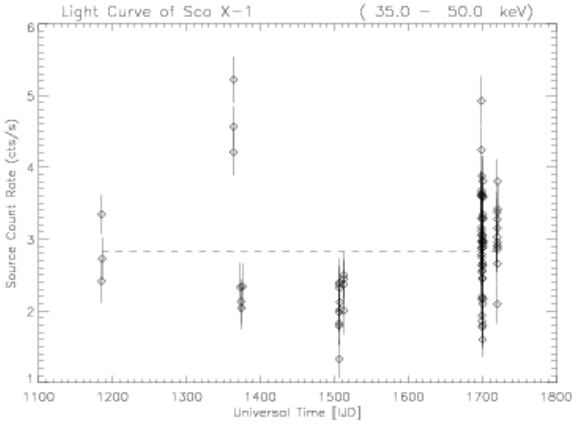


ISGRI Light curves



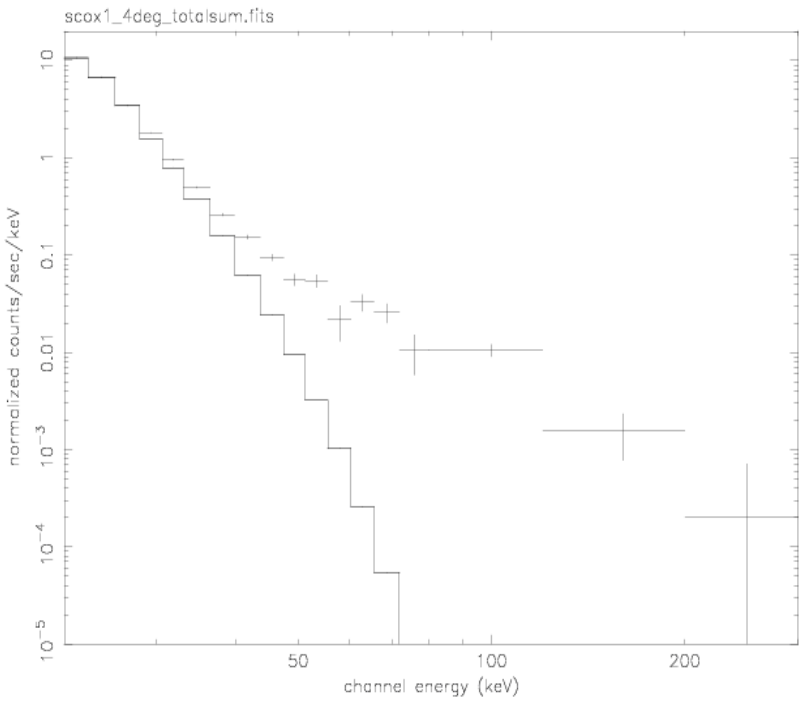




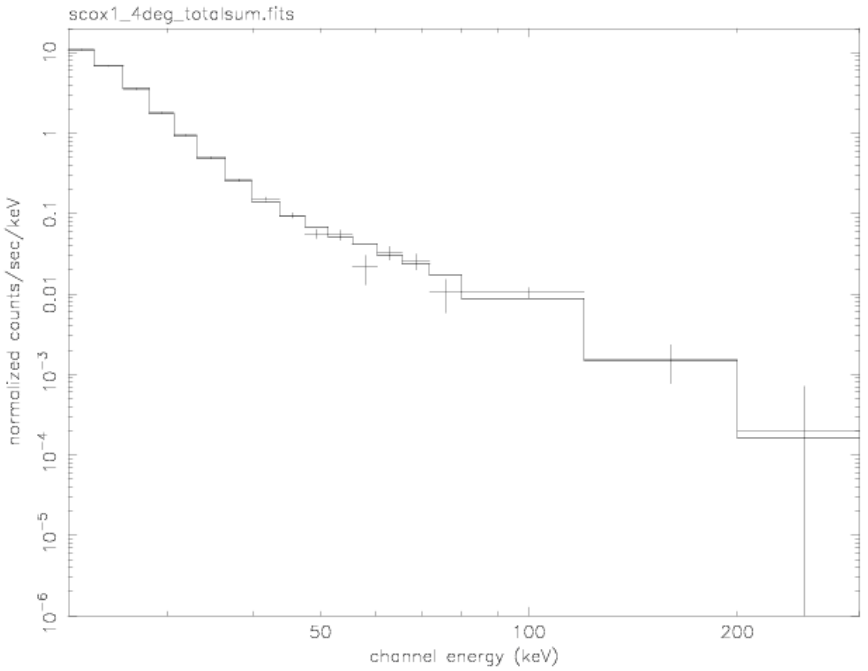


Energy band	15-20	20-35	35-50	50-75	75-100	100-200
Count rate	60.9(62.6) +/-0.03(8)	69.1(68.5) +/-0.04(8)	2.2(2.2)+/-0.02(4)	0.59(0.59) +/-0.03(6)	0.26(0.36) +/-0.02(5)	0.184(0.2) +/-0.036(6)

ISGRI Count Spectra<4 degrees



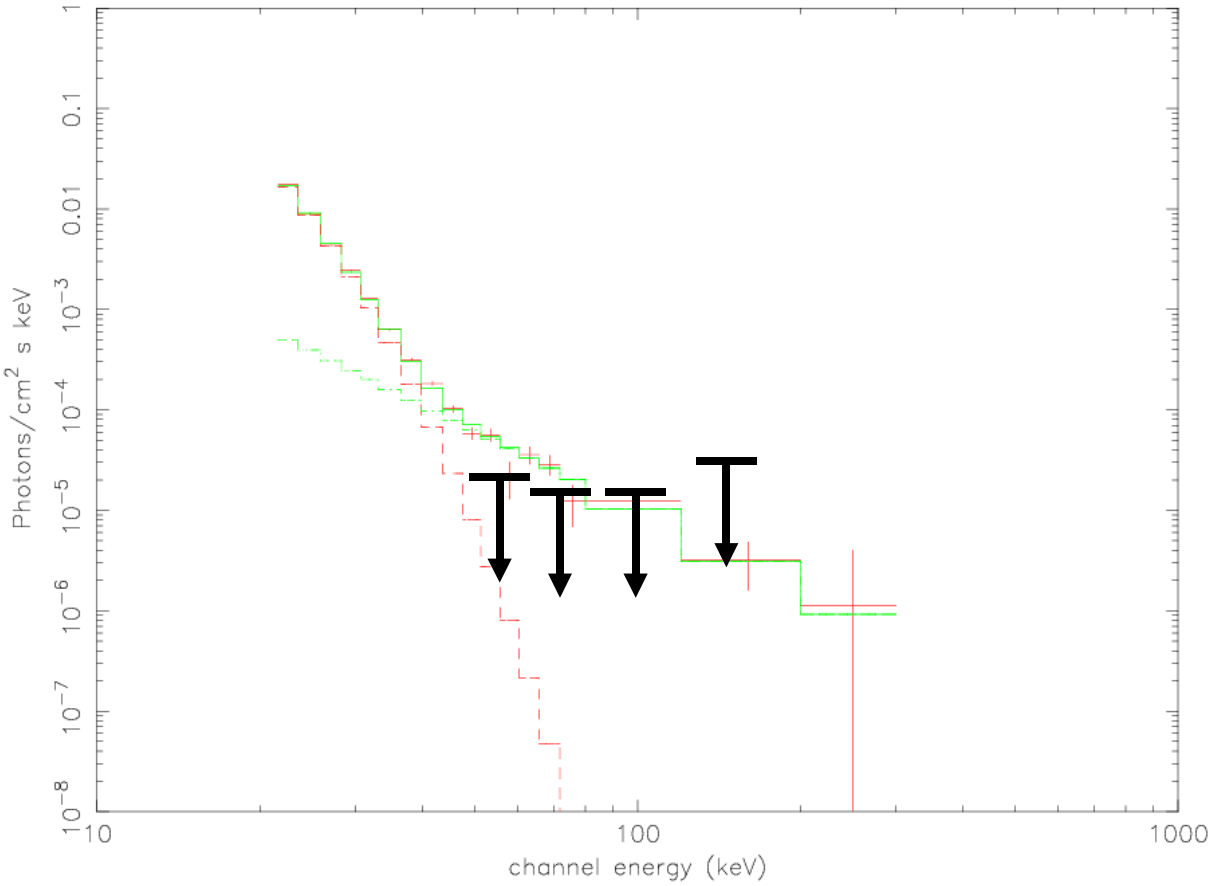
Bremsstrahlung kT~4.32
$?^2_?$~27



Bremsstrahlung kT~4.25 +/-0.08
Power Law Index ?~2.68+/-0.07
$?^2_?$~1.51; kT compt > 45 keV
Fl (75-220 keV)~1.4 x 10^{-10} erg cm^{-2} s^{-1}

Texp ~ 3.7 x 10^4 sec; Systematics 3 %

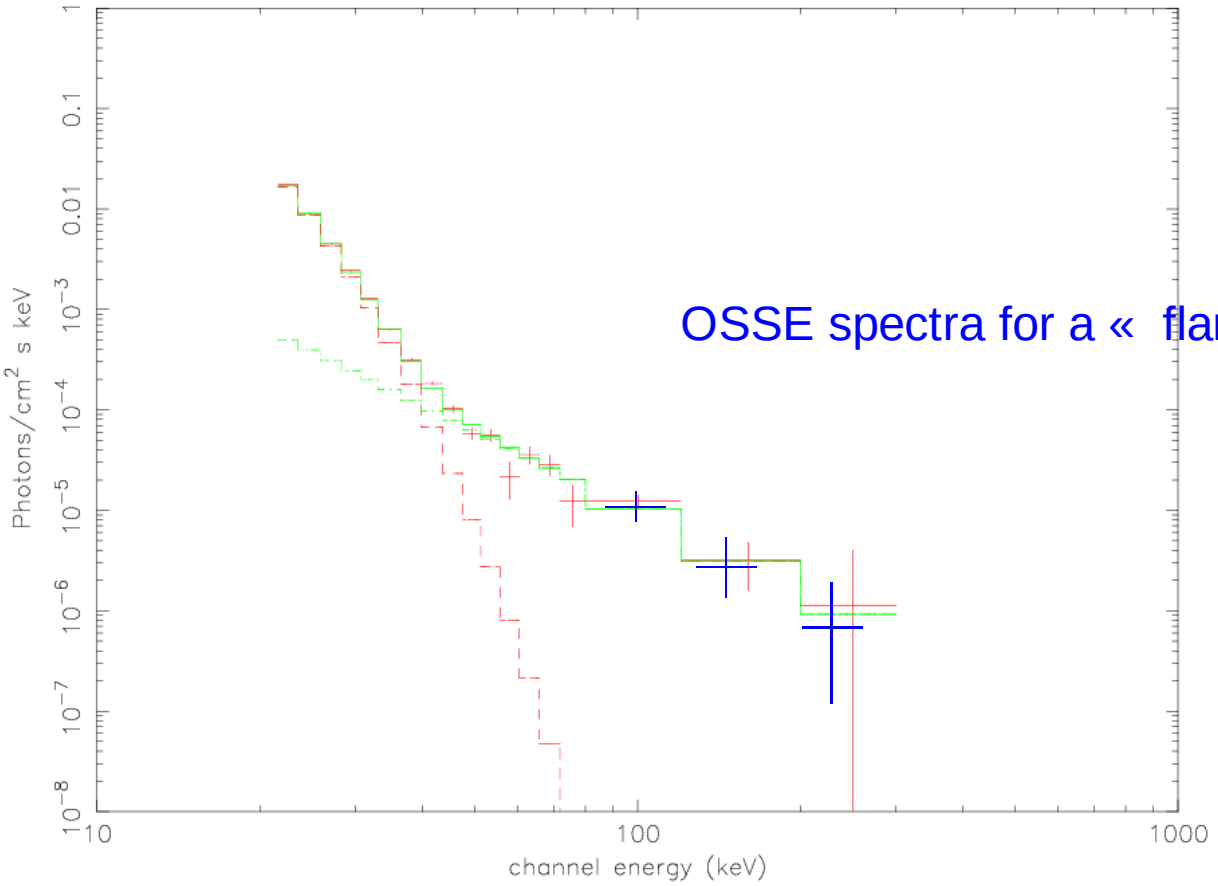
ISGRI Photon-Energy Spectra < 4 degrees



Inconsistent with HEAO-1 results at ~ 60-80 keV,
Maybe consistent at higher energies.

Texp ~ 3.7 x 10^4 sec; Systematics 3 %

ISGRI Photon-Energy Spectra < 4 degrees

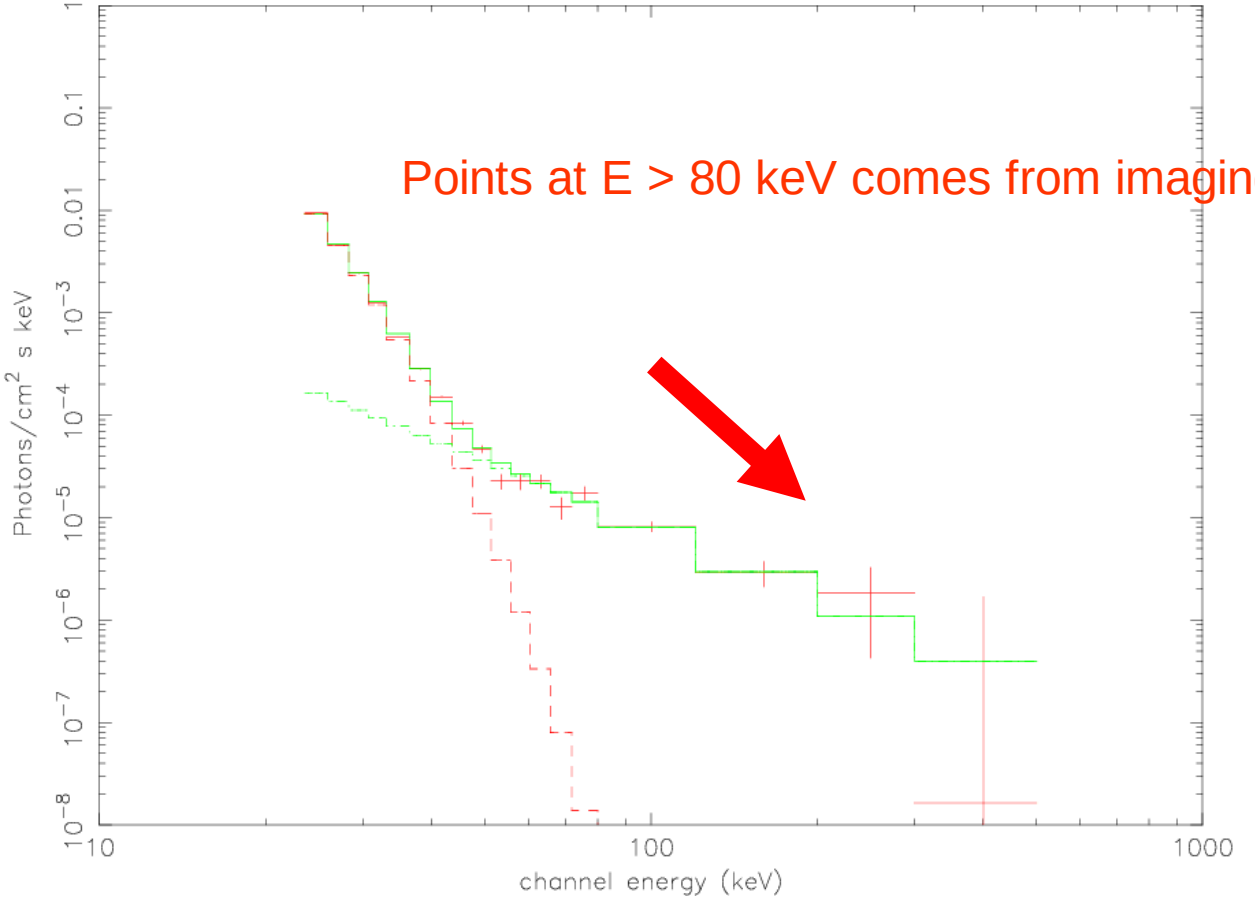


OSSE spectra for a « flare »

These results are consistent with OSSE-detected flares, although kT bremms lower

Texp ~ 3.7 x 10^4 sec; Systematics 3 %

ISGRI Energy Spectra < 8 degrees



kT ~ 4.3+/-0.1
Spectral index
? ~2.25+/-0.05
$?^2_?$~1.8
kTcomp > 50 keV

Consistent with extrapolation of previous spectra <4 degrees but spectral extraction problems !!

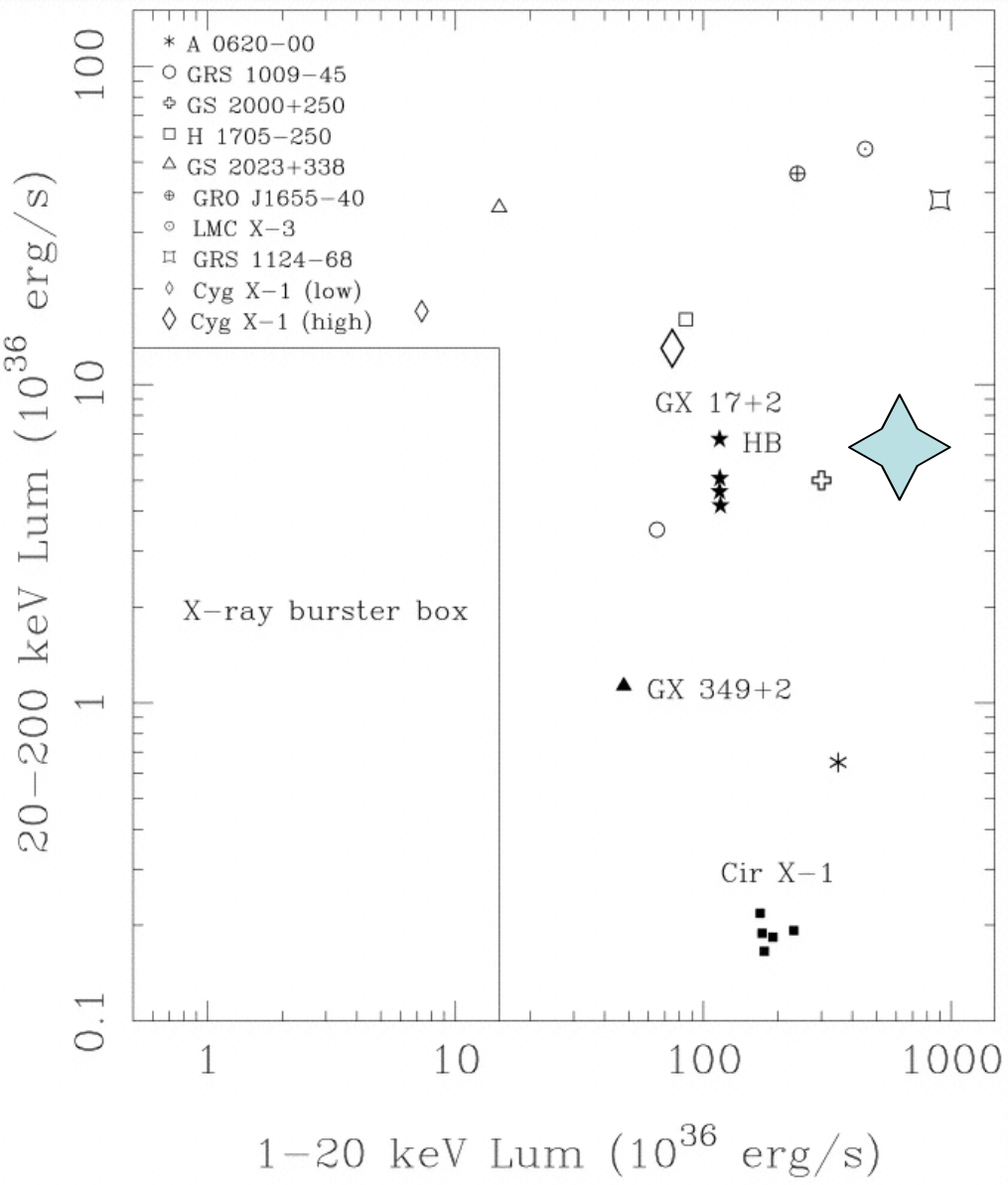
Texp ~ 1.5 x 10^5 sec; Systematics 4 %

Comparison with previous observations

Consistent with P.O. and with OSSE « flares »; partly consistent with RXTE (but fainter)

Inconsistent with some of the nondetections (~100 times stronger than UCSD/MIT non detection)

Most obvious explanation would be variability, anyway, ScoX-1 Is well outside the « burster box »



Conclusions

INTEGRAL consistently detects a « high energy component » for Sco X-1. The results are consistent with previously reported OSSE data but not with several non-detections in the past. State change ?

The origin is possibly non thermal as there is no break up to ~ 200 keV. Thermal origin requires kT > 50 keV. The relative faintness of the non thermal component prevents a more detailed, time-resolved, analysis

Contemporaneous VLBI/optical observations will be analysed

A more continuous hard X-ray INTEGRAL will be needed to determine to what extent the hard tail is variable. A more detailed program could help determine whether correlations exist with soft X-rays, radio and optical emission.