

The discovery of hard spectral tails in anomalous X-ray pulsars at soft g-rays

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Outline of presentation

Introduction: Anomalous X-ray pulsars in a nutshell
(status before end 2003/early 2004)

Results from follow-up analyses (RXTE PCA/HEXTE data
and data from deep INTEGRAL exposures):

Overview current high-energy status (> 10 keV)

Summary

Prospects

anomalous X-ray pulsars (status before early 2004)

- No rotation powered pulsar!
- No X-ray pulsar in LMXB/HMXB (no accretion-powered pulsar)

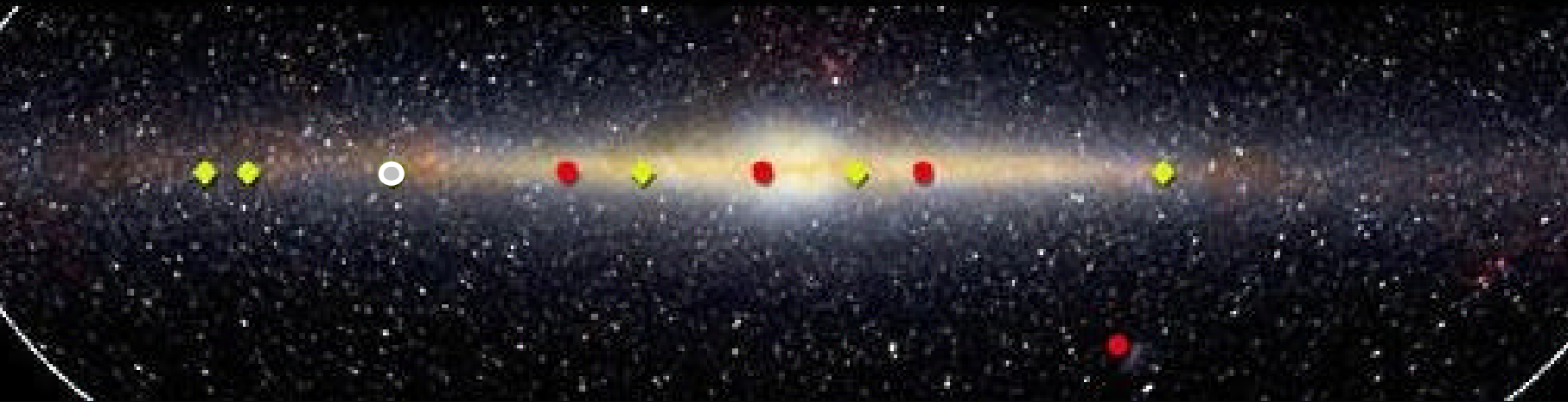
$$L_X \gg L_{sd}$$

steady spin-down; no apparent optical counterpart; no periodic Doppler delay in X-ray timing

characteristics:

- a) Pulse periods: 5 - 12 s
- b) "Steady" spin-down like rotation powered pulsars (glitches observed also)
- c) X-ray luminosities: 10^{34-36} erg/s (steady, but outbursts also detected; transient AXPs)
- d) (very) soft X-ray (0.5-10 keV) spectra: BB (0.35 - 0.6 keV) + PL (2 - 4)
- e) Similar to Soft Gamma-Ray Repeaters (glitches; (out)bursts) → **Magnetars** (neutron stars with $B \sim 10^{14-15}$ Gauss powered by decay of B-field)
- f) Young population concentrated along galactic plane (sky distribution)

Known magnetar candidates

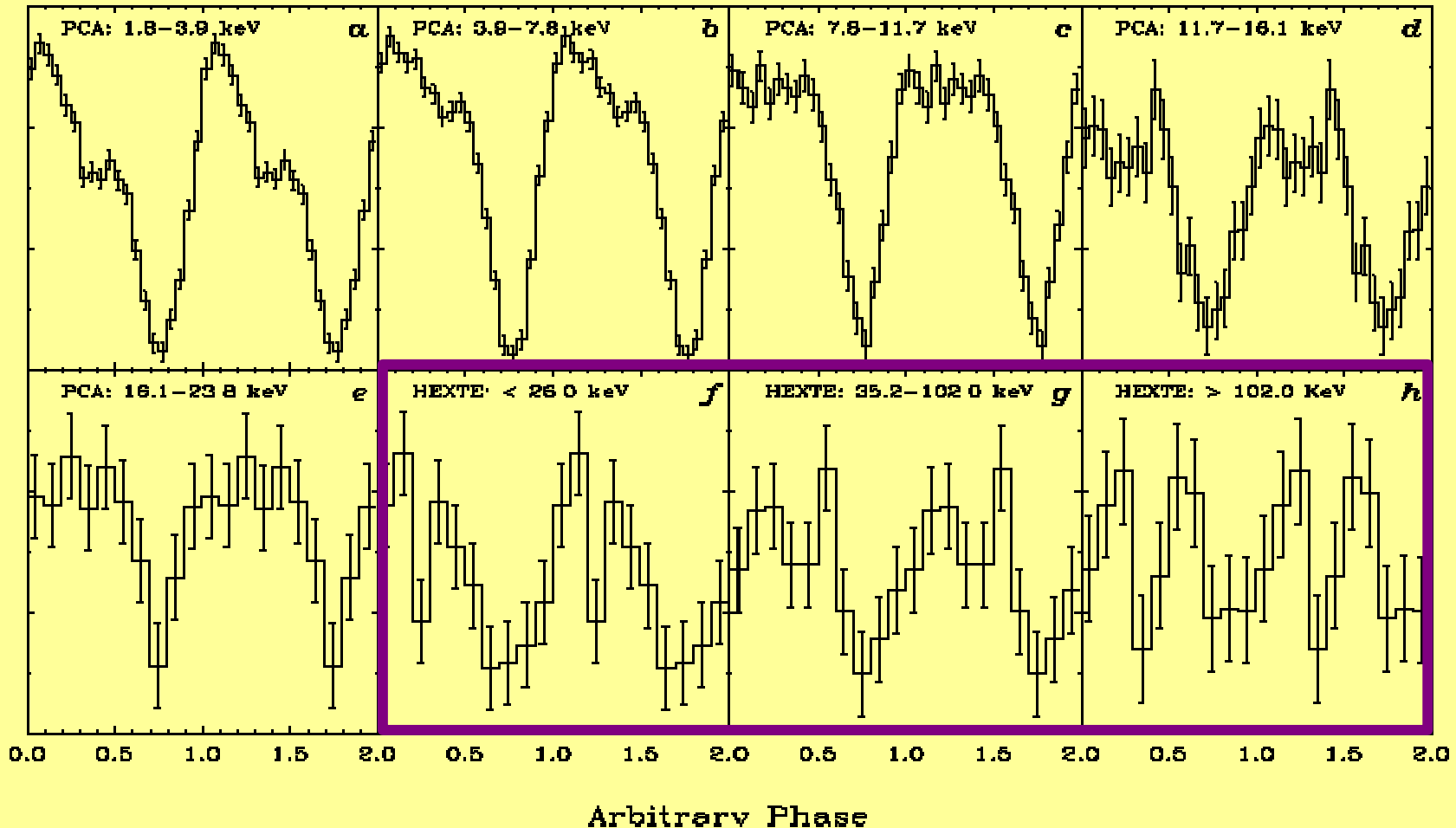


AXP	Discovery	P[s]	B[10 ¹⁴ G]
1E2259+586 (SNR)	1981	6.98	0.6
1E1048-594	1985	6.45	5.0
4U 0142+614	1993	8.69	1.3
1RXS J1708-4009	1997	11.00	4.6
1E1841-045 (SNR)	1997	11.77	7.1
AX J1845-026	1998	6.97	?
CXOU J0110-721 (SMC)	2002	8.02	?
XTE J1810-197	2003	5.54	2.6

map at Kes 73 (Molkov et al. 2004)

Analysis of archival RXTE PCA/HEXTE data of 1E1841-045

(Kuiper, Hermsen & Mendez, 2004 ApJ 613, 1173)



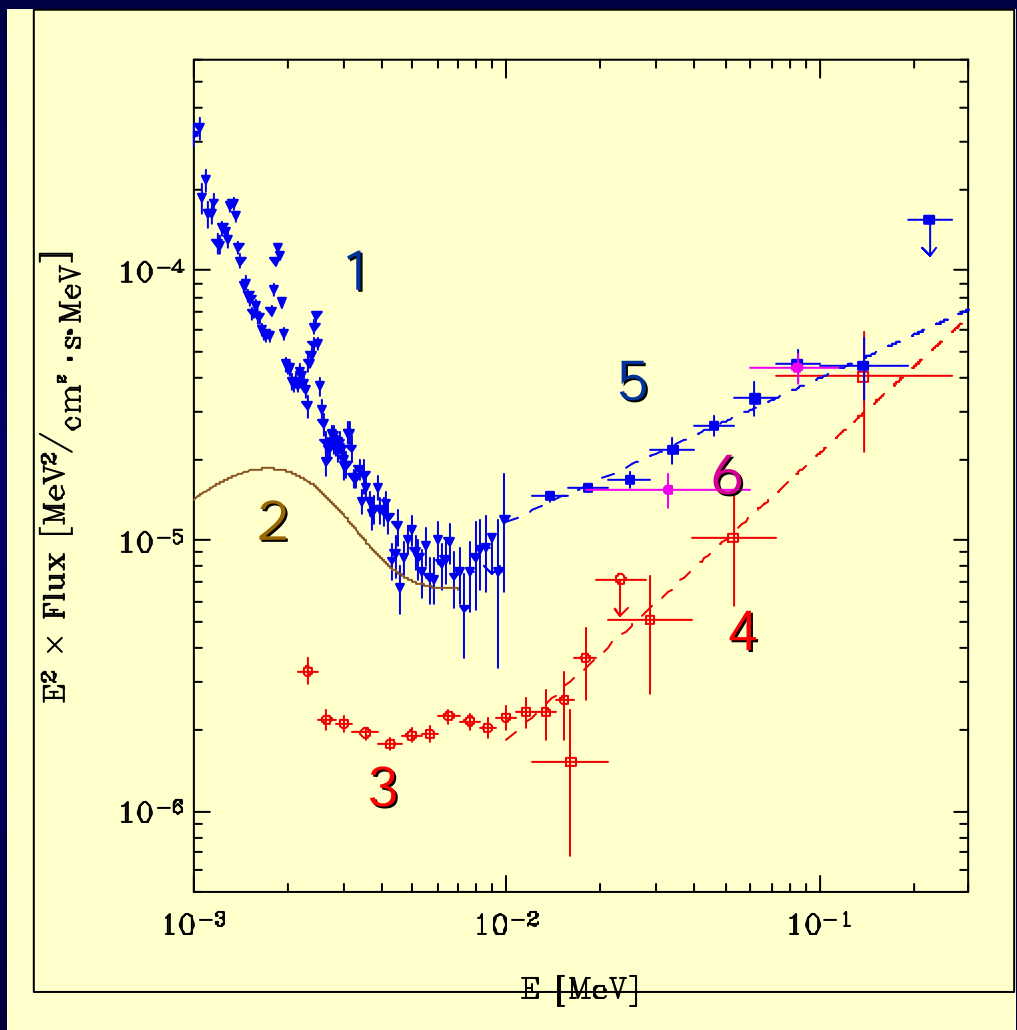
High-energy spectra Kes 73 and AXP 1E 1841-045

(Kuiper, Hermsen & Mendez, 2004, ApJ 613, 1173)

1) Kes 73 +
1E 1841-045;
XMM-Newton

2) Total
1E 1841-045;
Chandra
(Galloway et al. 2003)

3) Pulsed
1E 1841-045;
RXTE/PCA
 $\beta = 1.93 \pm 0.01$



6) Kes 73 (?)
1E 1841-045
INTEGRAL
(Molkov et al 2003)

5) Kes 73 (?)
1E 1841-045
RXTE/HEXTE
 $\beta = 1.47 \pm 0.03$
(Galactic ridge
contribution)

4) Pulsed
1E 1841-045;
RXTE/HEXTE
 $\beta = 0.94 \pm 0.16$

1E1841-045/Kes 73

RXTE PCA/INTEGRAL IBIS ISGRI Revs. 49-70 contemporaneous)

ISGRI timing analysis

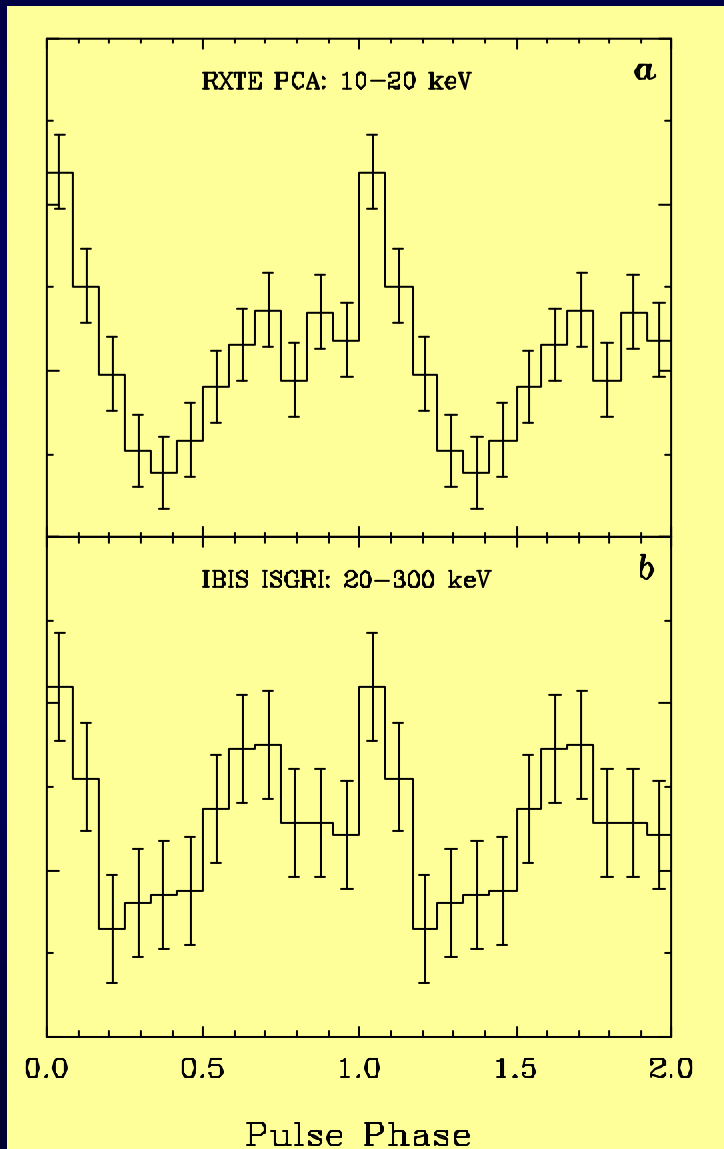


neutron radiation belts

$F > 25\%$

neutron center event times

based on accurate phase
connected ephemeris



IBIS ISGRI
6s 1.2 Ms GTI exposure

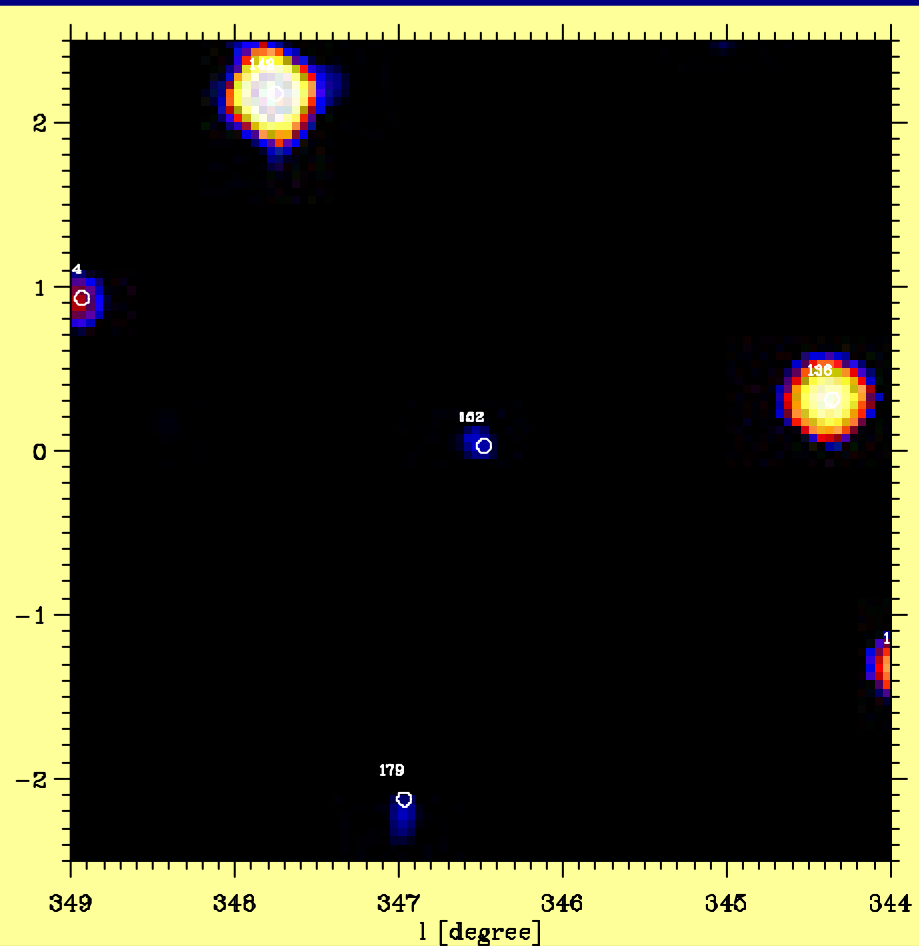


493 ks eff. on-
exposure

3s

Kuiper et al
2005 in pre

1RXS J170849.0-400910



Discovery >18 keV reported by
Revnivtsev et al. 2004

IBIS I SGRI
Revs. 36-106
1.92 Ms
(Kuiper et al. 2005)

35-60 keV

(1.1)

IRAS 17091-3610 (RXTE PCA/HEXTE)

Kuiper et al
2005 in pre

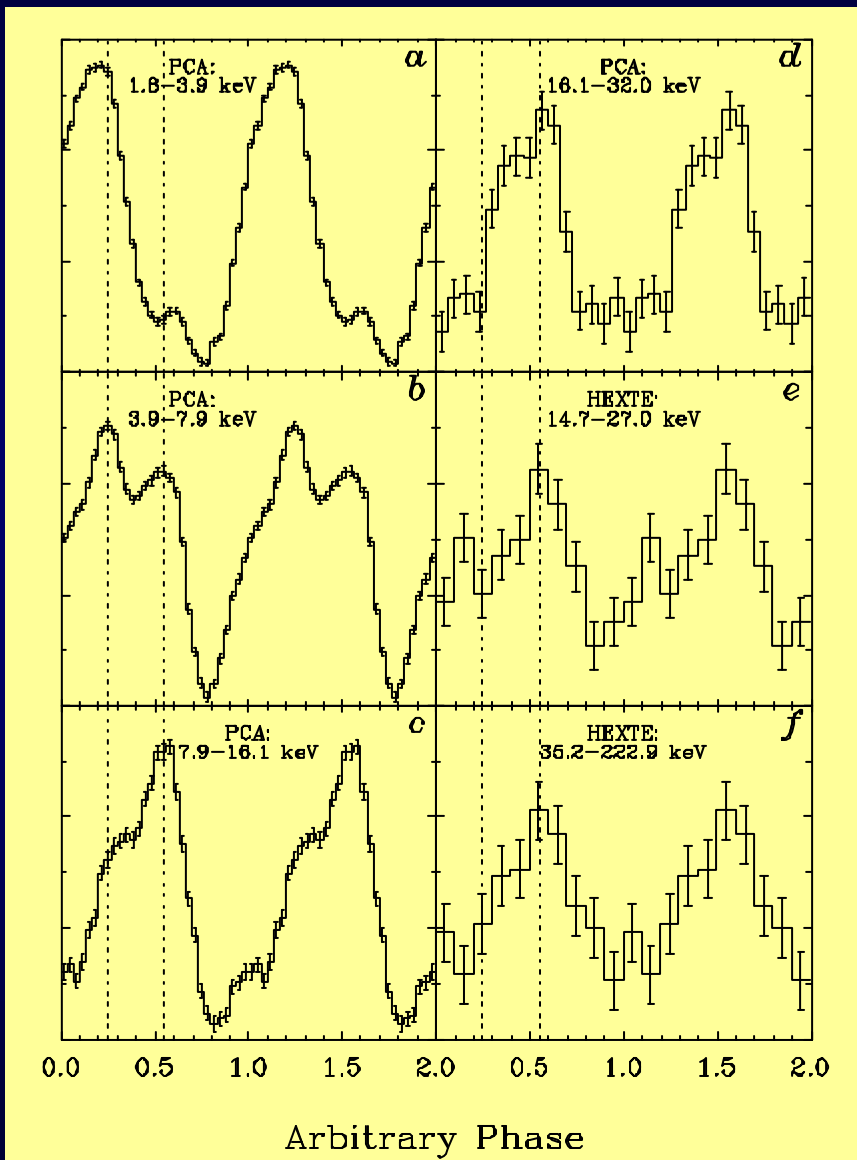
opened PCU-2
exposure: 308 ks

(0125-80098)

RXTE PCA:
Xenon layers
used!



Significant
improvement
S/N



← 14.2s

← 5.8s

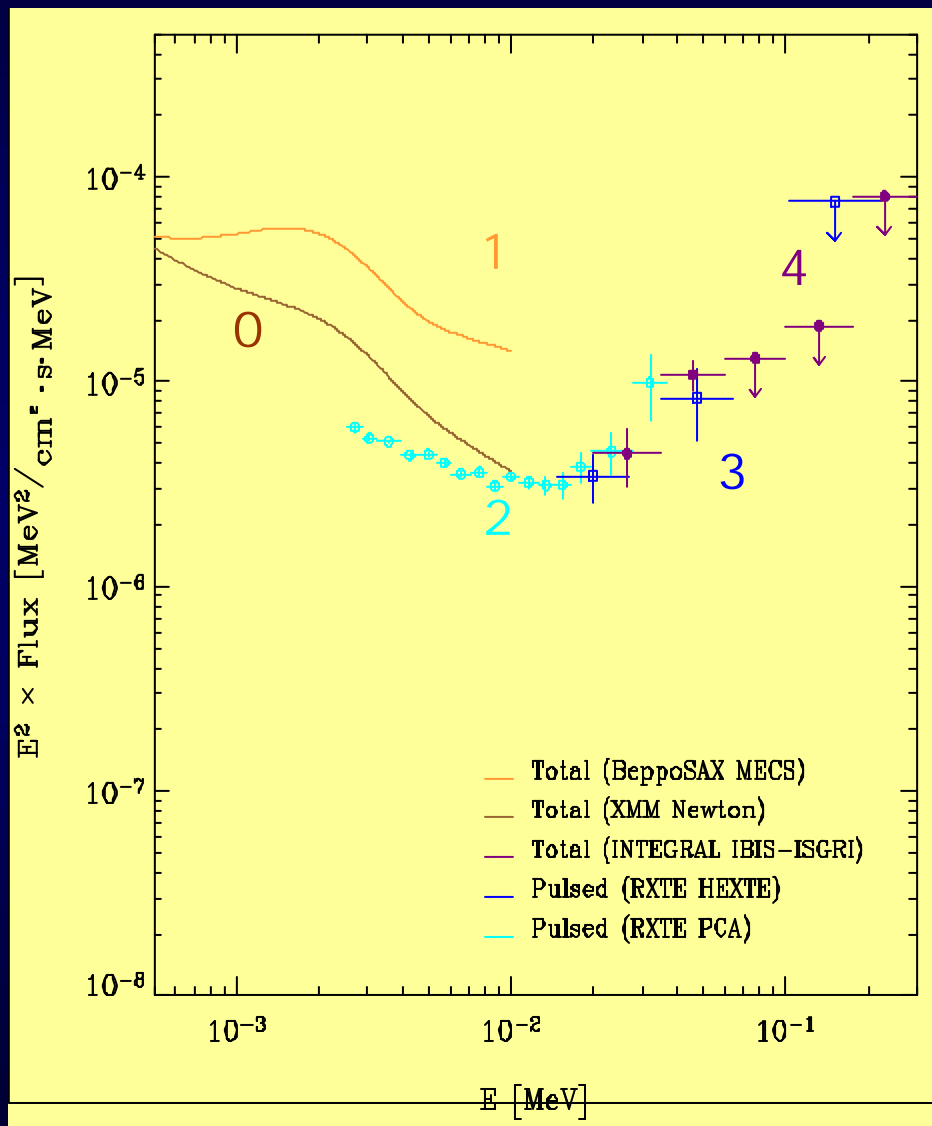
← 5.2s

1RXS J170849.0-400910

0) Total
XMM Newton
(Kuiper et al. 2005)

1) Total
BeppoSAX
(Kuiper et al. 2003)

2) Pulsed
RXTE PCA
 $g \sim 2.4$



3) Pulsed
RXTE/HEXTE

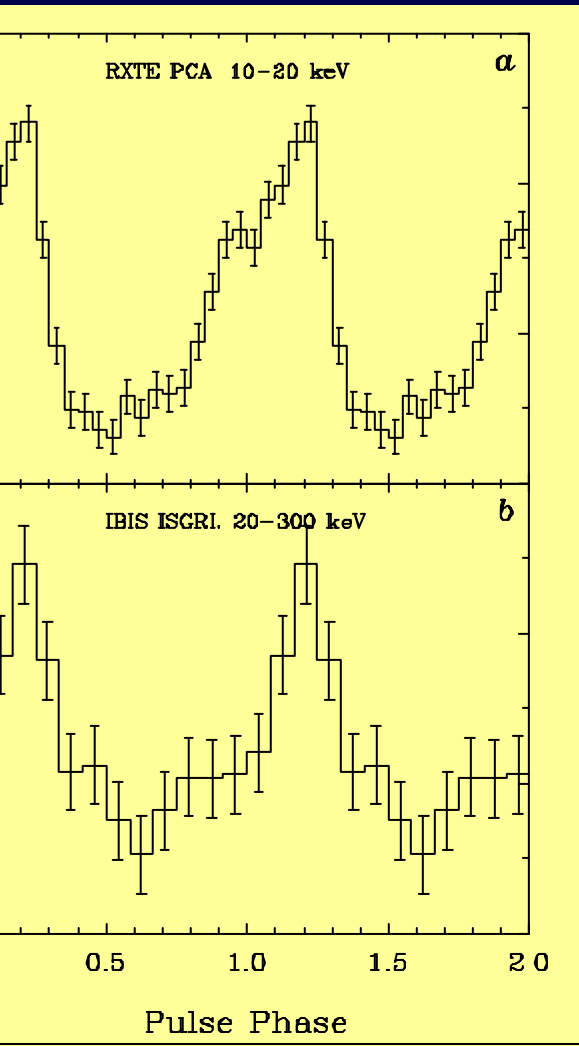
4) Total
INTEGRAL
Kuiper et al. 2005

HEXTE Total based
on ON/OFF pointing
unreliable: # of sources
in ON/OFF field



Need imaging instruments
IBIS ISGRI

1RXS J170849.0-400910 (RXTE PCA/INTEGRAL IBIS ISGRI Revs 36-106/116-120)



IBIS ISGRI
1.92 Ms GTI
exposure

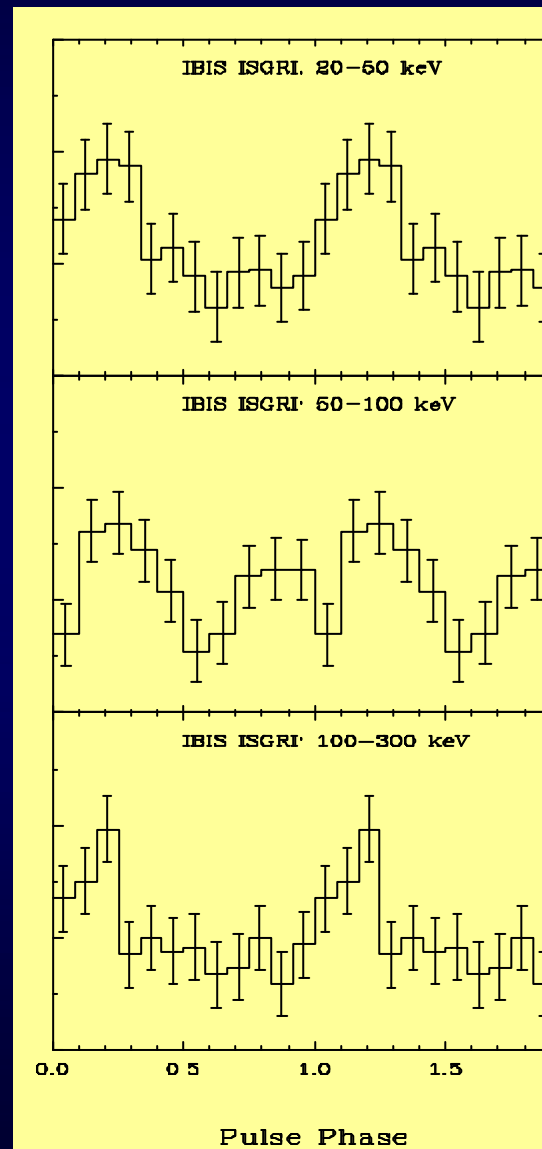
Kuiper et al.
2005 in prep.

5.7s

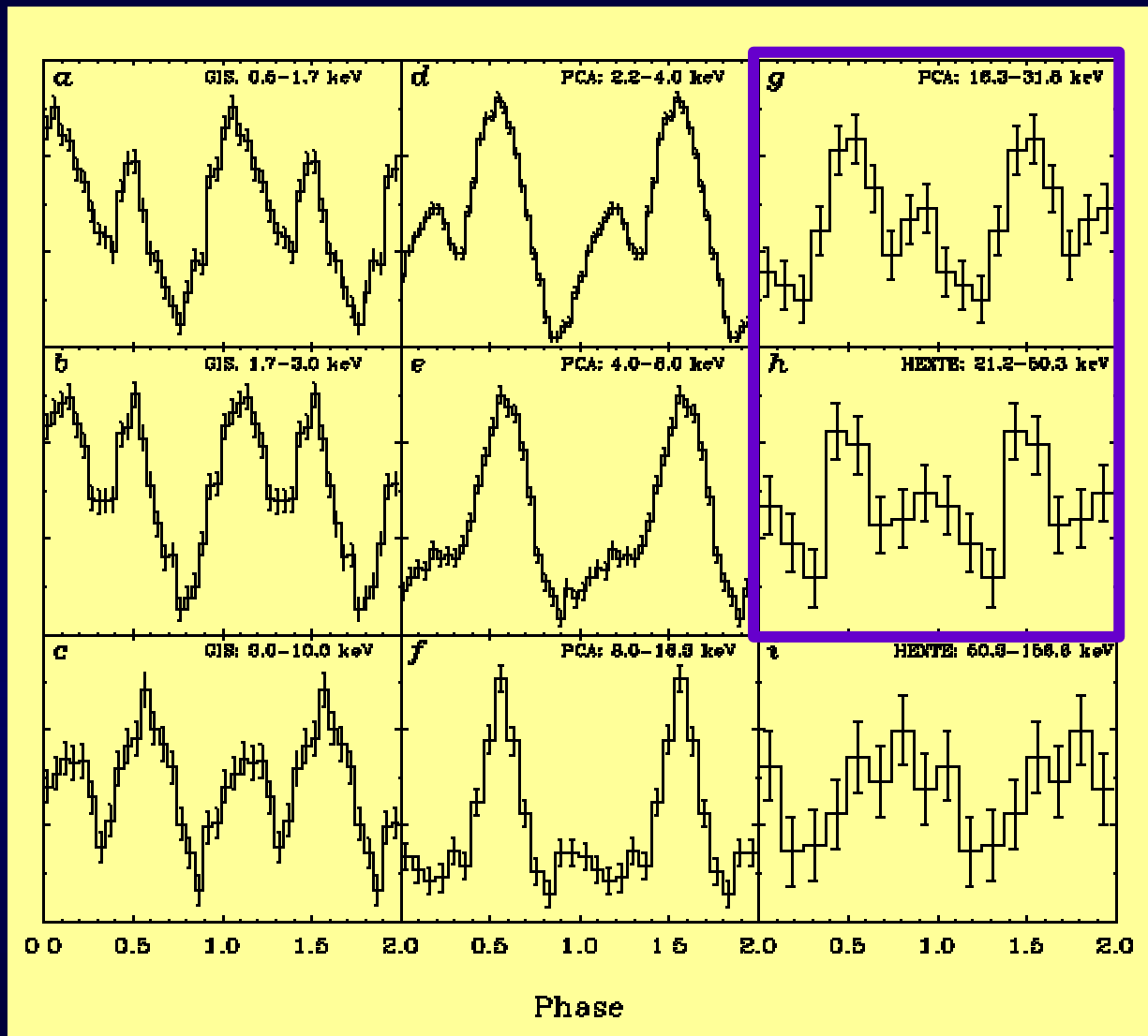
3.8s

3.1s

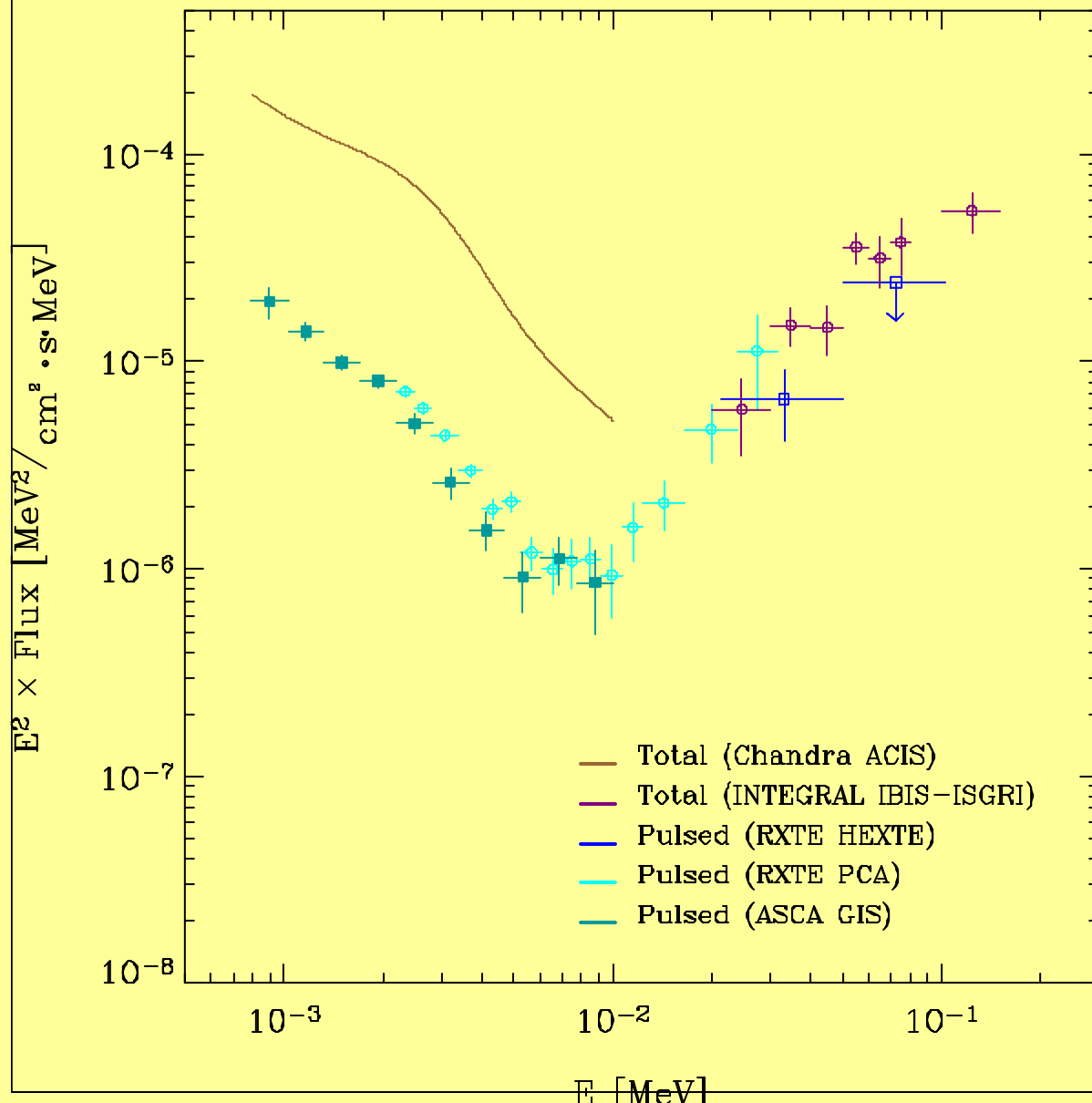
3.1s



4U0142+614



4U0142+614



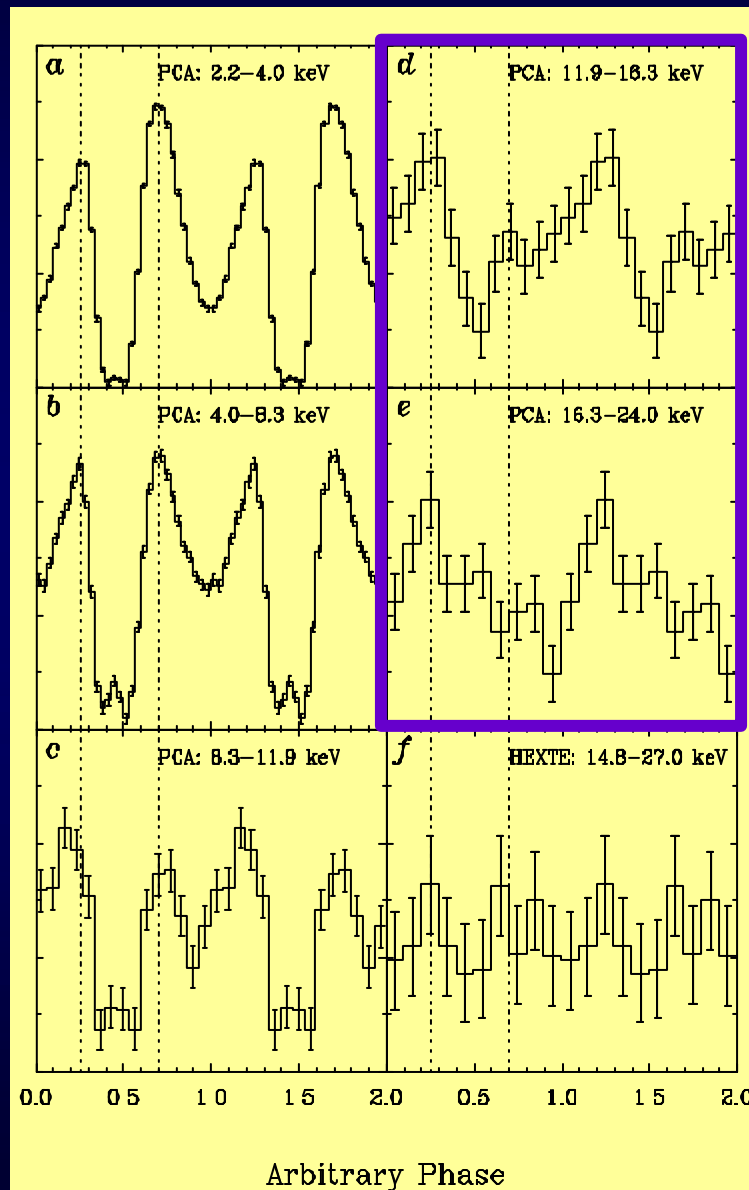
1E2259+586 (CTB 109) RXTE PCA/HEXTE

Screened PCU-2 exposure
747 ks!

5.2s

3.1s

Onset hard tail!

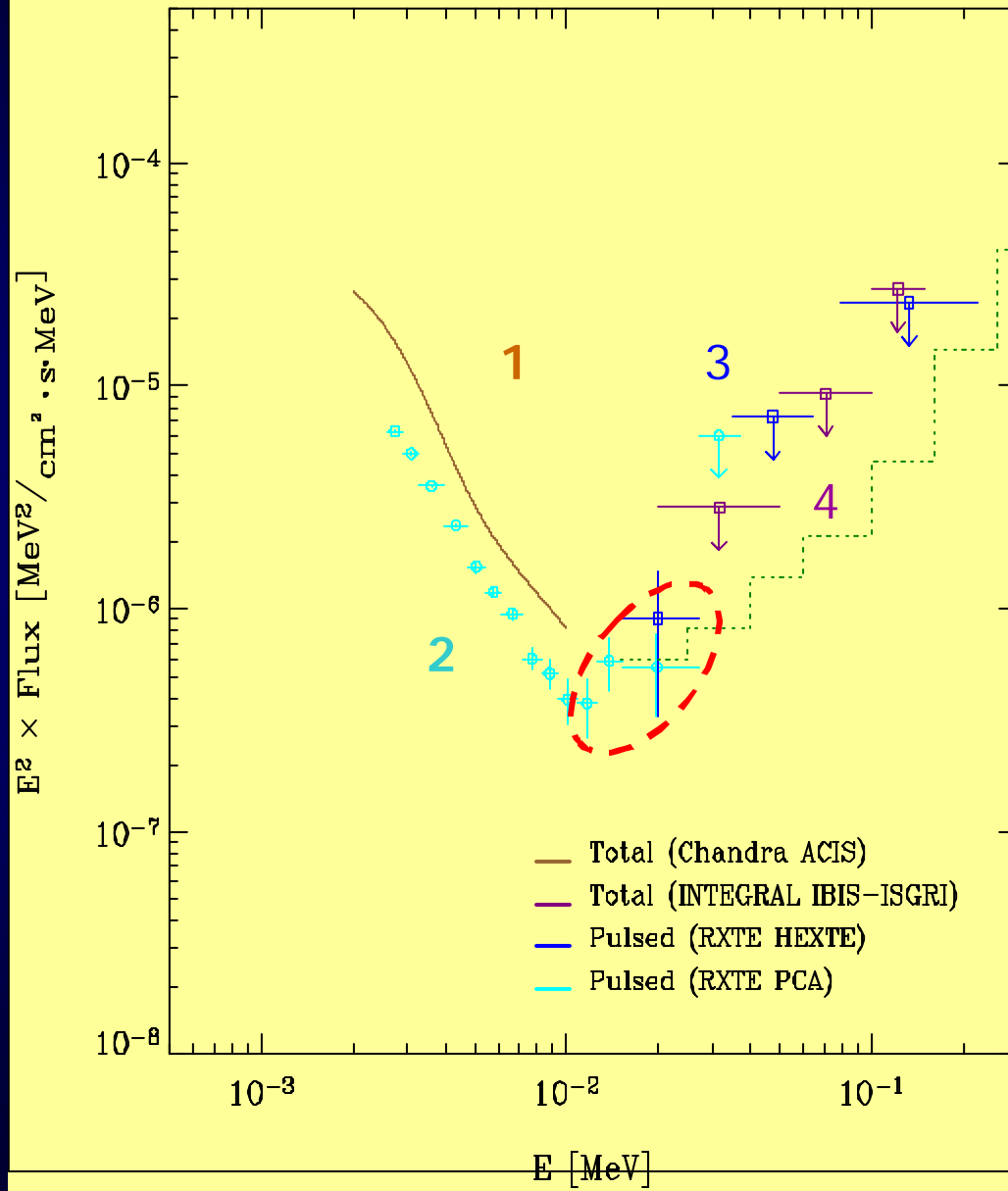


0.6s

1E2259+586 (CTB 109)

1) Total
Chandra ACIS
(S.K. Patel;
AJ 156, 2001)

2) Pulsed
RXTE PCA



3) Pulsed
RXTE/HEXTE

INTEGRAL 3
sensitivity for
(Ao1+Ao2+Ao3)

4) Total
INTEGRAL
(Kuiper et al. 2003)

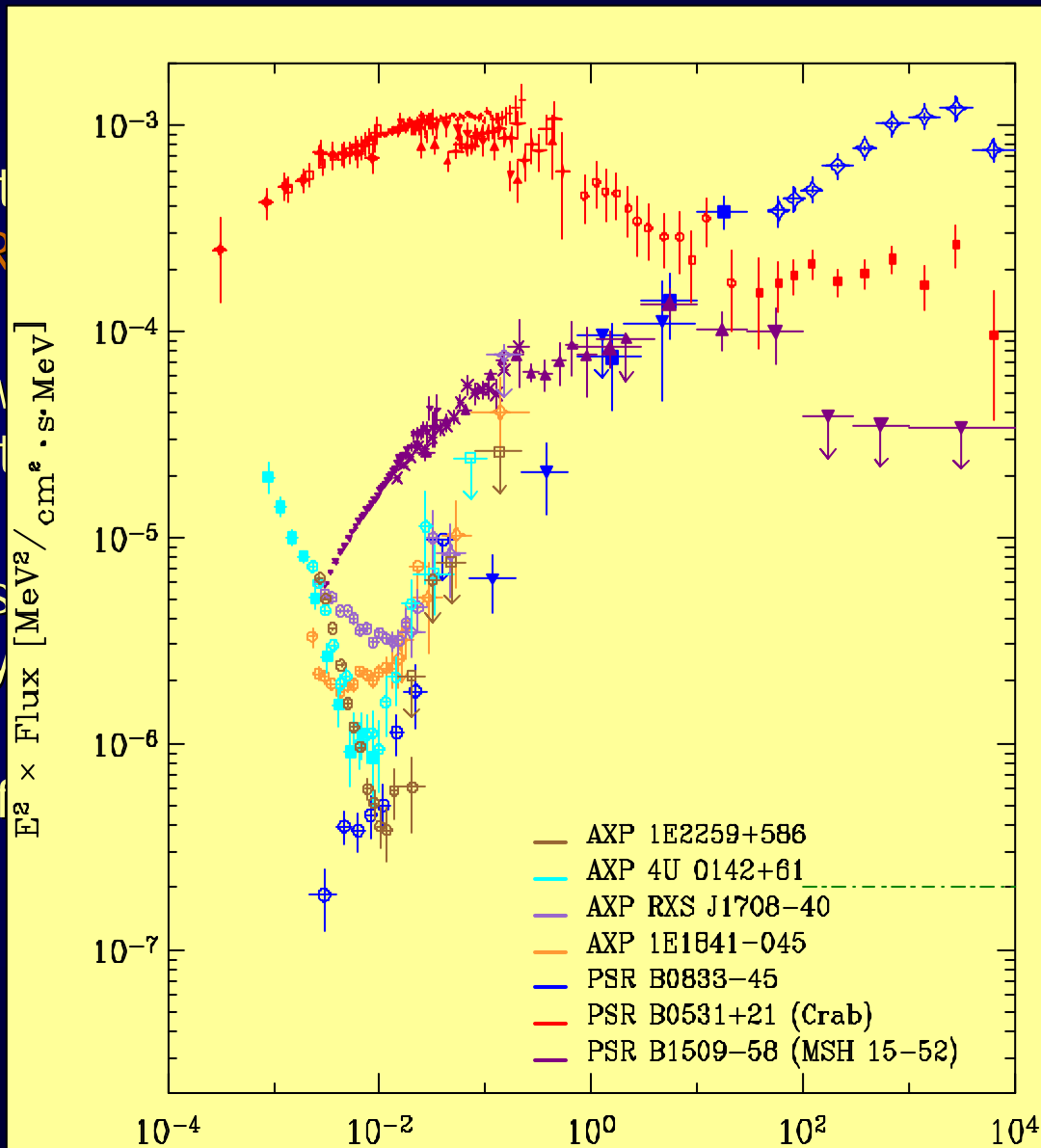
Summary

Hard spectral t
1E1841-045; 1R

A new energy w
diagnostic to st

The hard (PL) s
not powered by

Still no signs of



6

an important

spheric origin
tion?!)

/ window

Prospects

Study the other AXPs e.g. 1E1048-594 and the transient AXPs

4U 0142+614 will be studied in great detail in the soft g-ray band using data from our approved 1 Ms AO3 INTEGRAL observation (grade-A; P.I. Kuiper)

Exploiting all available and coming INTEGRAL IBIS ISGRI data on AXPs/SGRs allows for an accurate determination of the high-energy (20-300 keV) characteristics of magnetars:

- 1) pulsed fraction vs. energy
- 2) phase resolved spectroscopy
- 3) possible g-ray lines → direct B measurement
- 4) spectral bend/break