Gamma-ray pulsar studies with INTEGRAL

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5 Years of INTEGRAL, October 2007

SRON
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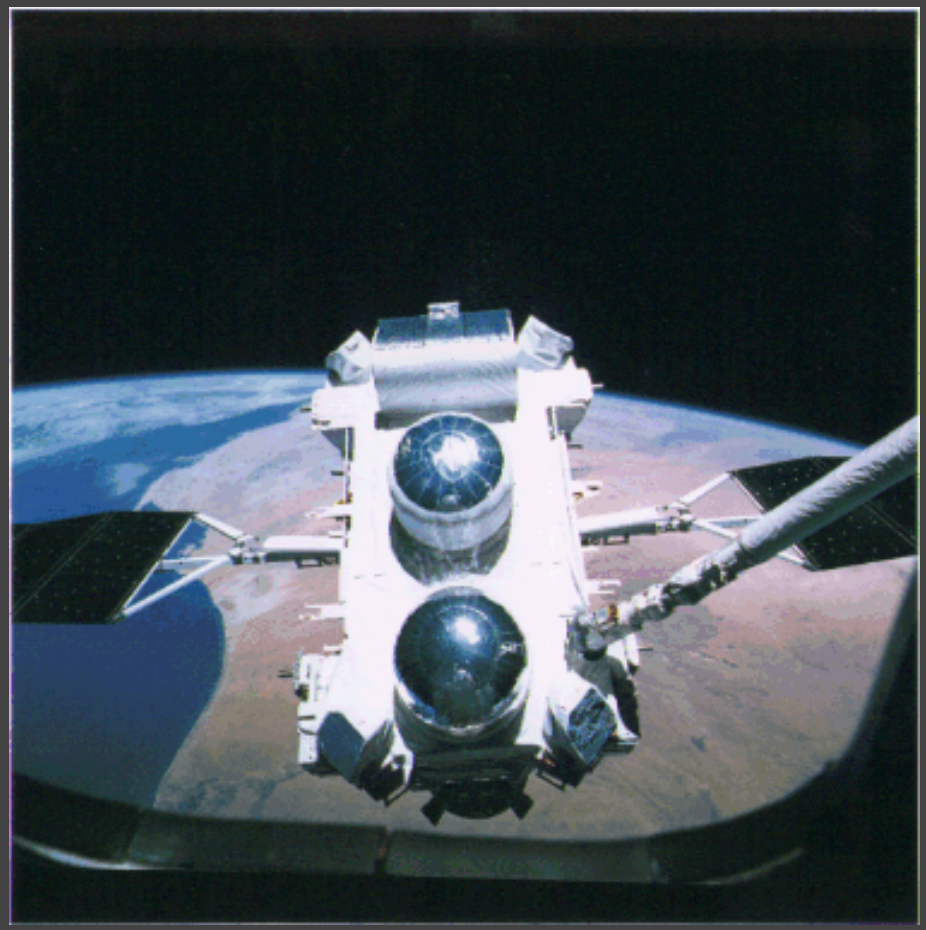
Outline of presentation

- Introduction:
  - Heritage of the Compton Gamma-Ray Observatory on γ-ray emission from radio pulsars
  - Why it is relevant to exploit the INTEGRAL data for pulsar studies
- INTEGRAL results:
  - Confirmation Crab, PSR B1509-58 and PSR B0540-69
  - New information for Vela
  - Detection of pulsed hard X-ray emission from 4 young pulsars
  - Some peculiar further candidates for study with INTEGRAL

Heritage
CGRO: 5 April 1991 – 4 June 2000
(20 keV – 30 GeV)



1) Classical γ-ray pulsars

PSR B0531+21 (Crab)
PSR B0833-45 (Vela)

2) Newly discovered high-energy γ-ray pulsars

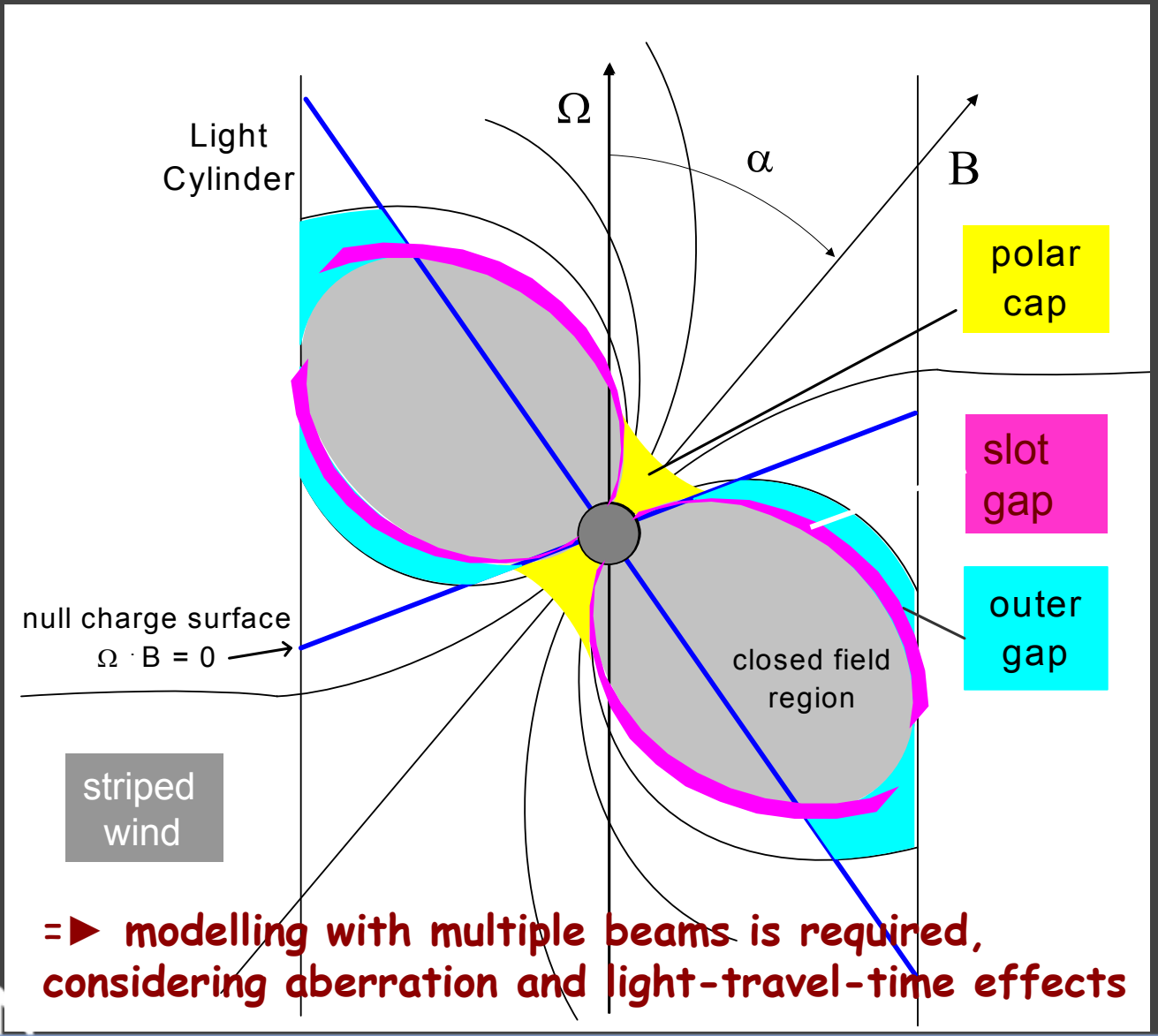
PSR B1706-44
PSR B1055-52
PSR B1951+32
Geminga
[PSR J0218+4232, msp!]
[PSR B0656+14]
[PSR B1046-58]

3) Newly discovered soft γ-ray pulsars

PSR B1509-58

PSR B0540-69 (RXTE HEXTE)
(de Plaa, Kuiper, Hermsen 2003)

Geometries of high-energy emission pulsar models



=► modelling with multiple beams is required, considering aberration and light-travel-time effects

Gamma-ray pulsars:

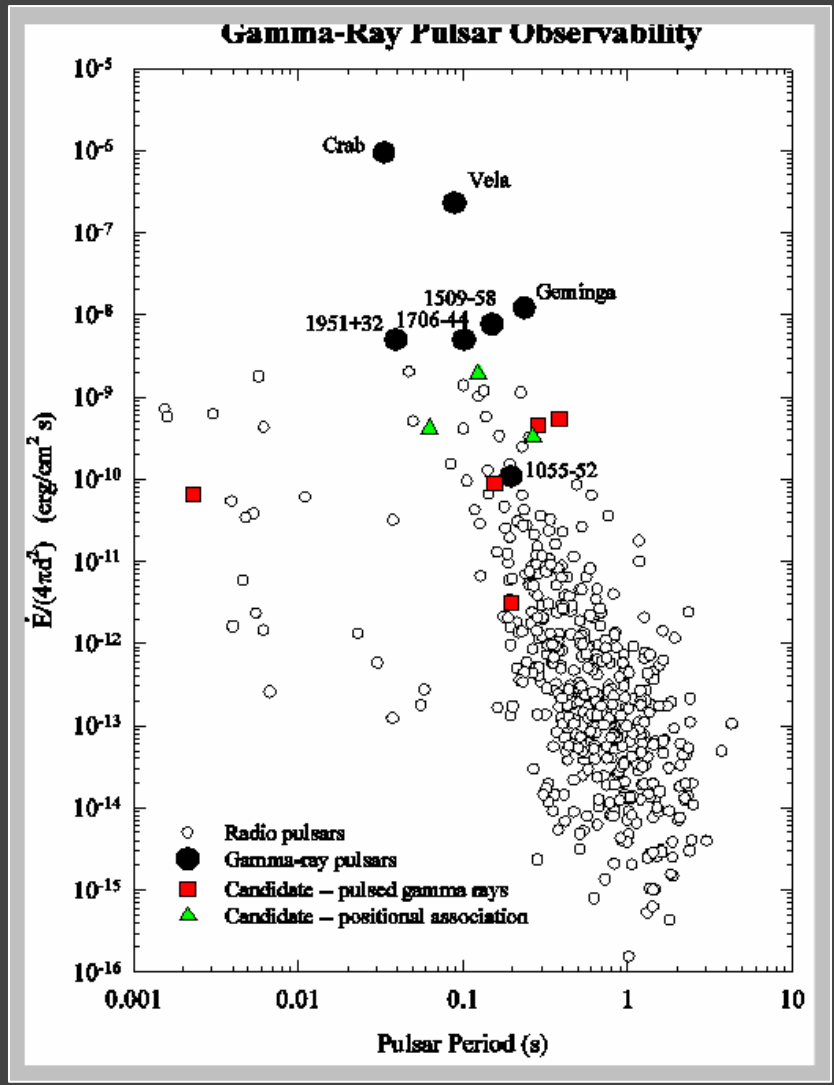
- All relatively young (≤ few 100 kyr) and energetic
- Established Galactic γ-ray source population, emitting over a wide high-energy range (0.5 keV – 10 GeV)
- But only 4 in INTEGRAL window!

3 young: PSR B0531+21 1.3 kyr (Crab)

PSR B1509-58 1.6 kyr

PSR B0540-69 1.7 kyr

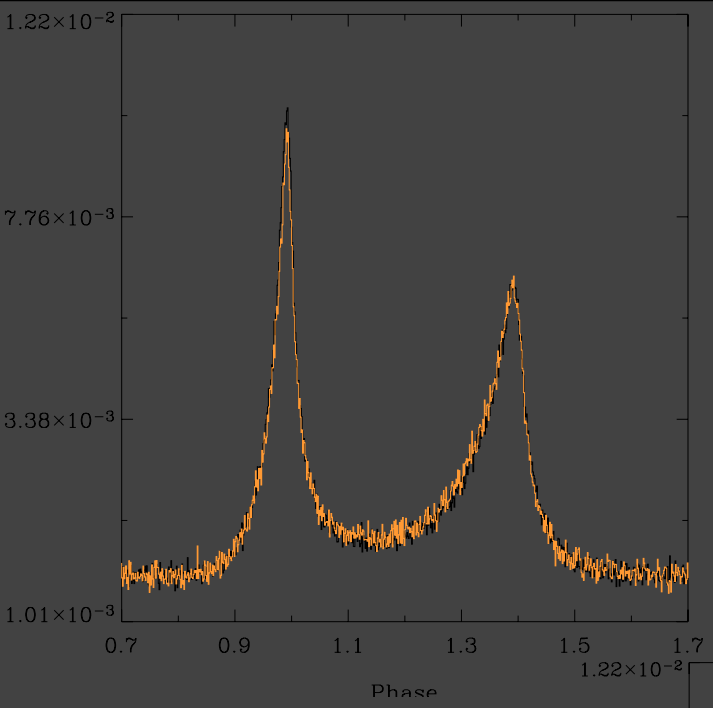
1 middle-aged: PSR B0833-45 11 kyr (Vela)



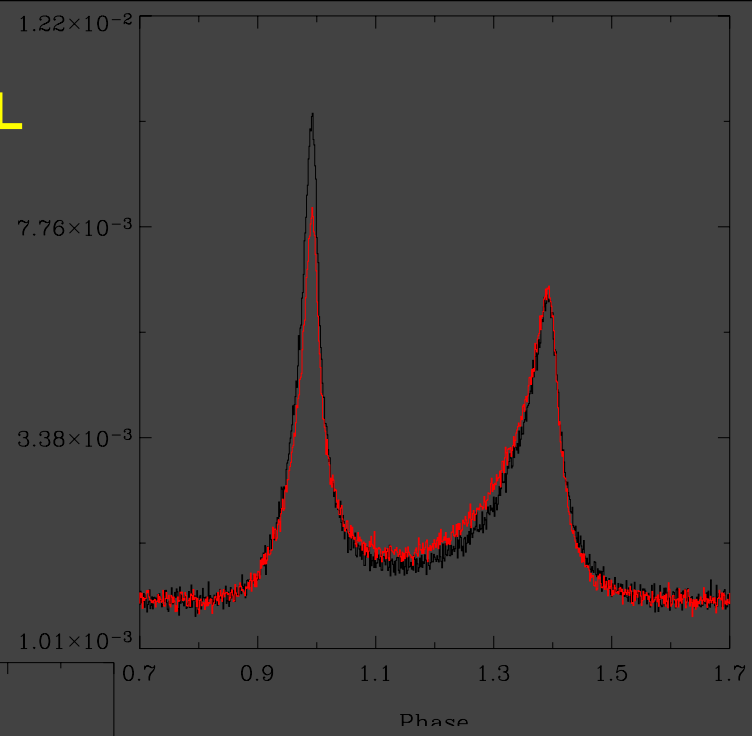
Thompson, Harding, Hermsen, Ulmer, 1997

INTEGRAL

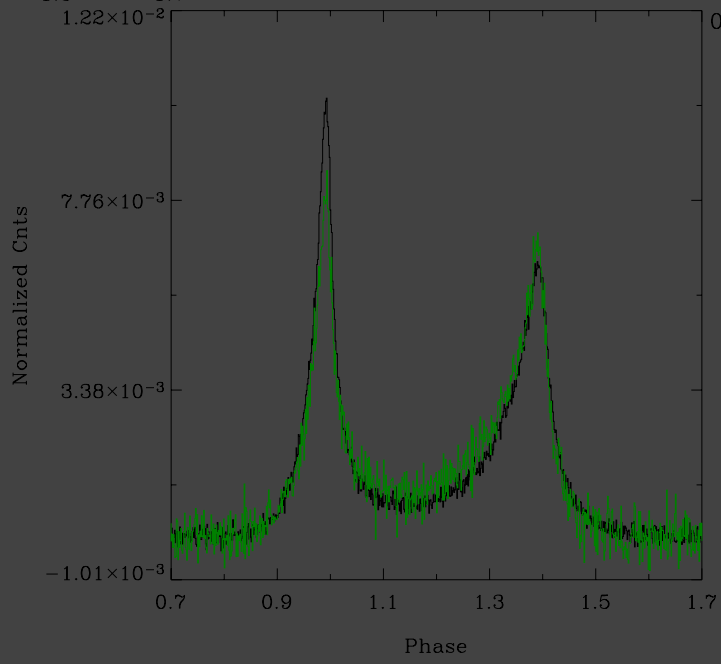
Results



SPI



ISGRI



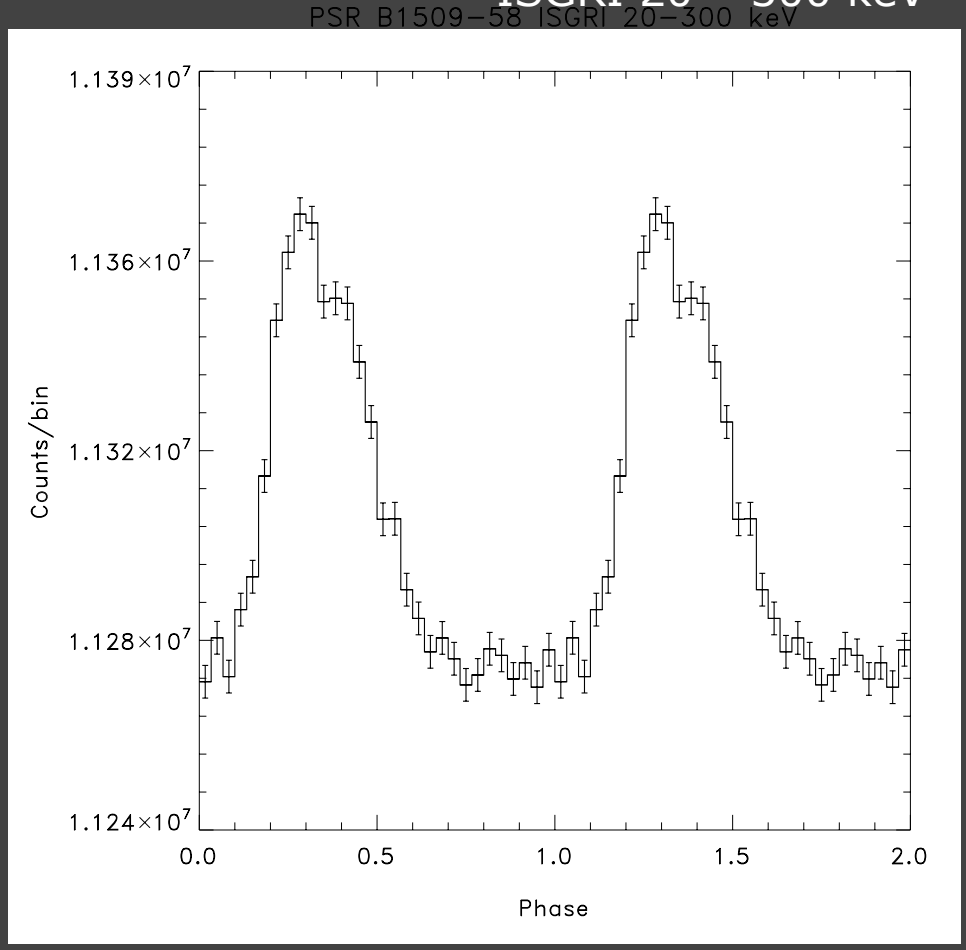
JEM-X

CRAB
Pulse Profiles

Kuiper, Hermsen, 2003

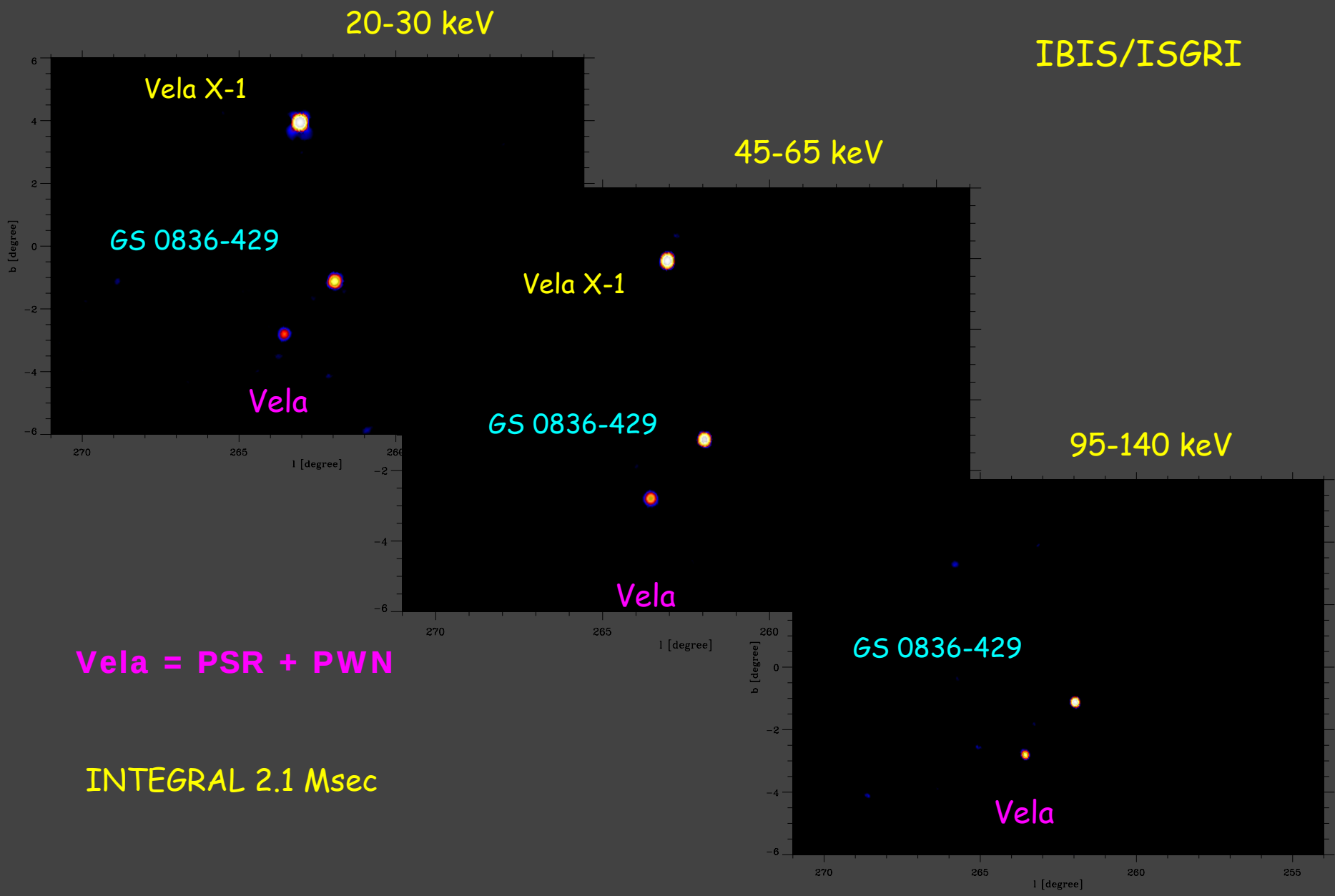
PSR B1509-58 in MSH 15-52 (G320-1.2)

ISGRI 20 – 300 keV



Pulse profile consistent with e.g. BATSE, RXTE,

but, INTEGRAL timing plus imaging gives results on the PWN, see Forot et al. 2006



Vela = PSR + PWN

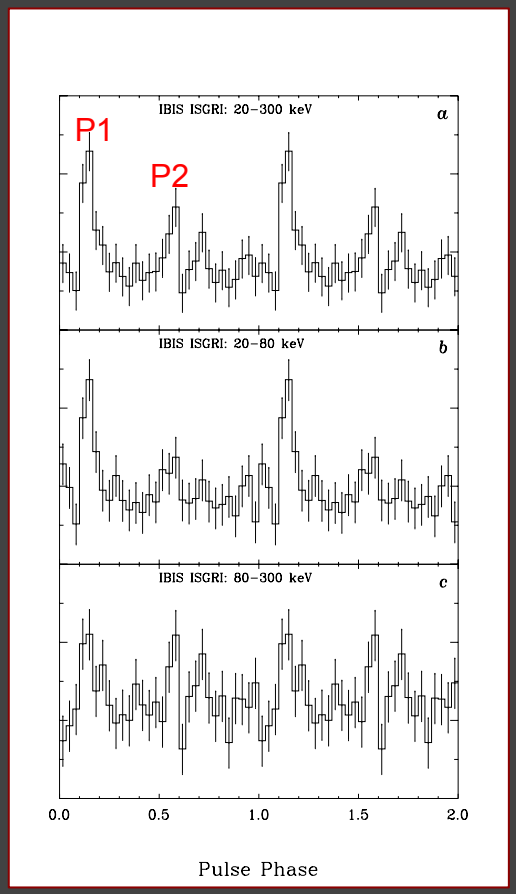
INTEGRAL 2.1 Msec

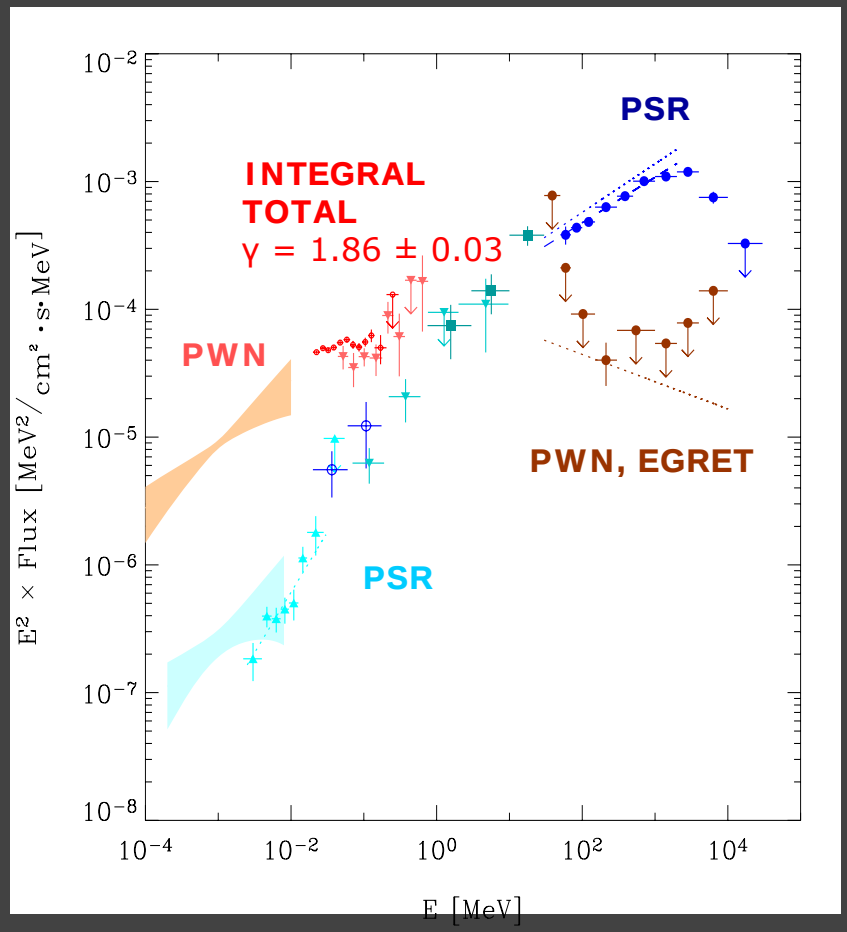
Vela Pulsar

INTEGRAL 2.1 Msec
IBIS / ISGRI

6.2 σ

(Z_N^2)



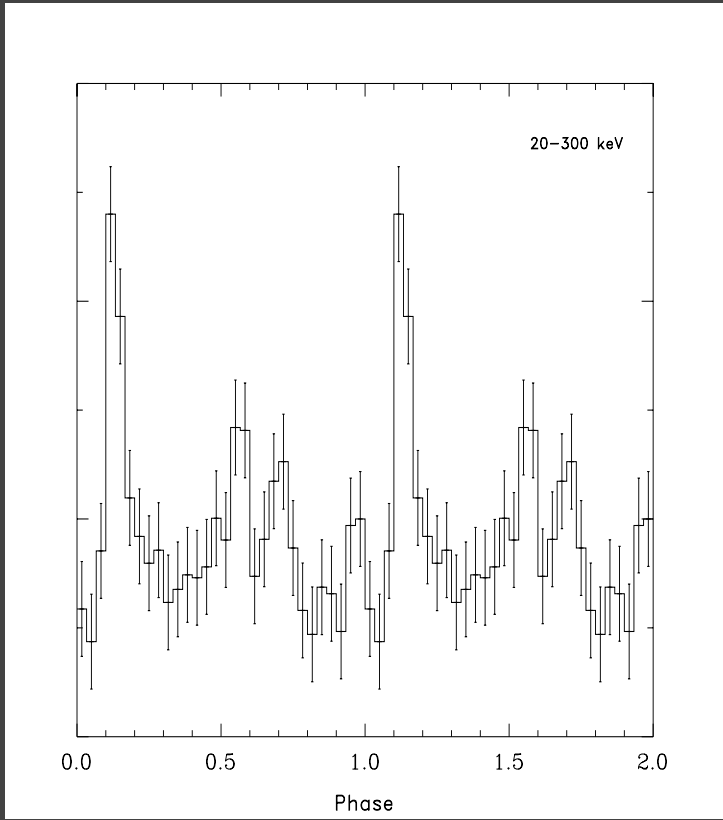


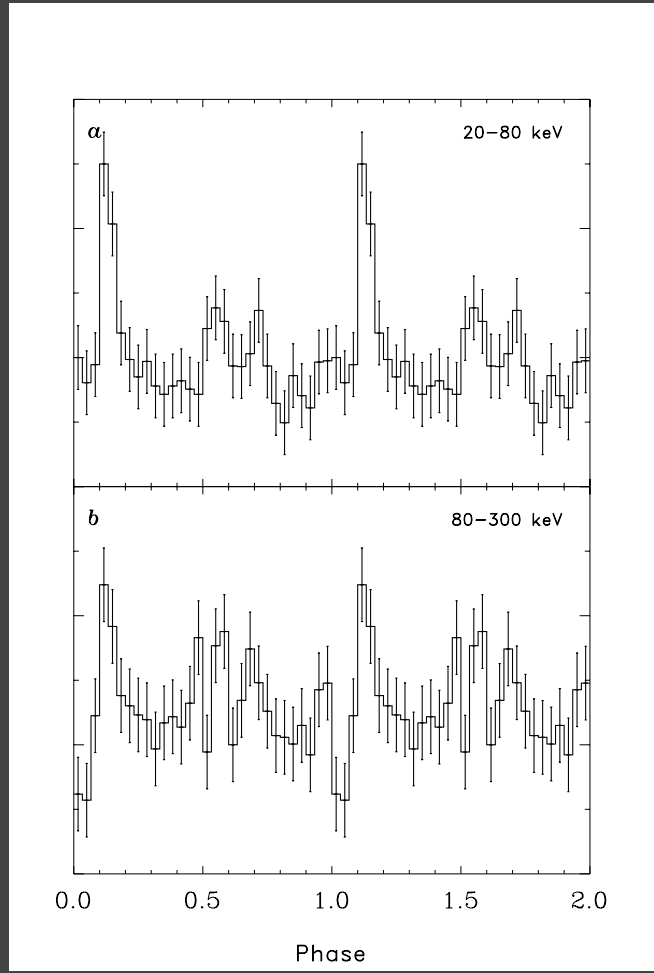
Vela Pulsar

INTEGRAL **5.1 Msec**

IBIS / ISGRI

7.9 σ



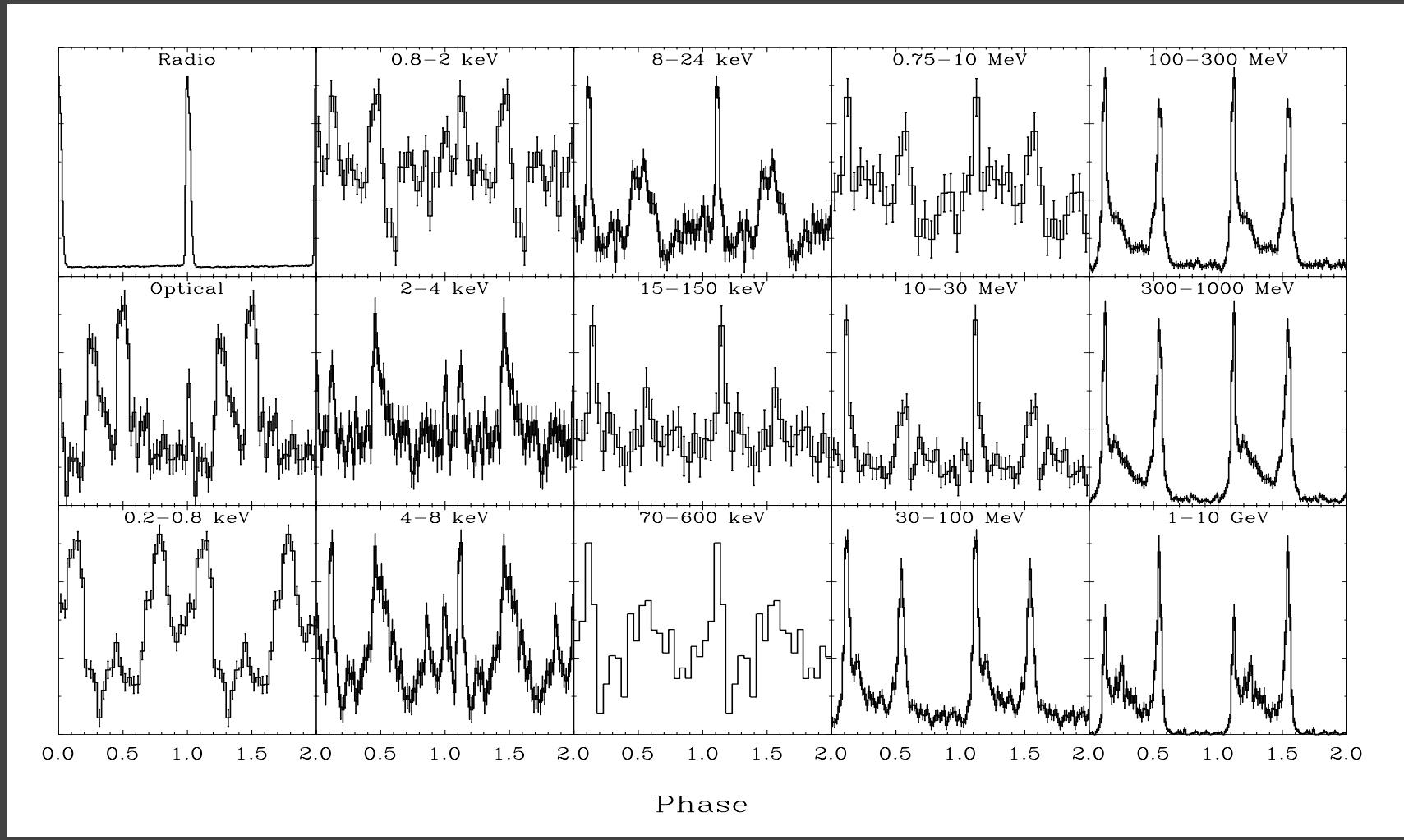


5.9 σ

4.0 σ

Vela pulse profiles from radio up to high-energy gamma rays

Hermsen & Kuiper in prep. for A&A



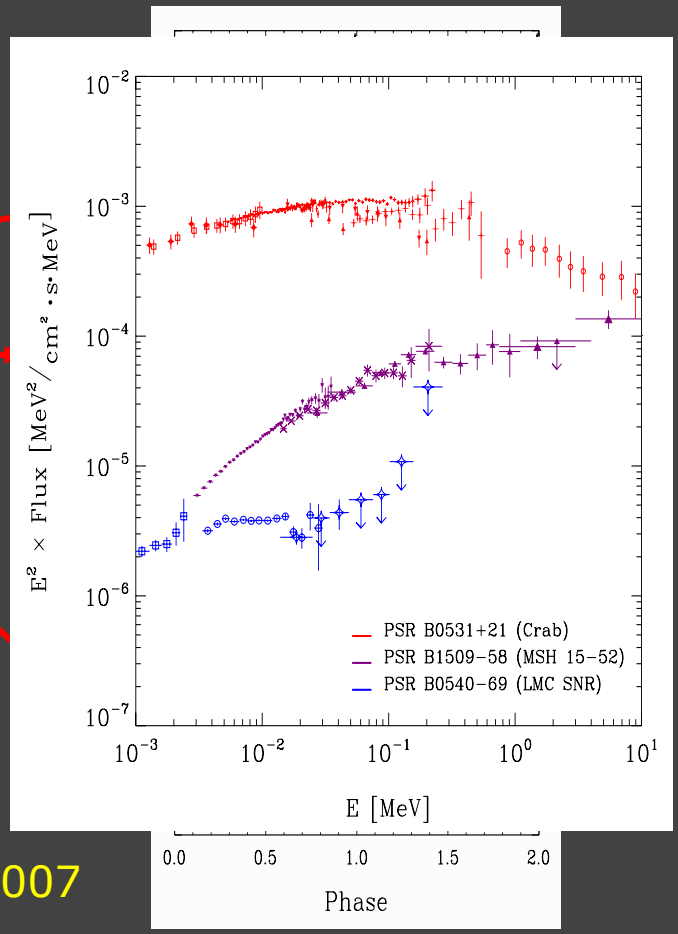
Young Pulsars

- Three young pulsars (< 10 kyr) so far studied at hard X-rays/soft γ-rays:

PSR B0531+21 (Crab)

PSR B1509-58

PSR B0540-69



- Different lightcurve shapes
- HE-spectra Crab and B0540 similar
- Maximum L_γ below 30 MeV
- $L_x/L_{\gamma\ \mathbf{GeV}}$ larger than for older pulsars

INTEGRAL profile:
Slowikowska et al. 2007

Increasing the small sample of 3 young pulsars with hard X-ray / soft gamma-ray emission

- Using mainly (archival) data from:

  a) RXTE PCA (2 - 60 keV; non-imaging)
  b) RXTE HEXTE (15-250 keV; non-imaging)
  c) INTEGRAL IBIS ISGRI (15-300 keV; **imaging**)

- Sample 1: radio quiet/(very) dim *young* rotation powered pulsars located in/near SNR's:

  PSR J1846-0258 (Kes 75) (radio quiet)
  PSR J1811-1925 (G11.2-0.3) (radio quiet)
  PSR J1617-5055 (near RCW 103) (radio dim)
  PSR J1930+1852 (G54.1+0.3) (radio very dim)

- Sample 2: candidates for detection by INTEGRAL of pulsar signal

  PSR J0205+6449 (3C58)
  PSR J0537-6910 (N157B)
  PSR J2229+6114 (in EGRET error box)

- Sample 3: Peculiar cases to follow up with INTEGRAL

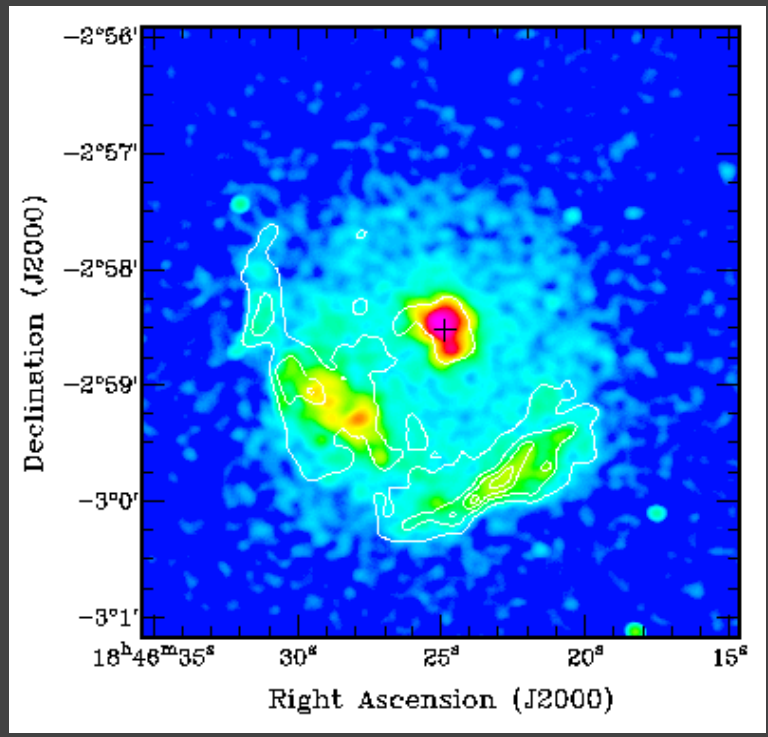
  PSR J1833-1034 in G21.5-0.9
  PSR J1119-6127 in G292-0.5

Sample 1: PSR J1846-0258 (G29.7-0.3)

- Discovered in RXTE and ASCA data by Gotthelf et al. (2000)
- "Slow" 324 ms pulsar; Characteristic age : 723 year
- Radio quiet rotation powered pulsar
- In centre of SN-remnant Kes-75 (G29.7-0.3)

  (Chandra ACIS; Helfand et al. 2003)
- Stable rotator: Breaking index n measured ➔ n=2.65(1)

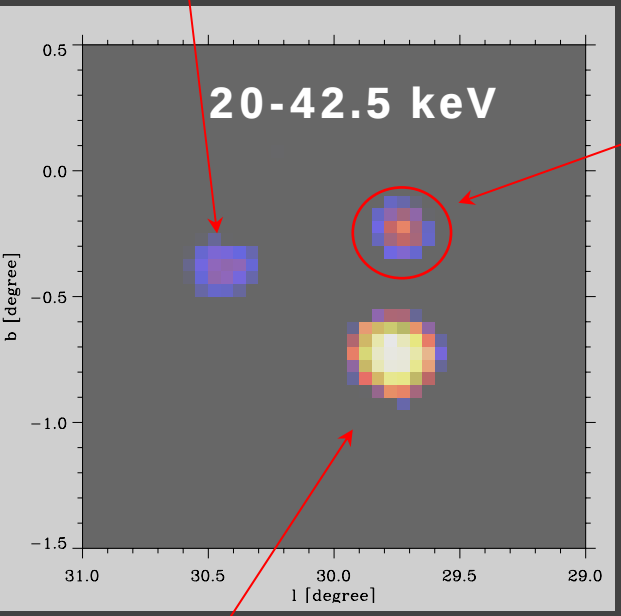
  (M. Livingstone, V. Kaspi, E. Gotthelf and L. Kuiper, 2006, ApJ 647, 1286)

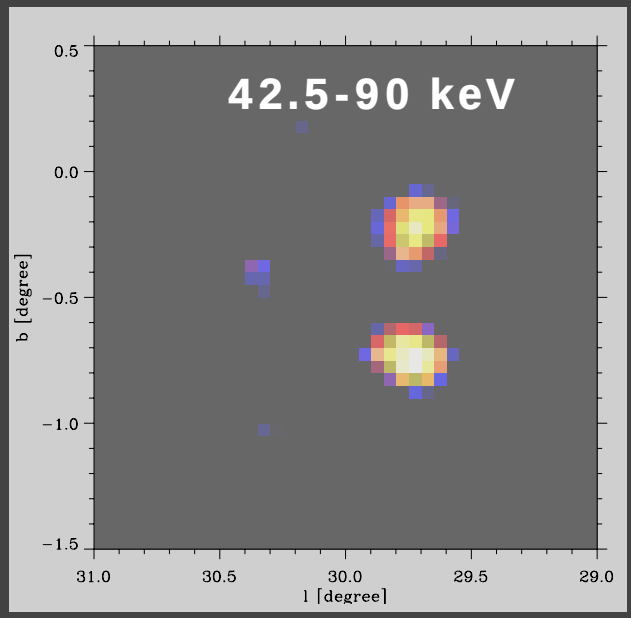


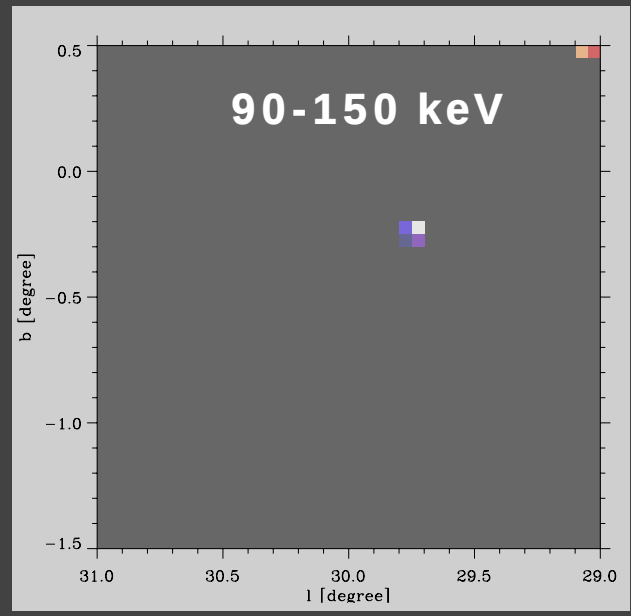
3A 1845-024

INTEGRAL IBIS ISGRI view (2^0x2^0) on PSR J1846-0258/Kes 75

Eff. exposure: 1.7 Ms







IGR J18483-0311
(ATEL #157)

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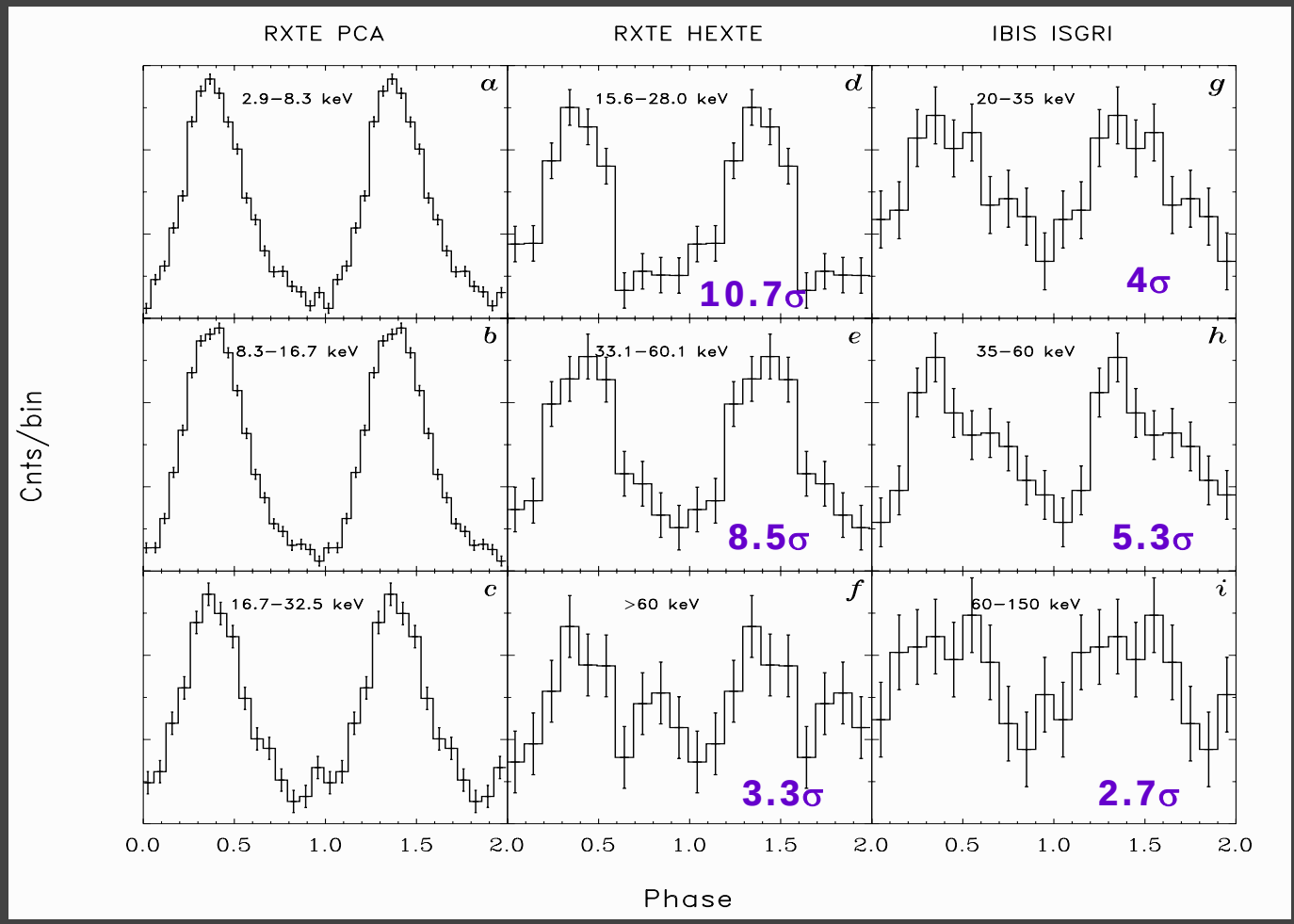
Pulse phase distributions of PSR J1846-0258

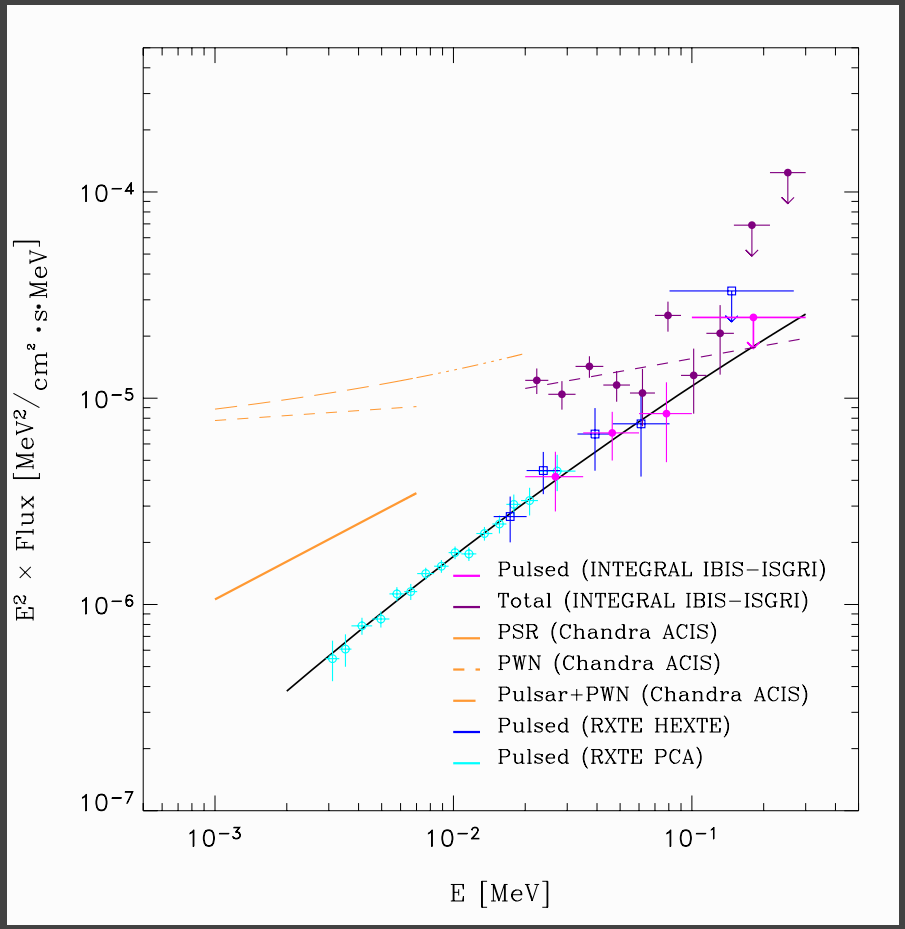


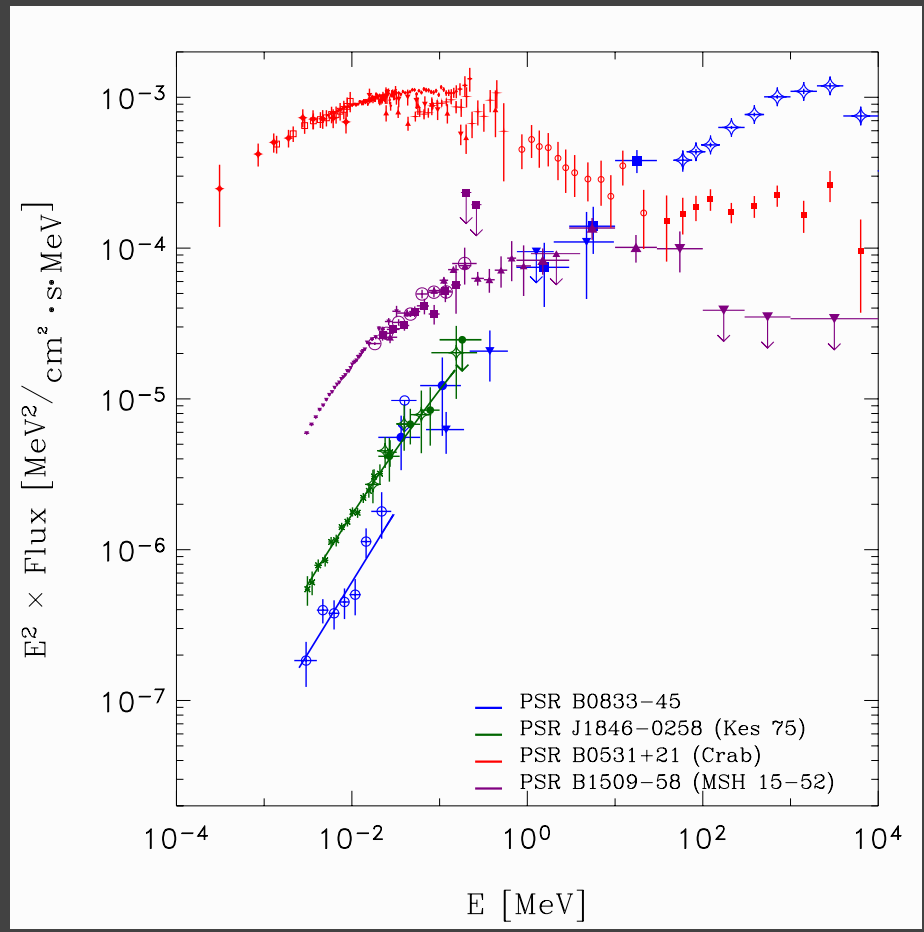
RXTE PCA : 940 ks (PCU-2)
RXTE HEXTE : 280 ks
IBIS ISGRI : 1.7 Ms

Significant pulsed emission above 60 keV!

High-energy spectrum of **PSR J1846-0258**

Pulsed emission





RXTE PCA : 940 ks (PCU-2)
RXTE HEXTE : 280 ks
IBIS ISGRI : 1.7 Ms

Photon index: -1.11(1)!

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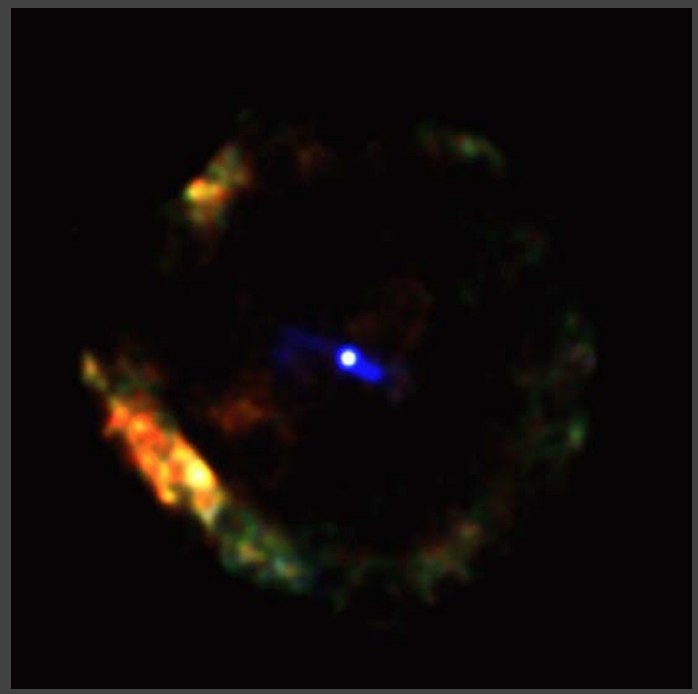
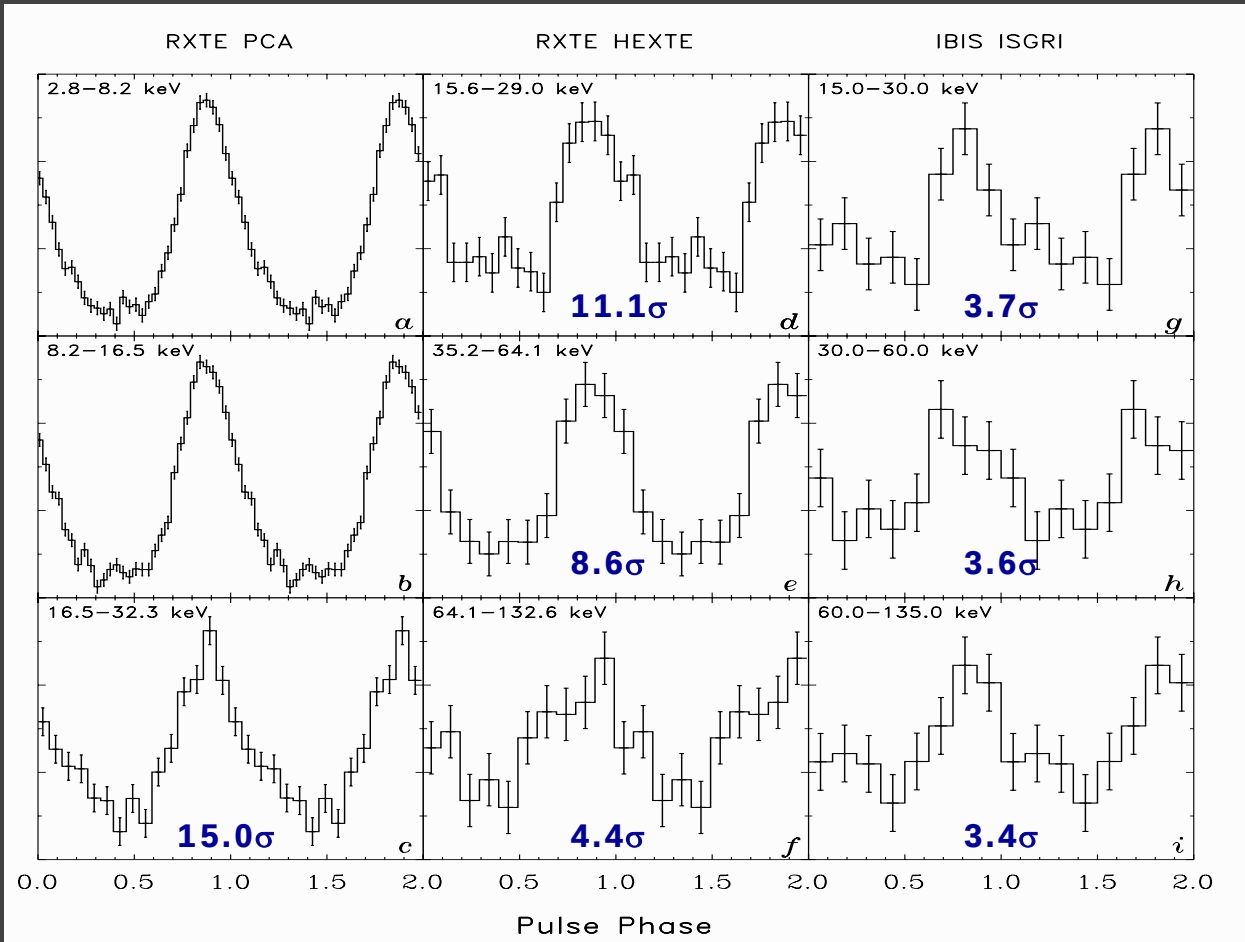
Sample 1: PSR J1811-1925 in G11.2-0.3

- Discovered by Torii et al. (1997) in ASCA data (April 1994)
- Fast 65 ms pulsar; Char. age : 24 kyr
- Radio quiet rotation powered pulsar
- In centre of SN-remnant G11.2-0.3 (Chandra ACIS Kaspi et al. 2001)

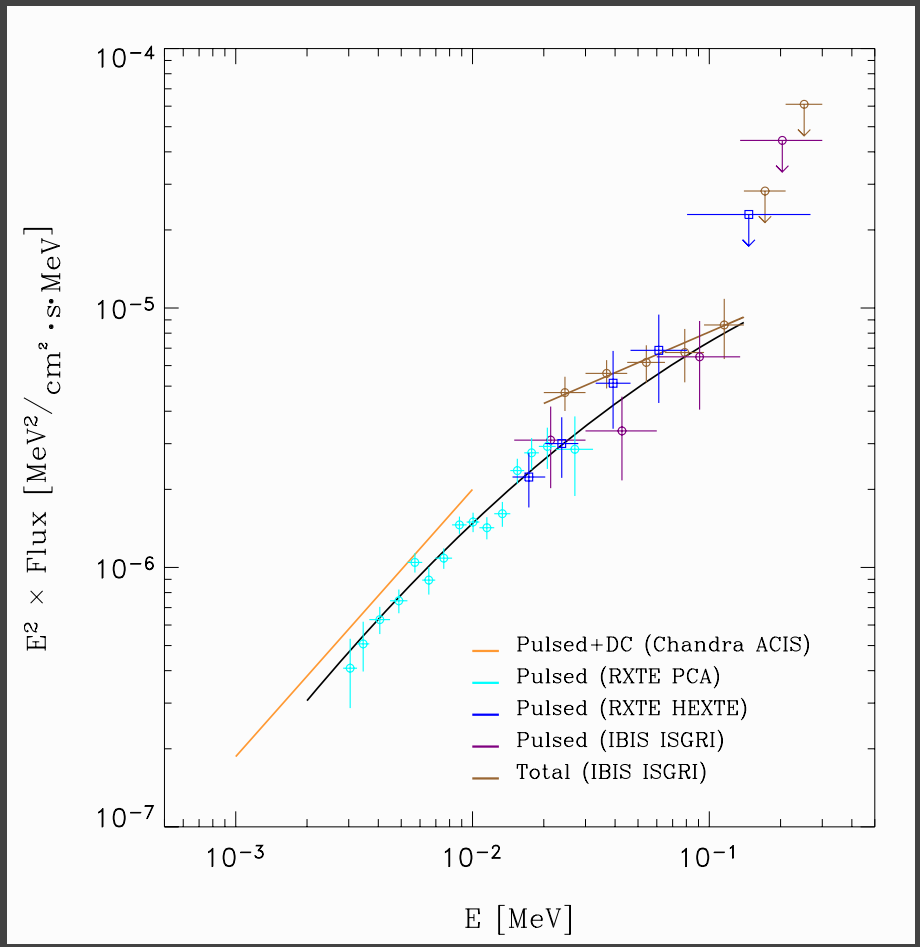


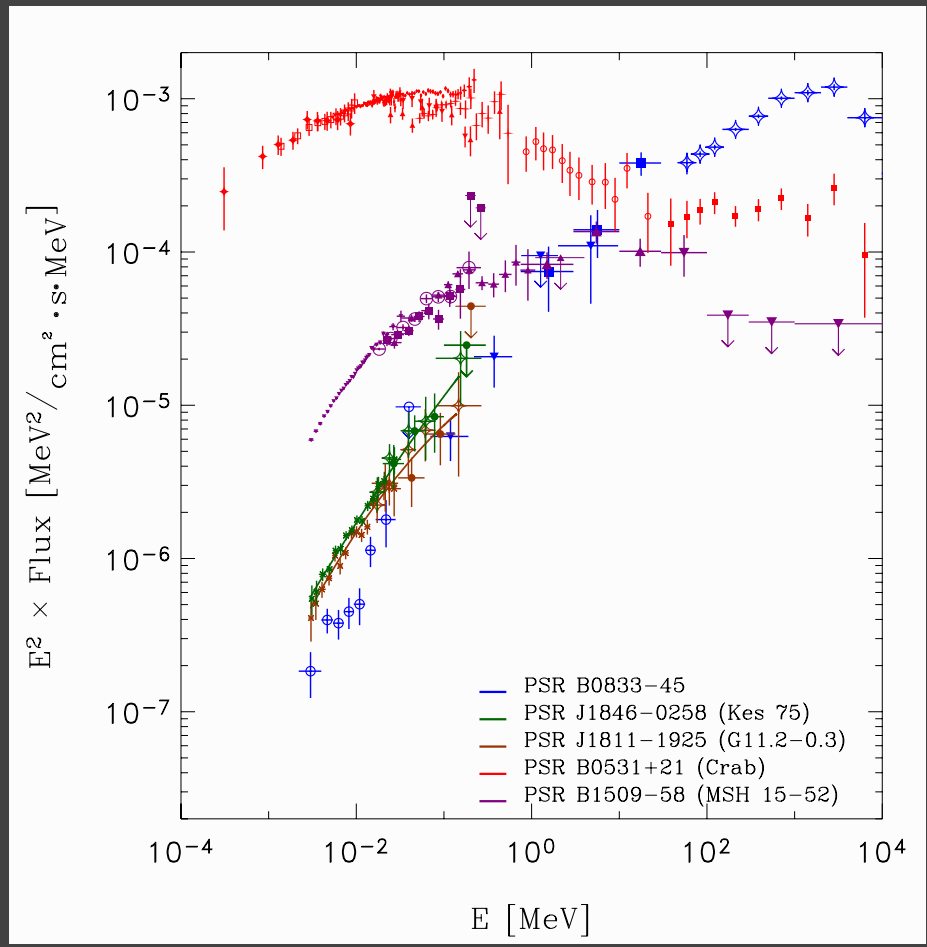
PSR J1811-1925 (G11.2-0.3)



PSR J1811-1925 (G11.2-0.3)

Pulsed emission



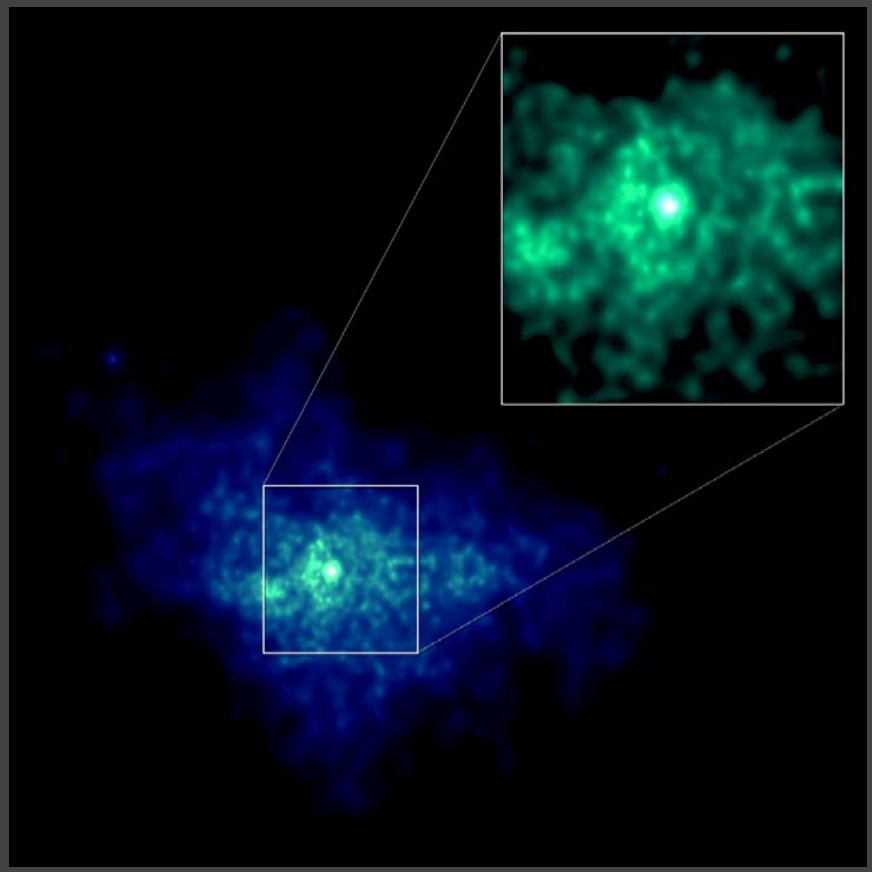


2-30 keV: $\Gamma \sim -1.11$

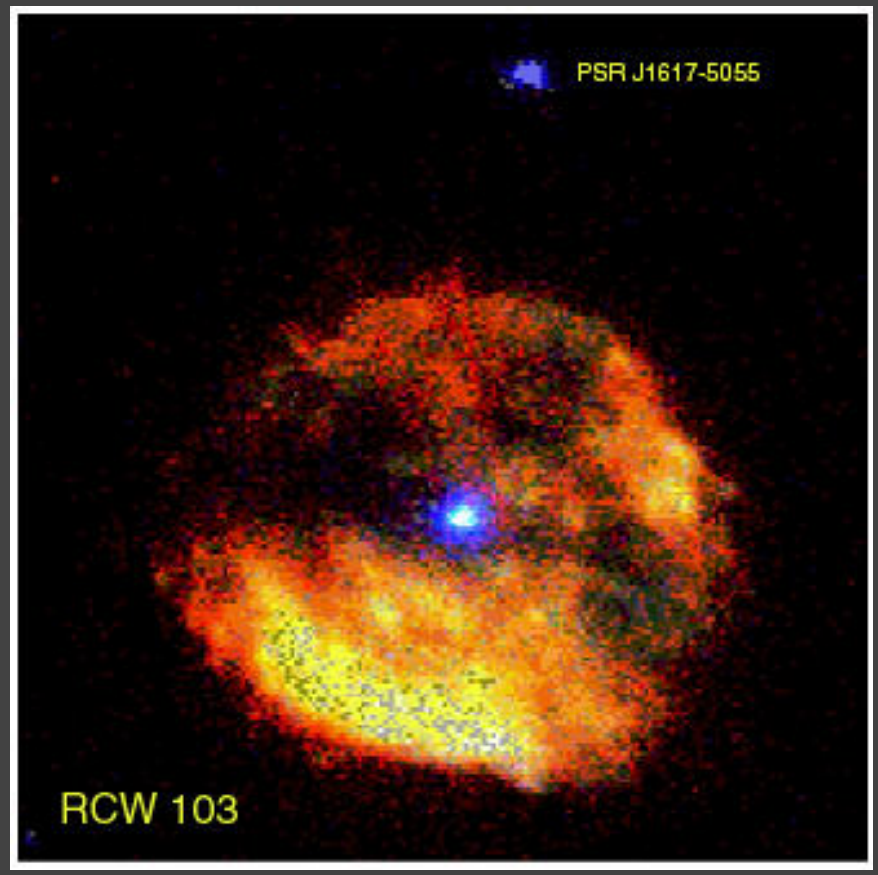
(Parallel analysis of RXTE data by Roberts et al. (2004))

Sample 1:

PSR J1930+1852 in G54.1+0.3

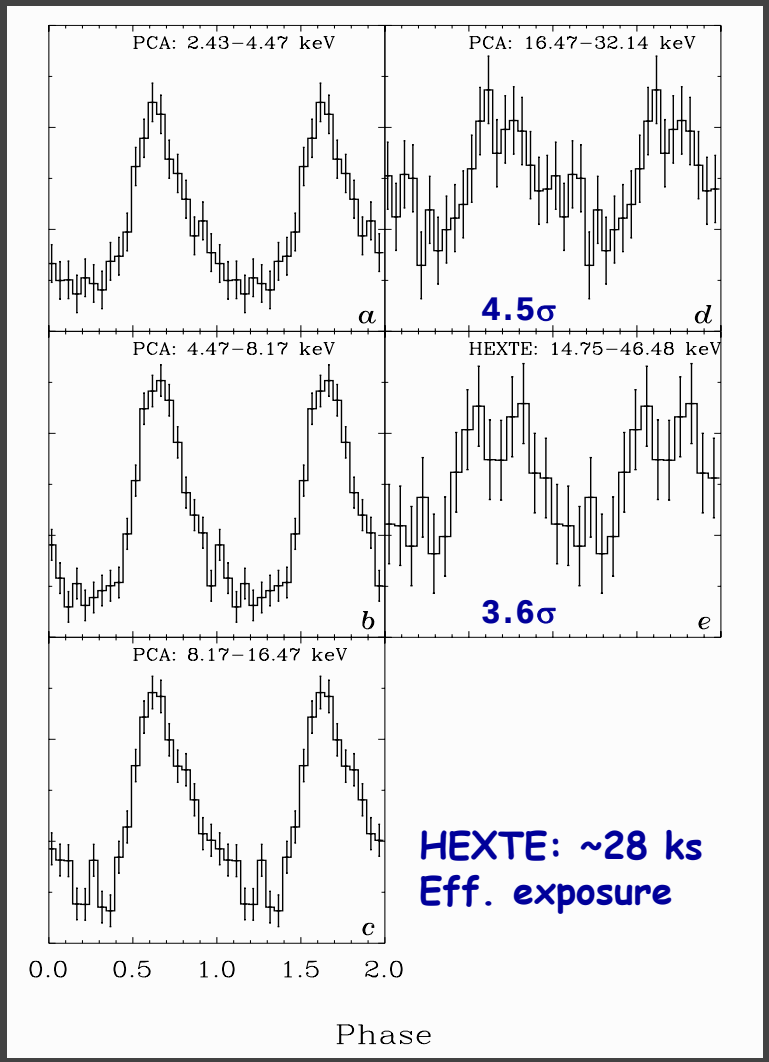


PSR J1617-5055



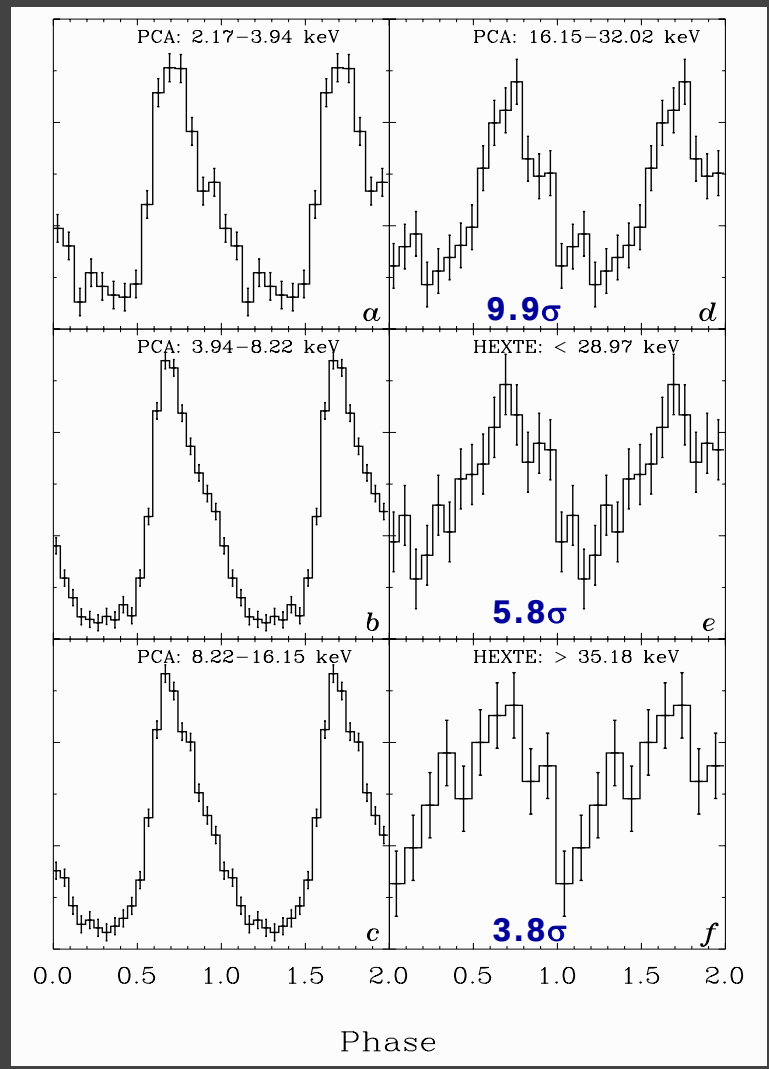
PSR J1930+1852 (G54.1+0.3)

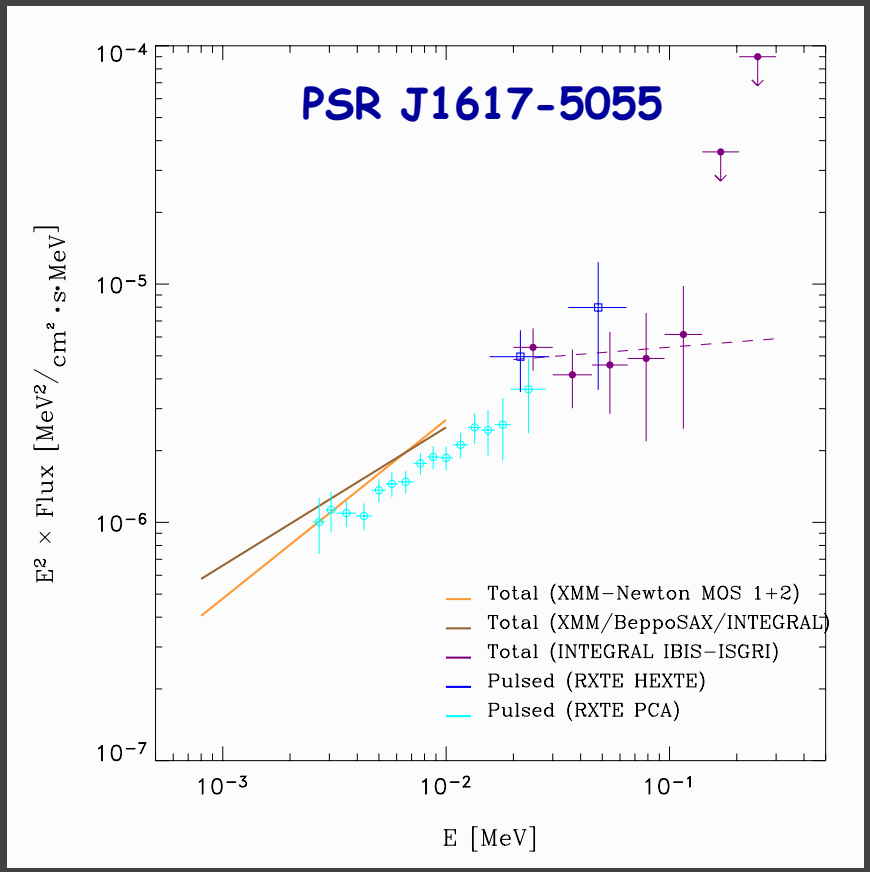
P ~ 136 ms

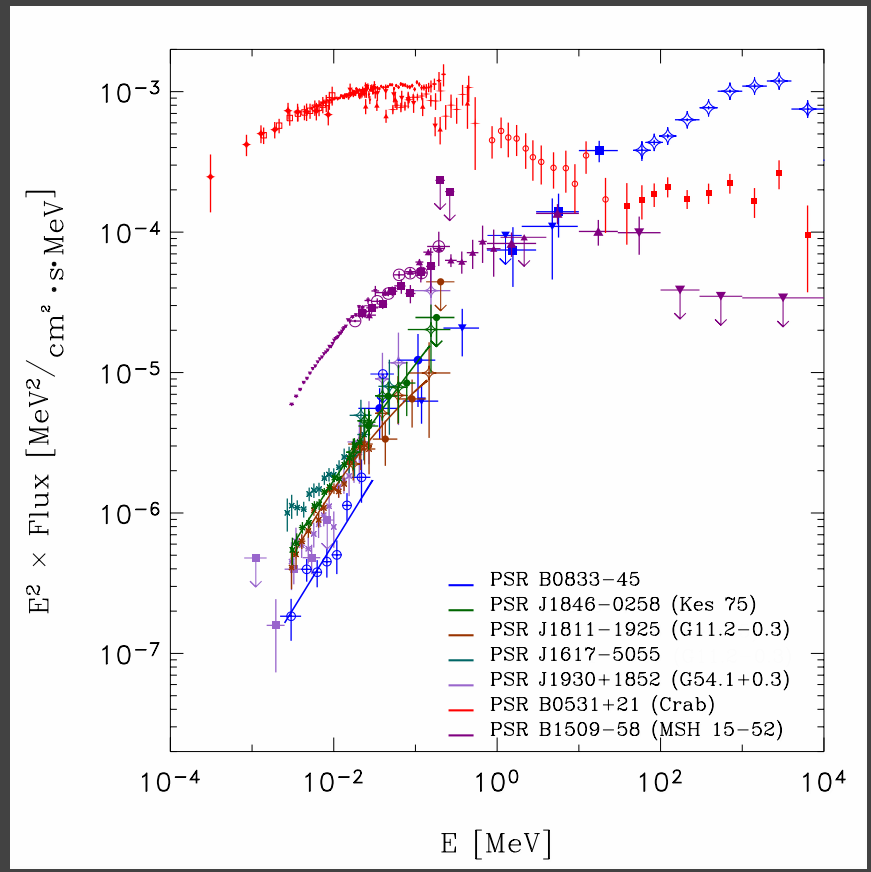


PSR J1617-5055

P ~69 ms





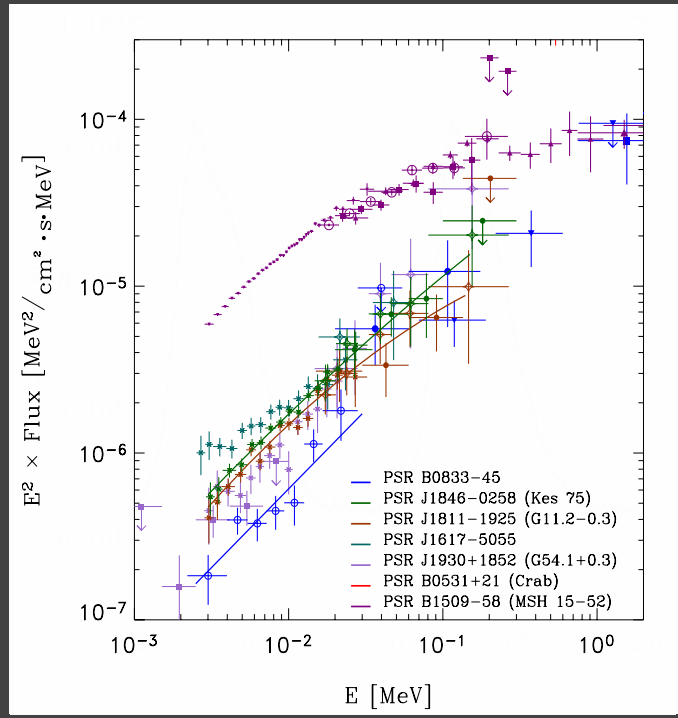


INTEGRAL ISGRI, see also R. Landi et al. 2007

Summary Sample 1

- Hard spectral tails (Γ: 1 - 1.3) detected for 4 energetic radio-dim/quiet pulsars, located in/or near young SN-remnants
- PSR J1846-0258, PSR J1811-1925 and PSR J1617-5055 detected by INTEGRAL up to ~100-150 keV
- Pulse profiles of this sample: very different from Crab, but similar to PSR B1509-58!

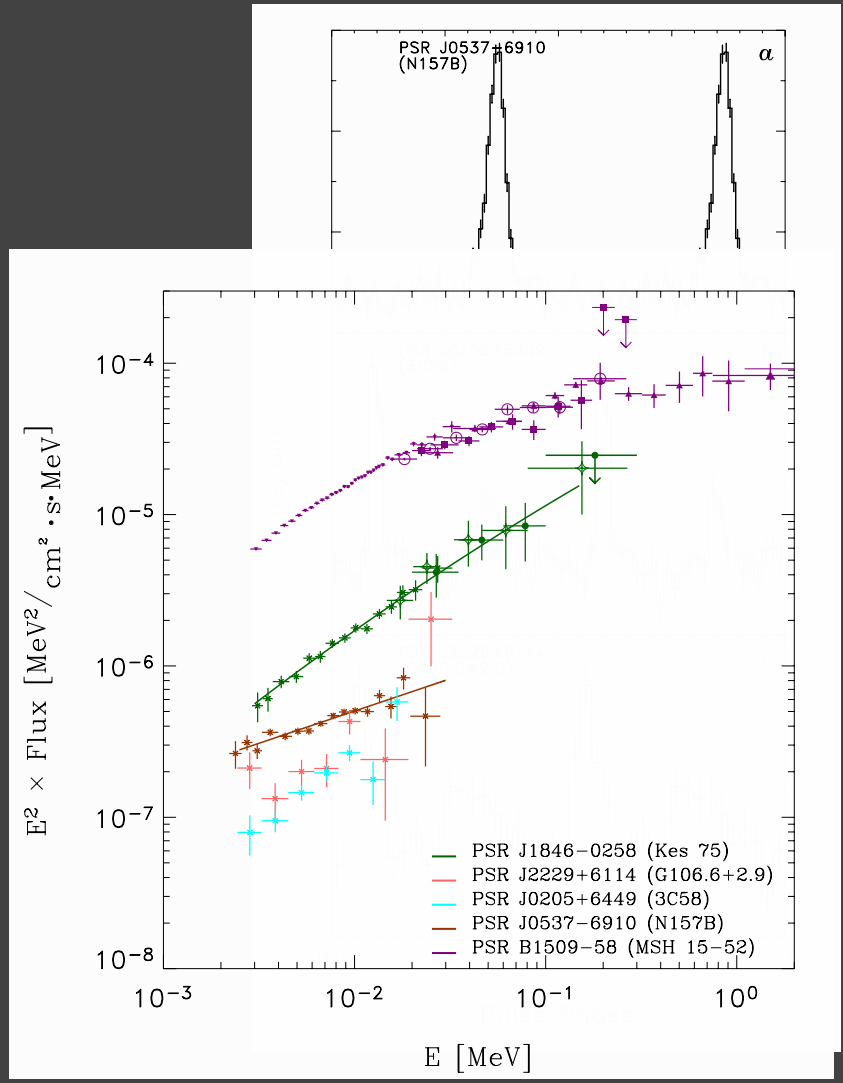
  asymmetric broad single pulse
- Spectral shapes of pulsed spectrum similar to PSR B1509-58!
- Good imaging of ISGRI allows study of total spectra, DC components, constraints on spectra PWNe



Sample 2:

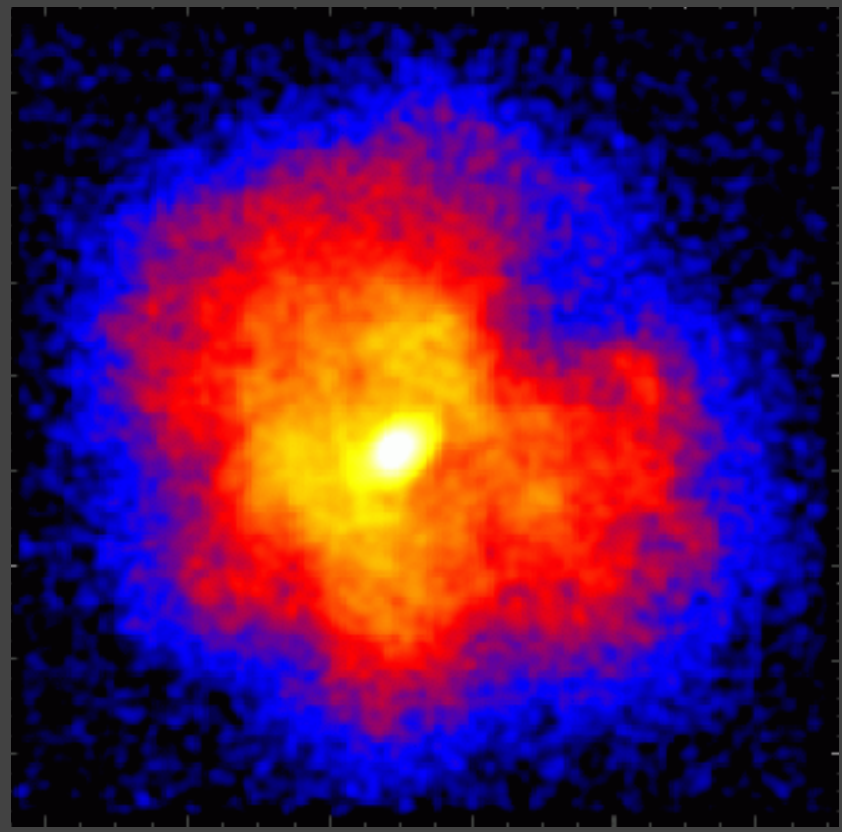
- PSR J0537-6910 (3C58)
- PSR J0205+6449 (N157B)
- PSR J2229+6429 (EGRET error box)

  - Pulsed signal up to 20-30 keV (RXTE)
  - Profiles not broad; diverse shapes
  - Different spectral slopes, but excellent candidates for INTEGRAL



Sample 3: PSR J1833-1034 in G21.5-0.9

P=61.8 ms; τ=4.8 kyr (Gupta et al. 2006, Camilo et al. 2006)



Very deep Chandra exposure

Zoom in PWN

a) No pulsed X-ray emission (0.5-10 keV) found yet!

b) Soft γ-rays up to ~150 keV from G21.5-0.9

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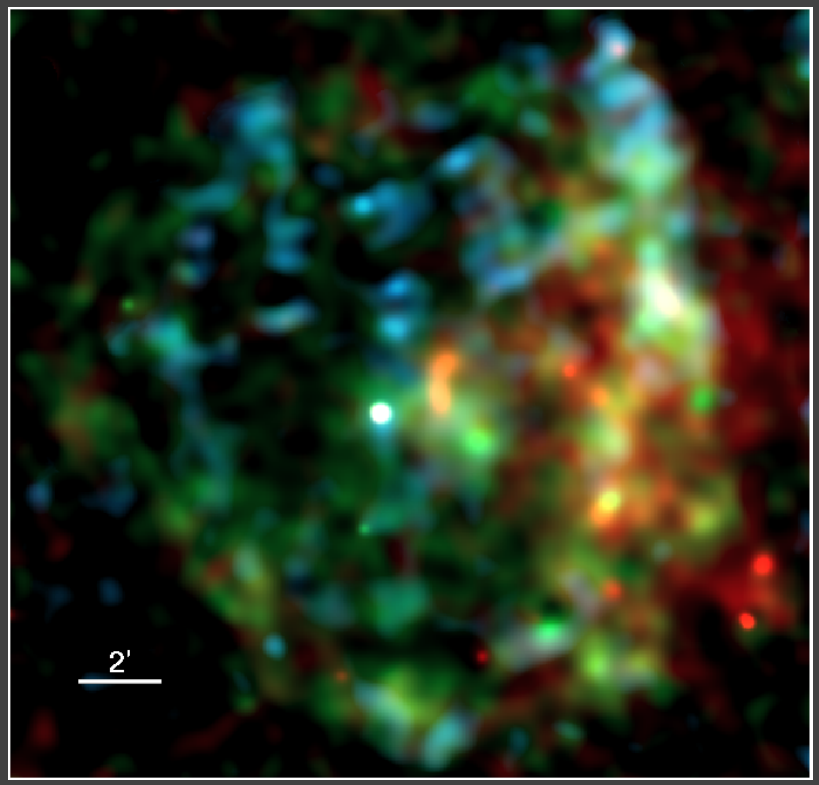
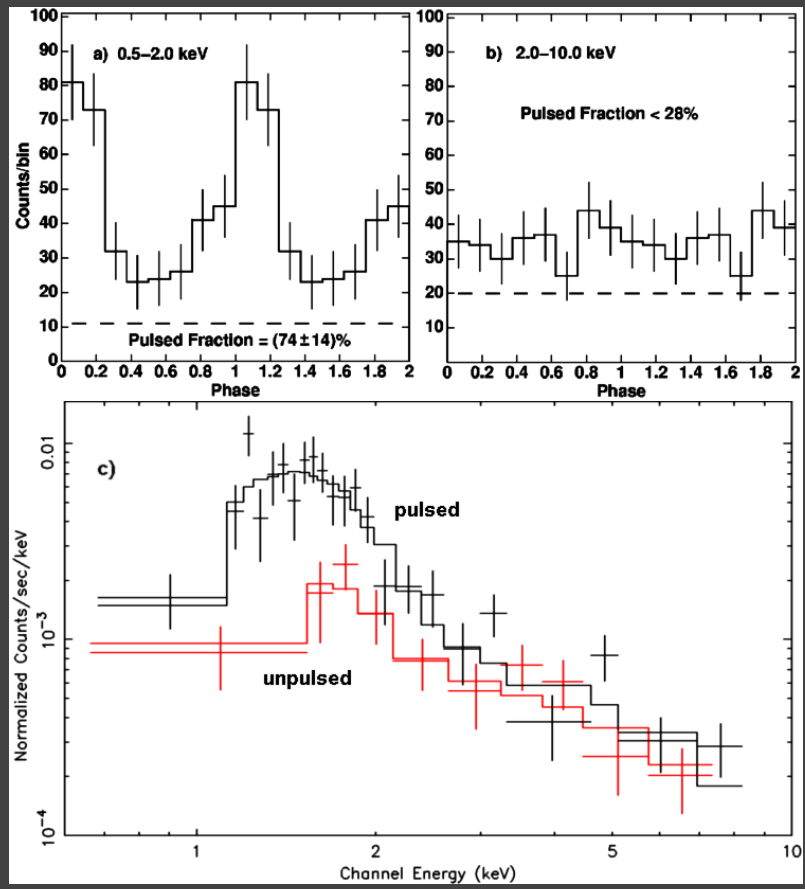
Sample 3: PSR J1119-6127 in G292.2-0.5

P=407 ms; τ=1.6 ky; B_s=4.1x10^{13} Gauss; n=2.91(5)
(Camilo et al. 2000; Gonzalez et al. 2005)



M. Gonzalez et al. 2007



Very soft pulsar with no significant pulsed emission above 2 keV!

INTEGRAL offering:

Good timing

Good imaging

Very long exposures

=> Unique for studying radiopulsars at hard X-rays / soft γ-rays

Give us 5 more years!!

Thank you for your attention!