High time resolution spectroscopy with XMM-Newton and XEUS

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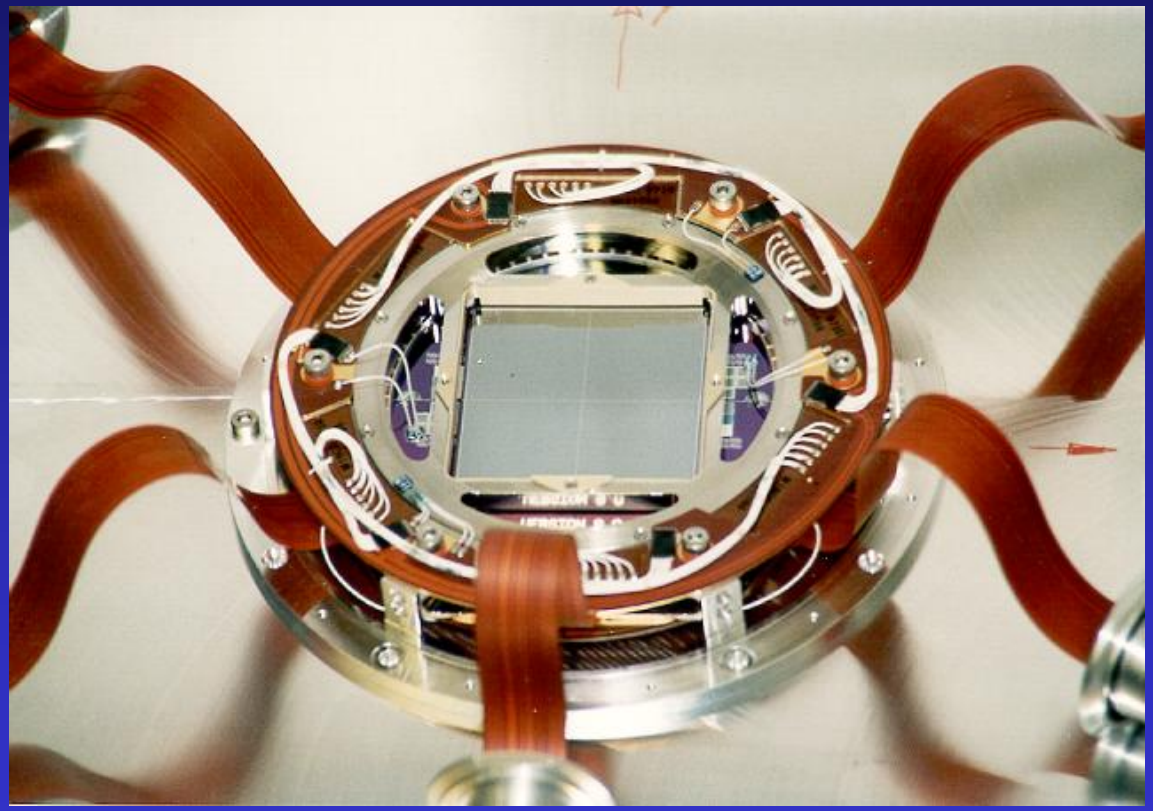
On behalf of E. Kendziorra

Outline

- Introduction
- High time resolution observations with XMM-Newton
  - pn-CCD camera
  - results from XTE J1751-305
  - results from Crab
- What can we expect from the Wide Field Imager on XEUS?

The EPIC-pn focal plane

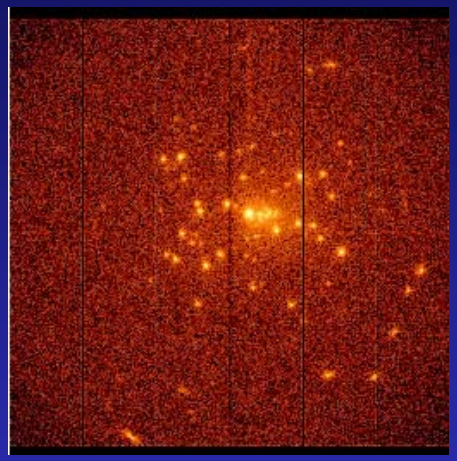


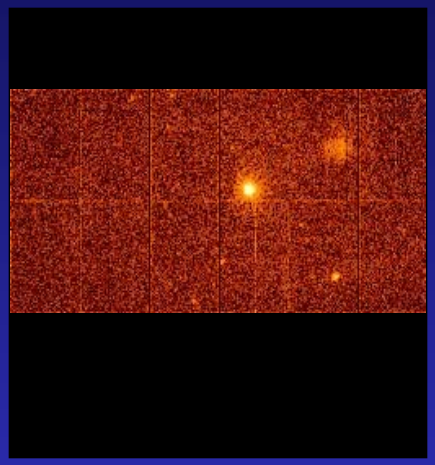
12 CCDs

- 280 μm Si
- 12 x 64 x 200 pixel
- pixel size: 150 x 150 μm^2
- pixel f.o.v.: 4.1” x 4.1”
- read out freq.:
  - 13.7 Hz (FF)
  - 175.4 Hz (SW)

pn-CCD: increase of time resolution by reduction of read out area

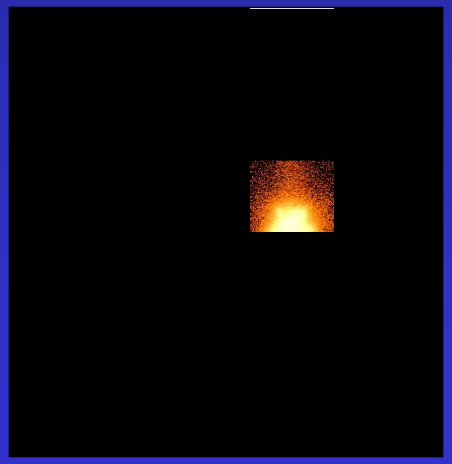
Full Frame & extended Full Frame





Large Window

Small Window

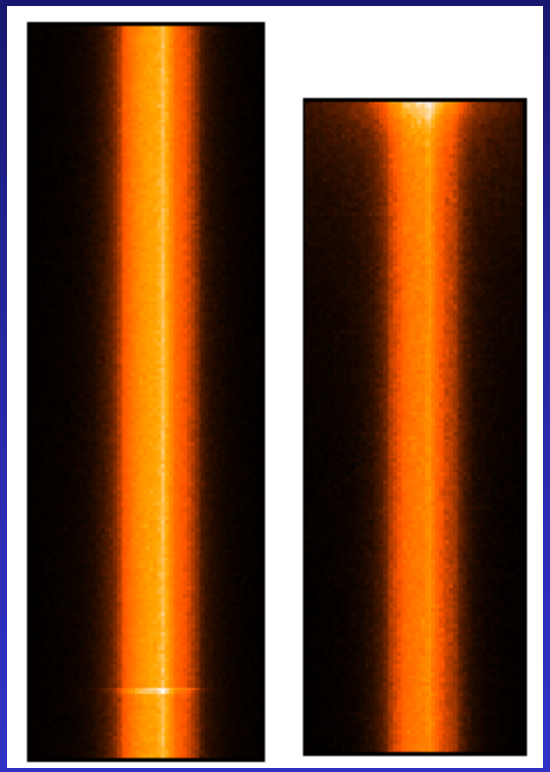


time resolution	
ext. FF:	199.0 ms
FF:	73.3 ms
LW:	47.6 ms
SW:	5.7 ms

Fast read out modes of the pn-camera

Timing mode

- CCD continuously read out
- macro pixels 150 x 1500 μm^2
- read out/row: 29.56 μs
- frame time: 5.965 ms
- time resolution: $\pm$ 30 μs



Burst Mode

- fast transfer of pixels under PSF
- photons recorded during 144 μs
- read out at normal speed (23 μs/row)
- life time only 3 %
- time resolution: $\pm$ 10.24 μs

XTE J1751-305

- accretion driven millisecond pulsar in binary system
  - P_{orb} = 2545.3 s (42 min)
  - P_{NS} = 2.297.. ms (f_{NS} = 435 Hz)

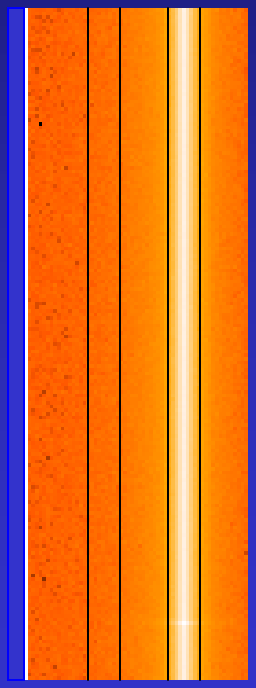
- mass function = 1.26 10^{-6} $M_\odot$
  $\rightarrow$ mass of compagnion $\geq$ 0.014 $M_\odot$

XTE J1751-305

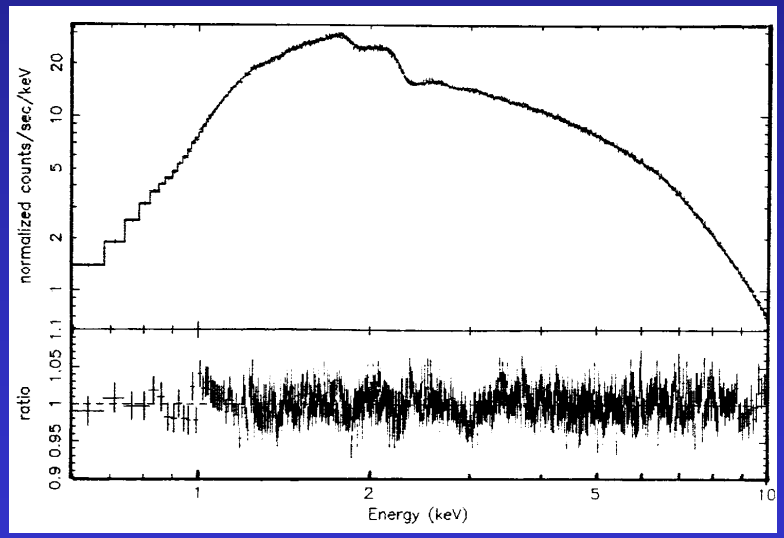
- ToO observation of XMM-Newton on 2002 April 7
  - pn in Timing mode for 33.7 ks

Source from columns 42 to 50

Bkg. from columns 24 to 32

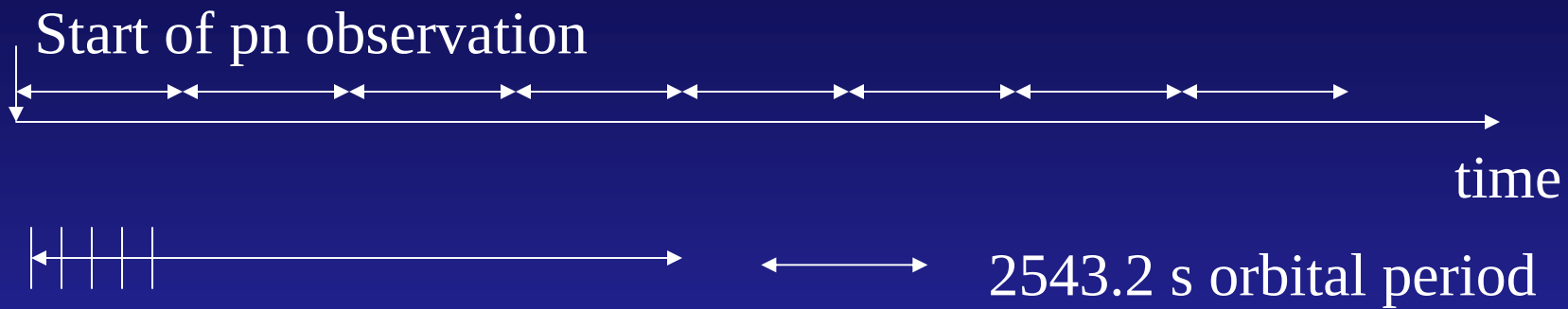


1 - 10 keV



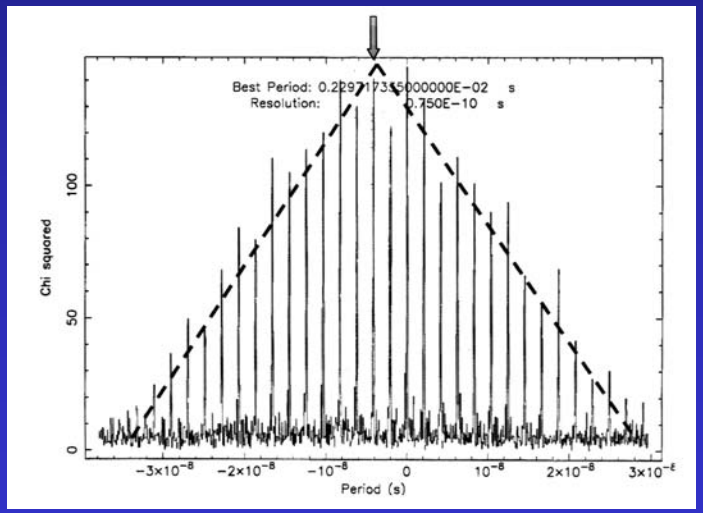
Spectrum:
PL + BB
kT=1.05±0.01 keV
Γ =1.44 ±0.01
χ^2_{red}=1.1

XTE J1751-305

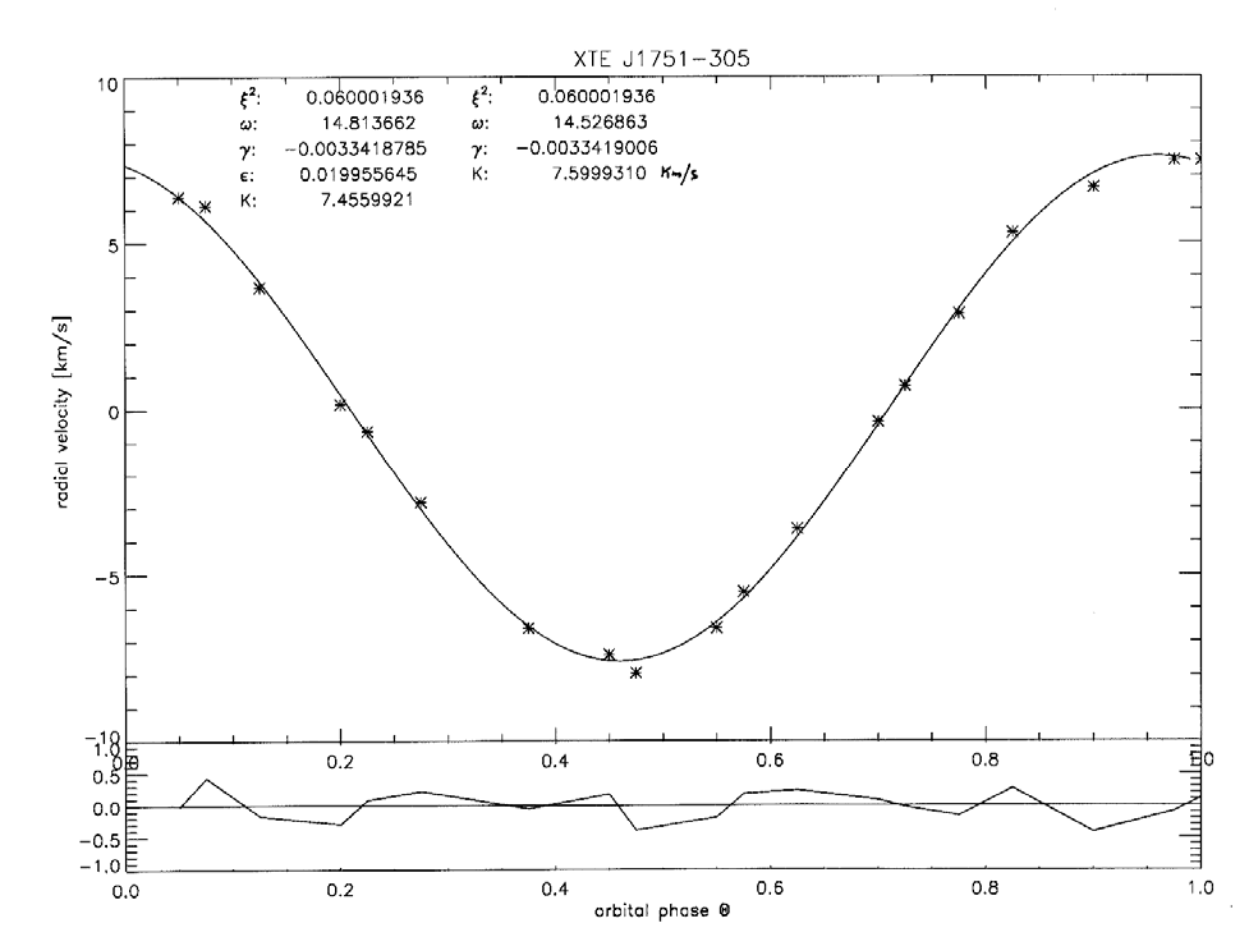


- Orbital period devided into 20 phase bins
- events from same phase bins collected in individual data sets
- for each data set period search χ^2 epoch folding

$\Rightarrow$ aparent period

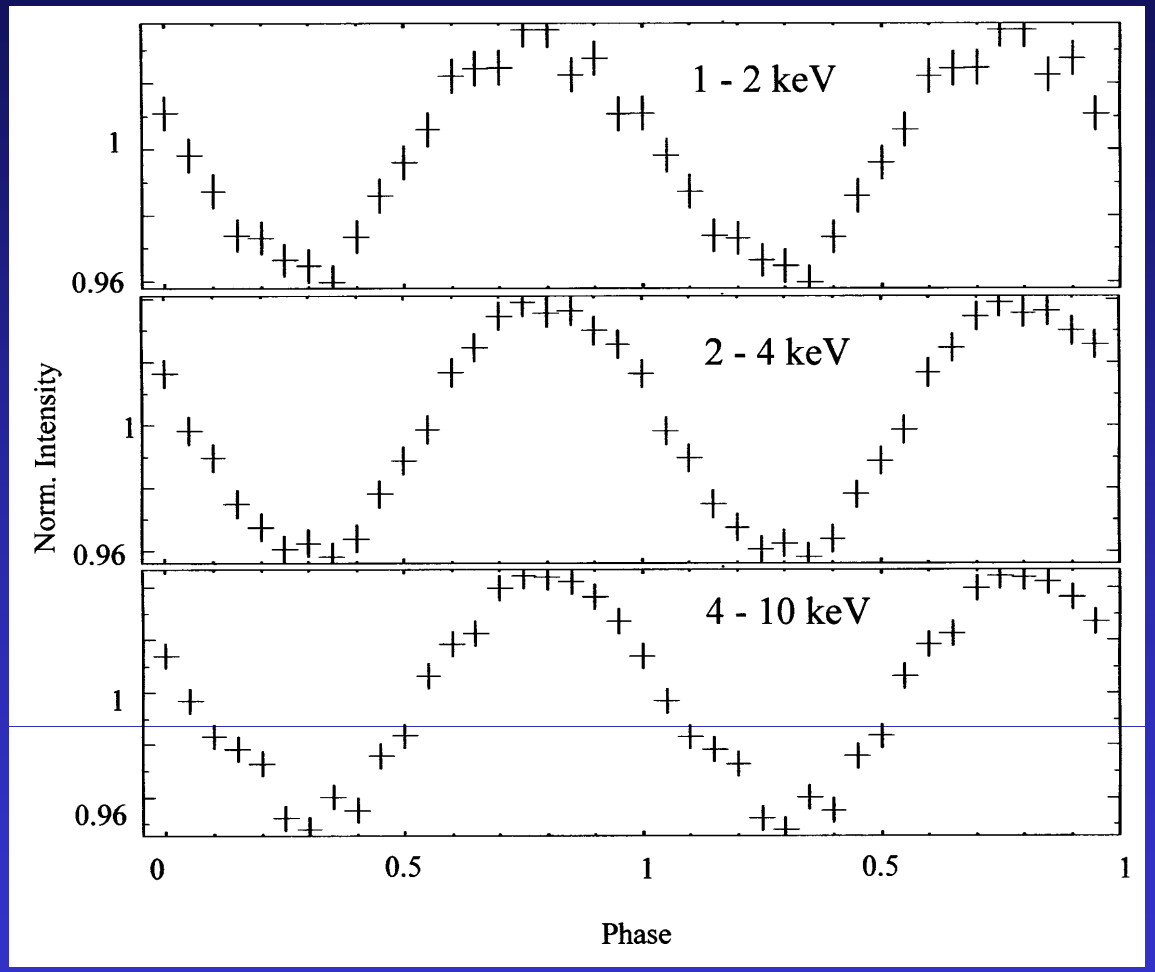


XTE J1751-305



XTE J1751-305

P = 2.29717211 ms

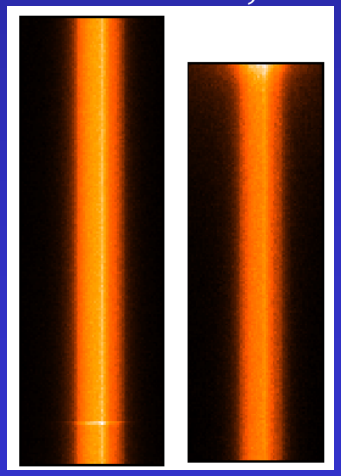


Observation of Crab pulsar with EPIC-pn

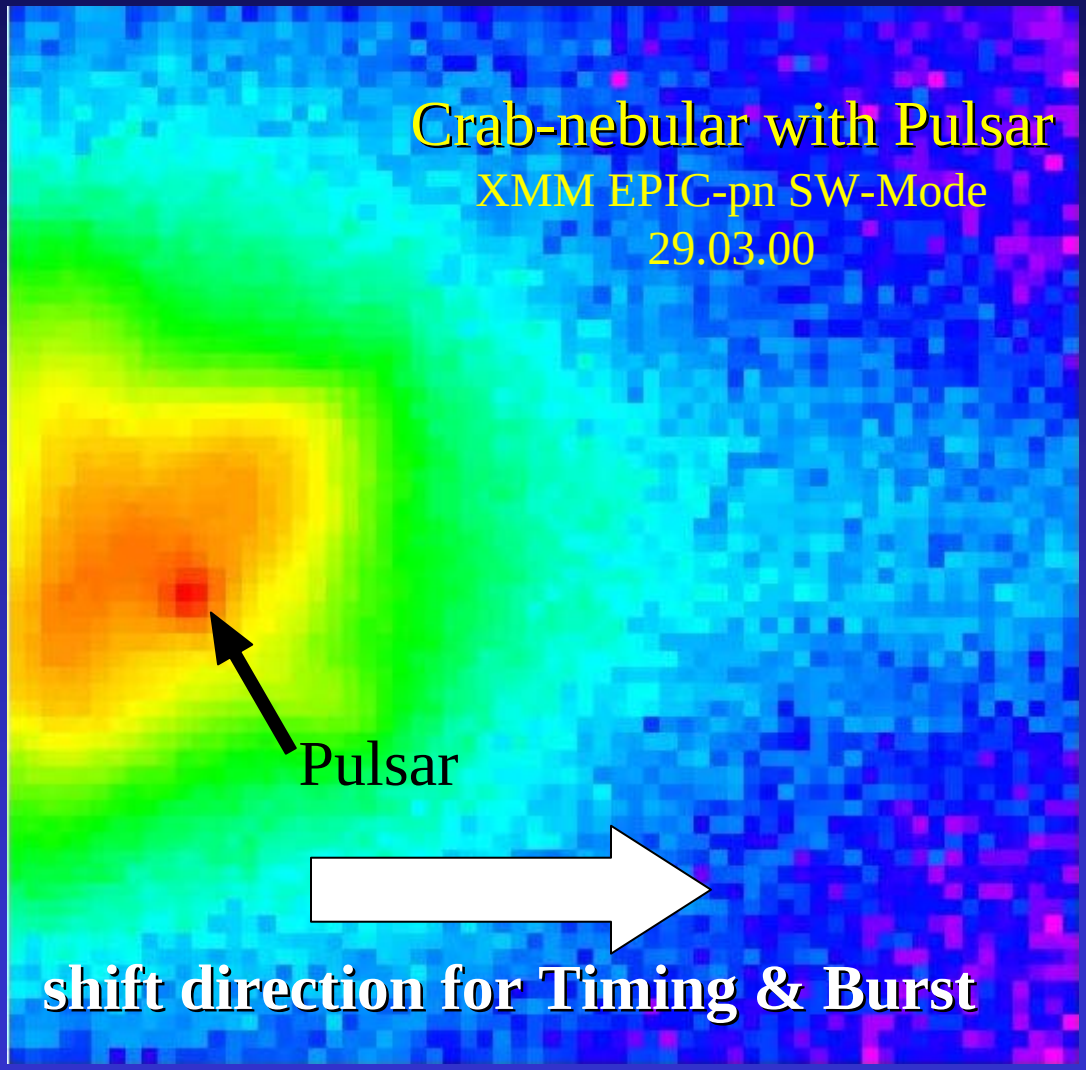
4 observations of Crab during rev. 411

Obs. ID.	201	301	401	501
Duration	4.6 ks	8.6 ks	9 ks	9 ks
Mode	Burst	Burst	Timing	Burst

401 201, 301,501



The Crab with EPIC-pn



Observation of Crab pulsar with EPIC-pn

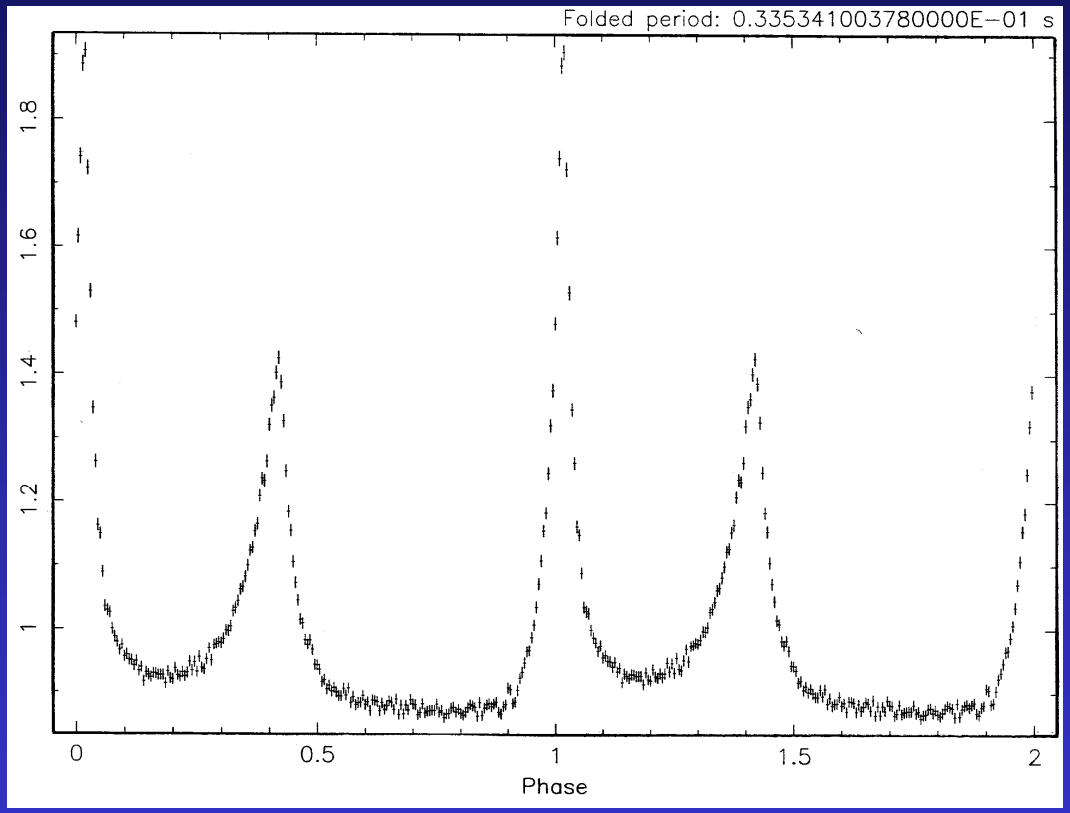
Period search with χ^2 epoch folding, dP/dt from Radio data

Same period for individual observations

$$P_{XMM} - P_{radio} < 2.5\ 10^{-10}\ s$$

(within stat. uncertainty for 9 ks obs.)

Observation of Crab pulsar with EPIC-pn



0.5 - 10 keV

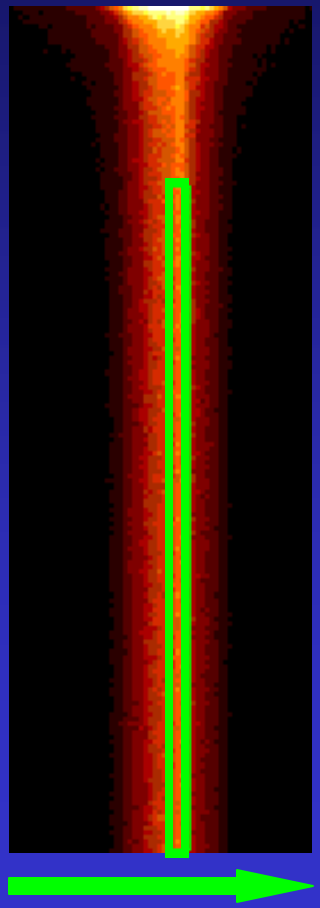
All data folded with Radio period

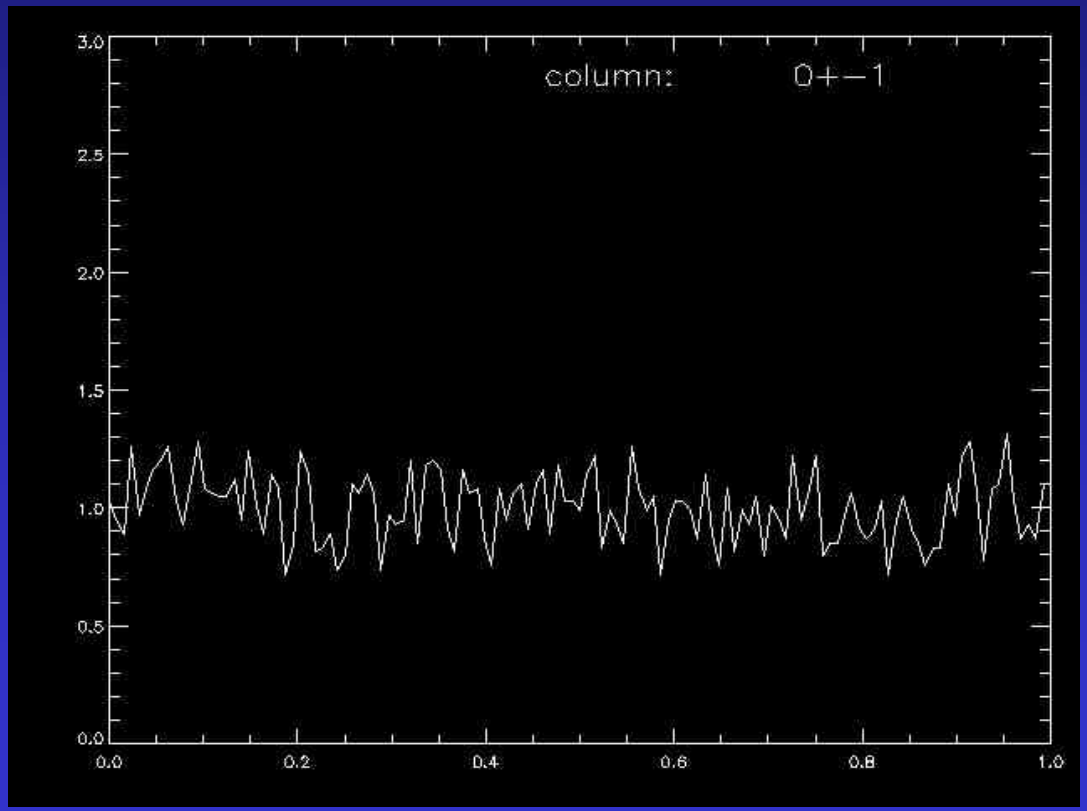
- Phaseshift between observations < 190 μs
- Time basis = 30.7 h

⇒ **Relat. time error with EPIC-pn < 10^{-9}**

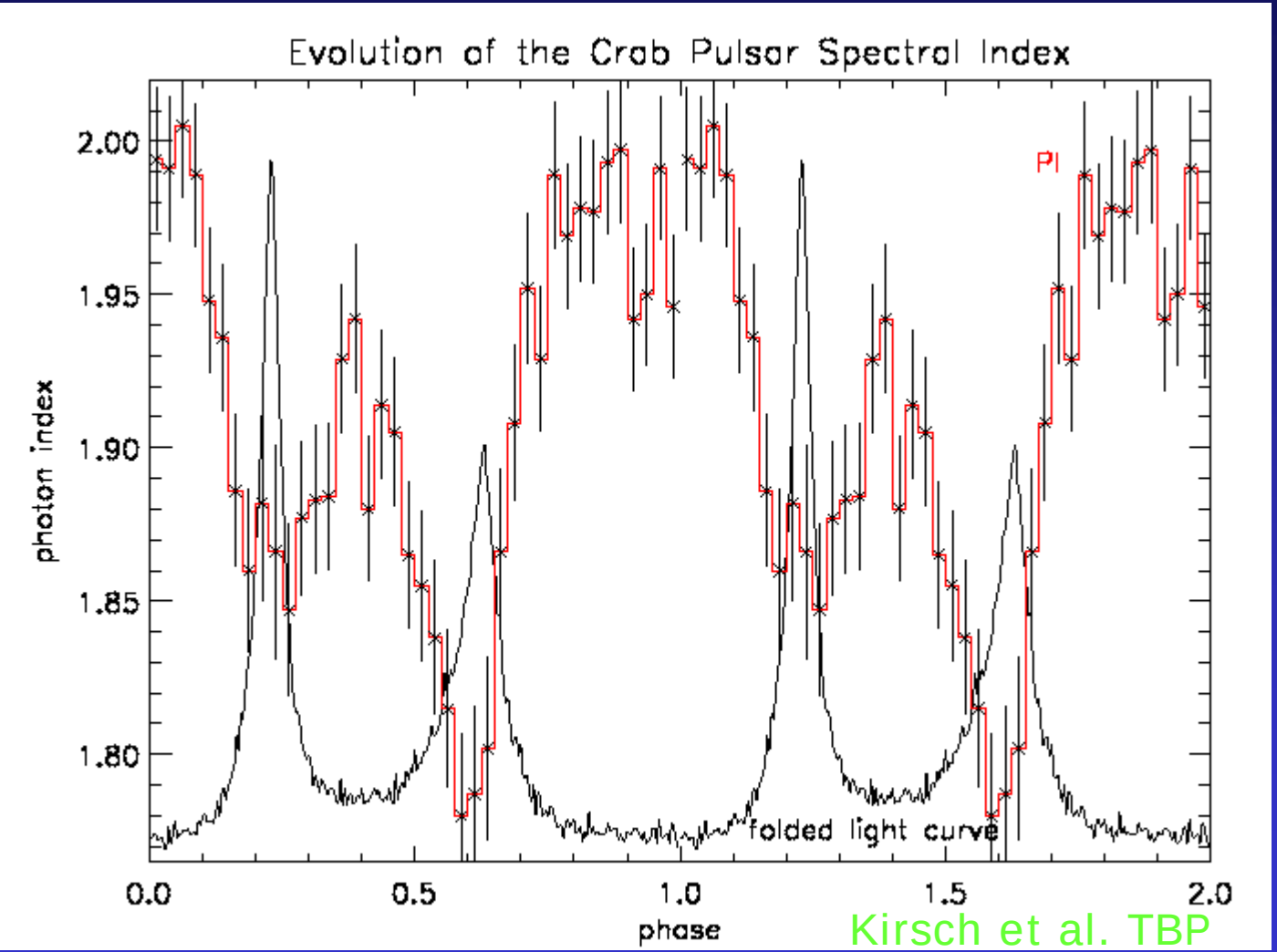
Observation of Crab pulsar with EPIC-pn

- localization of pulsar:
  running window in x direction and folding
  shows: pulsar is located in raw 36±2.5





Phase resolved spectroscopy of the Crab Pulsar



Kirsch et al. TBP

The XEUS Mission

XEUS

- focal length: 50 m
- effective area: ~20 x XMM-Newton (I)
  (6 m^2 at 1 keV, 3 m^2 at 8 keV)
- plate scale: 0.25 mm/arcsec

model payload

2 Narrow Field imager (cyrogenic)

f.o.v: 1 arc min

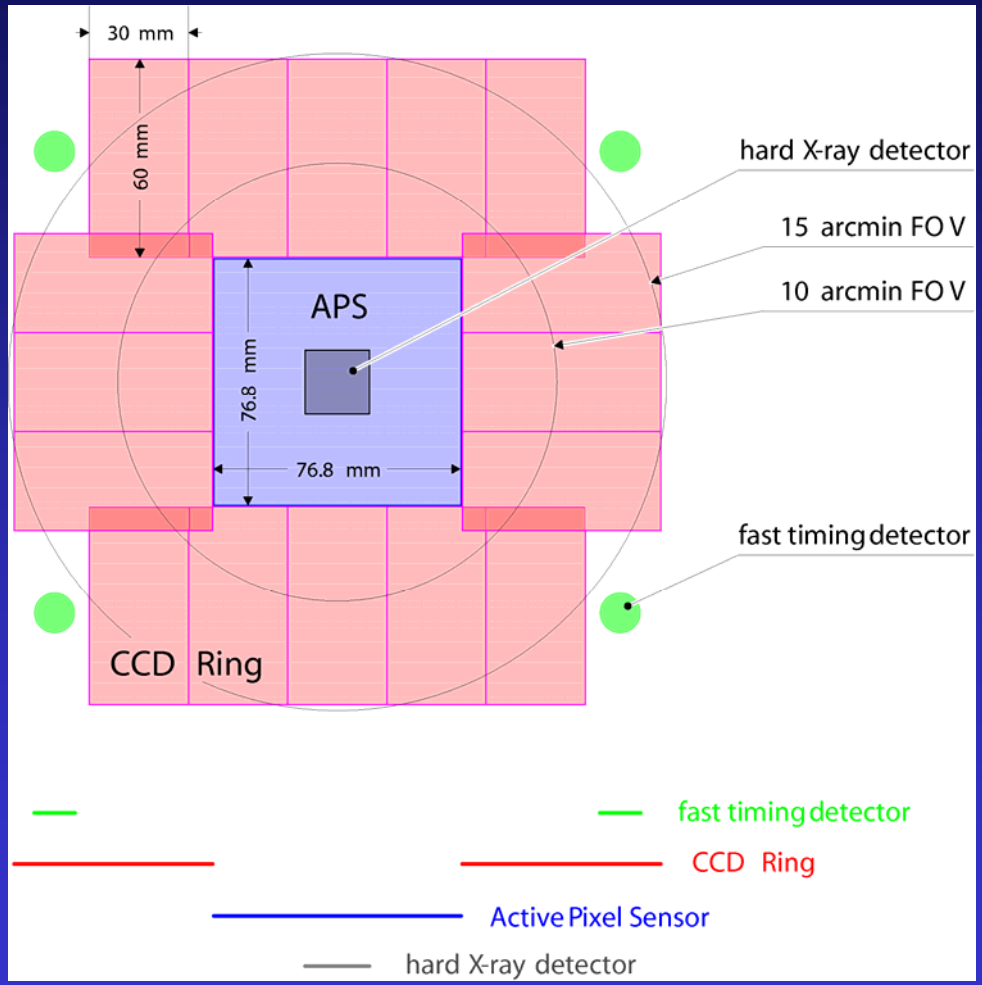
ΔE at 1 keV: 1-2 eV

1 Wide Field imager

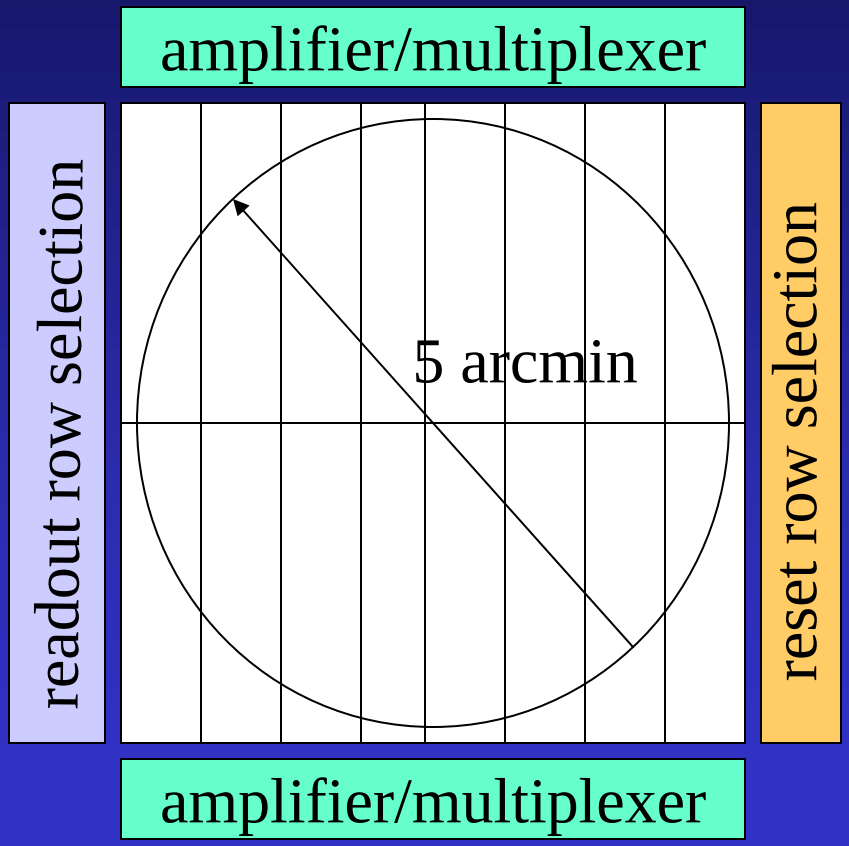
f.o.v.: >5 arc min

ΔE at 1 keV: 50 eV

The Wide Field Imager (WFI)



Readout of the Active Pixel Sensor (APS)

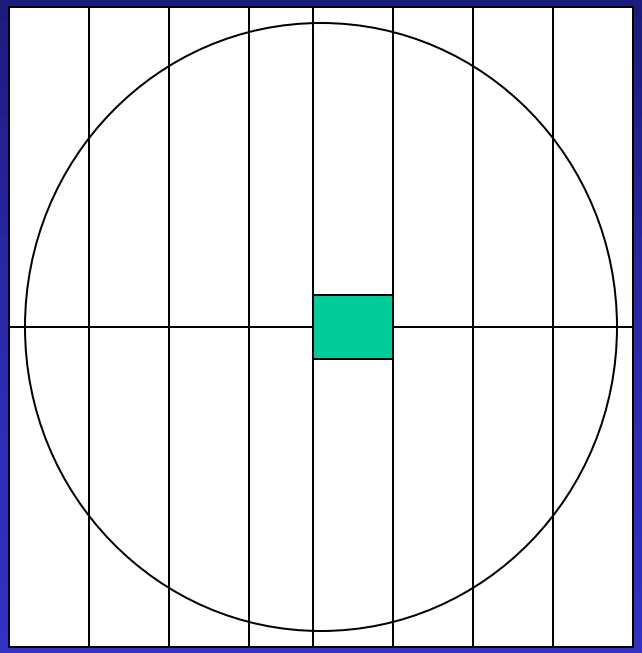


1024 x 1024 pixel
76.8 x 76.8 mm^2
(0."3 x 0."3 pixel f.o.v)

- 16 independent readout channels
- 2.5 μs readout/row (128 pixel/row)

⇒ 1.28 ms / detector

APS Window Modes



for bright point source
only a small window is read

two windows modes:

20 x 128 pixel ⇒ 25 μs
(*60 x 128 pixel ⇒ 75 μs*) §
128 x 128 pixel ⇒ 160 μs

§depending on mirror PSF
(HEW: 2 arcsec or 6 arcsec)

Pile-up

Pile-up: > 1 event/pixel during integration time (pixel pile-up)
pattern from different events in direct contact (pattern pile-up)

Pile-up probability scales with :

- integration time
- pattern size
- pixel size
- 1 / mirror HEW

expected pile-up limit for XEUS APS

pile-up limit for EPIC-pn: 1 event/frame

	pn-CCD	APS on XEUS (2 arcsec HEW)
# pixel under HEW :	11	35
average # pixel/photon :	1.5	2.3
pile-up limit in ph/frame:	**1**	2
pile-up limit for FF:	14 ph/s	1.6 $\cdot 10^3$ ph/s
pile-up limit for SW (20x128):		80 $\cdot 10^3$ ph/s

From Crab we expect 250 $\cdot 10^3$ ph/s for XEUS 1

→ Fast timing channel is need for observation of very bright sources

Conclusion

- APS on XEUS will offer 25 μs time resolution
  at full spatial resolution
- background should be much smaller as compared to
  fast readout modes of pn-CCD
- APS ideal instrument for observation of faint (background limited)
  millisecond pulsars outside our Galaxy