Recent Results from XMM and Chandra observations of Neutron Stars

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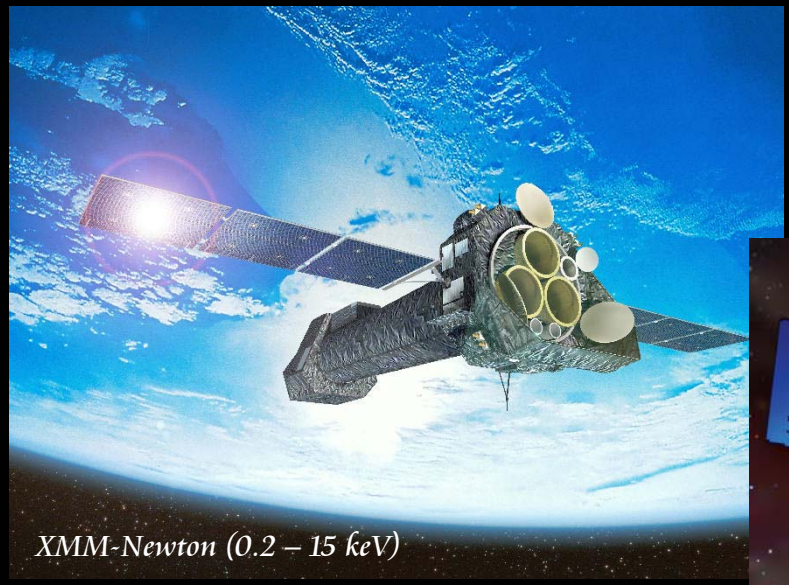
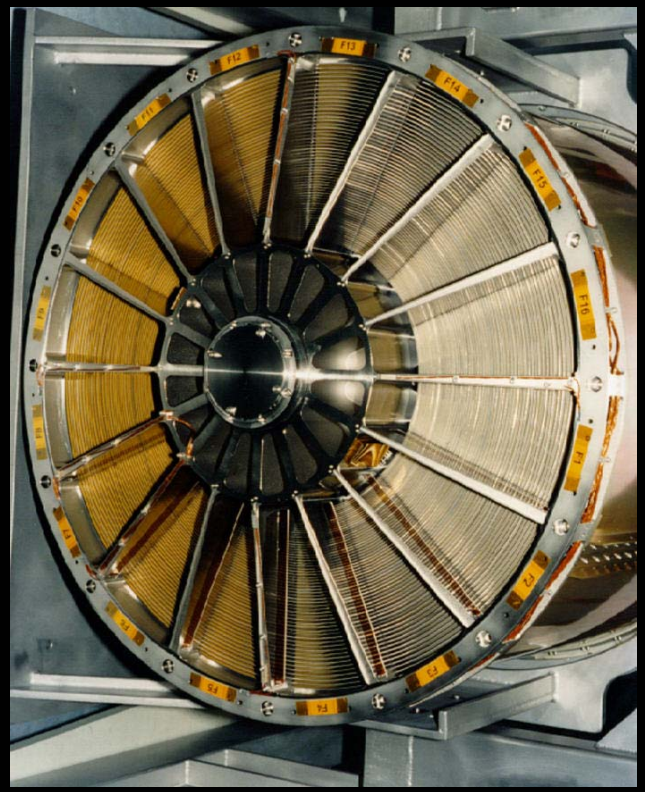


Collecting power of recent X-ray Missions

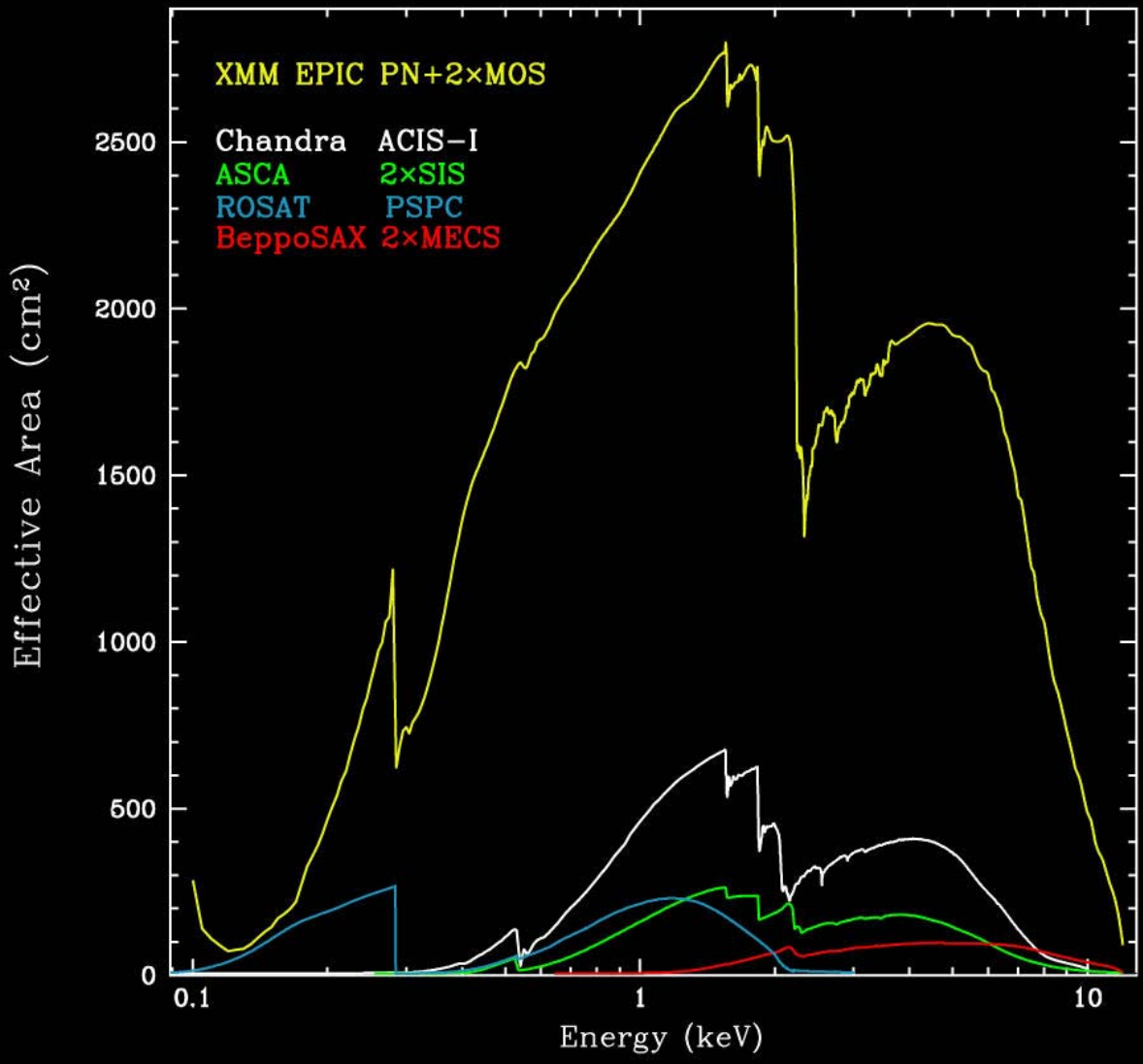
Chandra X-ray mirrors

XMM X-ray mirrors



Aschenbach & Bräuninger et al. 2000

Collecting power of recent X-ray Missions



XMM timing modes and clock stability

EPIC PN Mode	Image size / pixel	FOV / arcmin	Temporal resolution
Small window	2D - 64 × 64	4.4′ × 4.4′	5.67 ms
Fast-timing	1D - 64 × 199	4.4′ × 13.75′	0.02956 ms
Burst	1D - 64 × 199	4.4′ × 13.75′	0.0072 ms

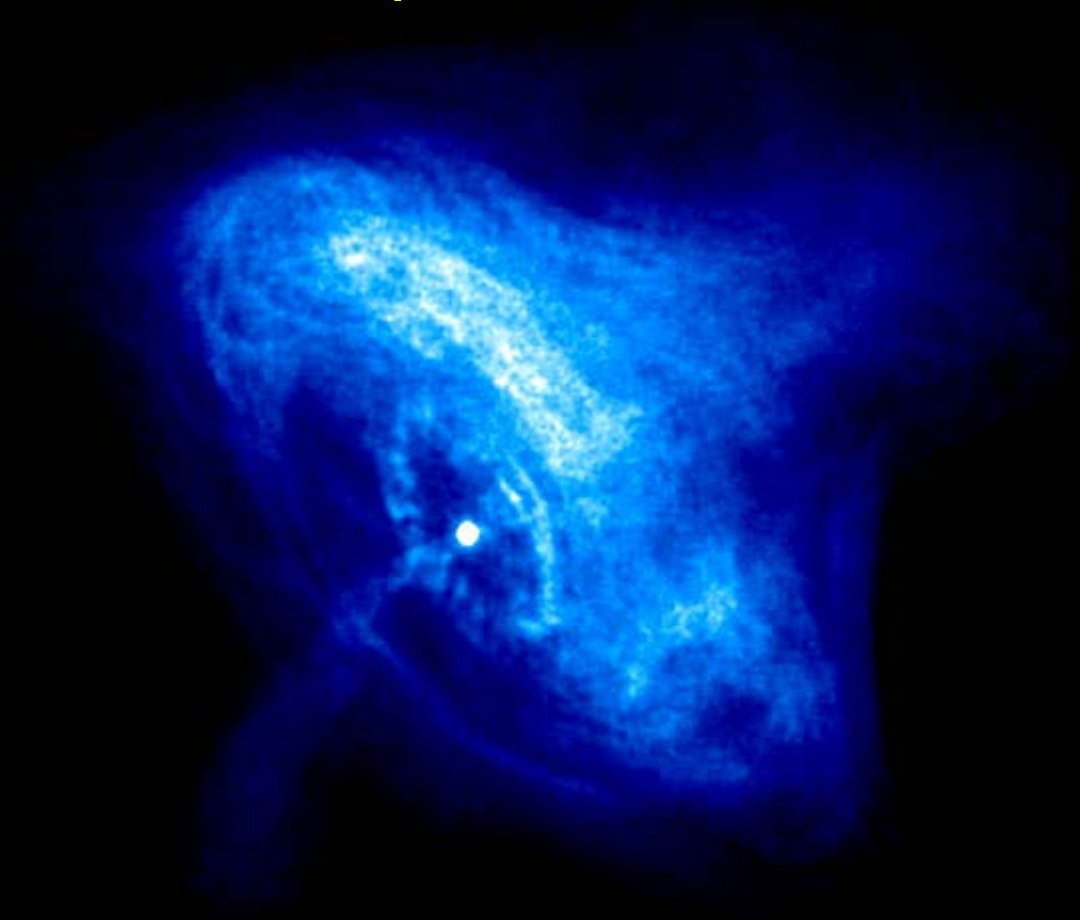
EPIC MOS Mode	Image size / pixel	FOV / arcmin	Temporal resolution
part. window1	2D - 100 x 100	1.8' x 1.8'	200 ms
part. window2	2D - 300 x 300	5.5' x 5.5'	700 ms
timing	1D - user defined pixel area		≥ 1.5 ms

EPIC PN-CCD

XMM timing accuracy and clock stability

- Crab observations in March 2000, 2001, 2002 in timing and burst mode
- Pulsar period matches to better than 2.5 x 10^{-10} s with the radio period
- Crab pulse observed by XMM leads the radio pulse by 0.047 in phase
- Clock accuracy against UTC differes by 1.27 – 1.57 ms (mod Crab Period)

The Crab as observed by Chandra:



Hester et al. 2001

Young Pulsars accepted for observations by XMM-Newton during AO1/2

Young Pulsars	Status	Instrument	Exposure
PSR B0531+21	obs	EPIC PN/MOS	CAL
PSR 0540-69	obs	EPIC PN/MOS	CAL
PSR 1509-58	obs	EPIC PN/MOS	20
PSR B0833-45	obs	EPIC RGS	90
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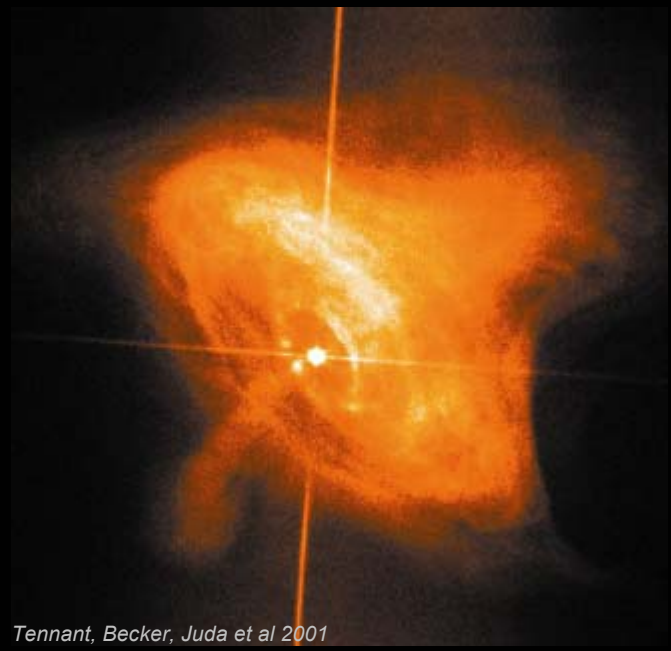

Tennant, Becker, Juda et al 2001

Photon index at various regions

Torus: 1.8 +- 0.006

Jet: 2.1 +- 0.013

Outer nebula: 2.34 +- 0.006

Pulsar: 1.63 +- 0.009

Becker & Aschenbach 2002, astro-ph/0208466

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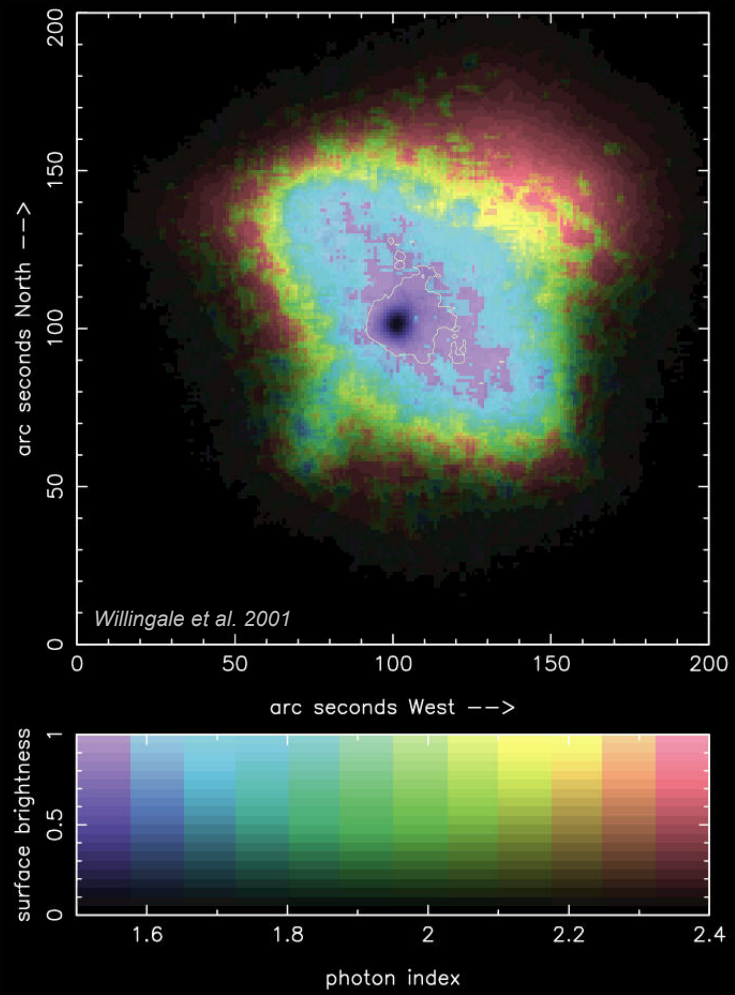

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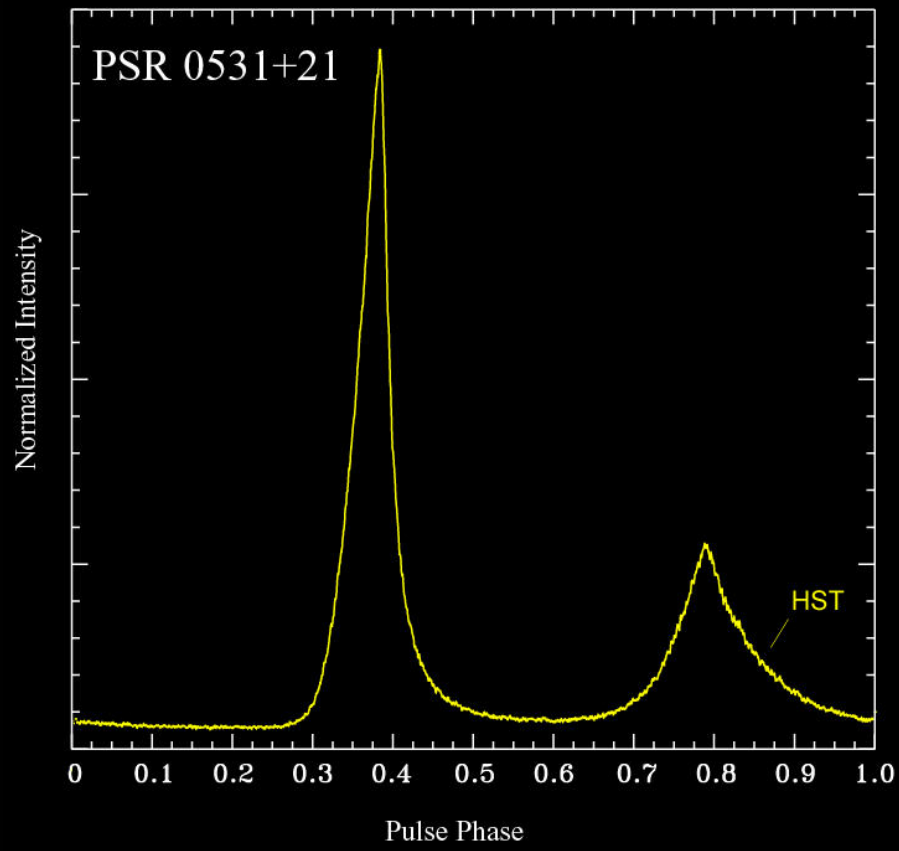

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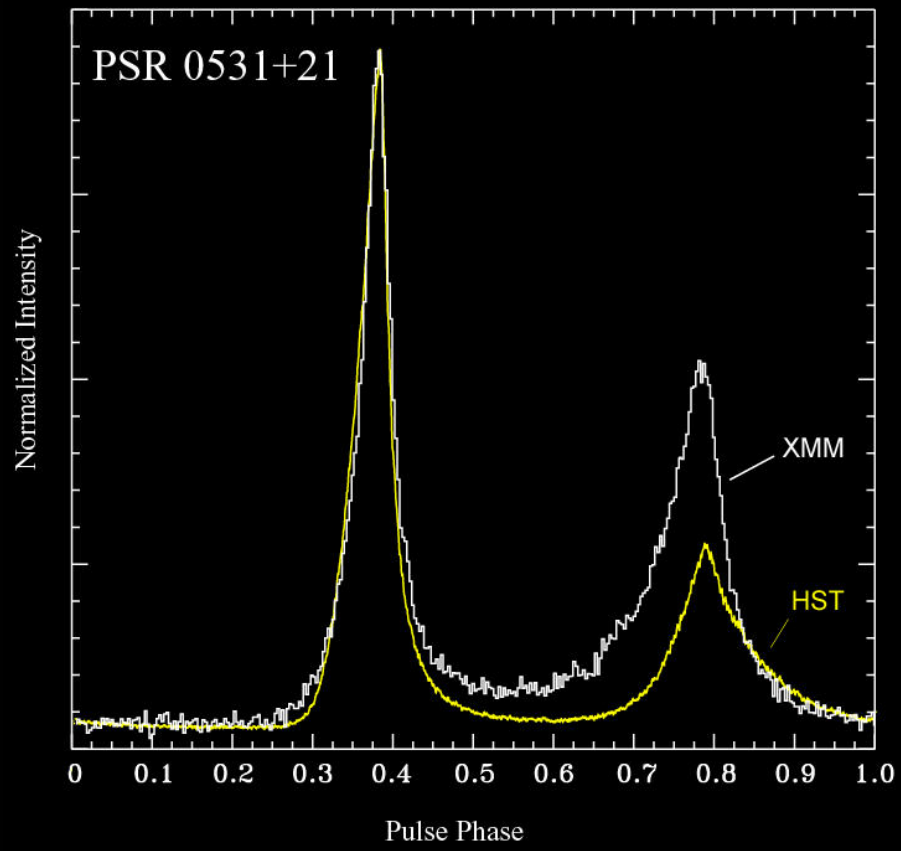

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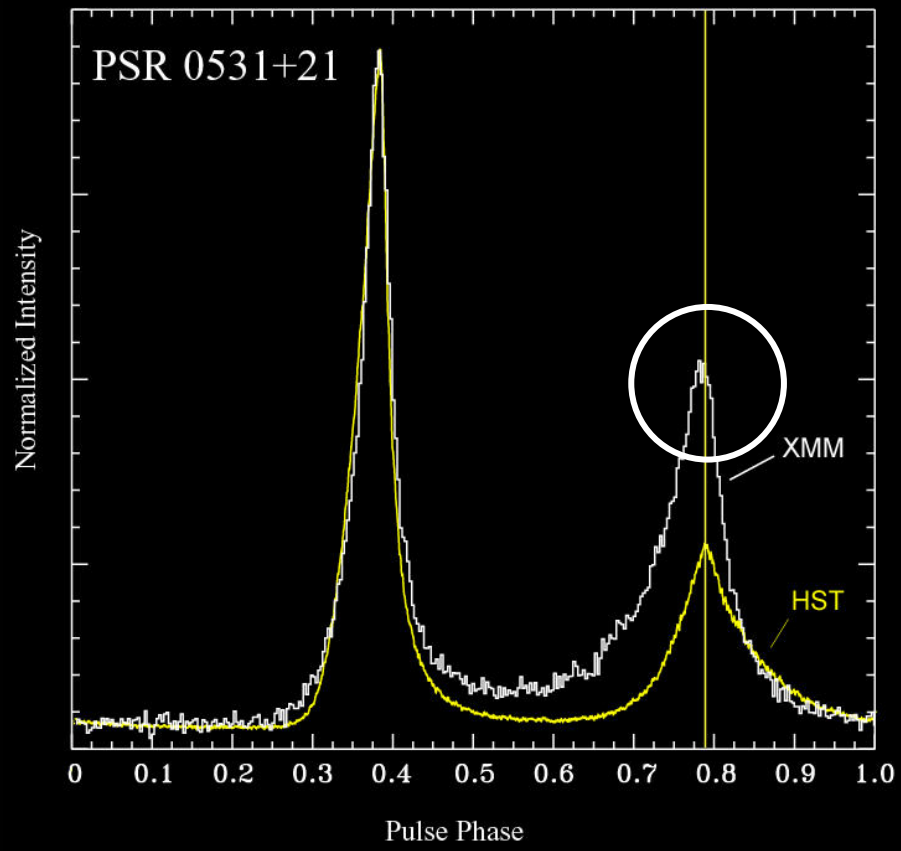

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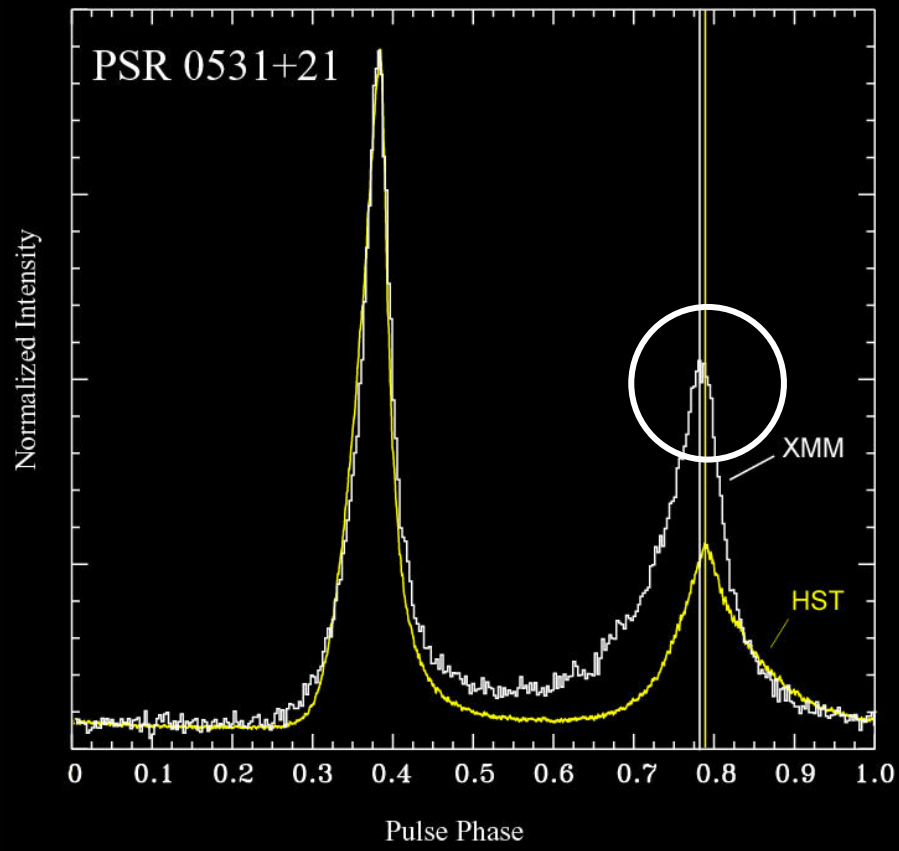

0.01 phase difference in pulse width

Is the first main pulse really in phase at optical and X-ray wavebands ?

Phase difference corresponds to a difference in the emission hights for X-ray and optical pulses of ~ 100 – 50 km

Contemporaneous observations with Chandra and OPTIMA scheduled for Sep. 2003

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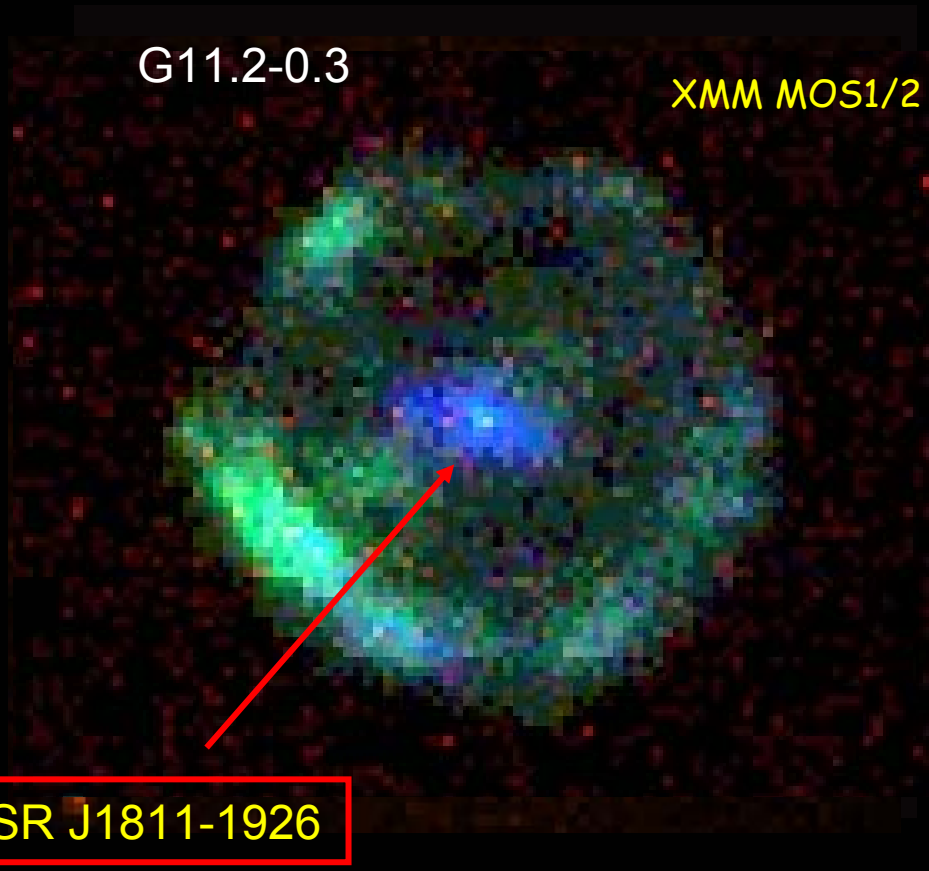
$P \sim 64\,\mathrm{ms}$

$\tau \sim 24000\ \mathrm{yrs}$

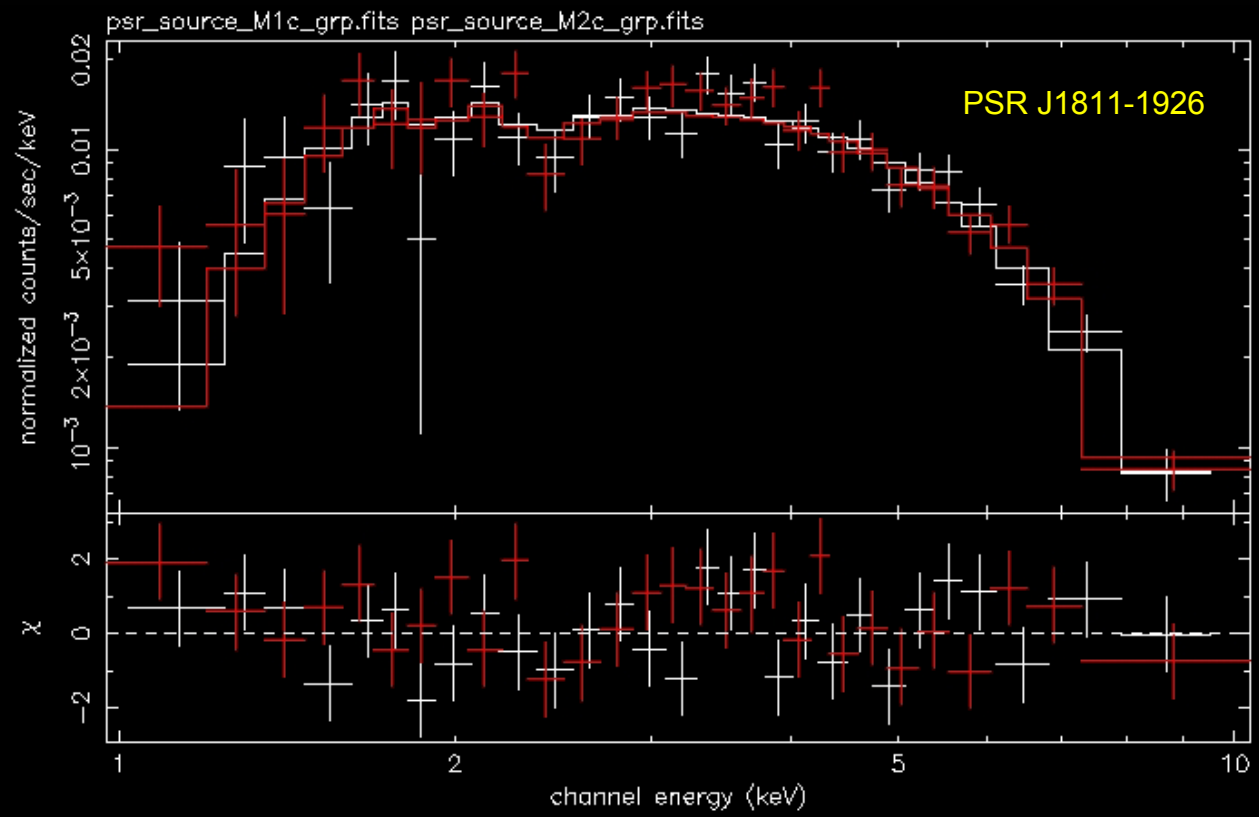
$d \geq 5\,\mathrm{kpc}$

$\log L_x \sim 36.8\ \mathrm{erg/s}$



Becker et al. 2003, in prep.

Young Pulsars accepted for observations by XMM-Newton during AO1/2



Pulsar Spectrum: non-thermal

$$f_x = 1.36^{+0.6}_{-0.35} \times 10^{-12} \text{ erg s}^{-1}\text{cm}^{-2}$$

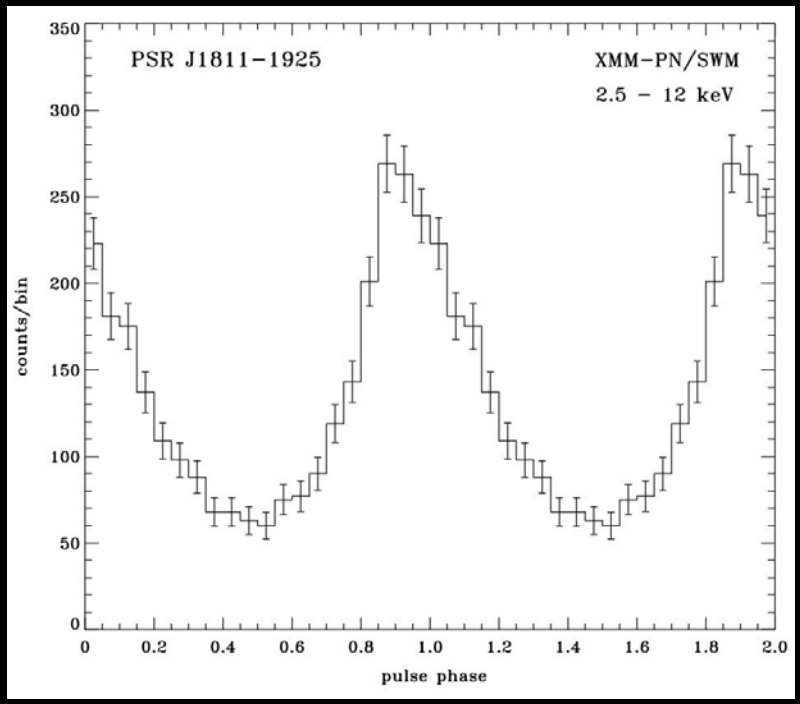
$$N_H = (1.857 - 2.735) \times 10^{22} \text{ cm}^{-2}$$

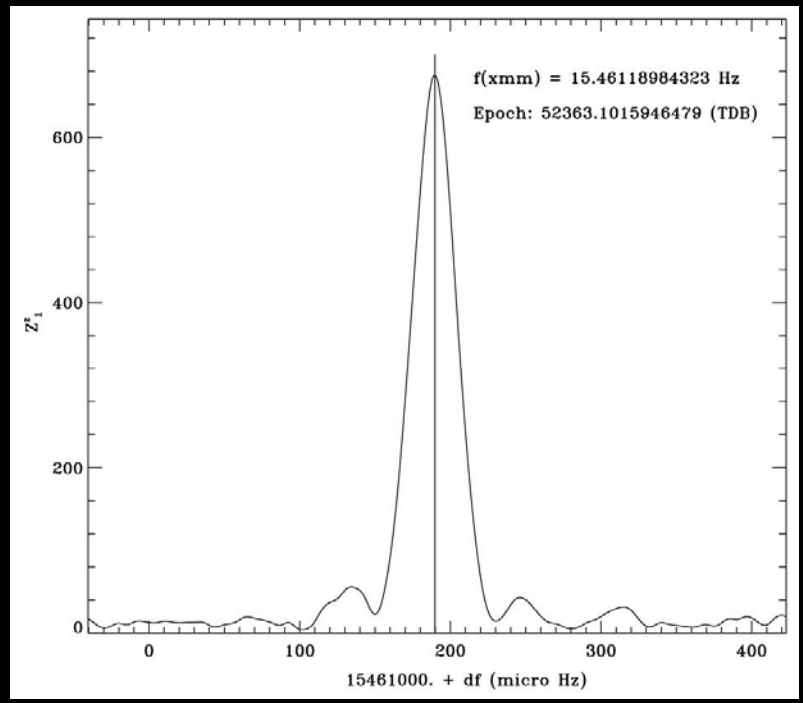
$$\alpha = 1.1 - 1.45$$

$$L_x (d = 5 \text{ kpc}) = 4.1 \times 10^{33} \text{ erg s}^{-1}$$

Becker et al. 2003, in prep.

Young Pulsars accepted for observations by XMM-Newton during AO1/2





- X-ray pulse single peaked, no strong energy dependence
- XMM data in agreement with no glitch inbetween the last BSAX and XMM observations

Becker et al. 2003, in prep.

Young Pulsars accepted for observations by XMM-Newton during AO1

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PSR B0531+21	obs	EPIC PN/MOS	CAL
PSR 0540-69	obs	EPIC PN/MOS	CAL
PSR 1509-58	obs	EPIC PN/MOS	20
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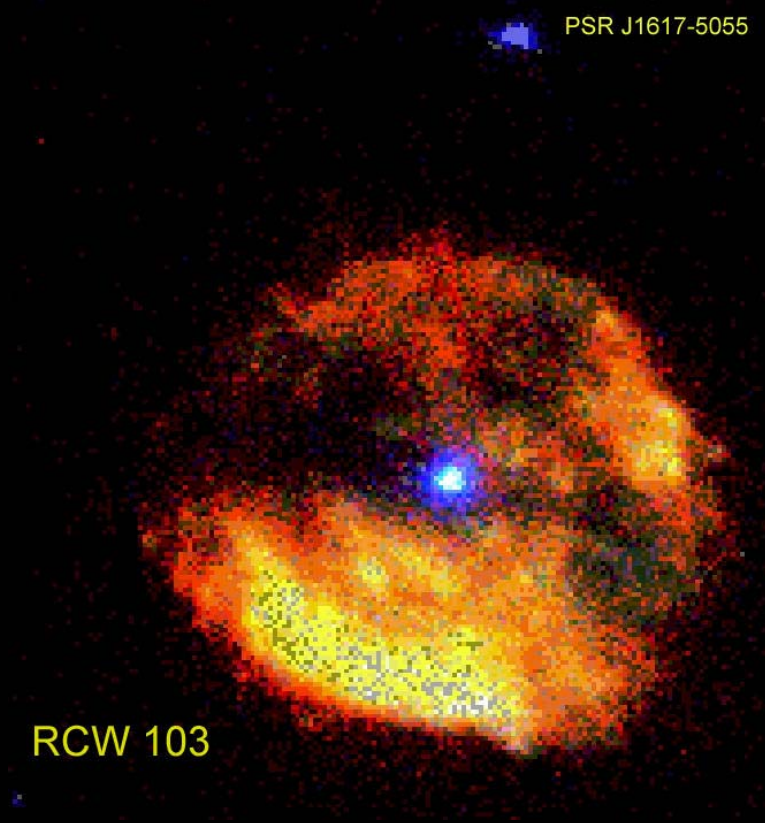
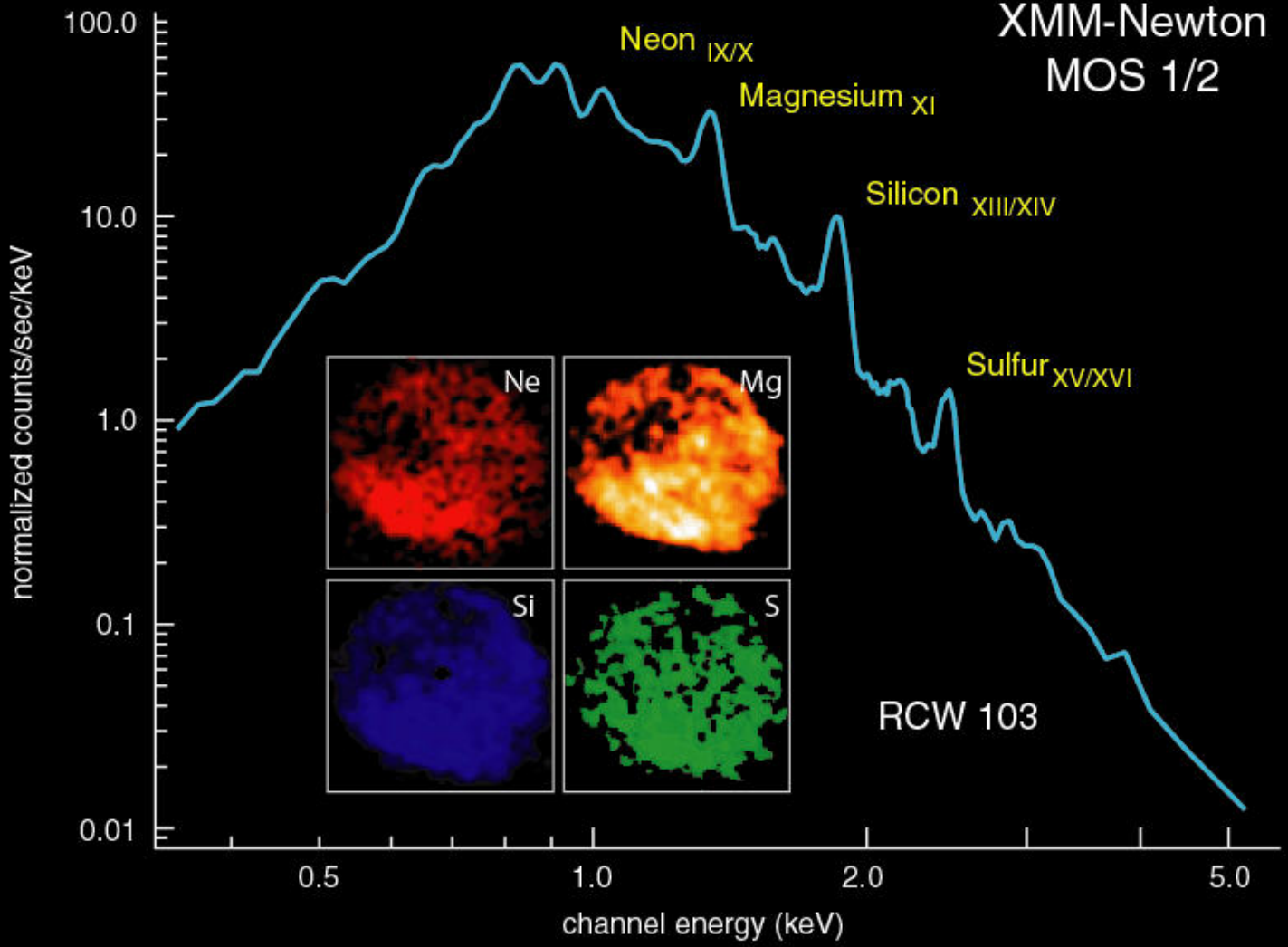


Becker & Aschenbach 2002, astro-ph/0208466



Schaudel, Becker & Aschenbach 2002

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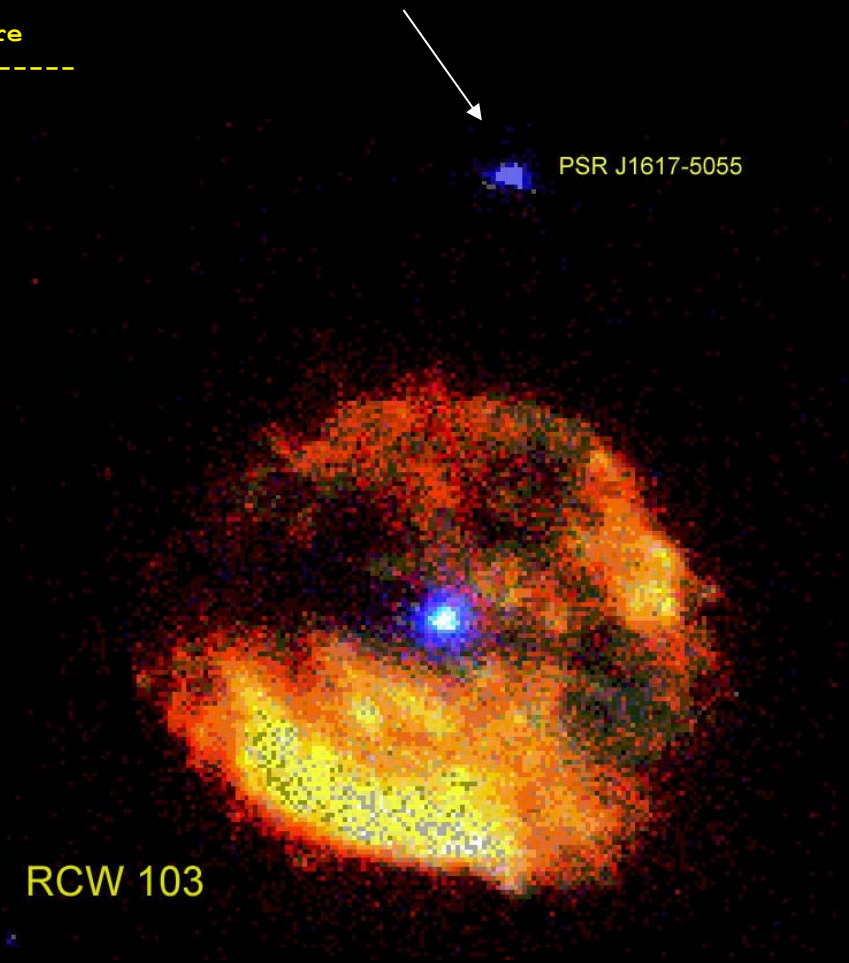

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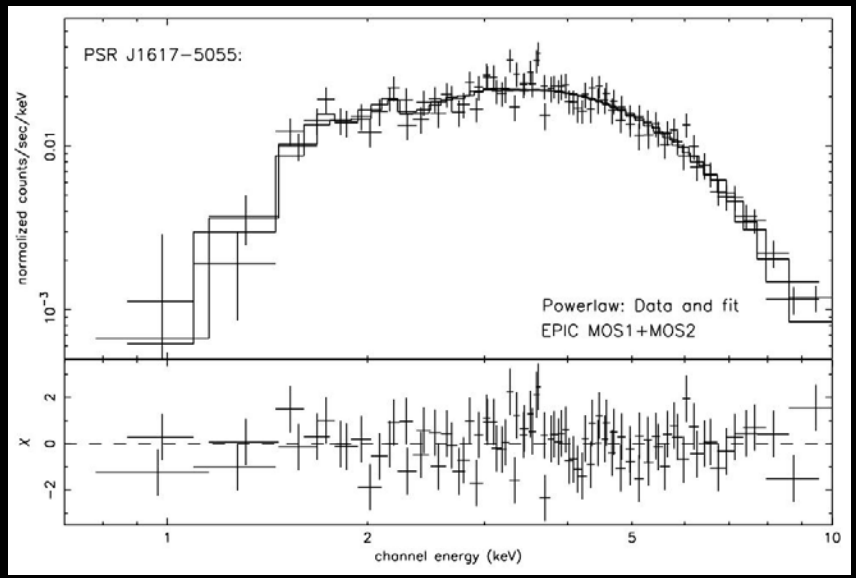
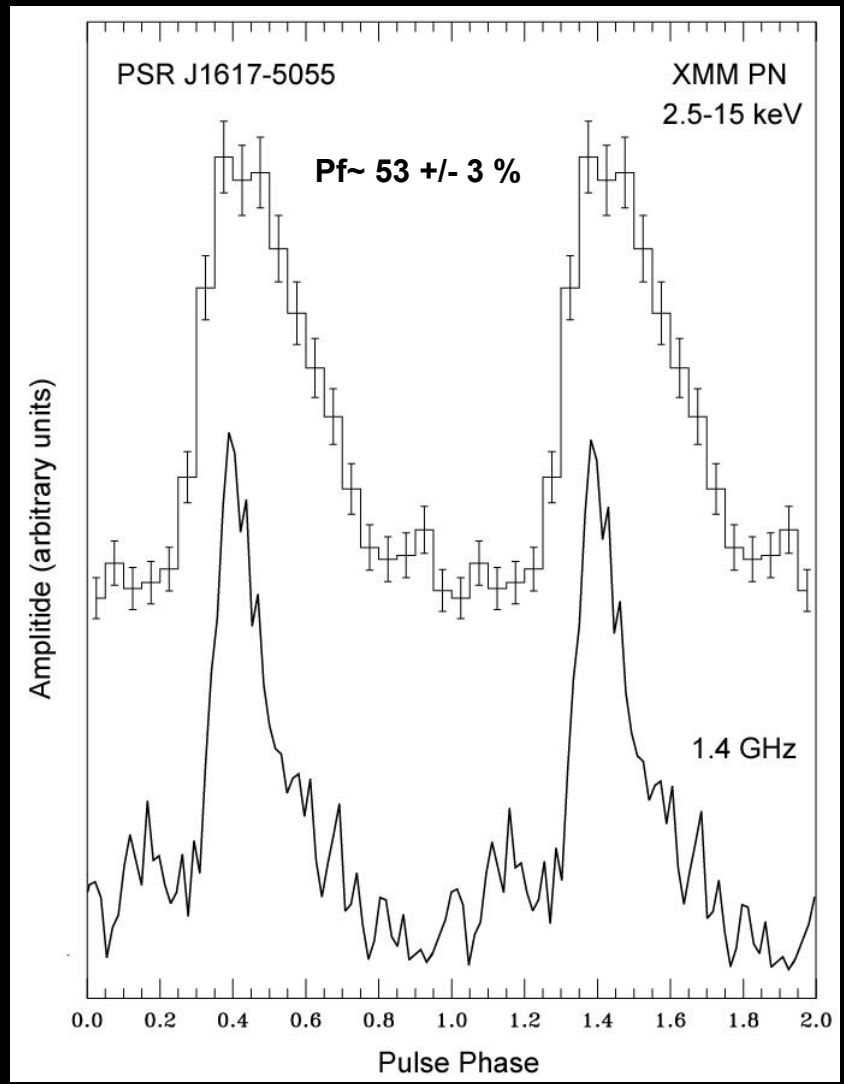
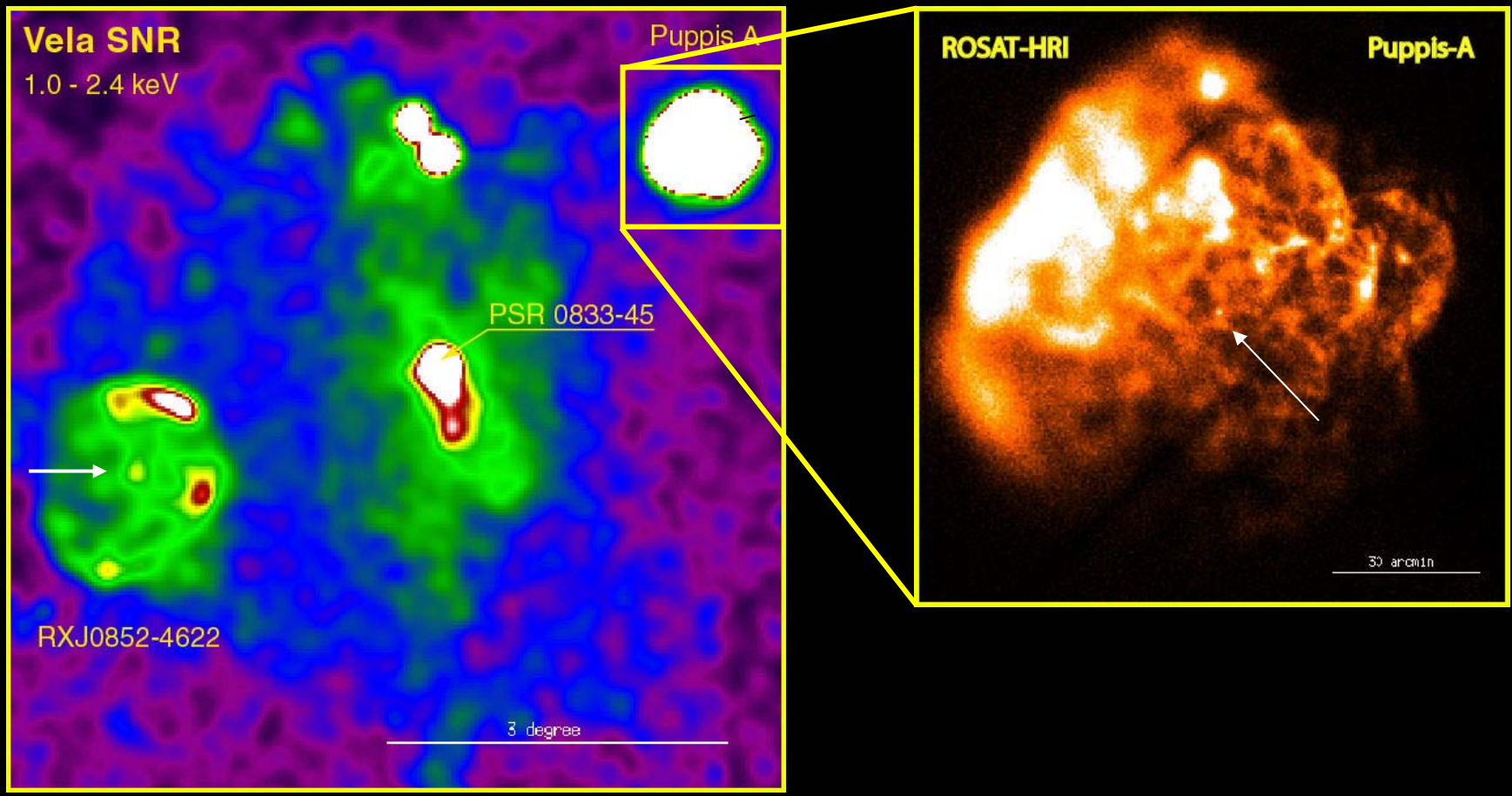




radio profile from Kaspi et al.

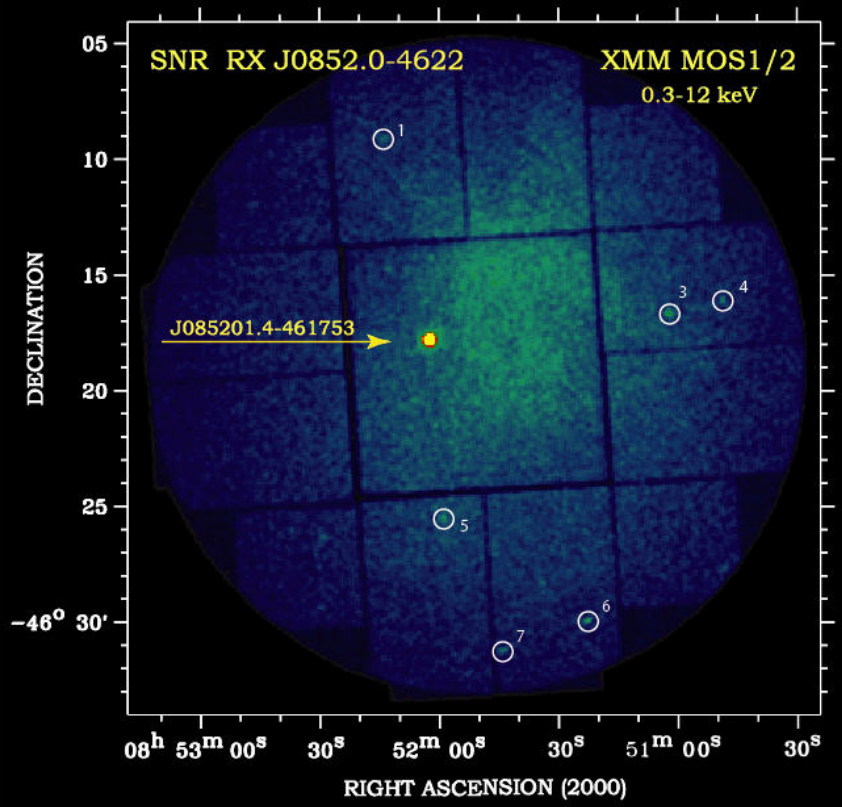
Becker & Aschenbach 2002, astro-ph/0208466

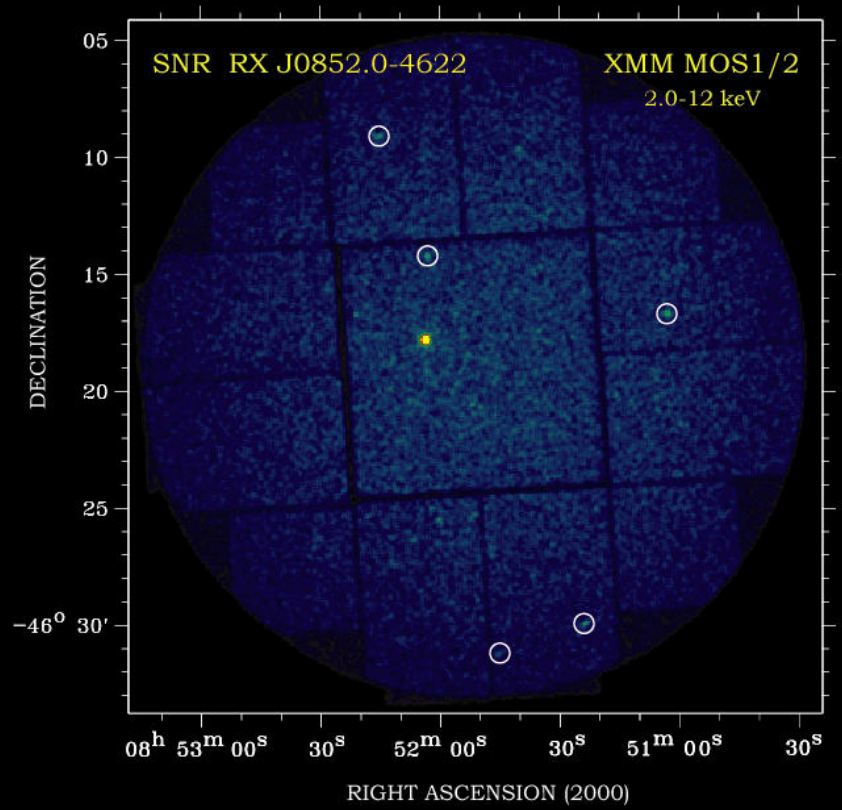
Vela and friends



Becker & Aschenbach 2002, astro-ph/0208466

Vela and friends: Vela-Jr.





Becker & Aschenbach 2002, astro-ph/0208466

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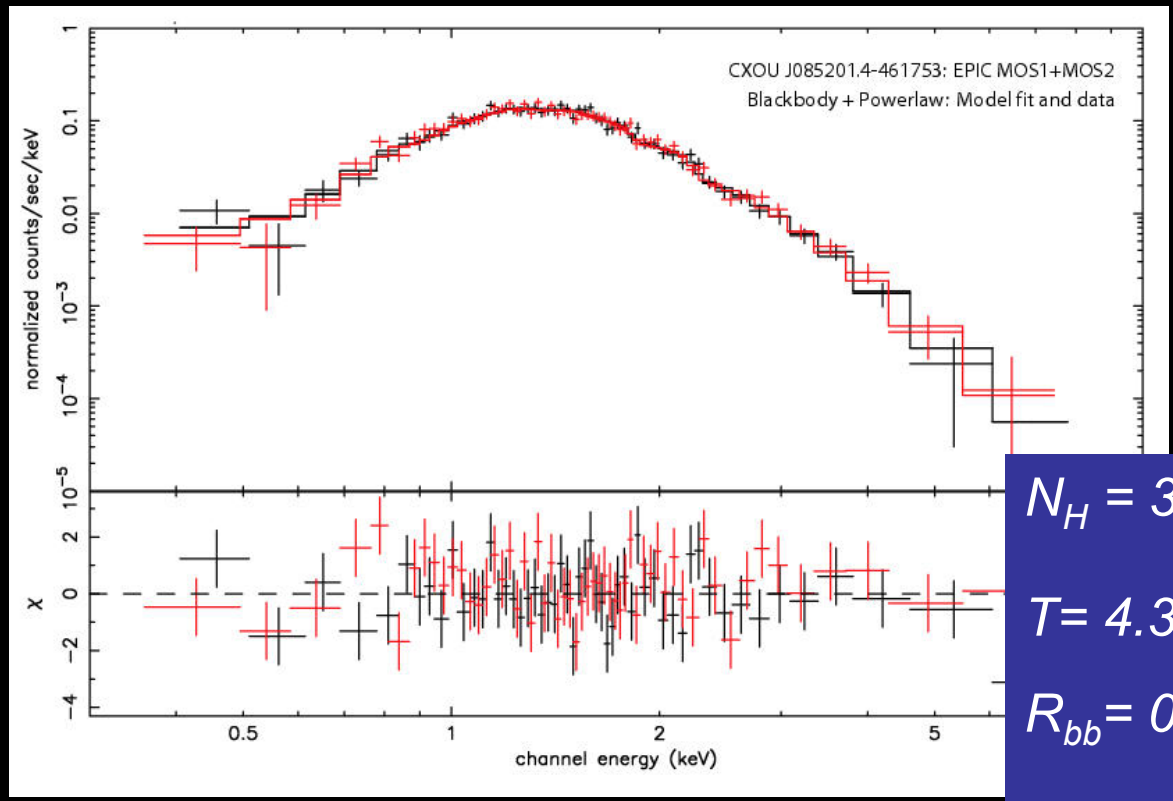


Becker & Aschenbach 2002, astro-ph/0208466

N_H = 3.7 – 4.3 10^{21} cm^2

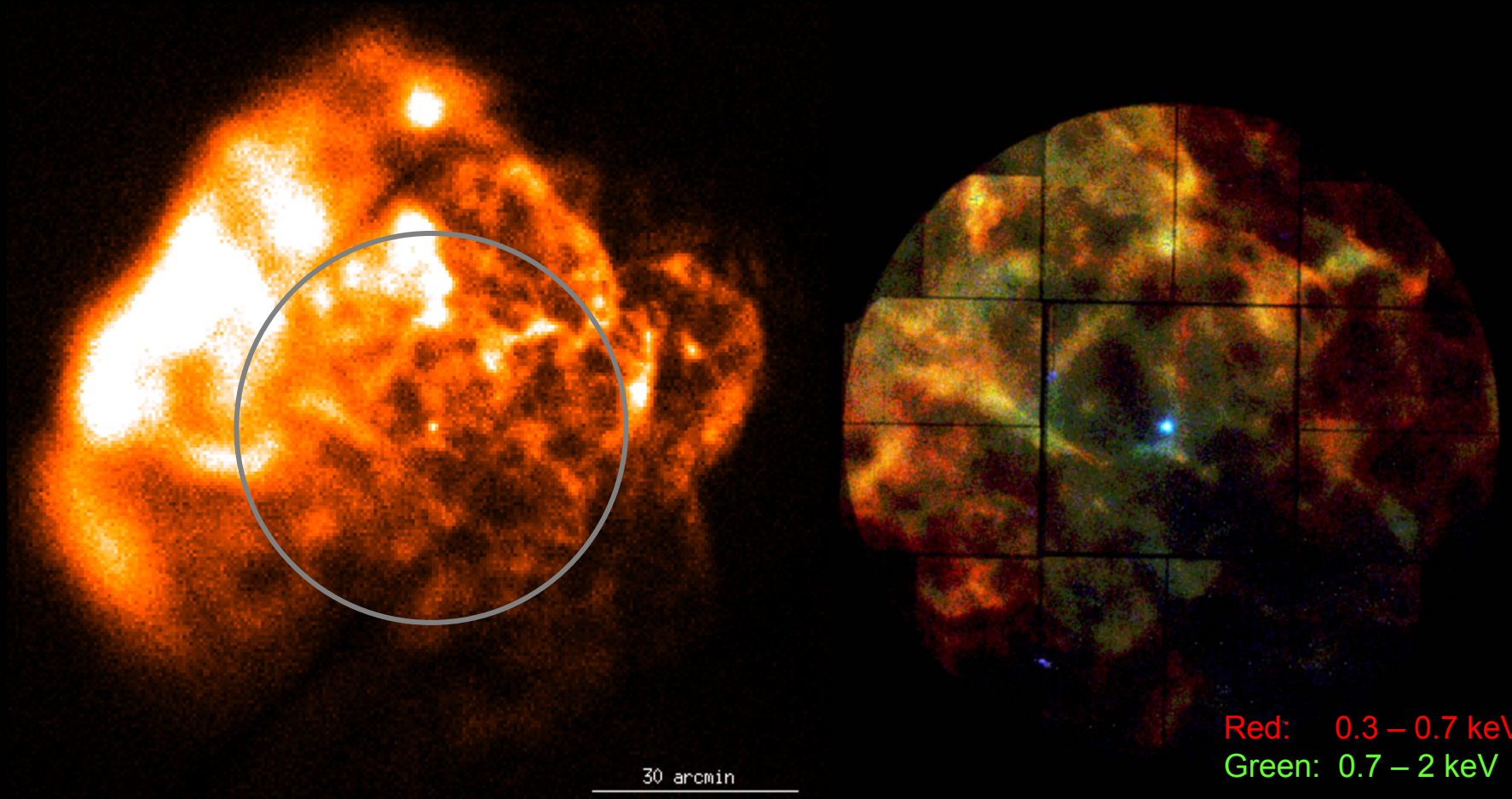
T= 4.3 – 4.5 10^6 K

R_{bb}= 0.3 – 0.4 km (d=1 kpc)

Photon-Index = 2.85 +/- 1.5

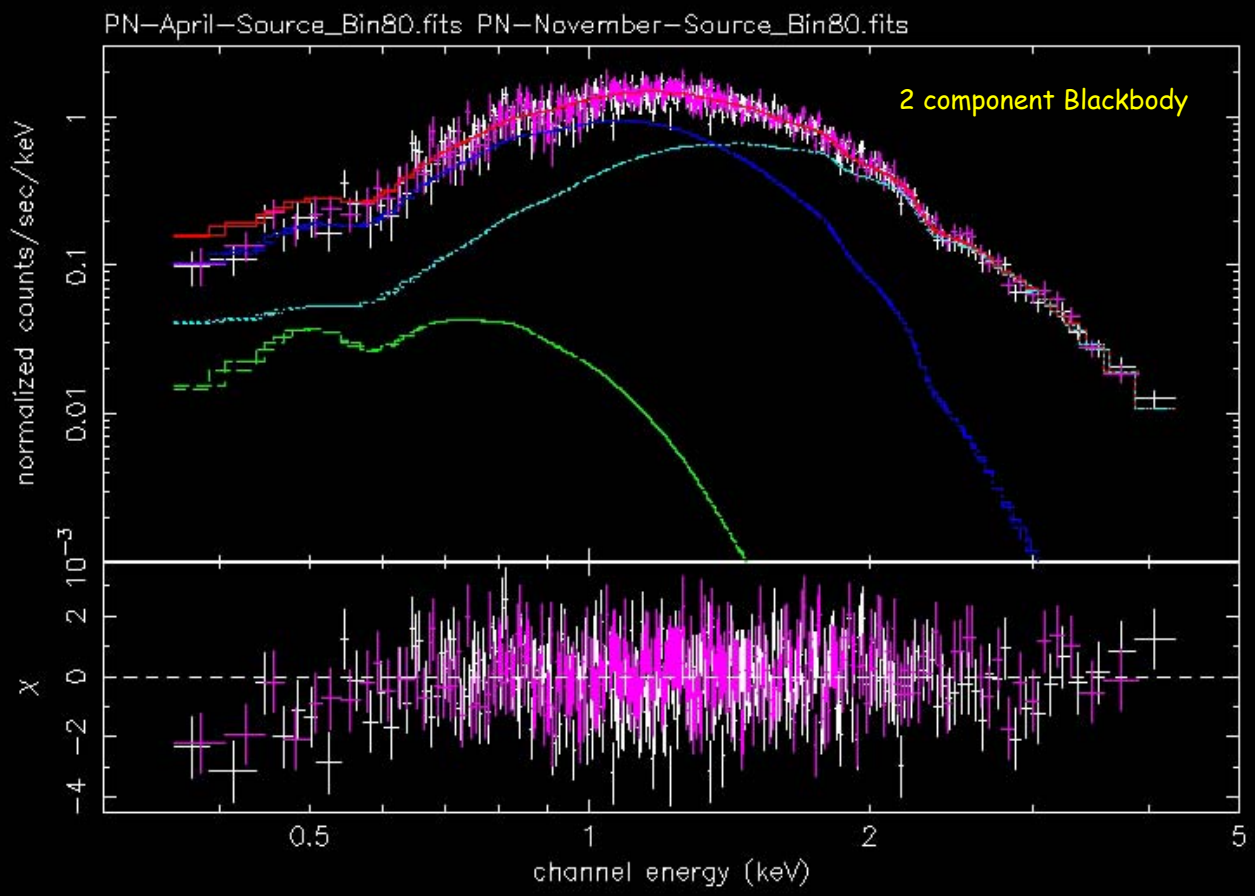
L_x (0.5-10 keV) = 2 - 3 10^{32} erg/s

Vela and friends: Puppis-A



Becker & Aschenbach 2002, astro-ph/0208466

Vela and friends: Puppis-A



$T_1 = 3.4 – 4\ 10^6$ K

$R_{bb} = 1.4 – 1.8$ km

$T_2 = 0.6 – 1.3\ 10^7$ K

$R_{bb} = 40 – 310$ m

Upper limit for T_s

$R_{bb} = 10$ km

$T_s < 1.13\ 10^6$ K

Becker & Aschenbach 2002, astro-ph/0208466

List of Pulsars which are accepted for observations by XMM-Newton during AO1/2

old nearby PSRs	Status	Instrument	Exposure
PSR B1929+10		EPIC PN/MOS	35
PSR B0950+08		EPIC PN/MOS	100
PSR B0823+26	obs	EPIC PN/MOS	50
PSR J1908+0734		EPIC PN/MOS	C30
PSR J2043+2740	obs	EPIC PN/MOS	20

$P \sim 96\,\mathrm{ms}$

$\tau \sim 1.2 \times 10^{6}$ yrs

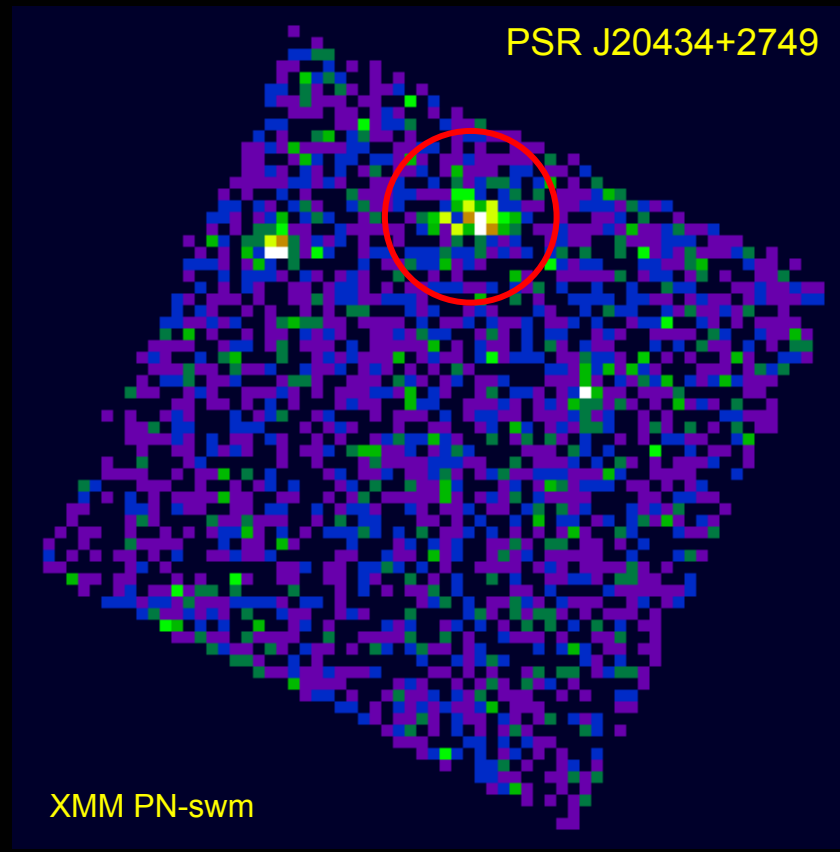
$\log B_{\perp} = 11.55\,\mathrm{G}$

$d \approx 1.3\,\mathrm{kpc}$

$\log \dot{E} = 34.75$ erg / s

$\log L_x \sim 30.65$ erg/s

Becker & Weisskopf 2003, in prep.

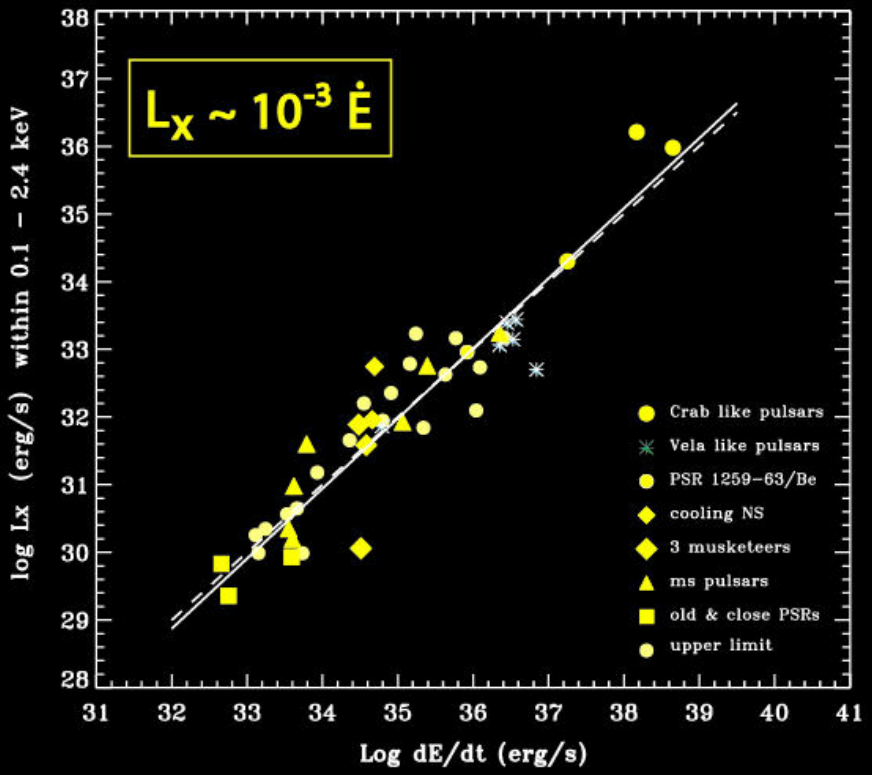


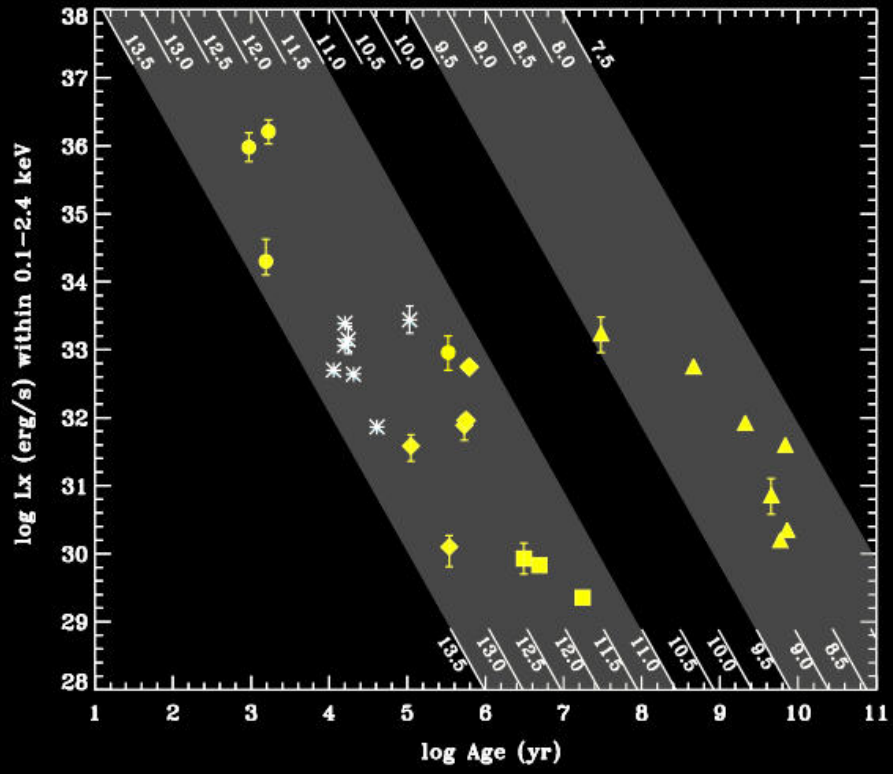
Exposure ~17 ksec

~120 source cts in PN-SWM

At the end of the ROSAT and ASCA Mission:

- 32 rot. powered Pulsars detected in the soft X-ray band

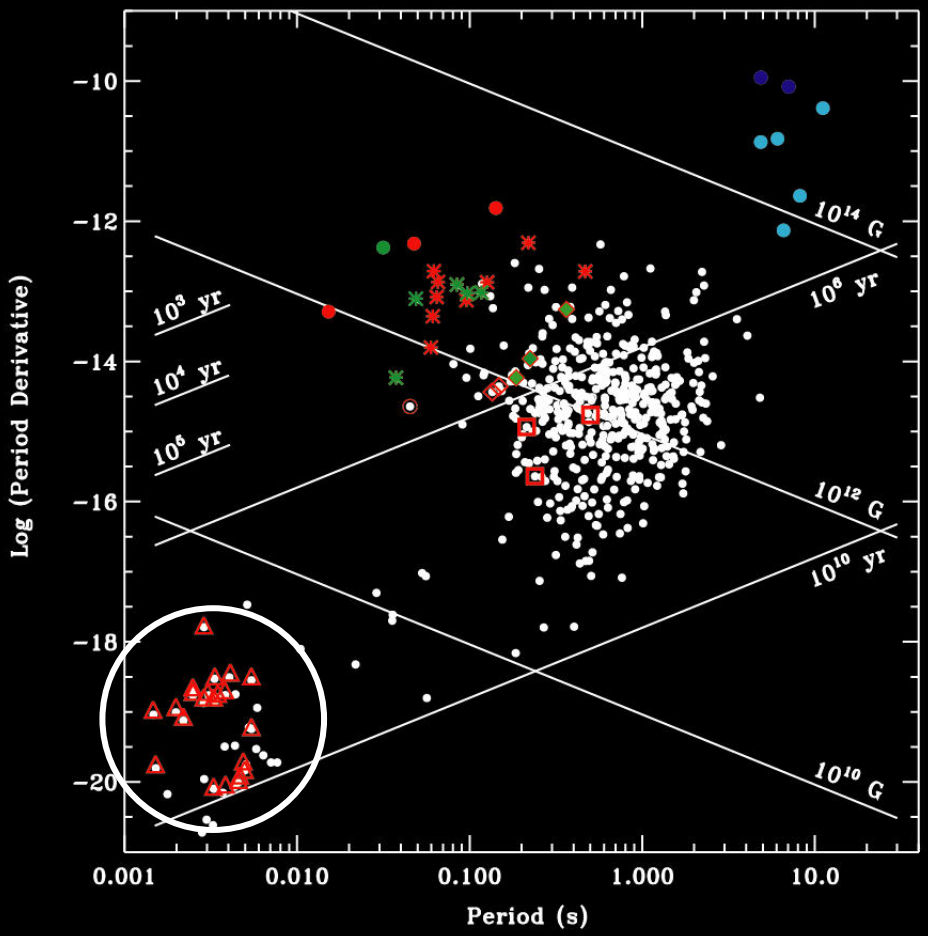




for a review see e.g. Becker & Trümper (1997, A&A, 326, 682)

Becker & Pavlov (2001, in *The Century of Space Science*, astro-ph/0208356)

53 rot. pow. Pulsars are detected in X-rays



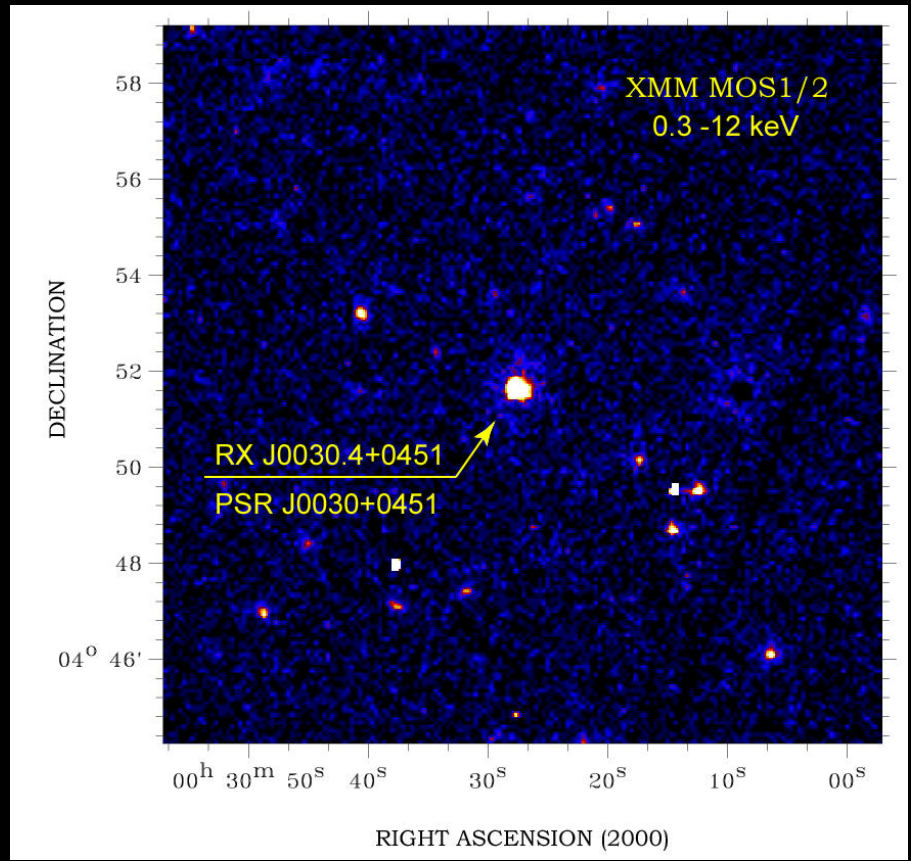
23 of them are ms-pulsars !! of which

12 are in the GC 47 Tuc

1 is in the globular cluster M28

List of Pulsars which are accepted for observations by XMM-Newton during AO1/2

ms-Pulsars	Status	Instrument	Exposure
PSR J0030+0453	obs	EPIC PN/MOS	30
PSR J0437-4715		EPIC PN/MOS	70
PSR J1024-0719		EPIC PN/MOS	80
PSR J2124-3358	obs	EPIC PN/MOS	70
PSR J0218+42	obs	EPIC PN/MOS	35
PSR J1012+53	obs	EPIC PN/MOS	20
PSR J0034-0534	obs	EPIC PN/MOS	30
PSR J0751+18	obs	EPIC PN/MOS	40
PSR B1821-24		EPIC PN/MOS	CAL



Becker & Aschenbach 2002, astro-ph/0208466

List of Pulsars which are accepted for observations by XMM-Newton during AO1/2

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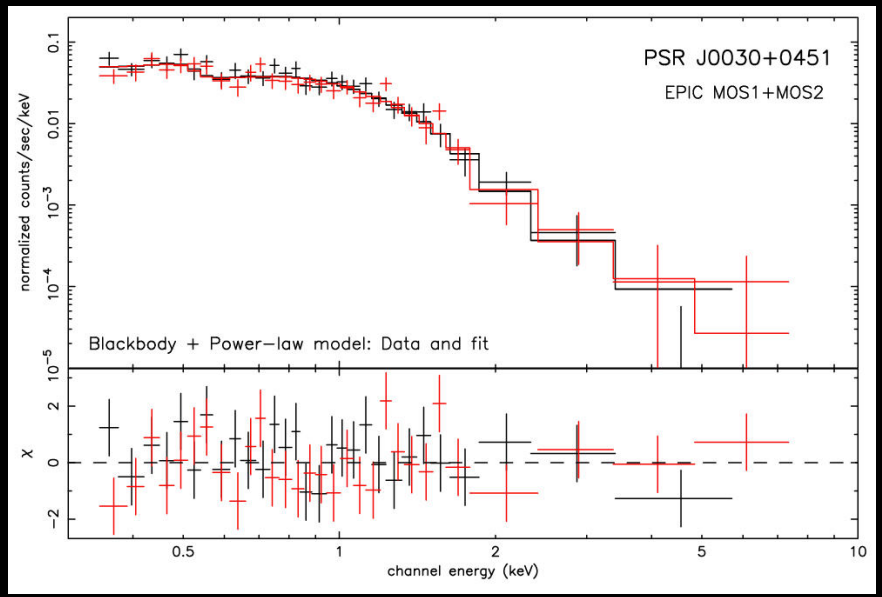
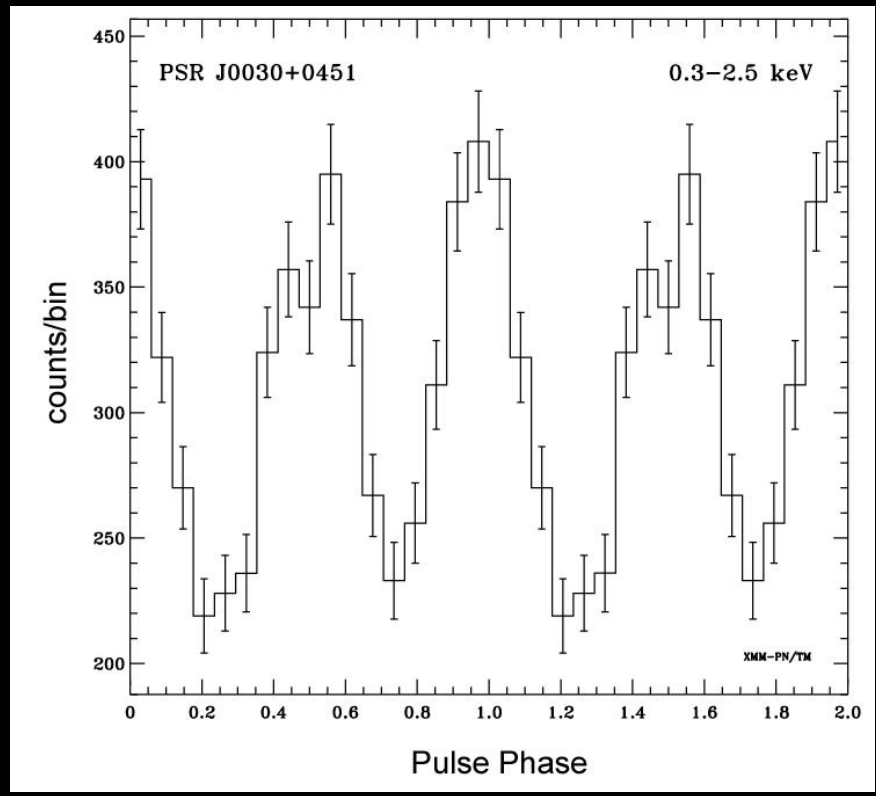
PSR J0034-0534	obs	EPIC PN/MOS	30
PSR J0751+18	obs	EPIC PN/MOS	40
PSR B1821-24		EPIC PN/MOS	CAL



Pulsed fraction 50 +-3 %

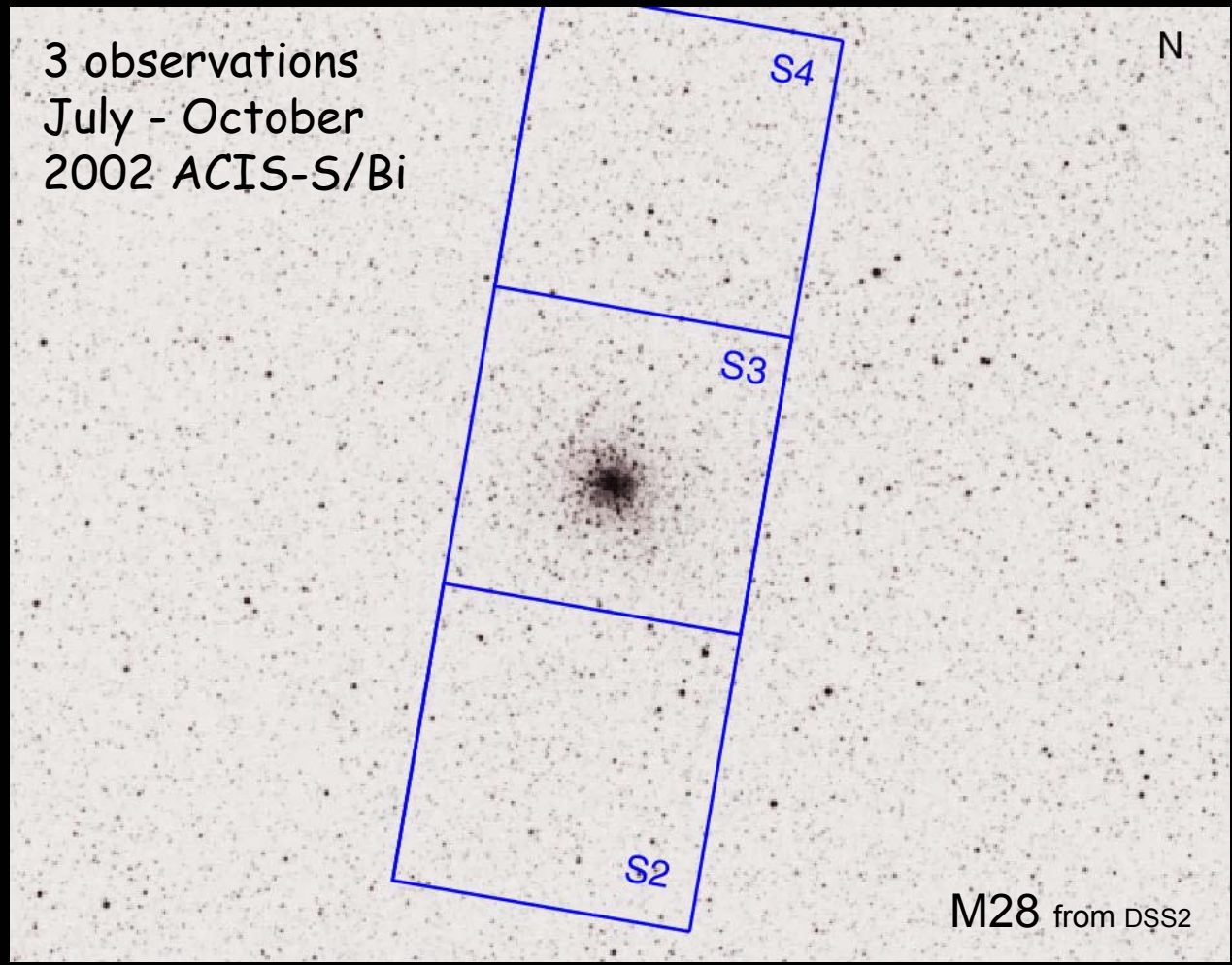


X-rays from ms-pulsars are due to a mixture of thermal and non-thermal emission

Becker & Aschenbach 2002, astro-ph/0208466

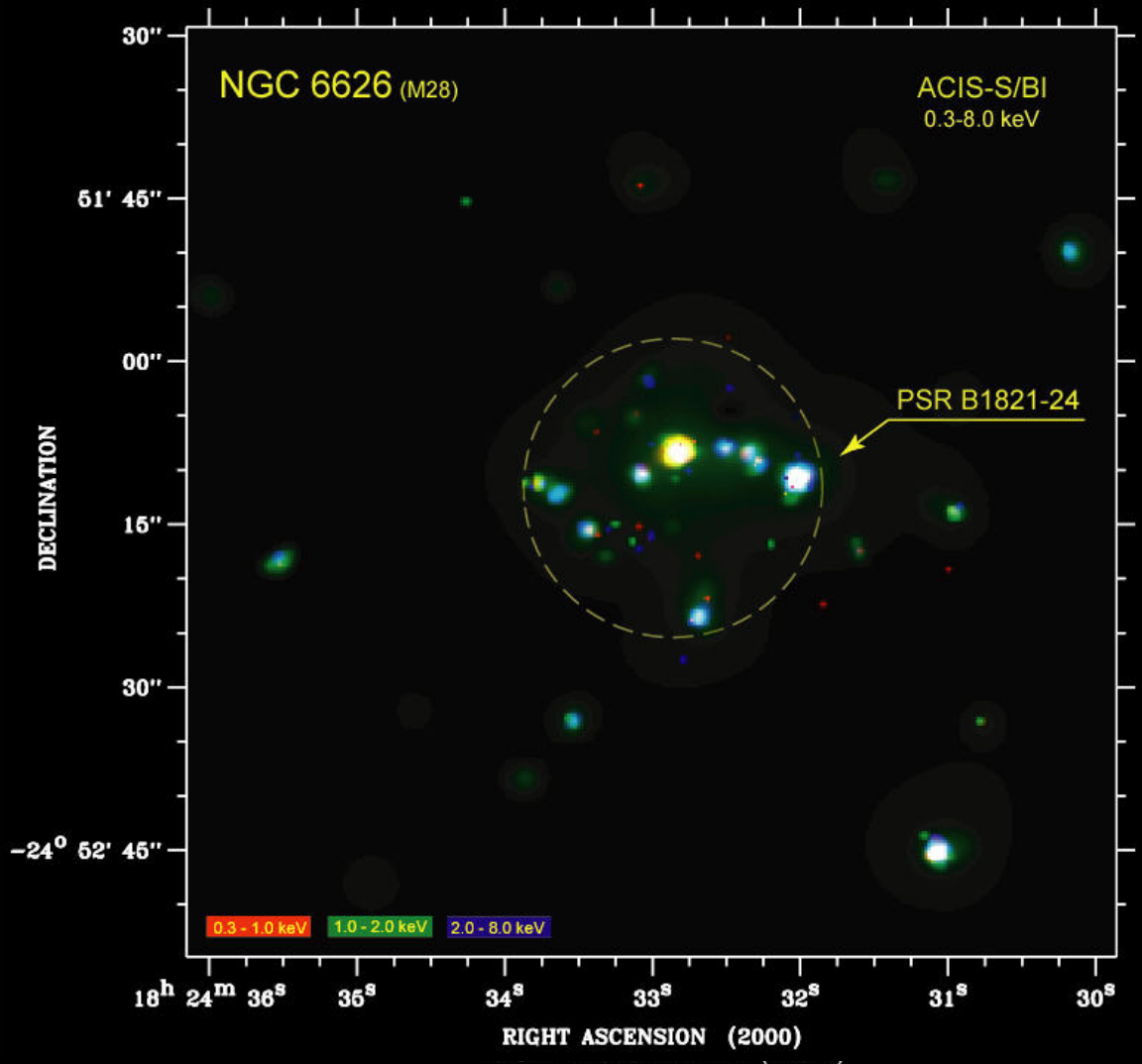
Chandra observations of the Globular Cluster M28 and PSR 1821-24

Becker, Swartz, Pavlov et al 2002



Chandra observations of the Globular Cluster M28 and PSR 1821-24

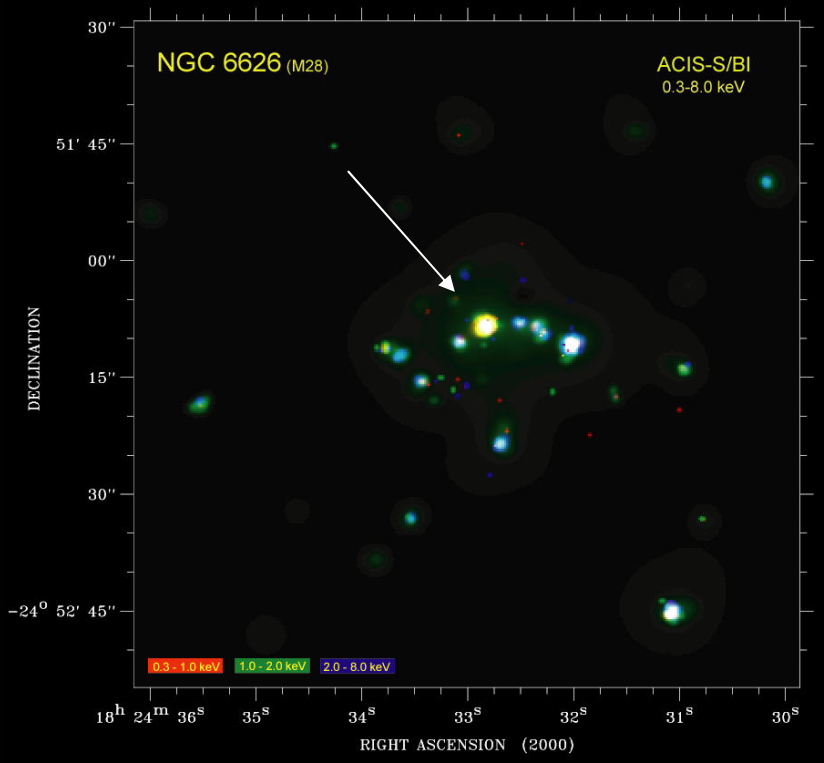
Becker, Swartz, Pavlov et al 2002

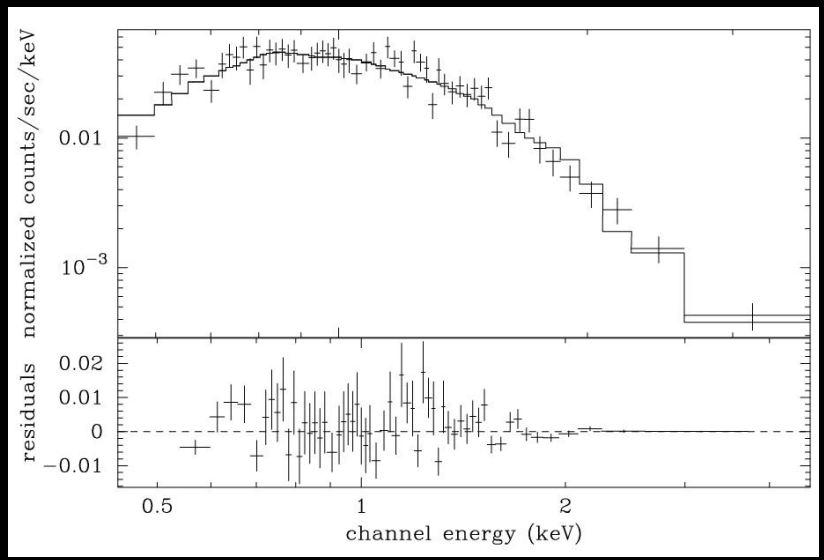


46 X-ray sources of which 12 lie within one core radius of the cluster center

Chandra observations of the Globular Cluster M28 and PSR 1821-24

Becker, Swartz, Pavlov et al 2002





Neutron star H-atmosphere Model

(Zavlin, Pavlov & Shibanov 1996)

Candidate LMXB in quiescence

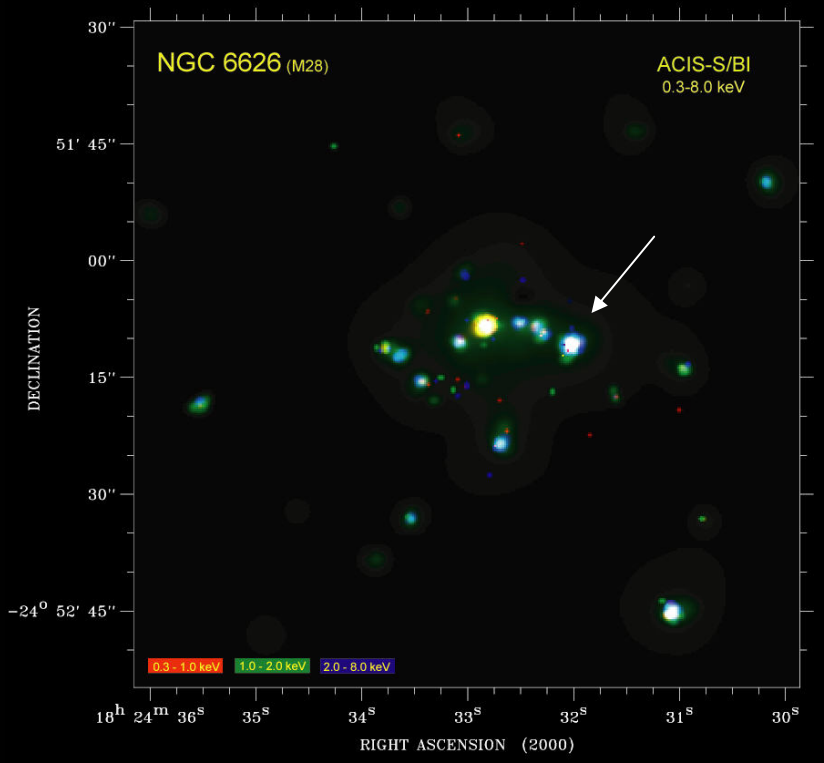
Flux variable on a time scale of month

$T = 0.9 – 1.4\ 10^6\ K$

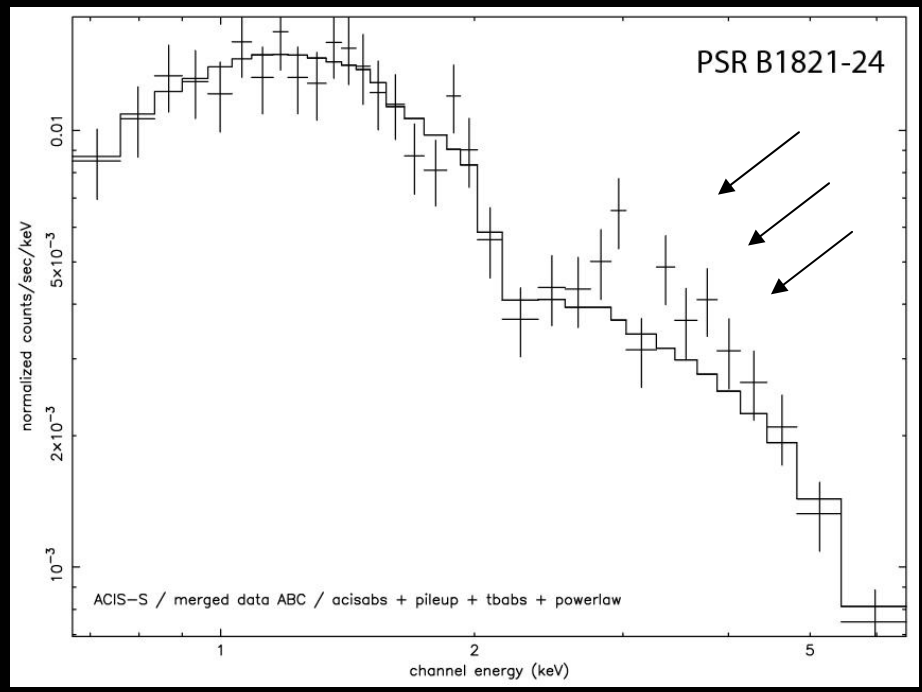
$R_{bb} = 11 – 22\ km$

Chandra observations of the Globular Cluster M28 and PSR 1821-24

Becker, Swartz, Pavlov et al 2002



Pulsar spectrum is hard and dominated by non-thermal emission



Evidence of a line feature which can be interpreted in terms of cyclotron emission from a corona above the pulsar's polar cap if the magnetic field is strongly different from a centered dipole

$$B_{surf} \approx 100 \times B_{\perp}$$