X-ray observations of "gamma-ray only" PSRs

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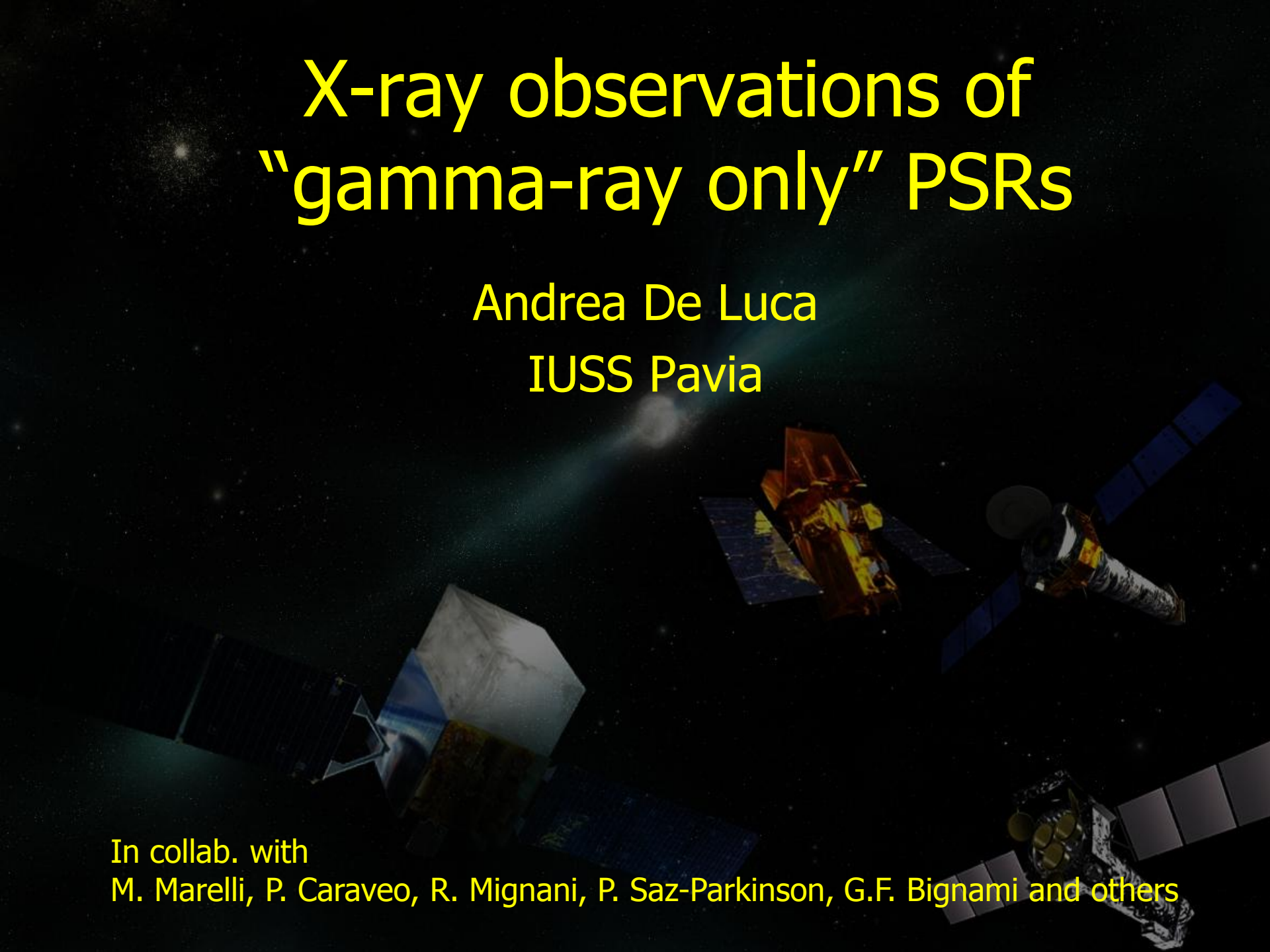


In collab. with
M. Marelli, P. Caraveo, R. Mignani, P. Saz-Parkinson, G.F. Bignami and others

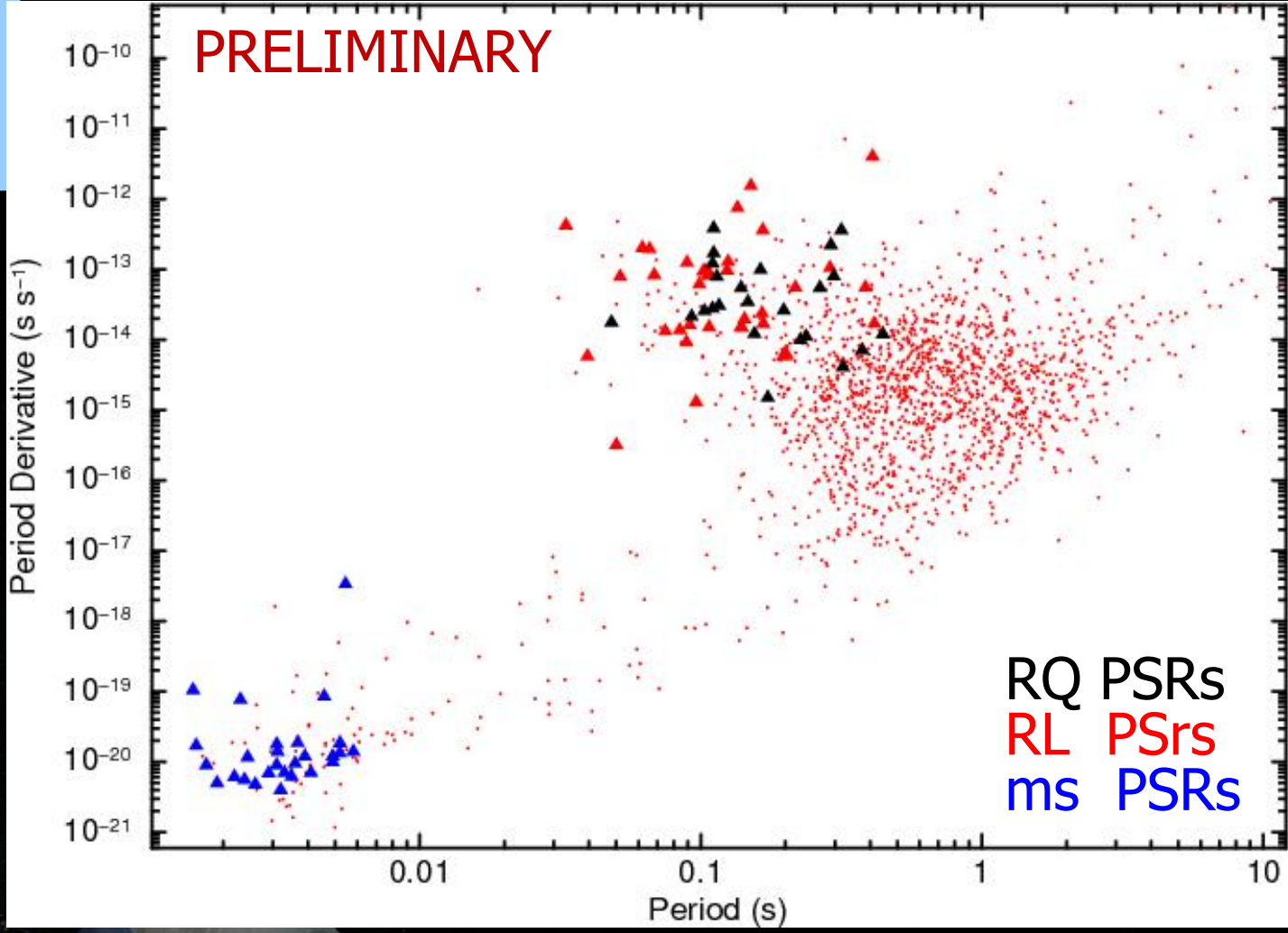
Fermi/LAT PSR sample

88
PSRs

64
radio loud

36 classical

27 millisecond



D. Smith's talk
& poster by
P. Saz Parkinson

26 discovered in BS (+Geminga)
24 "gamma-ray only" PSRs

Erot in $5 \cdot 10^{33}$ - $1 \cdot 10^{37}$ erg s^{-1}

The X-ray side

NH

surface thermal emission

hot polar cap emission

magnetospheric emission

PWN

SNR

Spectroscopy

timing

phase-resolved spectroscopy

imaging

limited by photon statistics

of particular interest for radio-quiet PSRs

The X-ray side

archival data

dedicated observations
Swift/XRT
XMM-Newton
Chandra

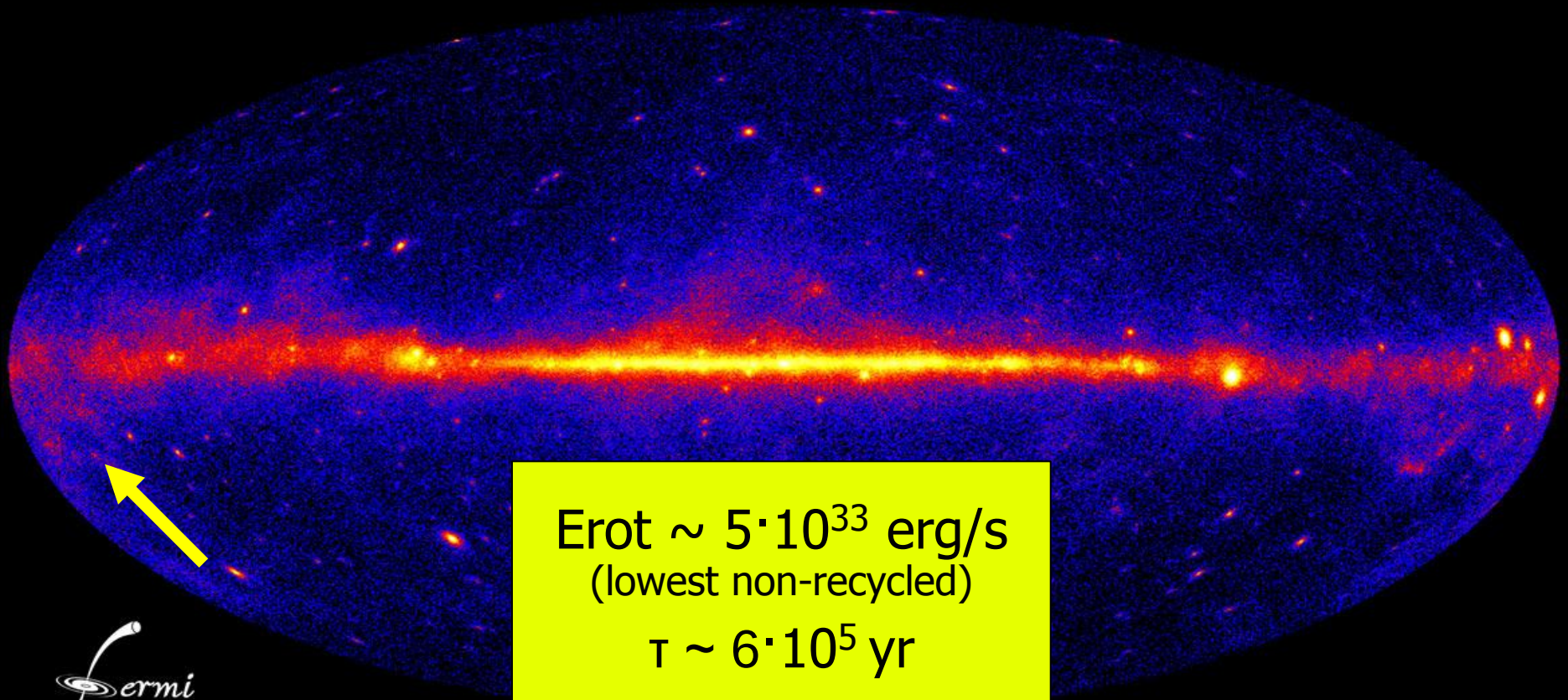
X-ray emission properties of LAT PSRs

RQ vs. RL

Highlights on 2 interesting PSRs

First look at the overall properties of the sample

The low Erot side: PSR J0357+32



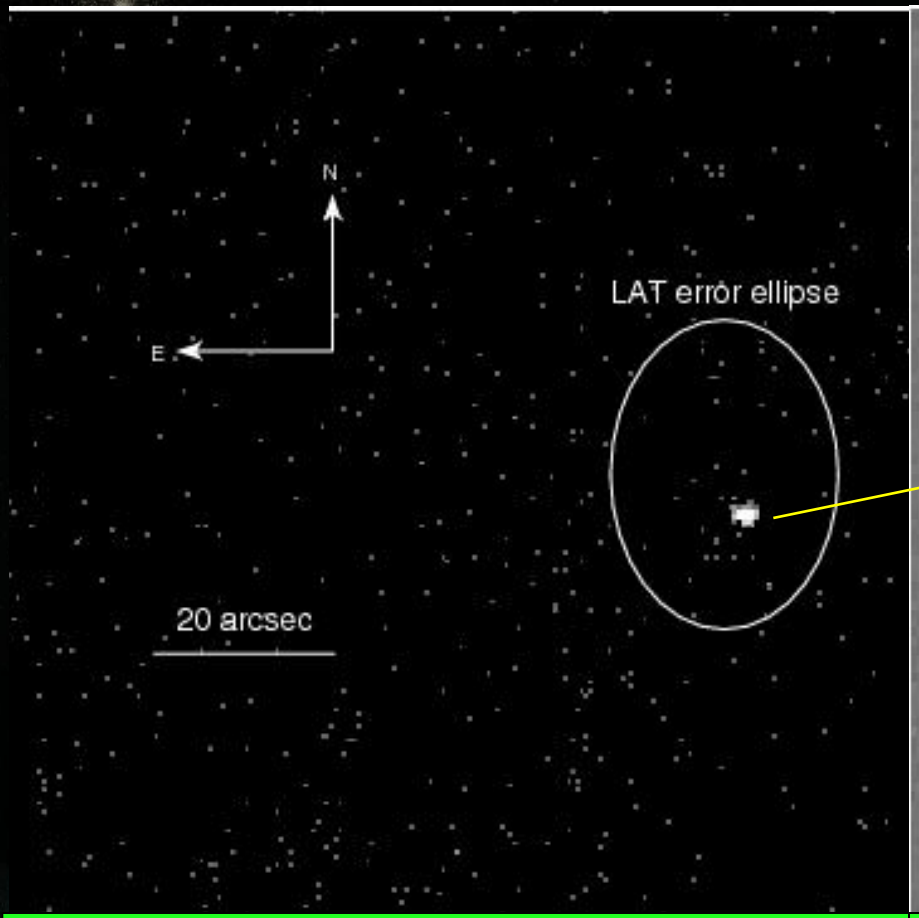
$E_{rot} \sim 5 \cdot 10^{33}$ erg/s
(lowest non-recycled)

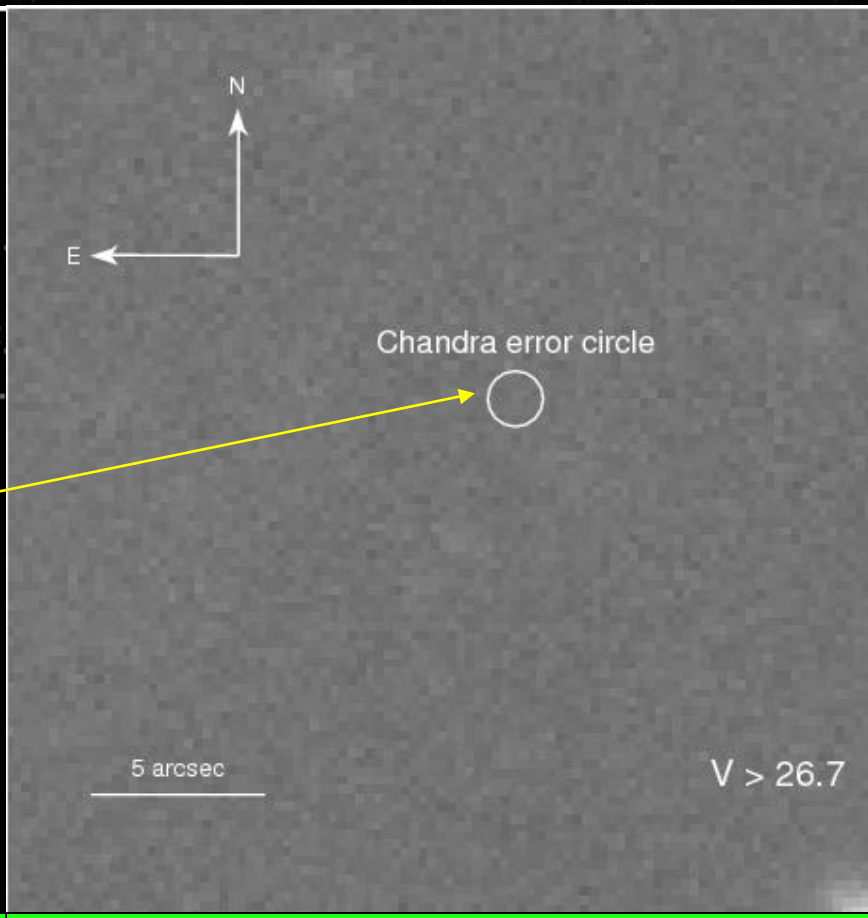
$\tau \sim 6 \cdot 10^{5}$ yr

A middle-aged PSR

Fermi Gamma-ray Space Telescope

The X-ray counterpart



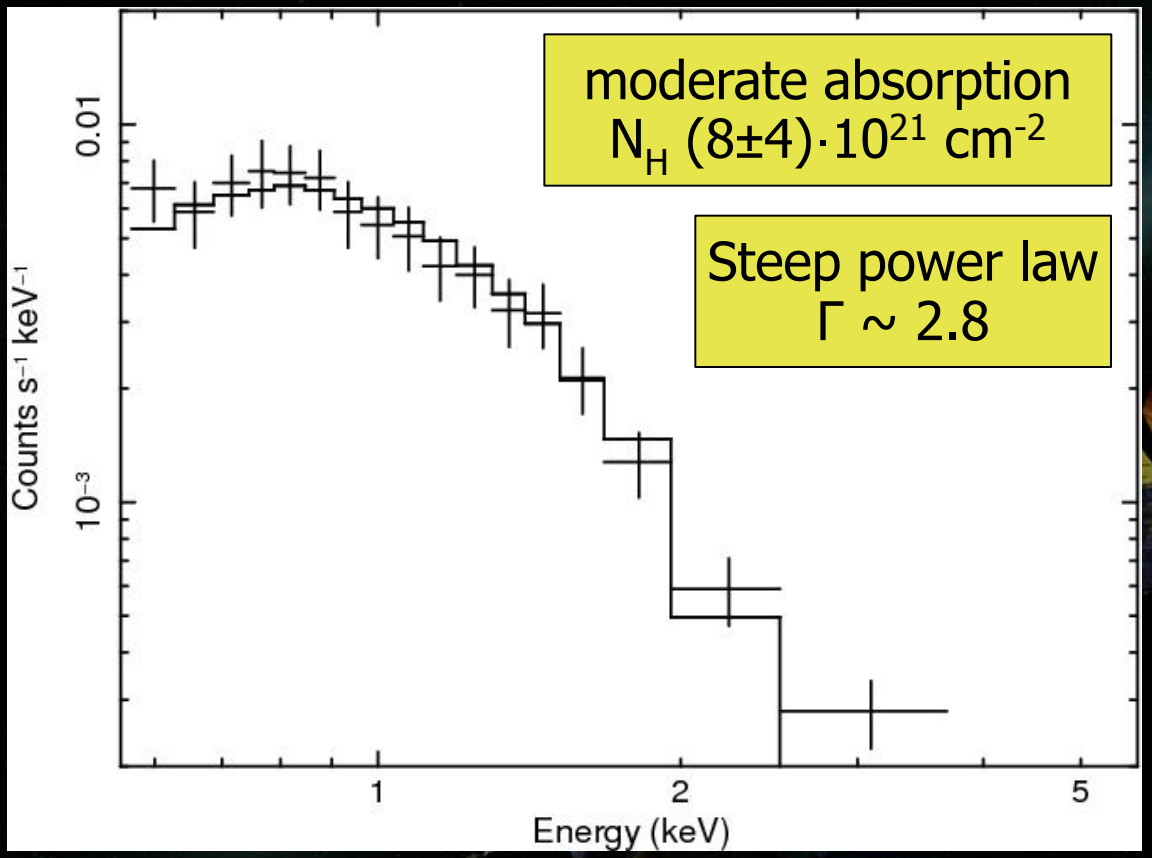


Chandra (77 ks)

NOAO/KPNO 4m (4 hr)

De Luca et al., 2011, ApJ in press, arXiv:1102.3278

PSR J0357+32: emission properties



Small distance

No thermal emission
the coldest NS
in its age range

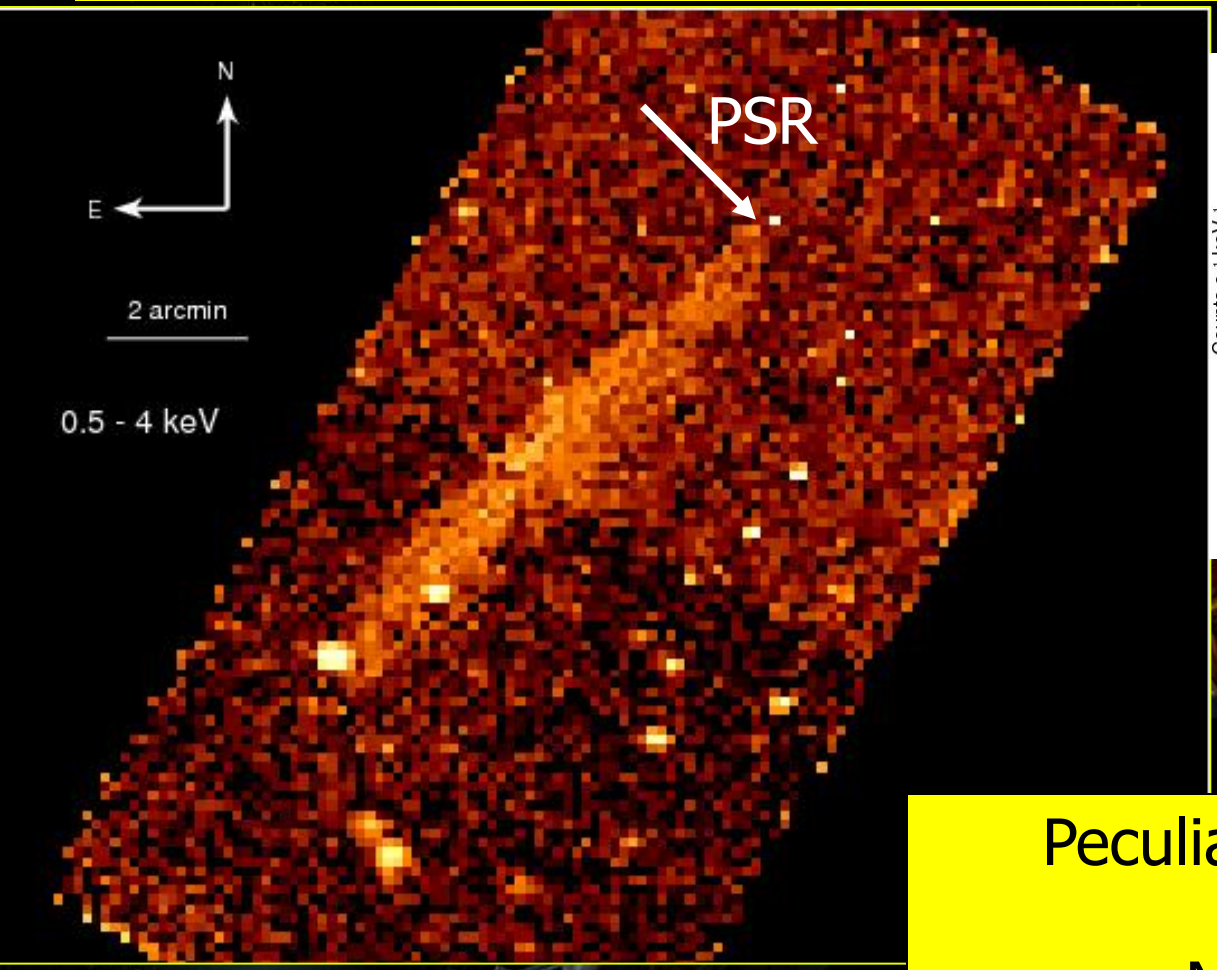
Unabsorbed flux
$F \sim 5.5 \cdot 10^{-14}$ erg cm^{-2} s^{-1}
(0.5-10 keV)

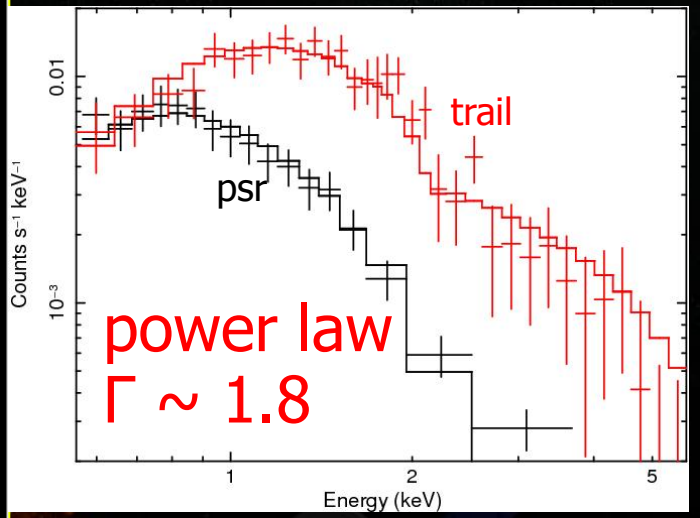
X-ray efficiency
$\eta_X \sim 2 \cdot 10^{-4}$
@500 pc

Reminiscent of *older* PSRs
(e.g. B1929+10)

De Luca et al., 2011

A parsec-long X-ray tail





$L_X \sim 1.5 \cdot 10^{-3}$ Erot
@ 500 pc

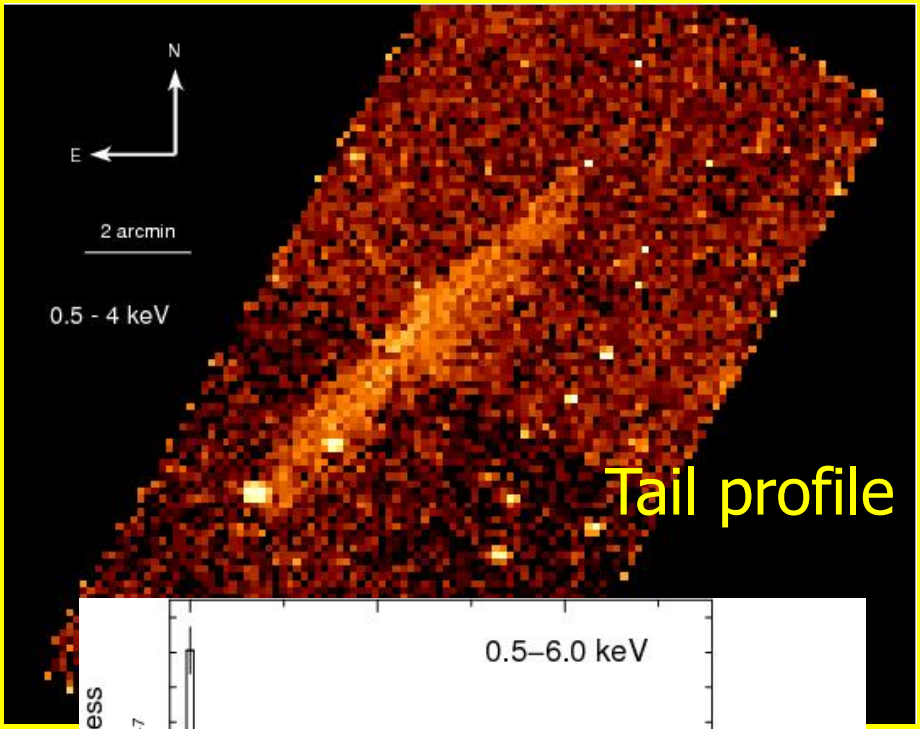
9 arcmin --> 1.3 pc @ 500 pc

also seen by Suzaku

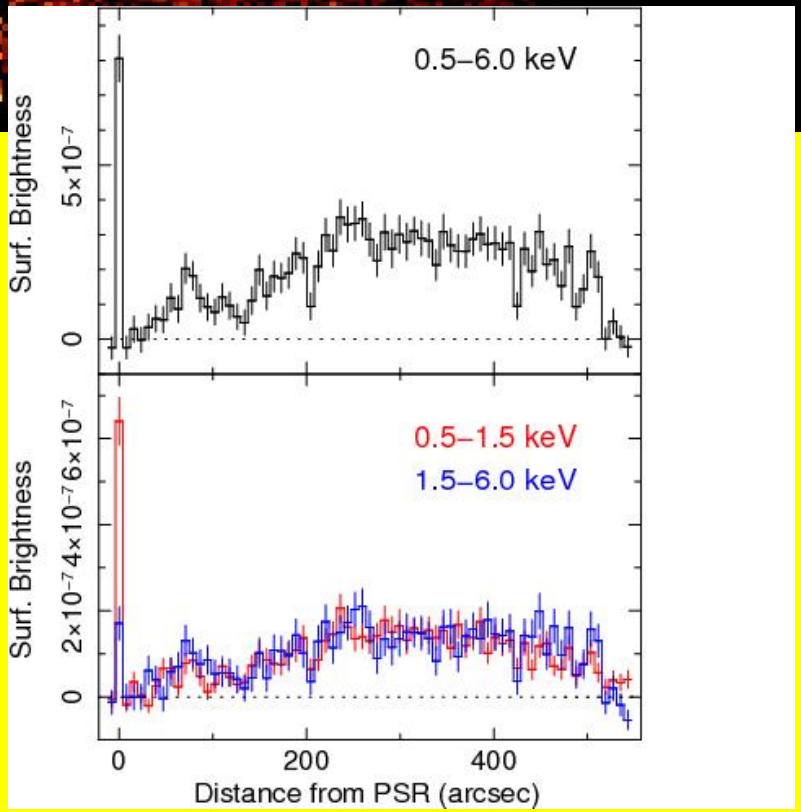
Peculiar brightness profile

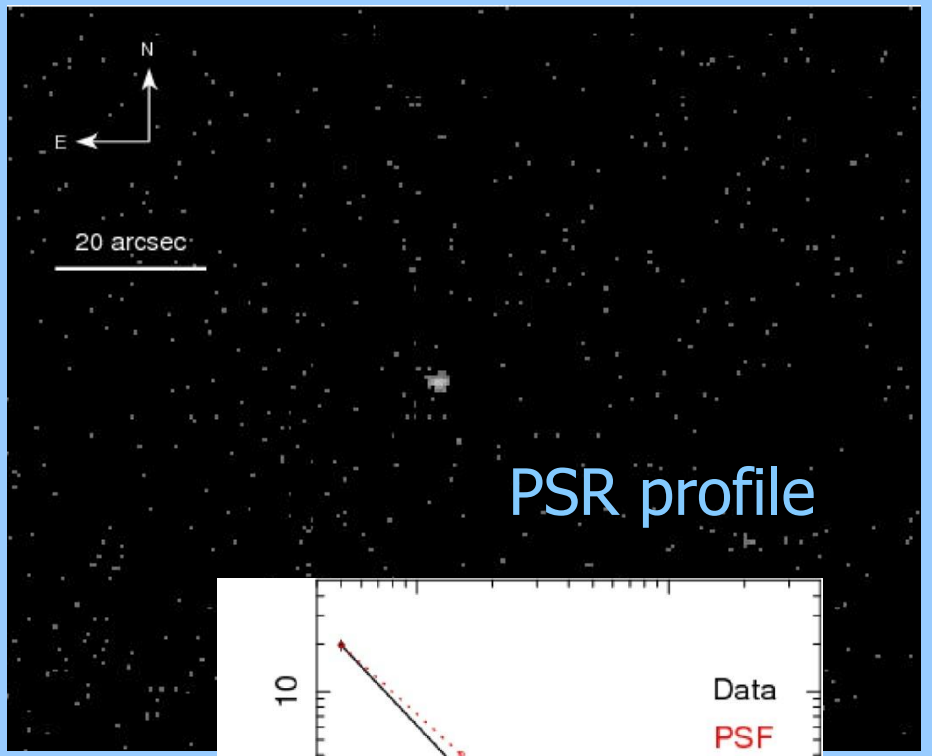
No measurable spatial/spectral evolution

A ram-pressure dominated PWN?

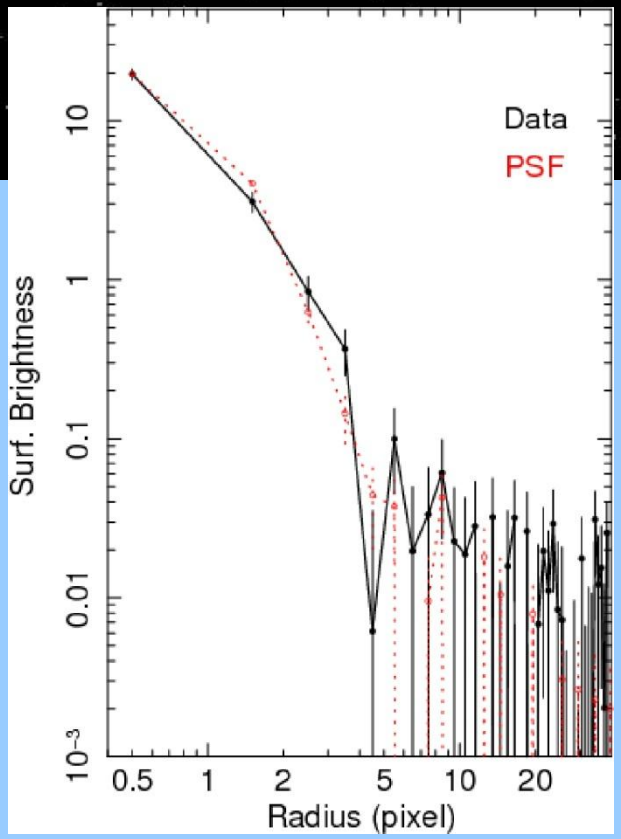


Tail profile

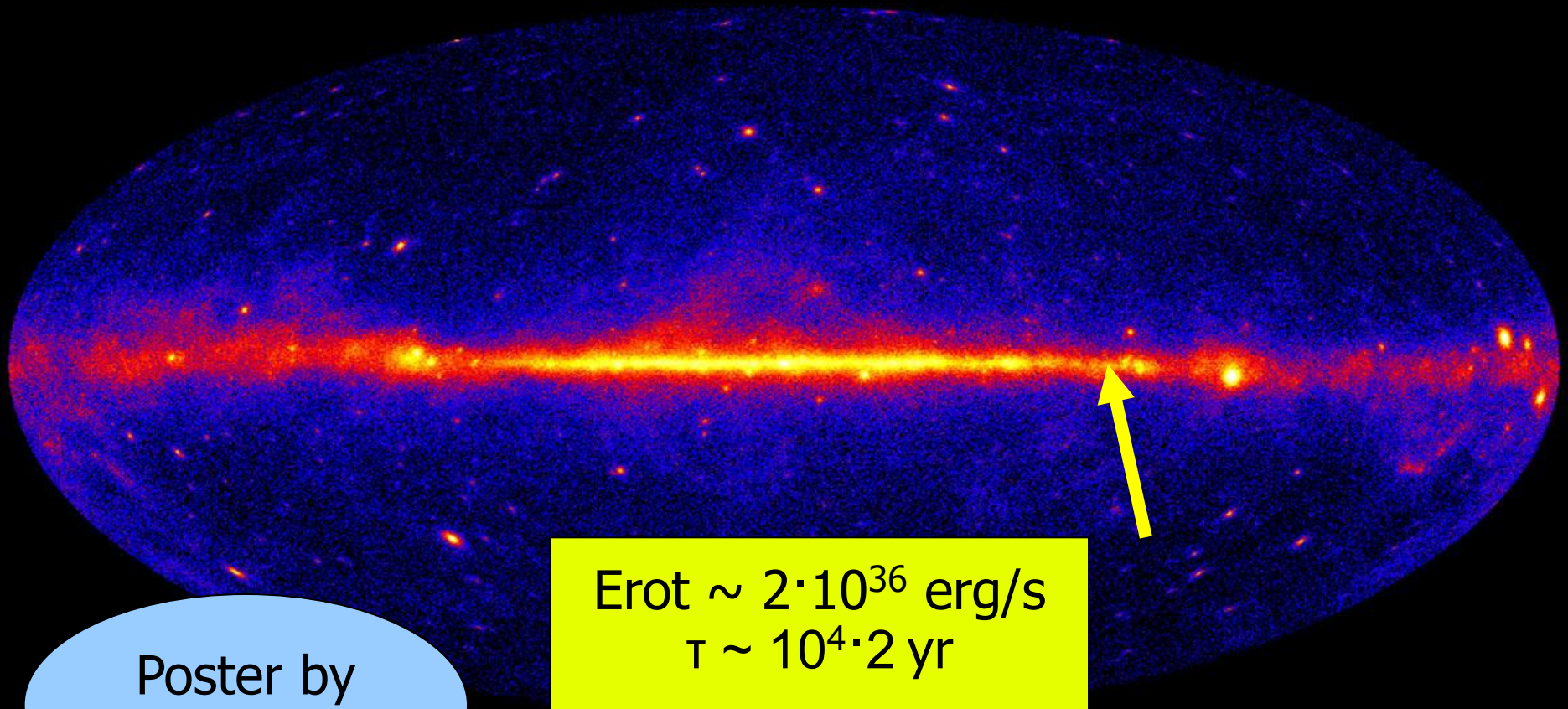




PSR profile



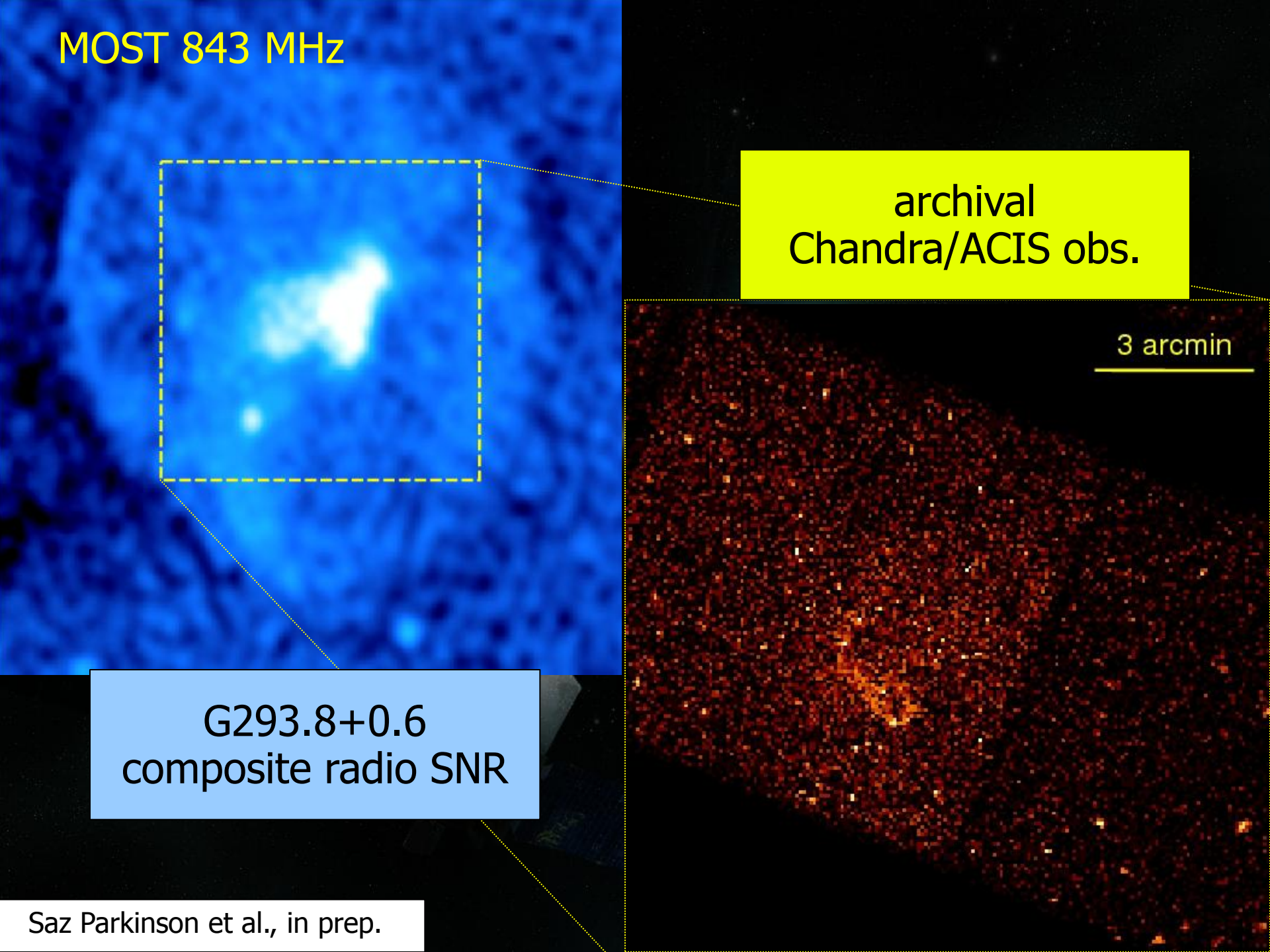
The last entry: PSR J1135-6055



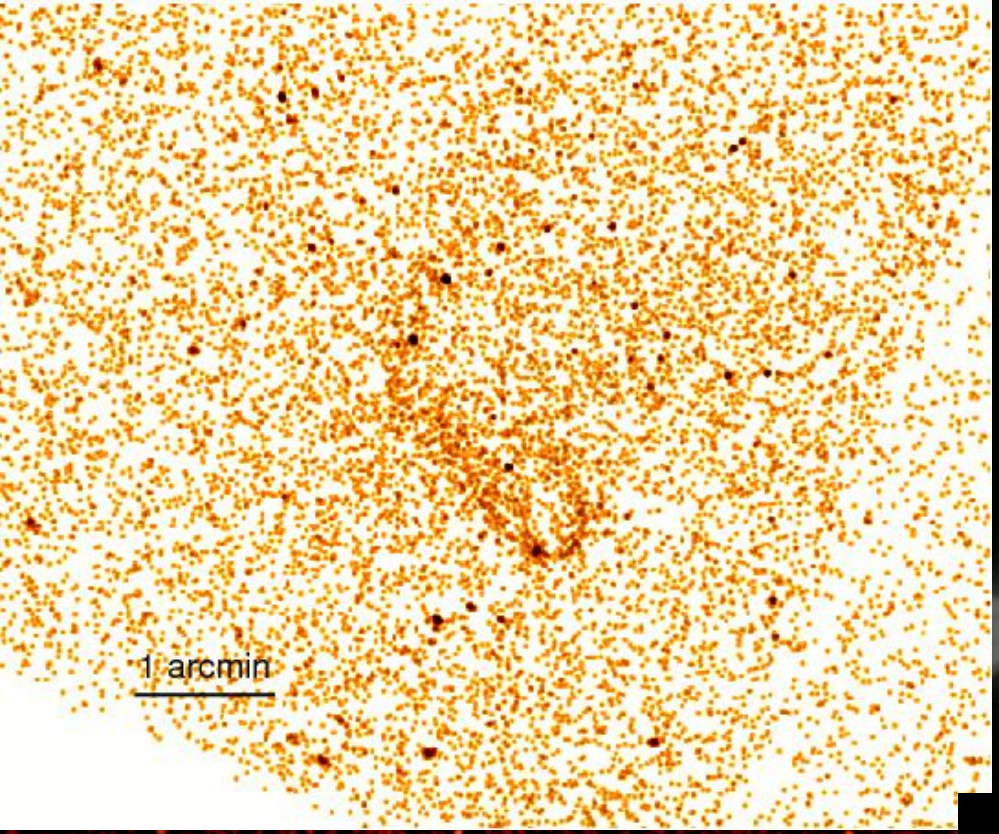
Erot ~ $2 \cdot 10^{36}$ erg/s
$\tau \sim 10^4 \cdot 2$ yr

A Vela-like PSR

Poster by
P. Saz Parkinson



Saz Parkinson et al., in prep.



Point-like src

possible compact (<3″) PWN
non-thermal

N_H $(4\pm1)\cdot10^{21}$ cm^{-2}
$\Gamma \sim 1.2$

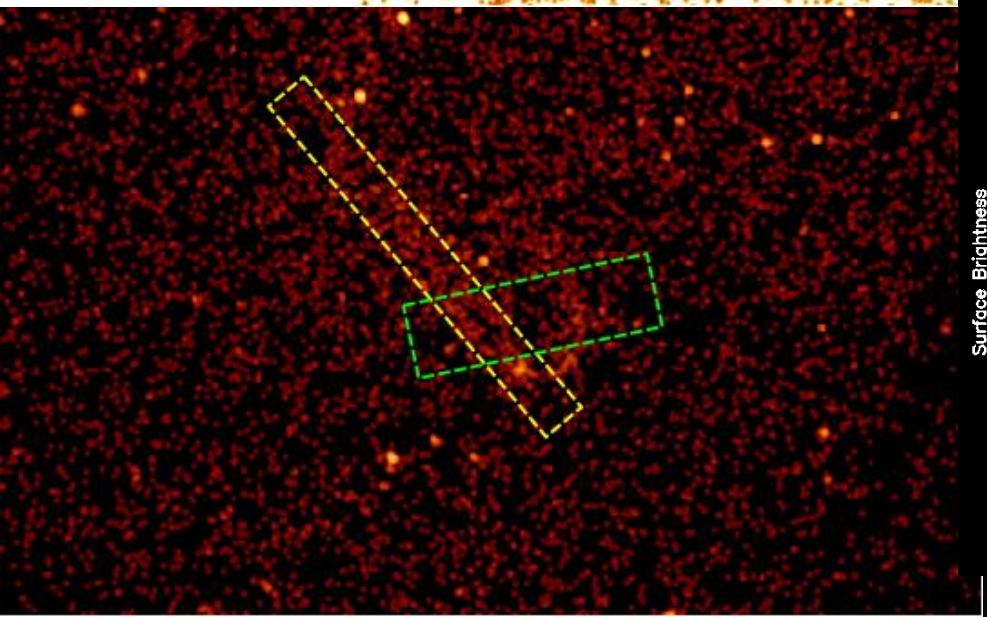
Unabsorbed flux

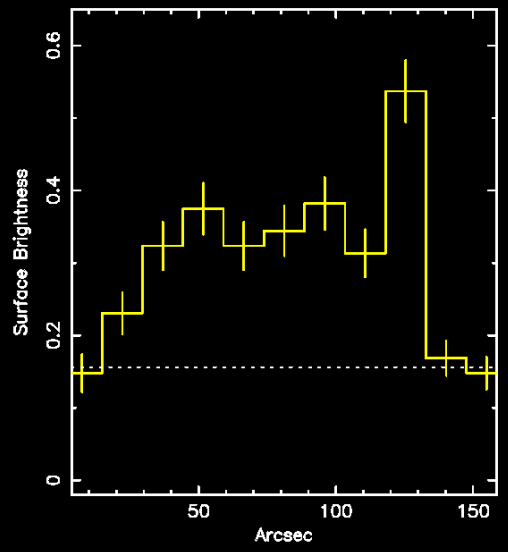
$4\cdot10^{-14}$ erg cm^{-2} s^{-1}

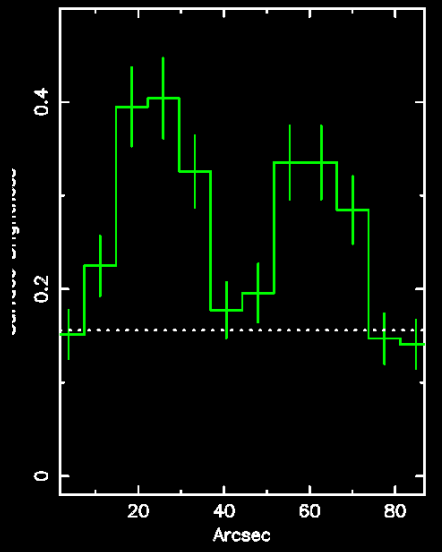
(0.5-10 keV)

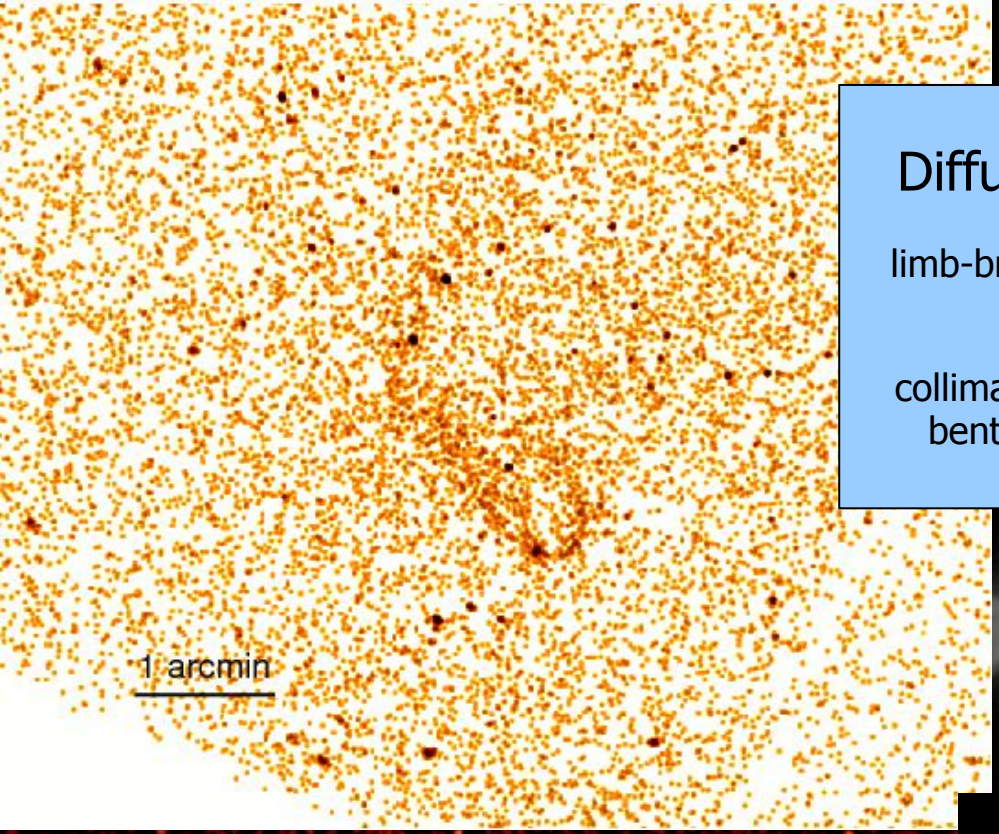
X-ray efficiency

$\eta_X \sim 2\cdot10^{-5}$
@2.9 kpc









Diffuse structures

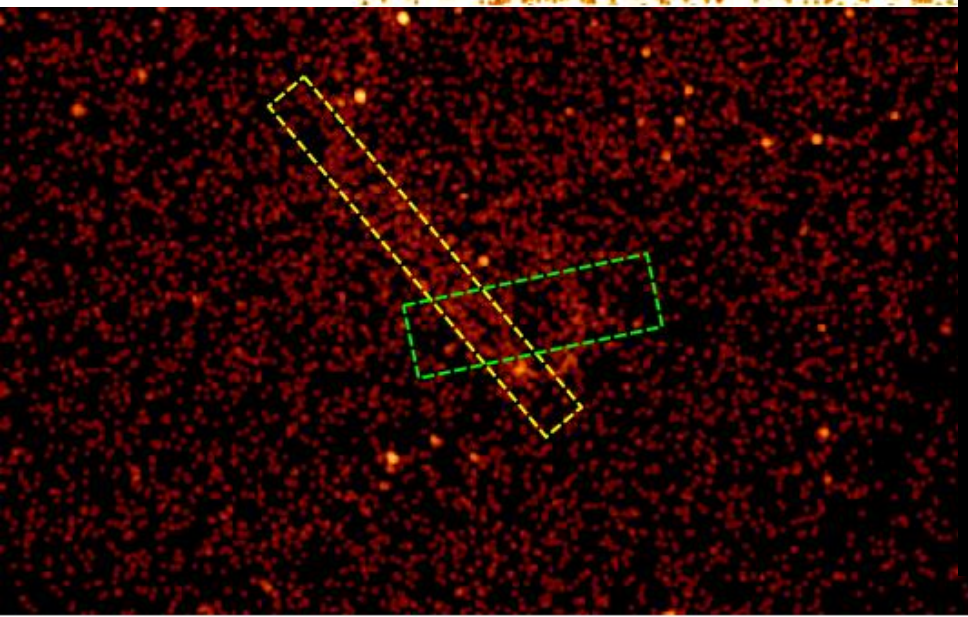
limb-brightened boundary of a "shell" ?

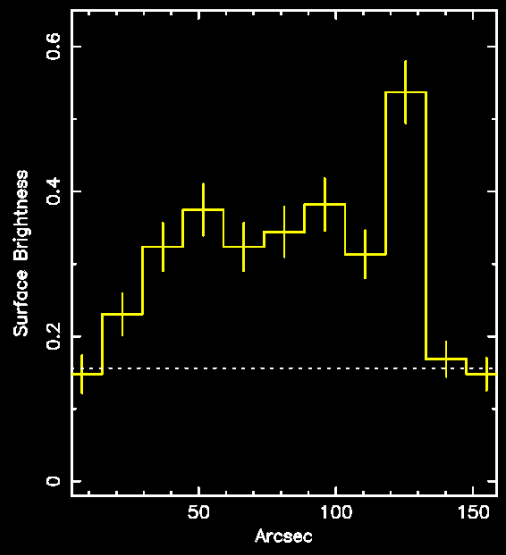
collimated outflows (jets) bent by ram pressure

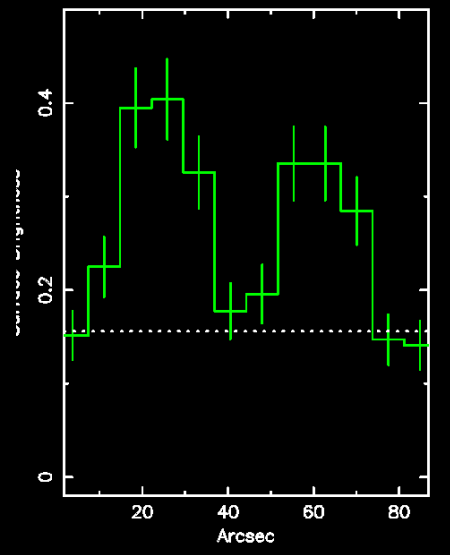
$\Gamma_1 \sim 1.8 \pm 0.4$
$\Gamma_2 \sim 2.6 \pm 0.7$

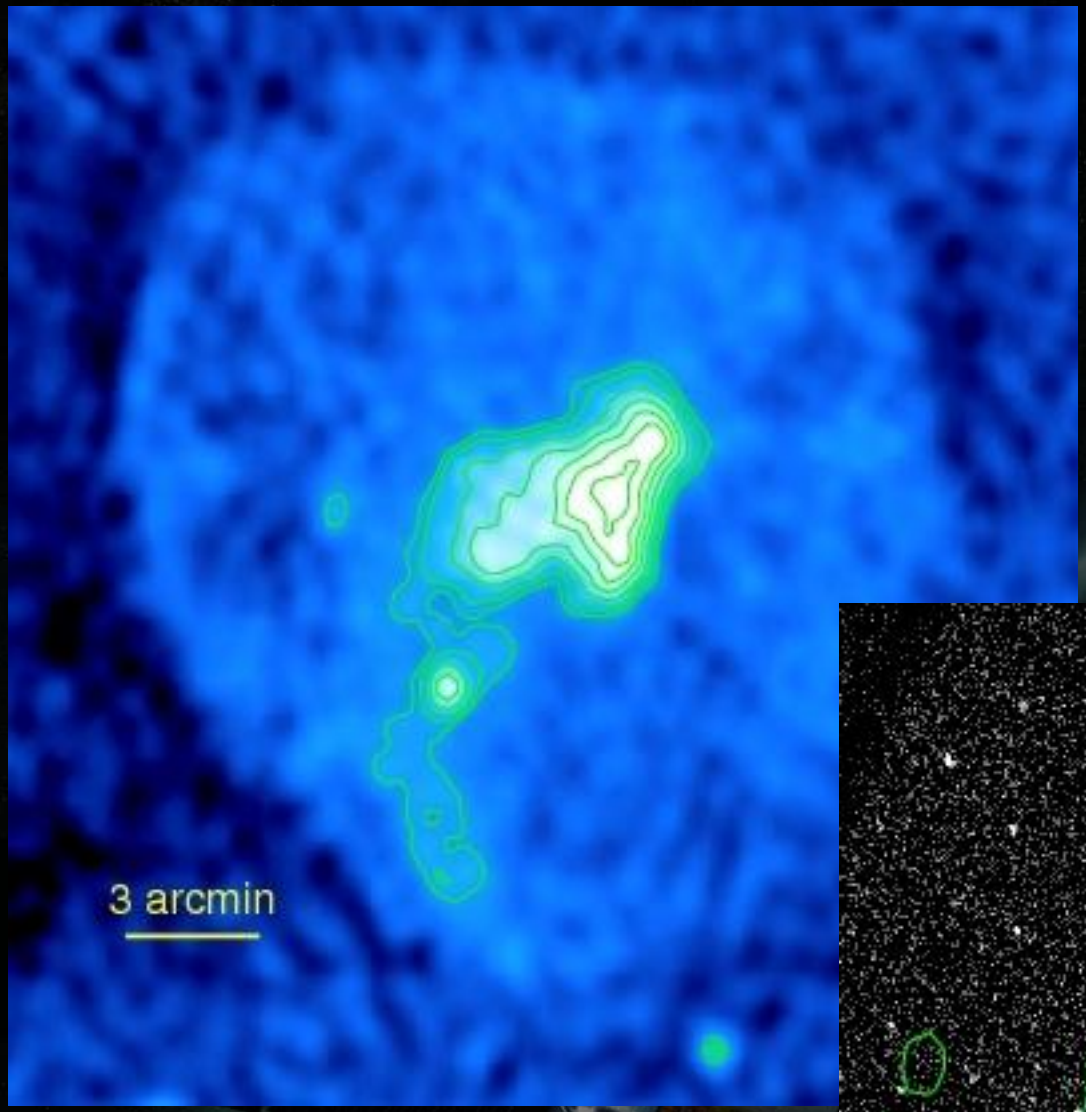
Unabsorbed flux
$2 \cdot 10^{-13}$ erg cm^{-2} s^{-1}
(0.5-10 keV)

X-ray efficiency
$\eta_X \sim 2 \cdot 10^{-4}$
@2.9 kpc



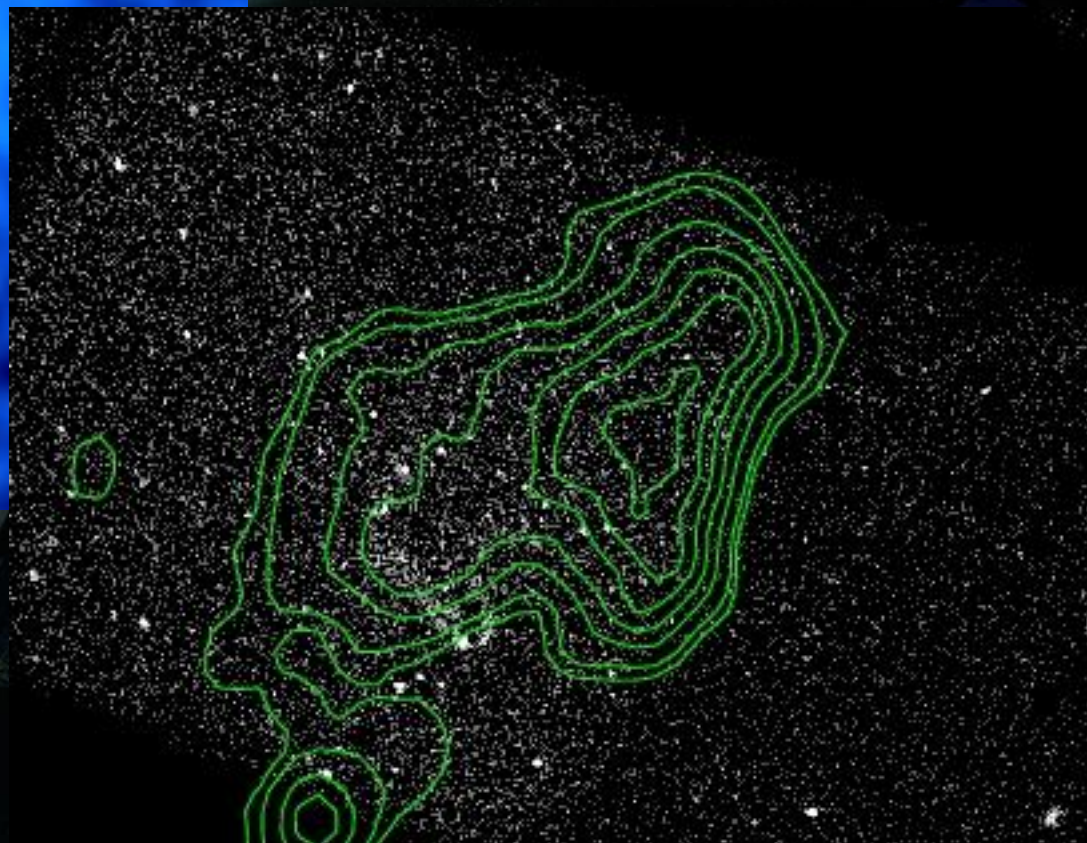






X-ray emission
significantly offset
wrt. radio PWN

moving PSR & relic PWN



X-ray properties of "gamma-ray only" PSRs: a first look

- 55 Fermi PSR with X-ray counterpart (15 radio-quiet)
- 49/55 have good X-ray data
- 42/49 have a reasonable distance estimate

non-thermal L_X vs. Erot

$F_\gamma/F_{X,\ non\text{-}th}$ vs Erot

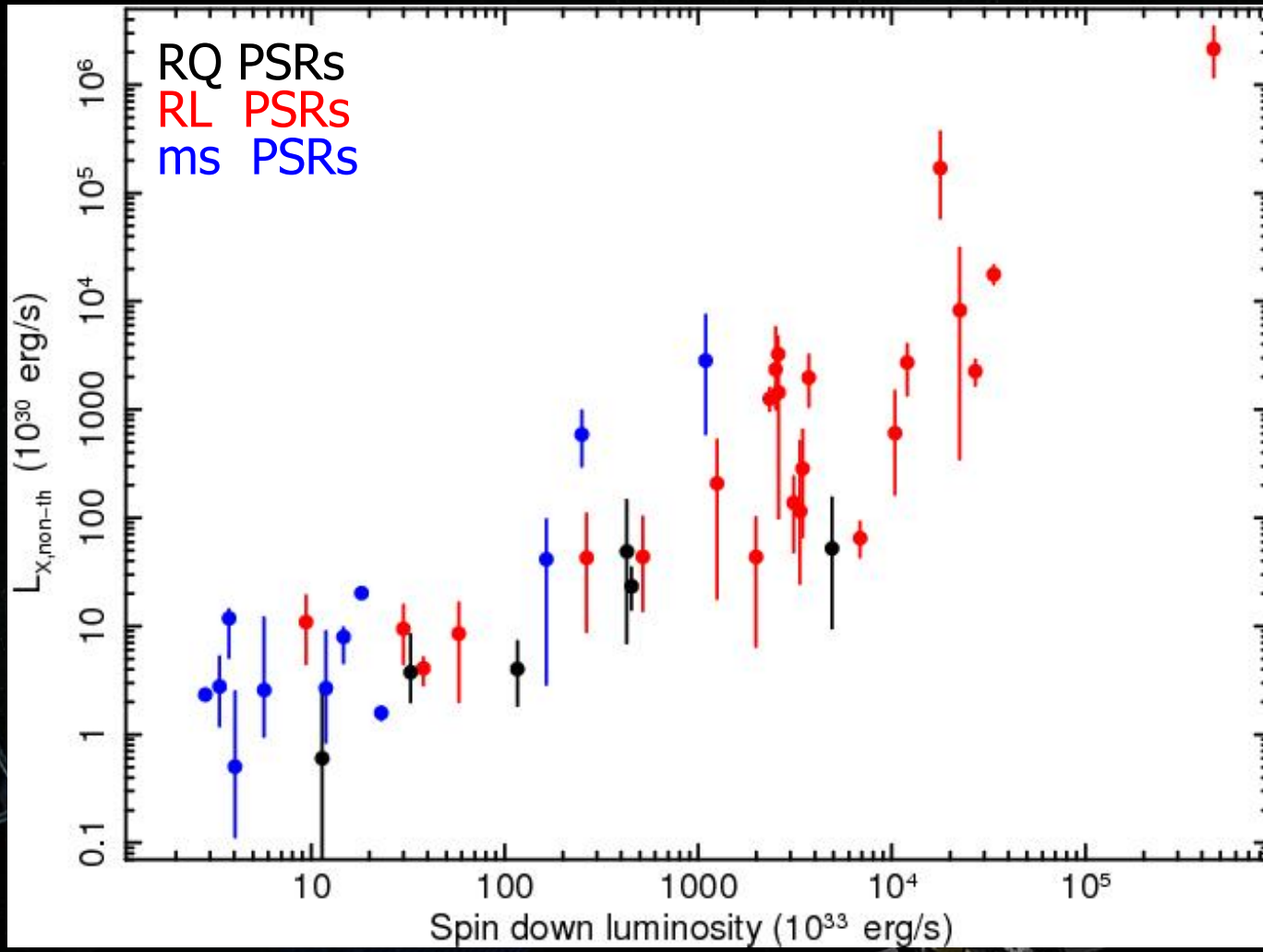
distance independent!

X-ray non-thermal luminosity vs. Erot

42 sources
good X-ray data,
'known' d

$L_X = f_X (4\pi F_X d^2)$
(f_X=1)

index = 1.04±0.09



Marelli et al., 2011, ApJ in press, arXiv:11

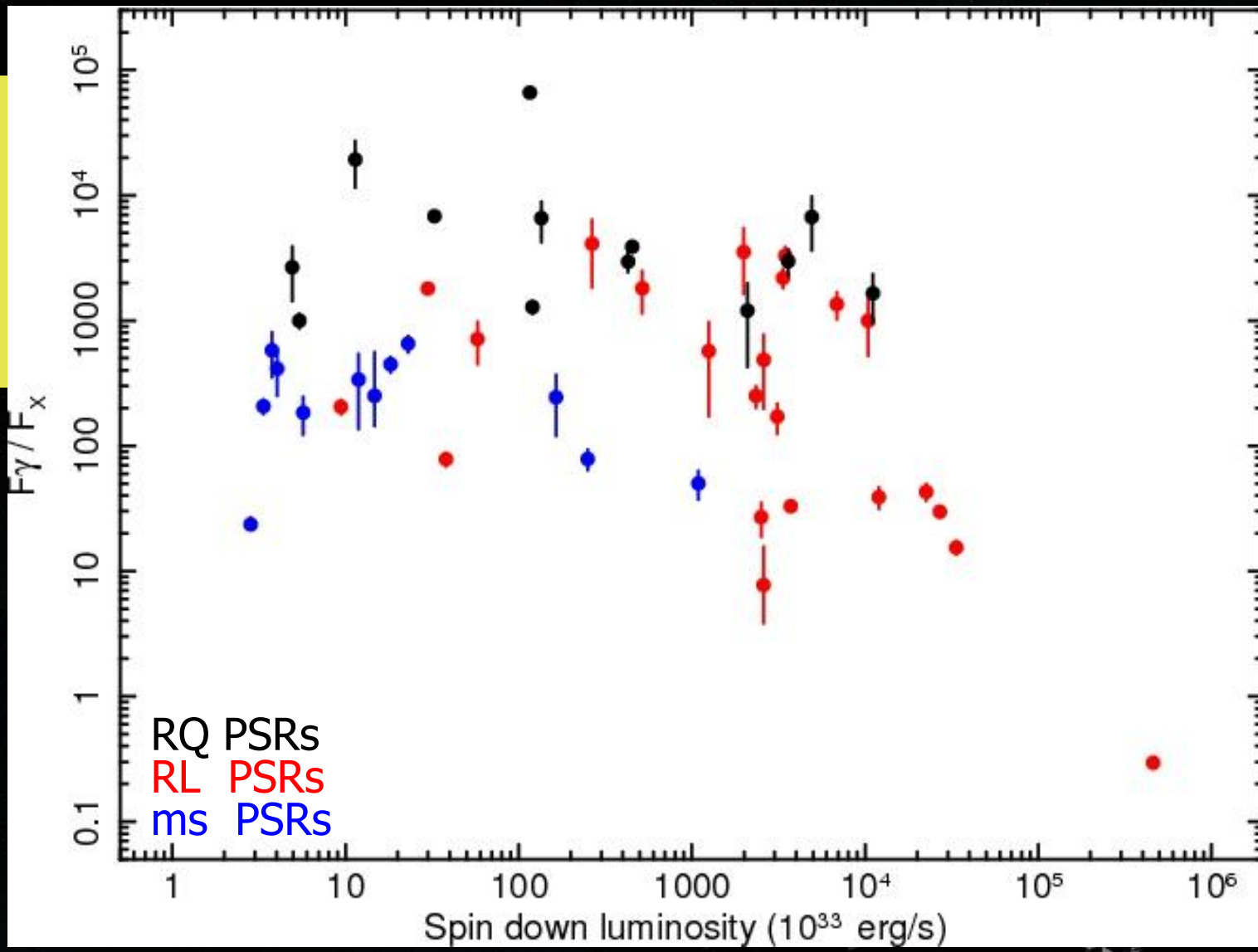
poster by M. Marelli

$F_\gamma / F_{X\ (non\text{-}th.)}$ vs. Erot

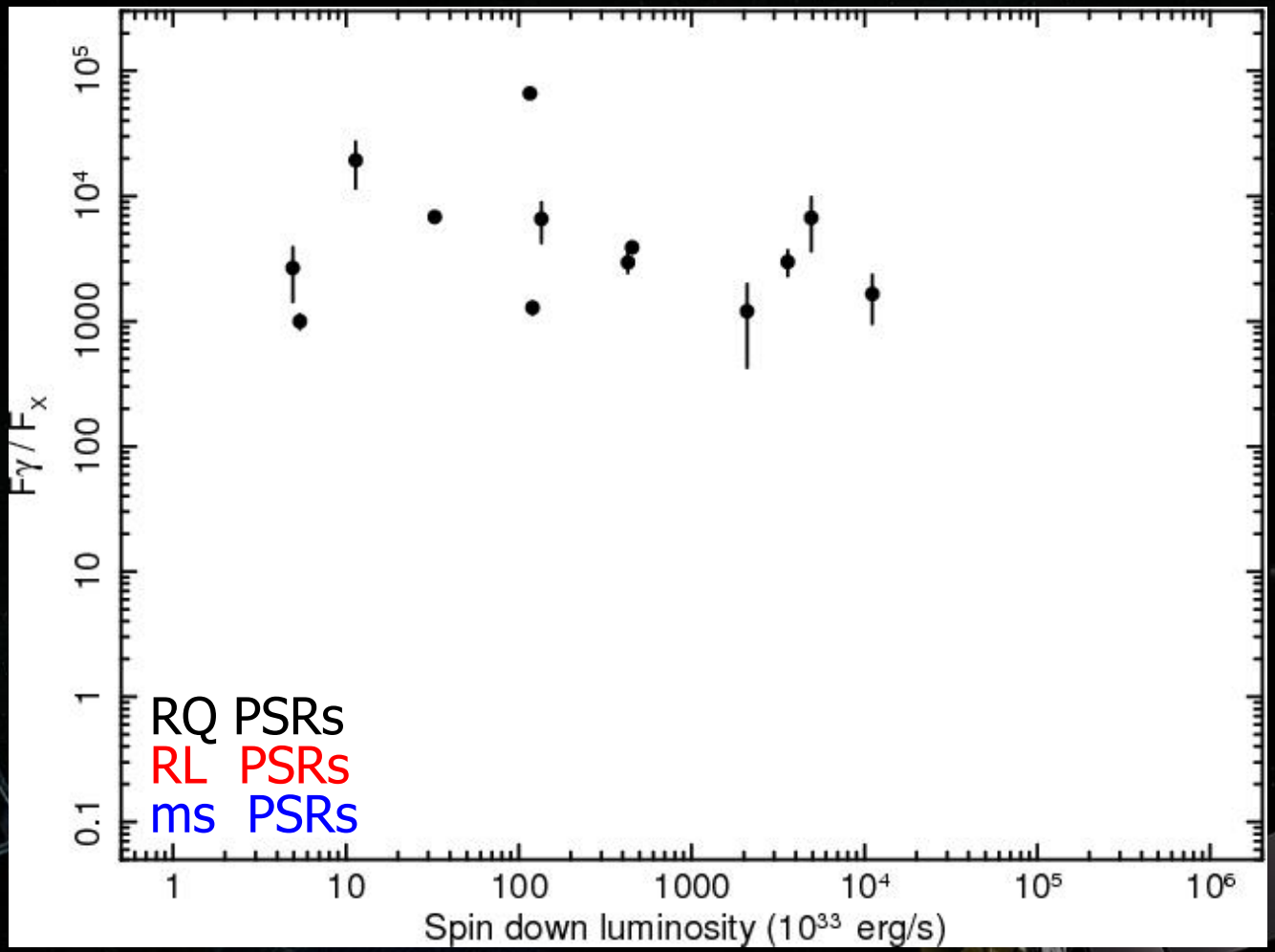
distance

independent

spread

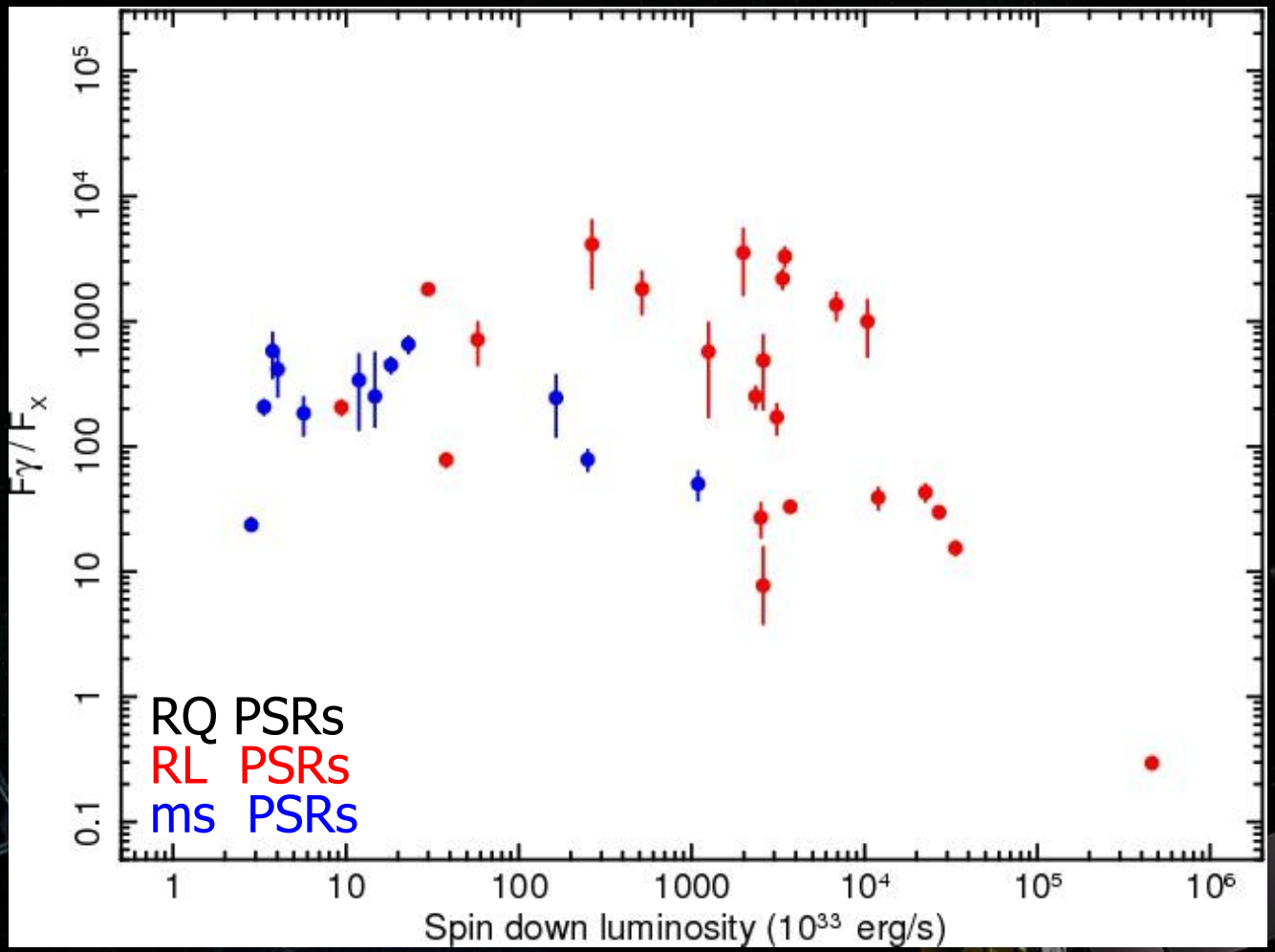


$F_\gamma / F_{X\ (non\text{-}th.)}$ vs. Erot



current sample of RQPSRs in the upper part

$F_\gamma / F_{X\ (non\text{-}th.)}$ vs. Erot



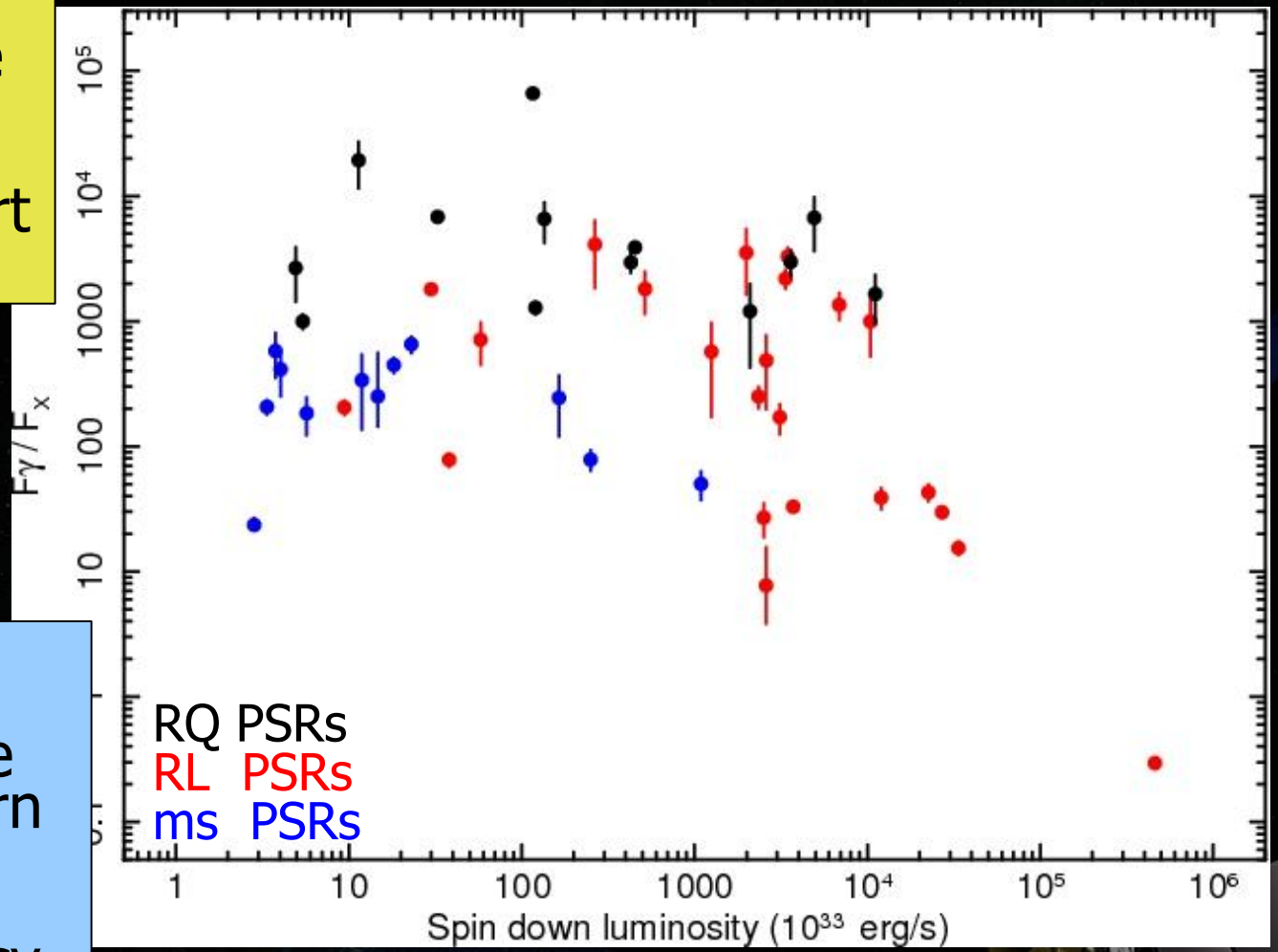
current sample
of RQPSRs
in the upper part

F_γ / $F_{X\ (non\text{-}th.)}$ vs. Erot

current sample
of RQ PSRs
in the upper part

beaming
&
efficiencies

our RQ PSRs:
more favorable
beaming pattern
and/or
higher efficiency
in γ-rays



The X-ray side

PSR J1135-6055
moving in a complex environment
with large-scale "jets"

PSR J0357+3205
nearby, looking older than its age
with a huge puzzling X-ray trail

RQ & RL PSRs follow the same L_X vs Erot trend

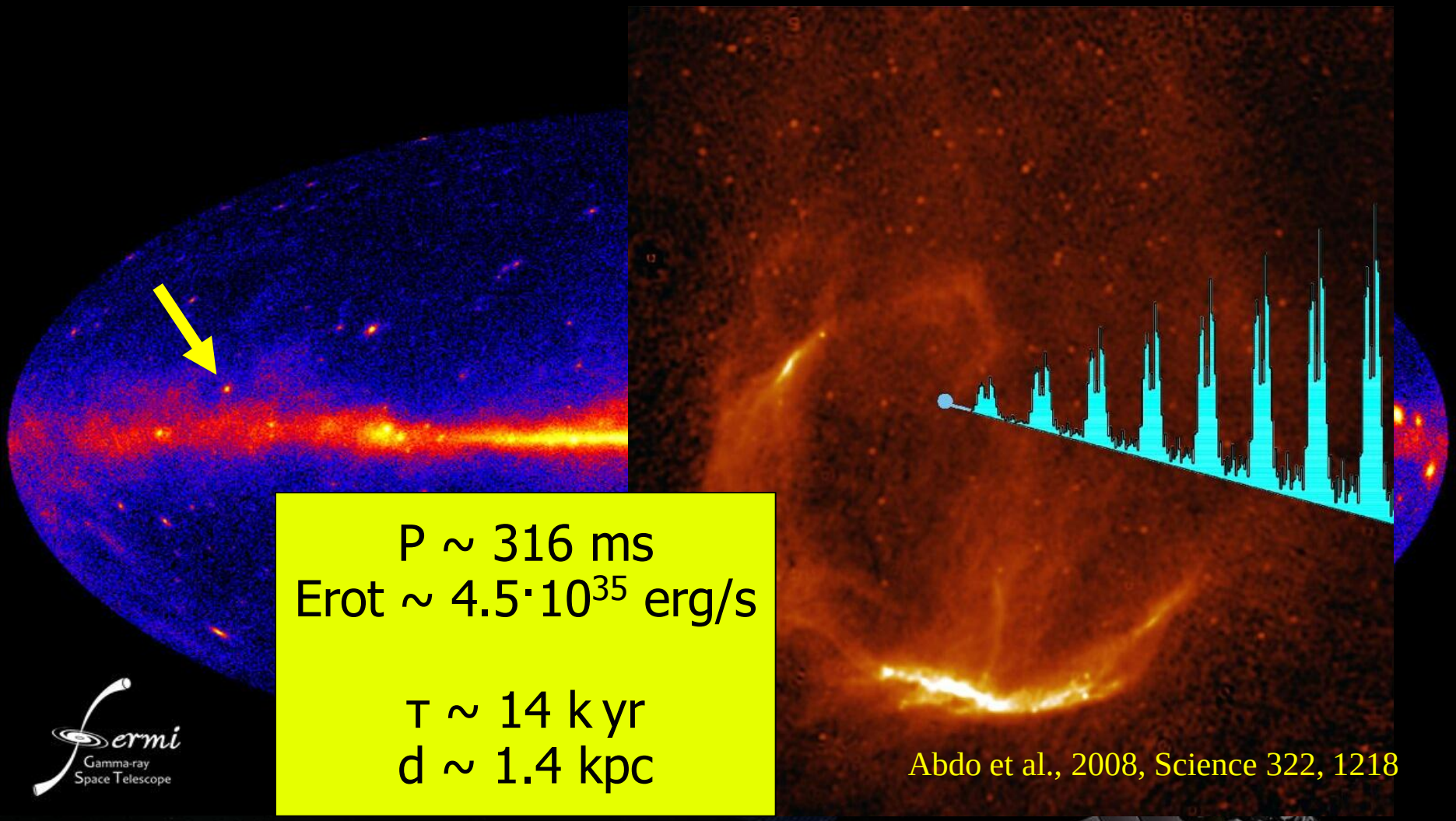
Factor 1000 scatter in distance-independent $F\gamma/F_X$

RQ PSRs: more favorable γ-ray beaming and/or efficiency

Geometry (and efficiency) affect
observed high energy phase-averaged fluxes
by orders of magnitude

Additional slides

The pulsar in the CTA-1 SNR



P ~ 316 ms
Erot ~ $4.5 \cdot 10^{35}$ erg/s

τ ~ 14 k yr
d ~ 1.4 kpc

Abdo et al., 2008, Science 322, 1218

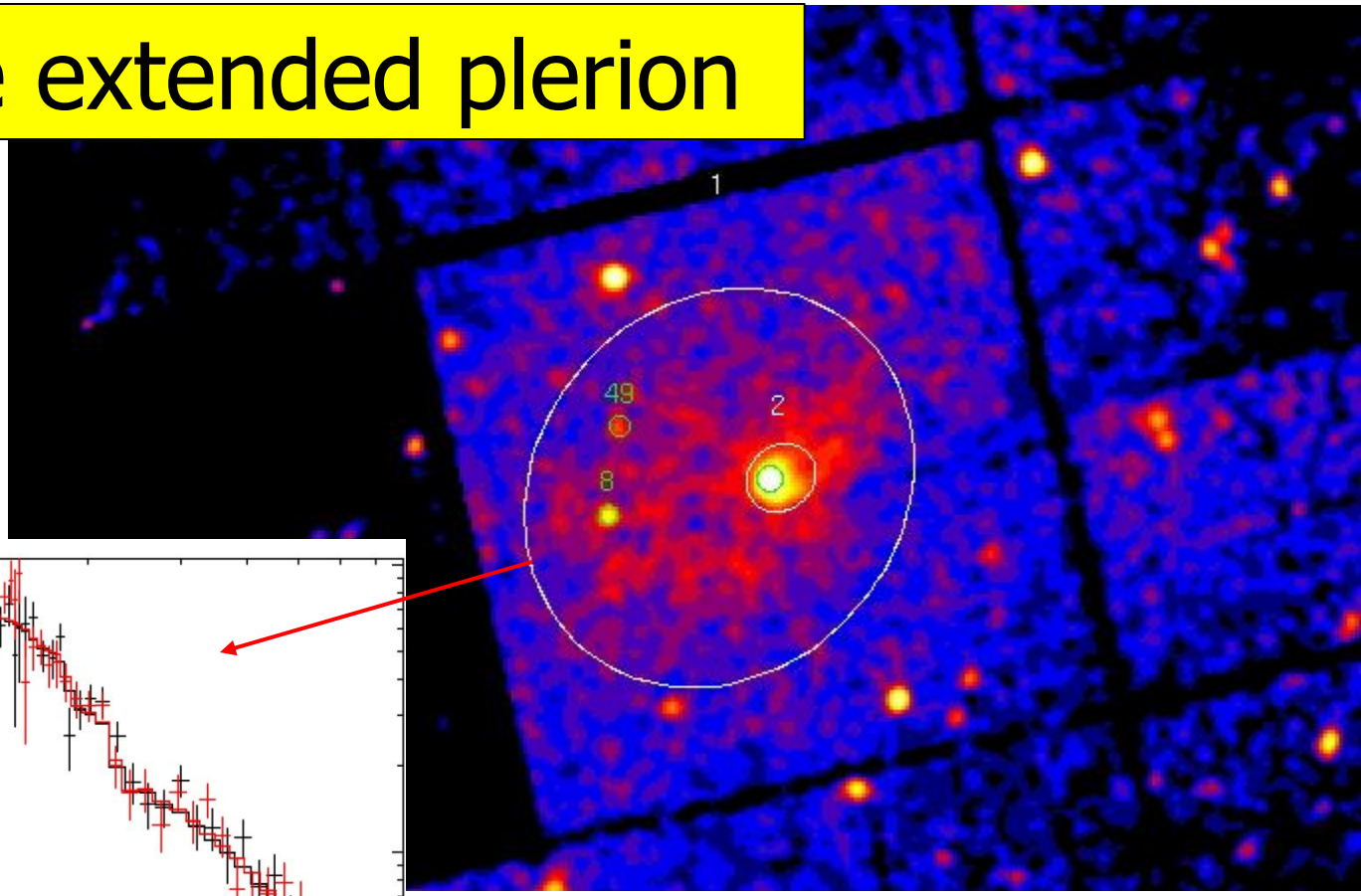
Fermi Gamma-ray Space Telescope

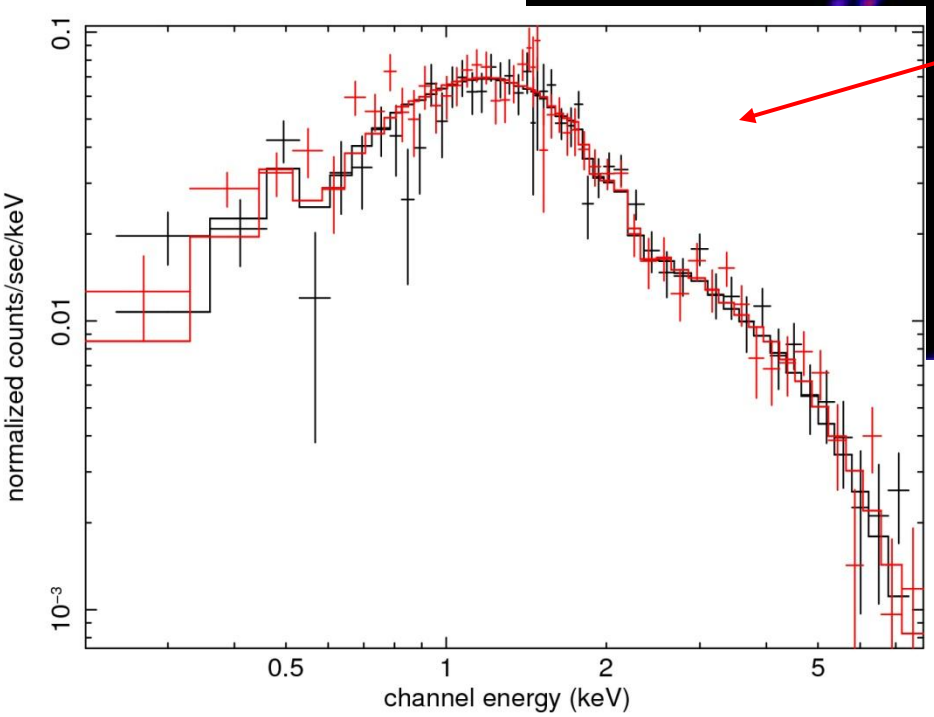
130 ks XMM-Newton observation

CTA1: The extended plerion

Already seen by ROSAT & ASCA

(Seward et al.1995, Slane et al.1997)



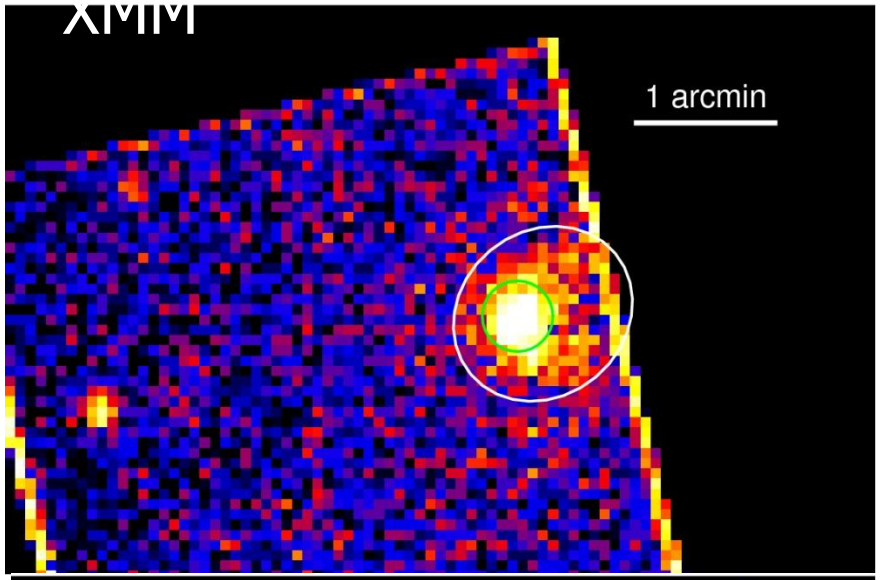


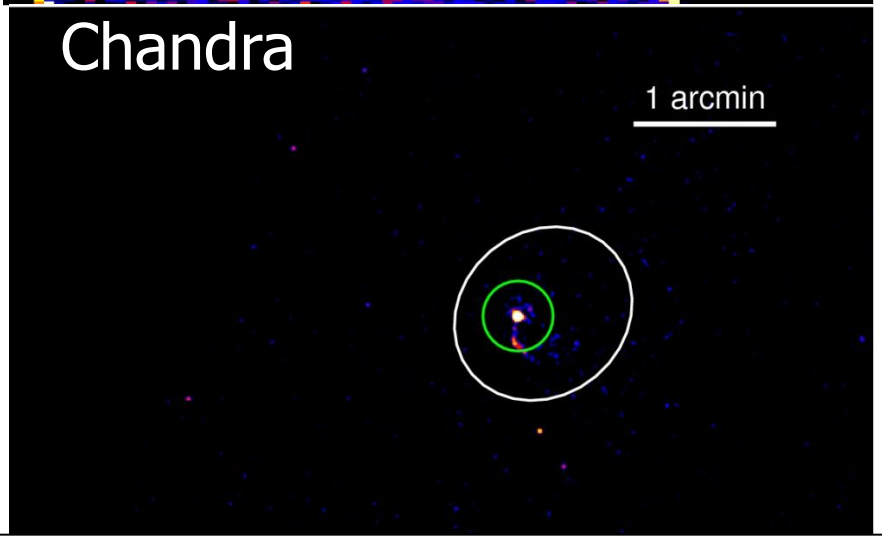
No significant thermal component within EPIC FOV

Spectrum steepens with radius

Caraveo et al., 2010, ApJ subm.

A deep XMM-Newton observation





Caraveo et al., 2010, ApJ subm.

Discriminating PSR from PWN

Spatial-spectral deconvolution

Simultaneous spectral fit using different EEF coefficients for PSR and PWN

PSR (point-like) ~ EPIC PSF

PWN (diffuse) ~ Chandra map

PSR: BB+PL

kT~0.1 keV, r~650 m

Γ~1.3

Inner PWN: PL

Γ~1.5

Obs.flux $1.3 \cdot 10^{-13}$ erg cm^{-2} s^{-1} (0.3-10 keV) 60% PSR, 40% PWN

PSR: 20% th, 80% non-th

X-ray pulsations

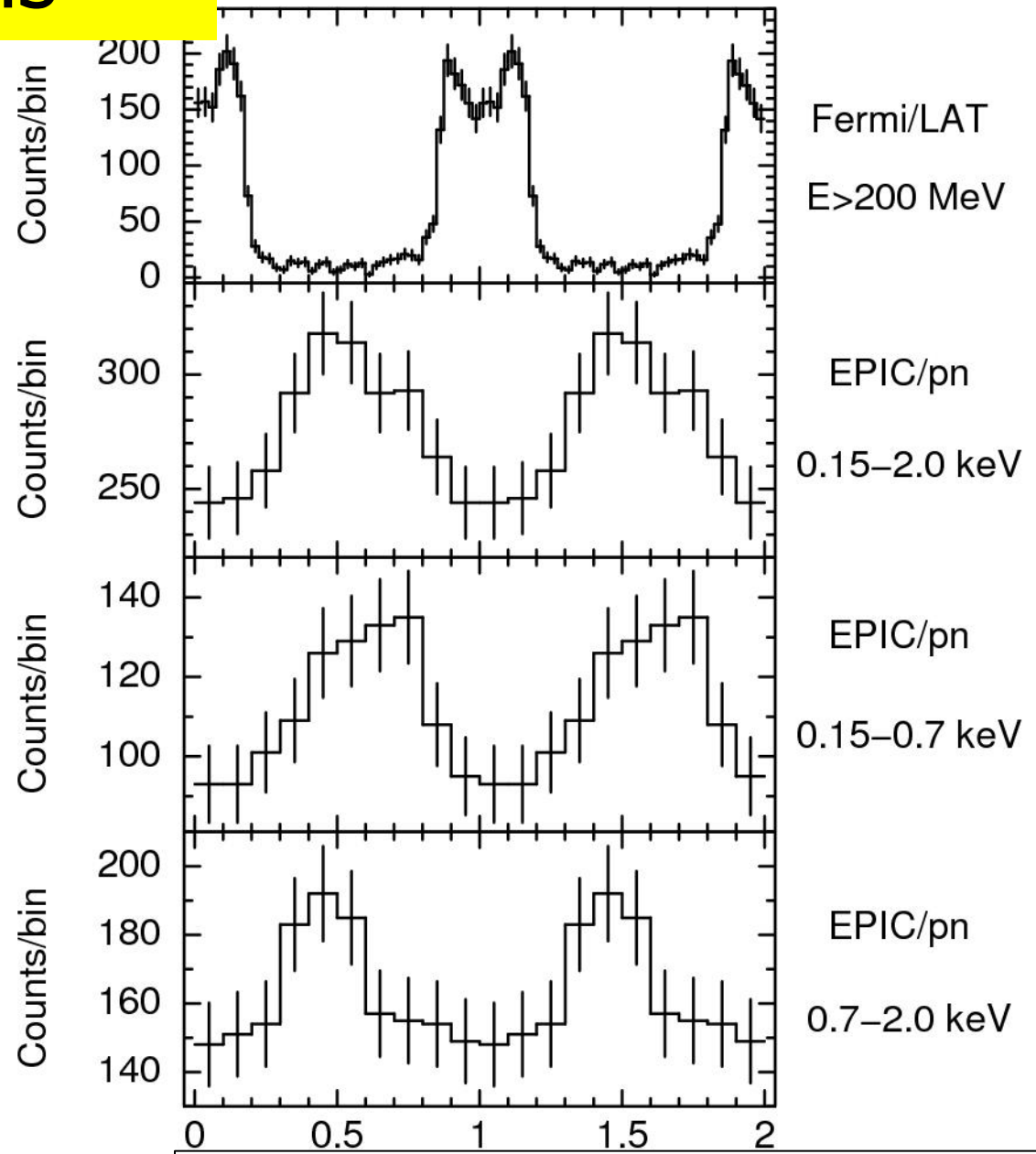
130 ks XMM not enough to detect pulsation in blind search!

Folding with LAT ephemeris

~80% pulsation below 0.7 keV

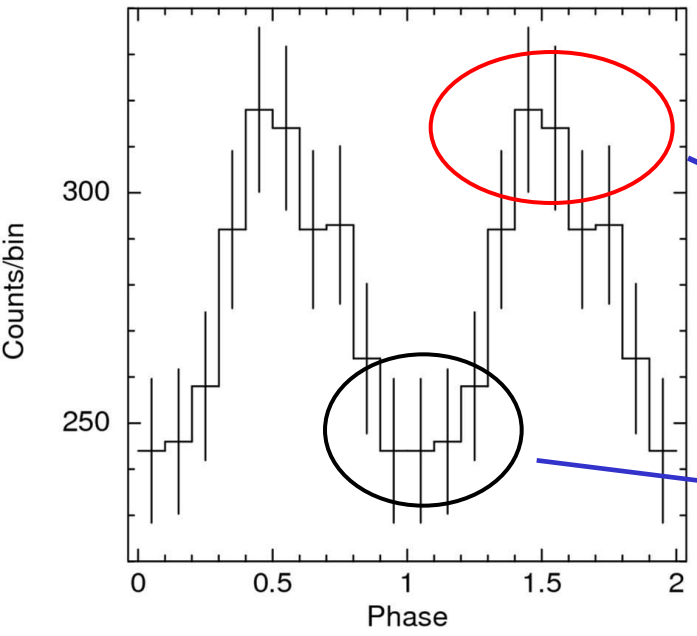
No evidence for modulation at E > 2 keV

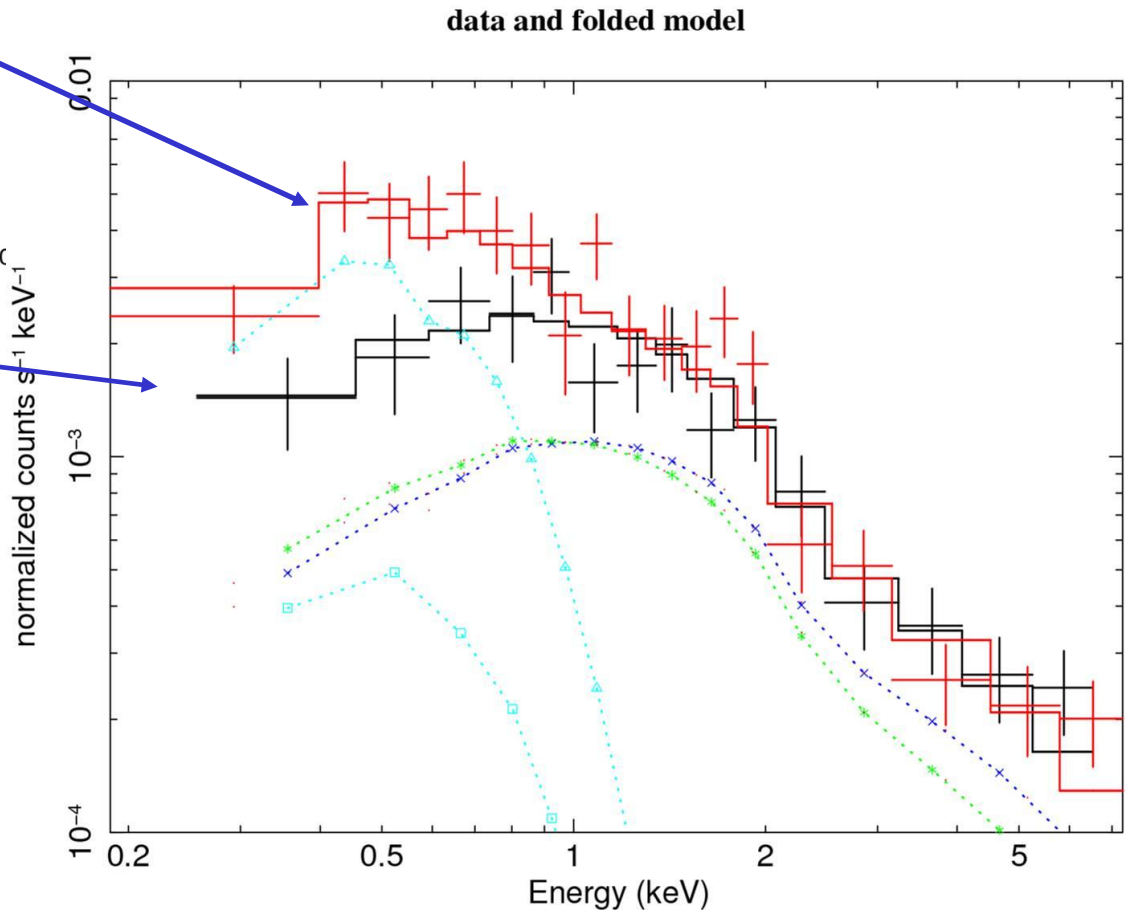
0.5 phase difference wrt γ-ray peak



Caraveo et al., 2010, ApJ subm.

Thermal pulsation !



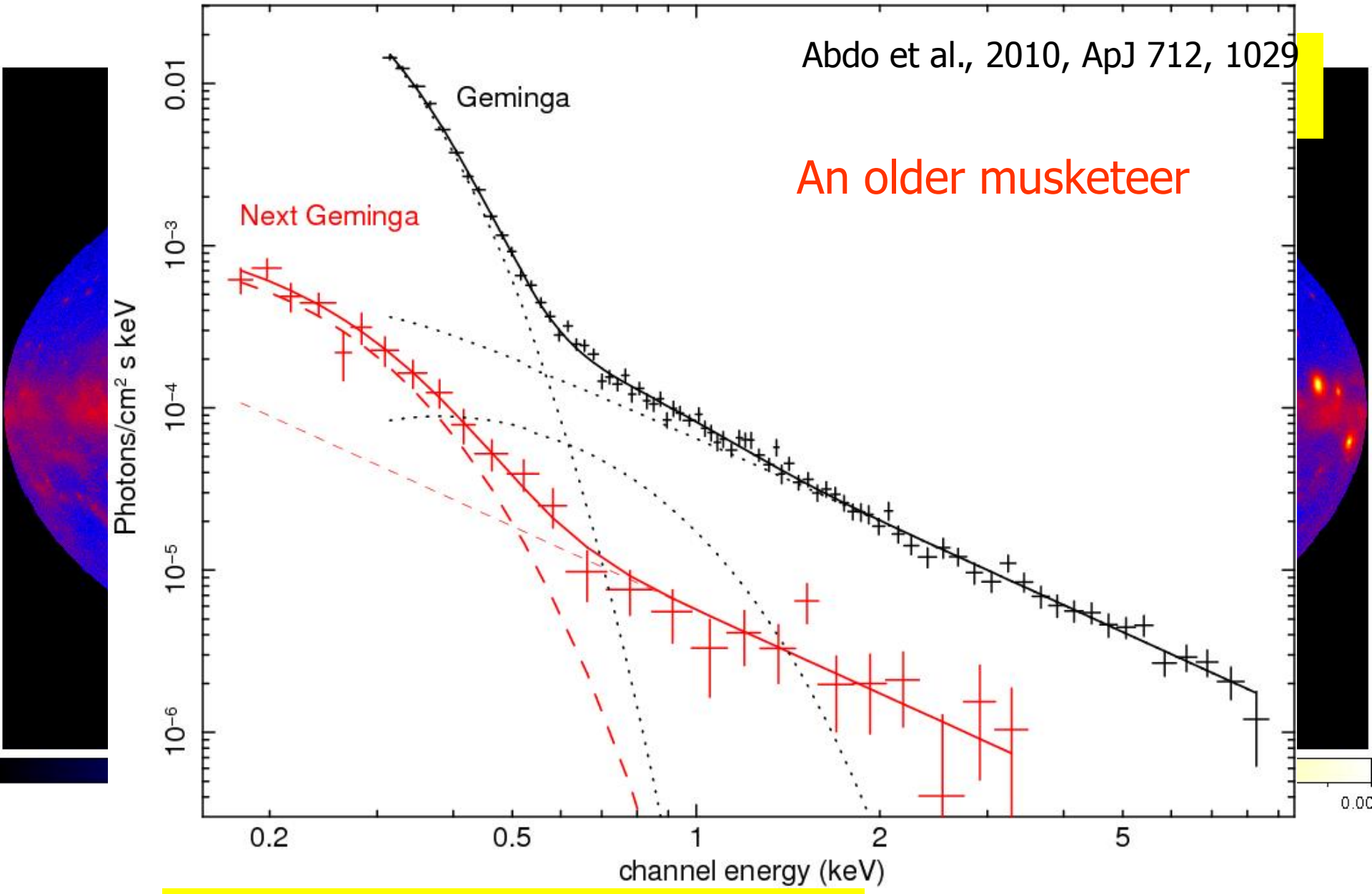


Spectral evolution best described by ~100% modulation of BB component

rotating hot spot
as seen in the "Three musketeers"

Caraveo et al., 2010, ApJ subm.

3EG J1835+5918 a.k.a. "Next Geminga"

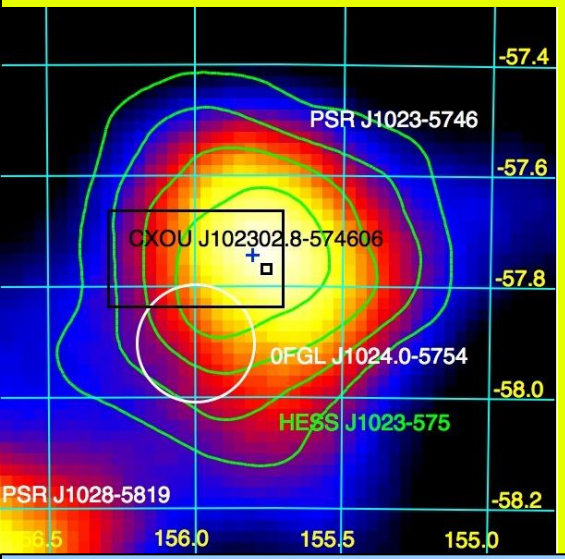


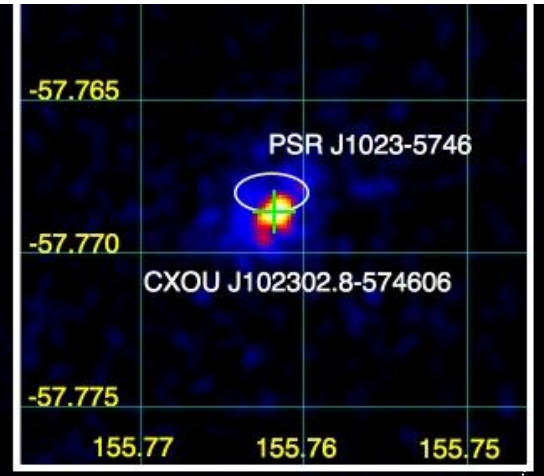
The high Erot side: PSR J1023-5746

Erot ~ $1.1 \cdot 10^{37}$ erg/s

Serendipitous detection
Chandra (Vesterlund 2)

HESS source





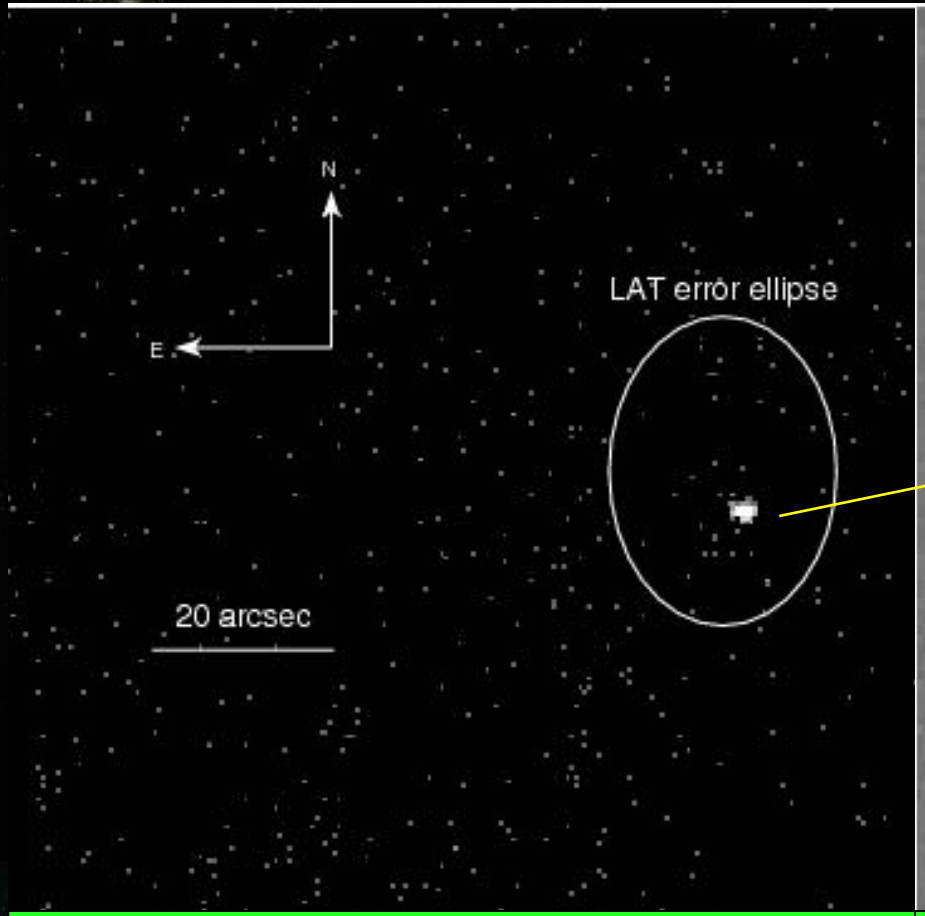
CXOU J102302.8-574606

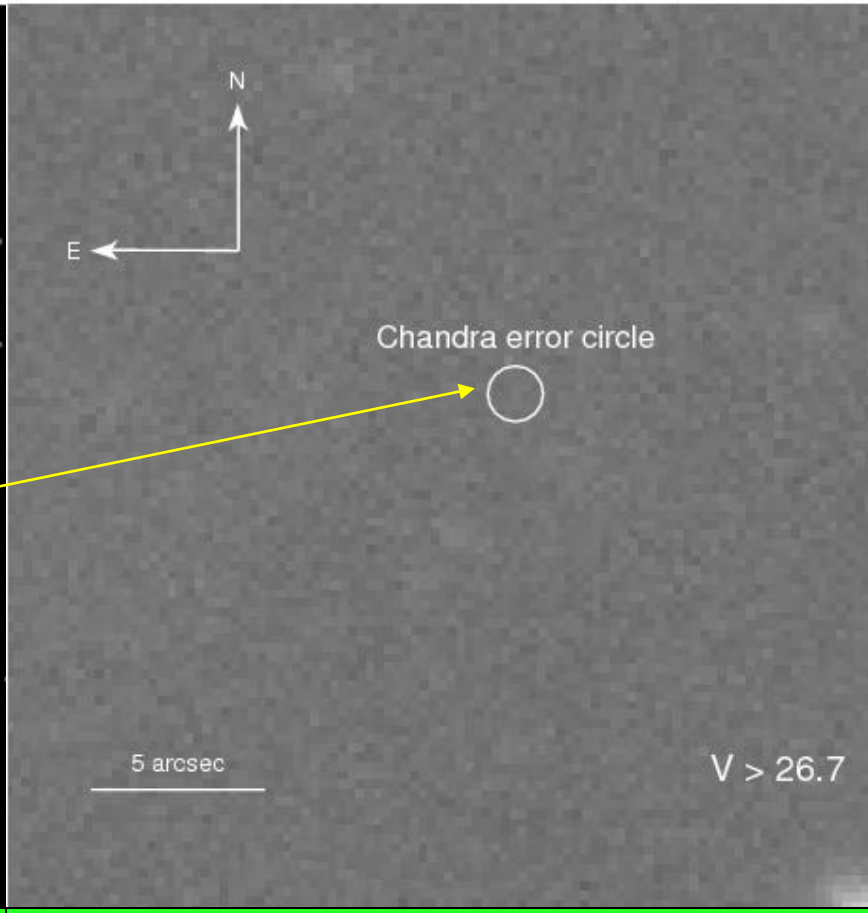
8 arcmin

Saz Parkinson et al., 2010, ApJ subm.

impossible to disentangle PSR/PWN	power law Γ~ 1.2 NH ~ $1.5 \cdot 10^{22}$ cm^{-2}	unknown distance (possibly very far)

The X-ray counterpart





Chandra (77 ks)

NOAO/KPNO 4m (4 hr)

De Luca et al., 2011, ApJ in press, arXiv:1102.3278

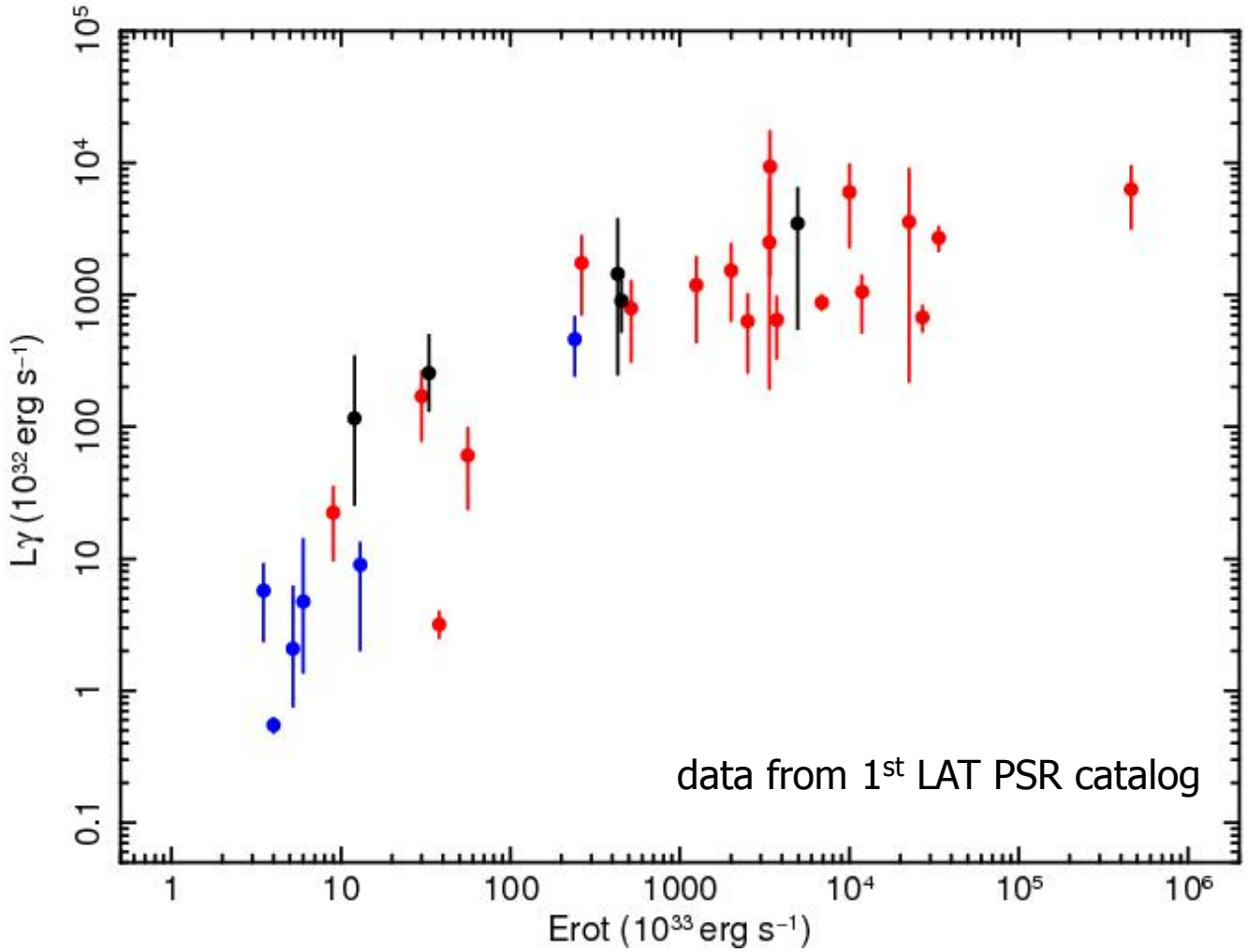
Gamma-ray luminosity vs. Erot

same sources as before

$L_\gamma = f_\gamma (4\pi F_\gamma d^2)$
$(f_\gamma=1)$

$E_{rot} < 3 \cdot 10^{35}$
index = 1.4±0.2

$E_{rot} > 3 \cdot 10^{35}$
index = 0.2±0.2

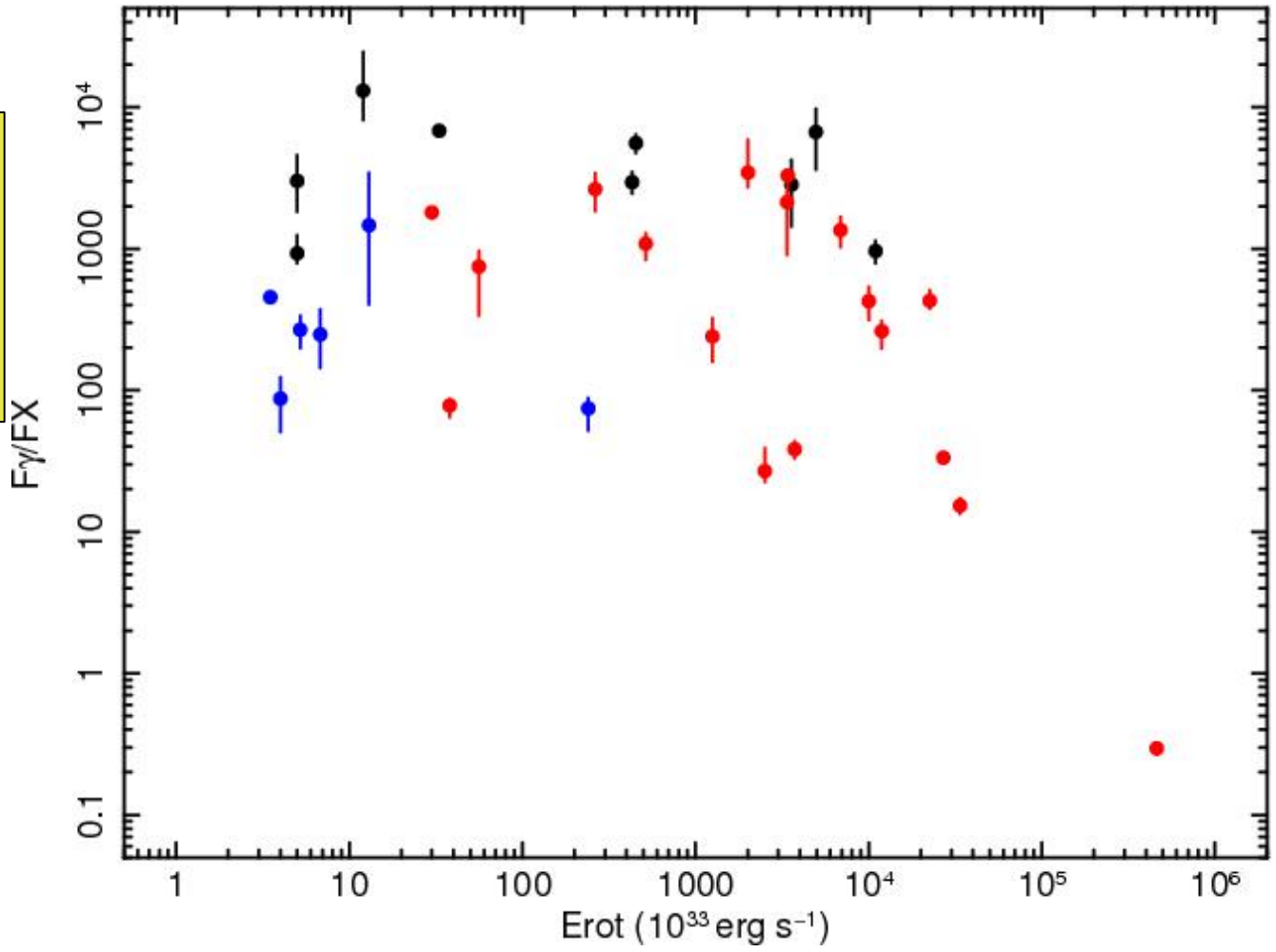


RQ PSRs
RL PSRs
ms PSRs

Marelli et al., 2010, ApJ subm.

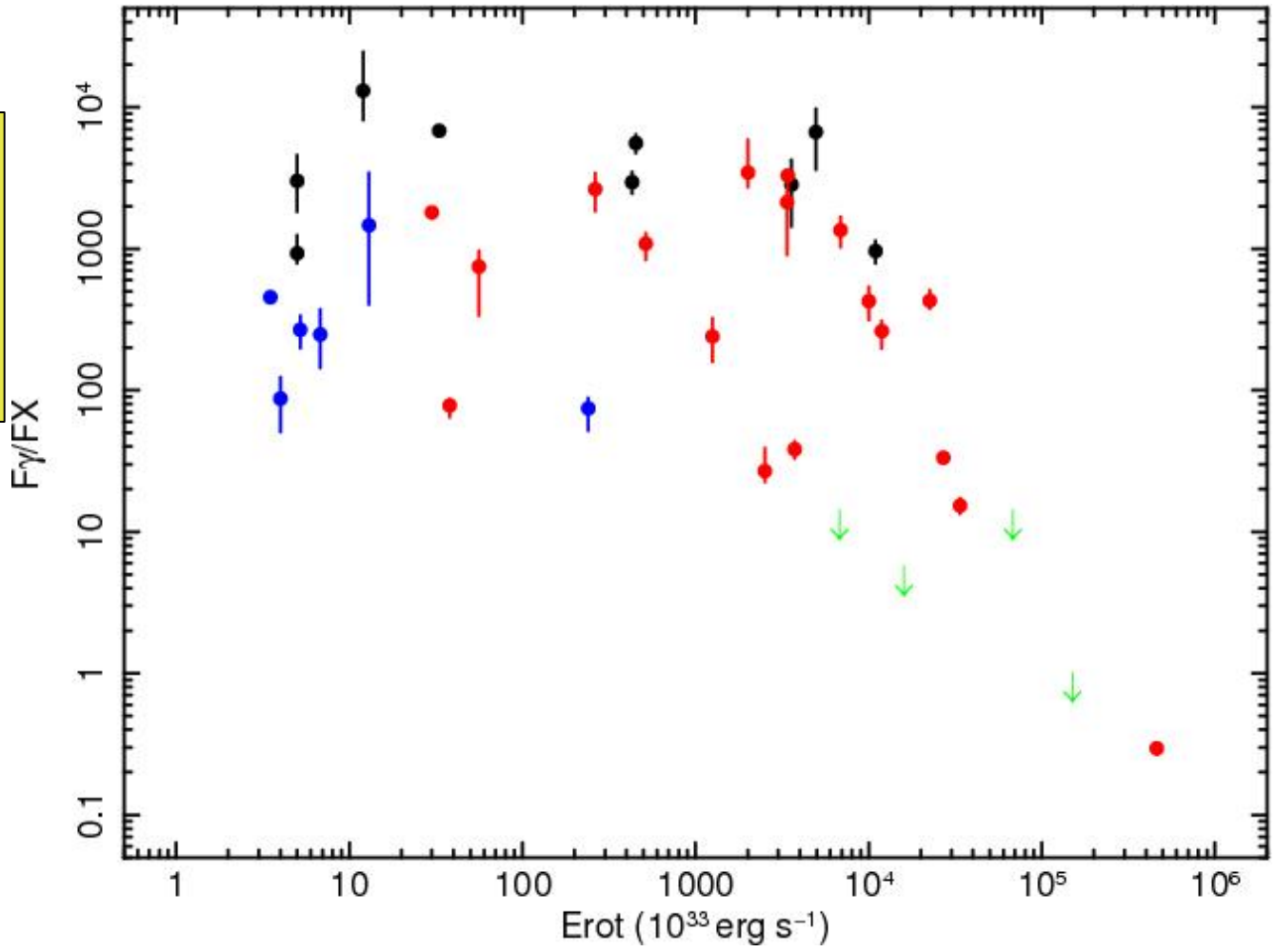
F_γ / $F_{X\ (non\text{-}th.)}$ vs. Erot

Any evolution with Erot ?



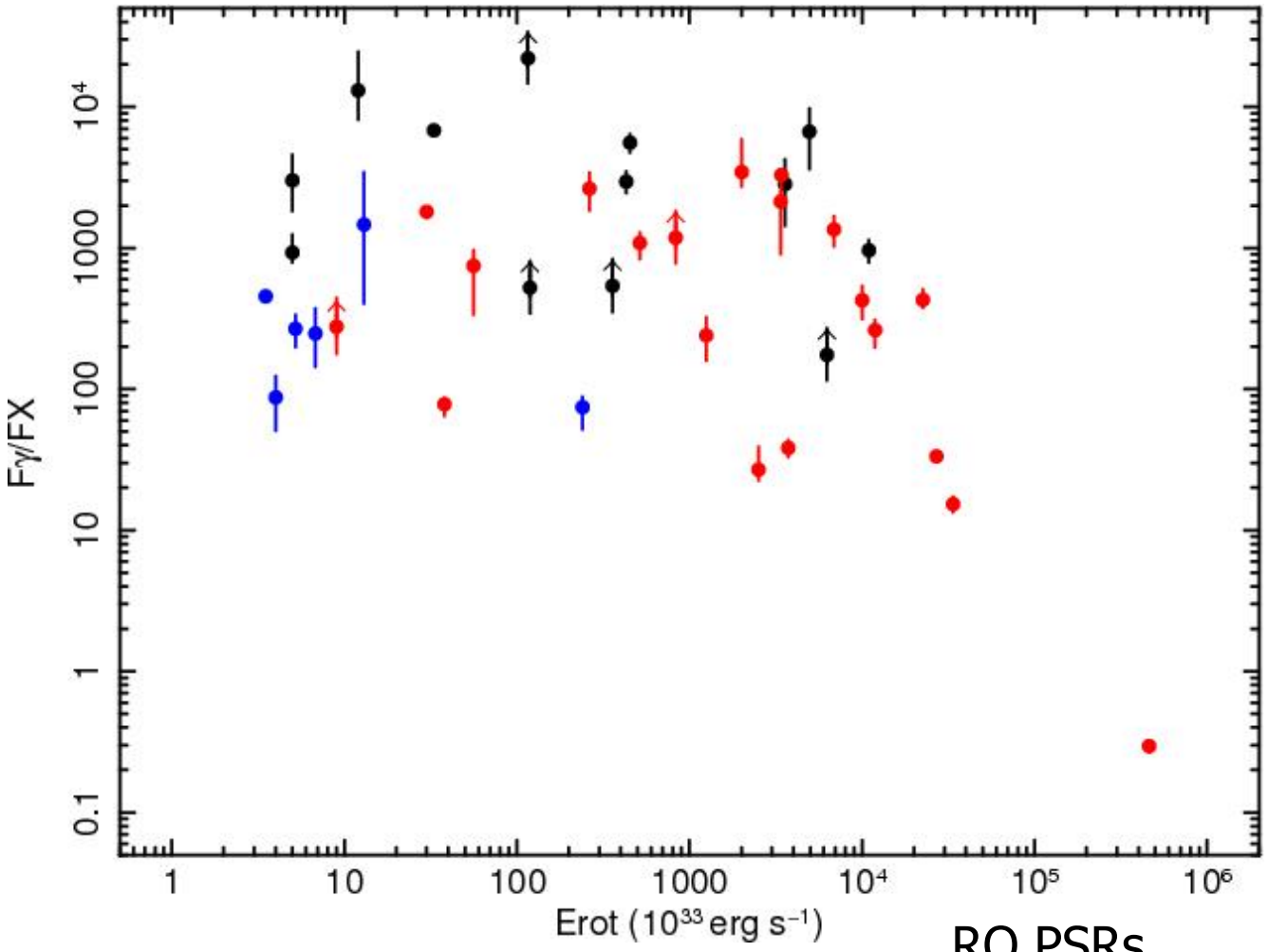
F_γ / $F_{X\ (non\text{-}th.)}$ vs. Erot

Or,
selection effects?



$F_\gamma / F_{X\ (non\text{-}th.)}$ vs. Erot

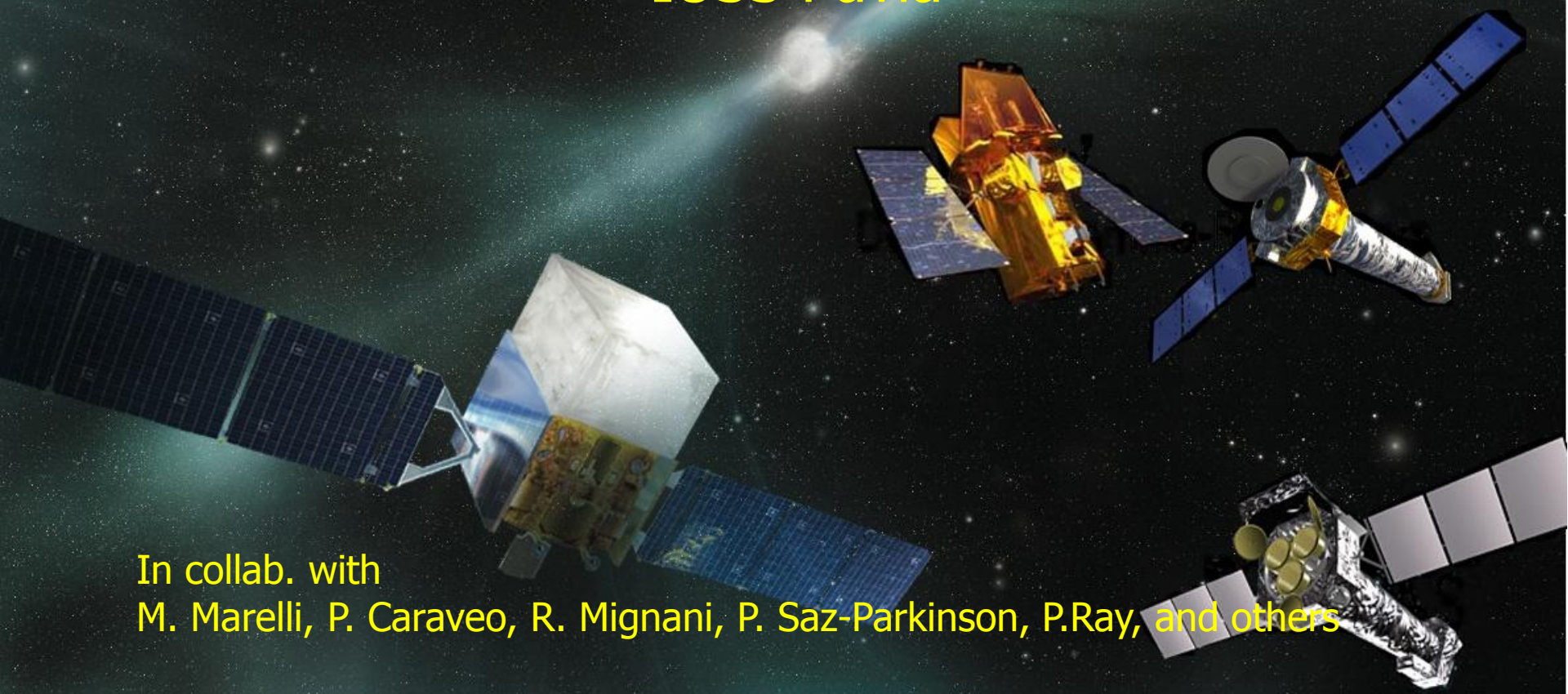
distance independent spread



RQ PSRs
RL PSRs
ms PSRs

X-ray observations of "gamma-ray only" PSRs

Andrea De Luca
IUSS Pavia



In collab. with
M. Marelli, P. Caraveo, R. Mignani, P. Saz-Parkinson, P.Ray, and others