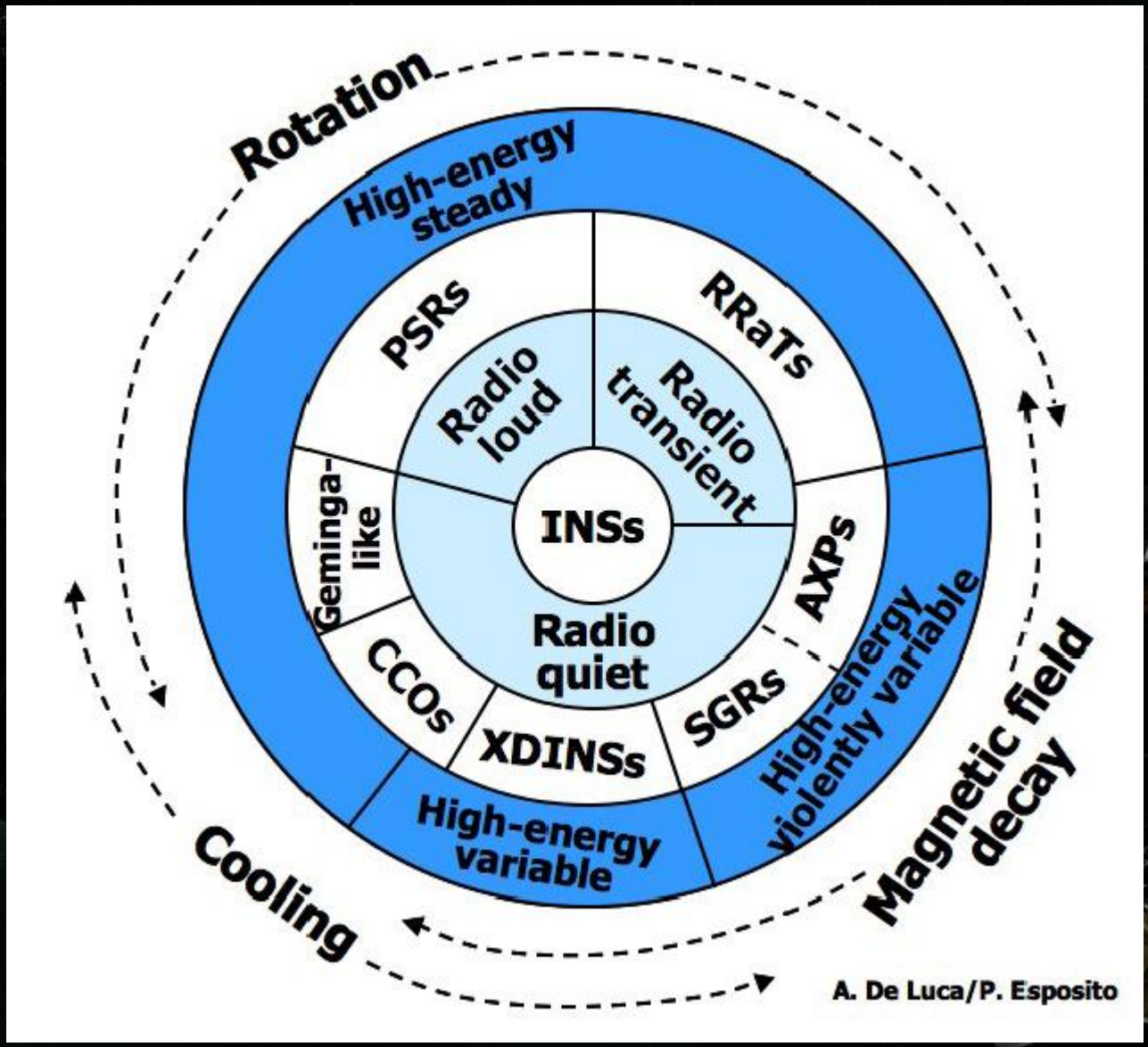
X-ray observations of "gamma-ray only" PSRs

Andrea De Luca

Astro-siesta , 2011/05/19

Pulsars in the isolated NS family



Rotation-powered emission

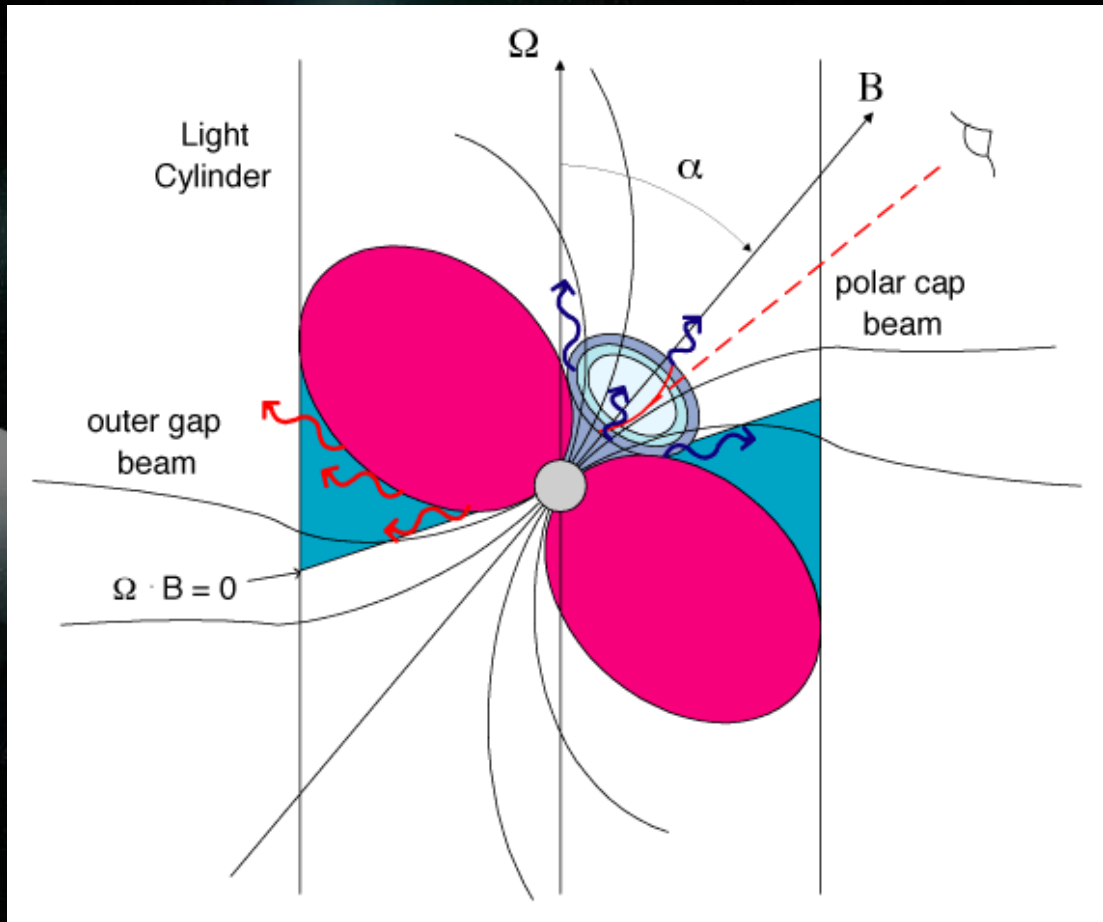
P, Pdot & rotating dipoles

PSRs as rotating, magnetized NS s radiating at the expense of rotational energy

Erot = 10^{28}-10^{38} erg/s

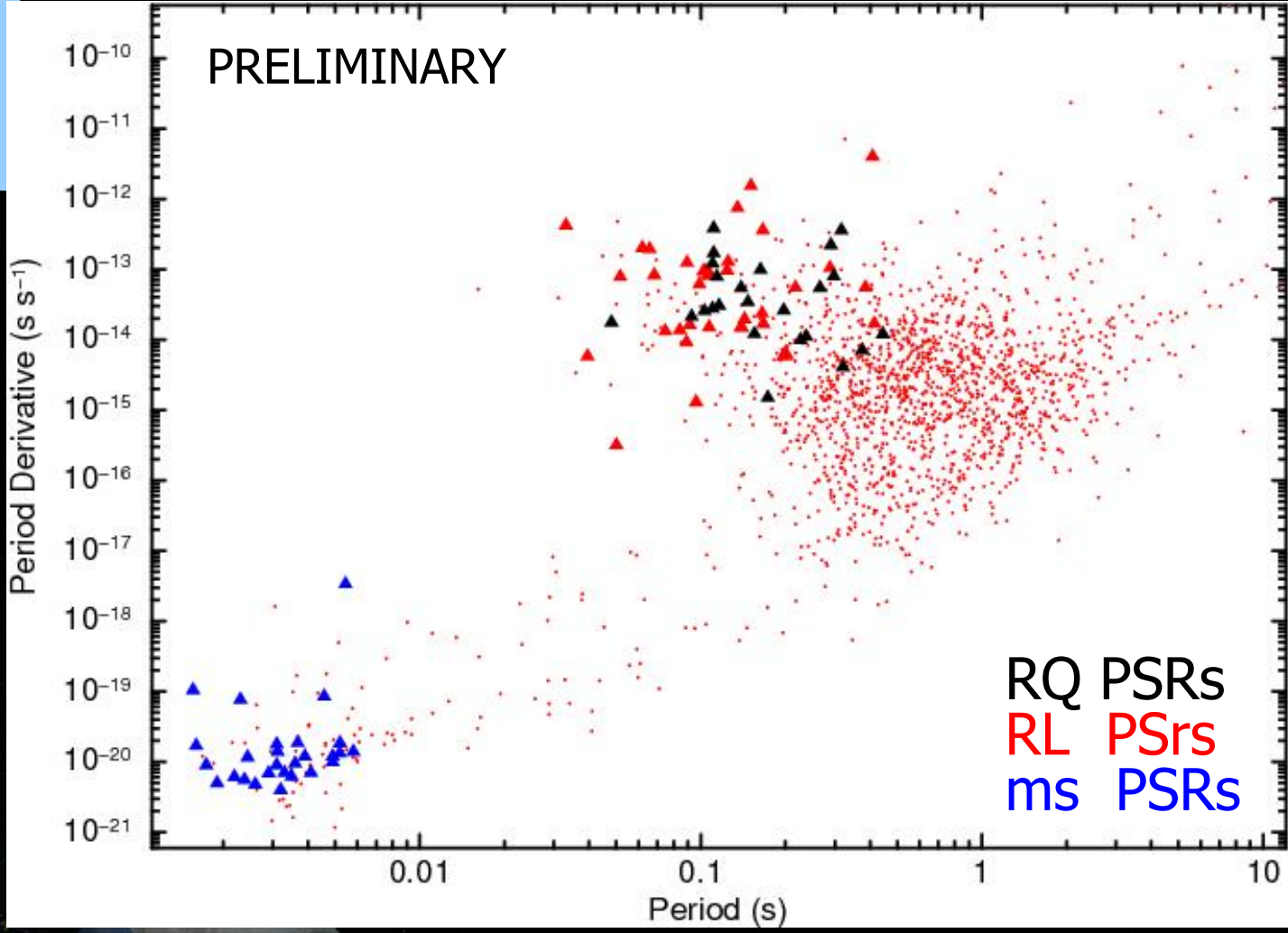
Efficiency $\eta_i = L_i / E_{rot}$
$\eta_{radio} = 10^{-6}$
$\eta_X = 10^{-3}$
$\eta\gamma = 10^{-1}$

Pulsar engine not yet understood



Fermi/LAT PSR sample

2011, May



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

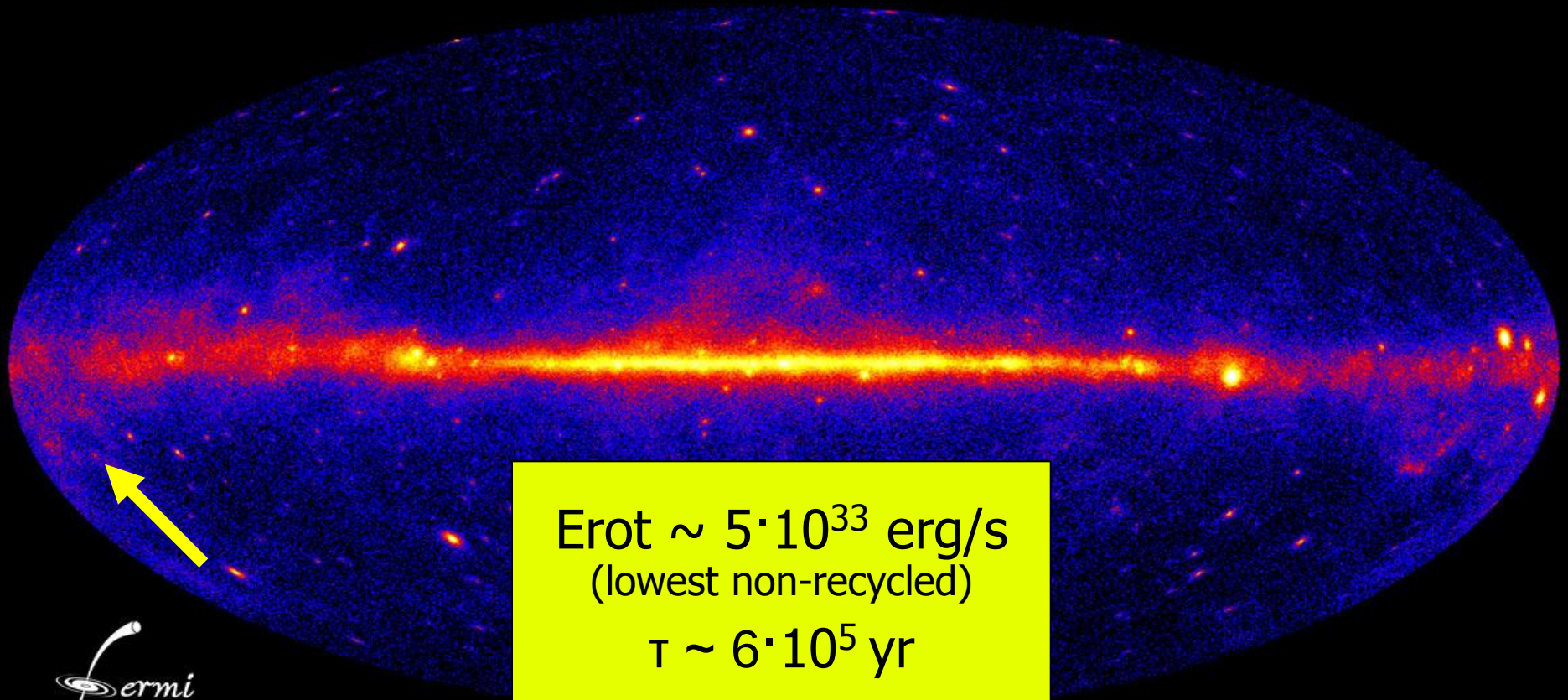
X-ray emission properties of LAT PSRs

RQ vs. RL

Highlights on 2 interesting PSRs

First look at the overall properties of the sample

The low Erot side: PSR J0357+32



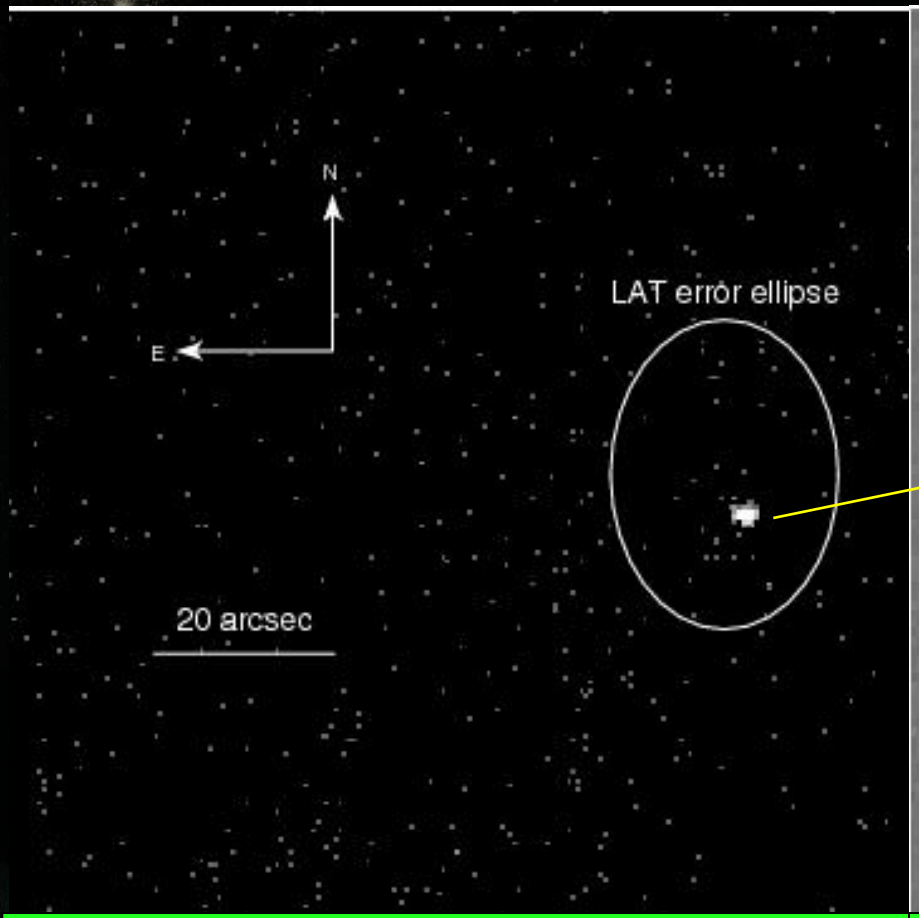
$E_{rot} \sim 5 \cdot 10^{33}$ erg/s
(lowest non-recycled)

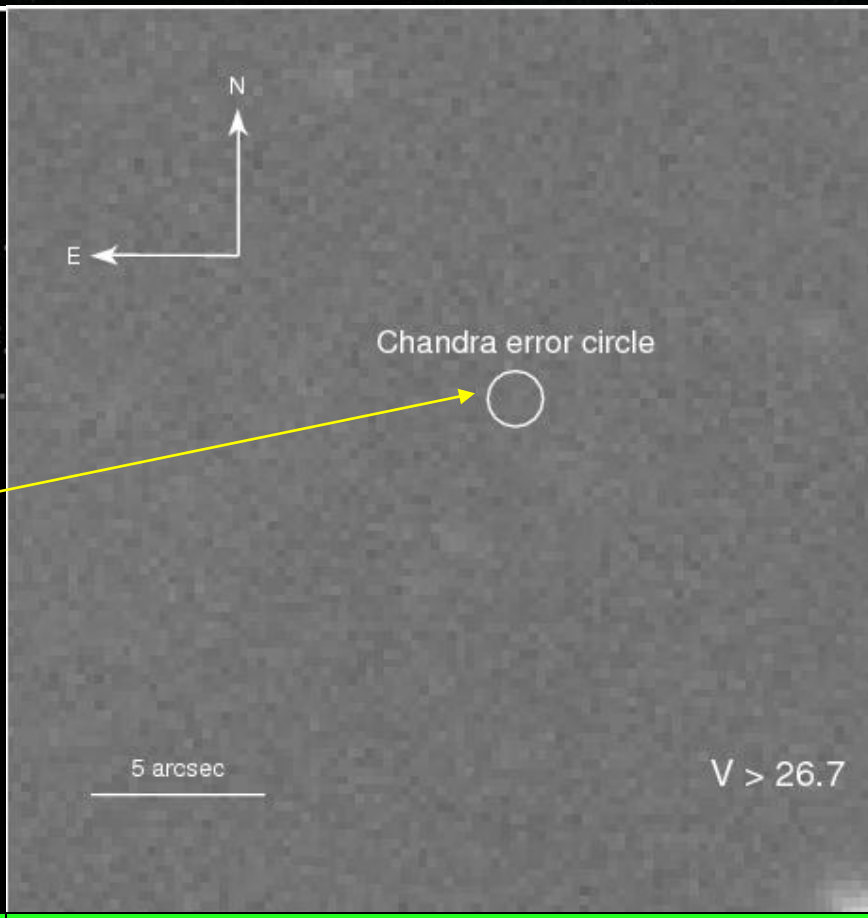
$\tau \sim 6 \cdot 10^{5}$ yr

A middle-aged PSR

Fermi Gamma-ray Space Telescope

The X-ray counterpart



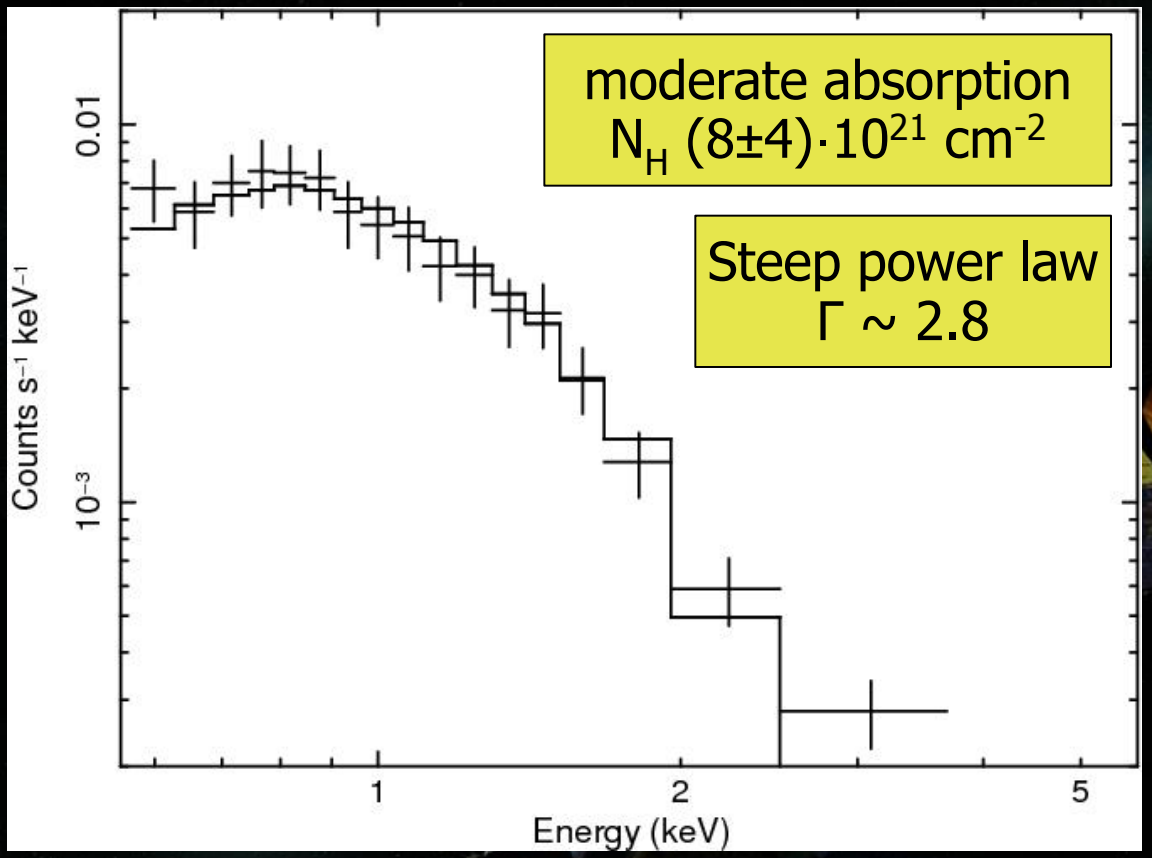


Chandra (77 ks)

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

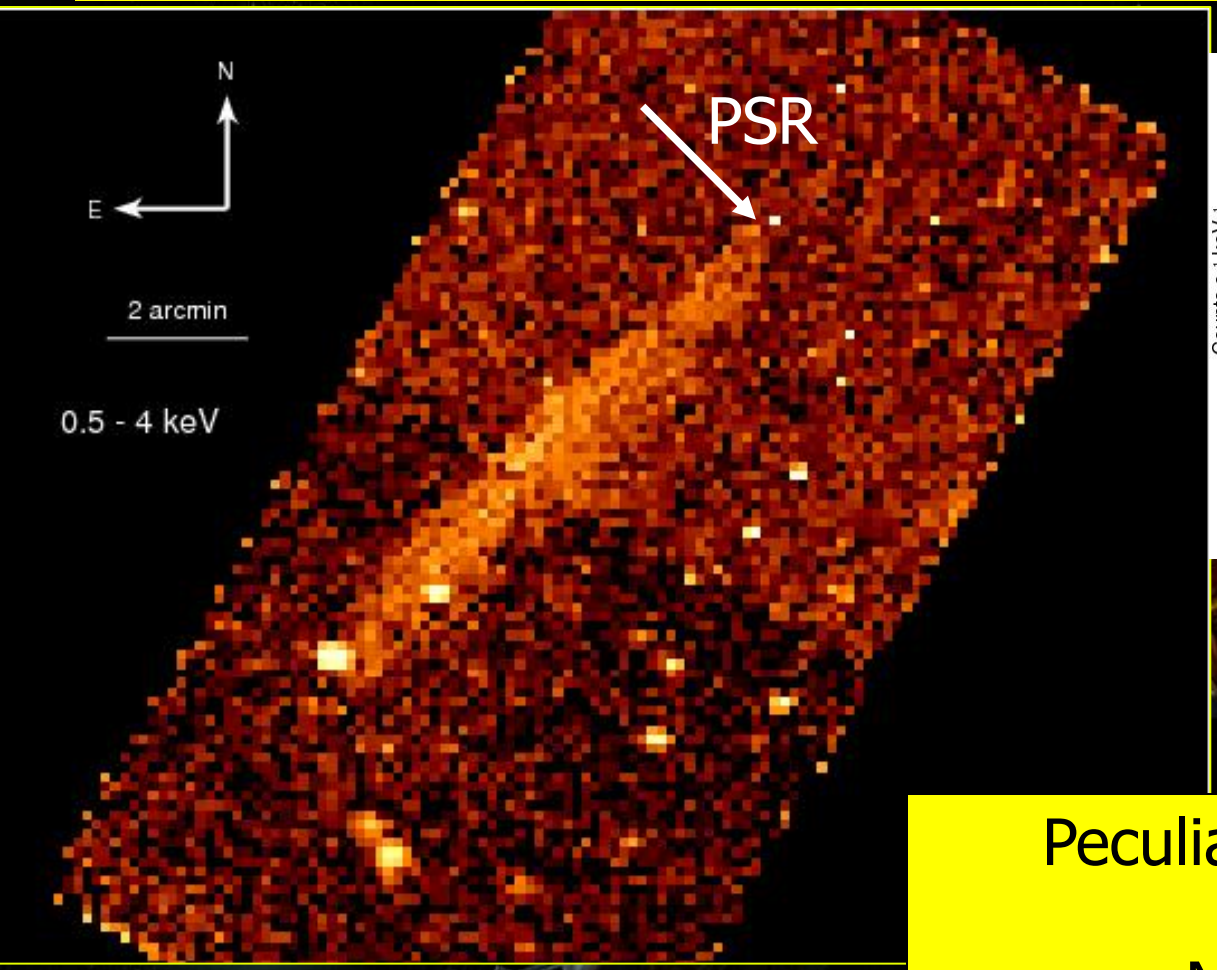
Unabsorbed flux
$F \sim 5.5 \cdot 10^{-14}$ erg cm^{-2} s^{-1}
(0.5-10 keV)

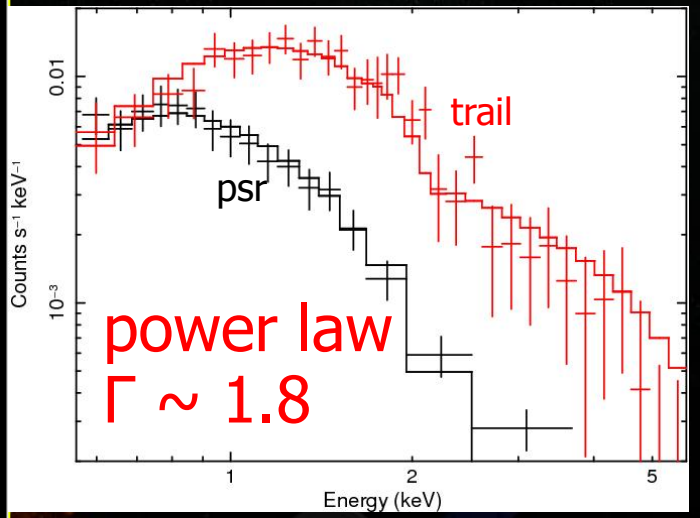
X-ray efficiency
$\eta_X \sim 2 \cdot 10^{-4}$
@500 pc

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

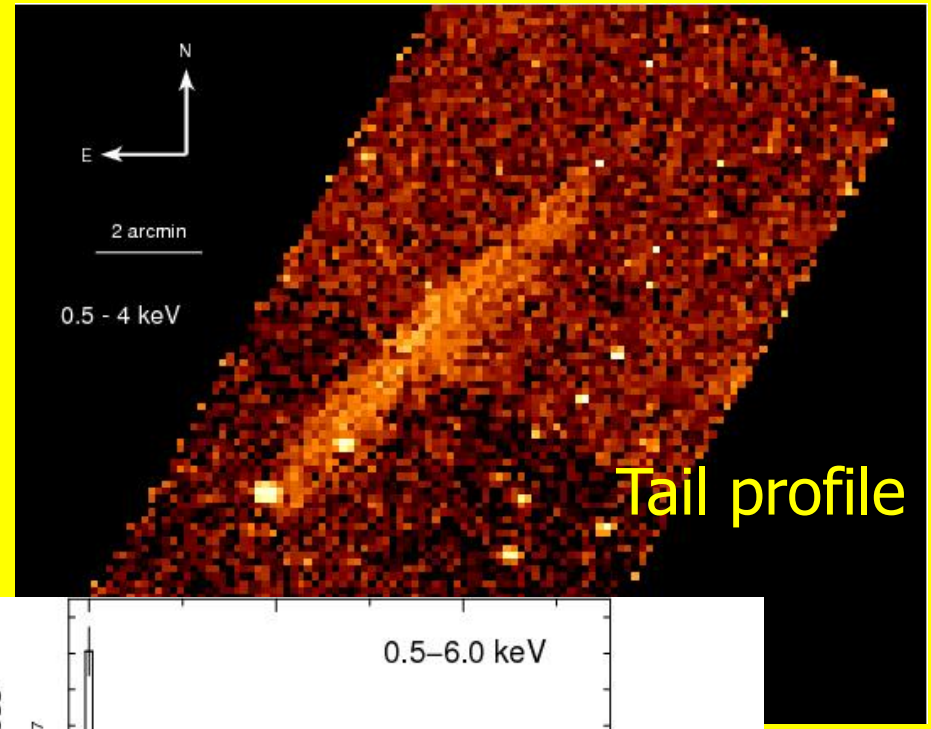
9 arcmin --> 1.3 pc @ 500 pc

also seen by Suzaku

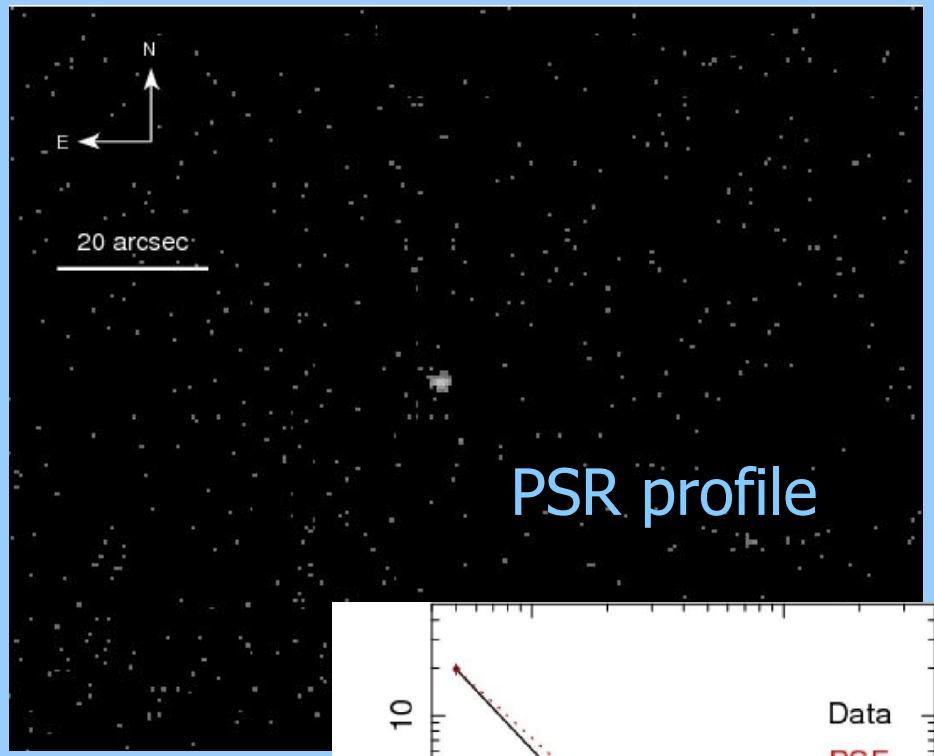
Peculiar brightness profile

No measurable spatial/spectral evolution

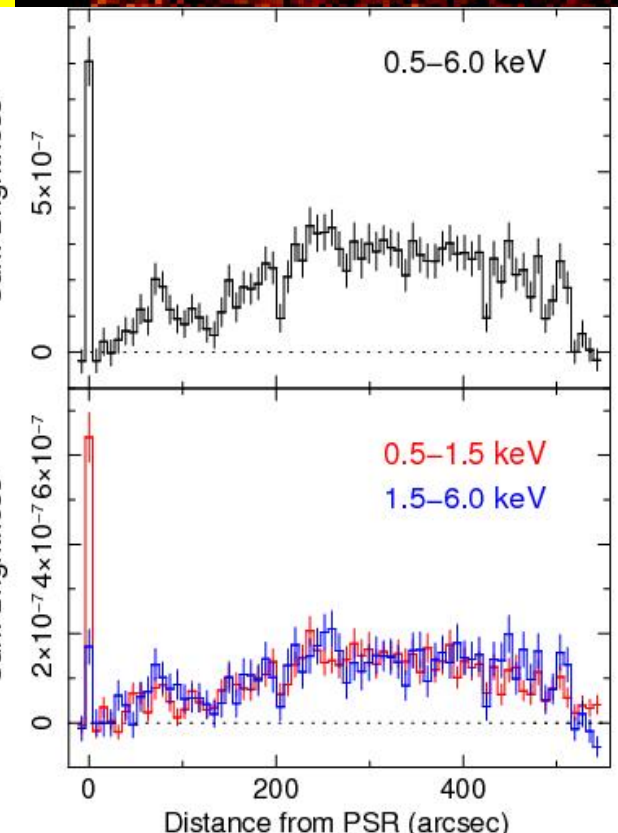
A ram-pressure dominated PWN?

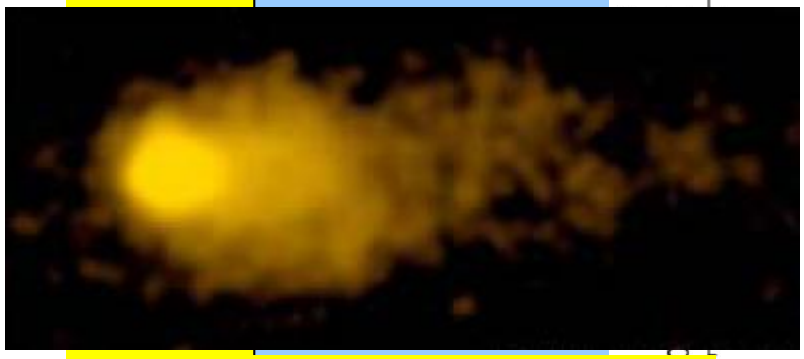


Tail profile

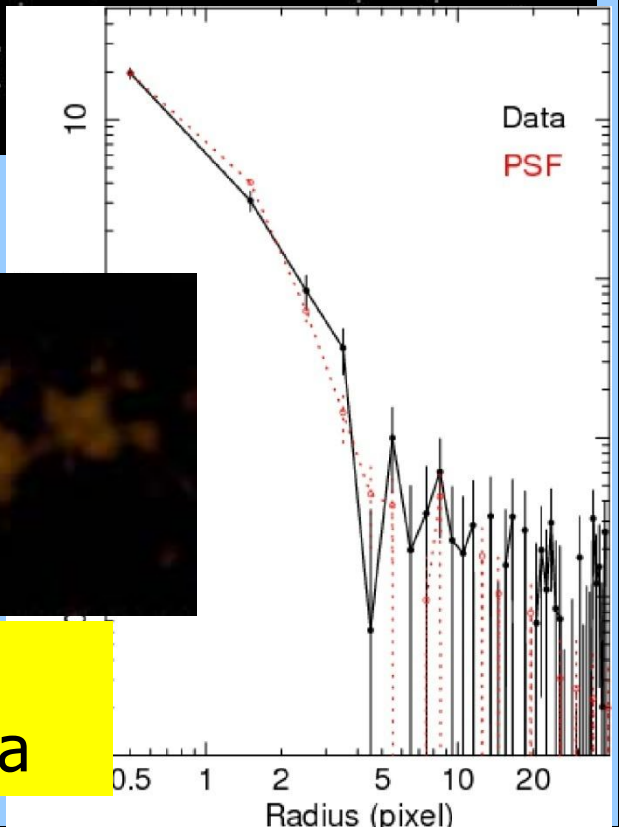


PSR profile

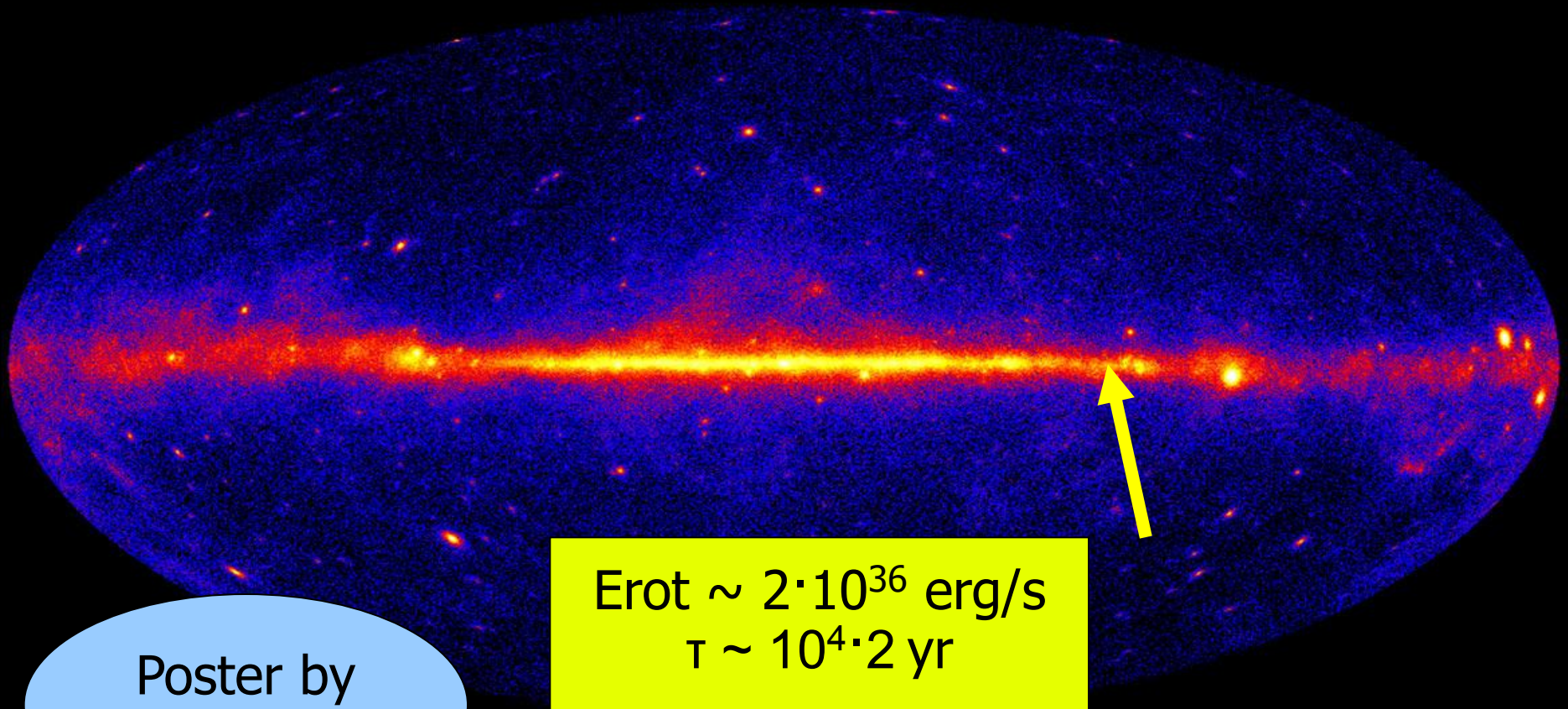




The "Mouse" as seen by Chandra



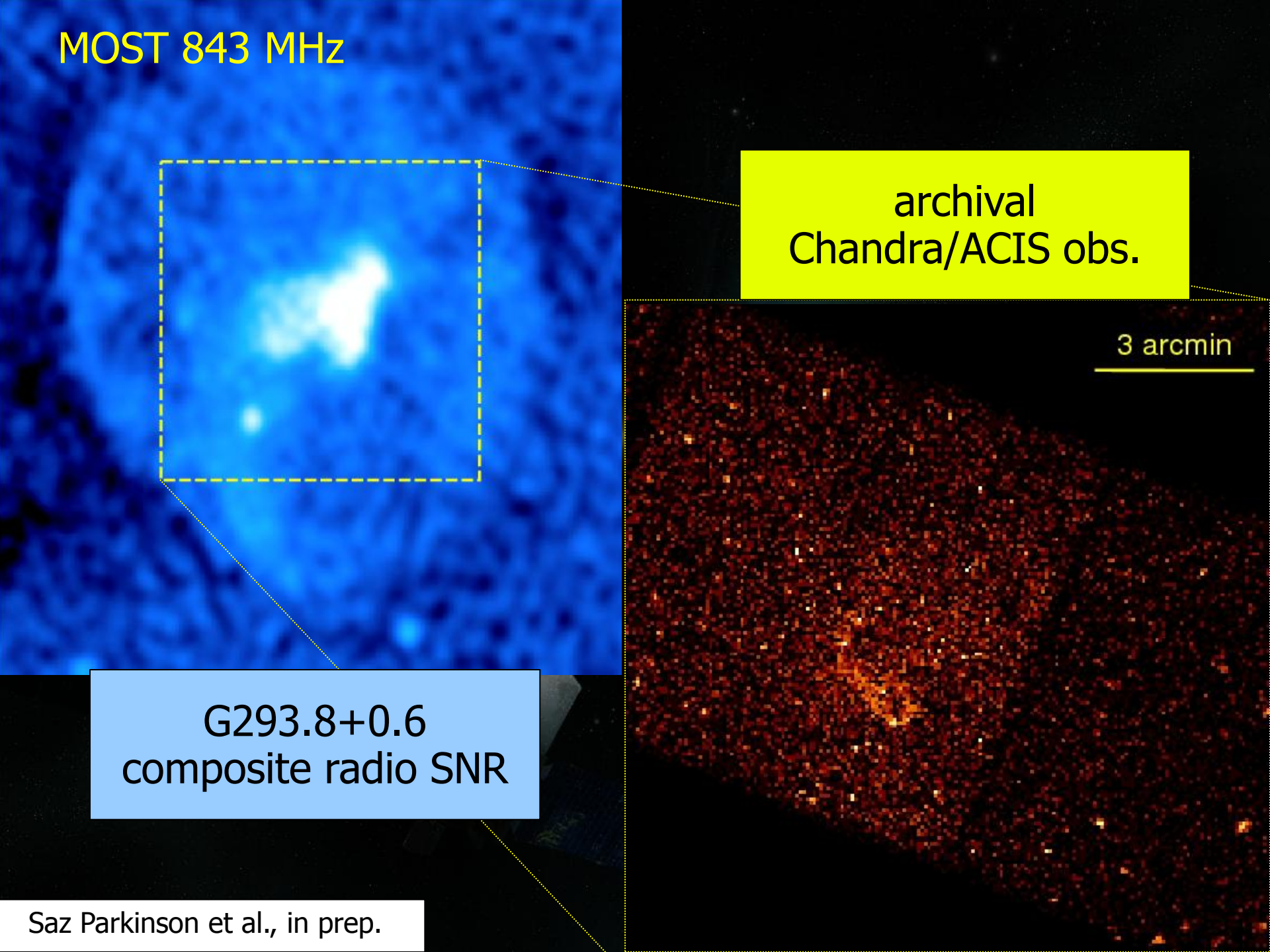
The last entry: PSR J1135-6055



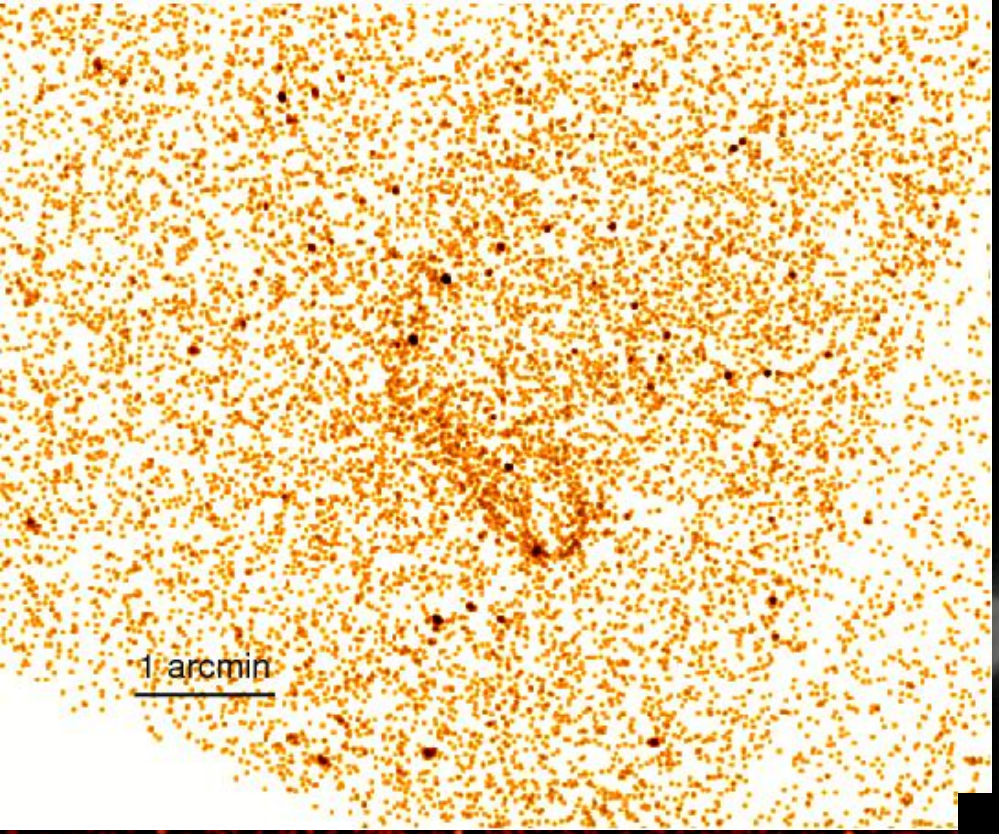
Erot ~ $2 \cdot 10^{36}$ erg/s
$\tau \sim 10^4 \cdot 2$ yr

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}
$\Gamma \sim 1.2$

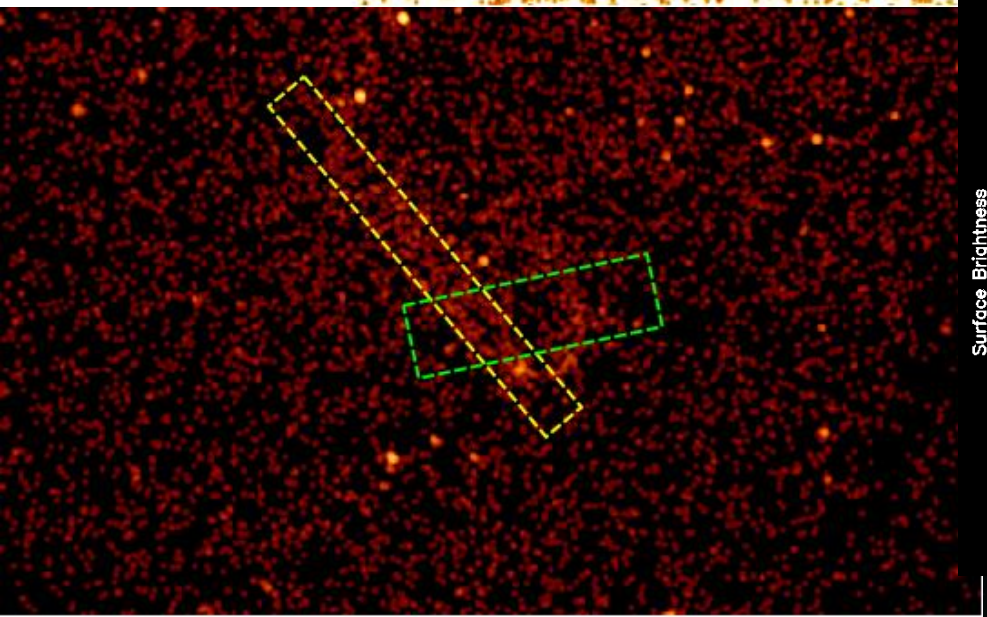
Unabsorbed flux

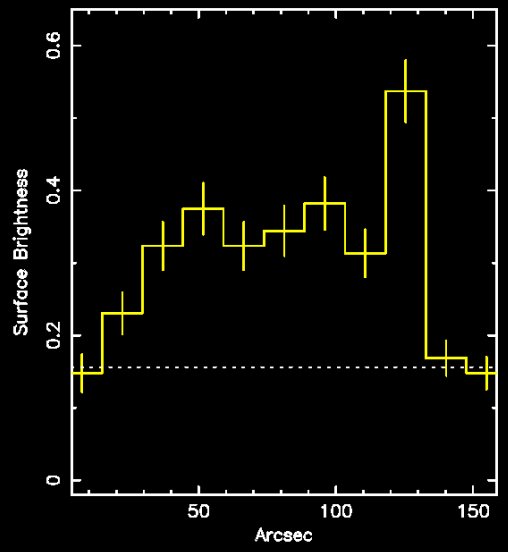
$4\cdot10^{-14}$ erg cm^{-2} s^{-1}

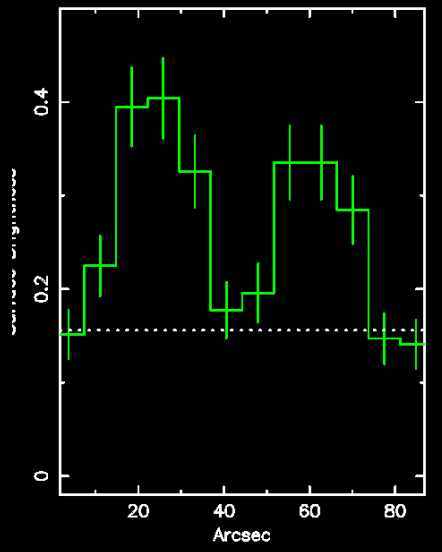
(0.5-10 keV)

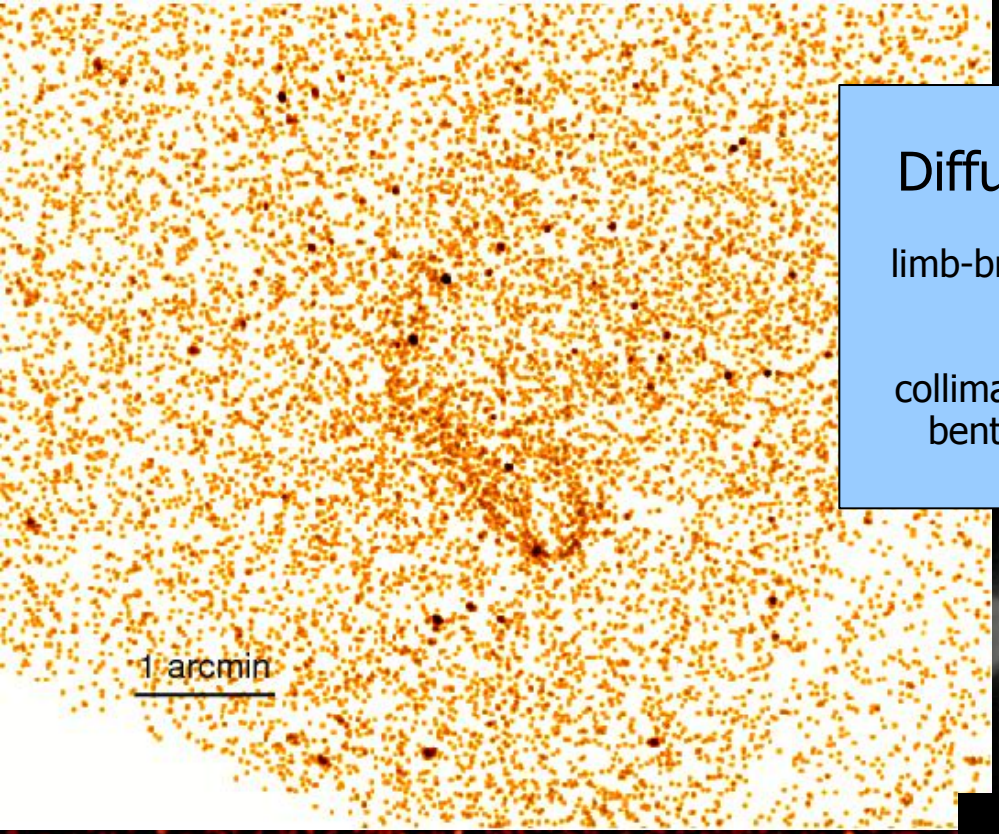
X-ray efficiency

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









Diffuse structures

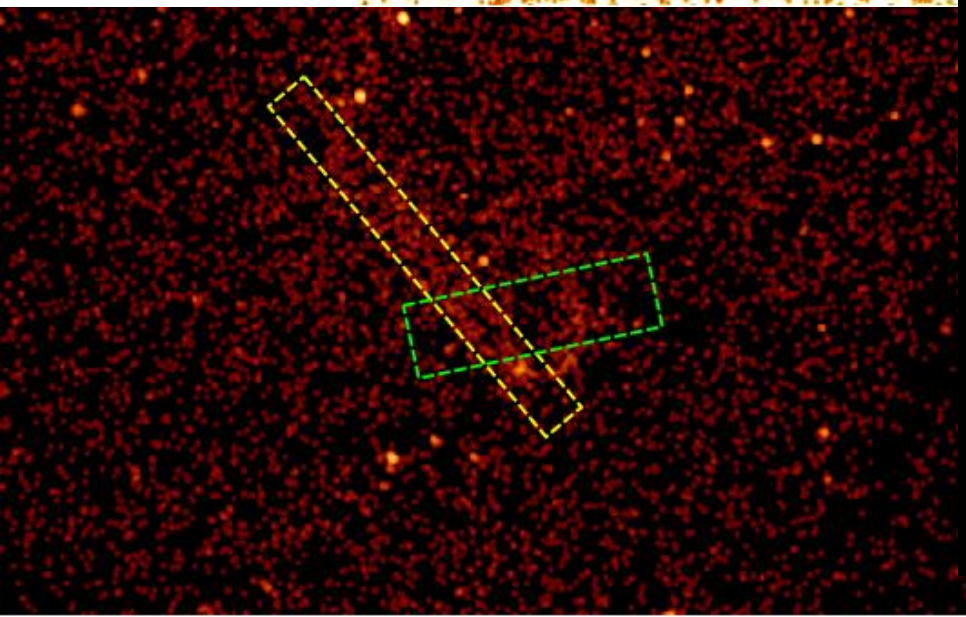
limb-brightened boundary of a "shell" ?

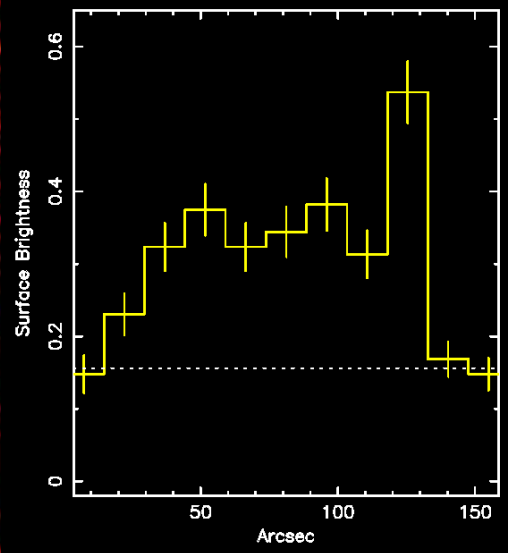
collimated outflows (jets) bent by ram pressure

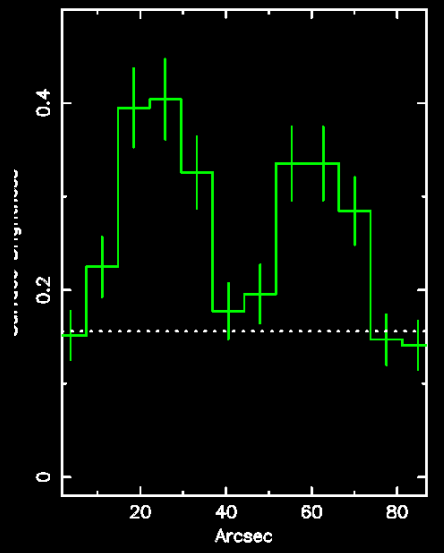
$\Gamma_1 \sim 1.8 \pm 0.4$
$\Gamma_2 \sim 2.6 \pm 0.7$

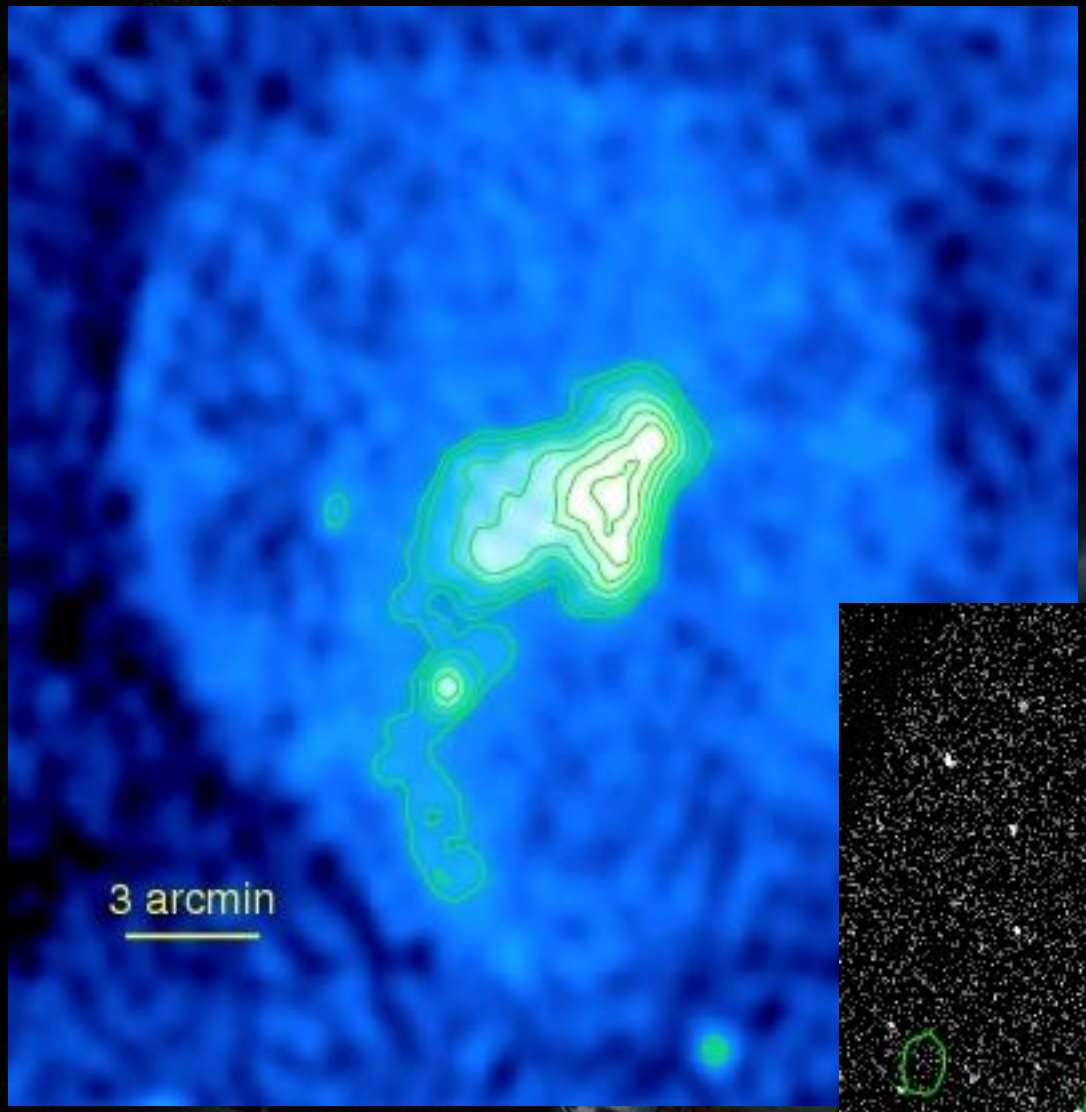
Unabsorbed flux
$2 \cdot 10^{-13}$ erg cm^{-2} s^{-1}
(0.5-10 keV)

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



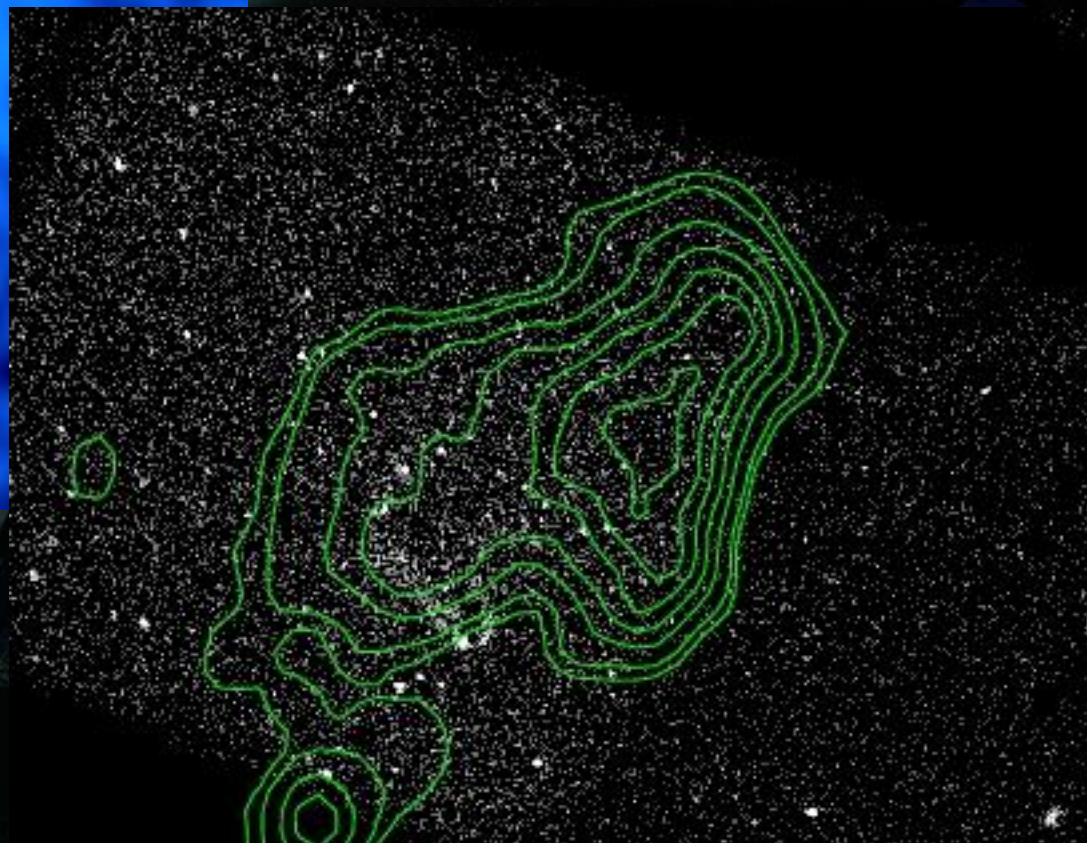






X-ray emission
significantly offset
wrt. radio PWN

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

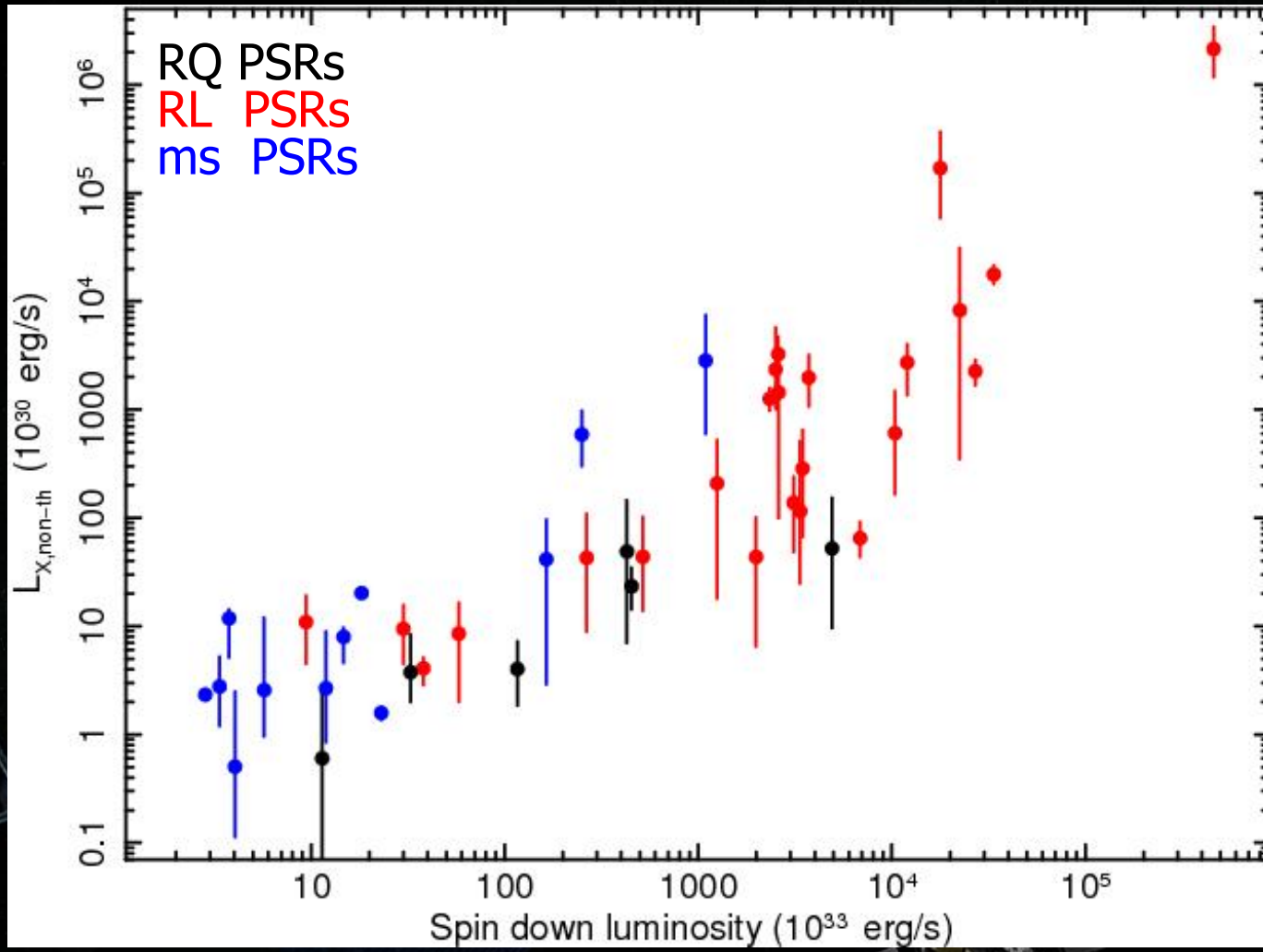
distance independent!

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

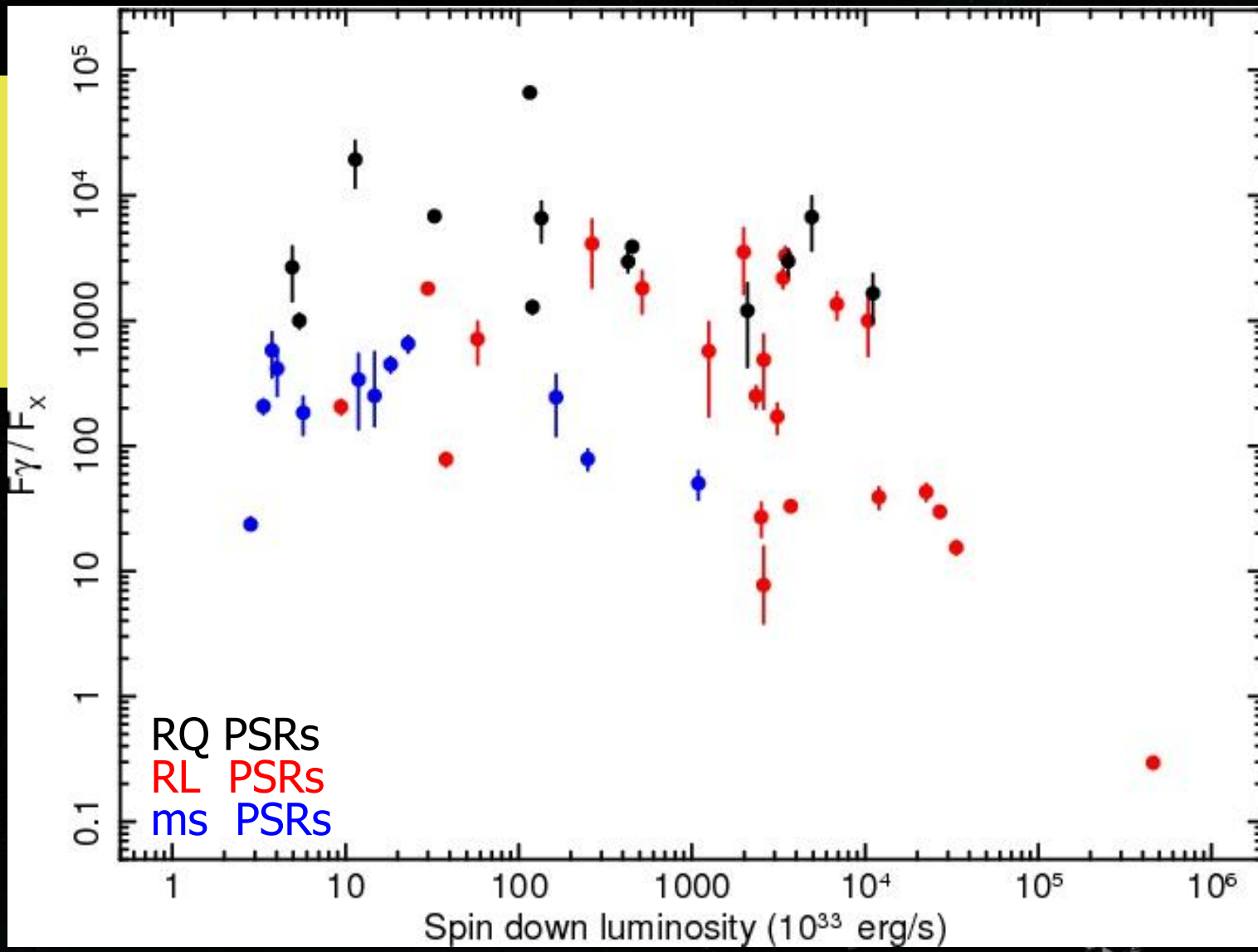
poster by M. Marelli

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

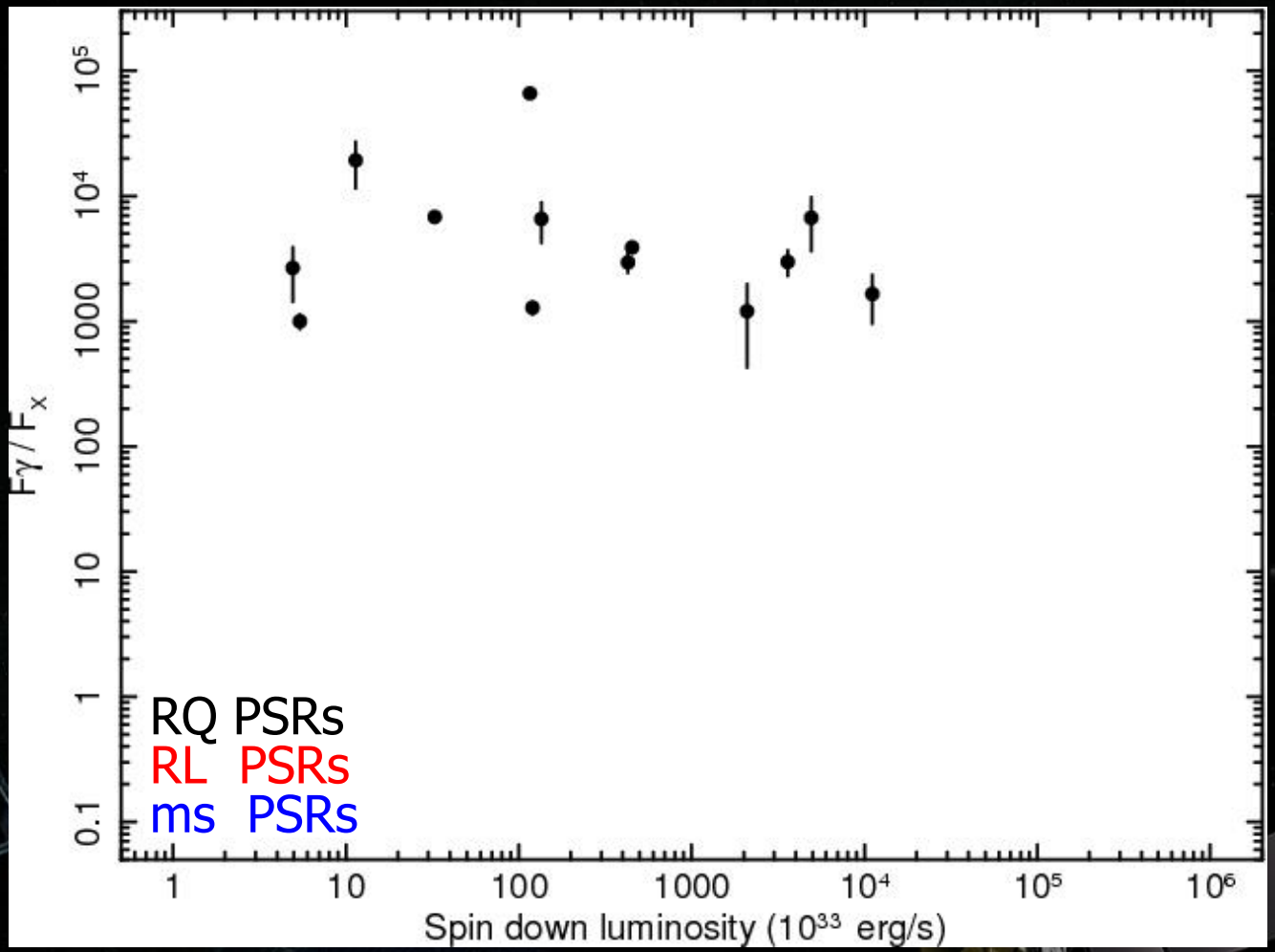
distance

independent

spread

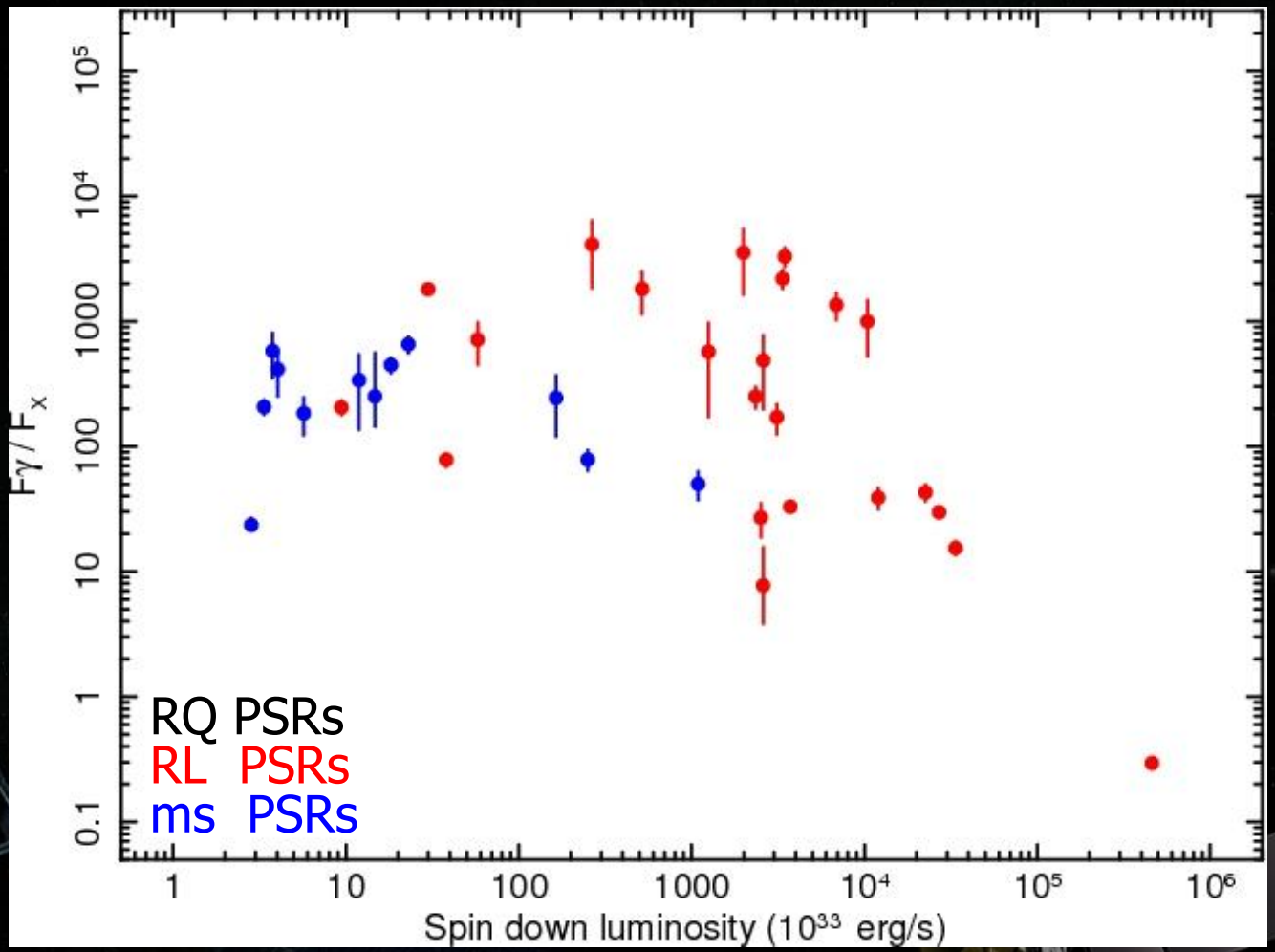


$F_\gamma / F_{X\ (non\text{-}th.)}$ vs. Erot



current sample of RQPSRs in the upper part

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



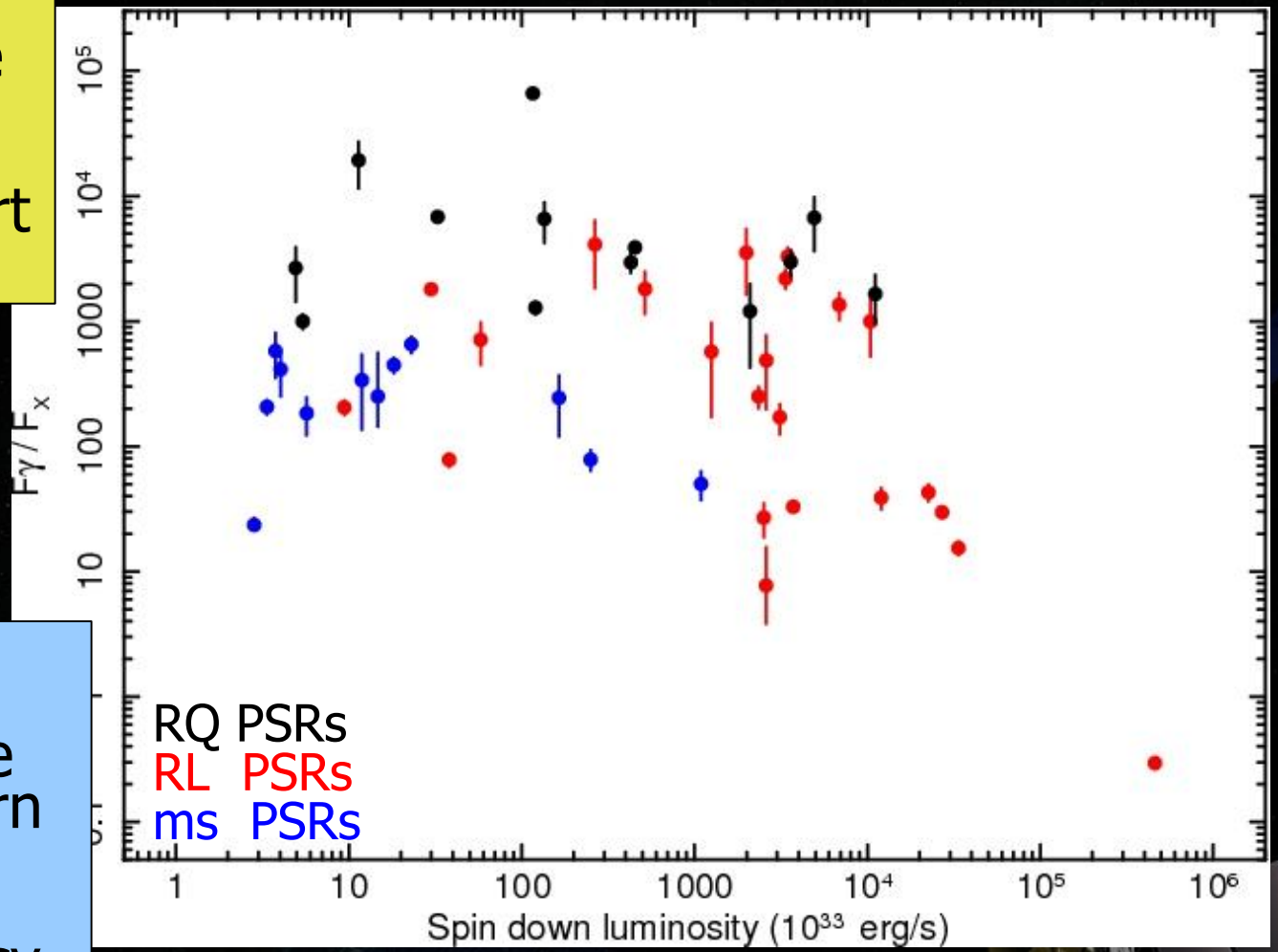
current sample
of RQPSRs
in the upper part

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