X-ray observations of “gamma-ray only” PSRs
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Astro-siesta, 2011/05/19
Pulsars in the isolated NS family

Rotation

High-energy steady

PSRs

Radio loud

SGRs

Radio transient

RRaTs

AXPs

Radio quiet

INSs

Magnetic field decay

High-energy violently variable

CCOs

High-energy variable

XDINSs

Cooling

A. De Luca/P. Esposito
Rotation-powered emission

P, Pdot & rotating dipoles

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

\[ \text{Erot} = 10^{28}-10^{38} \text{ erg/s} \]

Efficiency \( \eta_i = \frac{L_i}{E_{\text{rot}}} \)

\( \eta_{\text{radio}} = 10^{-6} \)
\( \eta_{X} = 10^{-3} \)
\( \eta_{\gamma} = 10^{-1} \)

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

- Surface thermal emission
- Hot polar cap emission
- Magnetospheric emission

NH

Spectroscopy
Timing
Phase-resolved spectroscopy
Imaging

PWN
SNR

Limited by photon statistics

Of particular interest for radio-quiet PSRs
The X-ray side

- archival data
- dedicated observations
  - Swift/XRT
  - XMM-Newton
  - Chandra

Highlights on 2 interesting PSRs

X-ray emission properties of LAT PSRs
  - RQ vs. RL

First look at the overall properties of the sample
The low Erot side: PSR J0357+32

$\text{Erot} \sim 5 \cdot 10^{33} \text{ erg/s}$

(lowest non-recycled)

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

A middle-aged PSR
The X-ray counterpart

PSR J0357+32: emission properties

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

- Steep power law \( \Gamma \sim 2.8 \)
- Moderate absorption \( N_H (8\pm4) \cdot 10^{21} \text{ cm}^{-2} \)
- Unabsorbed flux \( F \sim 5.5 \cdot 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \) (0.5-10 keV)
- X-ray efficiency \( \eta_X \sim 2 \cdot 10^{-4} \) @500 pc
- Small distance \( d \sim \) few hundred parsecs
- No thermal emission, the coldest NS in its age range

De Luca et al., 2011
A parsec-long X-ray tail

Peculiar brightness profile
No measurable spatial/spectral evolution

A ram-pressure dominated PWN?

$L_X \sim 1.5 \times 10^{-3} \ E_{\text{rot}}$

@ 500 pc

9 arcmin $\rightarrow$ 1.3 pc @ 500 pc

also seen by Suzaku
The “Mouse” as seen by Chandra
The last entry: PSR J1135-6055

Erot $\sim 2 \cdot 10^{36}$ erg/s
$\tau \sim 10^{4.2}$ yr

A Vela-like PSR

Poster by P. Saz Parkinson
G293.8+0.6 composite radio SNR

Saz Parkinson et al., in prep.
Unabsorbed flux
\[ 4 \cdot 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \]
(0.5-10 keV)

X-ray efficiency
\[ \eta_X \sim 2 \cdot 10^{-5} \]
@2.9 kpc

Point-like src
possible compact (<3”) PWN
non-thermal
\[ N_H (4\pm1) \cdot 10^{21} \text{ cm}^{-2} \]
\[ \Gamma \sim 1.2 \]
Diffuse structures

limb-brightened boundary of a “shell”?

collimated outflows (jets) bent by ram pressure

$\Gamma_1 \sim 1.8\pm0.4$
$\Gamma_2 \sim 2.6\pm0.7$

Unabsorbed flux
$2\cdot10^{-13}$ erg cm$^{-2}$ s$^{-1}$
(0.5-10 keV)

X-ray efficiency
$\eta_X \sim 2\cdot10^{-4}$
@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-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

Taking $F_{\gamma} / F_X$ (non-th.) vs. $E_{\text{rot}}$.

Distance independent spread

RQ PSRs
RL PSRs
ms PSRs

Spin down luminosity ($10^{33}$ erg/s)
$F_{\gamma} / F_X^{\text{(non-th.)}}$ vs. Erot

Current sample of RQPSRs in the upper part
current sample of RQPSRs in the upper part
$F_{\gamma} / F_X^{(\text{non-th.})}$ vs. $E_{\text{rot}}$

Current sample of RQ PSRs in the upper part

Beaming & efficiencies

Our RQ PSRs: more favorable beaming pattern and/or higher efficiency in $\gamma$-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 $L_\gamma$ vs Erot trend

Factor 1000 scatter in distance-independent $F_\gamma/F_\gamma$

RQ PSRs: more favorable $\gamma$-ray beaming and/or efficiency

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