IASF-INAF contributions on

Isolated Neutron Stars

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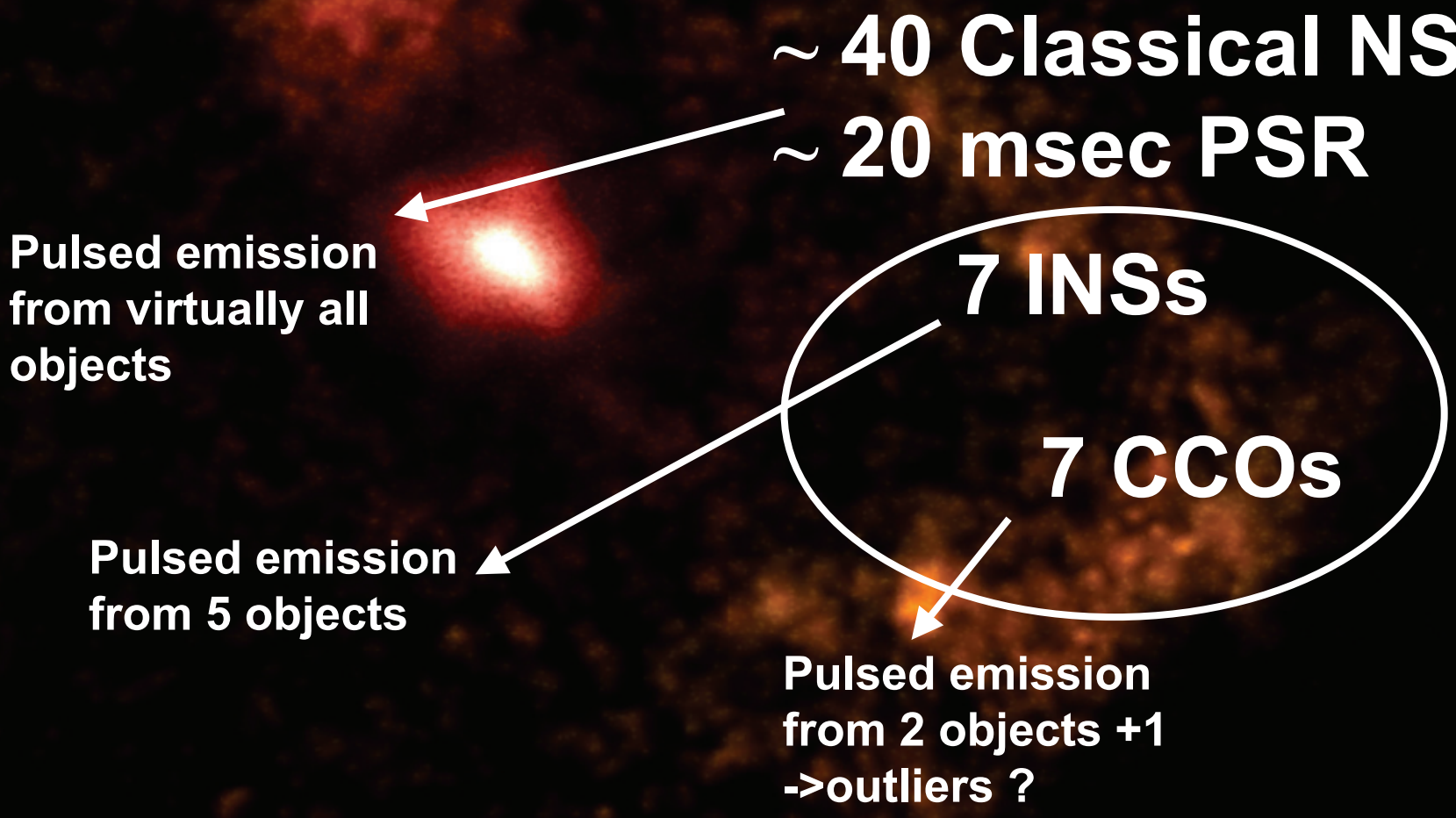
A NS is a source of

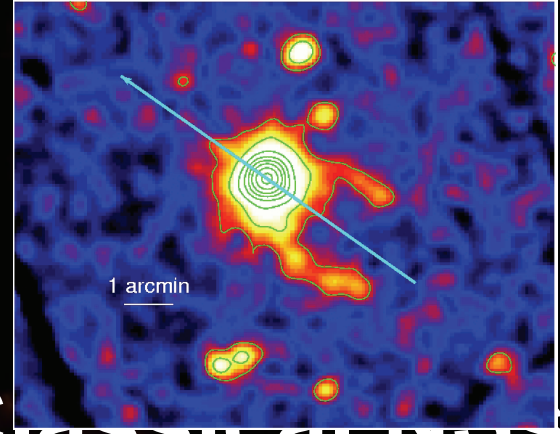
- **Thermal emission (somewhat PULSED)**
  from its (rotating) surface
  tiny radius, very high T
  optical/UV, soft X-ray
- **Non thermal emission**
  (strongly PULSED)
  from its(rotating) magnetosphere
  radio, optical, X-ray, γ-ray
- **Non thermal emission (NON pulsed)**
  from its surroundings
  radio, optical, IR, X-ray

NSs as X-ray emitters



•AXP, SGR

Our contributions



Phase resolved spectroscopy (4)

Search for new sources

Binary system

~ 40 Classical NSs

~ 20 msec PSR

7 INSs

7 CCOs +

Detection of pulsation from RXJ1856.5-3754

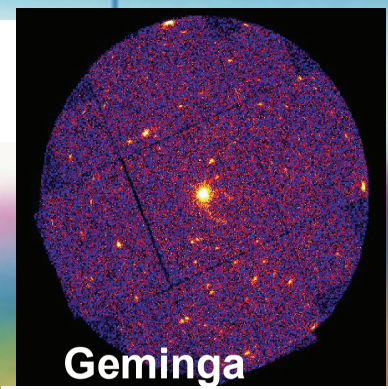
Detailed studies of 1E1207 and 1E1613, more CCOs

•AXP, SGR

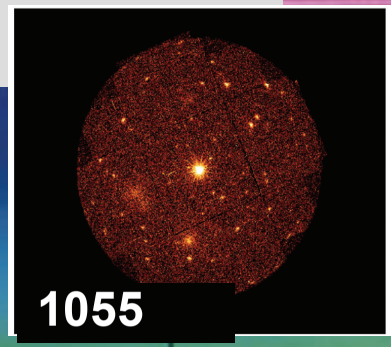
Phase-resolved spectroscopy

Applied to PSRs with composite spectra

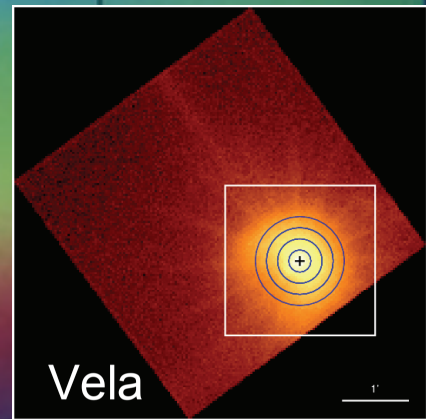
P.A. Caraveo, A. DeLuca, S.Mereghetti, A. Pellizzoni, G.F. Bignami
Phase resolved spectroscopy of Geminga shows rotating hot spot(s)
Science, **305**, 376, 2004



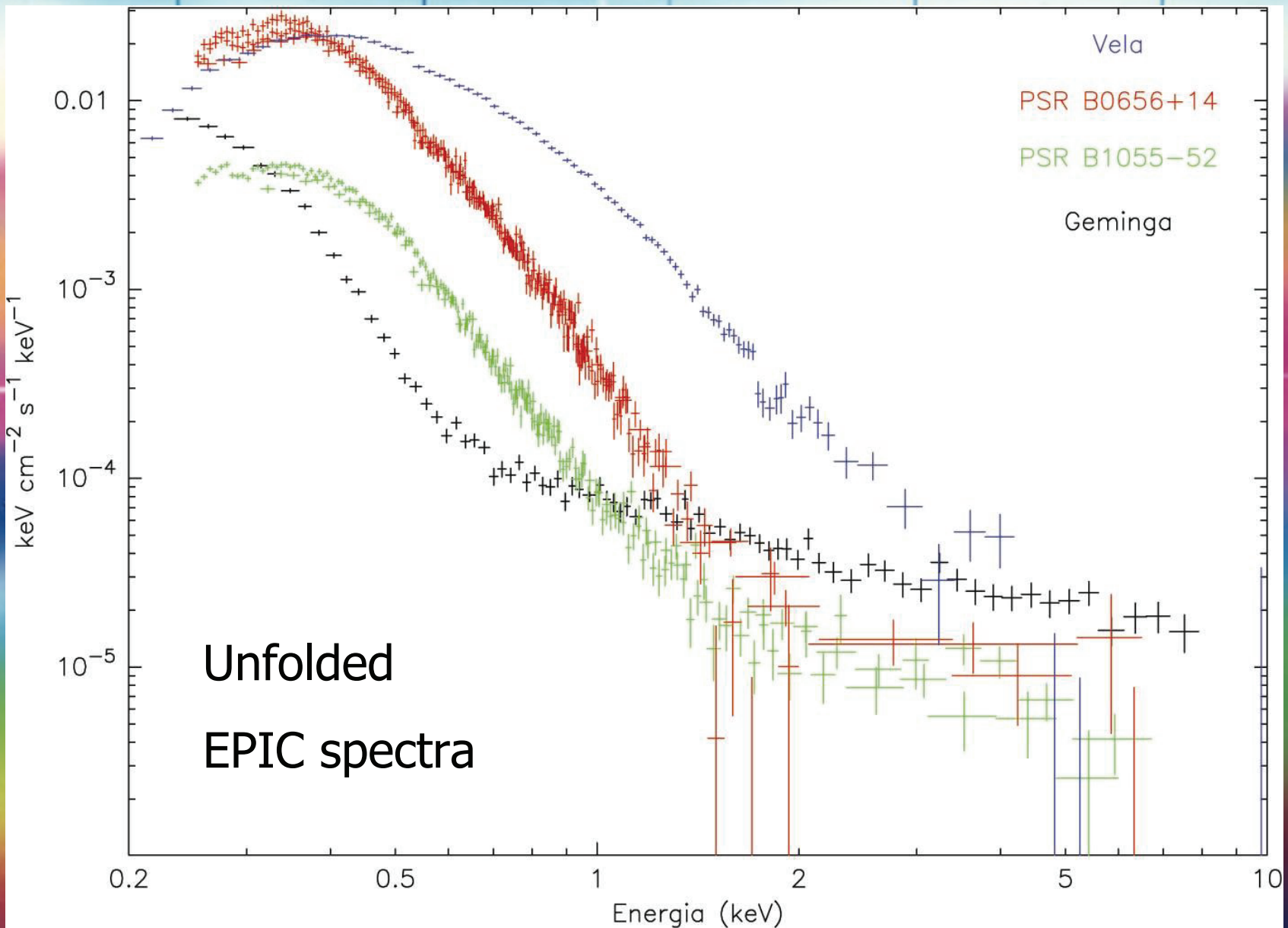
A. DeLuca, **P.A. Caraveo,** S.Mereghetti, M. Negroni, G.F. Bignami
On the polar caps of the three musketeers
ApJ **623**,1051, 2005

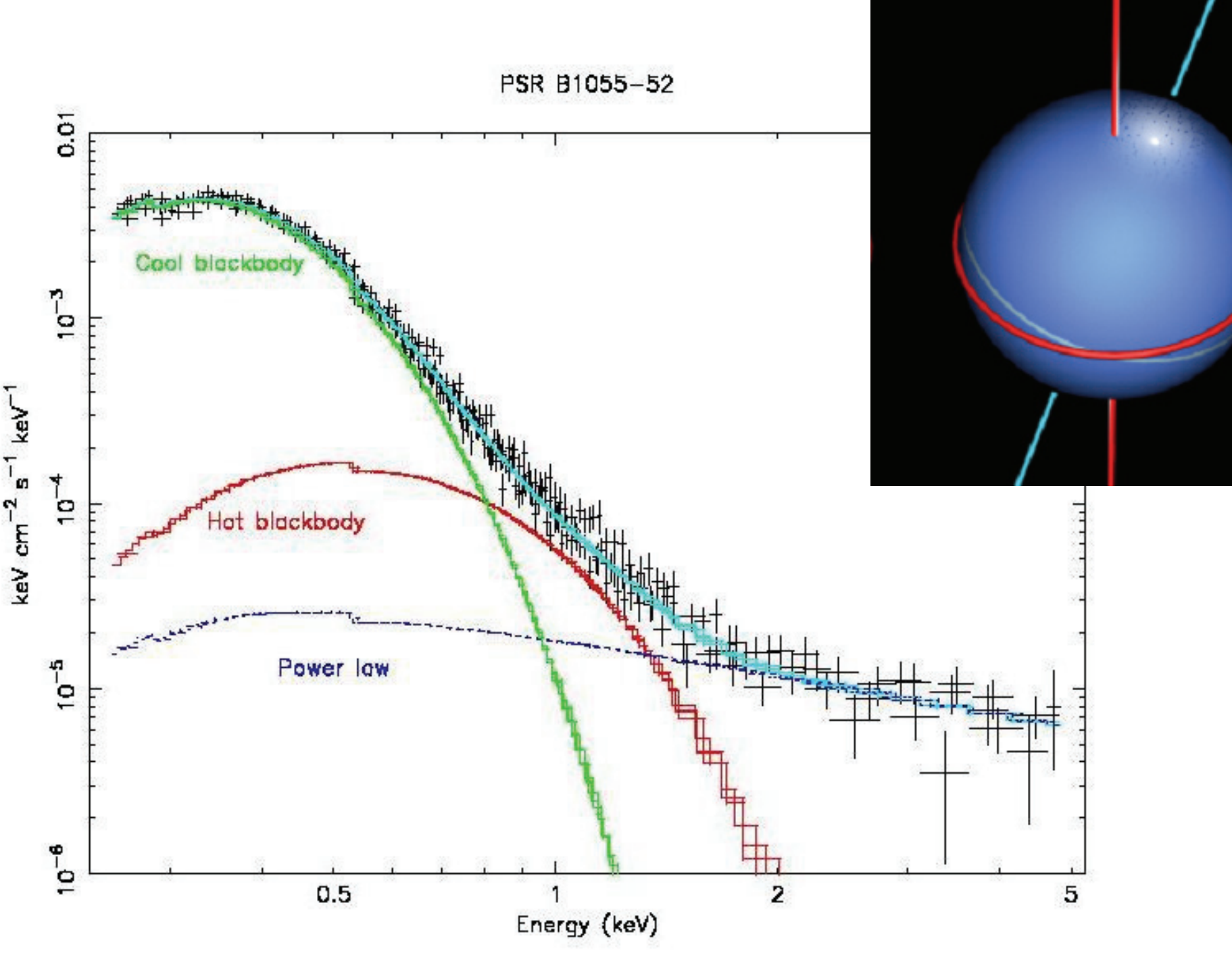


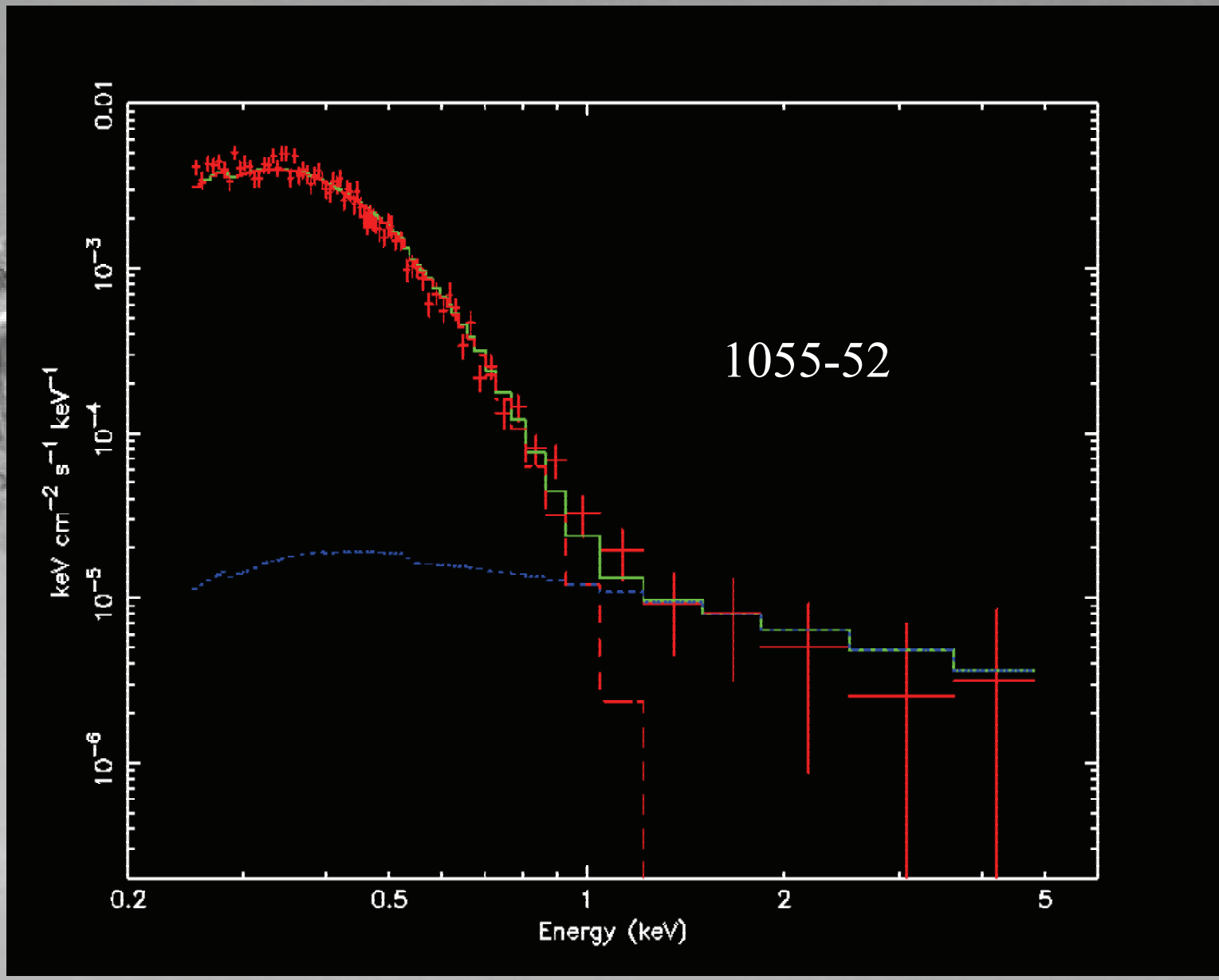
A.Manzali, A. De Luca, P.A. Caraveo
Phase Resolved Spectroscopy of the Vela Pulsar with XMM-Newton
ApJ. 669,570, 2007

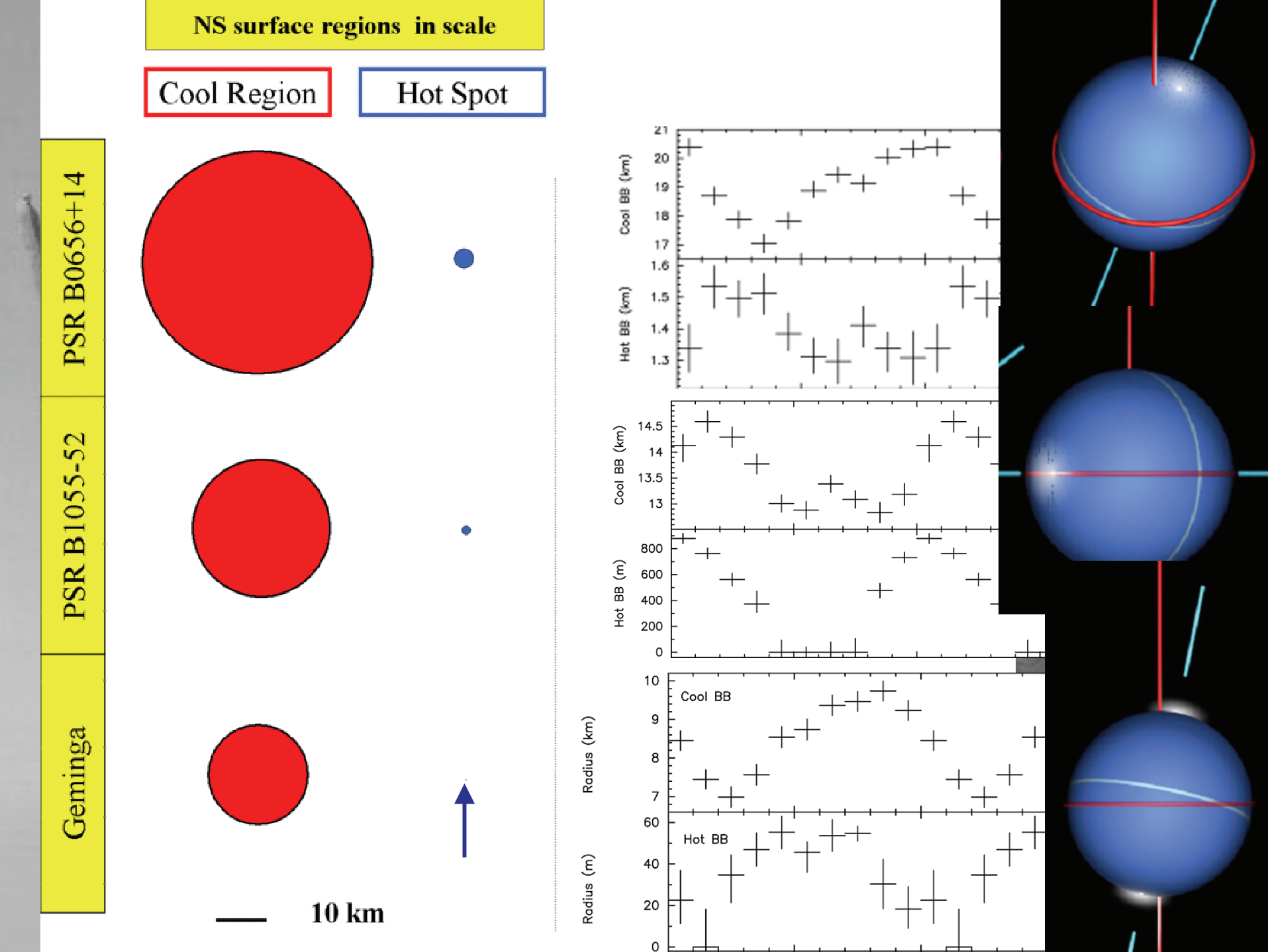


4 similar objects

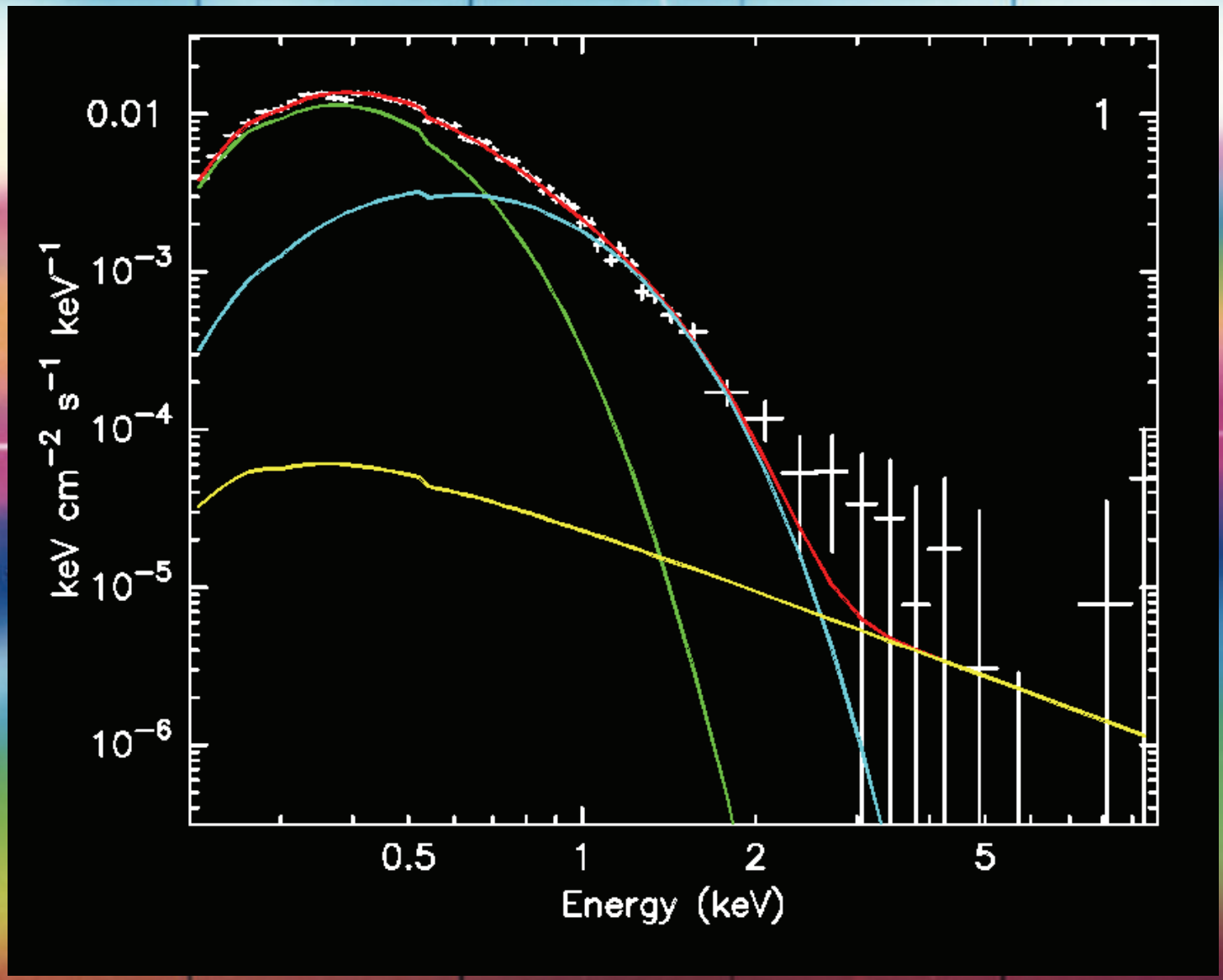



PSR B1055−52
Cool blackbody
Hot blackbody
Power law
keV cm^{-2} s^{-1} keV^{-1}
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.5
1
2
5
Energy (keV)

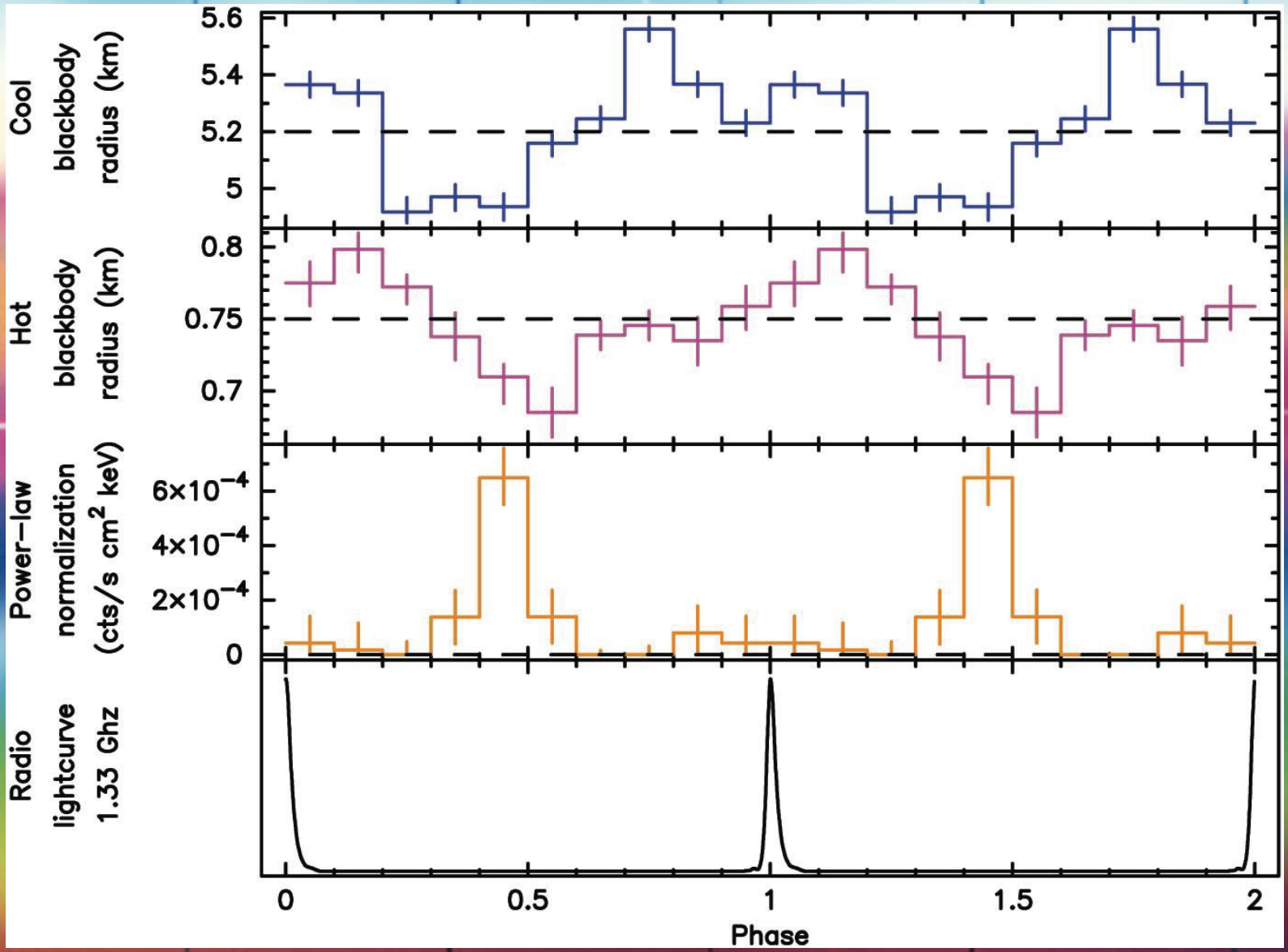

1055-52
keV cm^{-2} s^{-1} keV^{-1}
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.2
0.5
1
2
5
Energy (keV)


NS surface regions in scale
Cool Region
Hot Spot
PSR B0656+14
PSR B1055-52
Geminga
10 km
Cool BB (km)
Hot BB (km)
Cool BB (km)
Hot BB (m)
Radius (km)
Cool BB
Radius (m)
Hot BB

and a somewhat different Vela



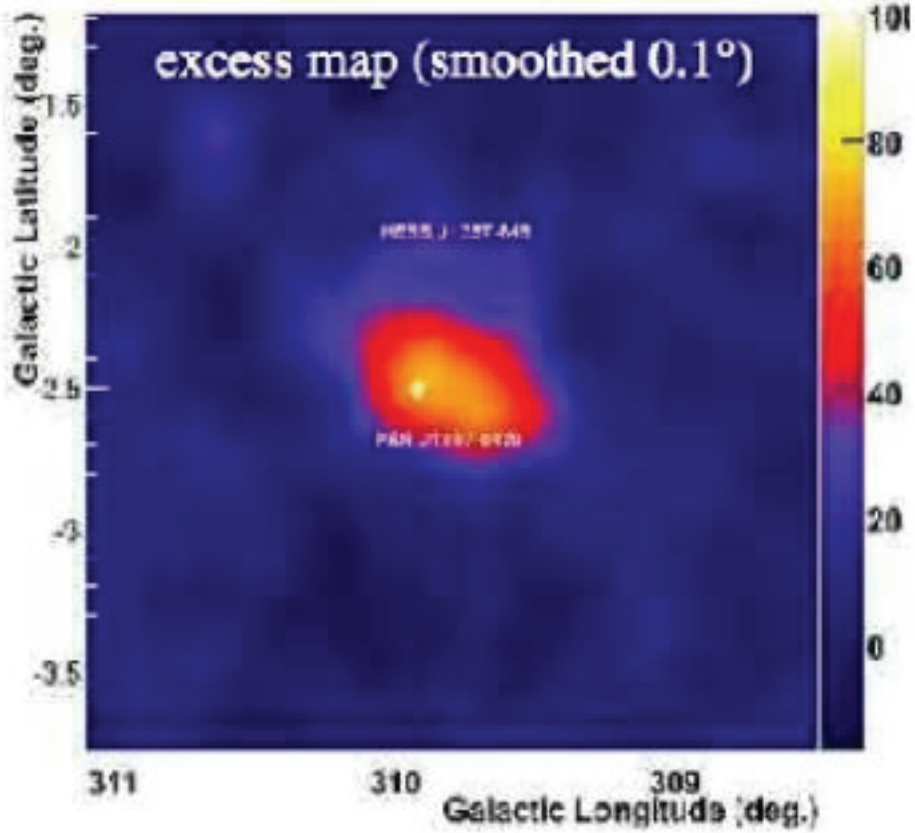
and Vela


Cool blackbody radius (km)
5.6
5.4
5.2
5
Hot blackbody radius (km)
0.8
0.75
0.7
Power–law normalization (cts/s cm^2 keV)
6×10^{-4}
4×10^{-4}
2×10^{-4}
0
Radio lightcurve 1.33 Ghz
0
0.5
1
1.5
2
Phase

PSR J1357-6429

Esposito, Tiengo, De Luca & Mattana 2007, A&A, 467, L45

We discovered its X-ray emission using XMM and CXO data.



(HESS collaboration 30th ICRC, July 2007)

- **Very young:** $P/2\dot{P} = 7.3$ kyr

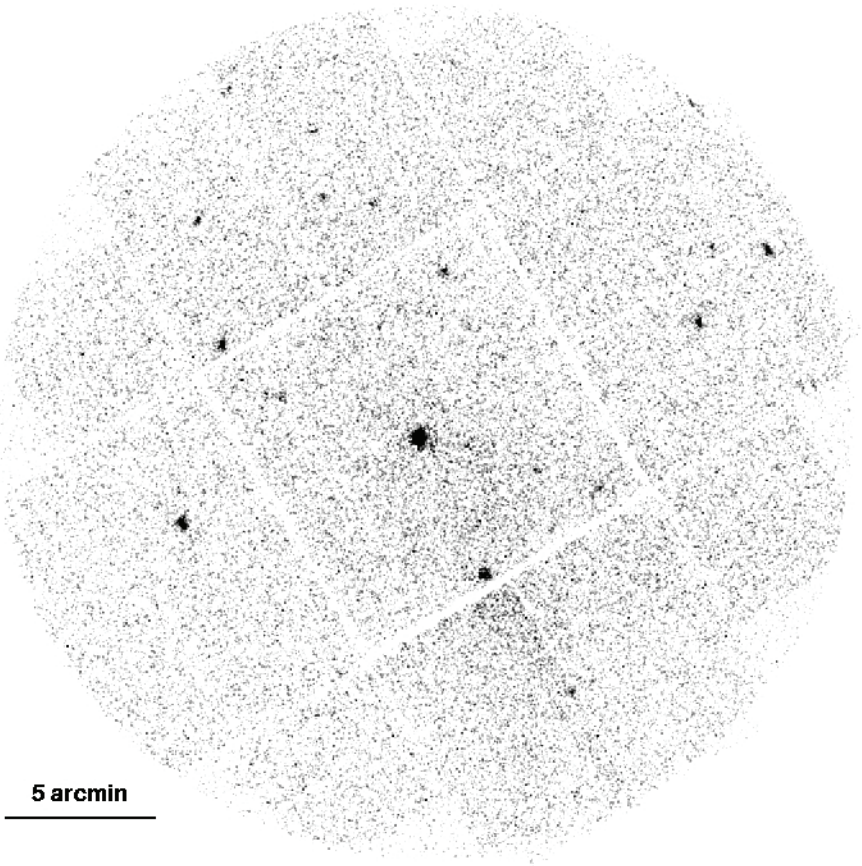
(9th youngest Galactic radio pulsar)

- **Thermal emission**
- **Some evidence (~3σ) of PWN**
- **Energetic (Edot ~ 3E+36 erg s^{-1}) and nearby (2.5 kpc).**

Hard γ-ray (>100 MeV) counterpart? To be observed with AGILE …

Positionally compatible with the new gamma-ray source HESS J1357-645.

RX J0002+6246: a fake NS



Our analysis of the XMM data.

Position consistent with that of a bright (non-degenerate) star present in various optical/IR catalogues.

Absence of X-ray pulsation and no associated SNR.

X-ray spectrum well described by an optically thin plasma model with kT typical of stellar atmospheres.

Optical/IR colours and X-ray flux consistent with a nearby (0.2 kpc) F7-type main-sequence star.

⇒ **RXJ is not a NS but rather a star!**

Double neutron star system 0737-3039

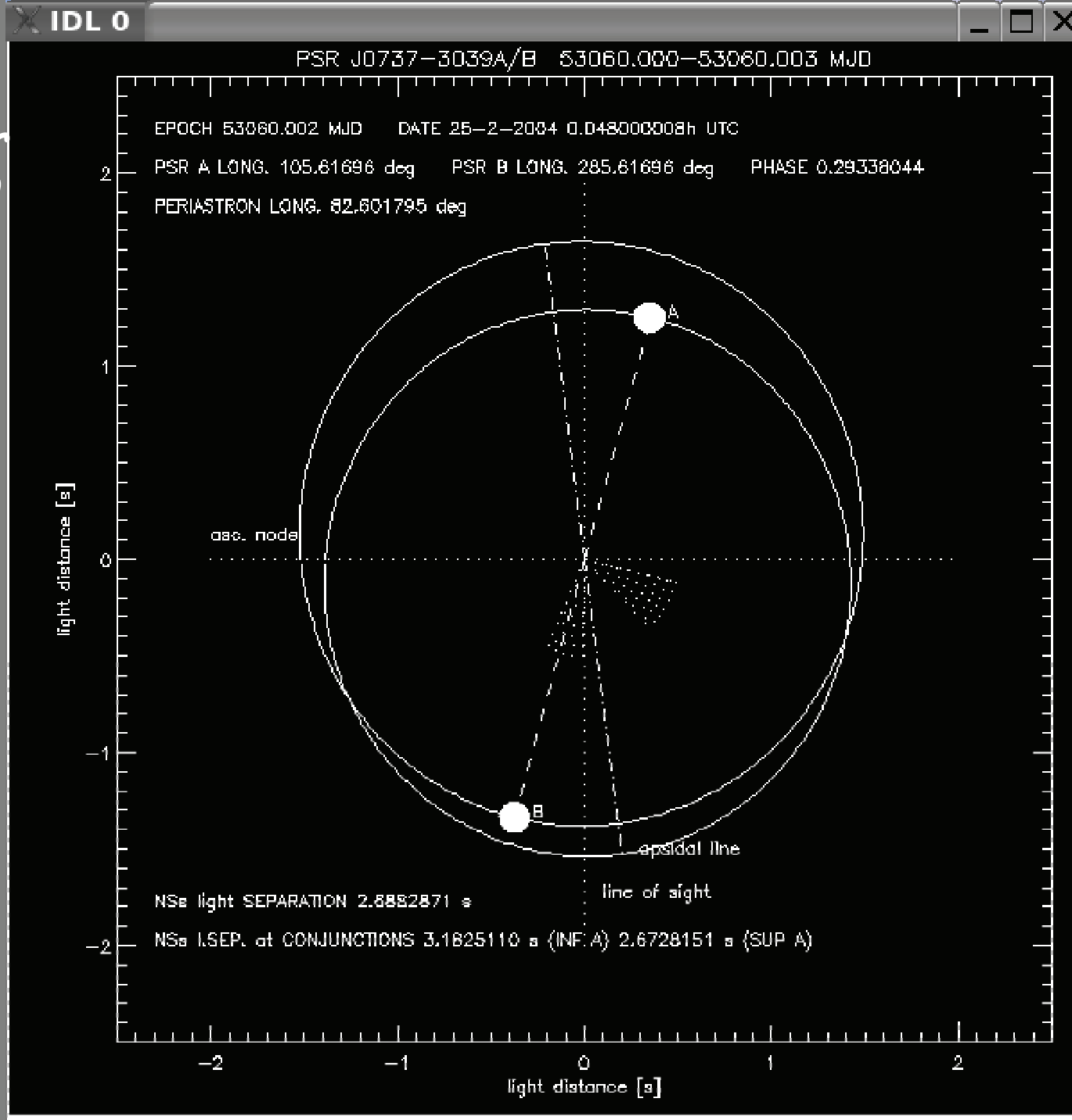
Orbital p.: 2.4 h

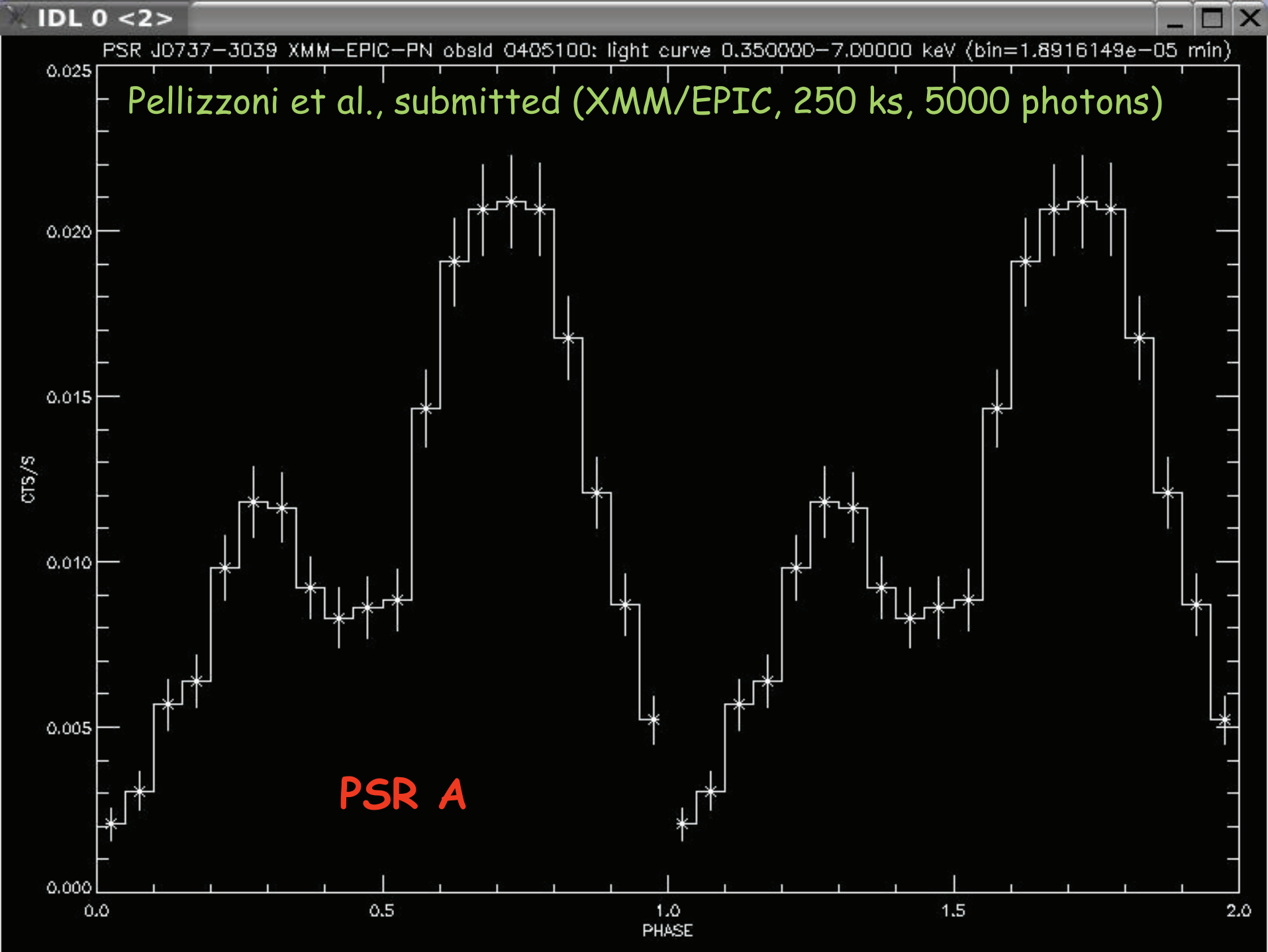
eccentricity=0.09

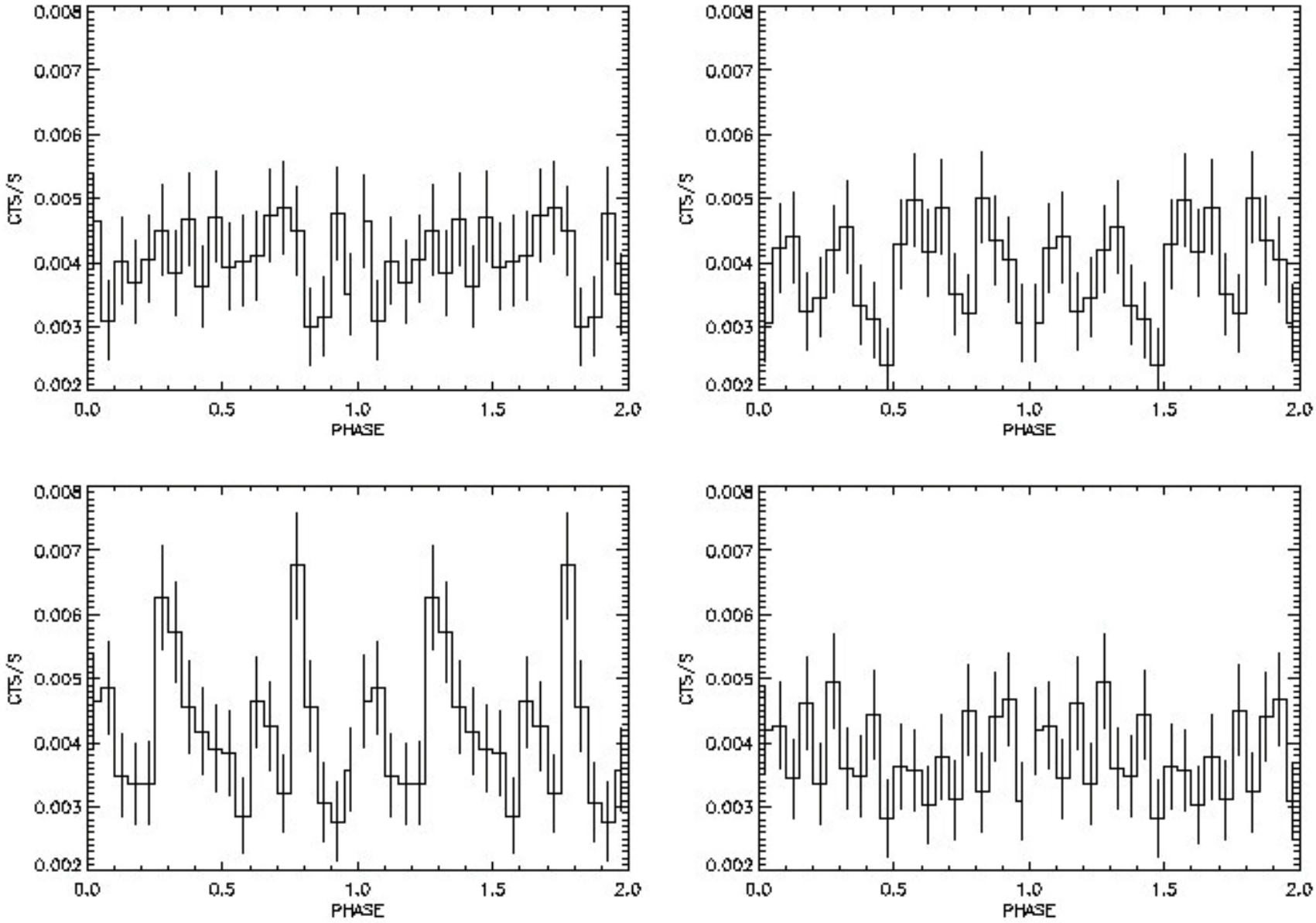
Separation 3 sec.

PSR A: P=22.7 ms
$E_{ROT}=6\times10^{33}$ erg/s,
τ=210 Myr
$B=6.3\times10^{9}$ G
1.337 M_{SOL}

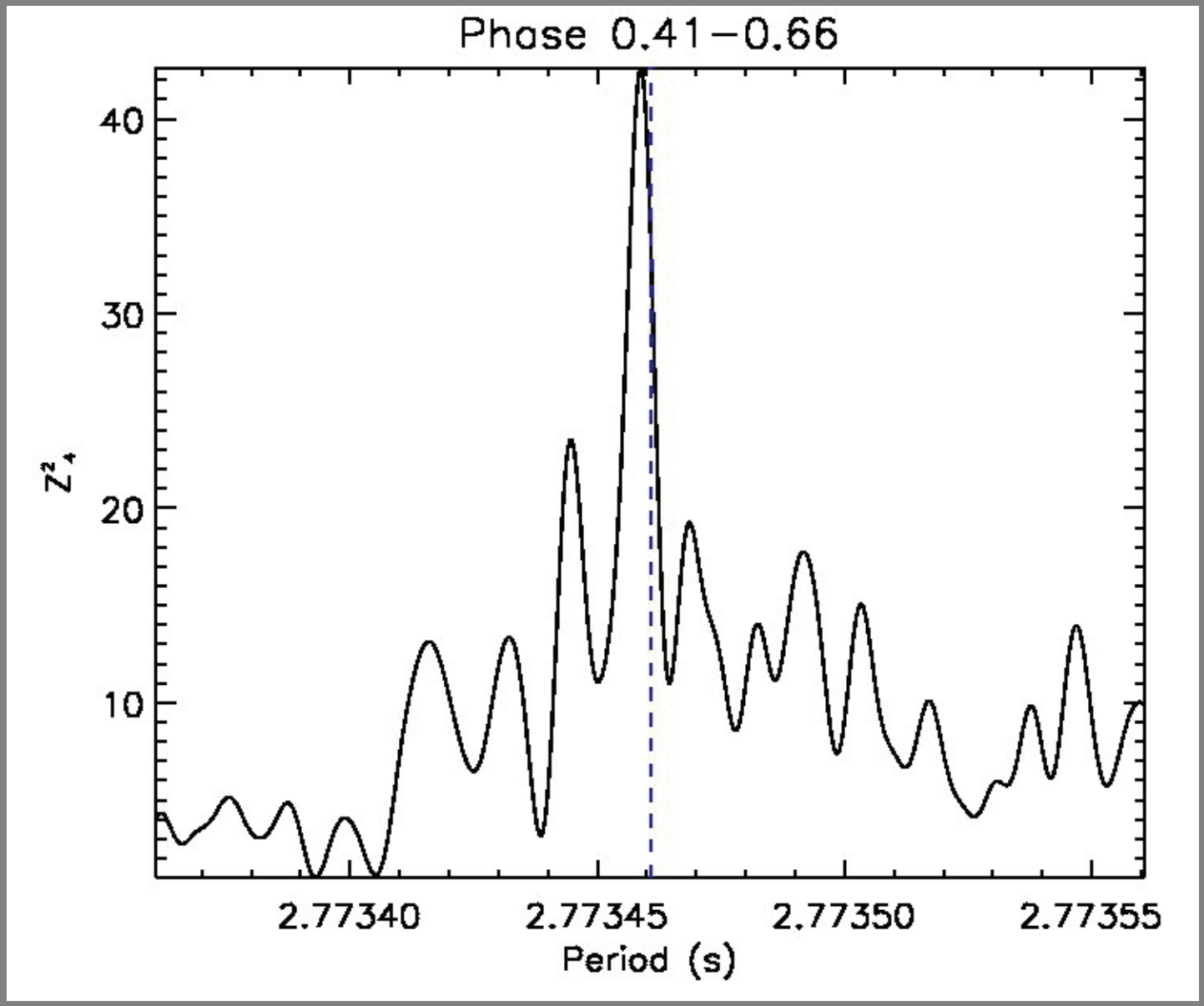
PSR B: P=2.7 s
$E_{ROT}=2\times10^{30}$ erg/s
τ=50 Myr
$B=1.2\times10^{12}$ G
1.25 M_{SOL}




IDL 0 <2>
PSR J0737−3039 XMM−EPIC−PN obsId 0405100: light curve 0.350000−7.00000 keV (bin=1.8916149e−05 min)
Pellizzoni et al., submitted (XMM/EPIC, 250 ks, 5000 photons)
PSR A
CTS/S
0.025
0.020
0.015
0.010
0.005
0.000
0.0
0.5
1.0
1.5
2.0
PHASE

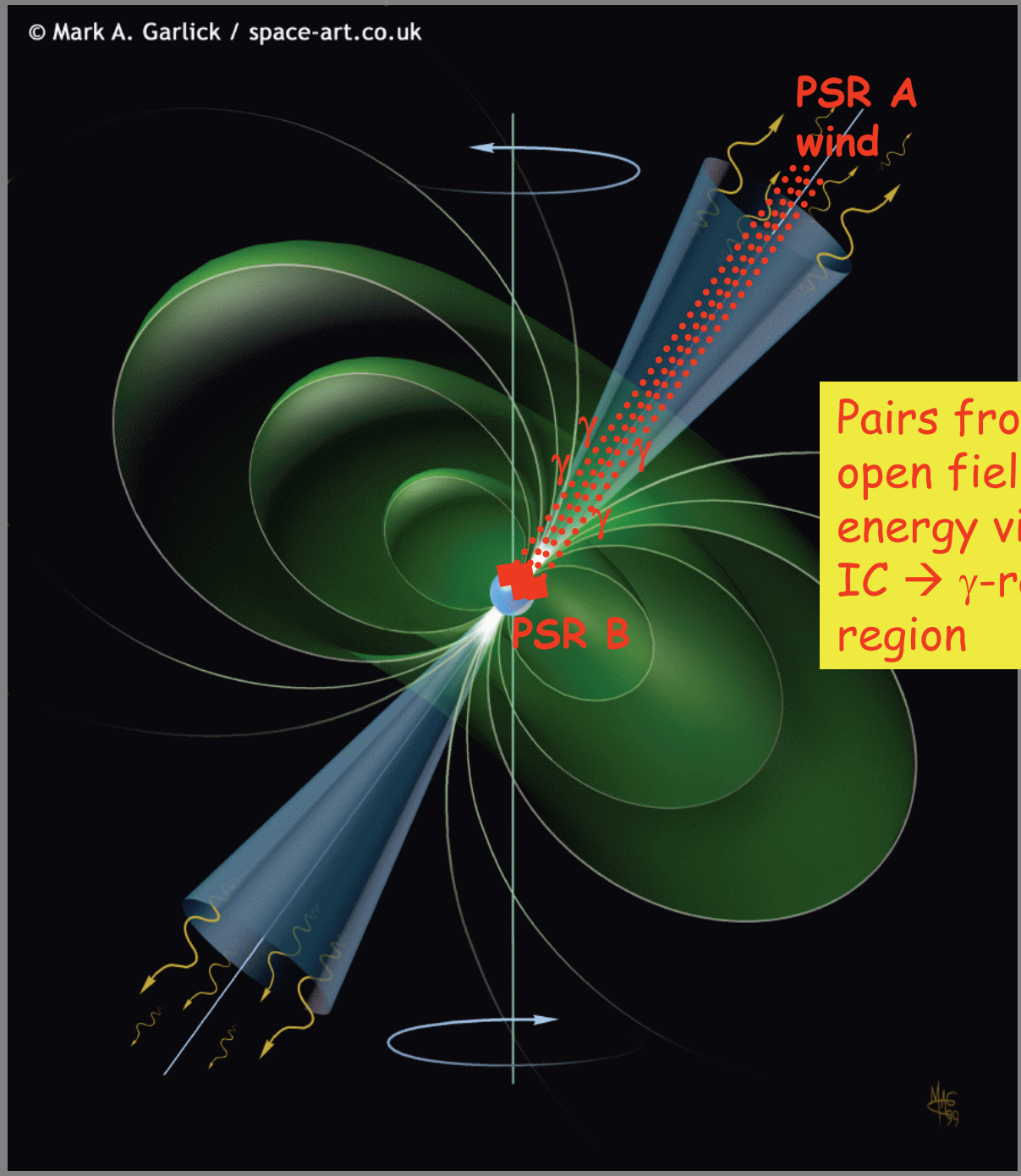


PSR B (detected around ascending node of the orbit)



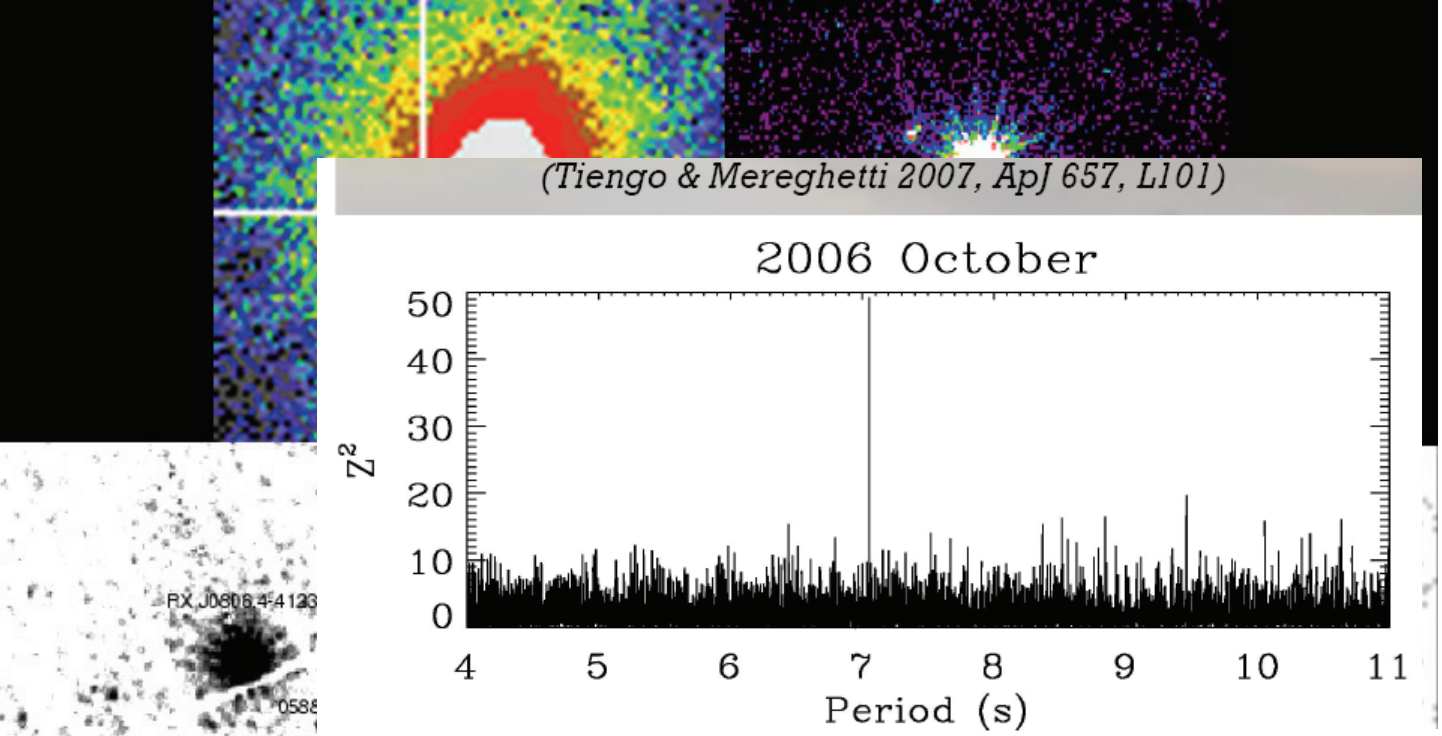
But Edot is not enough

PSR B (detected around ascending node of the orbit)

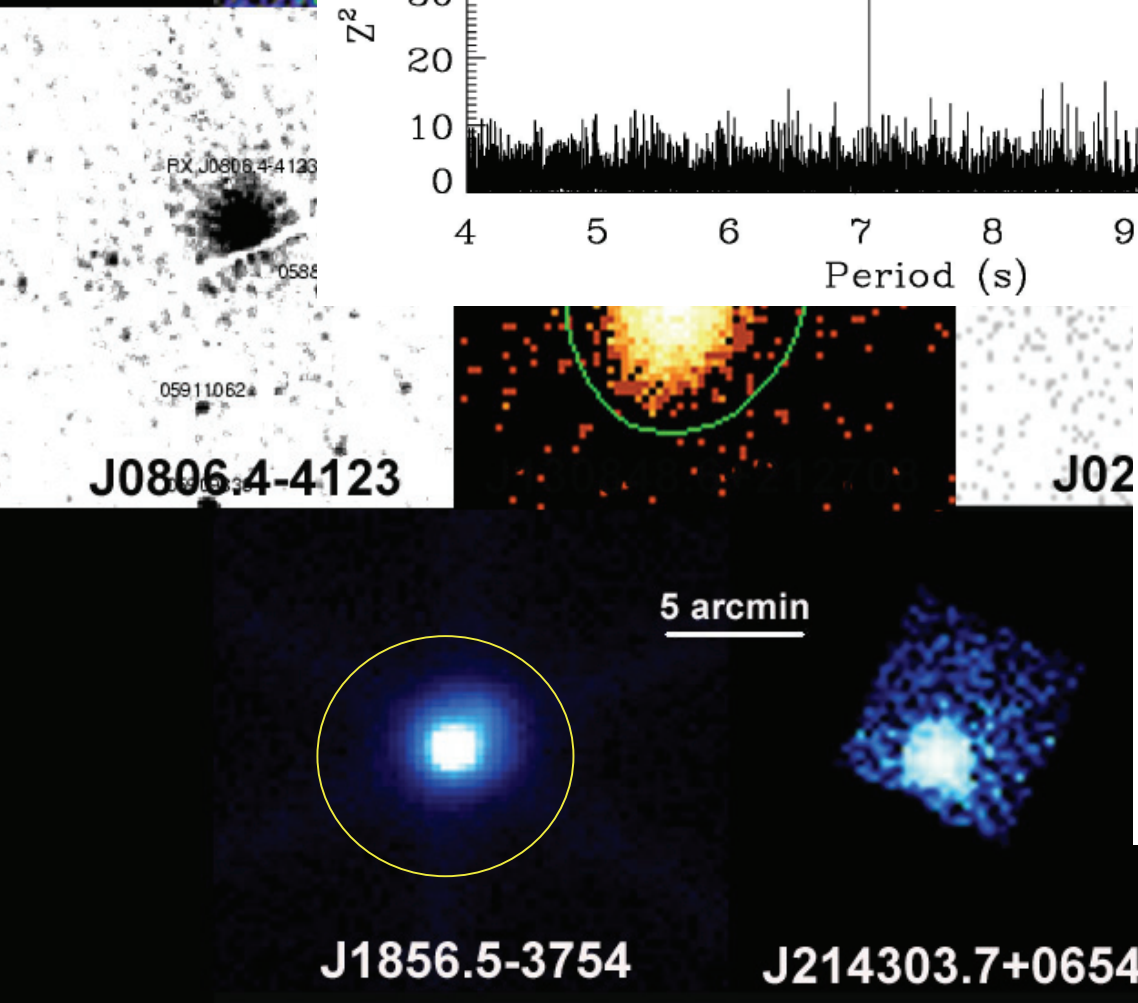


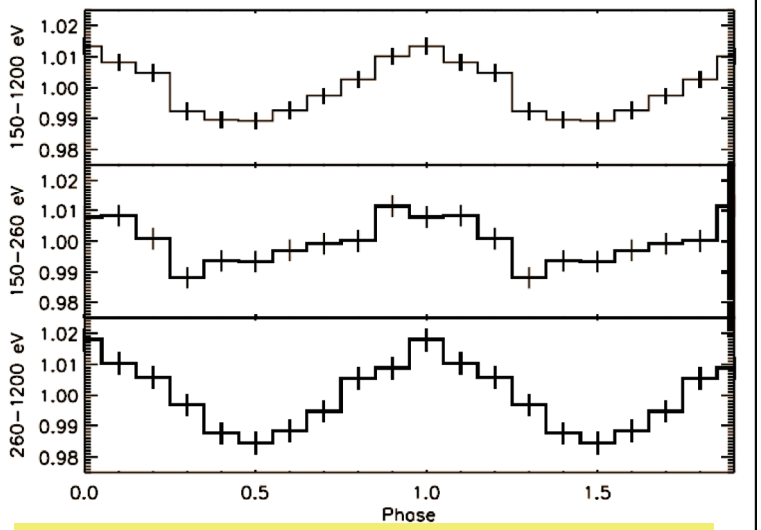
Pairs from A's wind flow into the open field line region of B and lose energy via curvature radiation and IC → γ-rays heating polar cap region

INSs

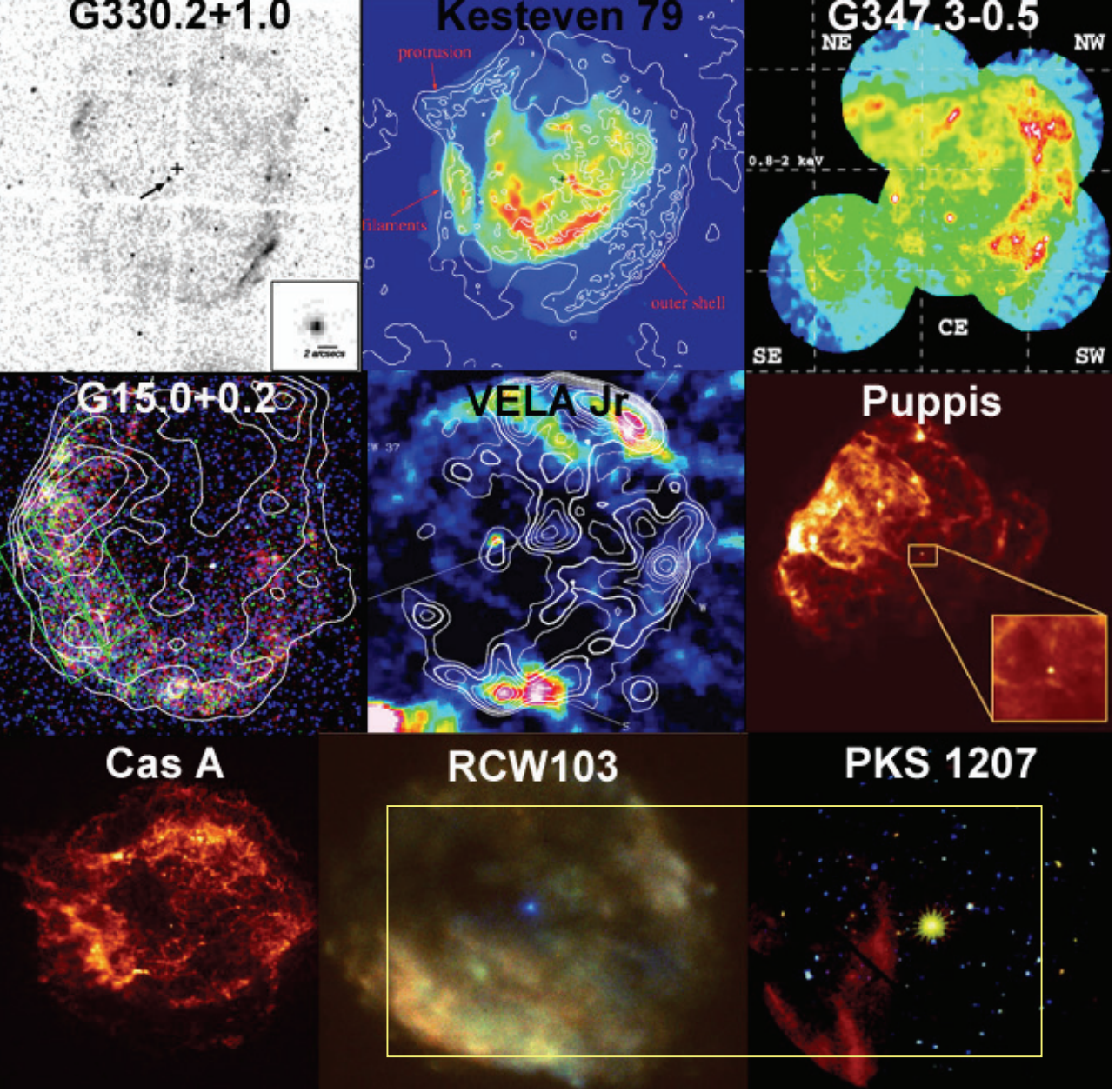


No radio em.
Faint optical em.
Thermal spectra
Low T
Whole surface
Shallow puls.





Pulsed fraction: ~1.2%

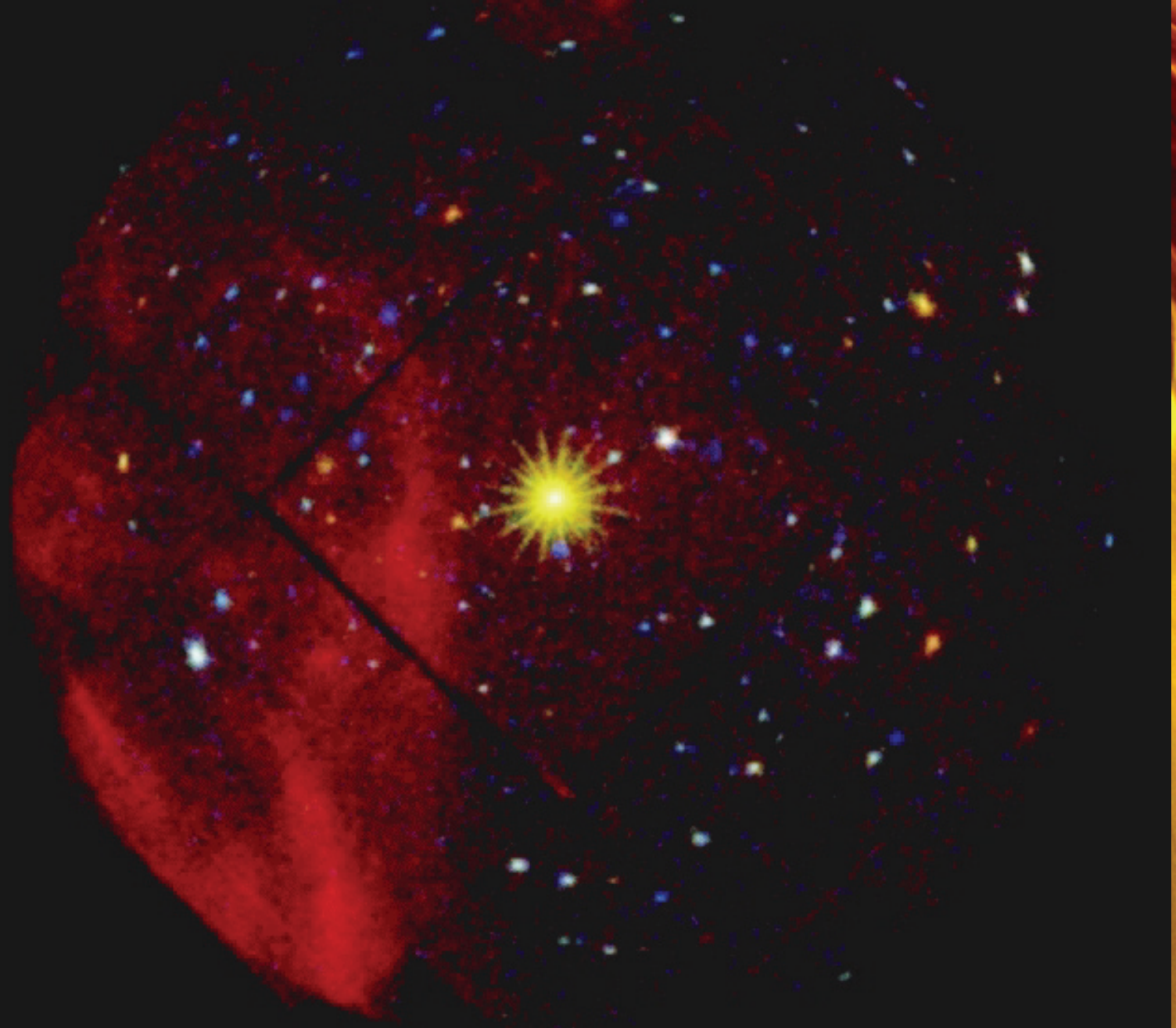


CCOs

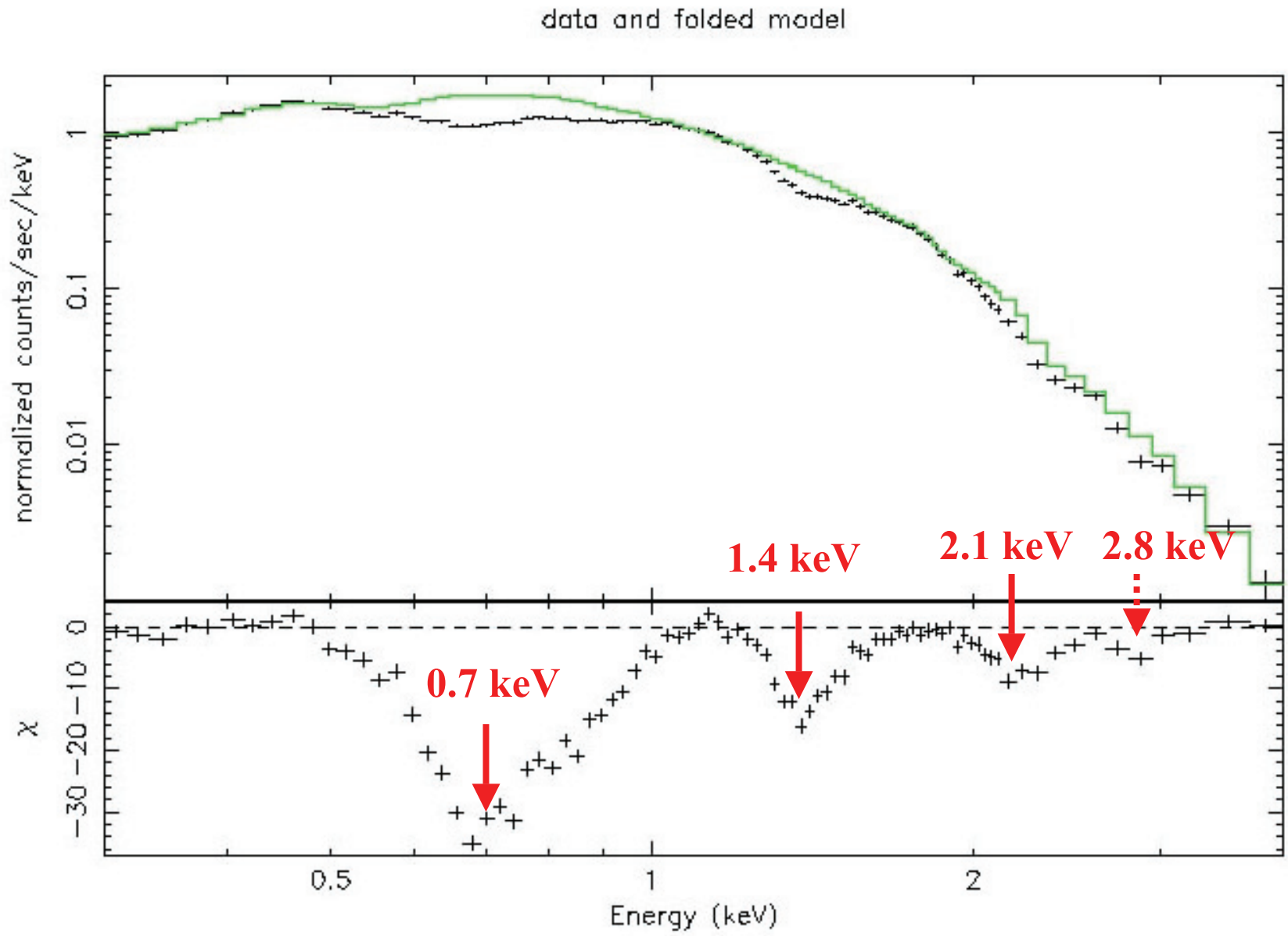
No radio emission
No optical emission

Thermal spectra
Small R, high T

EPIC view of 1E1207.4-5209 : 260 ksec



Pn data 208,000 photons



Bignami et al, Nature 2003

De Luca et al, A&A 2004

IF electron cyclotron: $\langle B \rangle$ 8 10^{10}

IF proton $\langle B \rangle$ 1.6 10^{14}

After a long debate, Gotthelf et al 2007 have shown that P is very stable

Thus, $B < 3.5\ 10^{11}$

→born slow

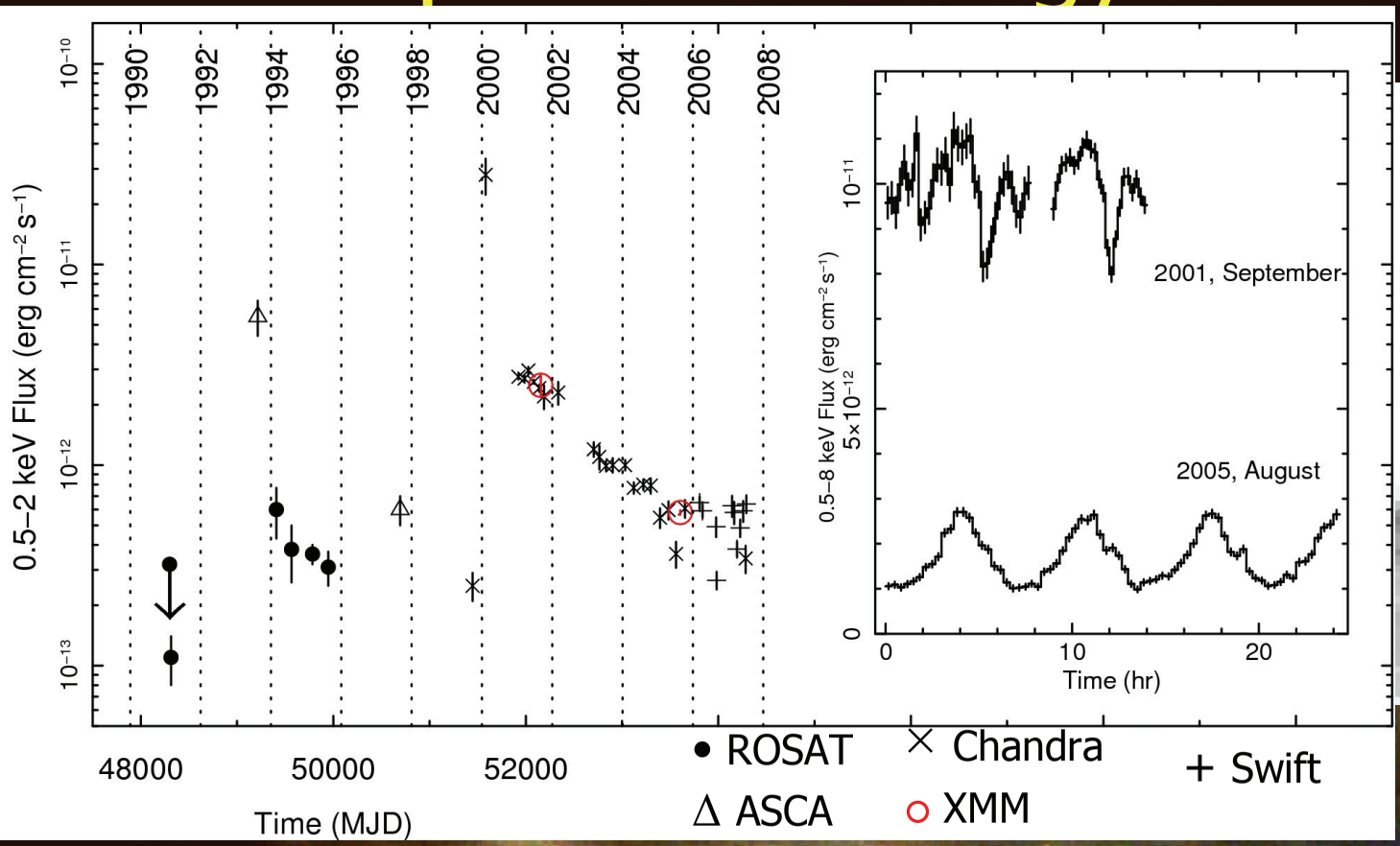
Edot $< 1.5\ 10^{32}$ → $L_x = 2\ 10^{33}$

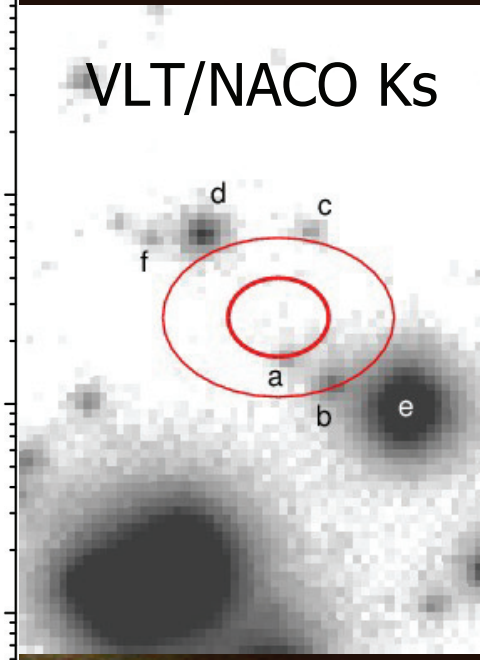
Fallback accretion???

CCOs as a class:
slow rotators, low B neutron stars?

Fallback accretion fuels X-ray em.
but hampers radio one.

The phenomenology of 1E1613





Genetically tied to a 2 ky-old SNR

Unique phenomenology

A young binary?

A peculiar INS?

De Luca et al, Science 313, 814, 2006

On the nature of 1E1613

A young binary?

IR data allow for M6-M8 companion

Binary system formation?

Luminosity/variability from accretion ?

Analog of a Polar featuring a magnetar ?

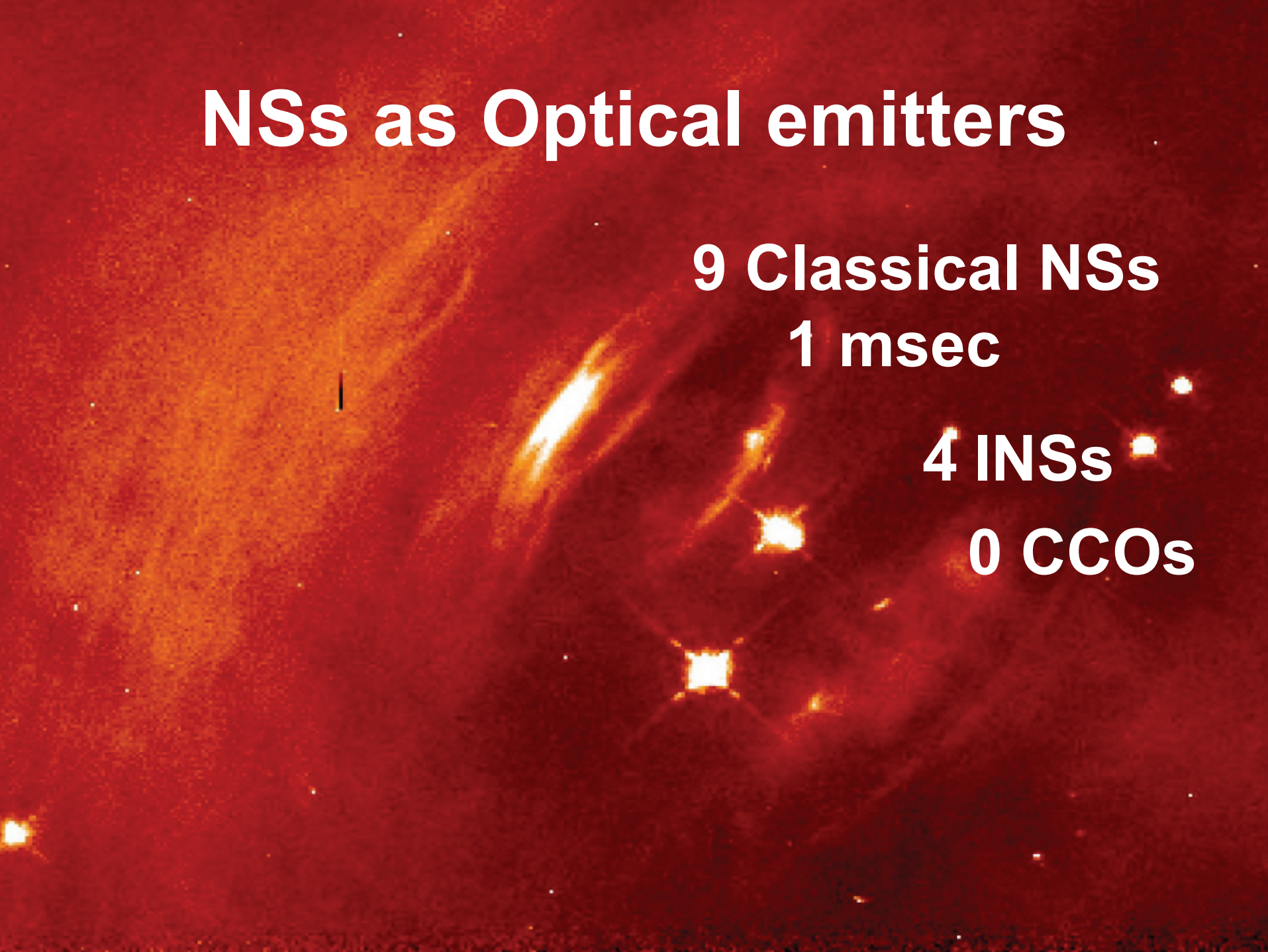
A peculiar INS?

Unique phenomenology points to “braked magnetar”

Spun down by propeller effect on debris disc

Spin history driven by fallback

NSs as Optical emitters



Our contribution (over 10 y.)

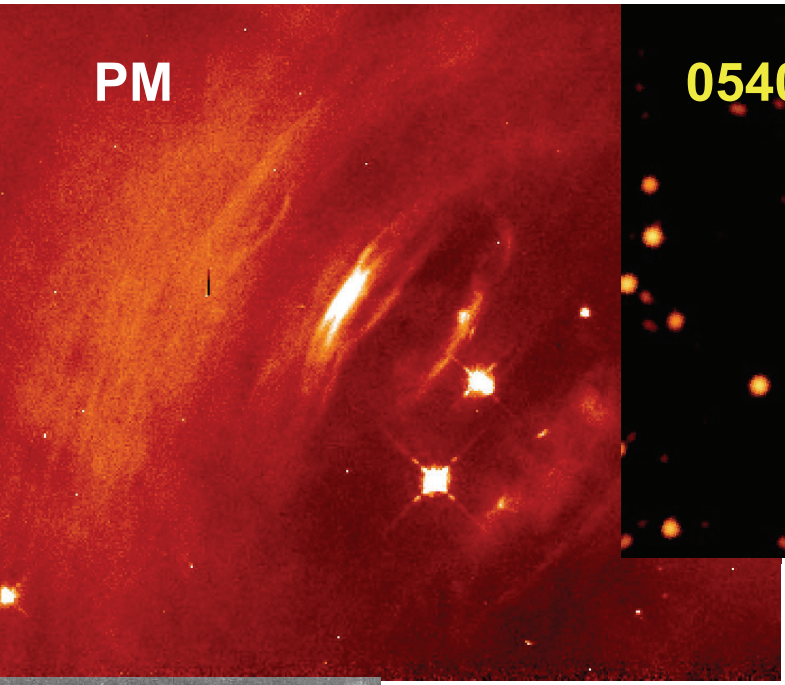
9 Classical NSs
1 msec

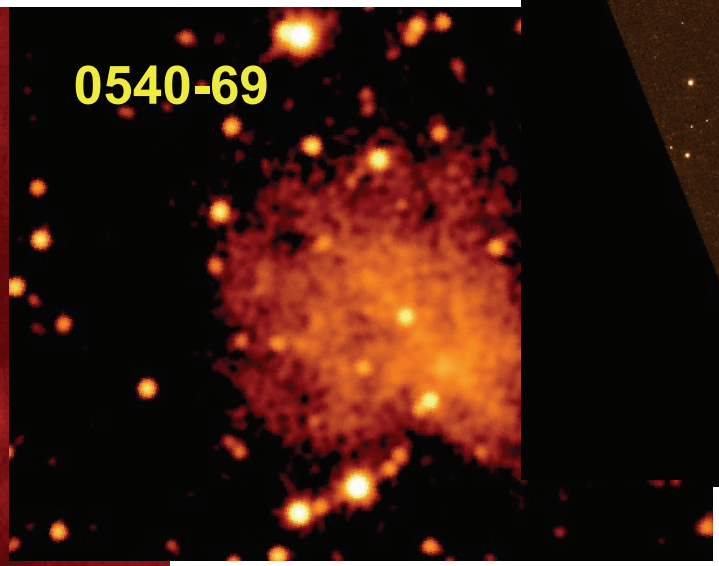
Discovery of 4 counterparts
Meas. of 5 PMs
Meas. of 2 parallaxes

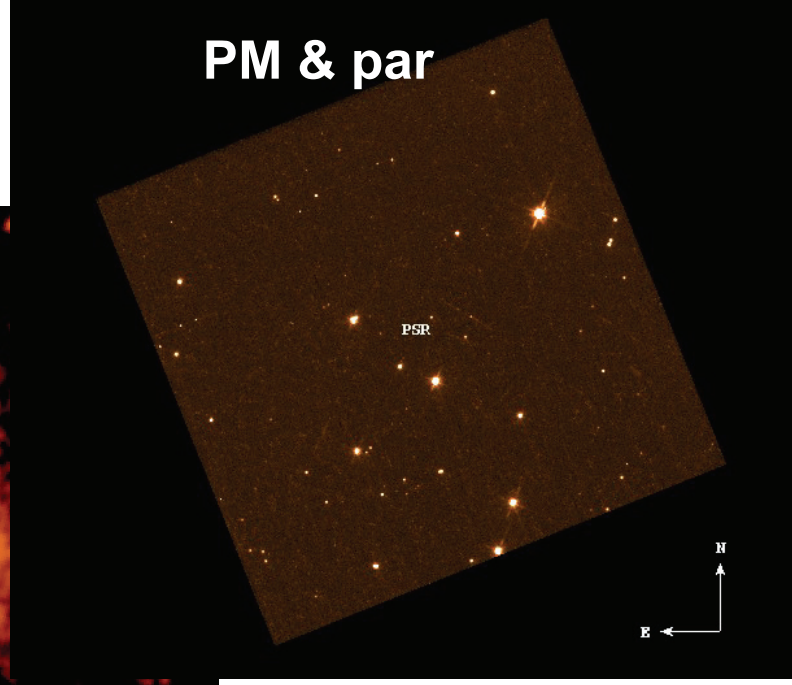
4 INSs
0 CCOs

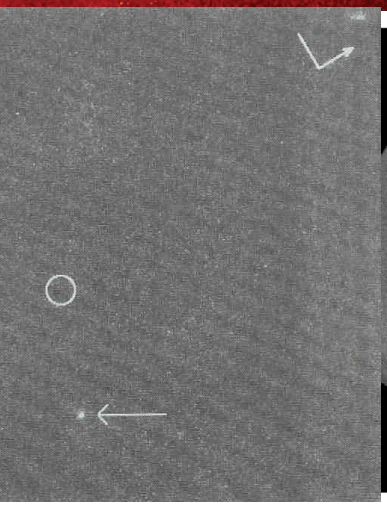
Search
for count.
1E1207
1E1613
Vela Jr.

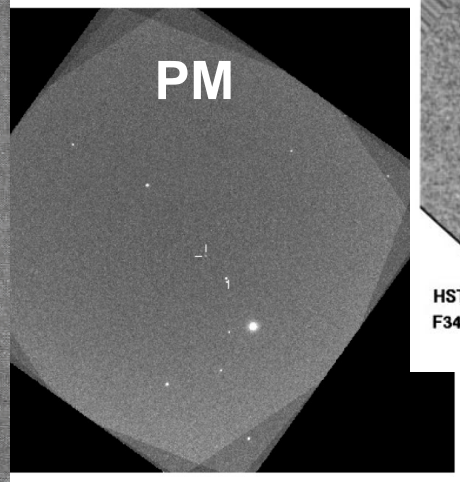
HST PSRs gallery

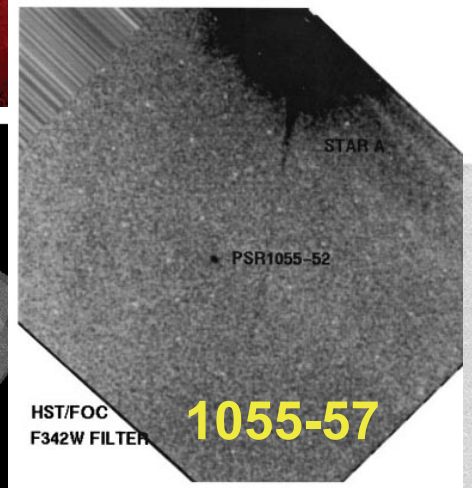


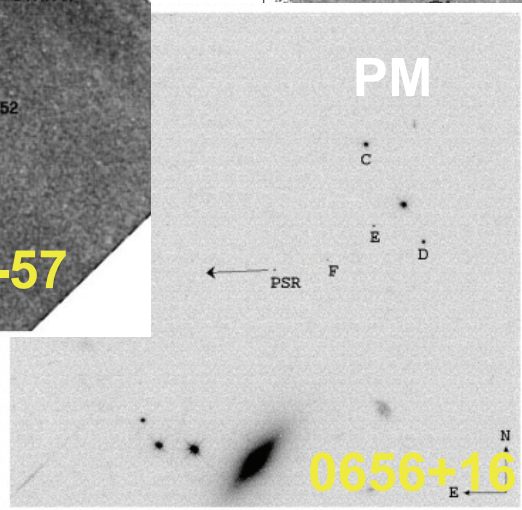


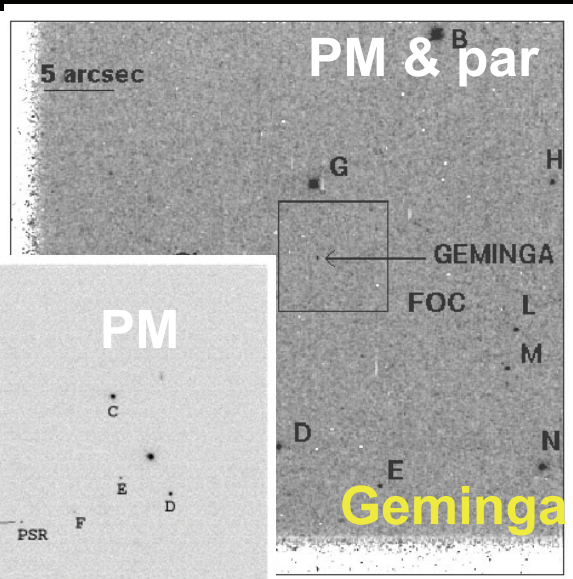




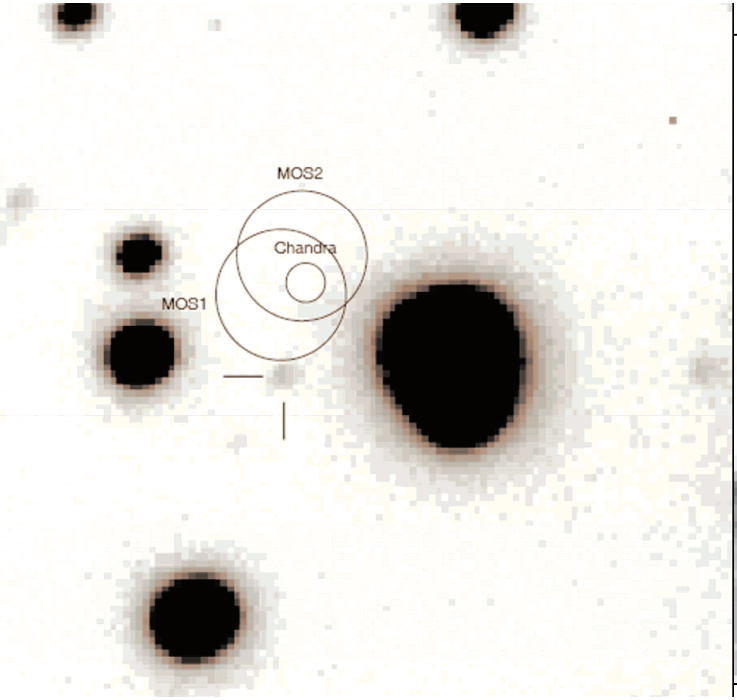




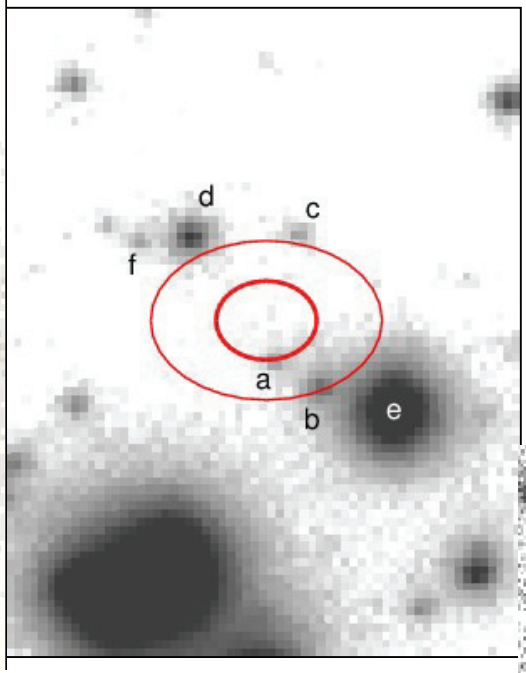




Elusive CCOs

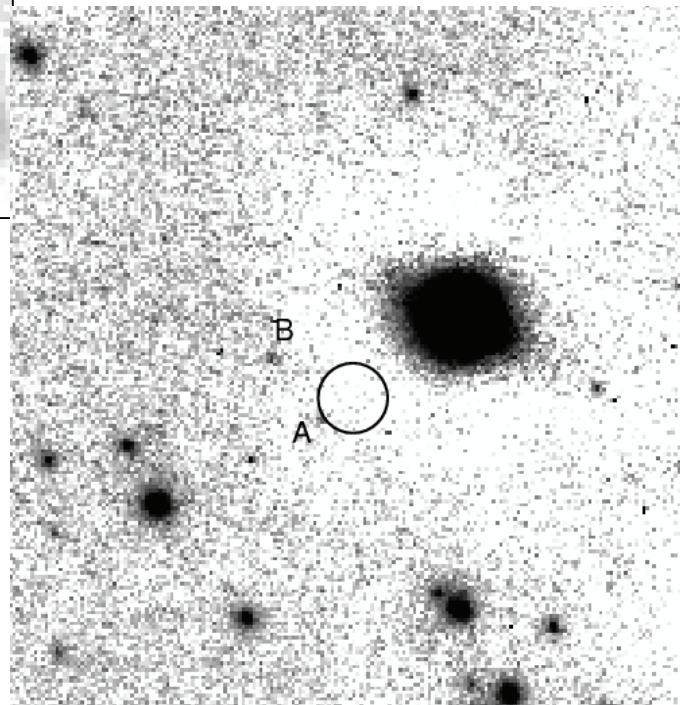


1E1207

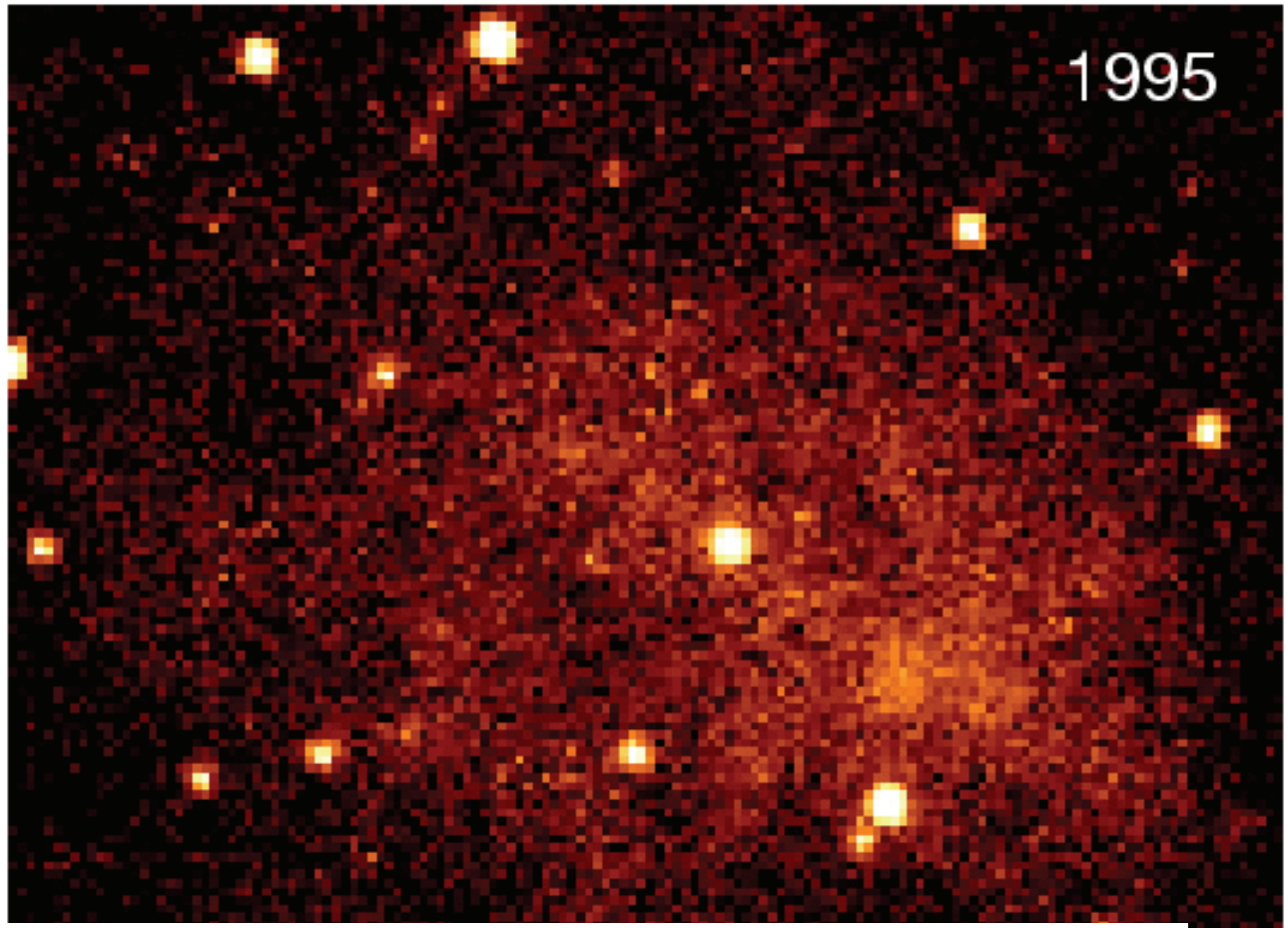


1E 1613

Vela Junior



A varying PWN for 0540-69



A. De Luca, R.P. Mignani, P.A. Caraveo, G.F. Bignami
HST multi-epoch imaging of the PSR 0540-69 system unveils a highly dynamic synchrotron nebula
ApJ. Lett 667, L77, 2007

Back to the future

Agile and Glast will discover many Geminga-like sources

We plan to lead the effort to identify them.
(G. Novara and F. Senziani)