Constraining the geometry of PSR J0855-4644: A nearby pulsar wind nebula

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1. CEA Saclay
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Vela Senior

Puppis A

1.

Vela cocoon

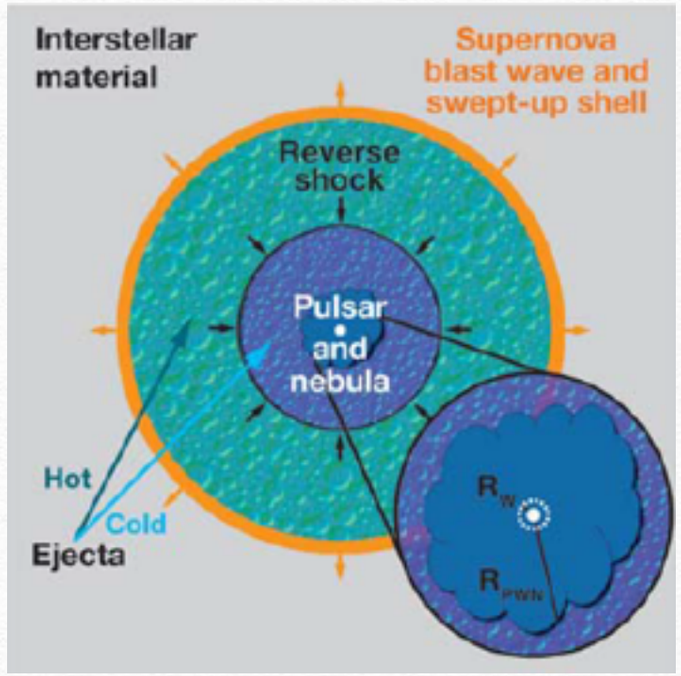
Vela Junior

PSR J0855

E < 1.3 keV
E > 1.3 keV
HESS

Maitra, Acero & Venter A&A, 2016 (submitted)

Pulsar Wind Nebulae (PWNe)



picture courtesy Gaensler & Slane 2008

- Confinement of pulsar wind in the ambient medium: probes of shock acceleration/interaction of high energy particles with the ambient medium

- Trace energy flow and evolution of pulsar/particle distribution of pulsar wind

- **Young PWNe often have axial symmetry: formation of equatorial torus and polar outflows (jets): Constraint on pulsar geometry**

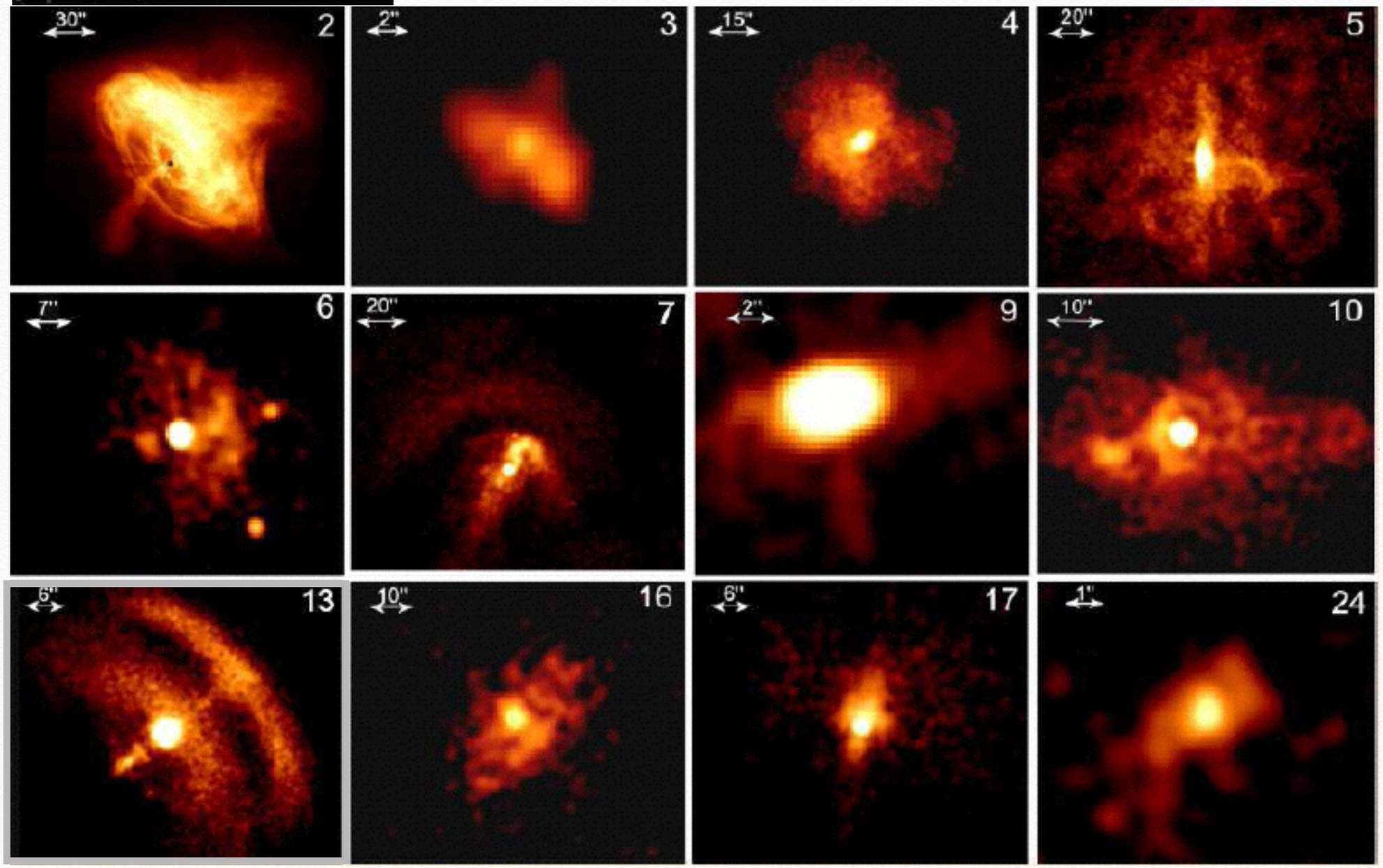
→ Resolved sub arc second structures of the PWNe:

a) **Anisotropic wind structures** (tori/jet)

b) **Bow shocks**

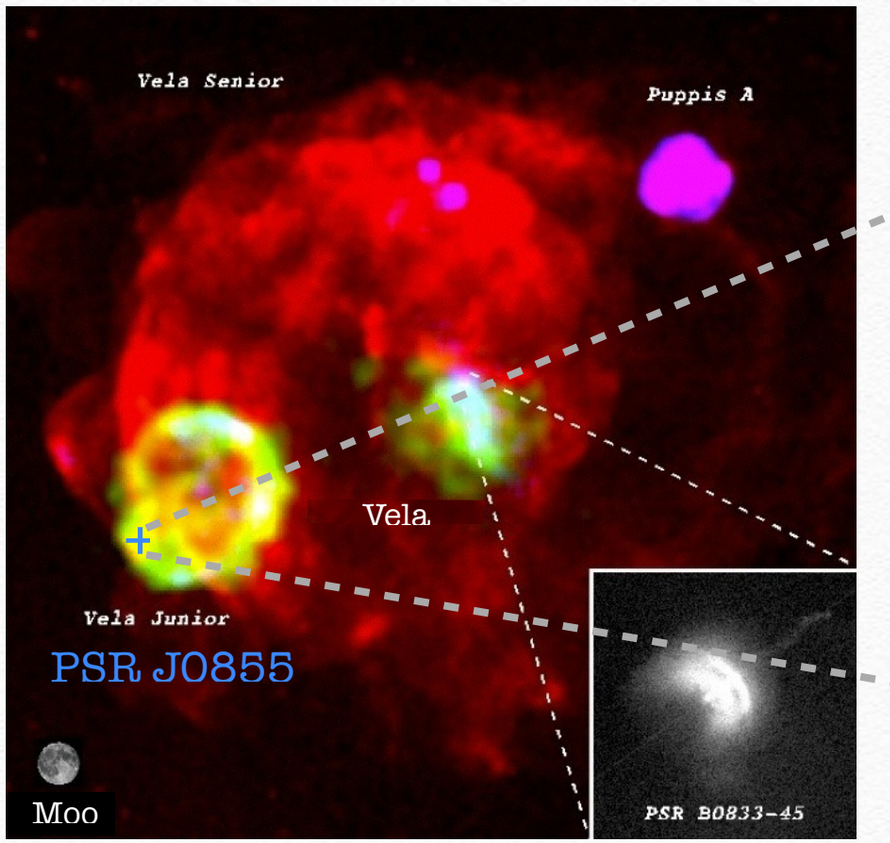
c) **Signatures of PWN interaction with ambient medium**

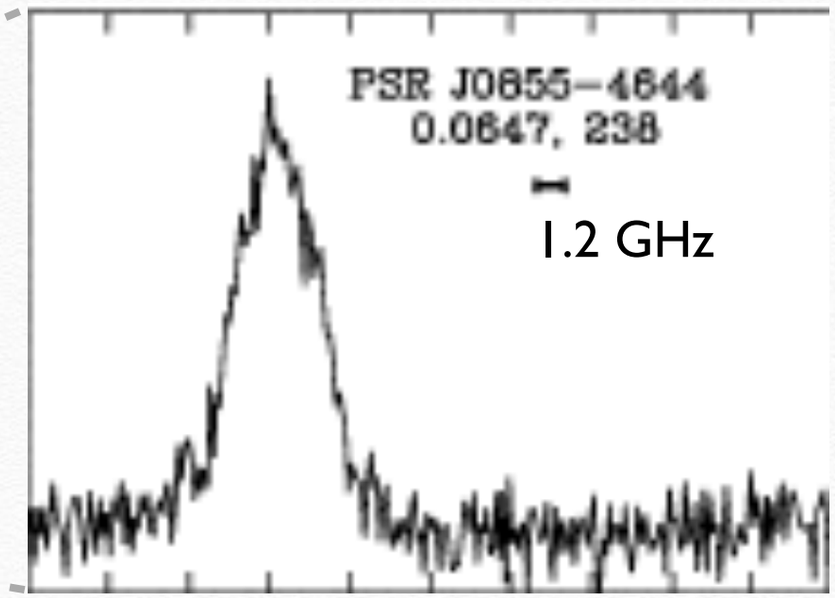
Crab:The classic PWN



Weisskopf 2000

PSR J0855-4644: nearby fast spinning, energetic radio pulsar





- Fast pulsar P = 65 ms, $\dot{P}$=7.26 *10^{-15} $\dot{E}$ =1.1 *10^{36} erg/s (from Parkes radio survey)

- Distance < 1 Kpc (X-ray Nh estimate) ; second most energetic pulsar after Vela at this distance

PSR J0855-4644: nearby fast spinning, energetic radio pulsar

- Why wasn't it discovered before?

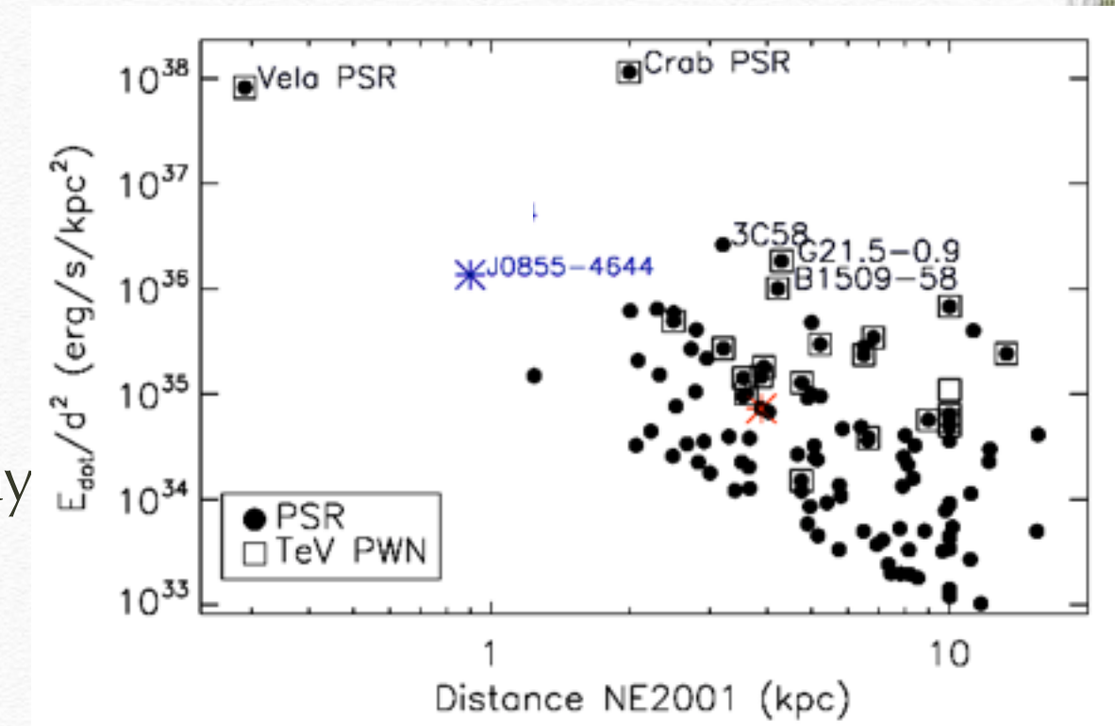
  embedded in a complex region

- Most high $\dot{E}/d^2$ pulsar have detected γ ray pulsed emission.

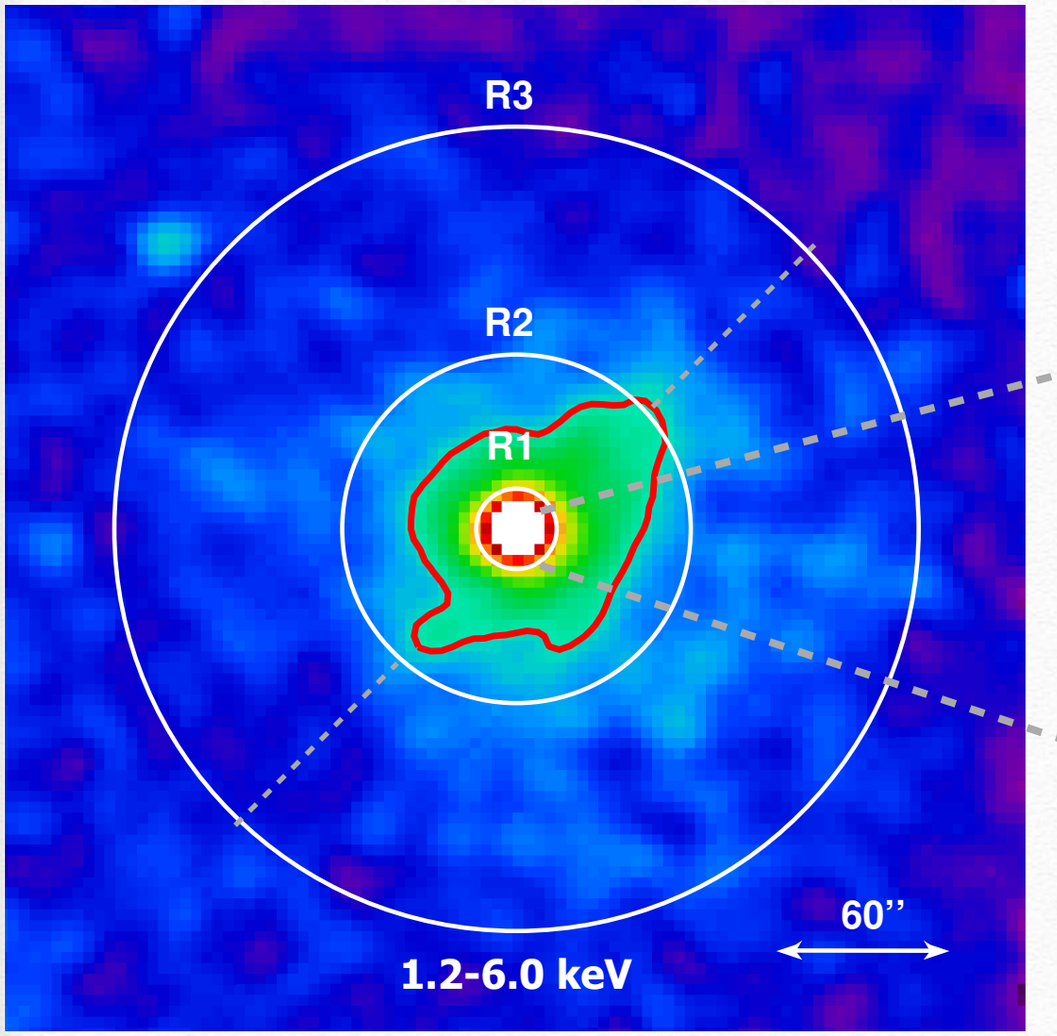
- **Radio loud**, γ **ray quiet** high pseudo luminosity $\dot{E}/d^2$

- Highest $\dot{E}/d^2$ system not seen by Fermi

- **Why no gamma rays ? Geometry ?**



Through the eyes of XMM-Newton



R1=15”

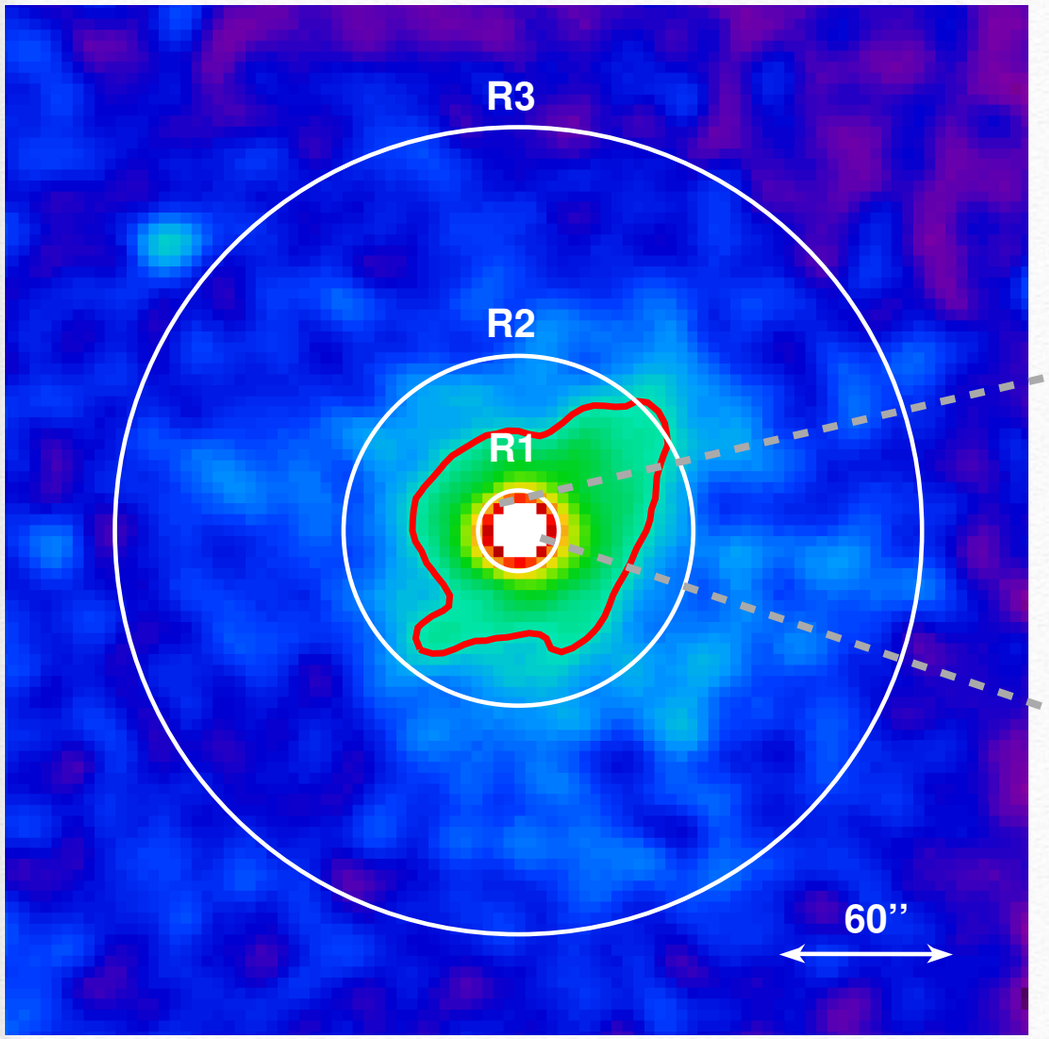
X-ray counterpart of pulsar

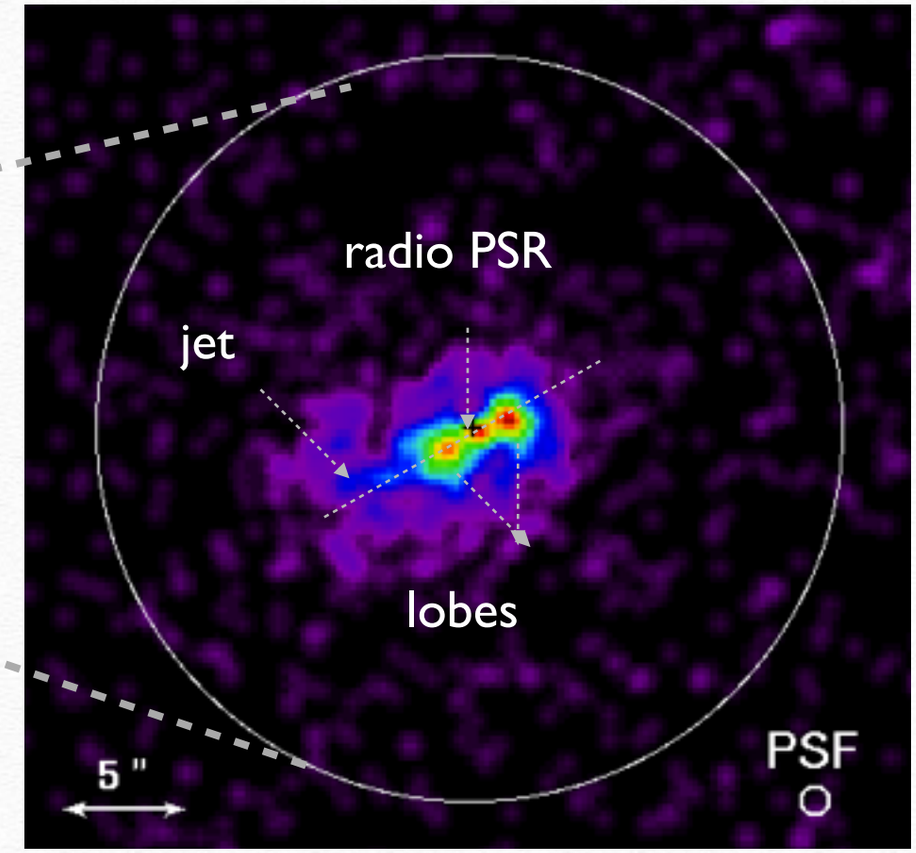
?

PWN revealed ~150 “ in extent

Acero et al. 2013, A&A, 551, A7

Through the eyes of Chandra: Structured PWN revealed!





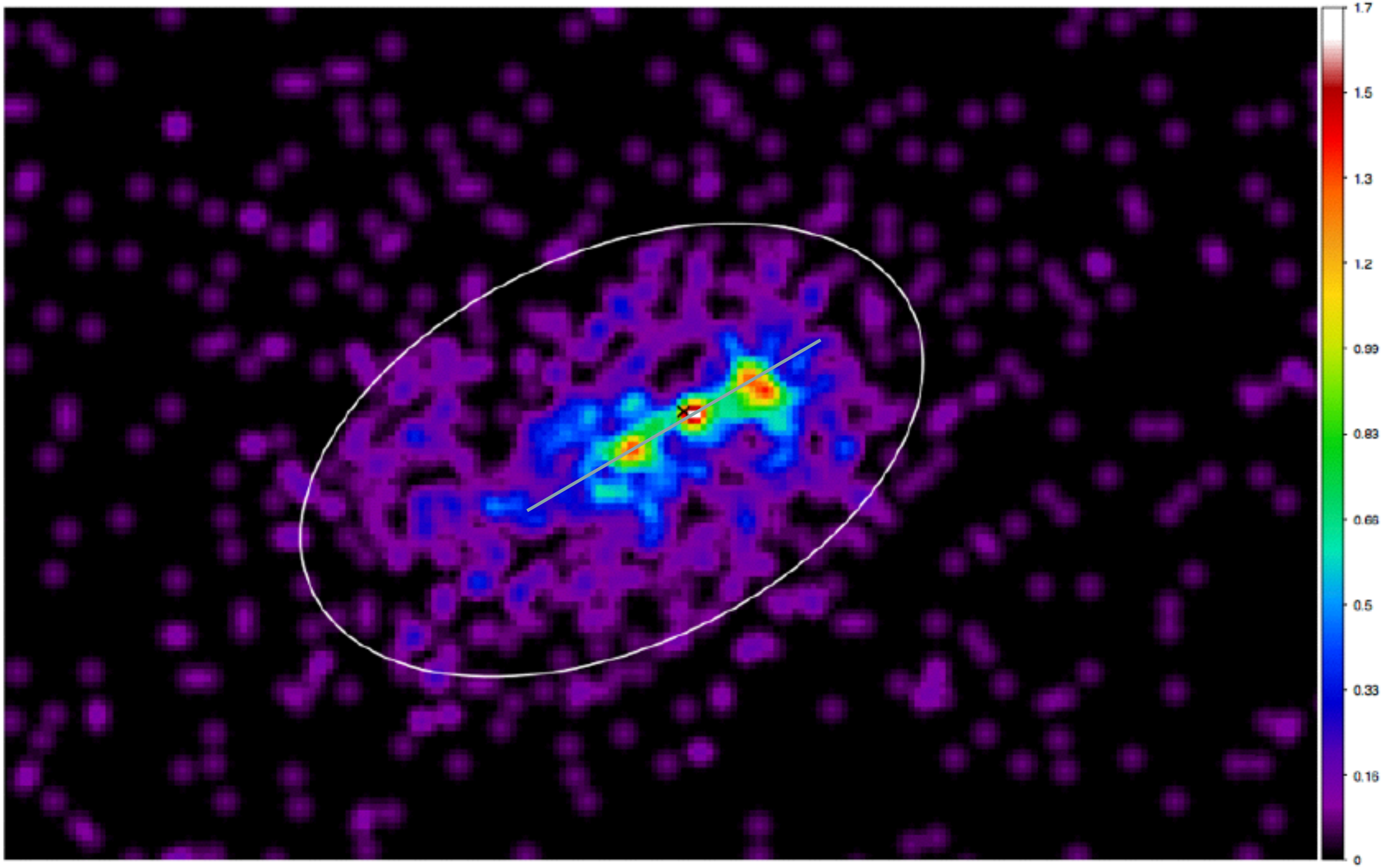
Chandra: ACIS-S observation

- What was thought to be X-ray pulsar: further resolved to 10″ compact PWN
- Two lobes symmetric about the pulsar → jets OR double torus+one sided jet

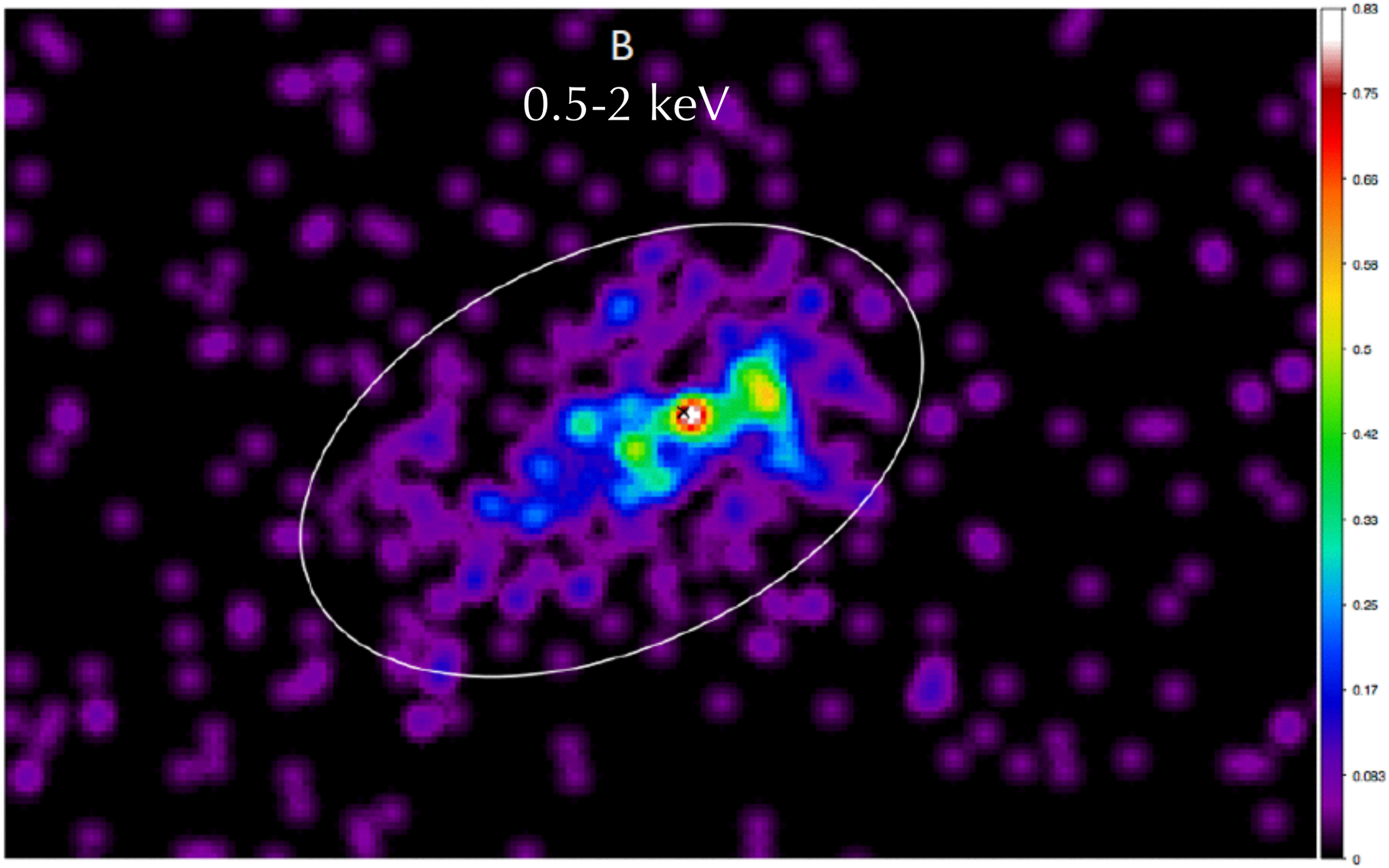
A close look at the PWN:

a) only third source after Vela & PSR J2021+3651 to show this morphology

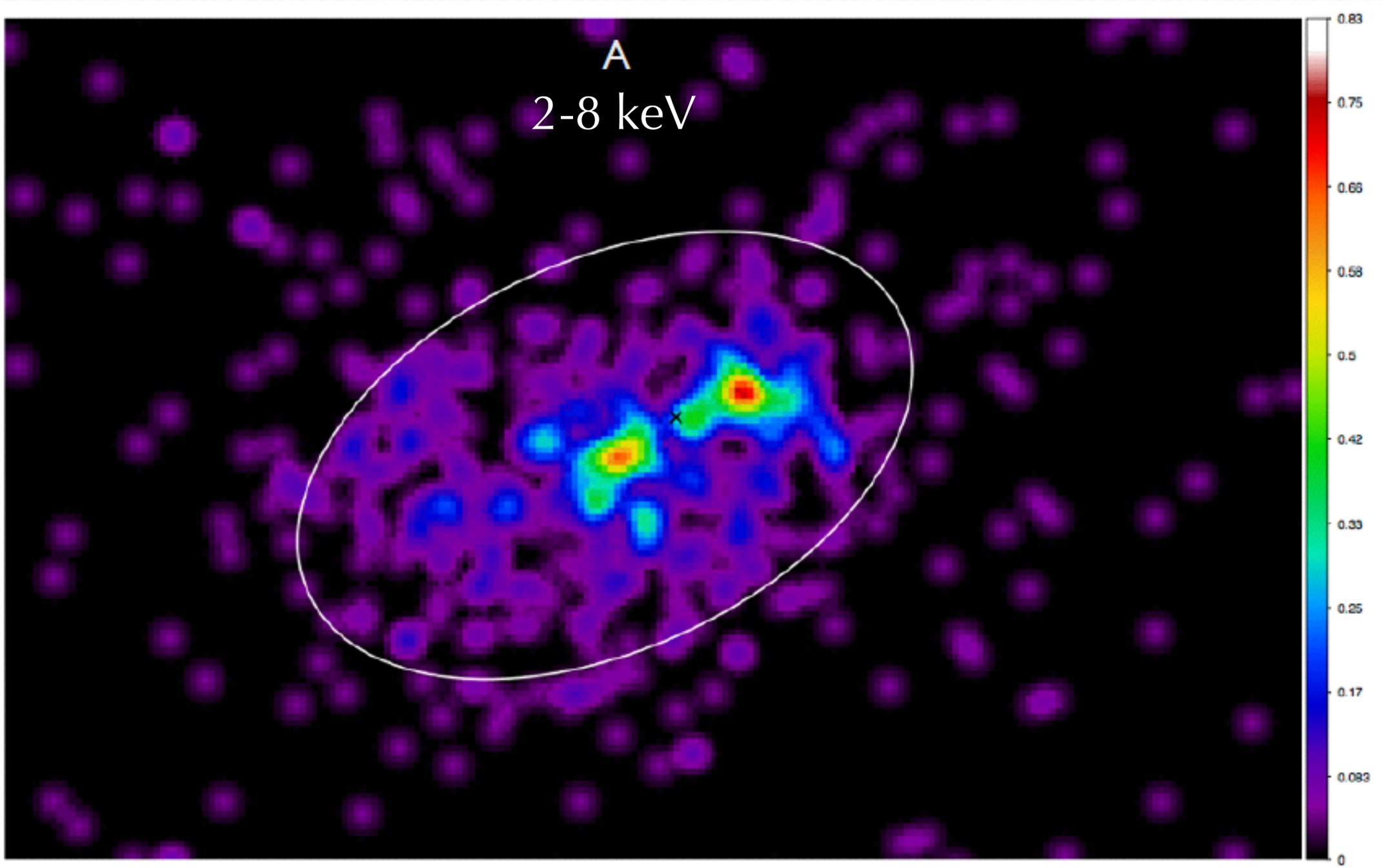
b) Nearby object (~ 900 pc): opportunity to study physics of equatorial & polar outflows in PWNe



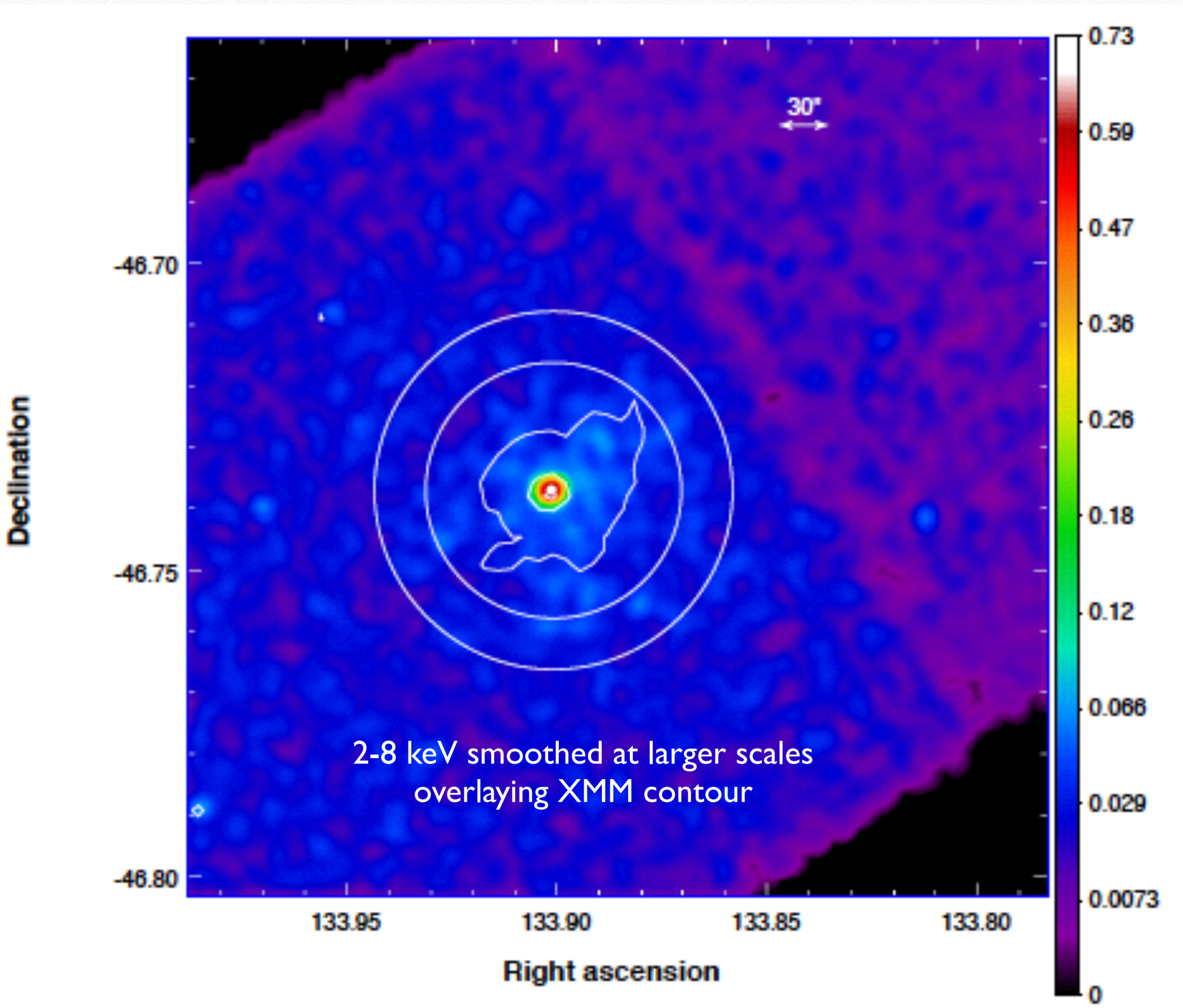
Energy resolved images



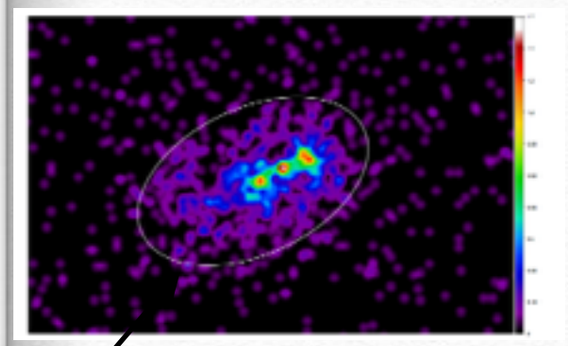
Energy resolved images



diffuse emission



X-ray Spectroscopy

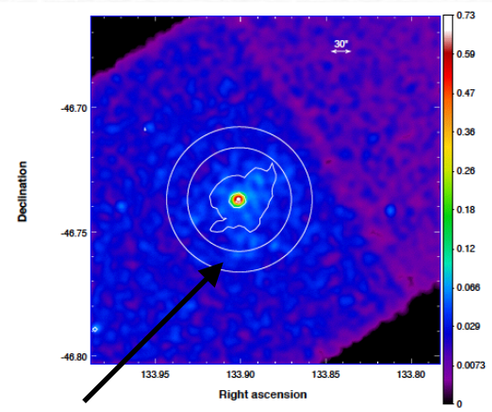


source

Confirming the XMM results

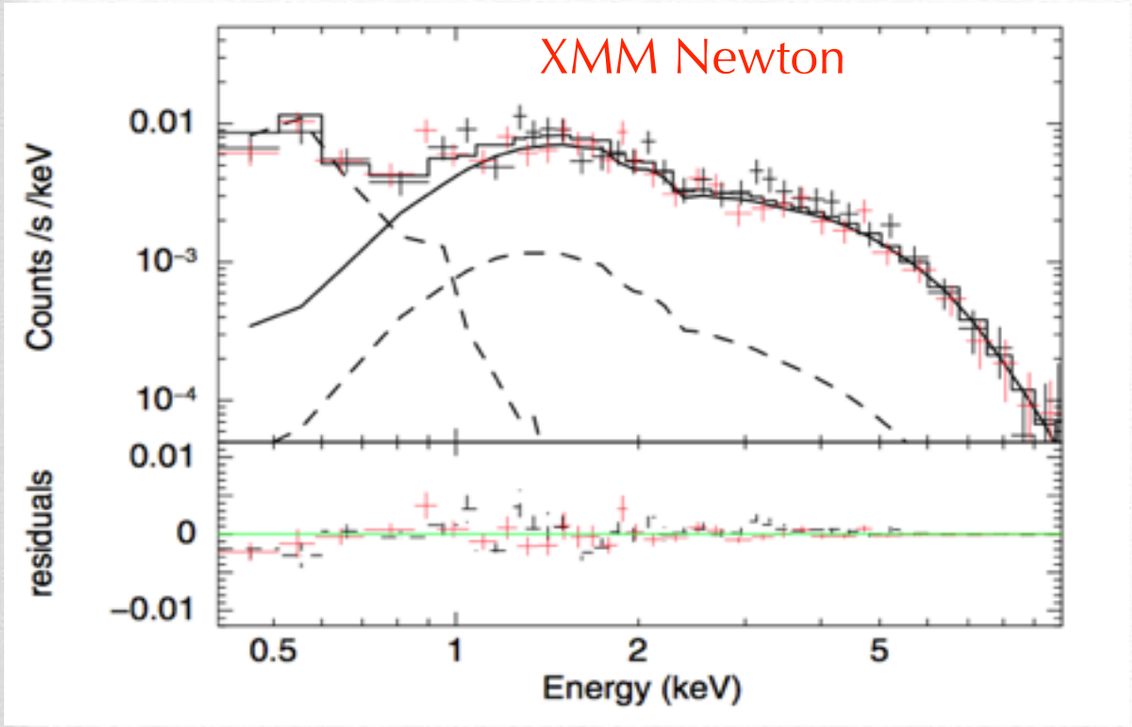
XMM (R: 15 “): NH=(0.64±0.12) x 10^{22} cm^{-2}

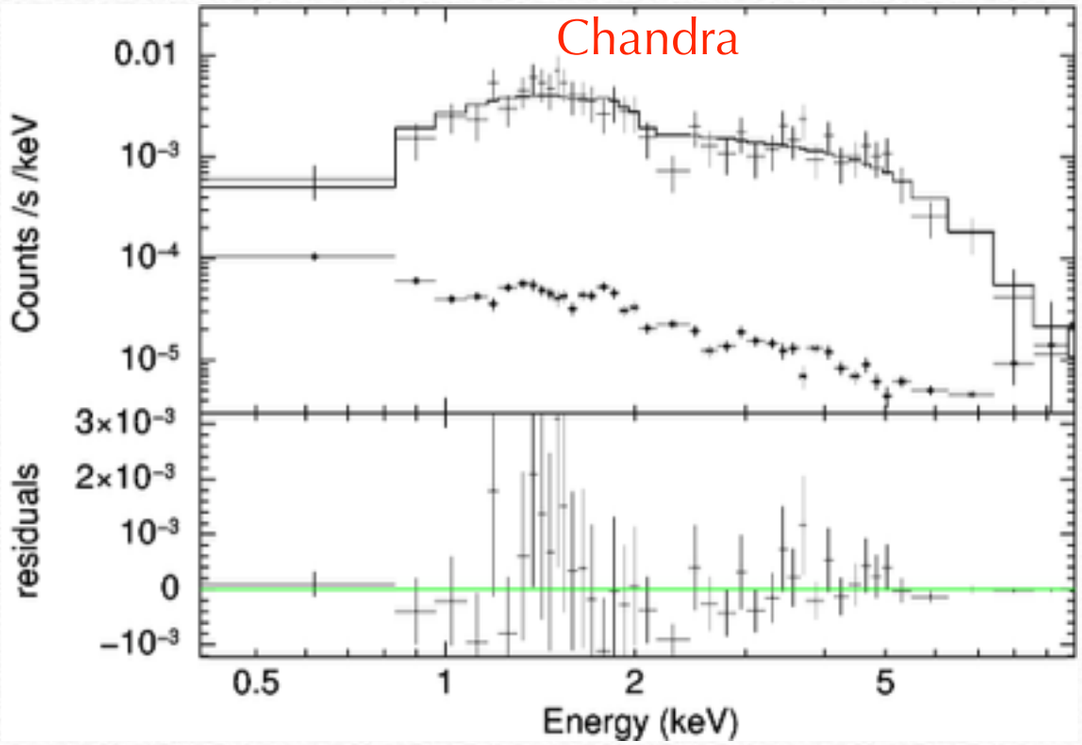
Chandra (R: 10”): NH=(0.70±0.20) x 10^{22} cm^{-2}



bgnd

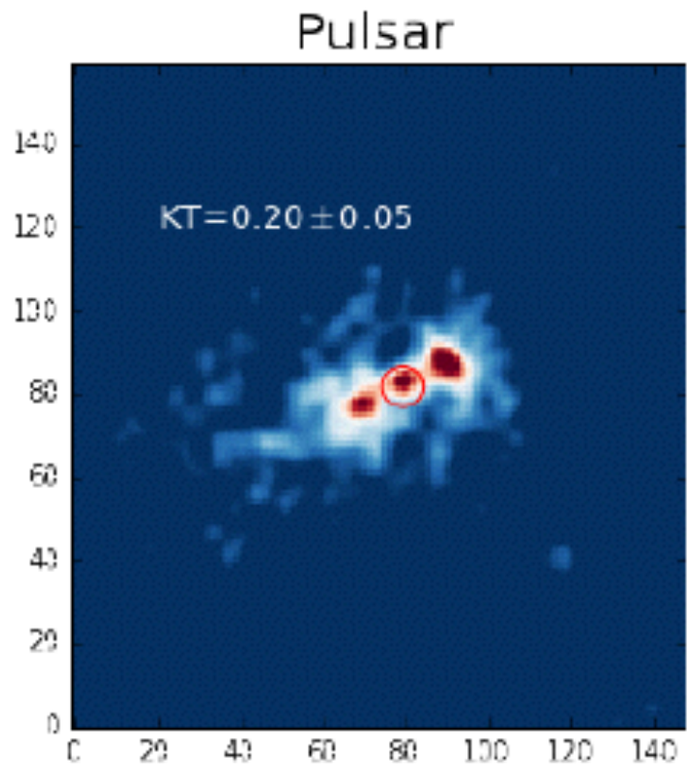
Reducing systematic uncertainties ⟶ Thermal emission 50 times less

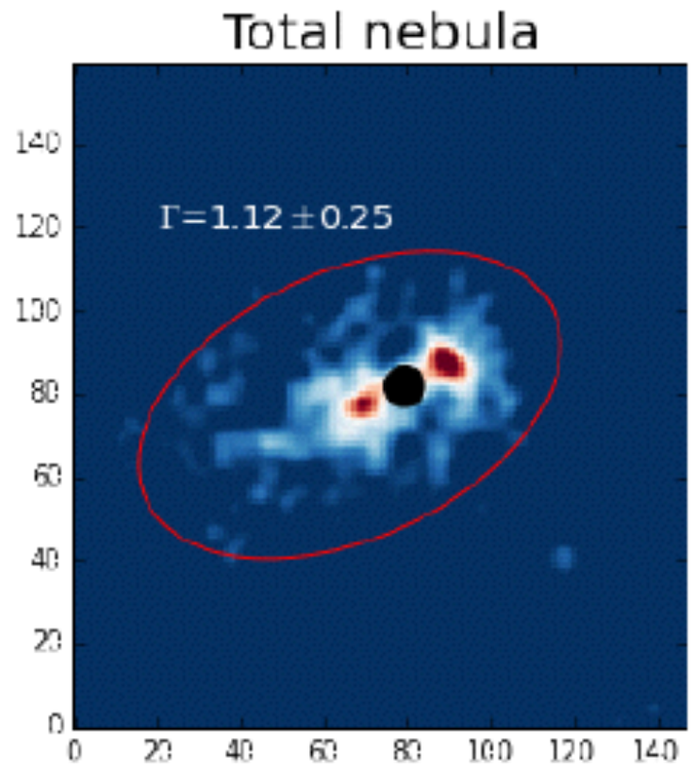


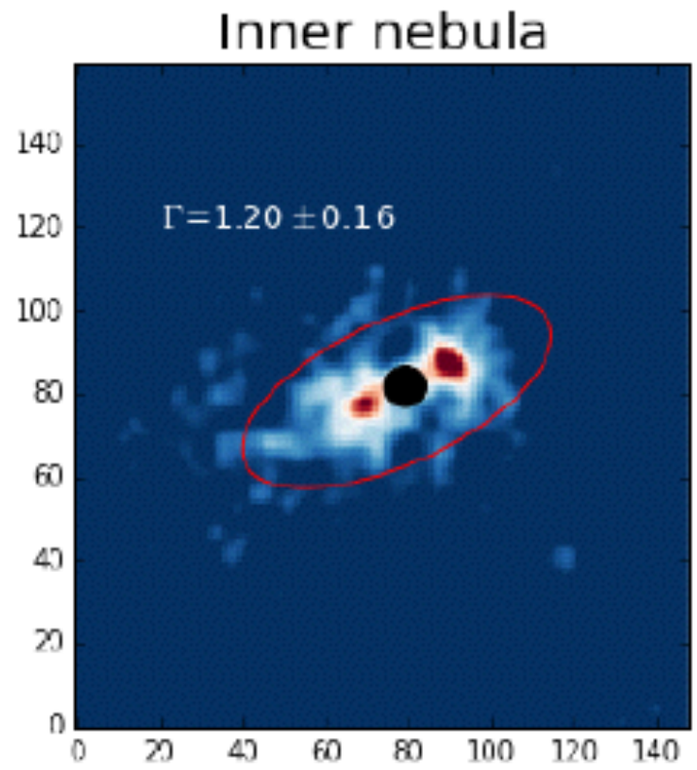


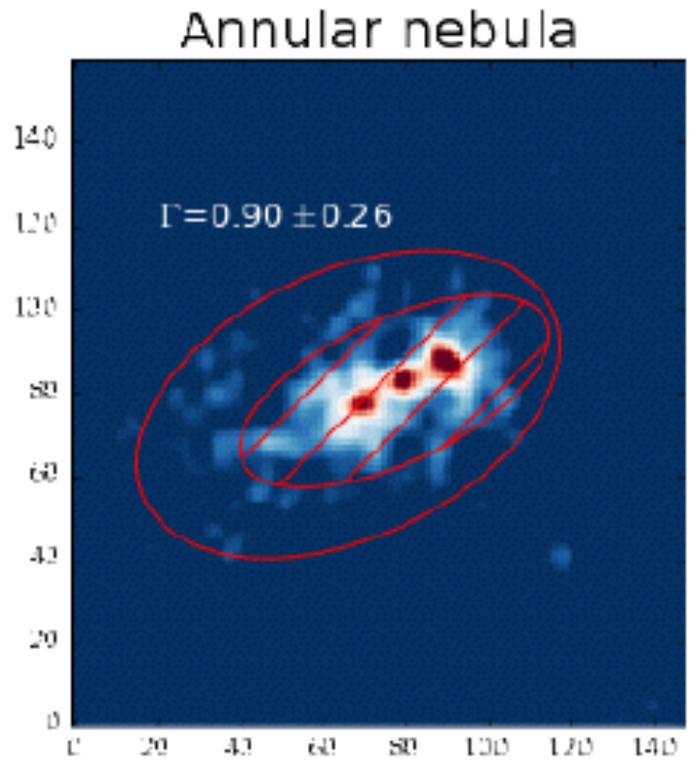
- Compare the spatially resolved structures of the PWN
- pulsar vs the axisymmetric structures

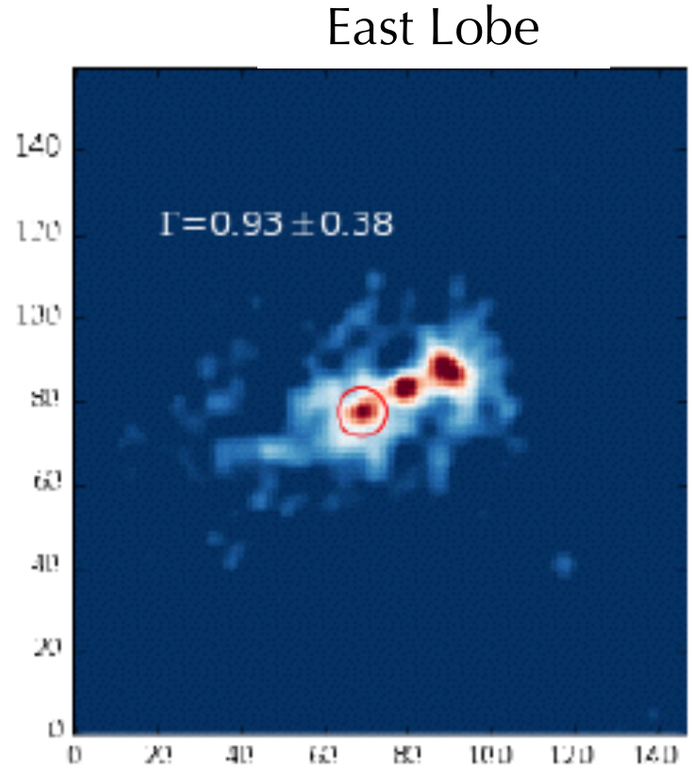
Spectroscopy of PWN structures

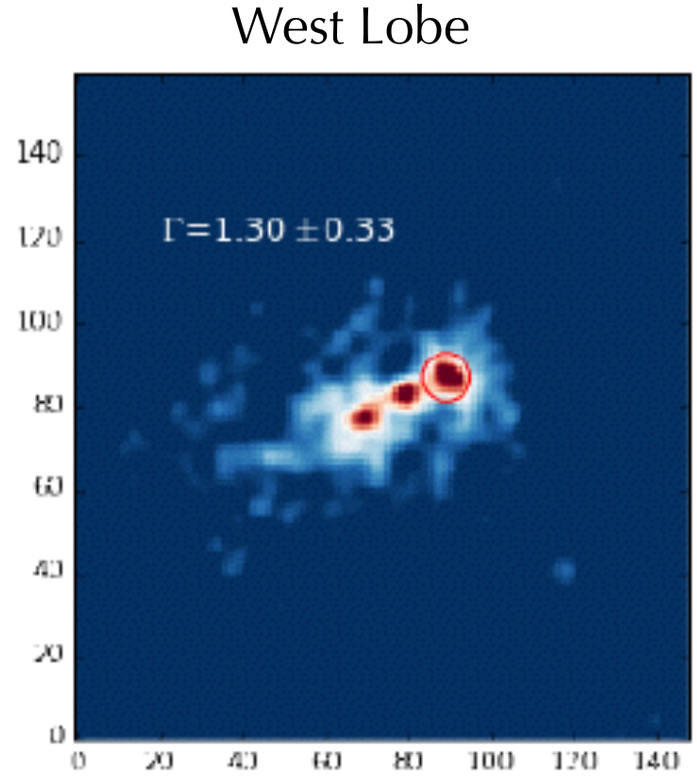




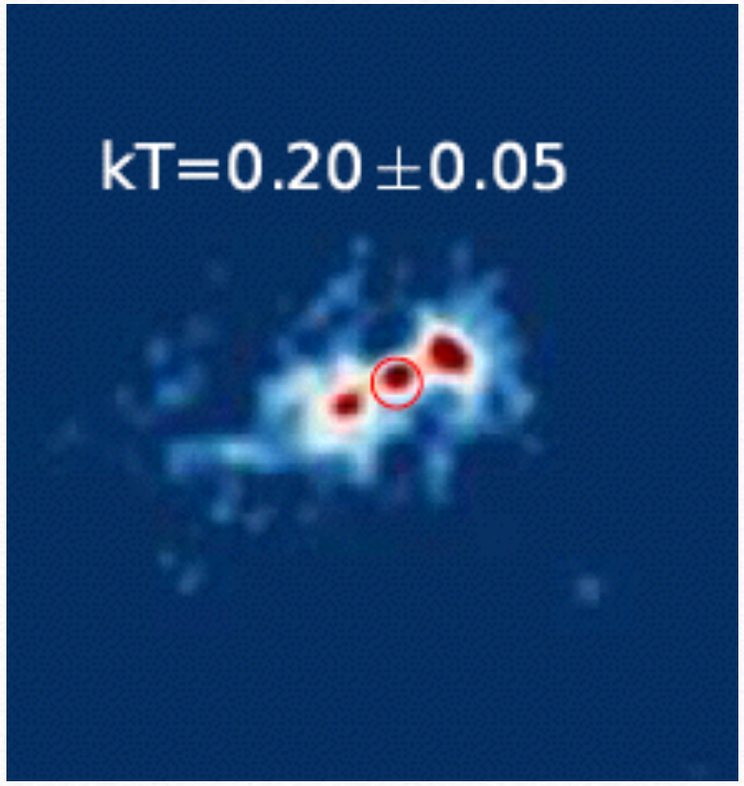




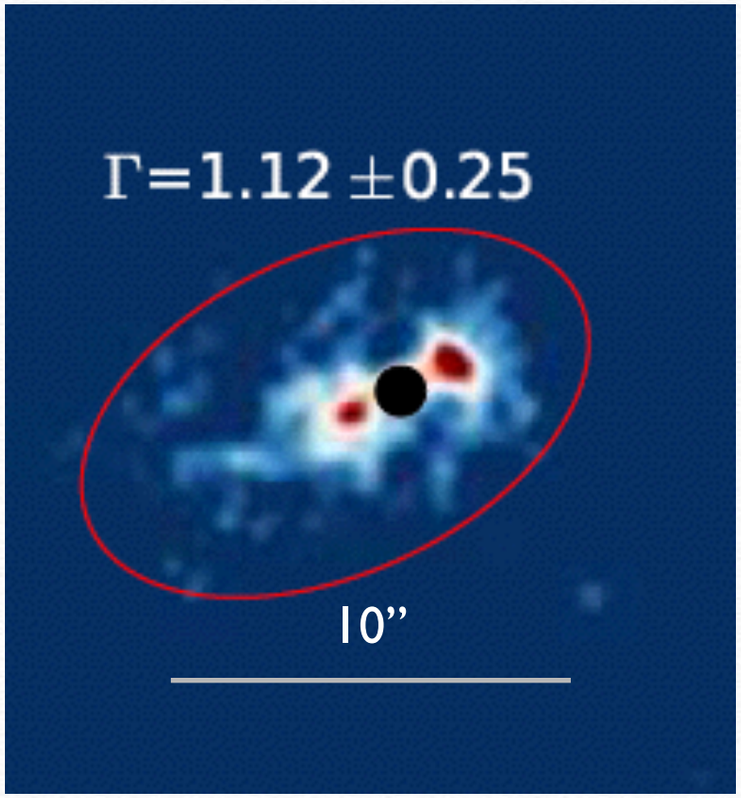




Faint soft pulsar & it's bright & hard nebula



Lx (0.5-8) = 1.3 X 10^{30} erg s^{-1}
Reff ~ 1.5 km : emission from hot spot of neutron star

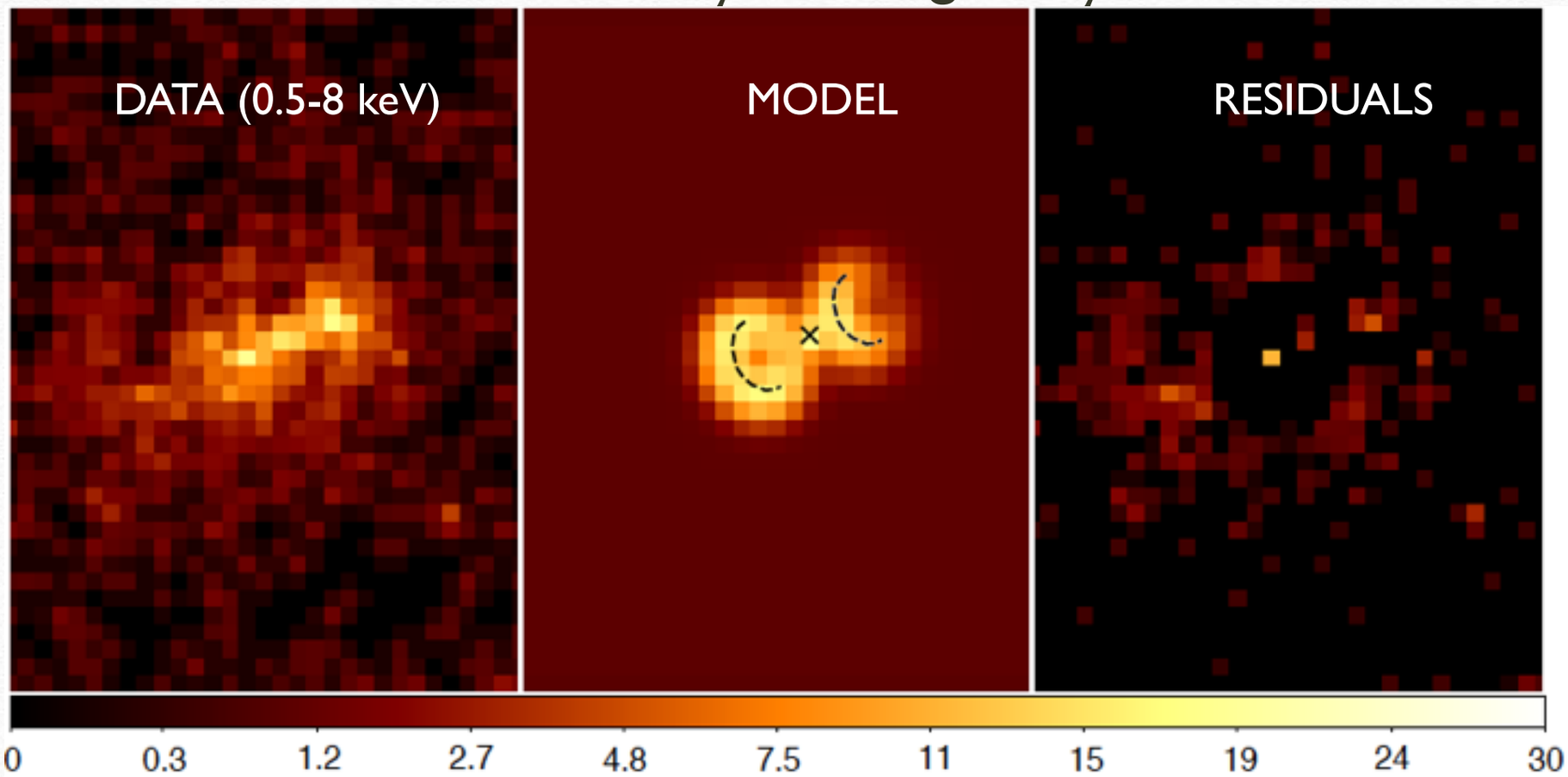


Lx (0.5-8) = 3.3 X 10^{31} erg s^{-1}
non-thermal emission
η≡Ė/Lx ~10-5
compact nebula ~0.06 pc (d=900 pc)

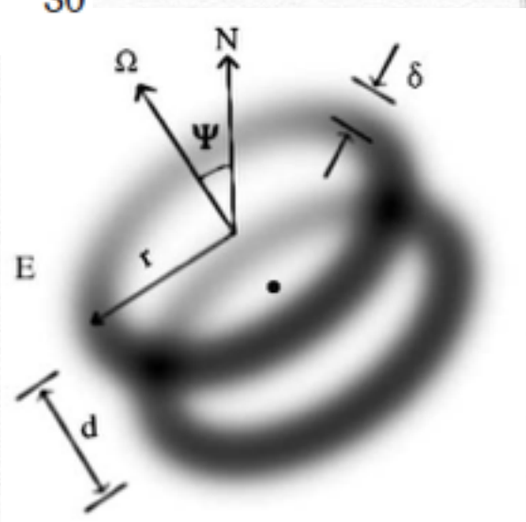
X-ray PWN of PSR J0855-4644

- Resolved the sub arc second PWN around PSR J0855-4644. Axisymmetric jets/torus features. compact PWN extends 0.06 pc (d=900 pc)
- Fainter diffuse PWN extends up to 0.6 pc showing jet like features
- Faint, soft X-ray pulsar compared to bright & hard compact nebula
- Only third source after Vela & PSR J2021+3651
- Most energetic pulsar after Vela in the nearby environment

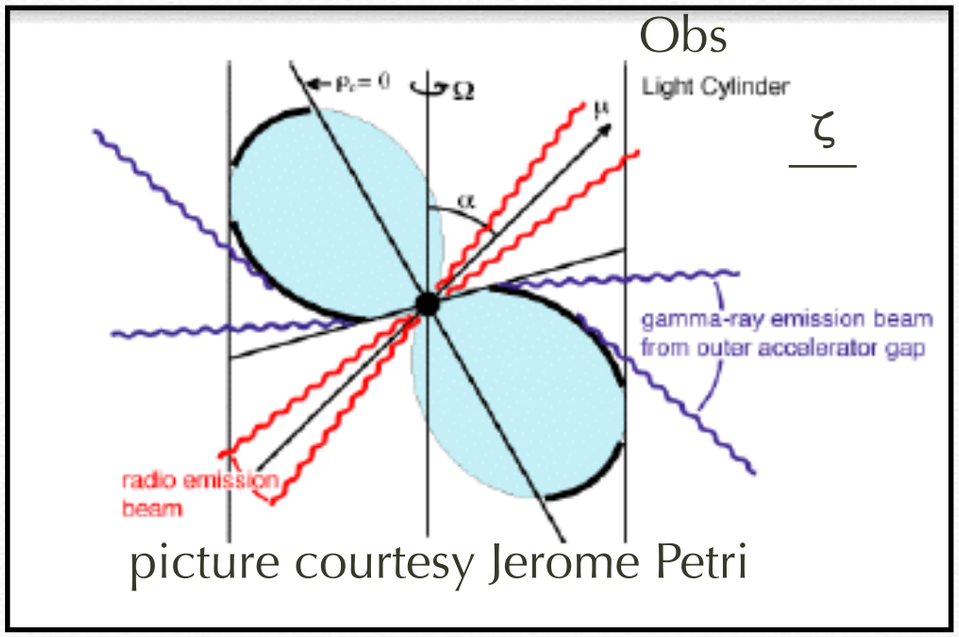
Spatial modeling Ng & Romani 2004: Can we answer why no γ ray emission?

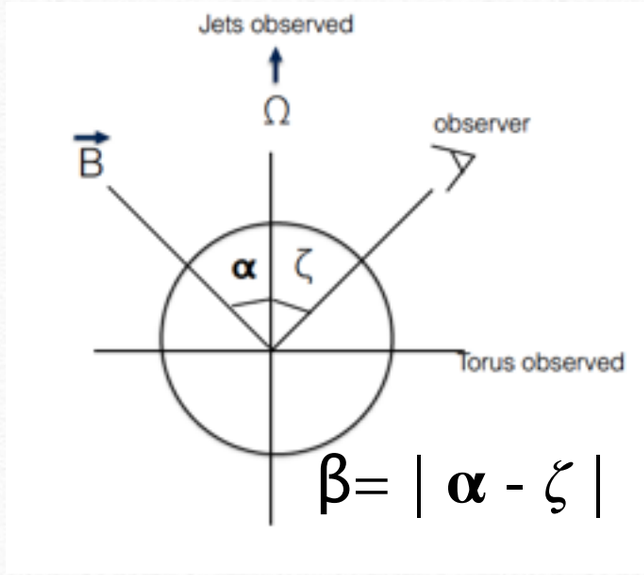


Parameter	Value
position angle Ψ	114.4±2.3°
	33.2±0.57±1.12°
Radius of Torus R	1.1±0.06″
postshock velocity β′	0.41±0.14
Distance d between torus d	3.6±0.26″



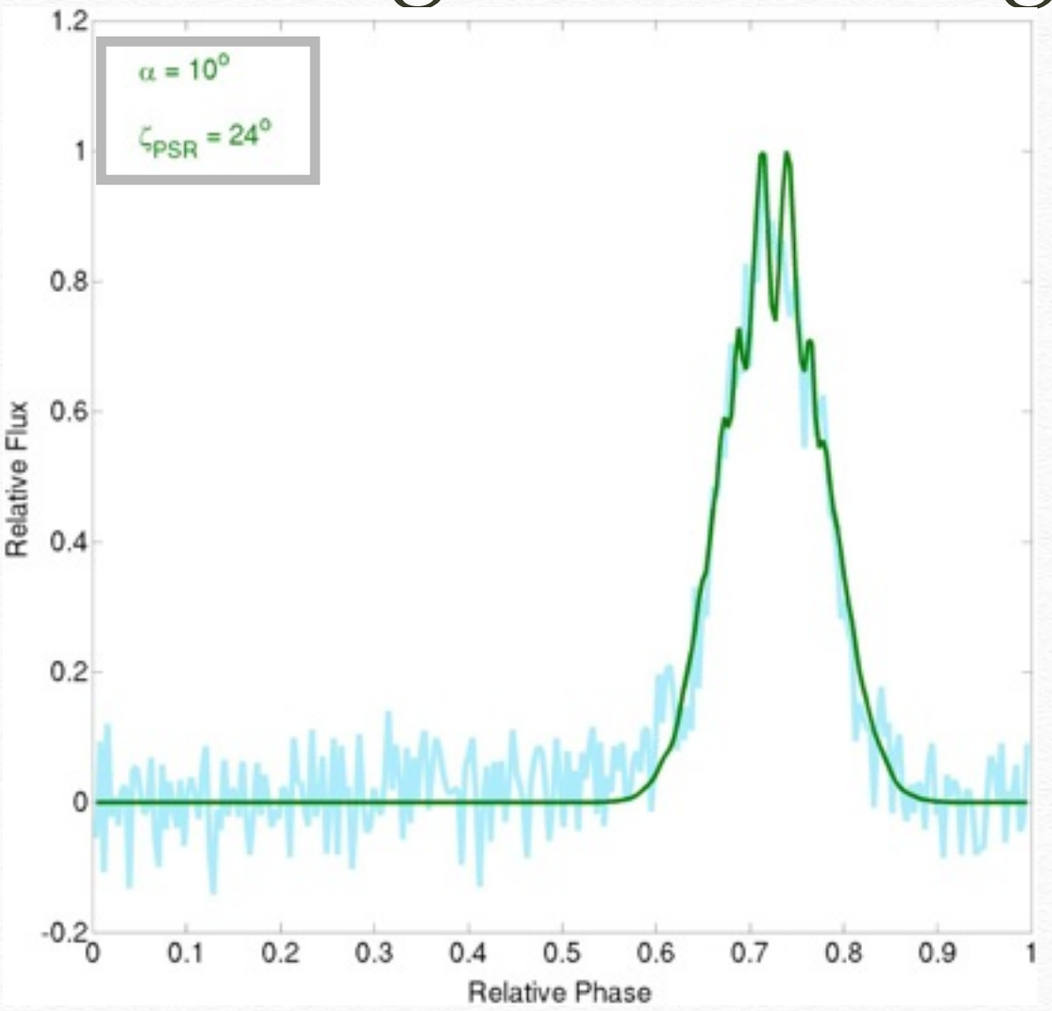
Emission from rotation powered pulsars

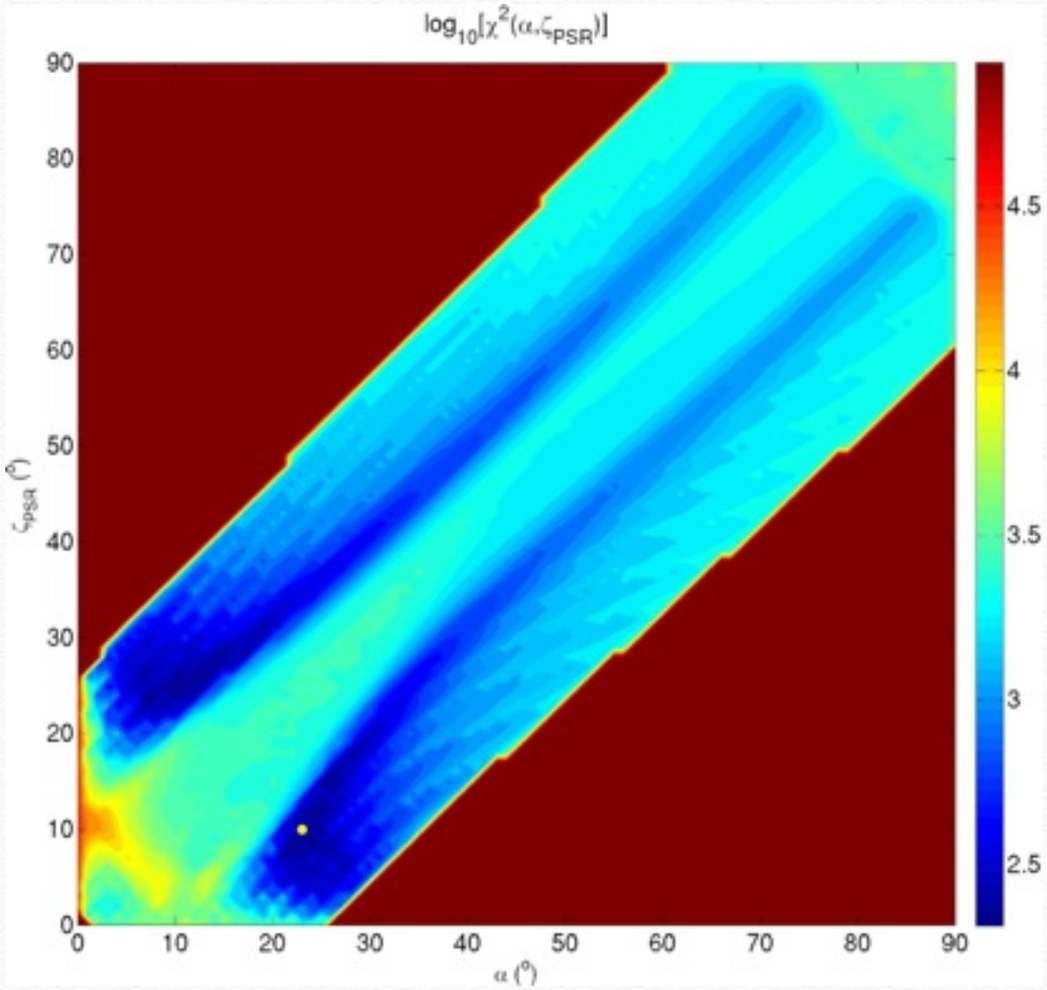




- Models of outer-gap emission of gamma rays predict ζ > 45 deg and large **α** - ζ > 30 deg (Romani & Yadigaroglu 1995& references): Constraint on pulsar geometry

Independent constraints from predictions of geometric light curve models





Geometry of PSR J0855-4644

- **small ζ: viewing the system close to the spin axis: Non-detection of ɣ-rays in high Ė/d² pulsar**
- **small β: viewing the system close to the magnetic pole**

PSR J0855-4644: further investigations

- Nearby energetic PWN showing jet +torus structures < 1 kpc
- Only third source after Vela & PSR J2021+3651 opportunity to probe
- Highest $\dot{E}/d^2$ pulsar with no ɣ ray pulsations

- Additional *Chandra* observation (AO 17 scheduled):to disentangle the jet or torus+jet scenario: test for change in position and brightness of the lobes of the compact PWN.

- Multi-messenger information: GMRT proposal submitted to detect the radio nebula: constraints on energetics and magnetic field of the nebula

Independent constraints from predictions of geometric light curve models:

i) radio visibility, ii) pair multiplicity & iii) peak width

- Geometric light curve models from (Dyks & Rudak 2003) TPC and OG (Romani 1996) generated to match the observed radio pulse profile for different combinations of $\boldsymbol{\alpha}$, ζ (5°,5° grid)
- P=65 ms and ν=1.2 GHz sets the beam width for radio.
- Beam width in conjunction with ζ sets radio visibility of the pulsar
- Radio light curve fit with geometric models to derive constraints on $\boldsymbol{\zeta}$, α and β