The intriguing double torus-jet PWN around PSR J0855-4644

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Vela Senior

Puppis A

Vela cocoon

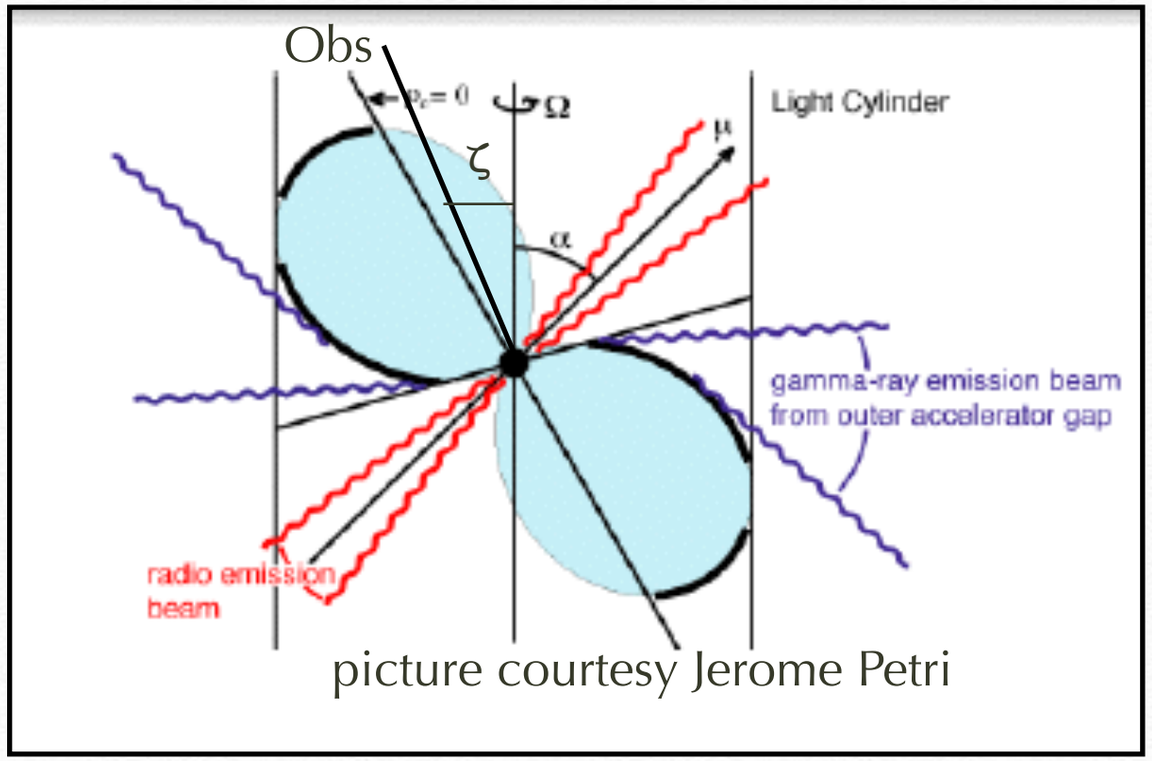
Vela Junior

PSR J0855

E < 1.3 keV
E > 1.3 keV
HESS

1. CEA Saclay
2. North West University

Standard picture of rotation powered pulsars



picture courtesy Jerome Petri

- Polar cap (Daugherty & Harding 1996): Particle acceleration & radiation at the magnetic poles: Radio

- Outer Gap (Romani 1996): Particle acceleration & radiation between caustic and light cylinder: X-rays and Gamma rays

- Models of outer-gap emission of gamma rays predict $\zeta > 45$ deg and large $\alpha - \zeta > 30$ deg (Romani & Yadigaroglu 1995& references)

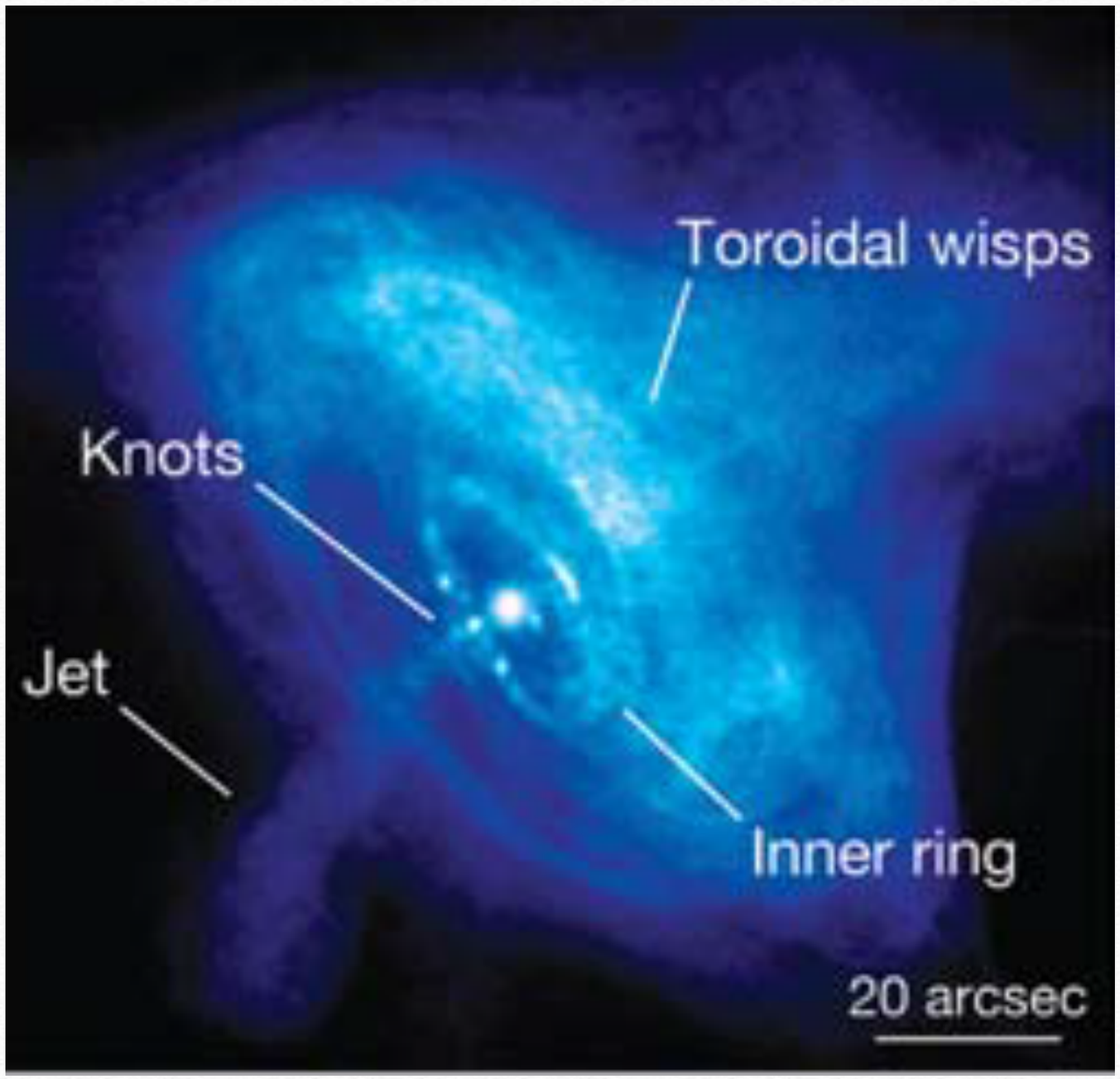
→ Resolved sub arc second structures of the PWNe:

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

b) **Bow shocks**

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

The classic PWN



Weisskopf 2000

→ Resolved sub arc second structures of the PWNe:

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

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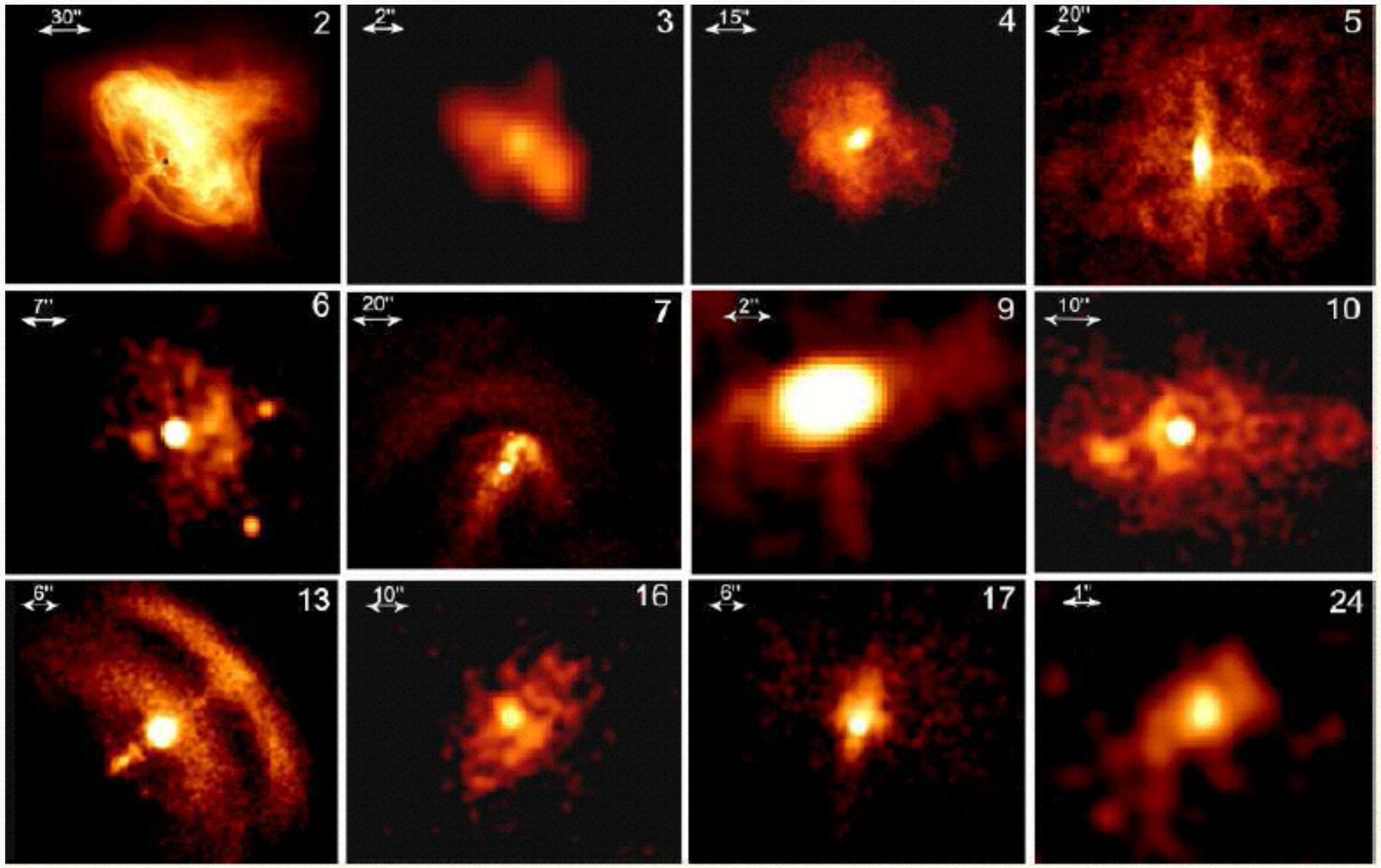
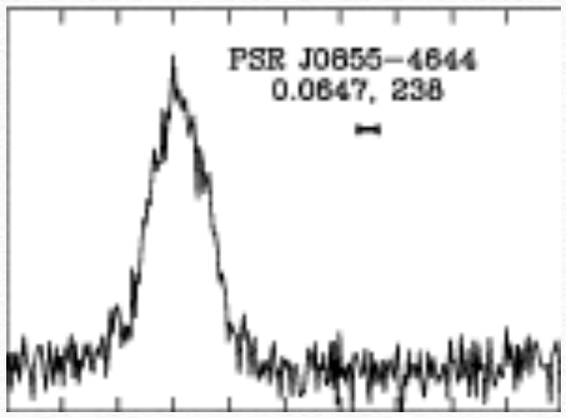
c) **Signatures of PWN interaction with ambient med**

PWNe ZOO



Pavlov & Kargaltsev 2006

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



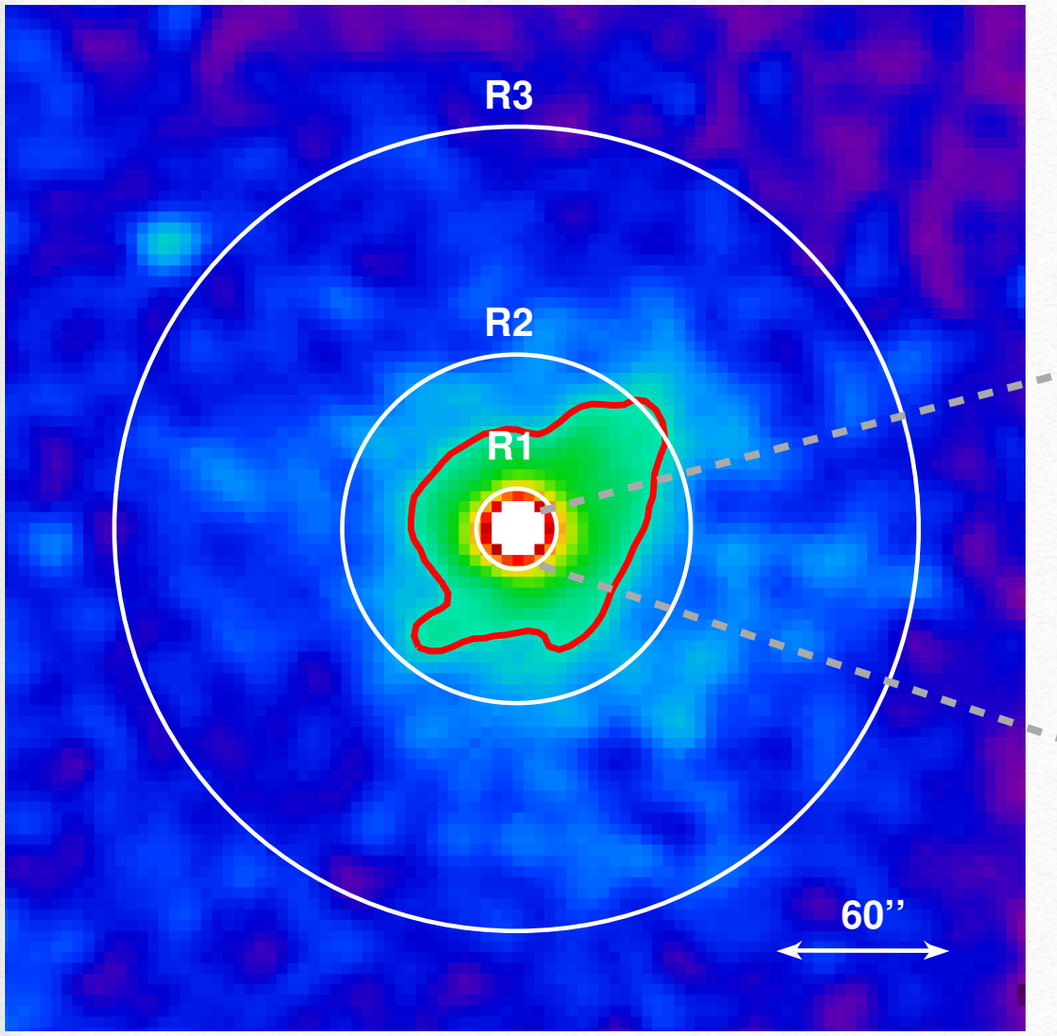
- Fast pulsar P = 65 ms $\dot{E}$ =1.1 *10^{36} erg/s (Parkes radio survey)

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

- Radio loud, Gamma ray quiet ⟶ high $\dot{E}/d^2$

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

Through the eyes of XMM-Newton



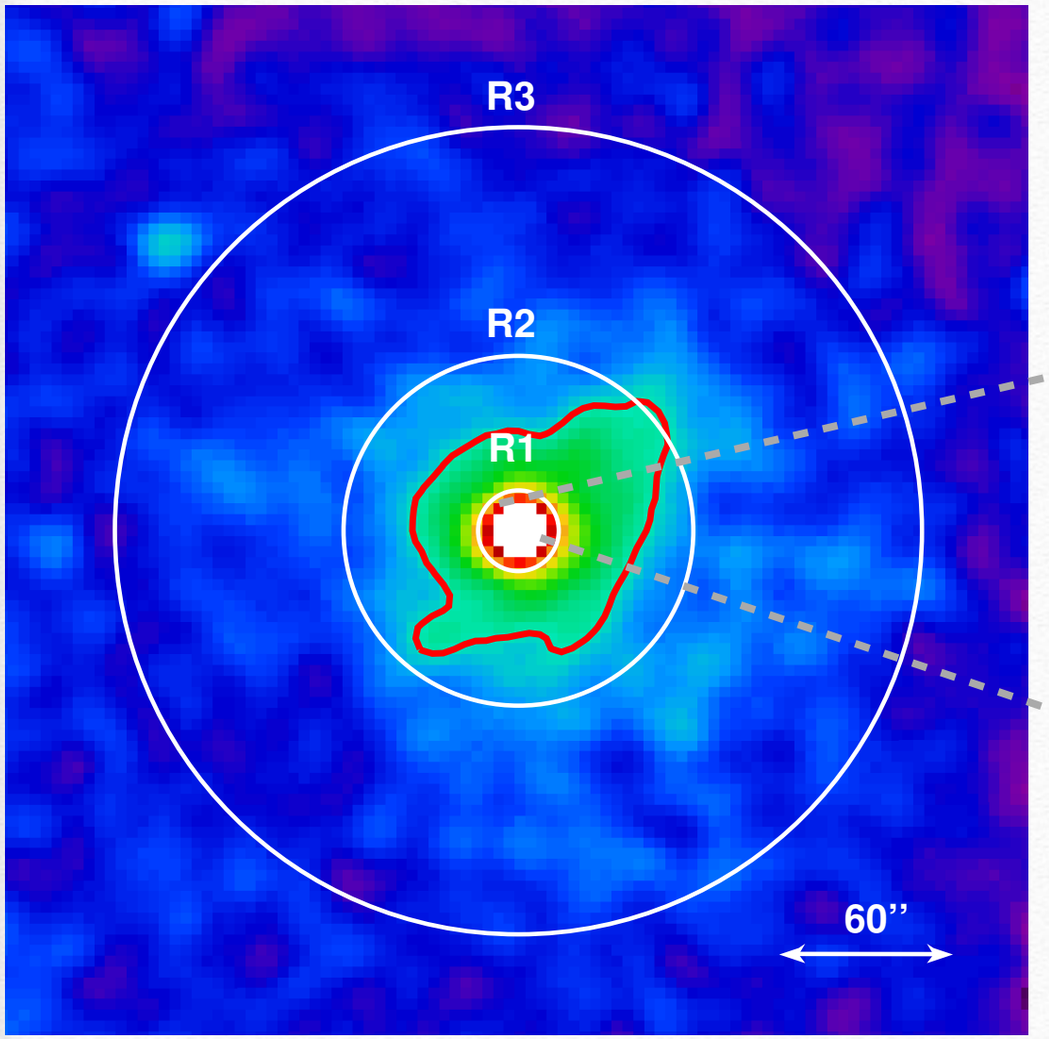
R1=15”

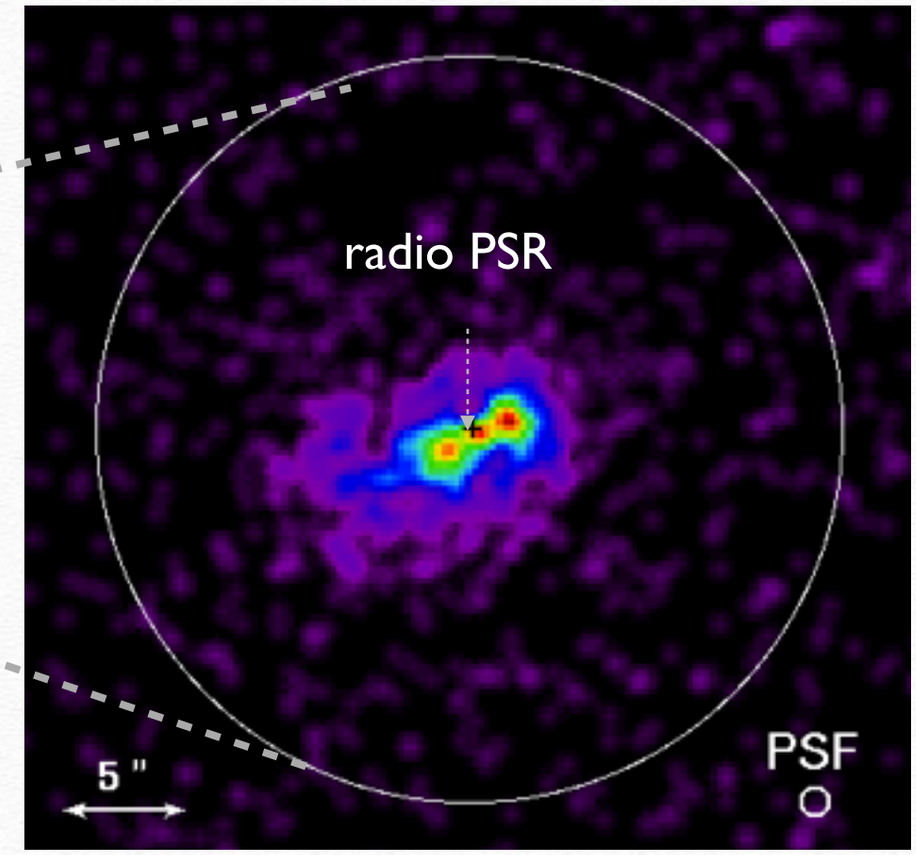
X-ray counterpart of pulsar

?

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

Through the eyes of Chandra: Structured PWN revealed!

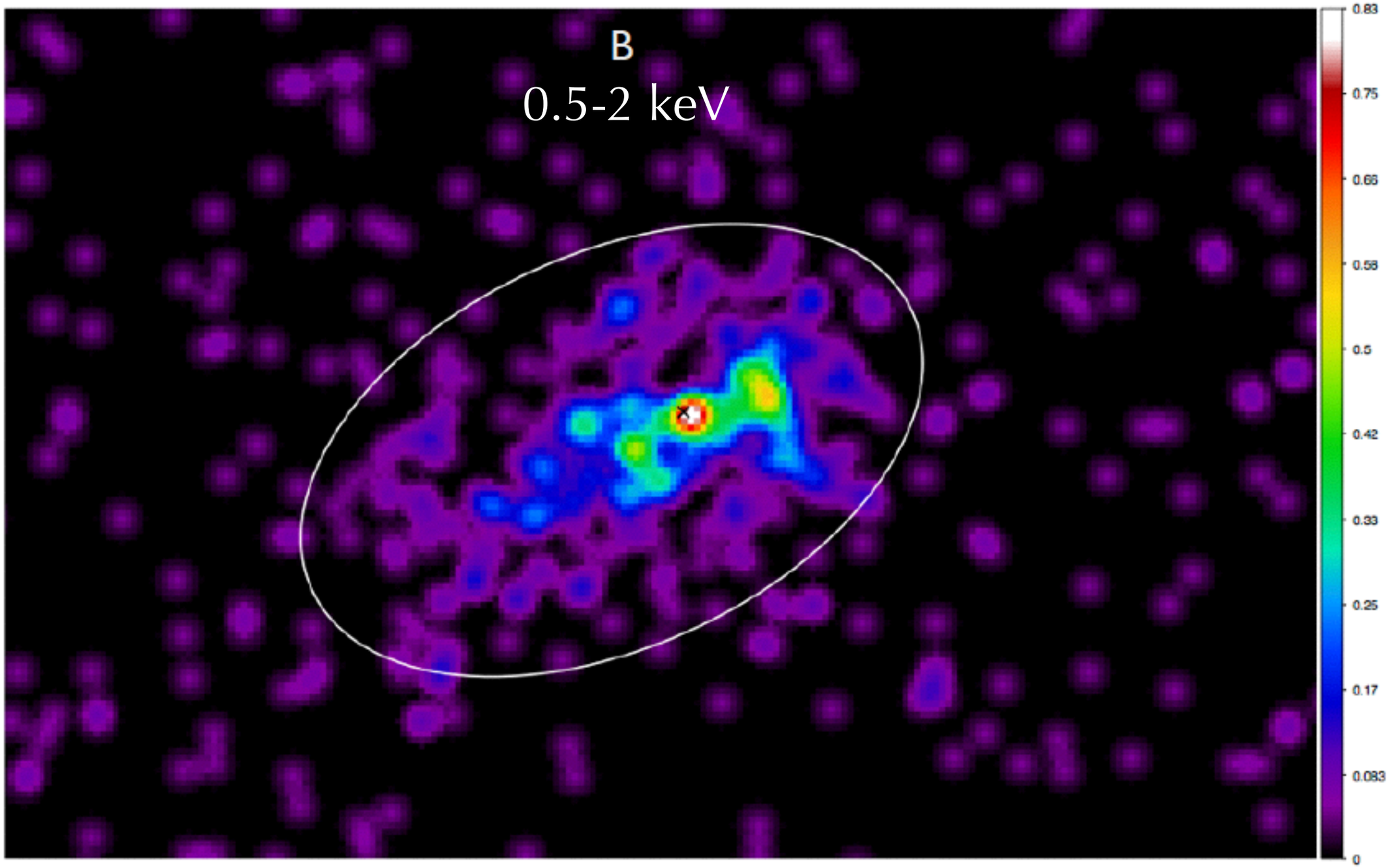




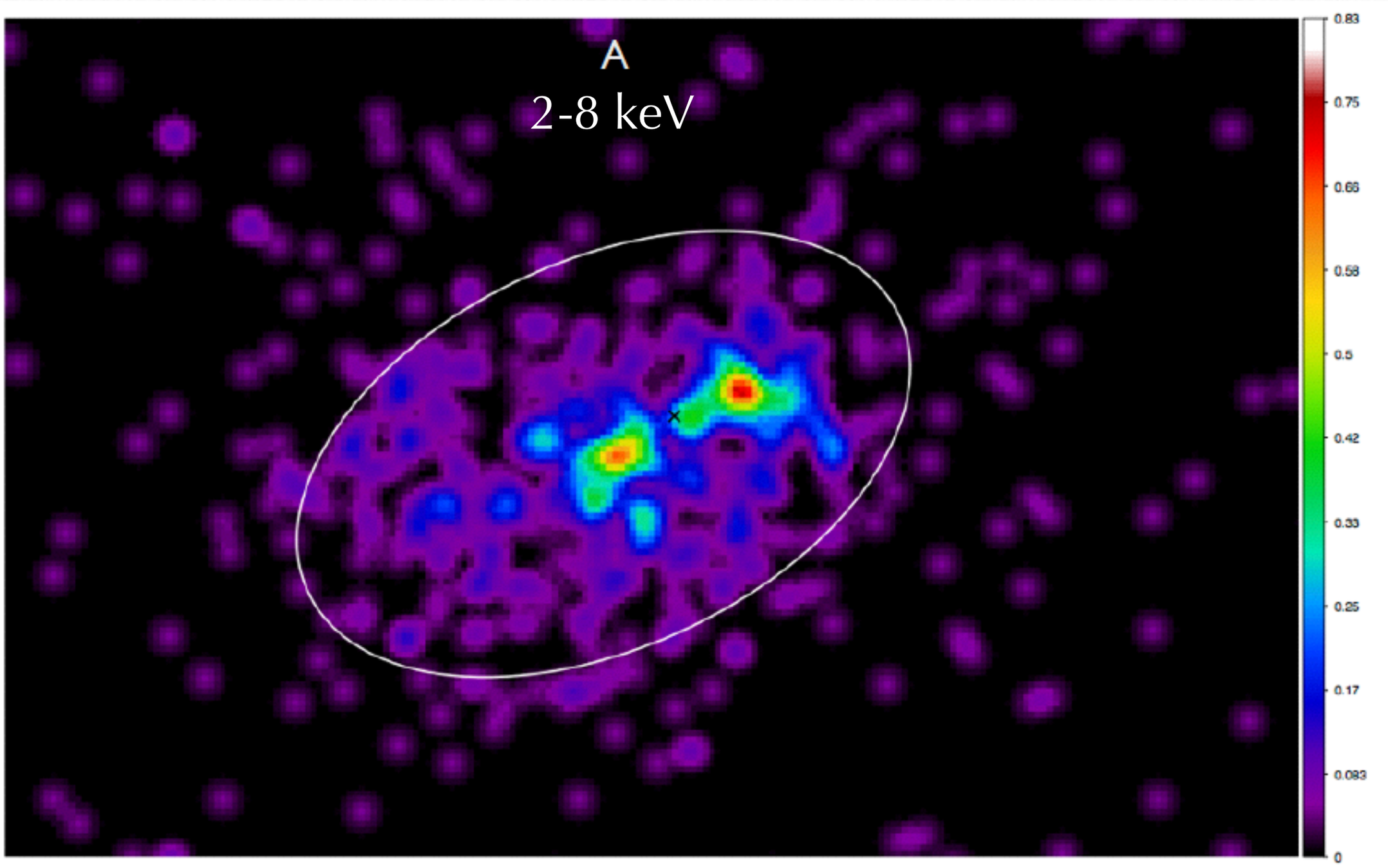
Chandra: ACIS-S observation

- What was thought to be X-ray pulsar: further resolved (< 0.05 pc)
- Axisymmetric structures like jets/torii:
- Further signatures of young energetic pulsar
- Very faint pulsar; factor of 10 fainter than nebula

Energy resolved images



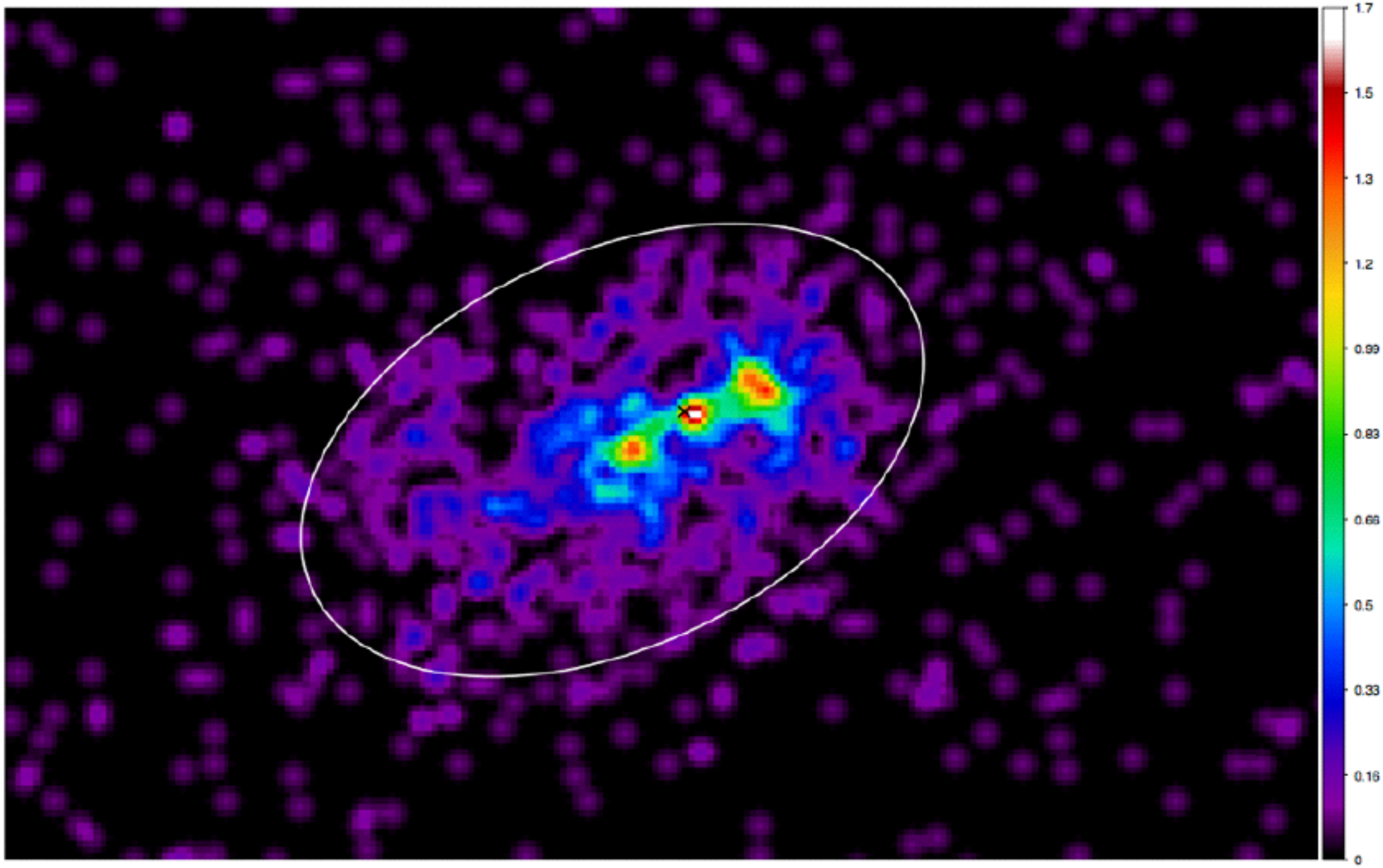
Energy resolved images



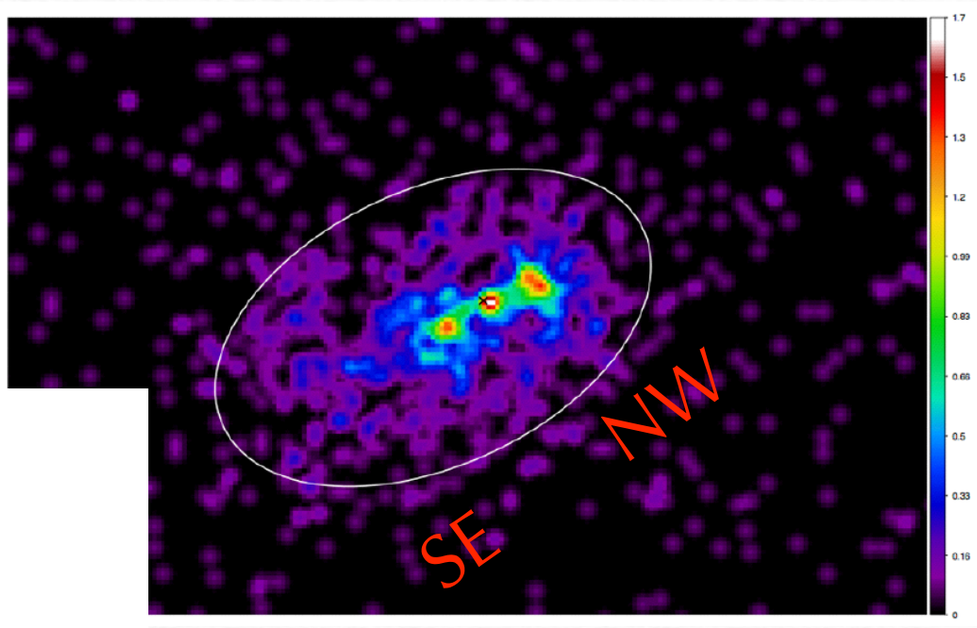
A close look at the PWN:

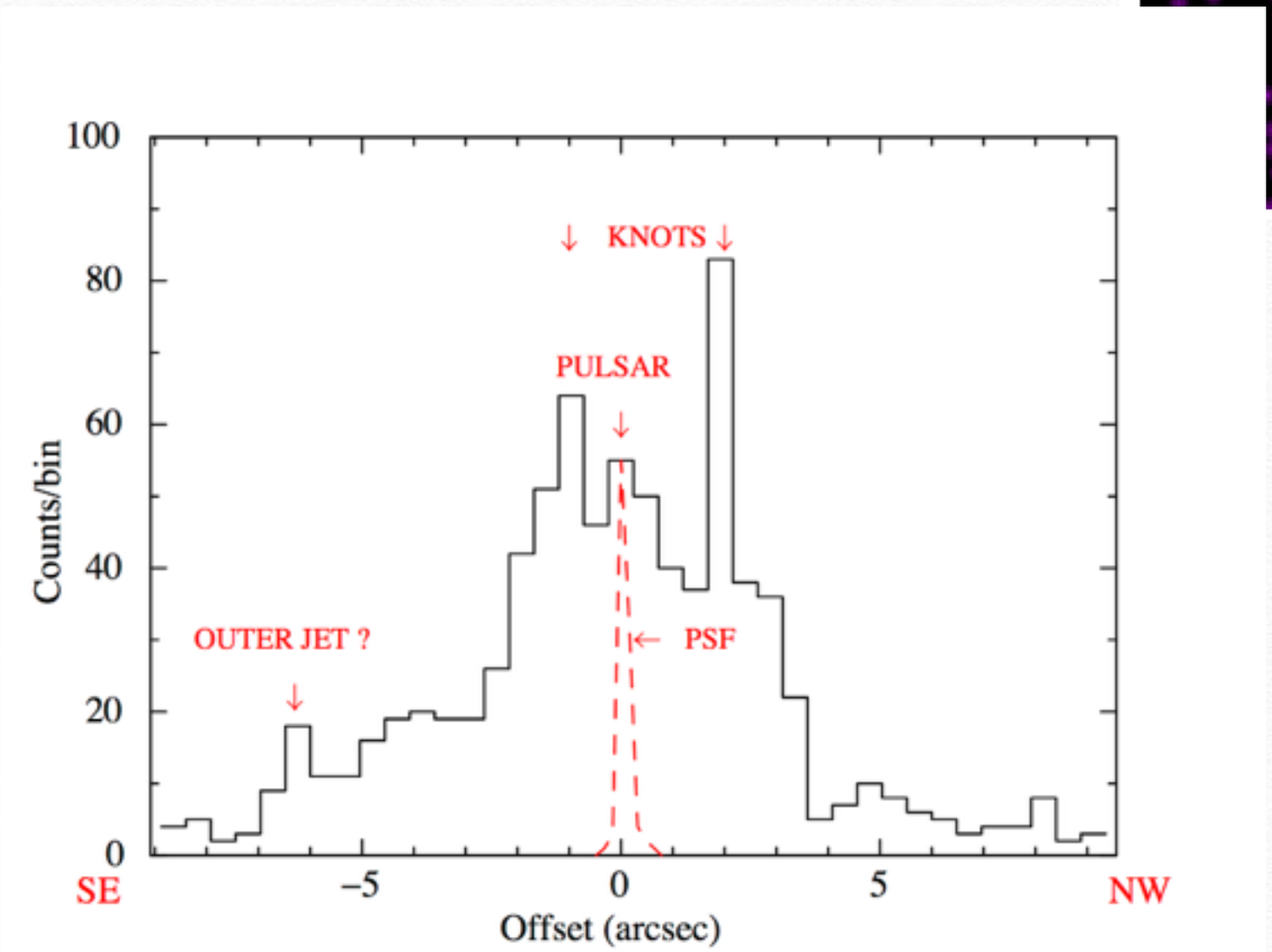
a) only third source after Vela & PSR J2021+3651 to show this morphology

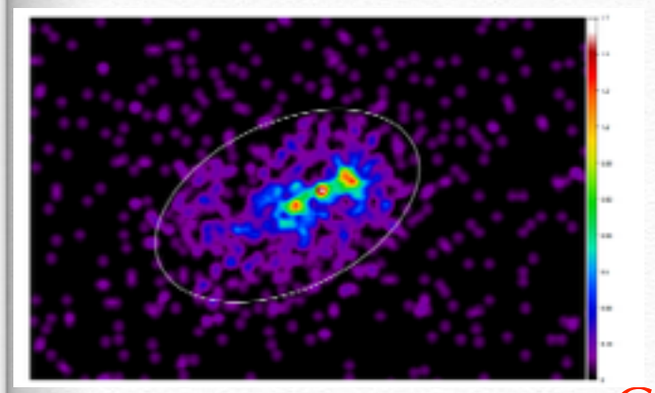
b) Nearby object: opportunity to study physics of equatorial & polar outflows in PWNe



Count profile







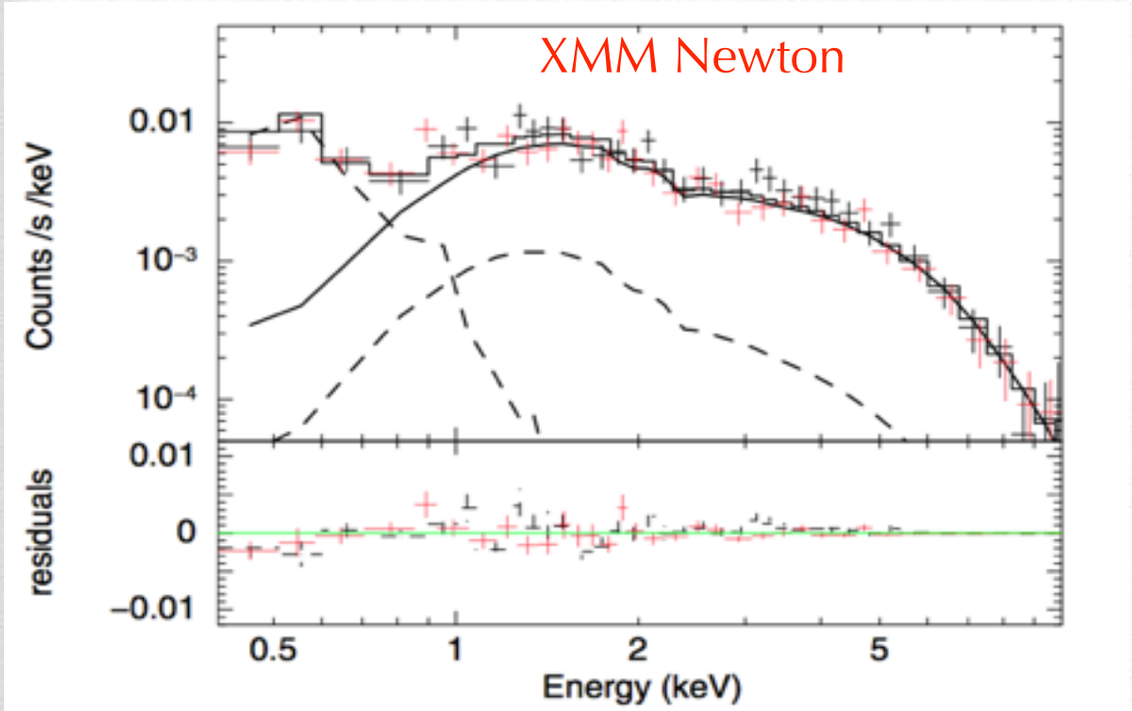
Spectroscopy

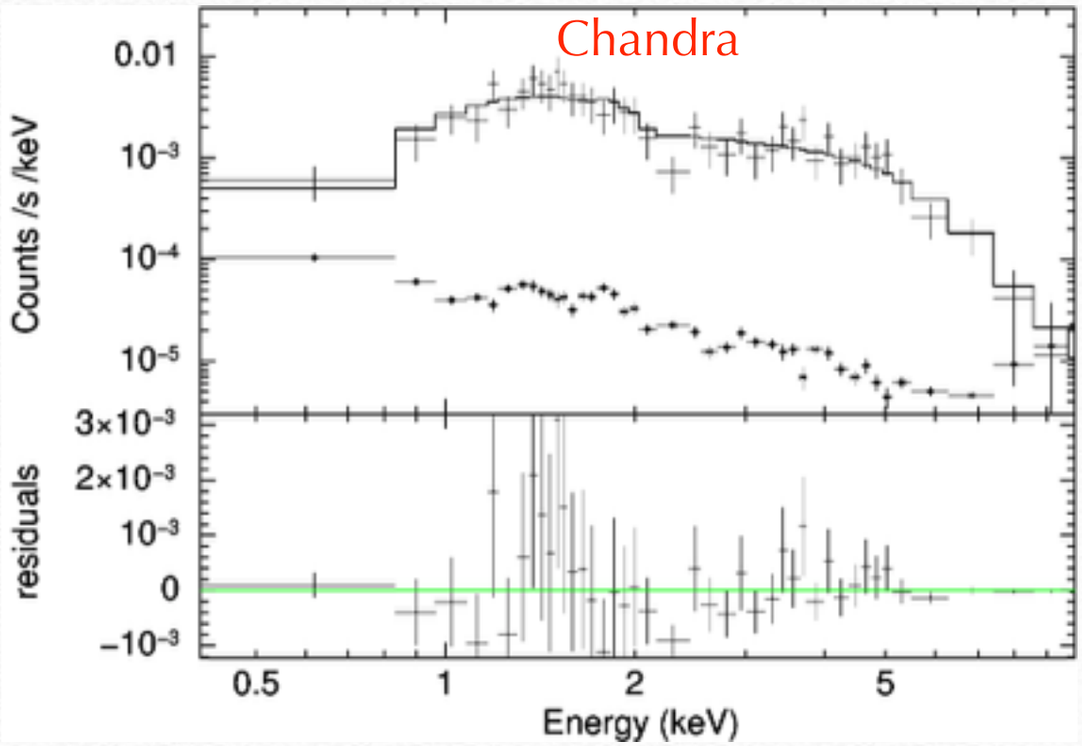
Confirming the XMM results

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

Chandra (R: 15”): NH=(0.70±0.20) x 10^{22} cm^{-2}

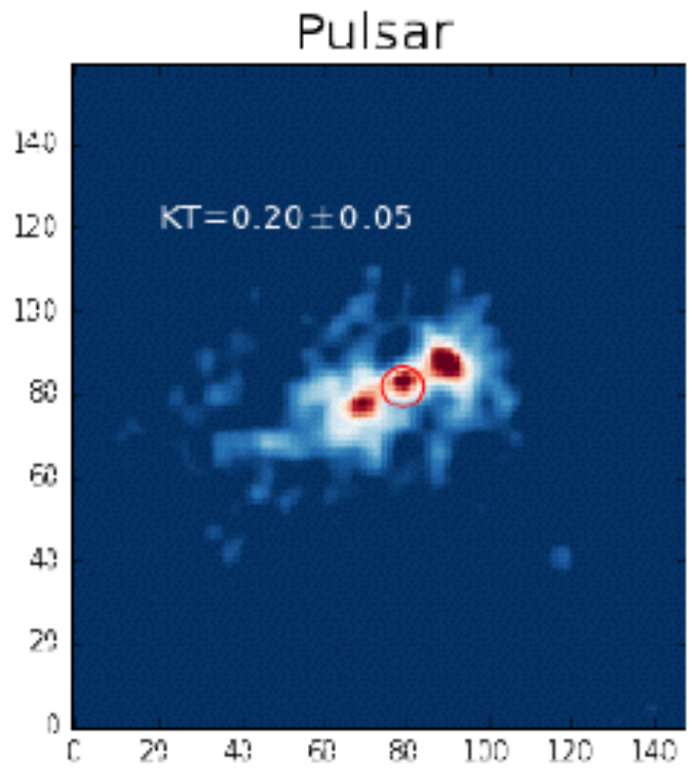
Reducing systematic uncertainties ⟶ Thermal emission 50 times less

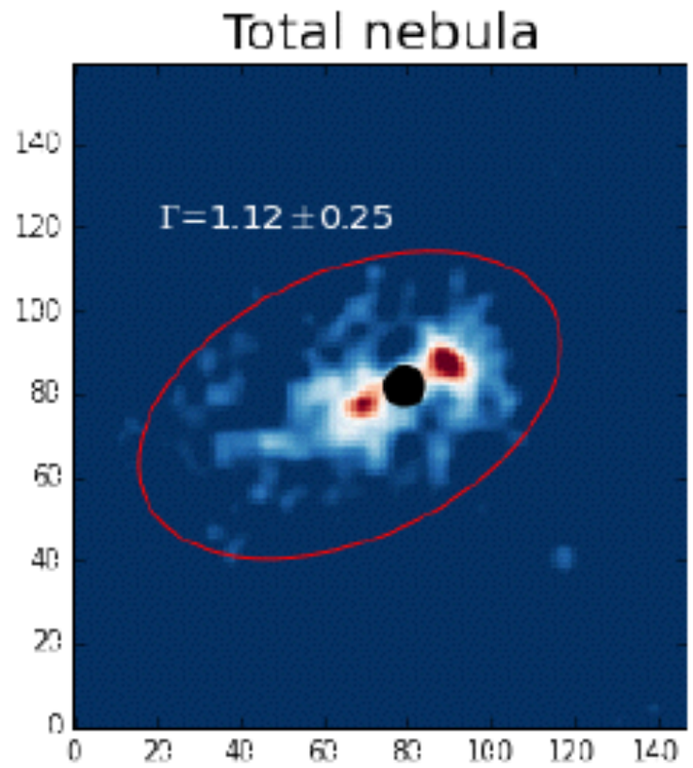


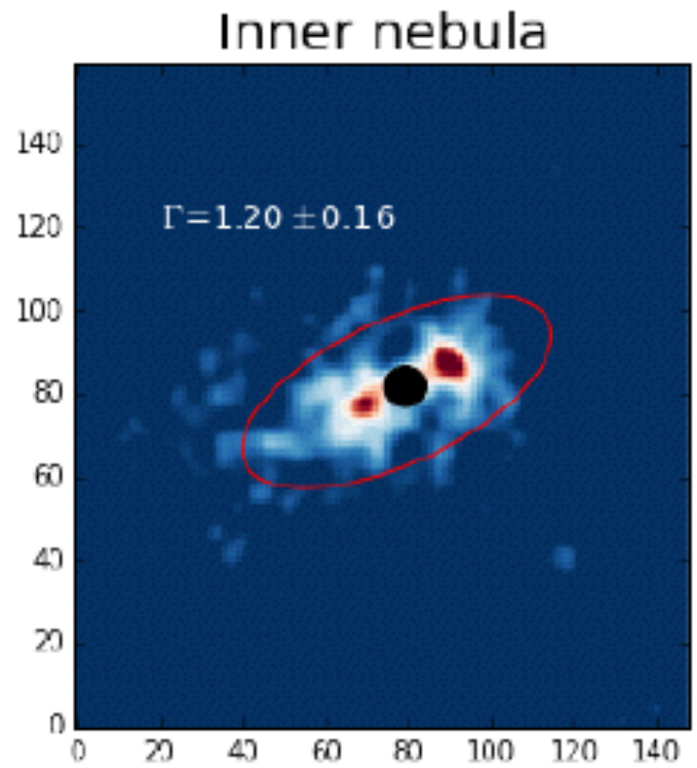


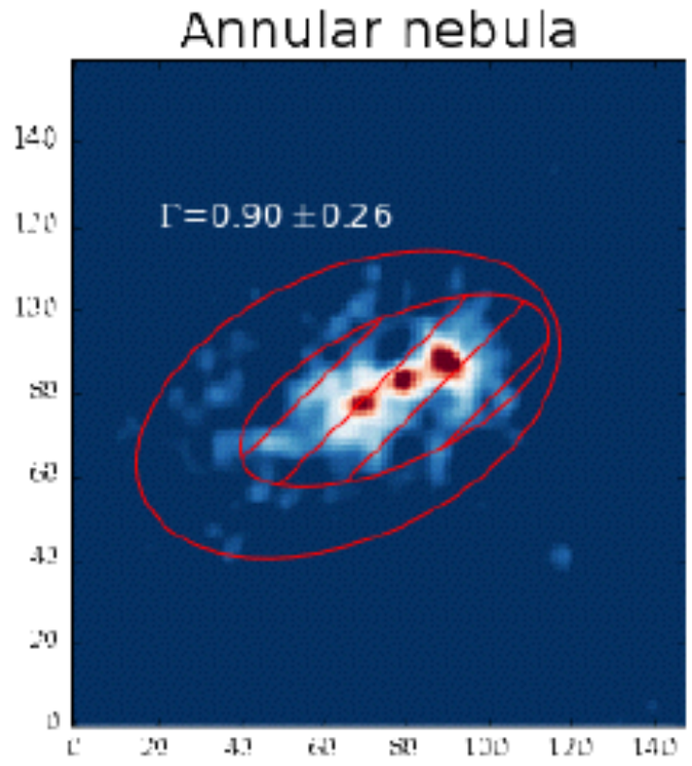
- Compare the spatially resolved structures of the PWN
- pulsar vs the axisymmetric structures

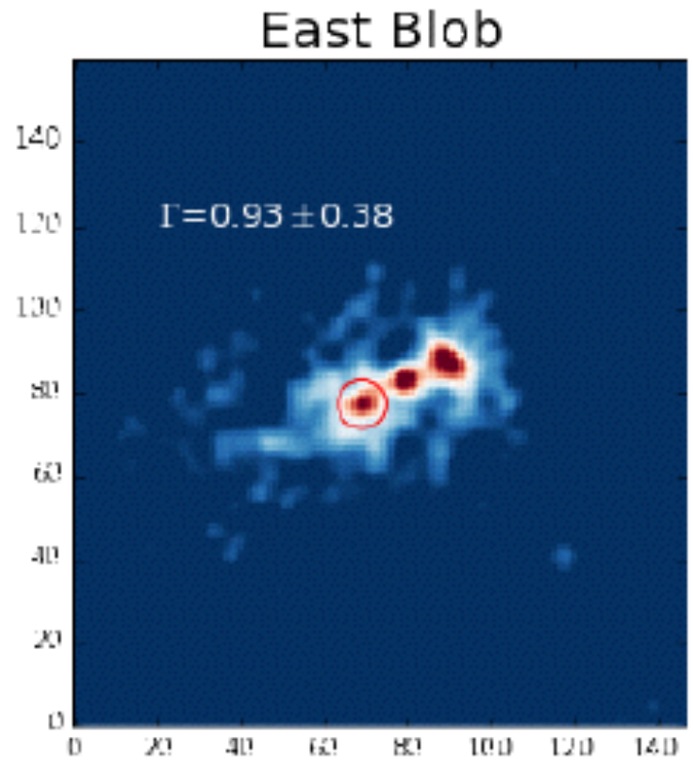
Spectroscopy of PWN structures

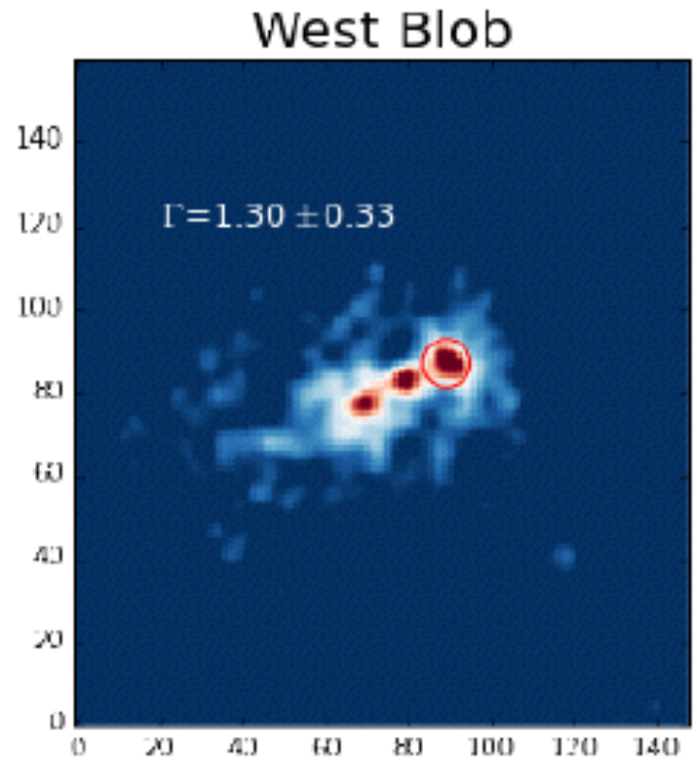












Spatial modeling: Can we answer why no Gamma ray emission?

Constraints from imaging & spectroscopy

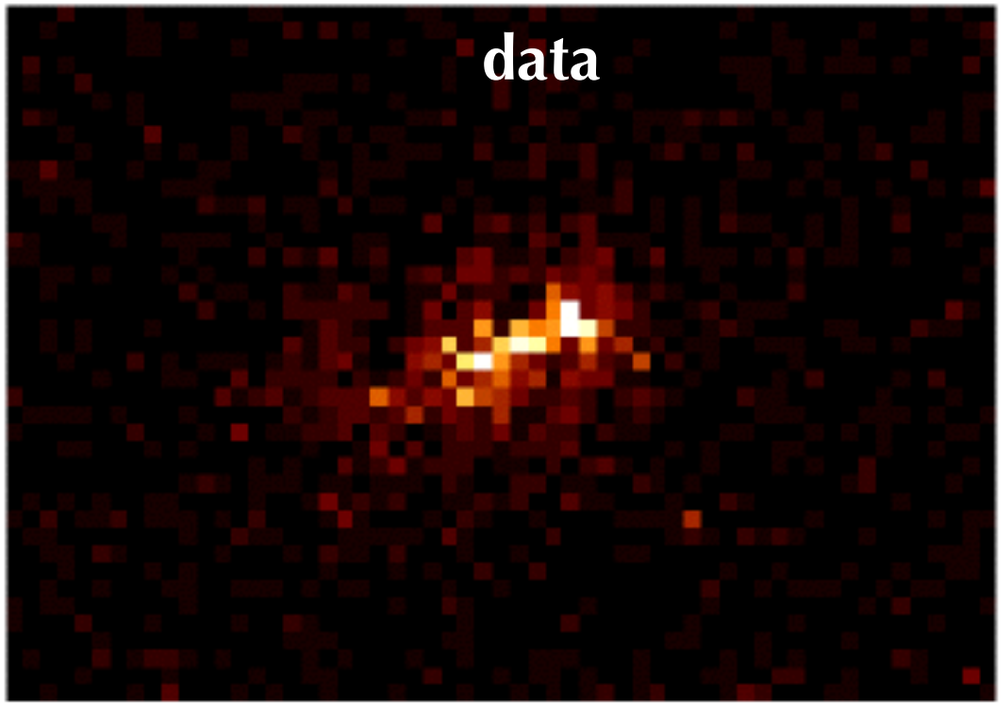
- One sided outer jet means intrinsically one sided outflow or it cannot be seen. Latter implies either high doppler boosted velocity or **low spin inclination ζ**
- Lack of non-thermal X-rays from pulsar implies, viewing of surface emission only —from the OG model it implies **low spin inclination ζ**

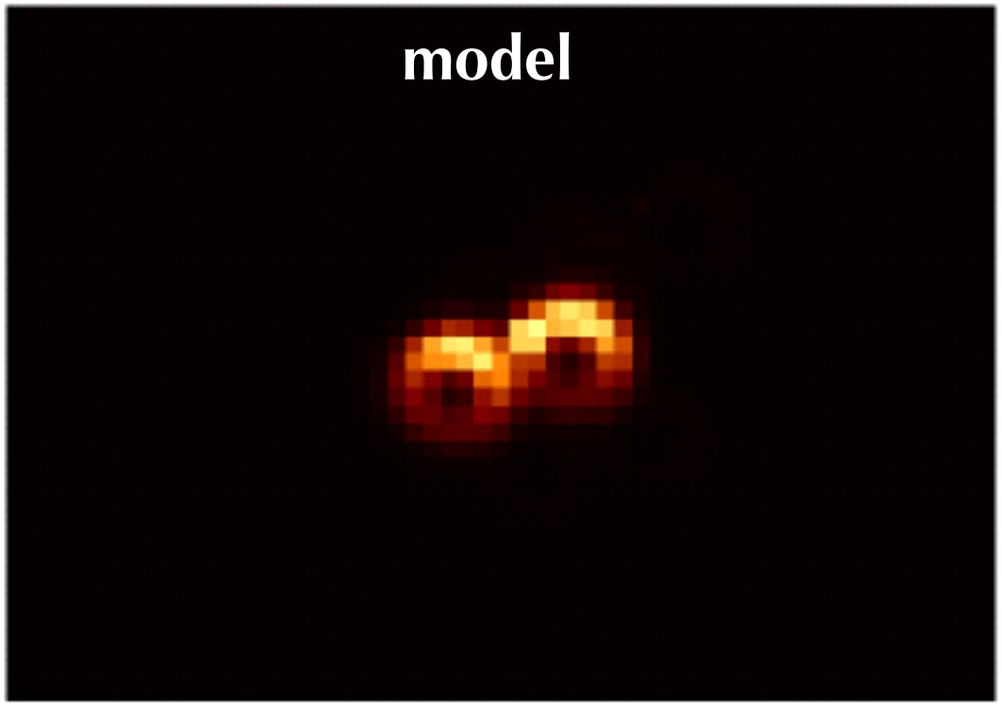
Morphological fitting of 'double torus' using Ng & Romani 2004 model.

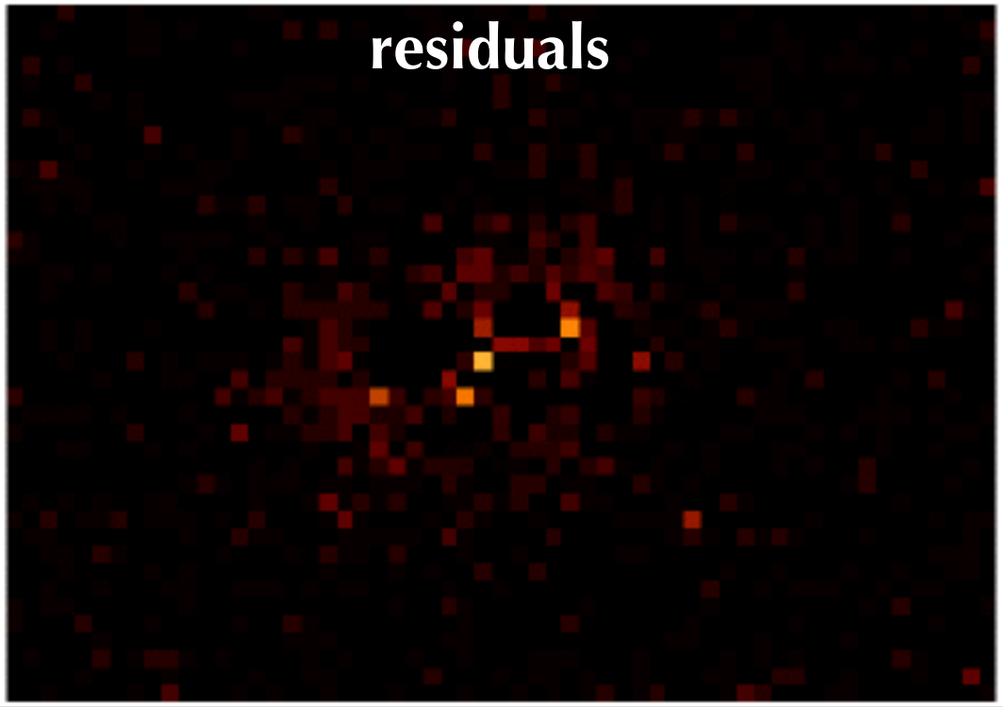
- Parameters PA Ψ (N to E), spin inclination ζ , torus radius (r), postshock velocity β
- To investigate effect of systematic errors east jet structure masked
- pulsar modeled with PSF, double tori model convolved with PSF

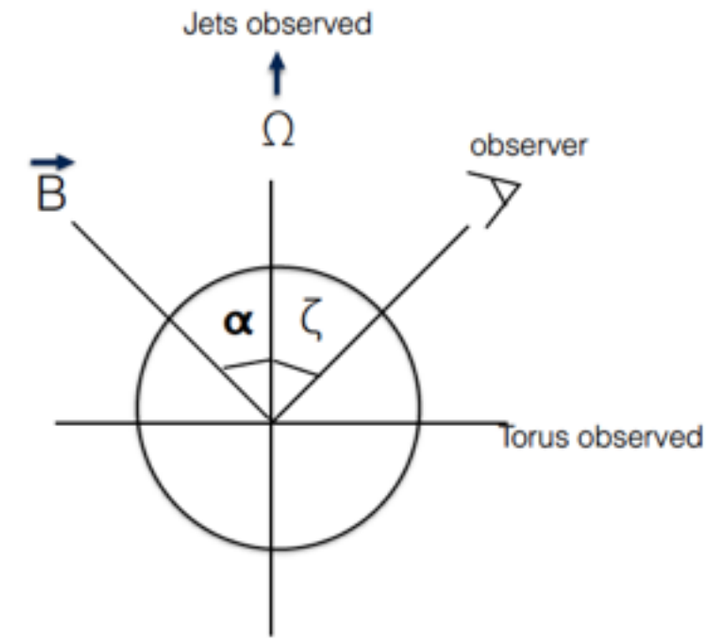
Results

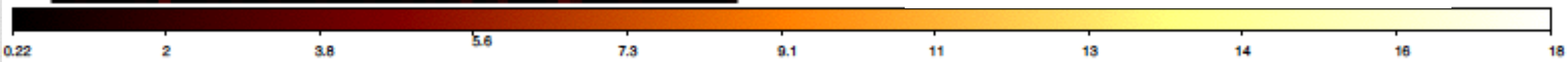
- Spin inclination angle ζ=34.6±1.4°±4.5°



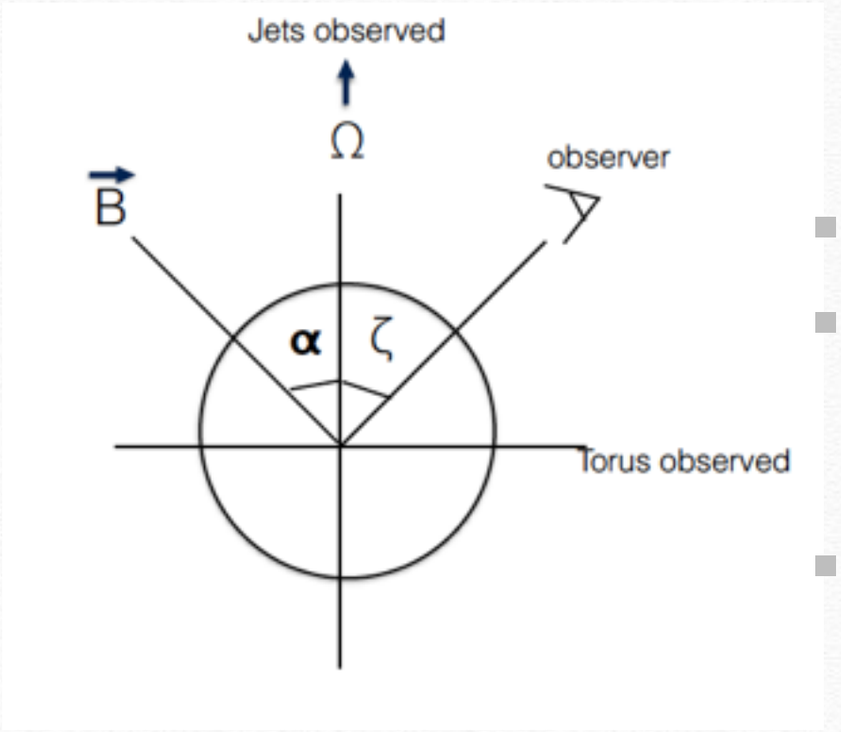




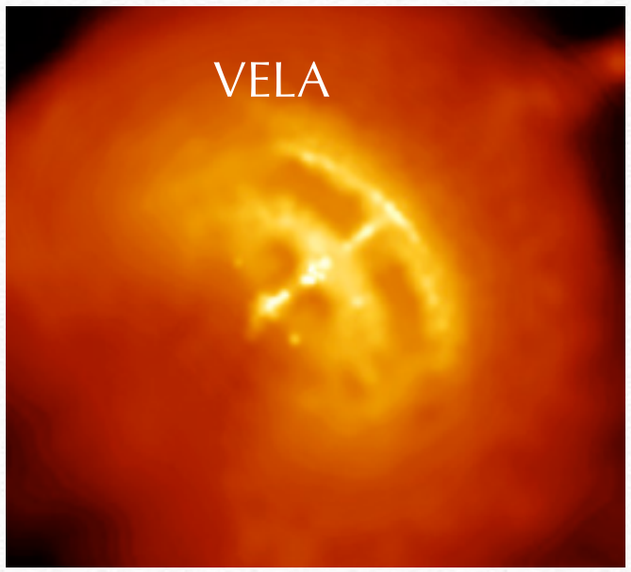


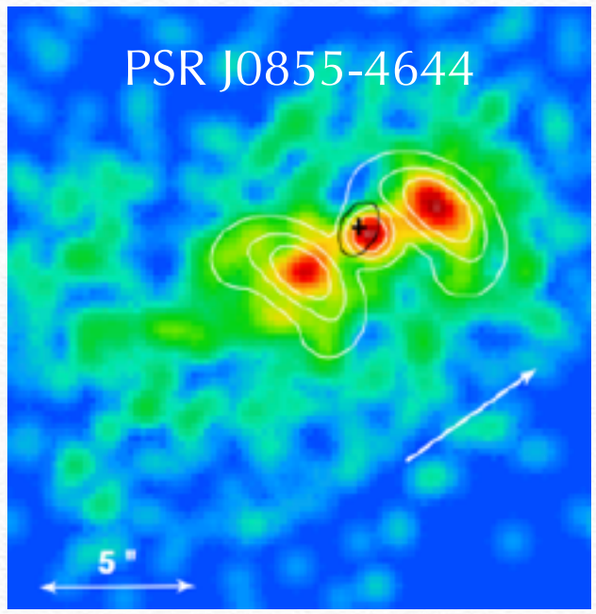


Geometry of PSR J0855-4644



- Double torii fit to the PWN implies $\zeta < |40|$ °
- Standard gamma ray OG models imply (α, ζ) < (40, 40 °), supported by absence of non thermal X-rays
- Small viewing angles limits access to X-ray/gamma ray beam ? Absence of gamma ray emission from a high $\dot{E}/d^2$ pulsar





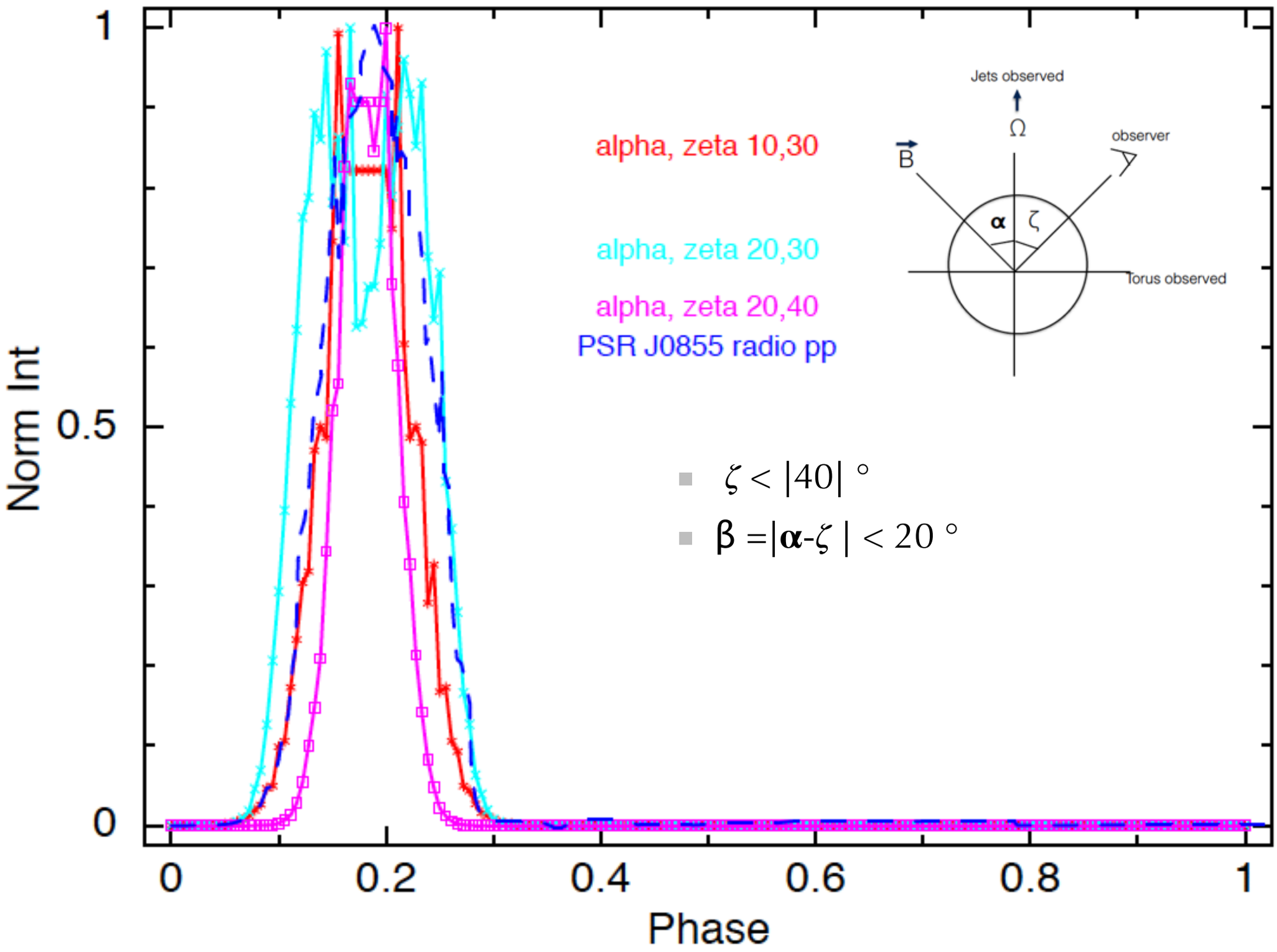
- Investigate further by phase plots/light curves from radio model

Generation of phase plots from radio model & comparison with observed radio profile

- Phase plots and light curves generated assuming the radio emissivity model with P=65 ms (beam width depends on P) & gamma ray emissivity model
- Results obtain for both PC and OG model to match the observed radio pulse profile for different combinations of α, ζ
- Derive α, ζ based on radio visibility, and gamma ray non-visibility constrain

  $\beta = | \alpha - \zeta |$
- Model does not predict flux, but match normalized pulse shape to the observed profile
- Details of method in reference **1)** C. Venter, A. K. Harding, L. Guillemot, 2009, ApJ, 707, 800 **2)** C. Venter, T. J. Johnson, and A. K. Harding 2012, ApJ, 744, 34

Comparison with observation



- $\zeta < |40|\ ^\circ$
- $\beta = |\alpha - \zeta| < 20\ ^\circ$

Summary

Resolved the sub arc second PWN around PSR J0855-4644. Axisymmetric jets/torii features. Only third source after Vela & PSR J2021+3651

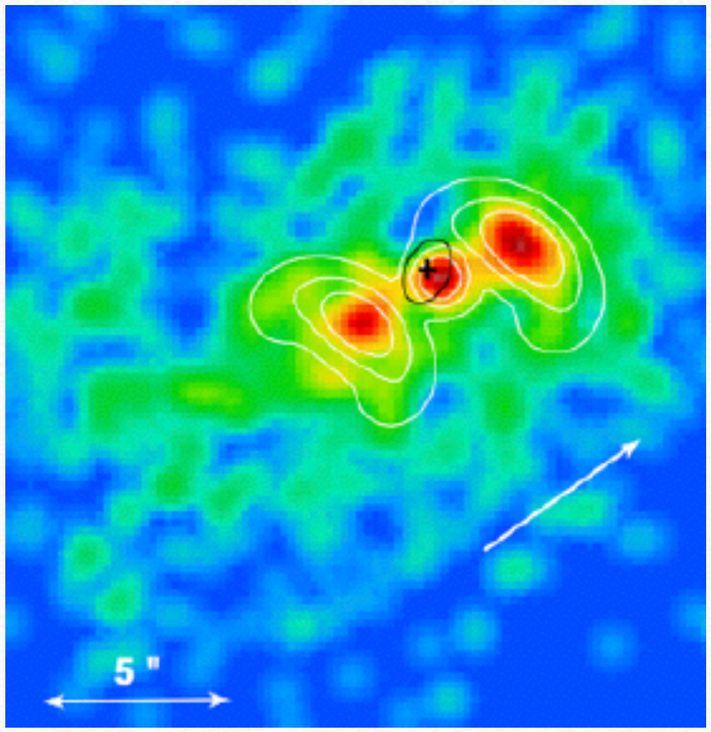
Spatial modeling by double torii

Non-detection of non-thermal X-rays

Radio pulse shape modeling & non-detectibility of gamma rays

- $\zeta < |40|$ °
- $\beta = |\alpha - \zeta| < 20$ ° & **OG** model of pulsar emission

Non-detection of gamma rays in a high $\dot{E}/d^2$ pulsar



VELA

THANK YOU