

# Revealing the nature of the unusual? PWN CTB87

Roland Kothes

Dominion Radio Astrophysical Observatory  
Herzberg Astronomy and Astrophysics Research Centre  
National Research Council Canada

Supernova Remnants II, Chania, June 6, 2019



National Research  
Council Canada

Conseil national de  
recherches Canada

Canada

# Collaborators

[Introduction to CTB 87](#)

[New Radio Study of  
CTB 87](#)

[The Nature of CTB 87](#)

[Summary and  
Conclusions](#)

- Wolfgang Reich  
Max Planck Institut für Radioastronomie
- Samar Safi-Harb  
University of Manitoba
- Benson Guest  
University of Manitoba
- Ernst Fürst  
Max Planck Institut für Radioastronomie



# Radio Observations of PWN CTB87

Introduction to CTB 87

Radio

X-ray

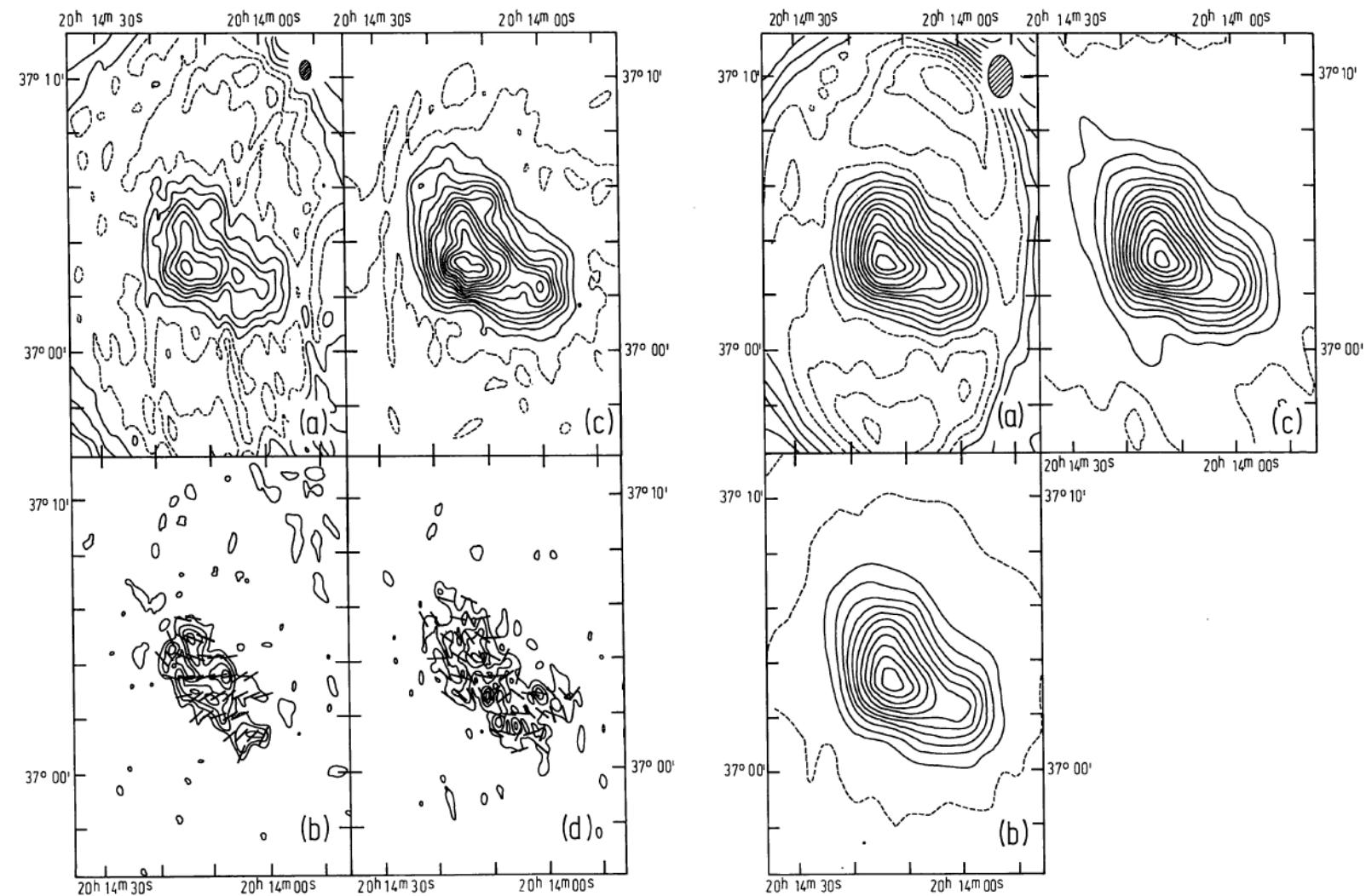
Environment

New Radio Study of  
CTB 87

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Summary and  
Conclusions

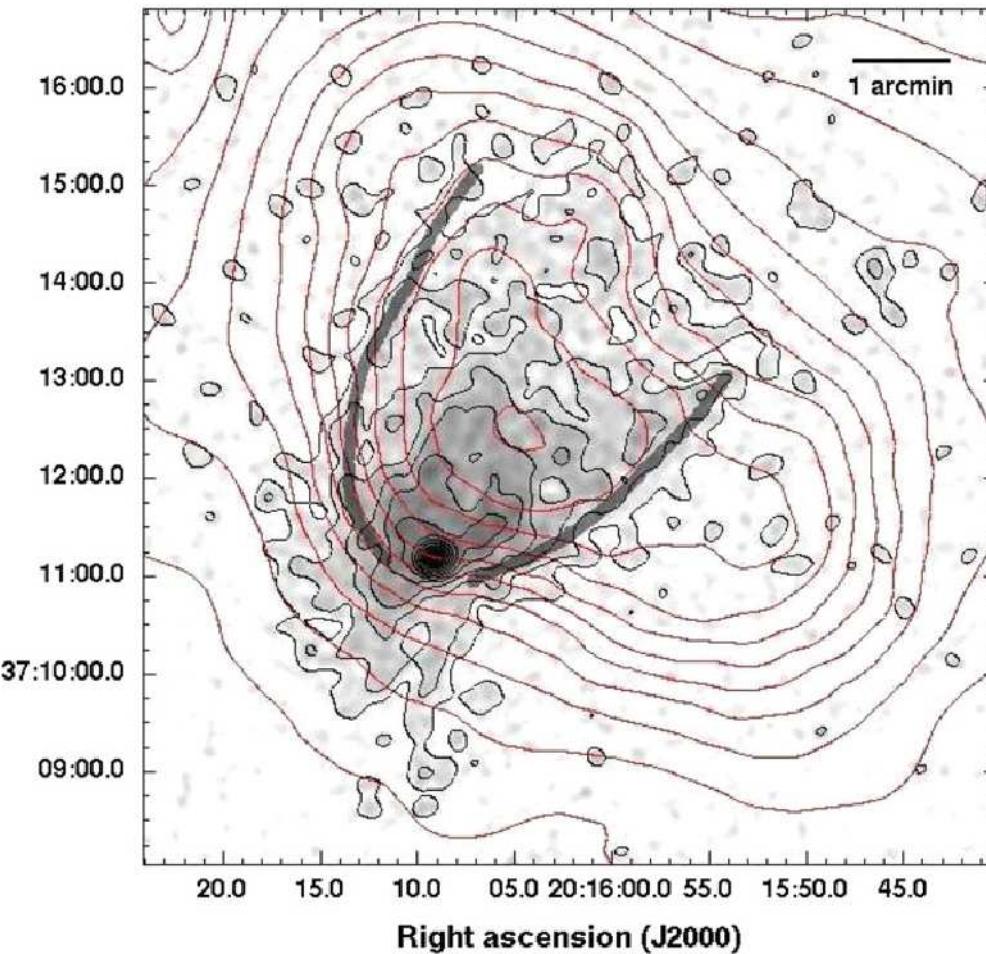
Weiler & Shaver, 1978 (WSRT):



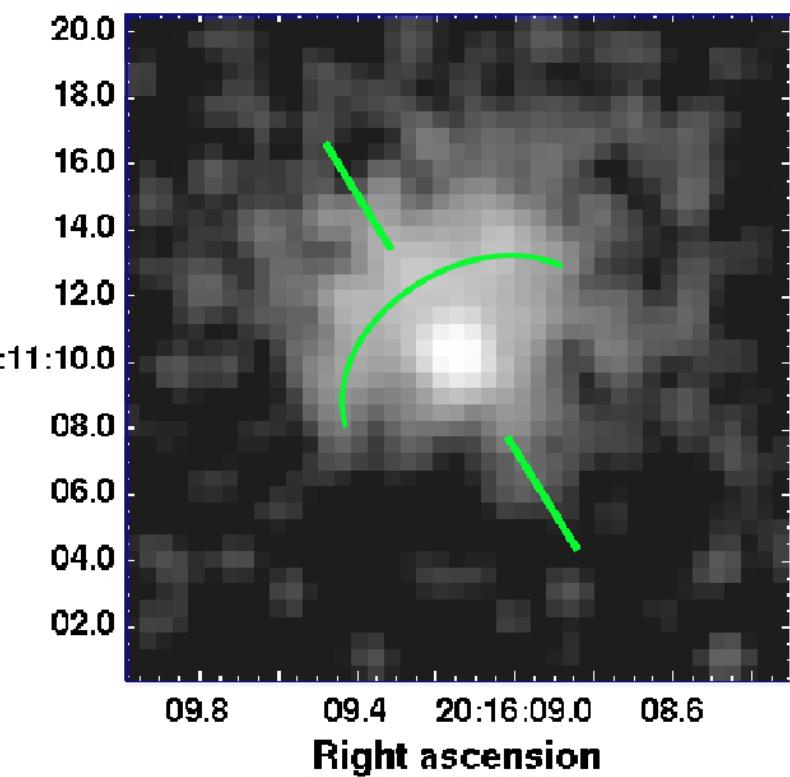
# CHANDRA X-ray Data from PWN CTB87

Matheson, Safi-Harb, & Kothes (2013):

Declination (J2000)



Declination

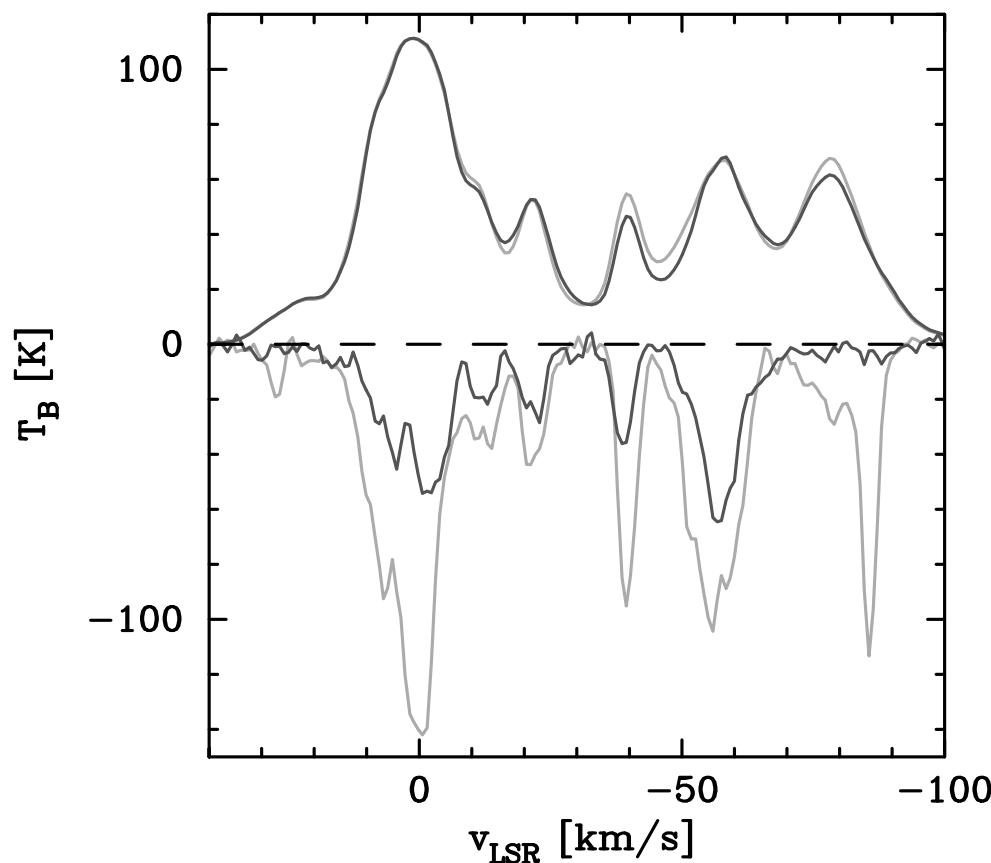


# Distance and Environment

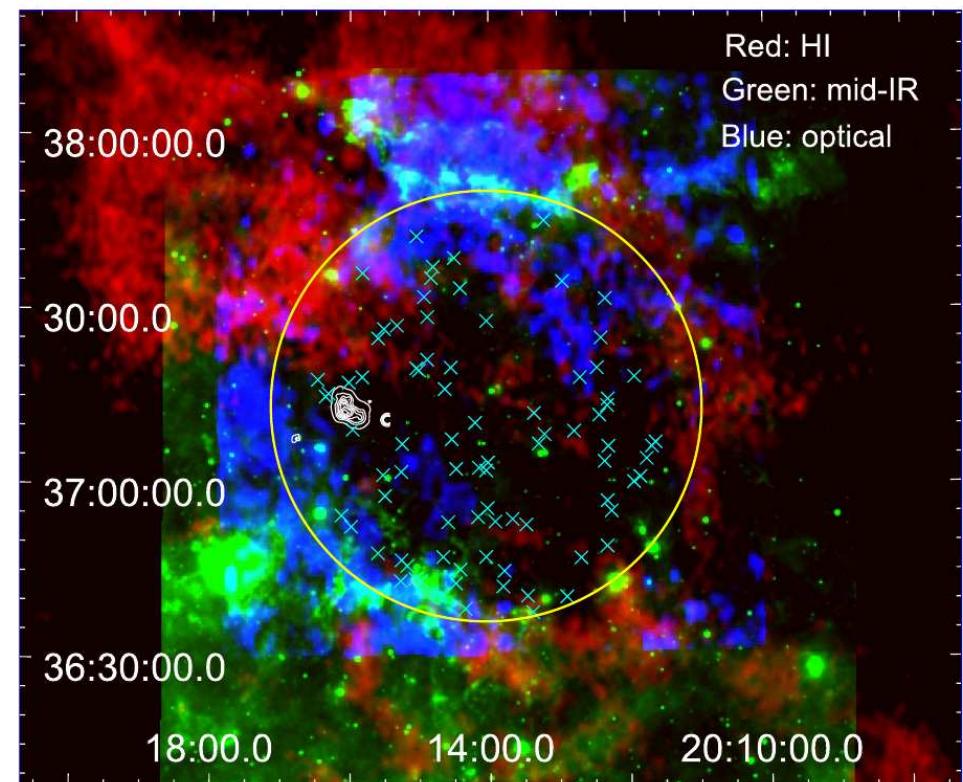
Kothes et al., 2003:

$$d = 6.1 \pm 0.9 \text{ kpc}$$

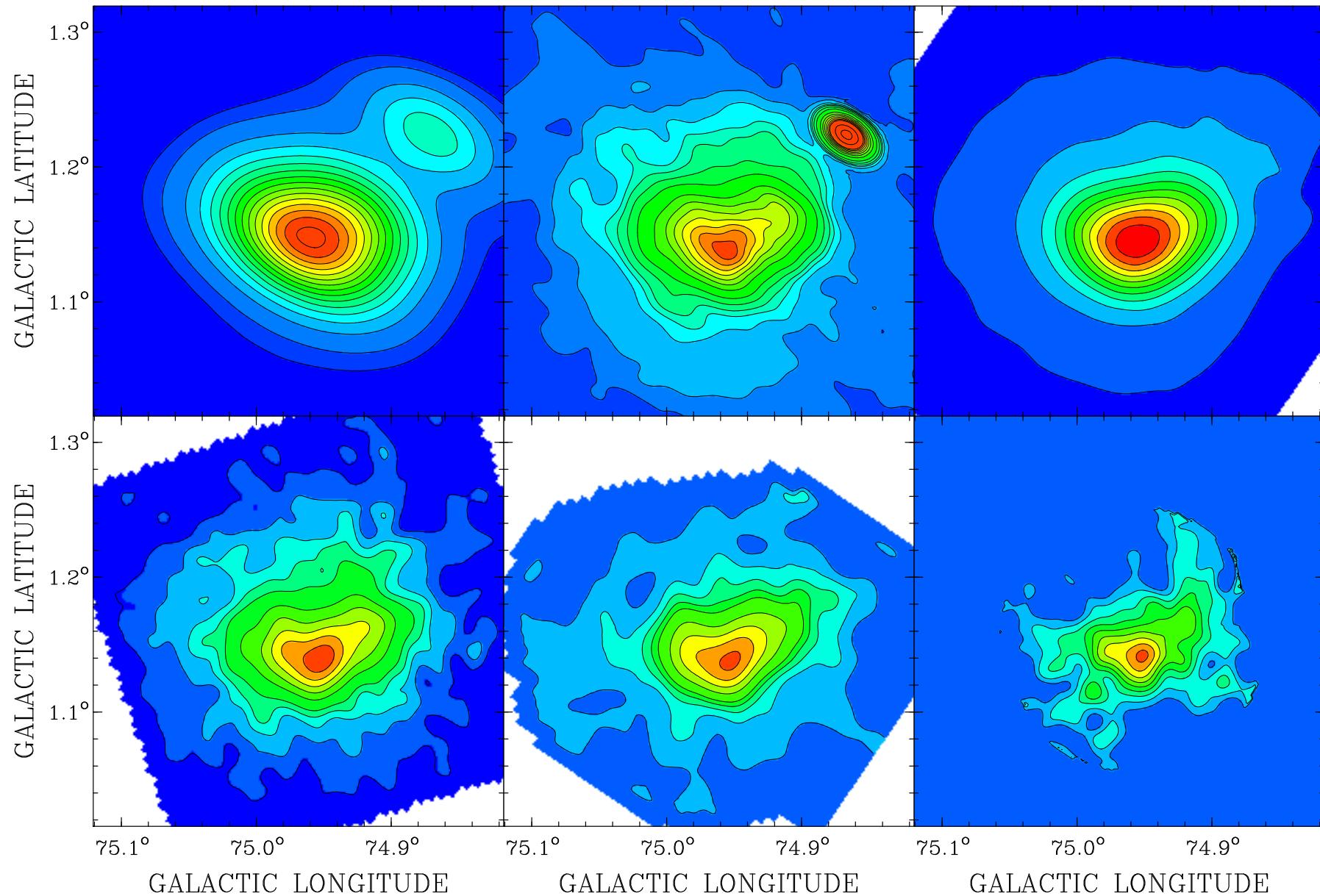
CTB87 + E 2013+370



Liu et al., 2018:



# Radio Observations of PWN CTB87



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Introduction to CTB 87

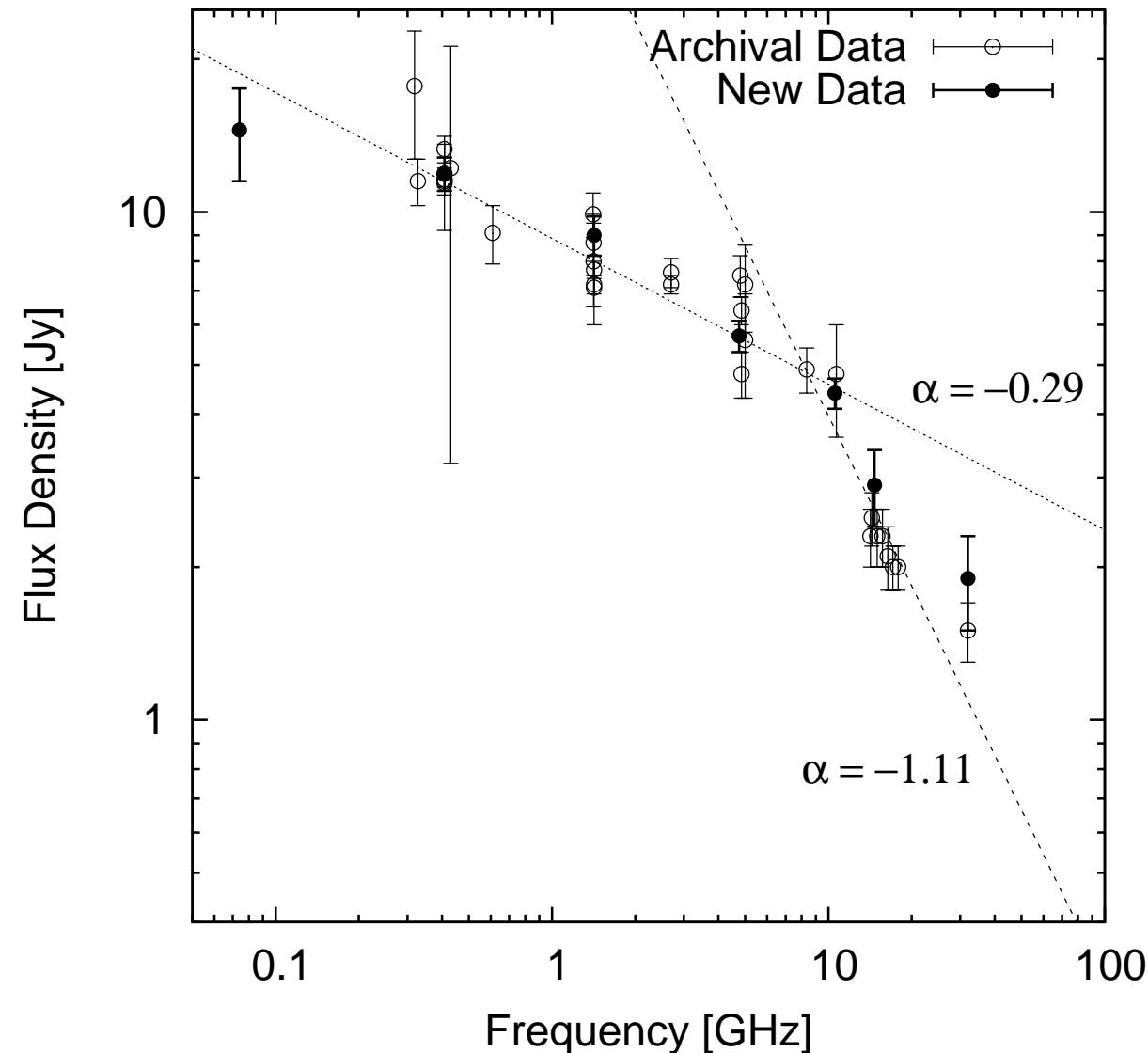
New Radio Study of  
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Radio Continuum

Radio Polarization

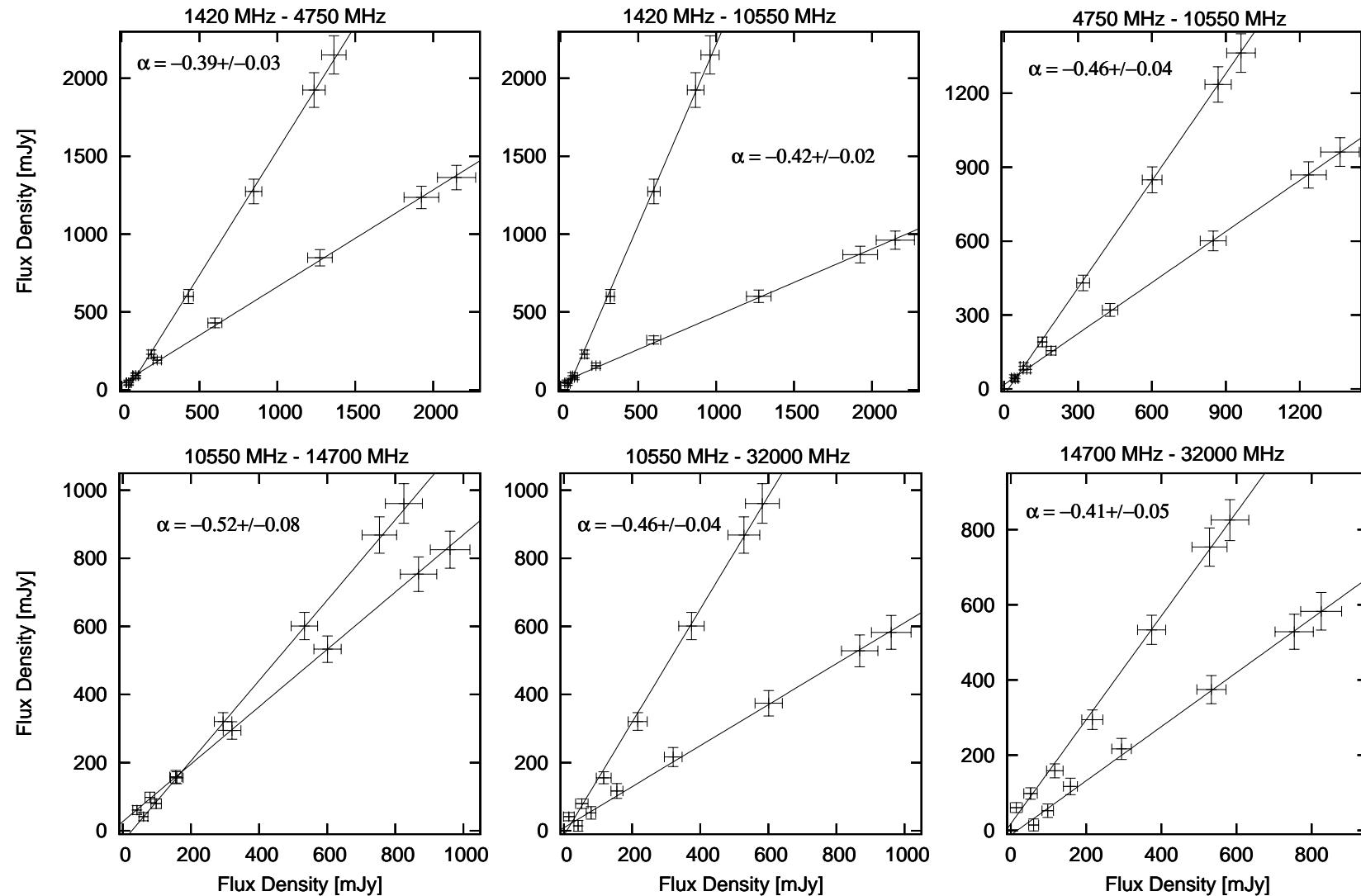
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# Radio Observations of PWN CTB87

## TT-Plots by Turtle et al, 1962



# Radio Observations of PWN CTB87

Background Filter by Sofue & Reich, 1979

GALACTIC LATITUDE

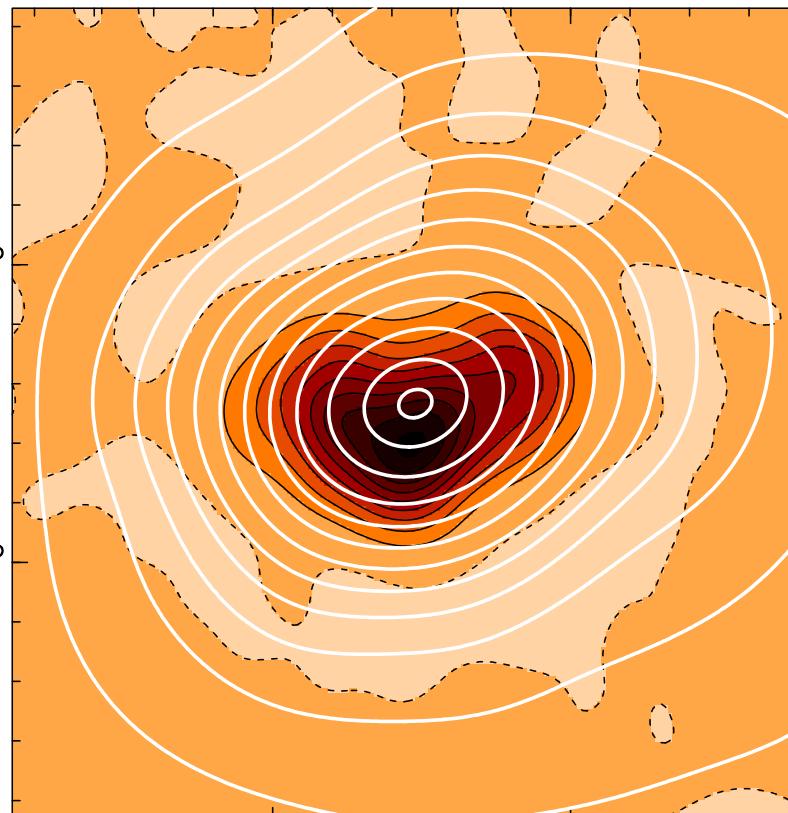
$1.2^\circ$

$1.1^\circ$

$75.0^\circ$

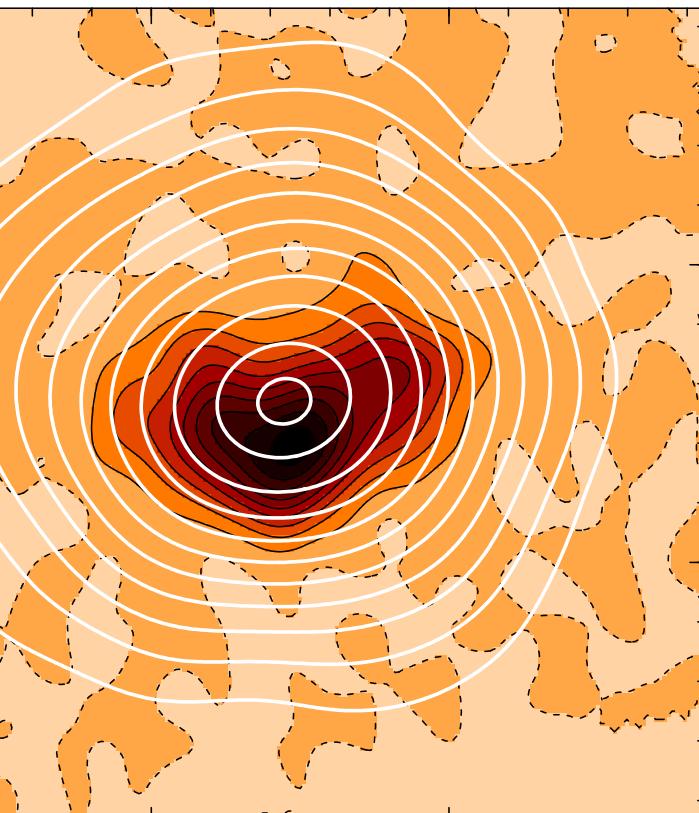
$74.9^\circ$

GALACTIC LONGITUDE

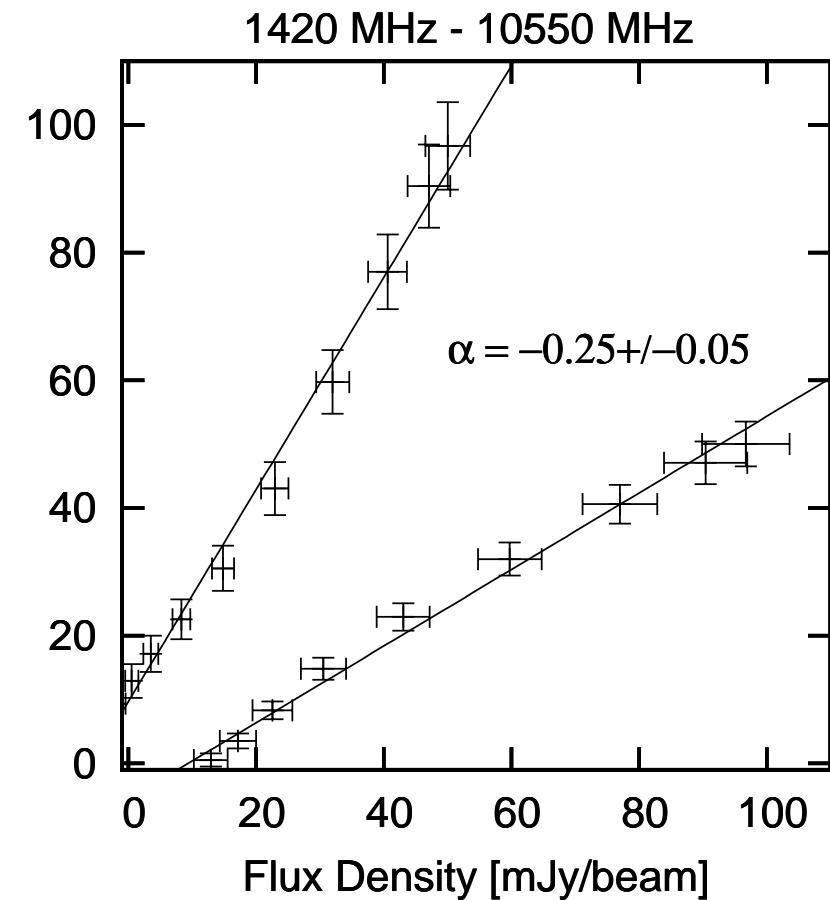
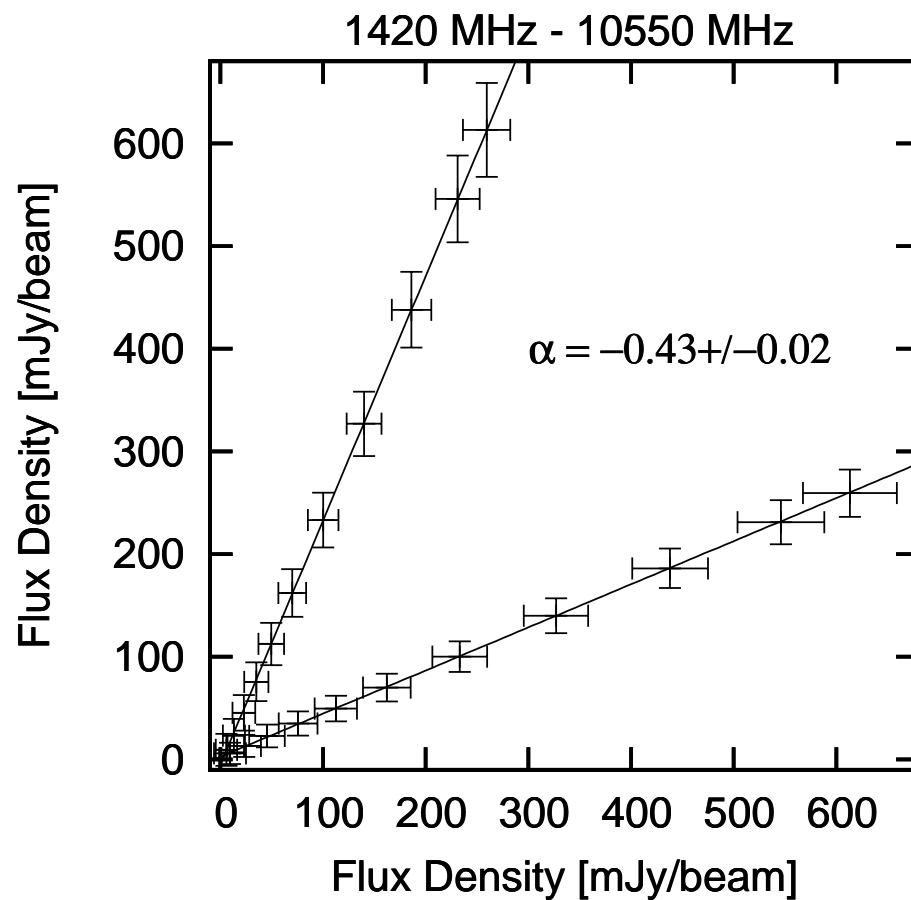


$75.0^\circ$

GALACTIC LONGITUDE



# Radio Observations of PWN CTB87



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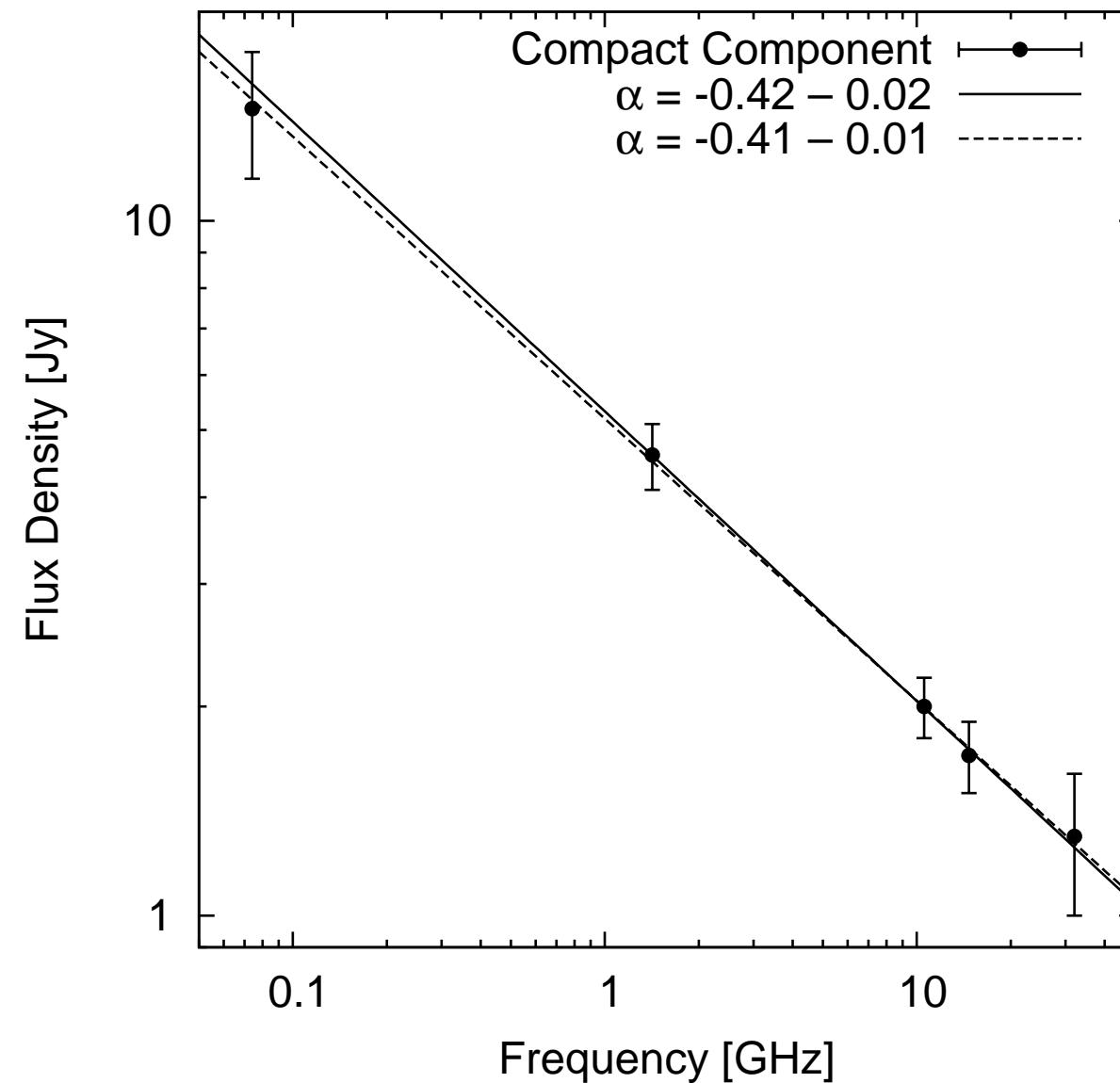
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# Radio Polarization of PWN CTB87

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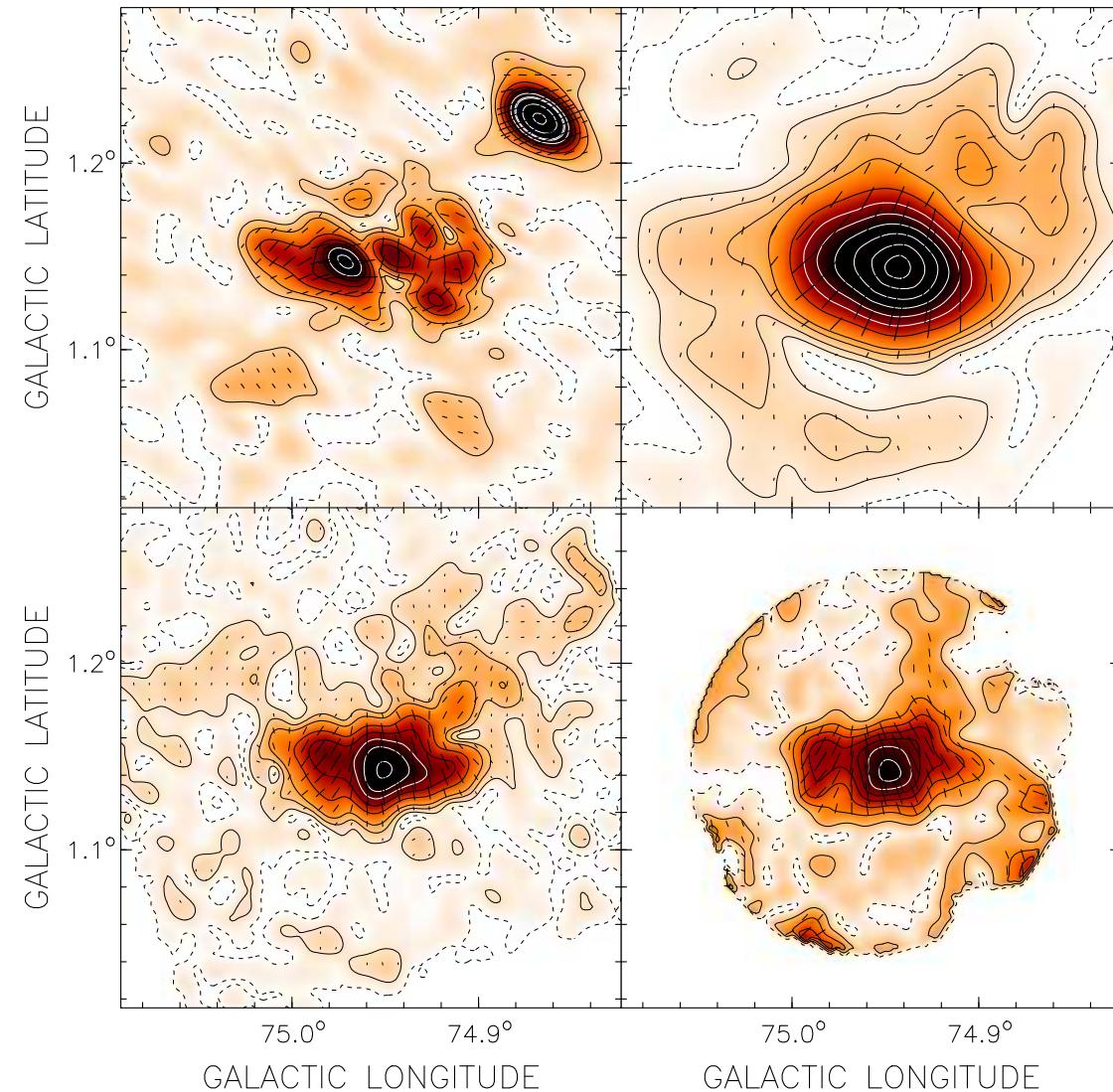
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# Radio Polarization of PWN CTB87

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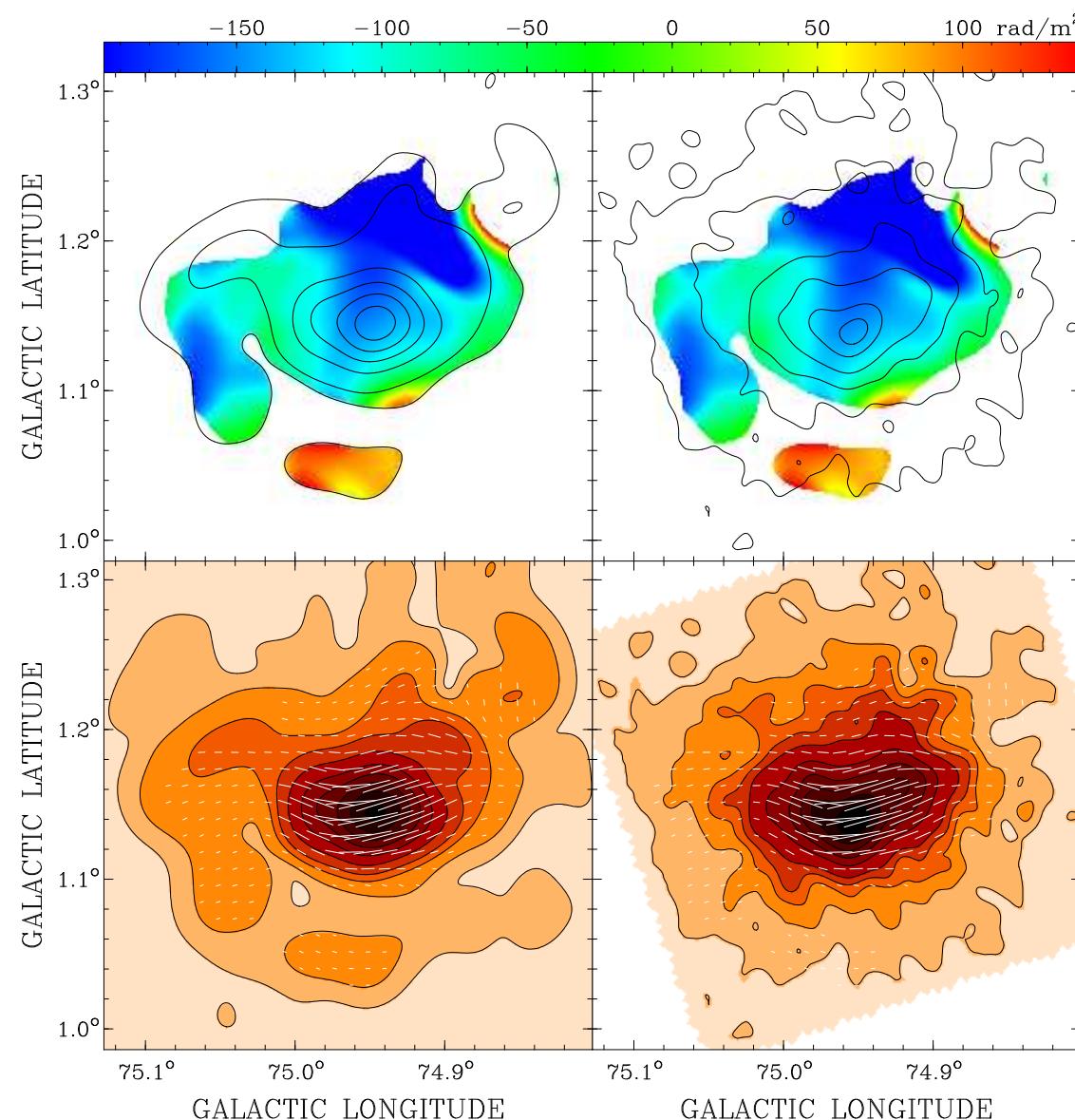
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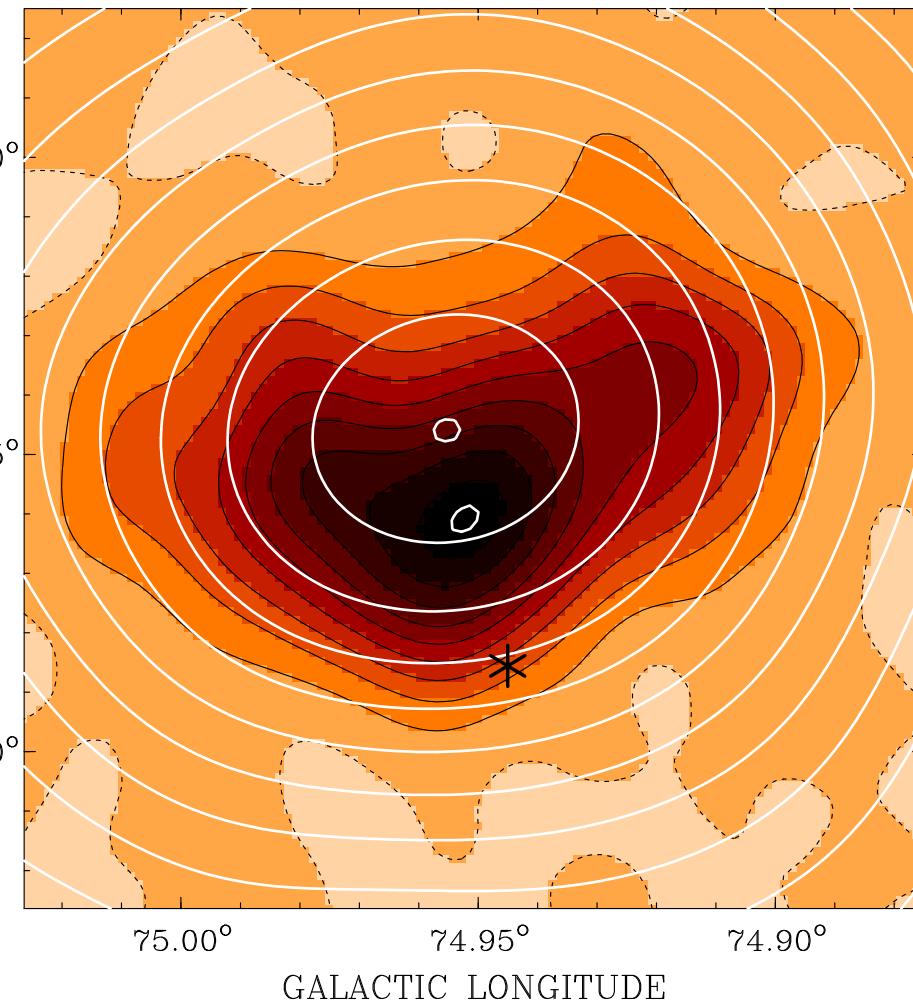
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# The Nature of CTB87

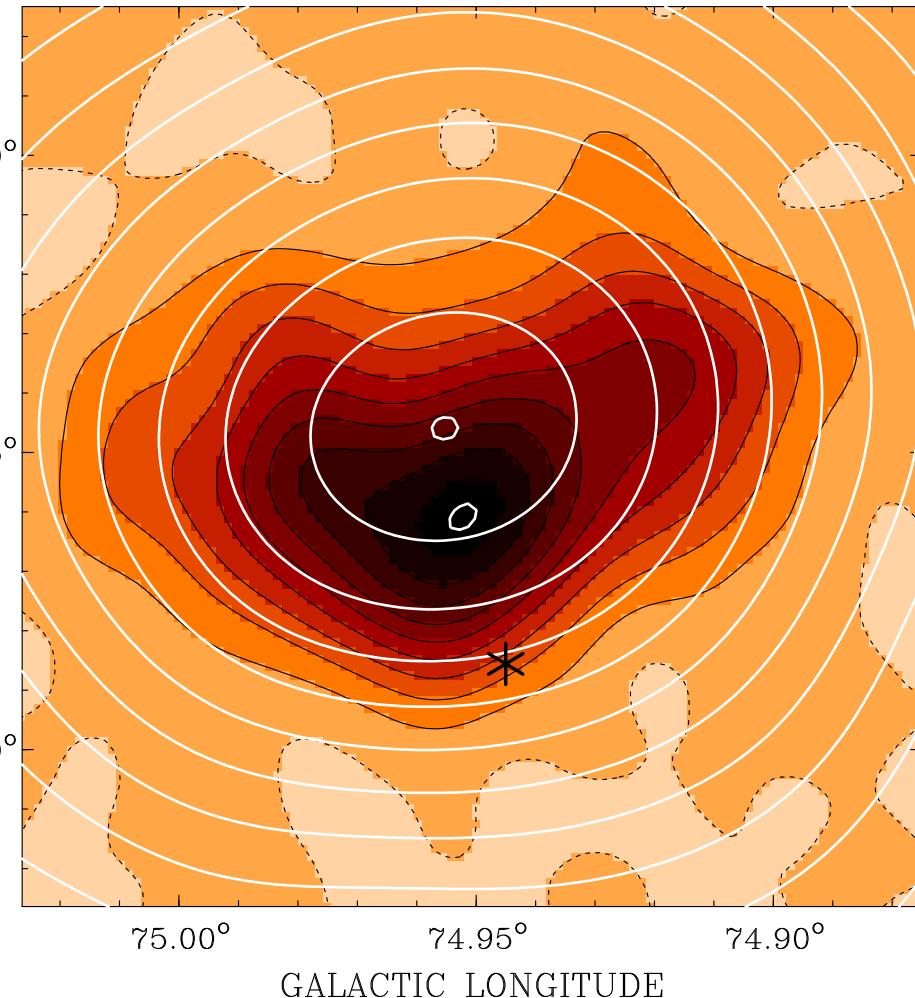
GALACTIC LATITUDE



- SNR expands inside a large cavity
- off-centered
- near a molecular cloud

# The Nature of CTB87

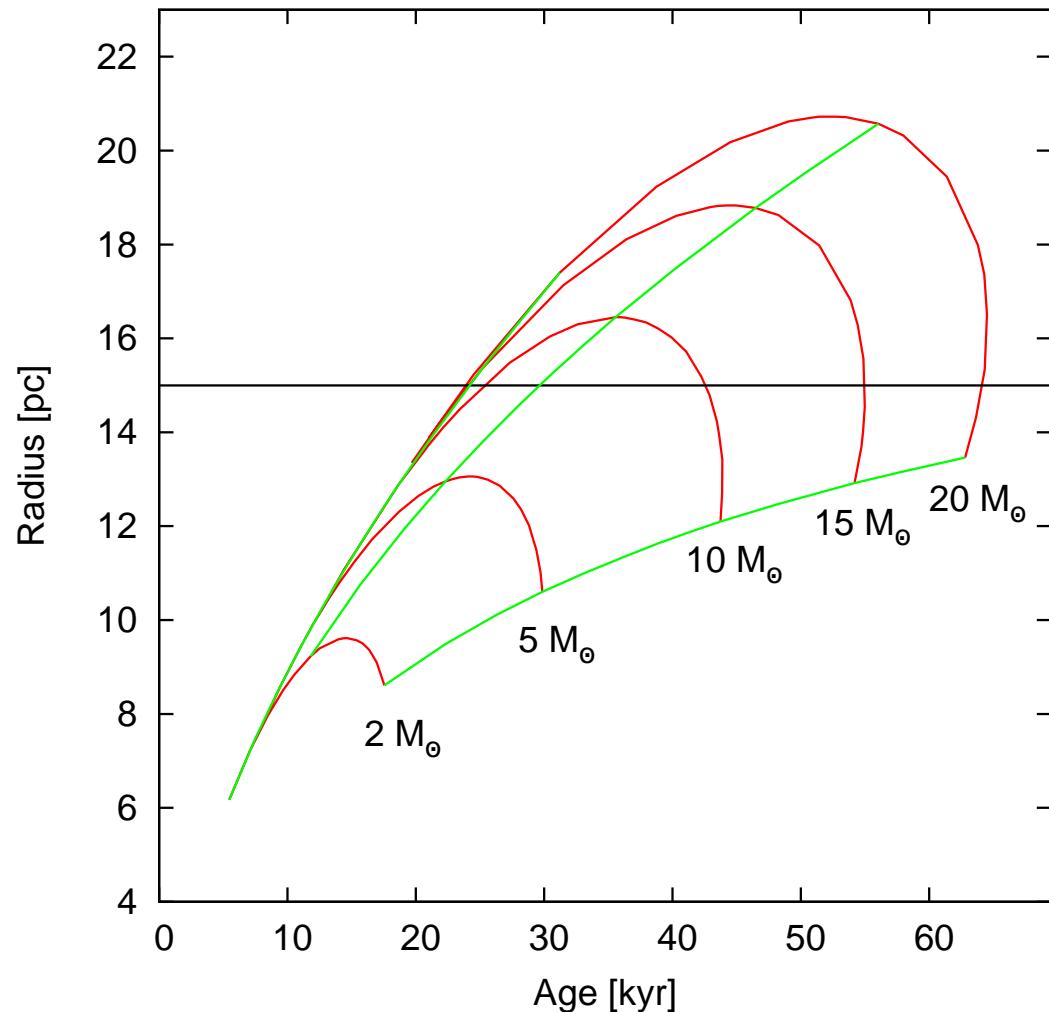
GALACTIC LATITUDE



- SNR expands inside a large cavity
- off-centered
- near a molecular cloud
- There are two PWN components
- The diffuse component represents the PWN expanding undisturbed inside the large cavity
- The Kidney-shaped feature is the relic PWN left behind after the interaction with the reverse shock

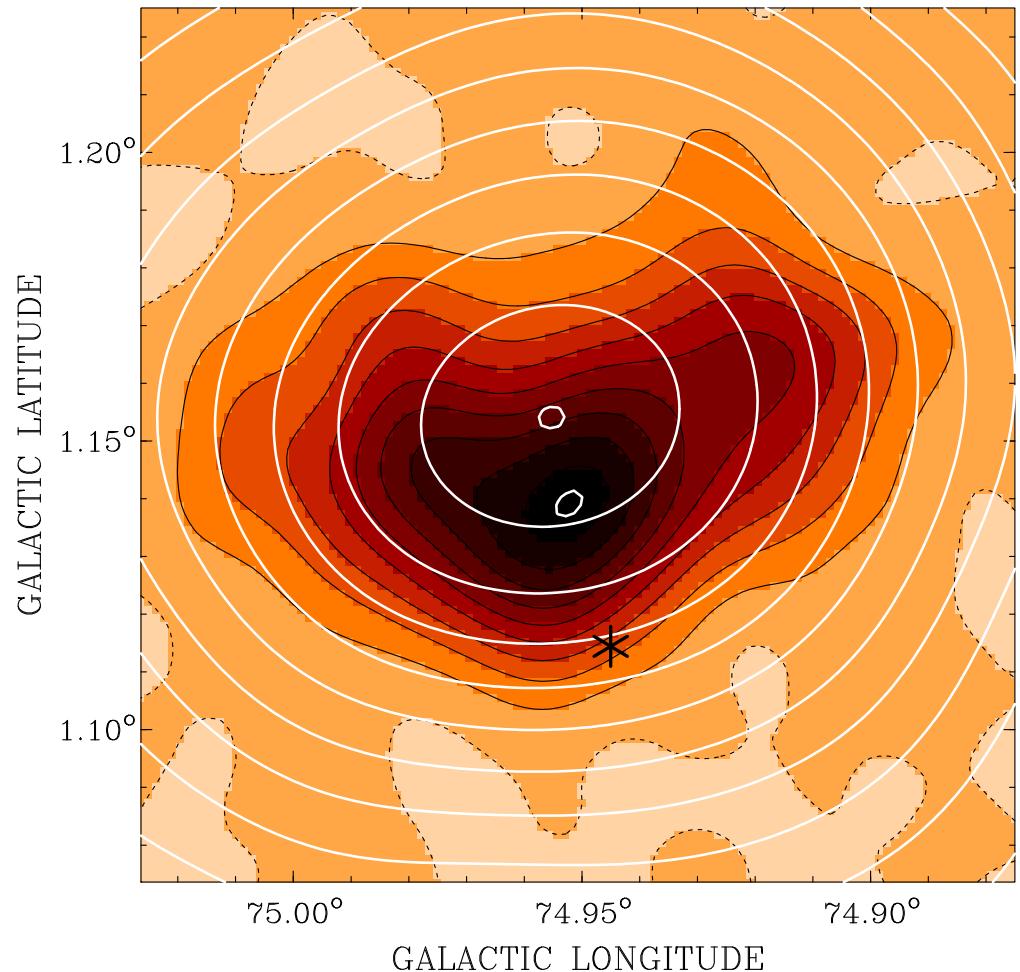
# The Diffuse PWN

- $R_{\text{diff}} = 15 \text{ pc}$
- $n_0 = 0.02 \text{ cm}^{-3}$
- $\dot{E} = 10^{37} \text{ erg s}^{-1}$ , from PWN X-ray luminosity using the empirical relationship of Li et al., 2008
- evolution of PWN inside SNR (Kothes et al., 2017)
- expansion of PWN inside ejecta (Chevalier 2004)
- expansion of SNR blast wave and reverse shock (McKee & Truelove, 1995)



# The relic PWN

- Blast wave expands inside the HI cavity and hits the molecular clouds at a radius of  $\geq 5$  pc.
- enters the cloud of density  $\approx 80 \text{ cm}^{-3}$  (Liu et al., 2018)
- reverse shock moves eventually back towards the PWN and interacts with pulsar wind
- kidney radio peak marks location where reverse shock meets pulsar



# The relic PWN

- $R_{\text{MC}} = 5 \text{ pc}$
- $\dot{E} = 10^{37} \text{ erg s}^{-1}$
- $t_{\text{col}} \approx 11,000 \text{ yr}$
- $E_0 = 2 - 3 \times 10^{50} \text{ erg}$
- $t \approx 30,000 \text{ yr}$
- $v_{\text{psr}} \approx 100 \text{ km s}^{-1}$
- $R_b^{\text{cav}} \approx 30 \text{ pc (17')}$



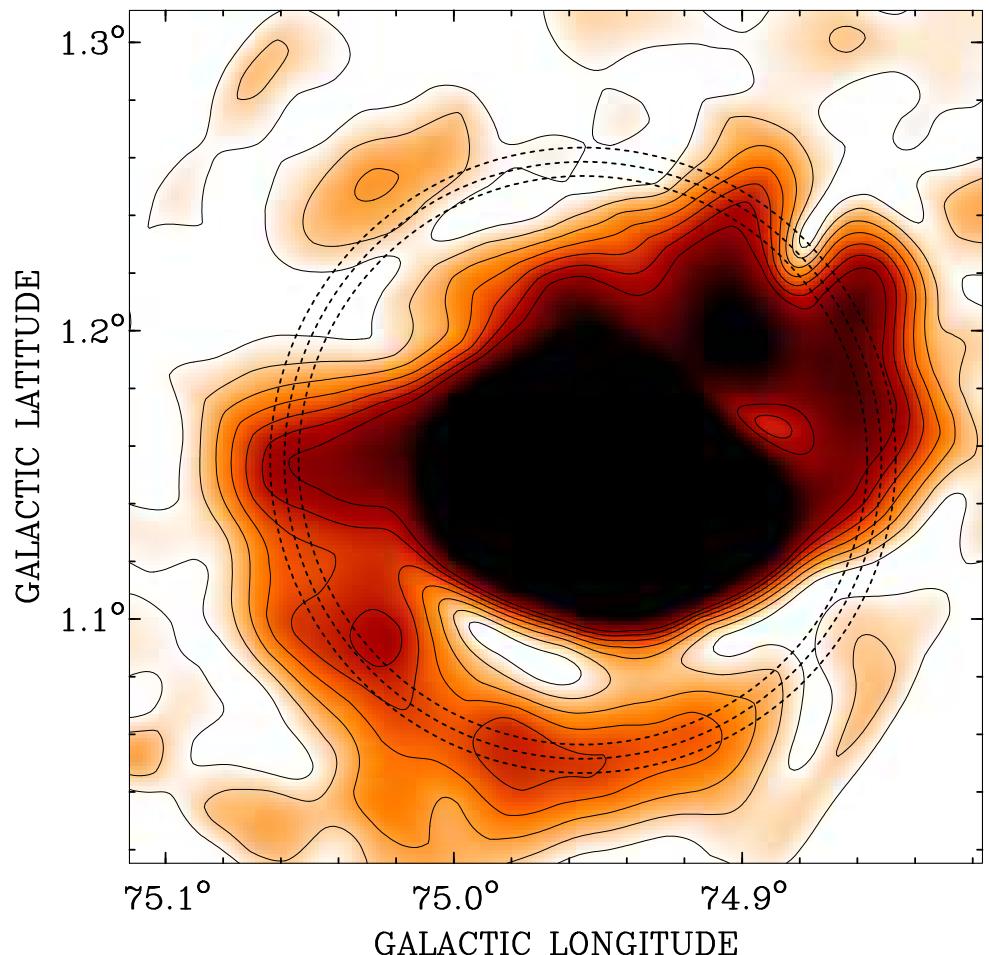
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- $M_0 = 10, 15, 20 M_{\odot}$
- $R_b^{\text{cloud}} = 10.5, 11, 11.5 \text{ pc}$



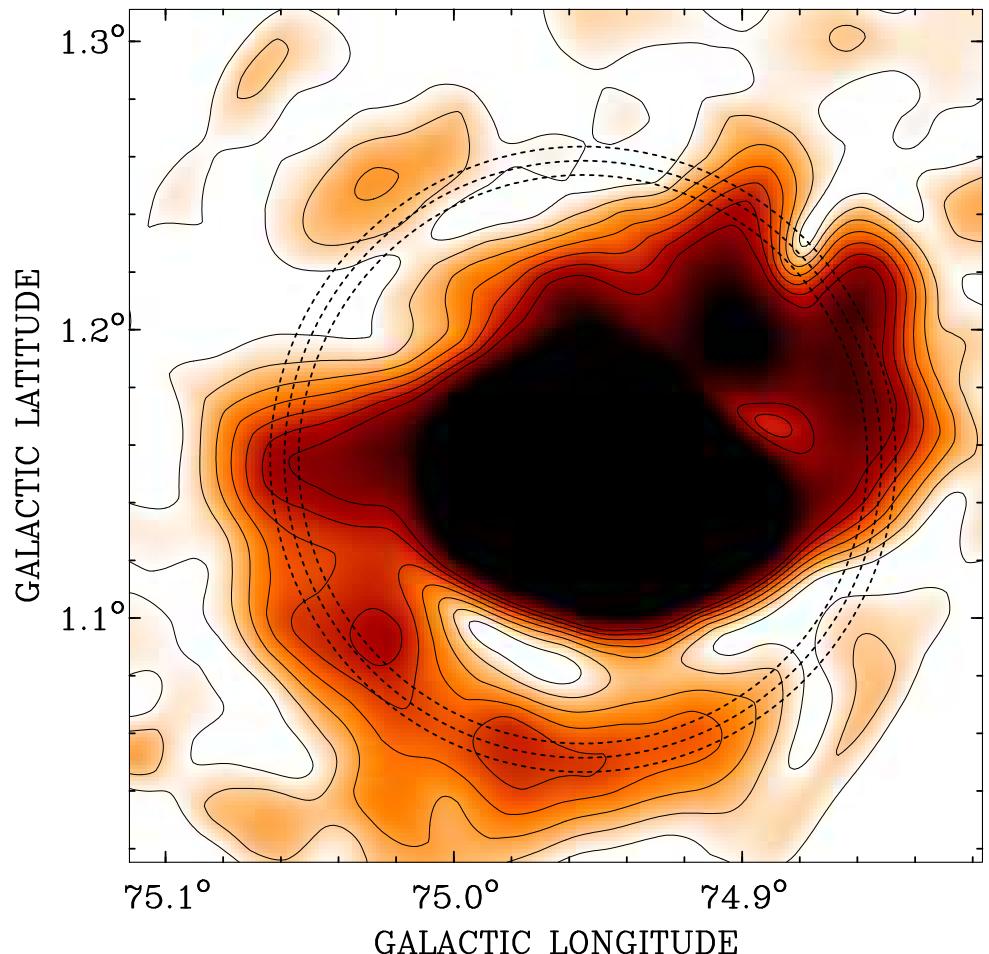
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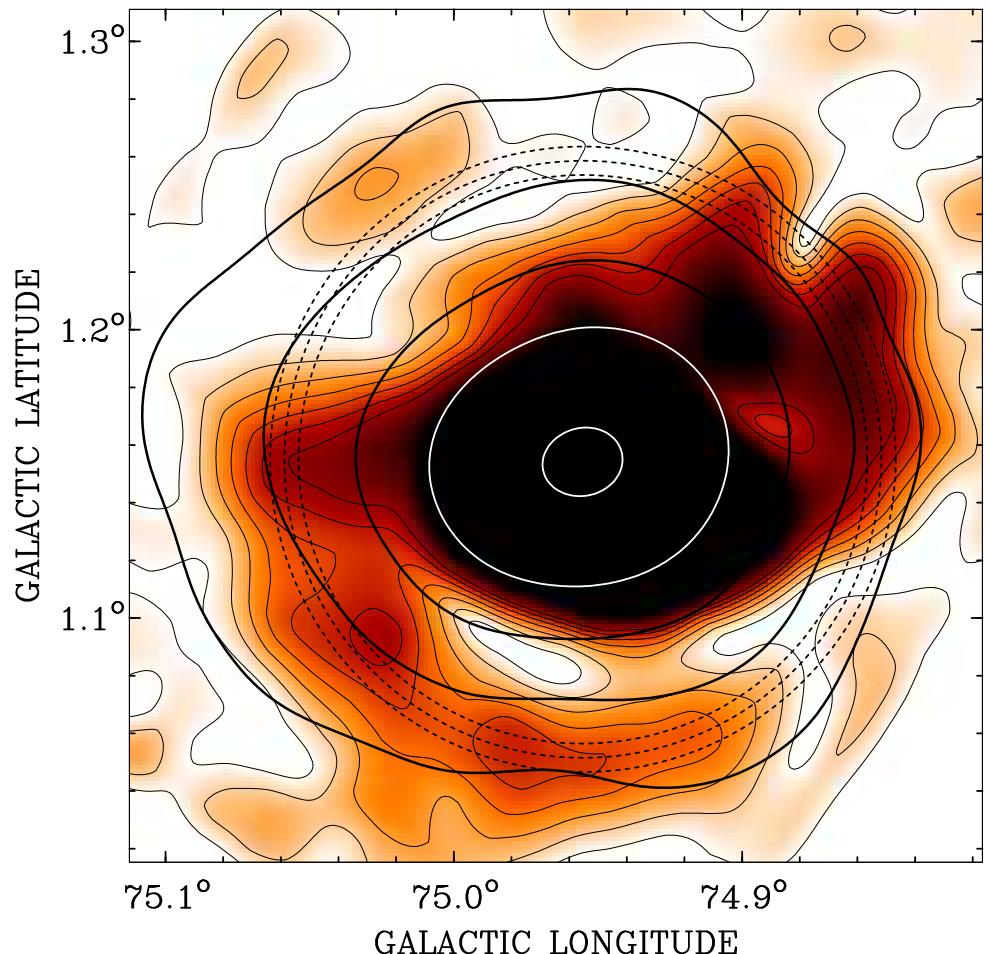
# The relic PWN

- $R_{\text{CO}} = 5 \text{ pc}$
- $\dot{E}_0 = 10^{39} \text{ erg s}^{-1}$
- $t_{\text{col}} \approx 5,500 \text{ yr}$
- $E_0 \approx 10^{51} \text{ erg}$
- $t \approx 15,000 \text{ yr}$
- $v_{\text{psr}} \approx 200 \text{ km s}^{-1}$
- $R_b^{\text{cav}} \approx 30 \text{ pc} (17')$
- $M_0 = 10, 15, 20 M_{\odot}$
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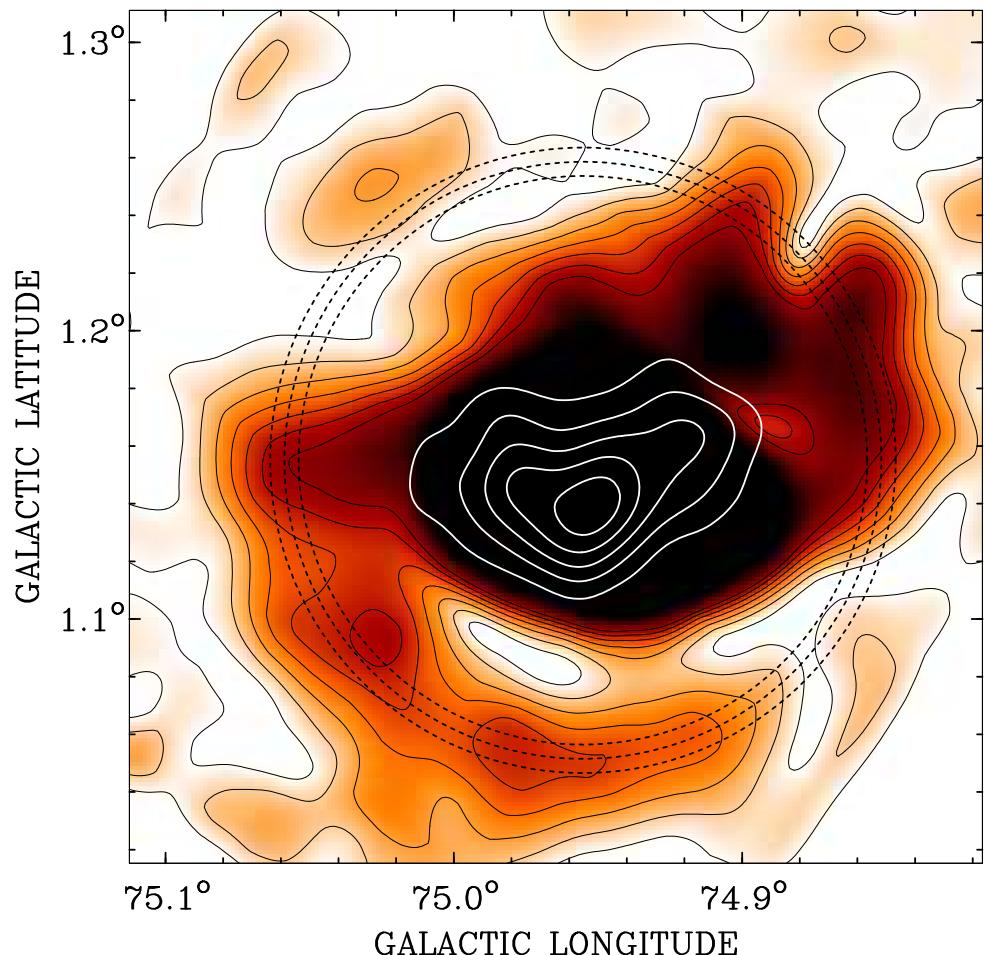
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# Summary and Conclusions

- We present radio continuum observations including polarization of the PWN CTB 87 over a wide radio frequency range.
- The PWN is located at an off-centre position inside a large HI cavity and is on one side interacting with a molecular cloud.
- We separate the radio source into two components: a PWN expanding undisturbed inside a HI cavity and a compact relic PWN.



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- We present radio continuum observations including polarization of the PWN CTB 87 over a wide radio frequency range.
- The PWN is located at an off-centre position inside a large HI cavity and is on one side interacting with a molecular cloud.
- We separate the radio source into two components: a PWN expanding undisturbed inside a HI cavity and a compact relic PWN.
- From simple simulations of the PWN's evolution inside the SNR, we found that the progenitor most likely exploded in a type II explosion about 15,000 yr ago.
- Most of the blast wave is still expanding freely inside a HI cavity/bubble, while a small part entered a molecular cloud of high density.
- Its reverse shock interacted with the PSR and its nebula, producing the relic PWN seen in radio and X-ray.
- The freely expanding blastwave did not produce a visible radio shell, yet, but the shockwave that entered the molecular cloud is indicated by a shell visible in linearly polarized radio emission.

