



The Remarkable Radio Tail of PSR J1509-5850

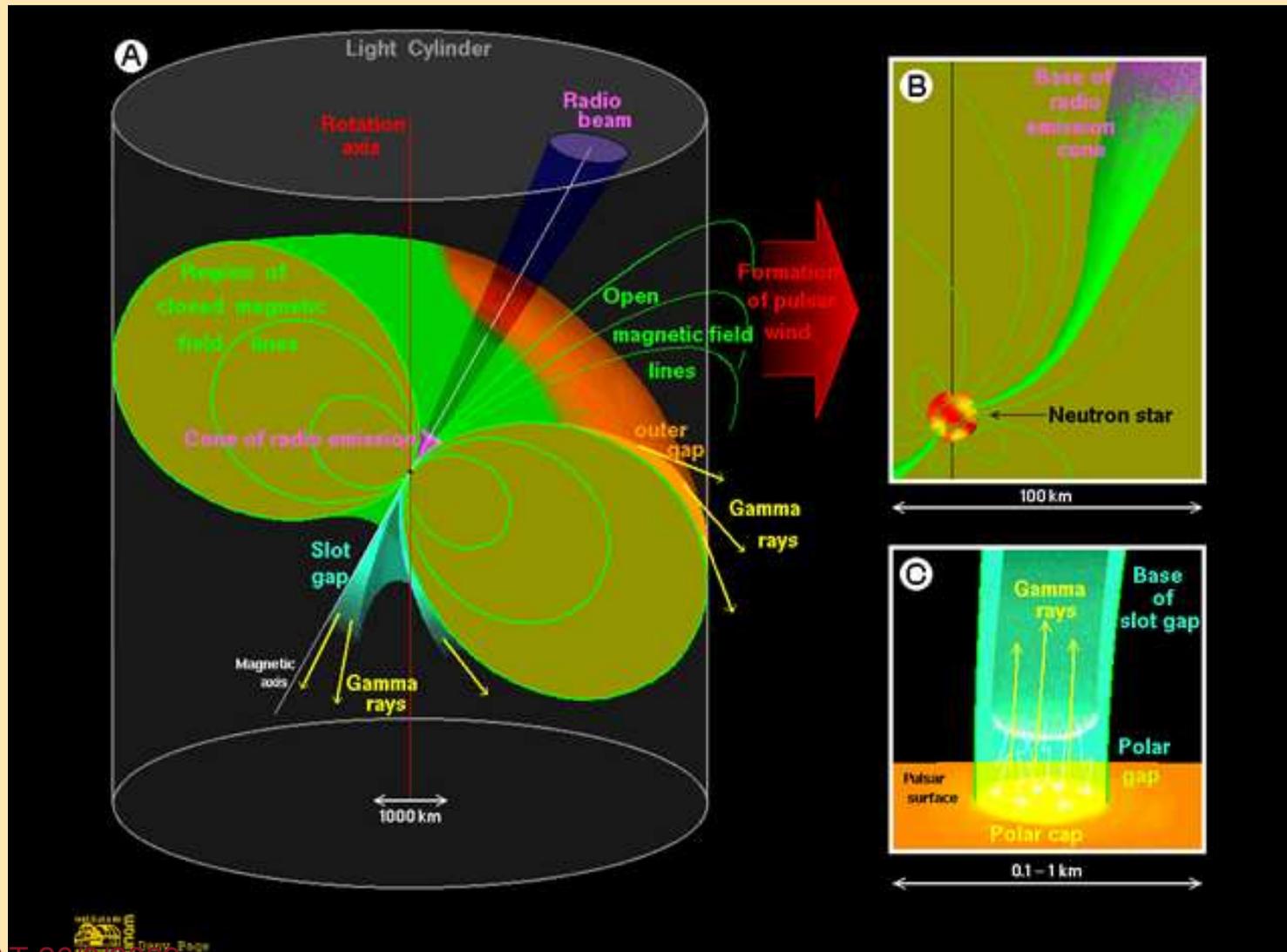


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-- with Bryan Gaensler, Shami Chatterjee & Simon Johnston



Pulsar Winds



HEAT 26/5/2009

<http://www.astroscu.unam.mx/neutrones/NS-Picture/MagSphe/MagSphe.html>



Pulsar Winds

Where does the rotational energy of a pulsar go?

- $\dot{E} > 10^{35}$ ergs/s
- < 10% in radiation (X-rays, γ -rays)
- > 90% in pulsar winds (KE of particles)

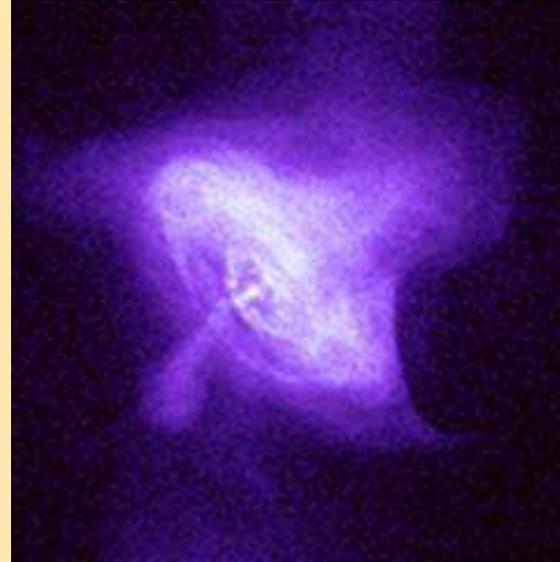
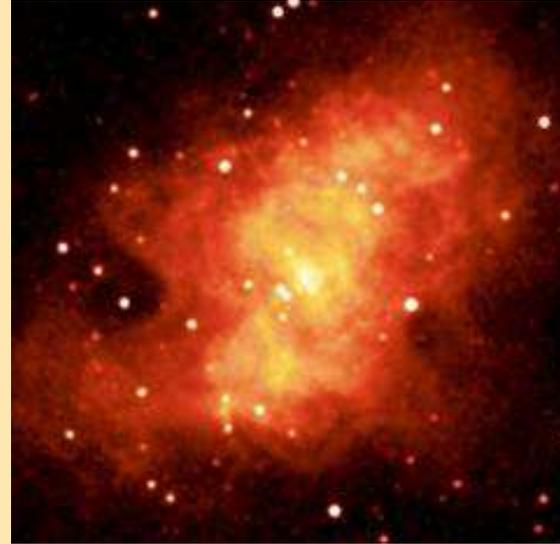
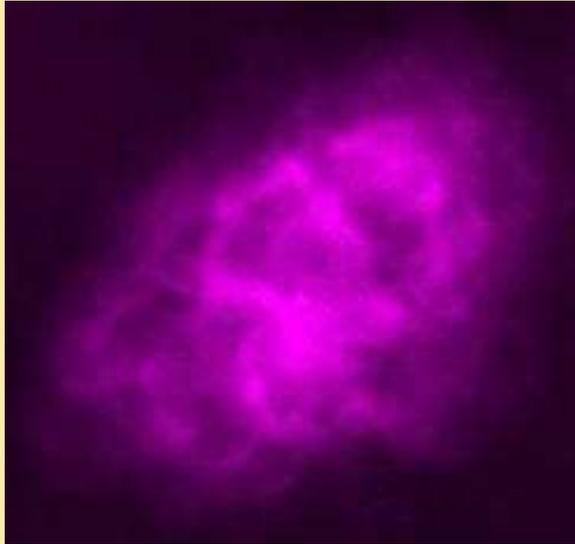


Radio PWN

- Direct calorimeter
- Polarization measurement
- Anomalous morphology
- Highly linearly polarized ($> 10\%$)
- Flat radio spectrum ($S_{\nu} \propto \nu^{\alpha}$; $\alpha = -0.3 - 0.0$)



Pulsar Wind Nebula



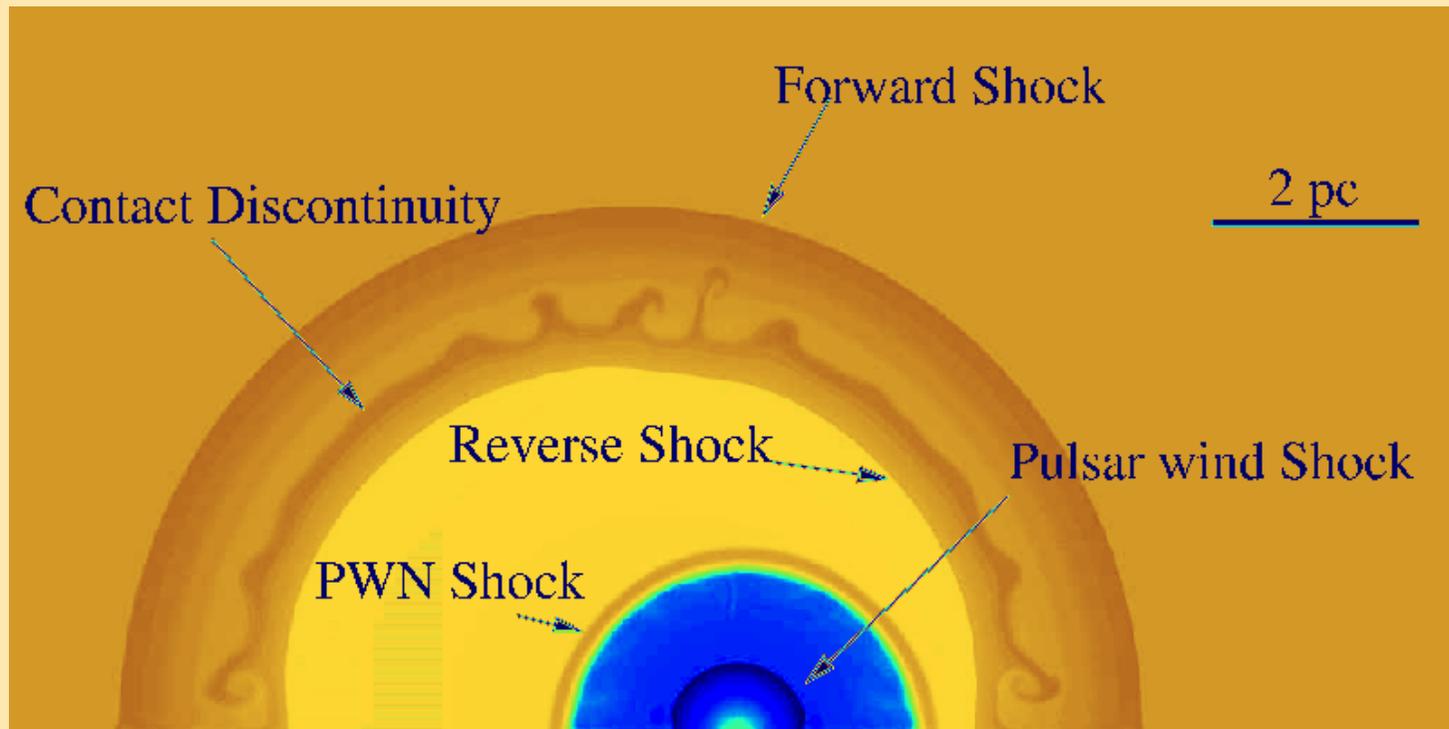
HEAT 26/3/2000

NASA/CXC/Palomar/2MASS/NRAO



PWN Evolution

- Free expansion phase
– e.g. the Crab

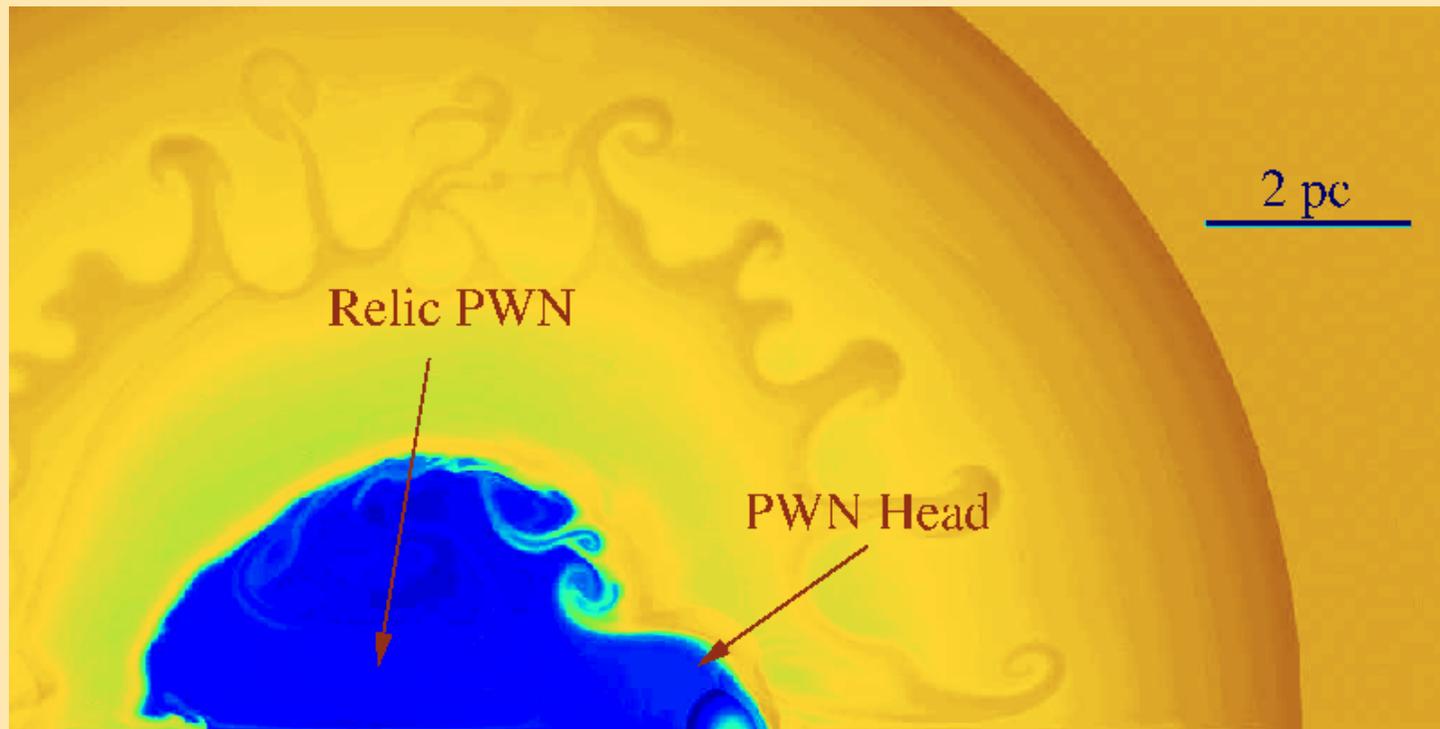


van der Swaluw et al. (2004)



PWN Evolution

- Reverse shock interaction
– e.g. G327.1-1.1

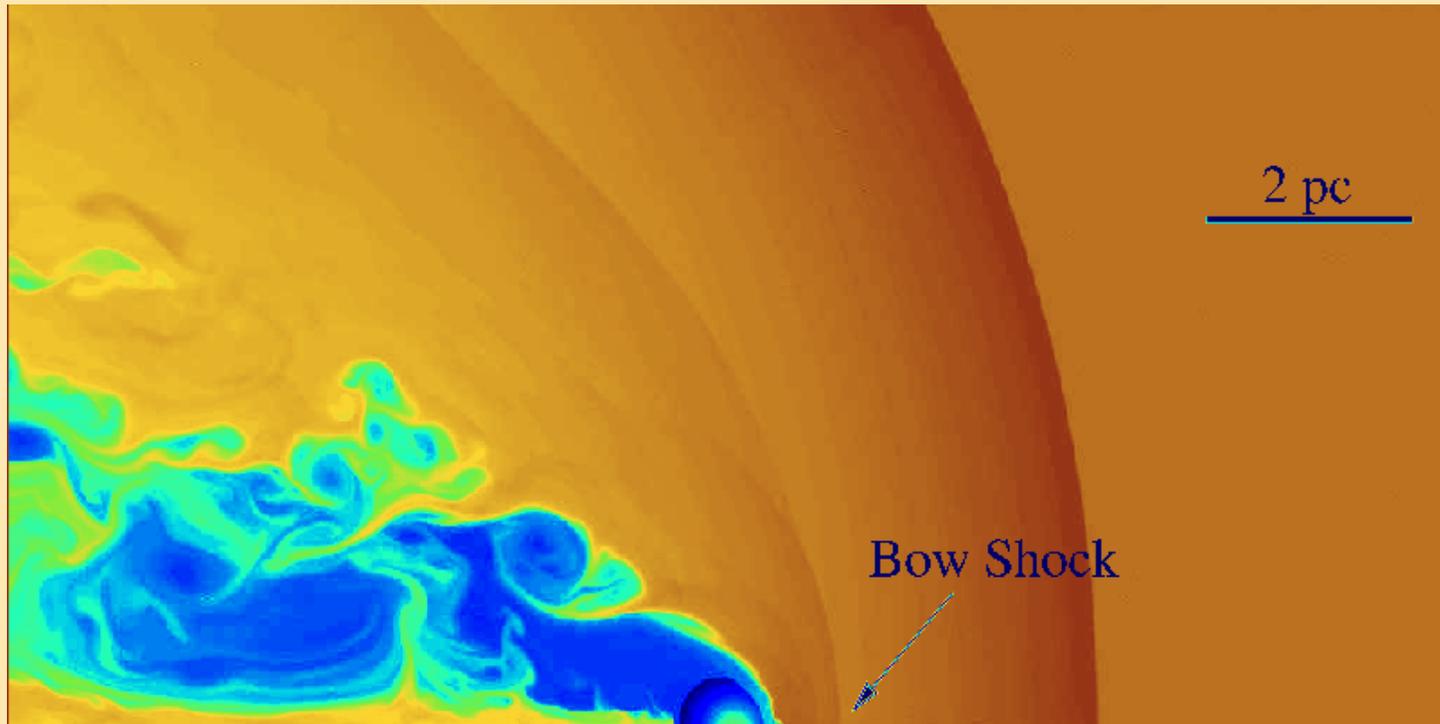


van der Swaluw et al. (2004)



PWN Evolution

- Bow shock
– e.g. the Mouse



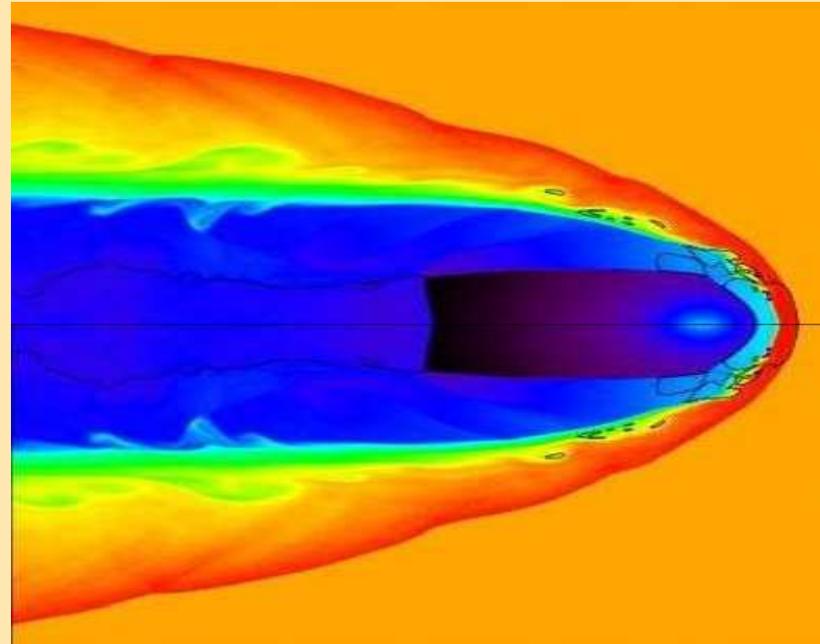
van der Swaluw et al. (2004)



Bow Shocks

- Late stage evolution
 - Supersonic PSR motion in ISM
 - Ram pressure confinement
 - Bullet head + long trails

$$\frac{\dot{E}}{4\pi r^2 c} = \rho v^2 = \gamma \mathcal{M}^2 P_{ISM}$$

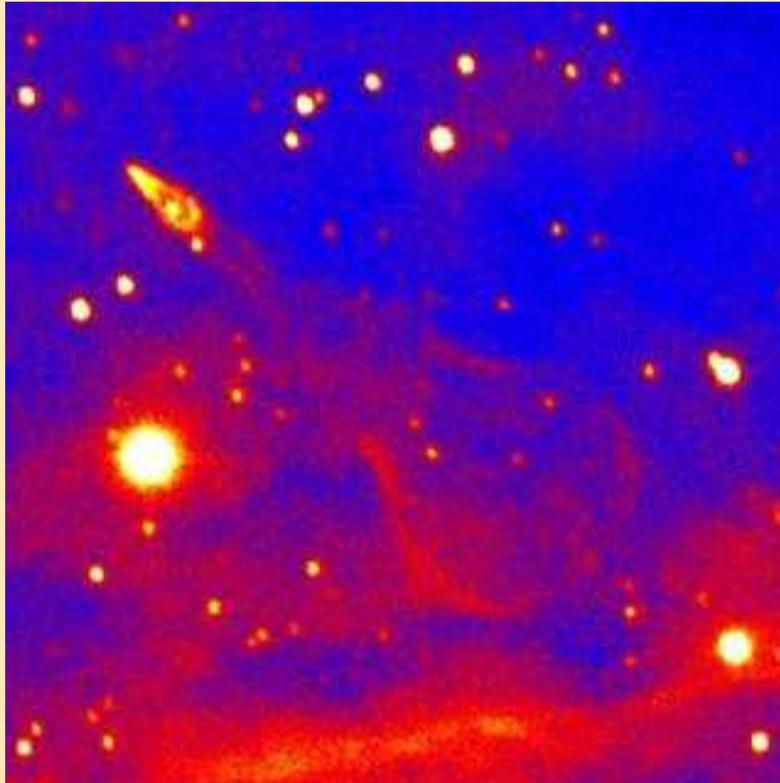


Bucciantini et al. (2005)



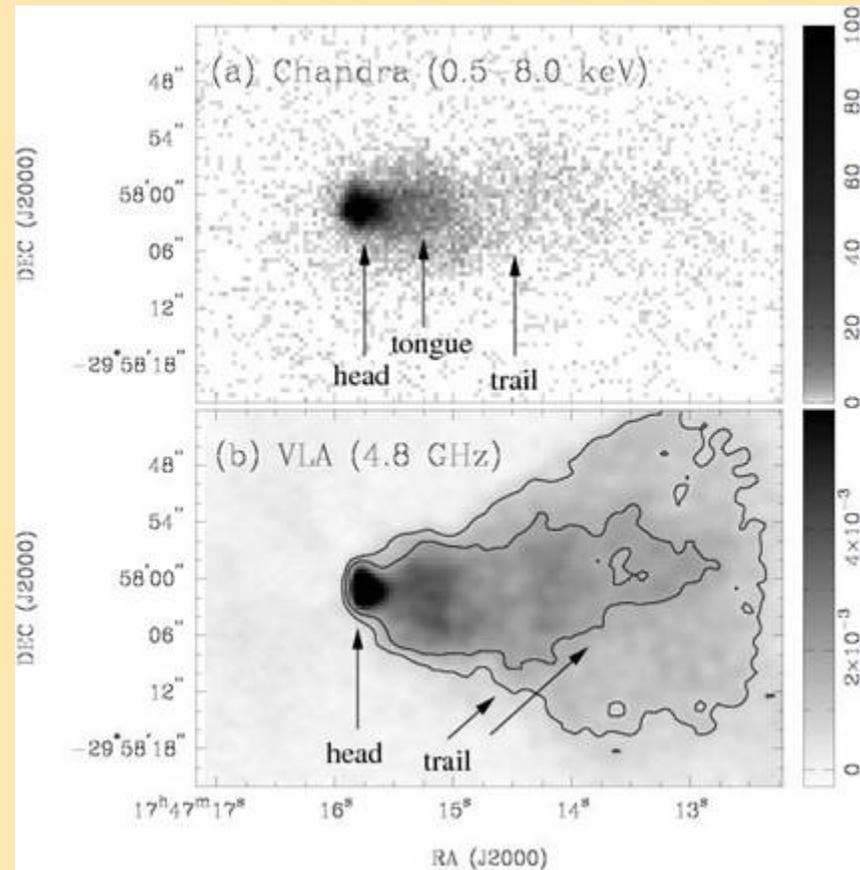
Bow Shocks

Guitar Nebula



Cordes et al. (1993)

Mouse PWN

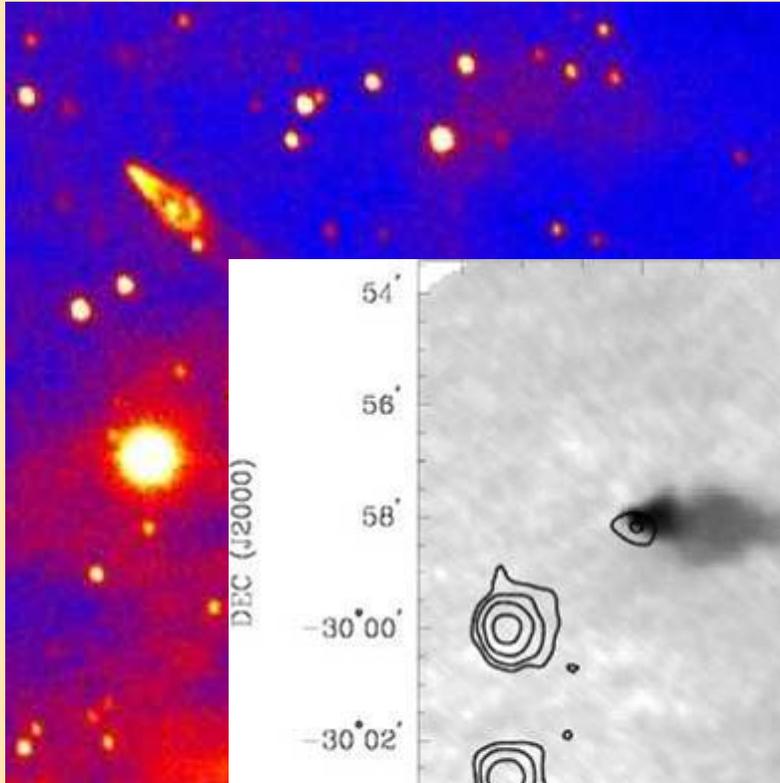


Gaensler et al. (2004)

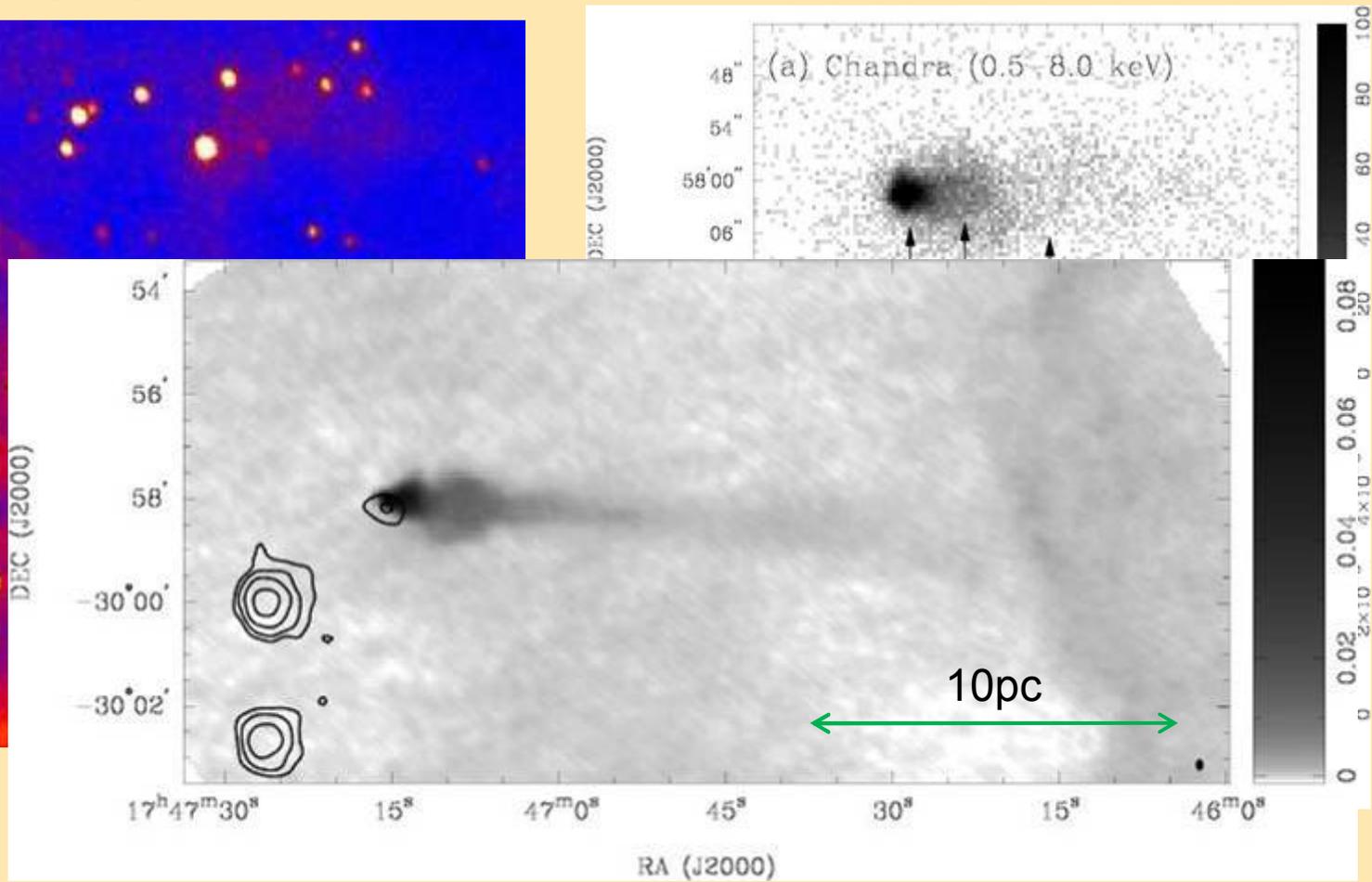


Bow Shocks

Guitar Nebula



Mouse PWN





PSR J1509–5850

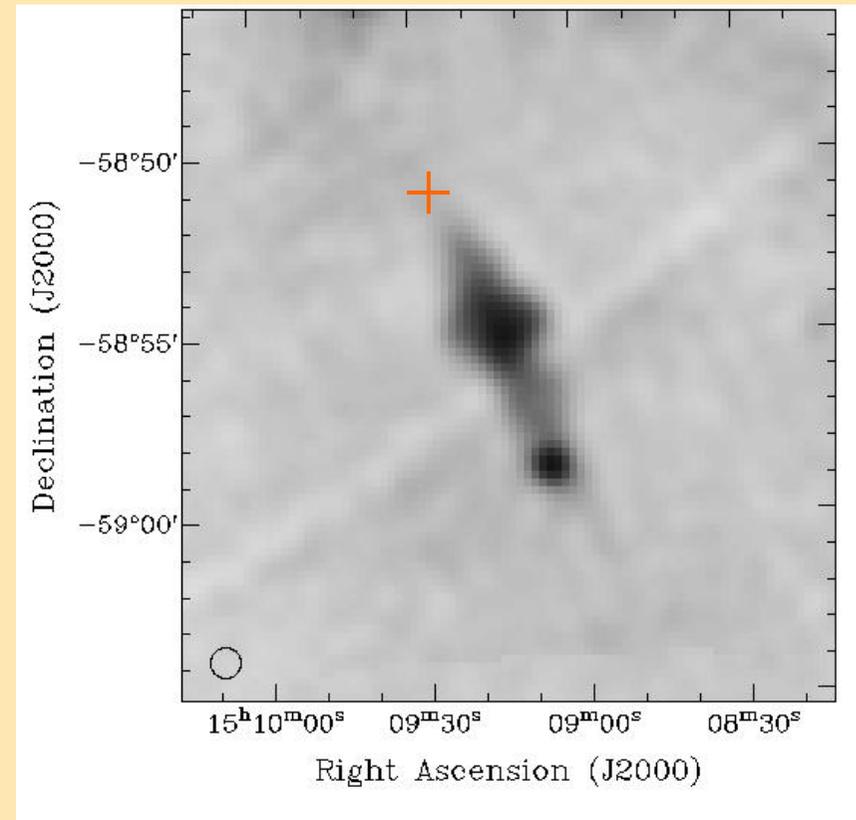
NOT B1509-58

- Discovered in the Parkes Multibeam Survey
- $P=89\text{ms}$, $\dot{E}=5\times 10^{35}\text{erg/s}$, $\tau_c=1.5\times 10^5\text{yr}$
- $d_{DM}=2.6\text{-}3.8\text{kpc}$ (Cordes & Lazio 2002, Taylor & Cordes 1993)
- Longest X-ray trail
 - 6.5pc (Kargaltsev et al. 2008)



MSC 319.9–0.7

- Discovered in the MOST survey
- 4' SW from PSR J1509–5850
- Elongated 12' x 3'





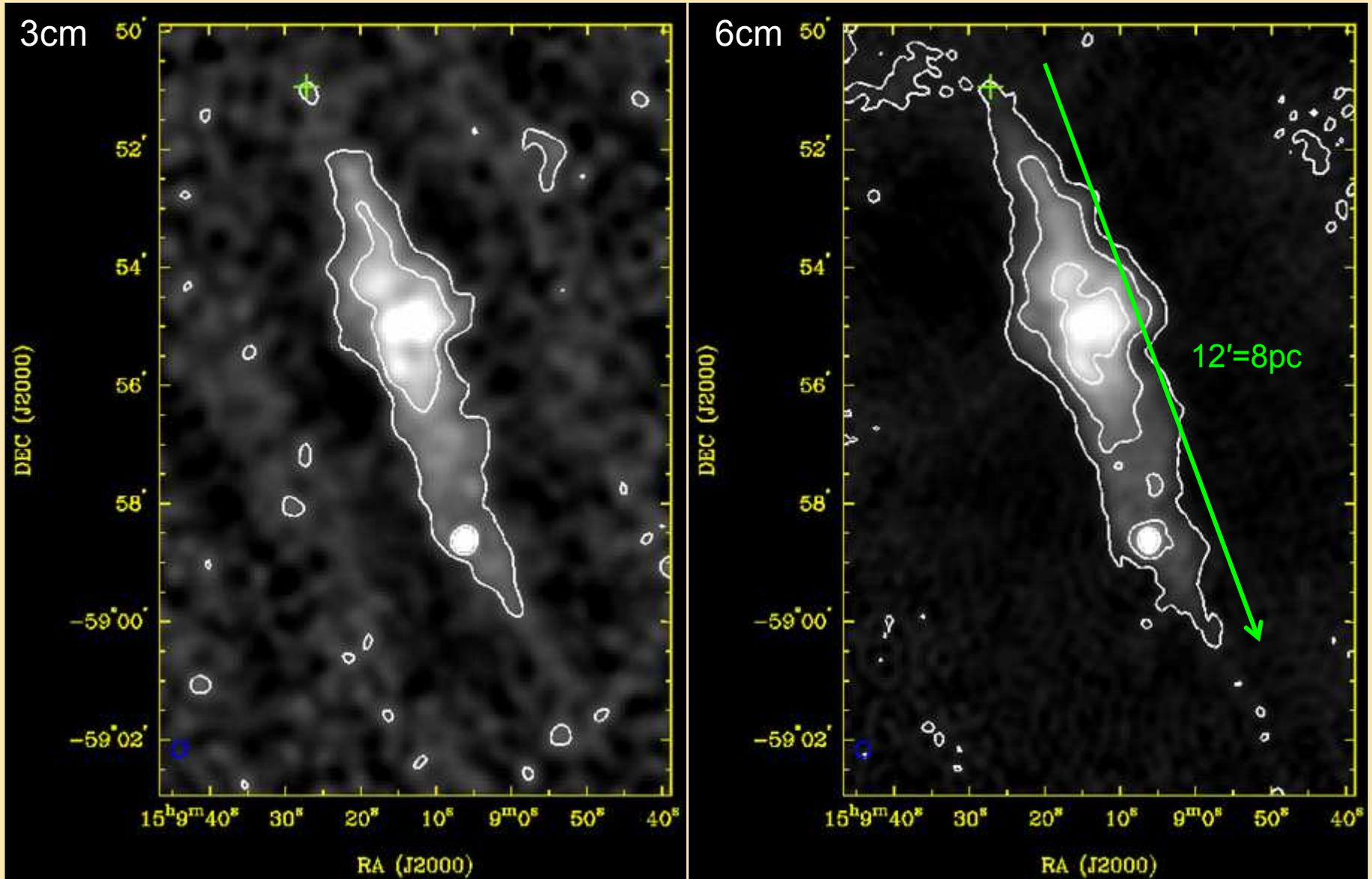
ATCA Observations

- 750C + EW 367 array configurations
- 2 x 12 hr integration time
- 3+6 cm



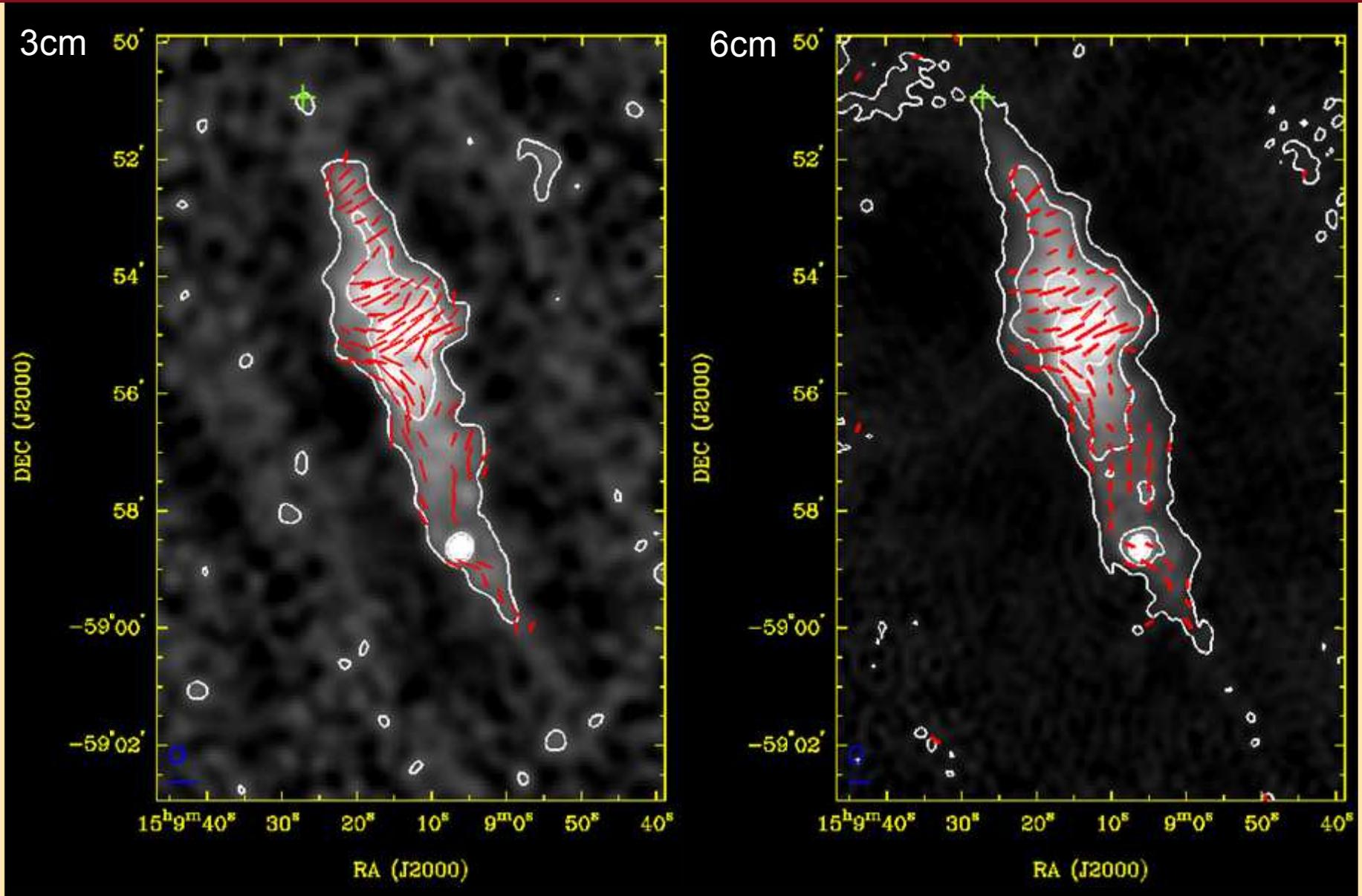


Intensity Maps





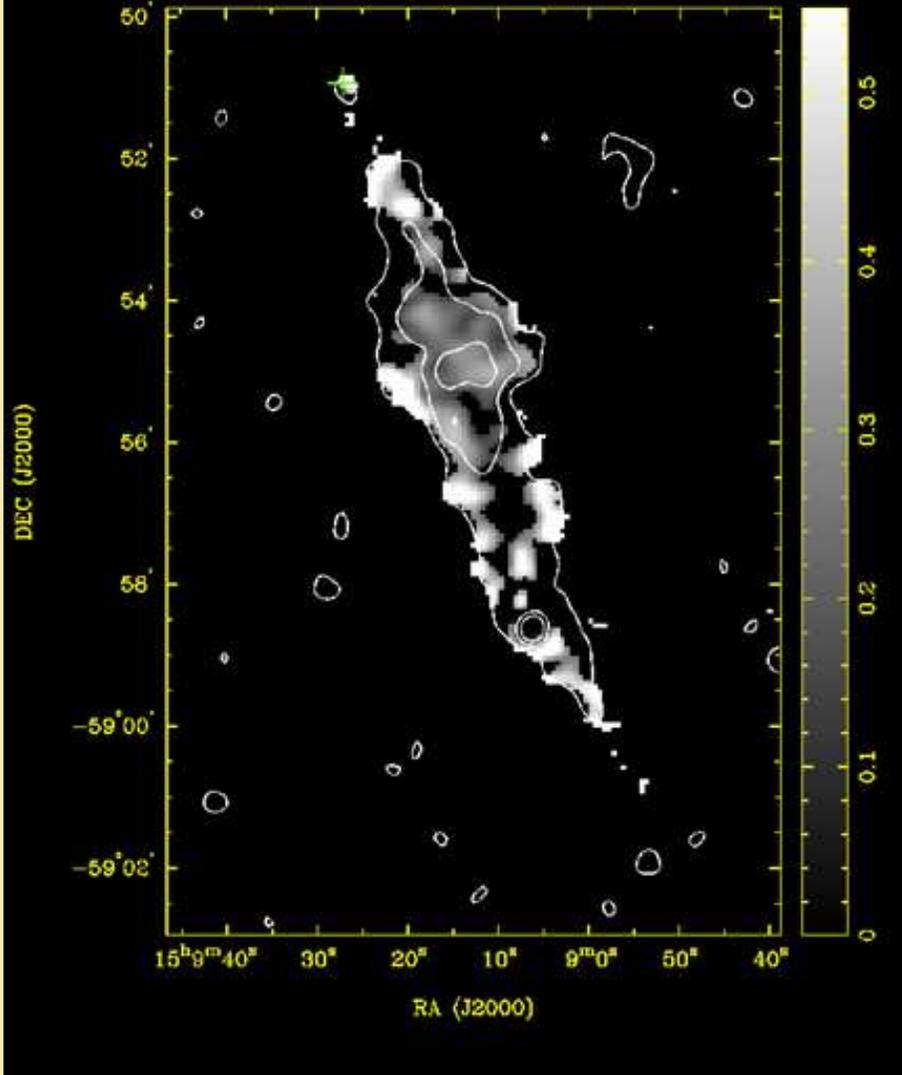
Polarization



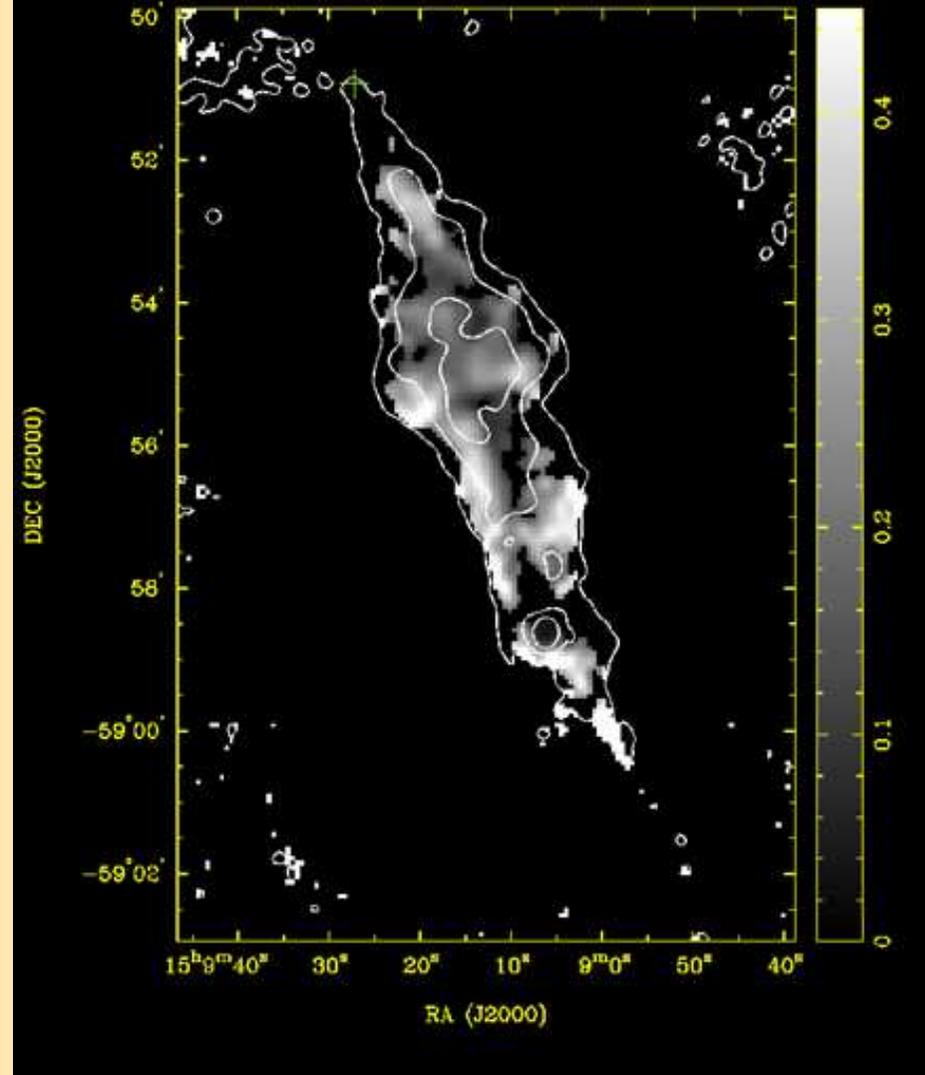


Polarization

3cm

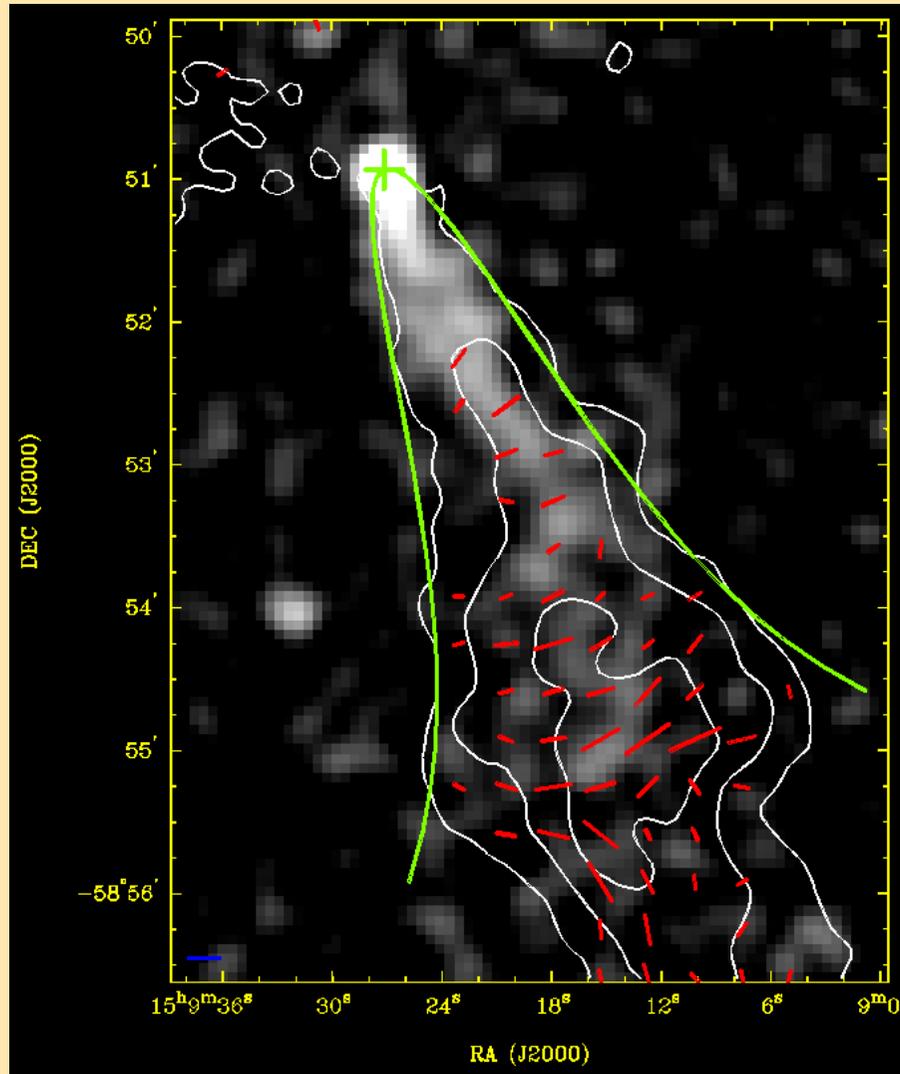


6cm

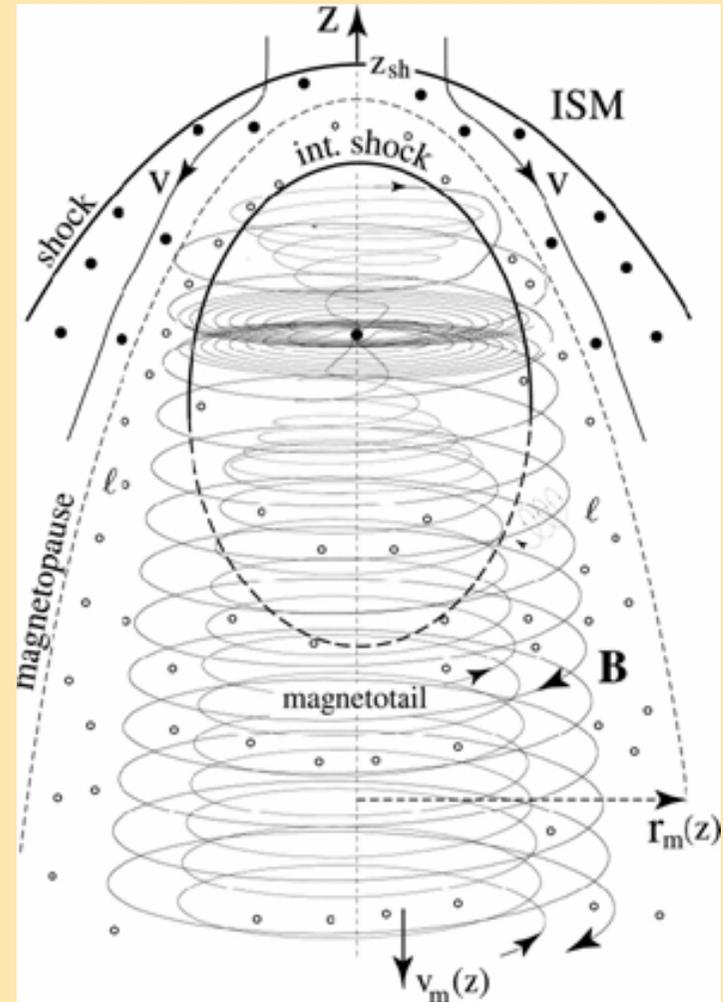




Magnetotail?



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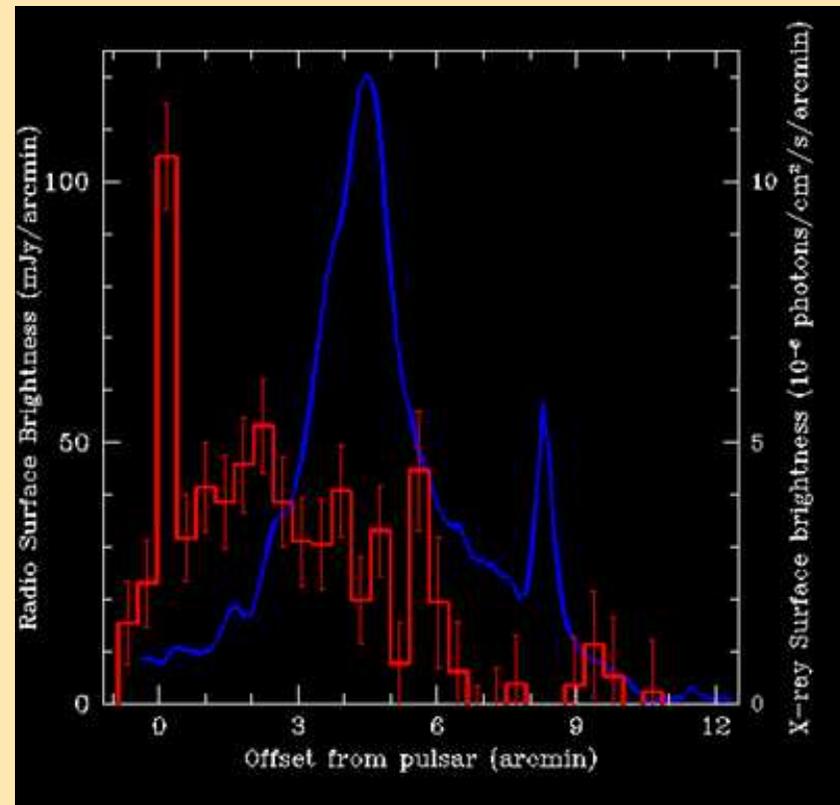
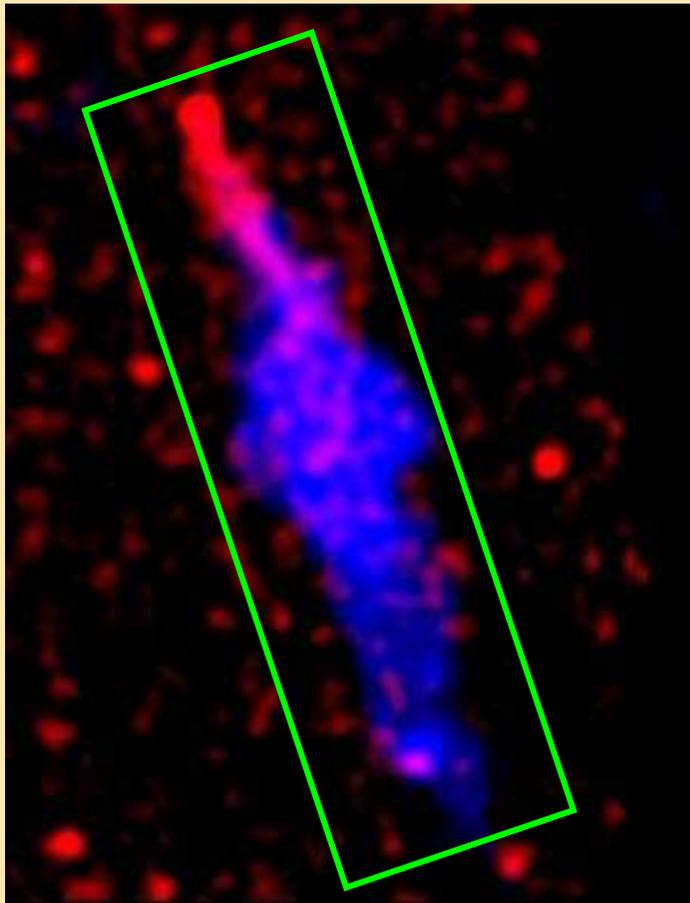


Romanova et al. (2005)



Multiwavelength Comparison

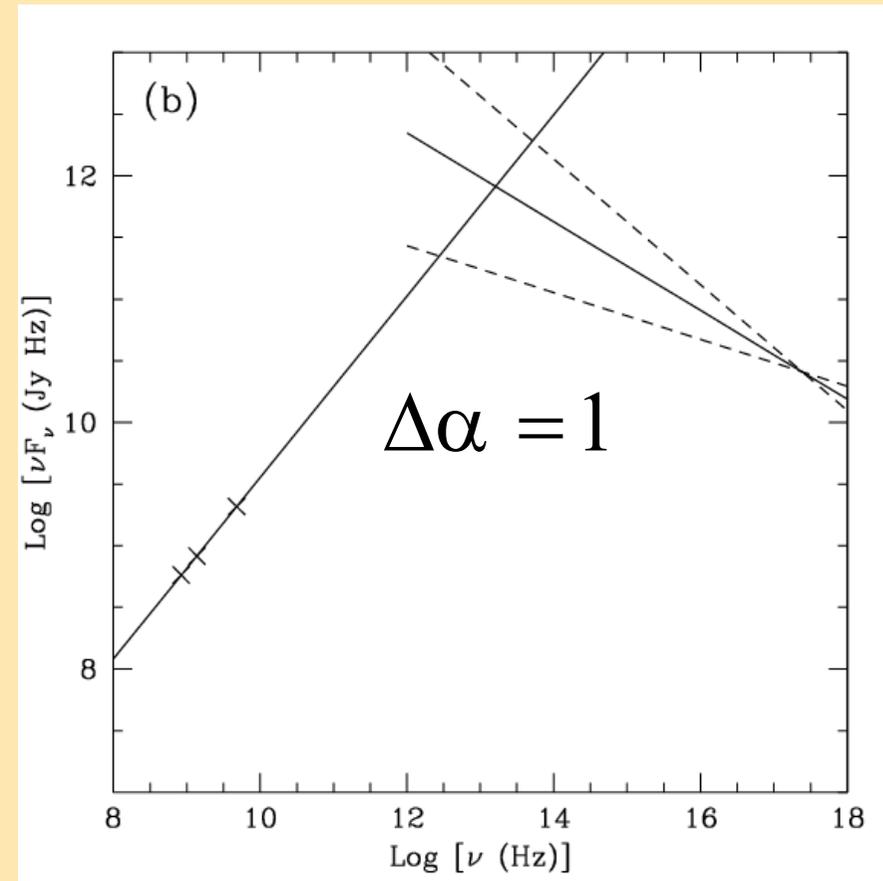
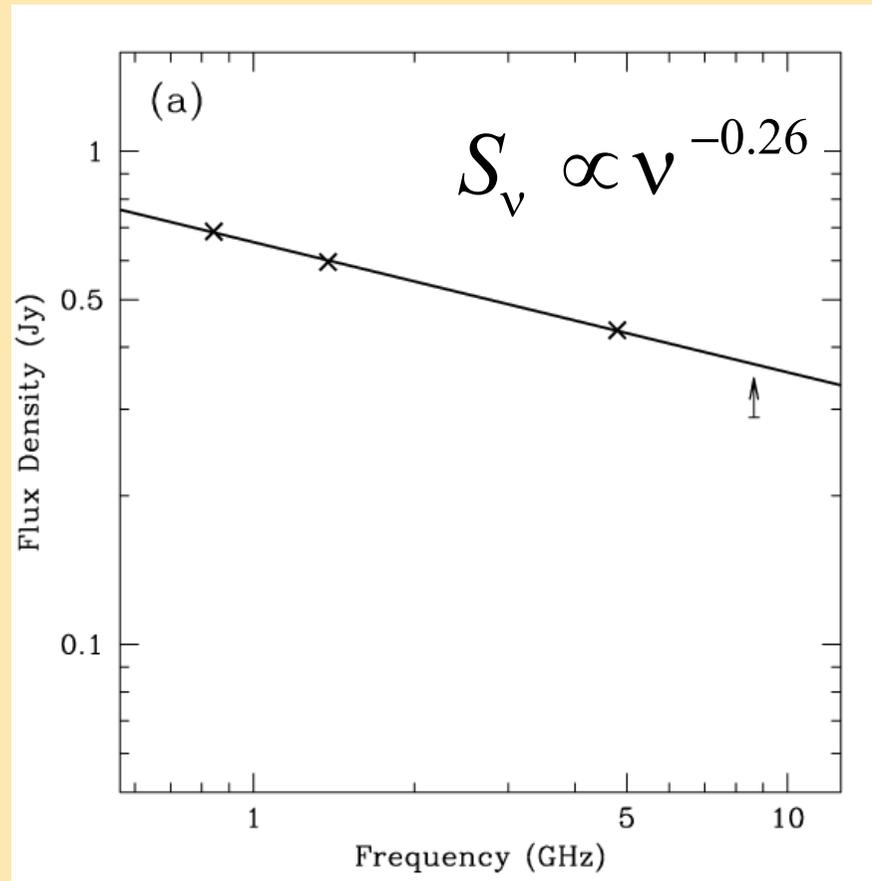
X-ray vs. radio



HEAT 26/3/2009 Chandra + ATCA

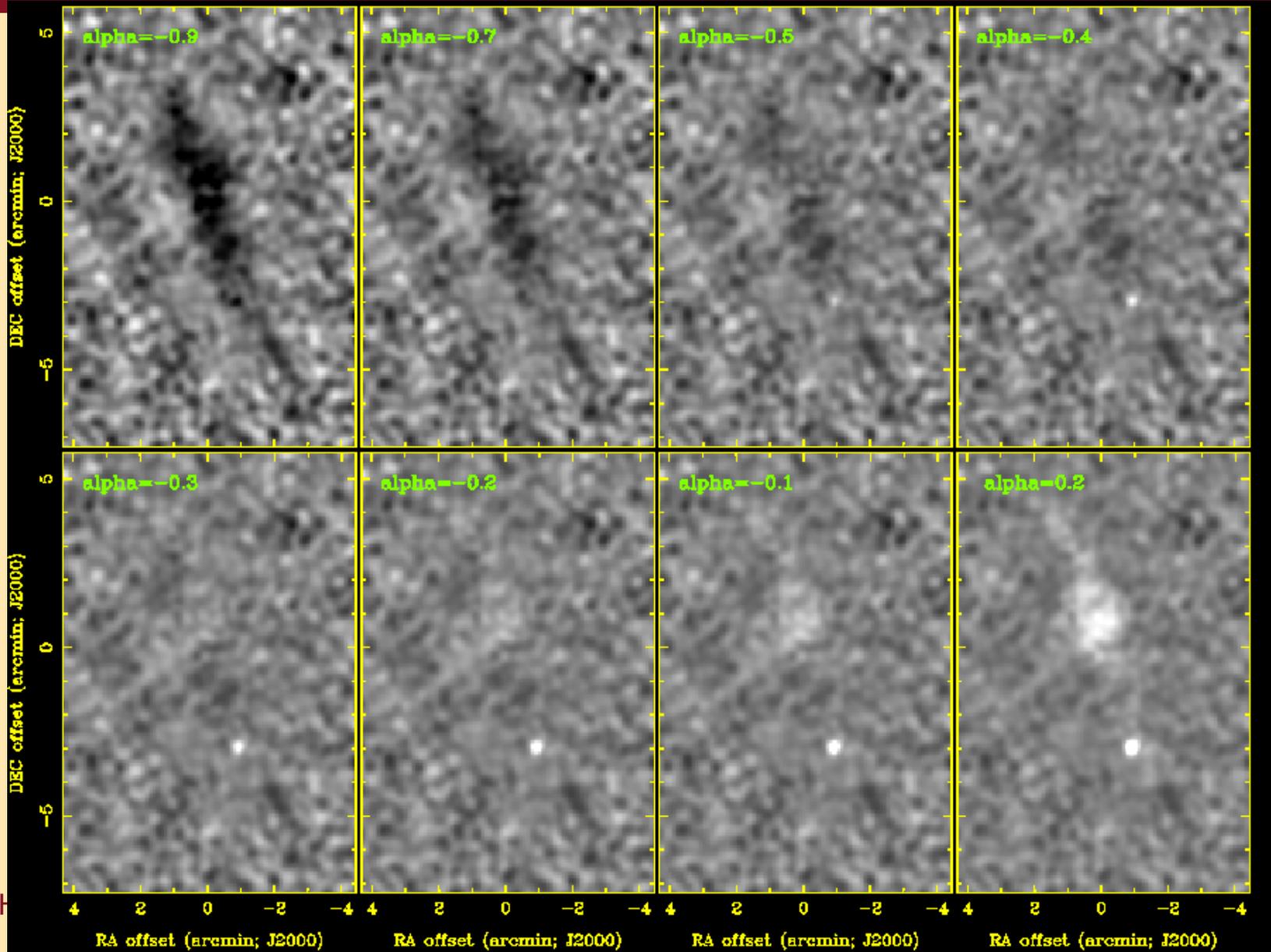


Spectral Index





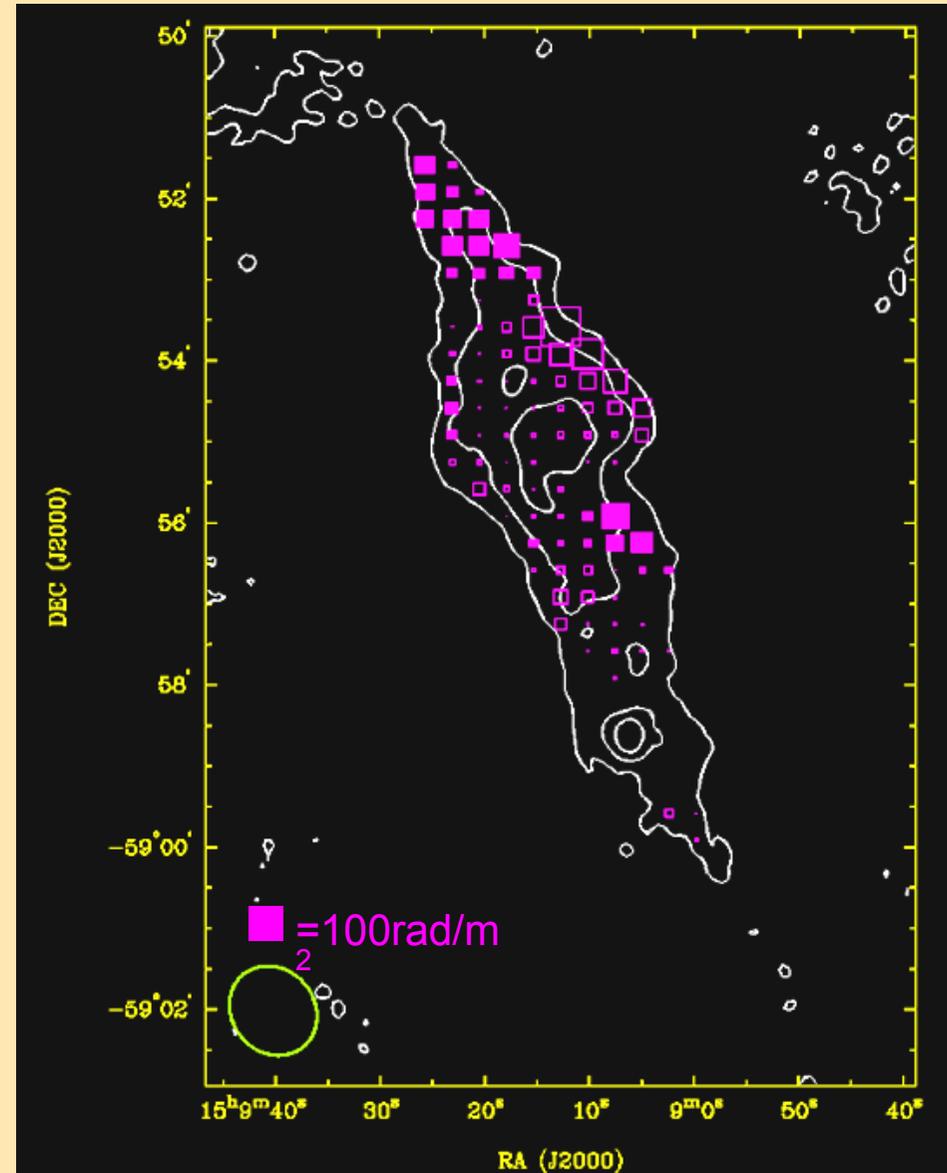
Tomography





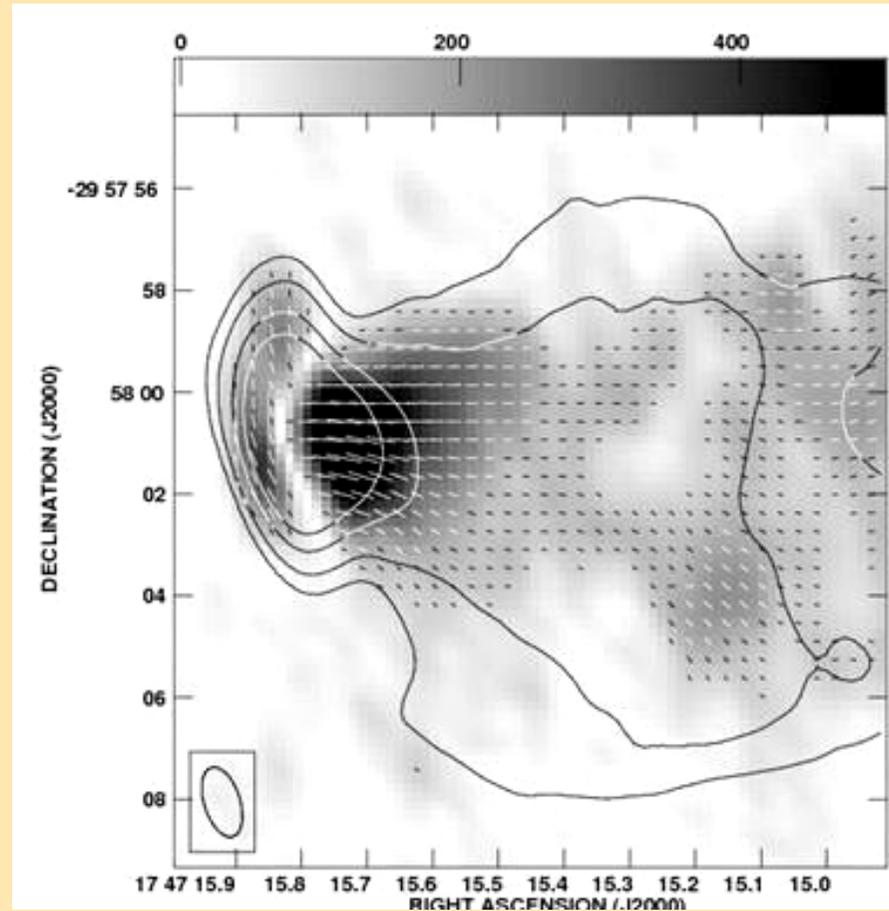
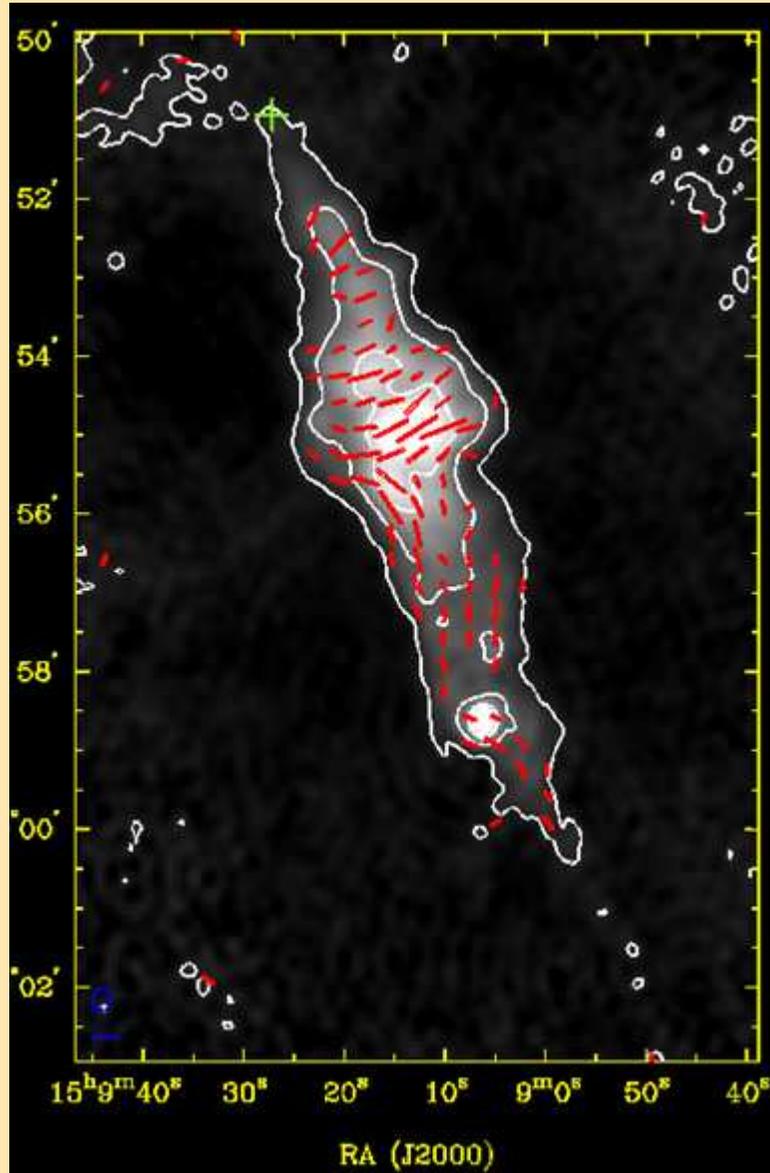
Rotation Measure

- 20cm SGPS data
- Faraday rotation mostly negligible at 3 & 6cm
 - consistent with a helical field





Compare to the Mouse



Yusef-Zadeh & Gaensler (2005)

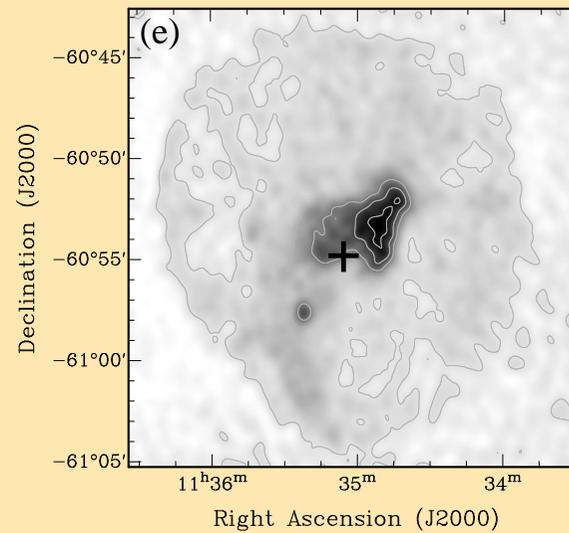
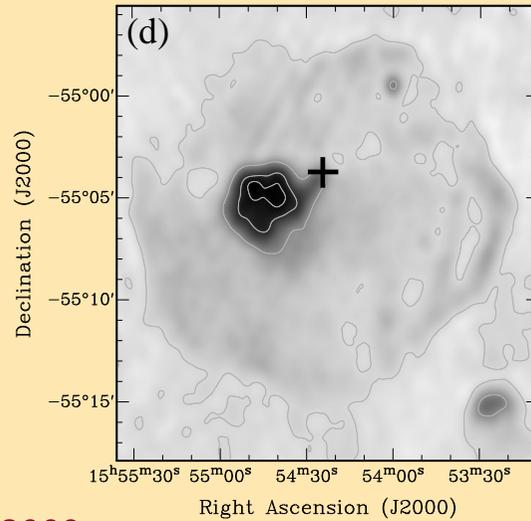
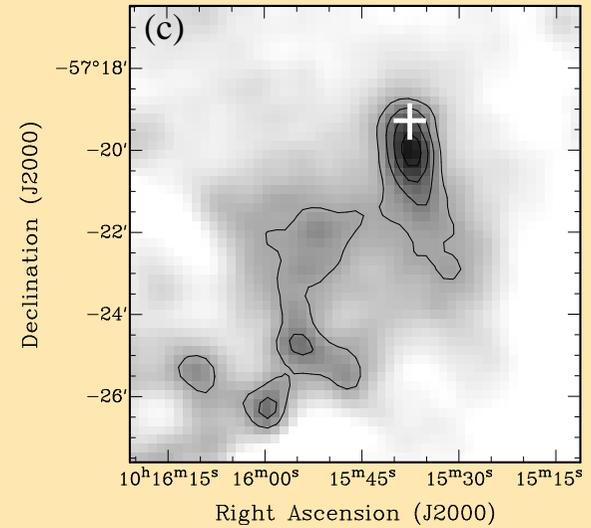
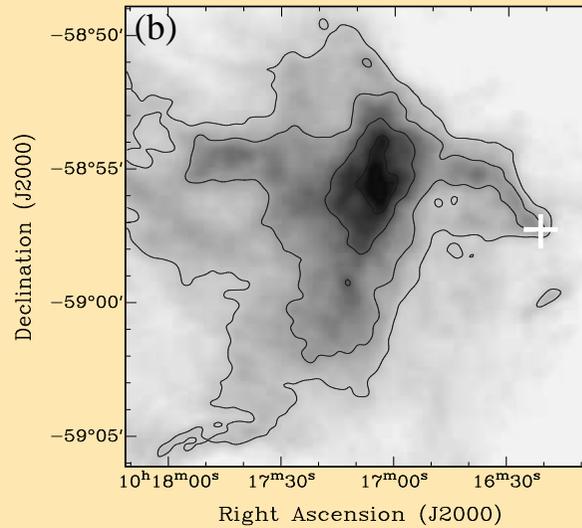
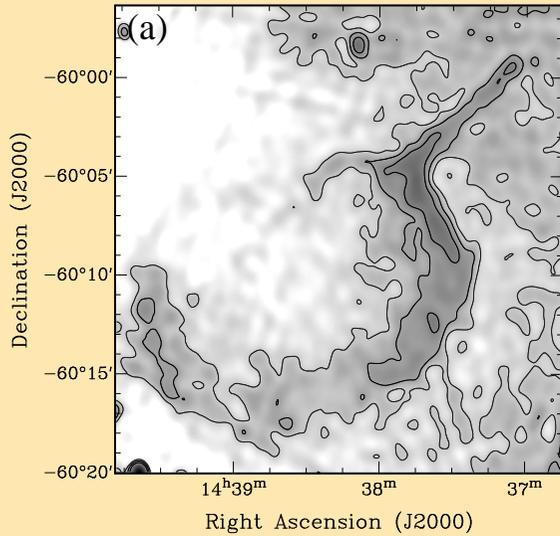


Compare to the Mouse

- Different Mach number?
 - $M \sim 30$ vs. $M \sim 60$ (Kargaltsev et al. 2008, Gaensler et al. 2004)
 - Direct proper motion measurement
- Different B-field?
- PSR spin and magnetic axes orientation?
 - $v_{\text{flow}} > 10,000 \text{ km/s}$ (Kargaltsev et al. 2008)
 - PSR polarization measurements



More Examples



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Summary

- Radio polarimetry provides a powerful probe of the physical conditions in a PWN
- MSC 319.9–0.7 as the radio PWN powered by PSR J1509–5850
- 2nd longest pulsar trail known in radio
- First evidence of a magnetotail
- Very different from the Mouse, more examples needed