The Radio Nebula produced by the 27 Dec. 2004 Giant Flare from SGR 1806-20

Joseph Gelfand (CfA)

Observers: C. Kouveliotou, B. Gaensler, G. Taylor, K. Newton-McGee, R. W. Hunstead, D. Campbell-Wilson, R. Fender, N. McClure-Griffiths, M.A. McLaughlin, M. A. Garrett, D.M. Palmer, N. Gehrels, P.M. Woods, A.J. van der Horst

Theorists: D. Eichler, Y. Lyubarsky, Y. Granot, E. Ramirez-Ruiz, R.A.M.J. Wijers

27 Dec. 2004 Giant Flare

- Third Giant Flare observed from a magnetar
- Bright in X-rays and Radio
  - Peak flux > 100 mJy at 1.4 GHz
- Triggered world-wide radio monitoring campaign
  - Over an order of magnitude in frequency coverage
  - Over 100 epochs so far

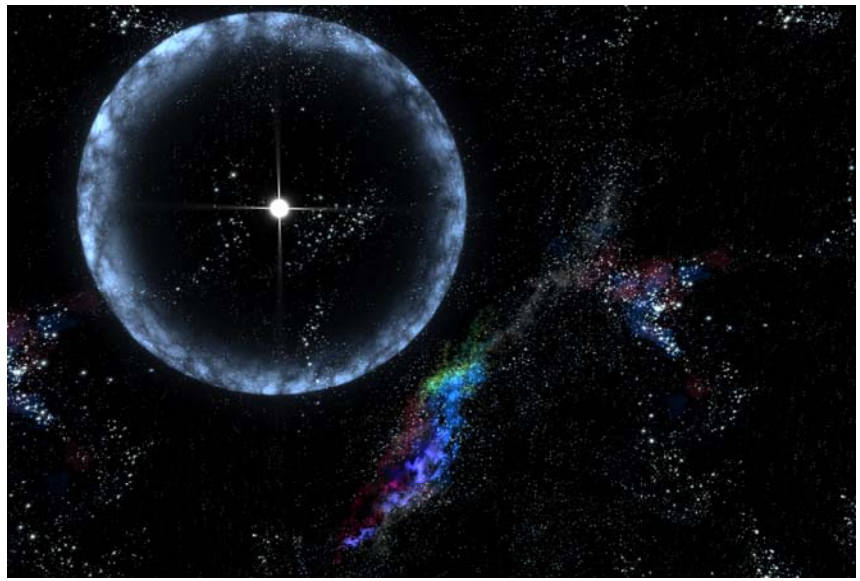
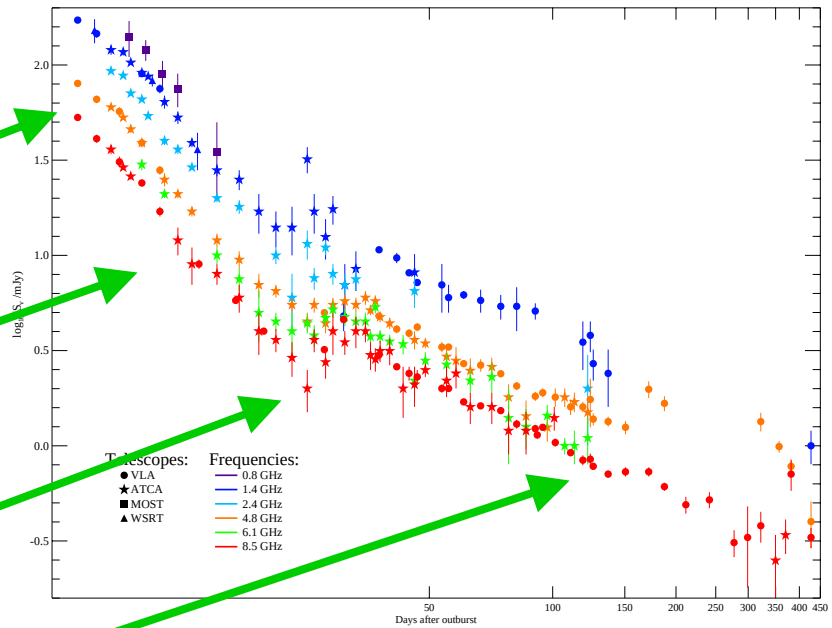


Image courtesy of NASA

Multi-Frequency Light Curve

- Similar behavior seen at all radio wavelengths:
  - Initially, flux decreases as $t^{-1.5}$ to t^{-2}
  - Between 9 and 25 days, flux decreases as t^{-3}
  - Source gets brighter, peaking at t~30 days
  - Afterwards, flux decreases as t^{-1}

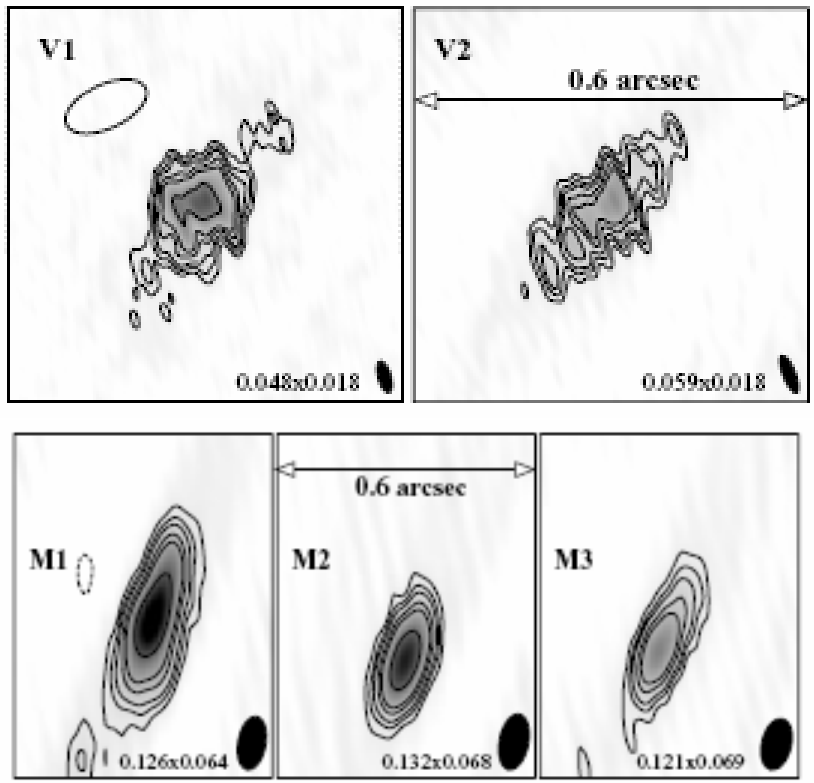


Gaensler et al. 2005, Gelfand et al. 2005

Radio Morphology

- Axis ratio of 2:1
- Position Angle -40° (North through East)
- Axis ratio, position angle constant for first ~30 days.

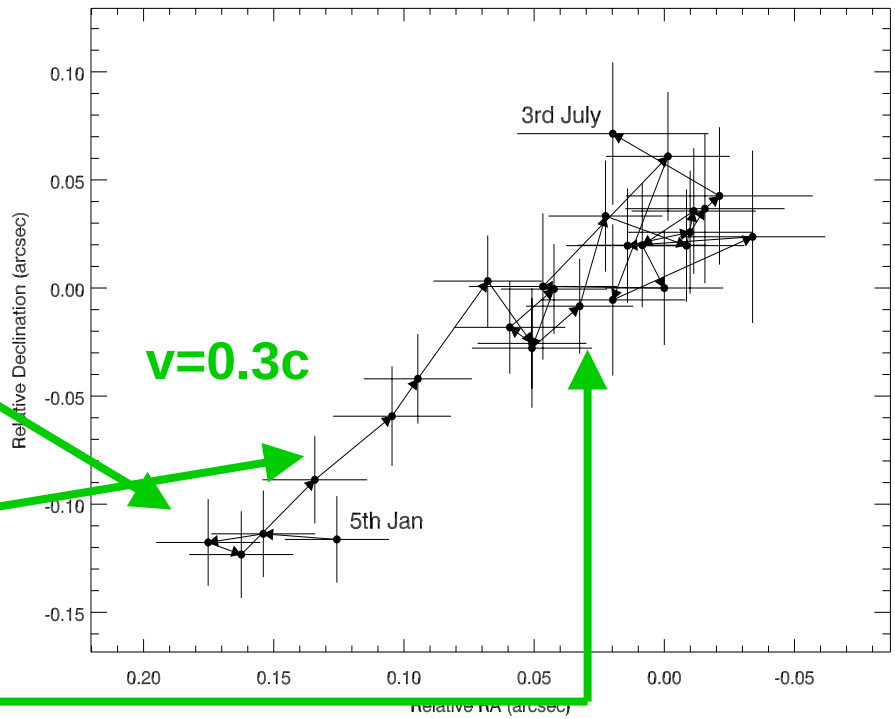
(Taylor et al. 2005, Fender et al. 2006)



Fender et al. 2006

Radio Position

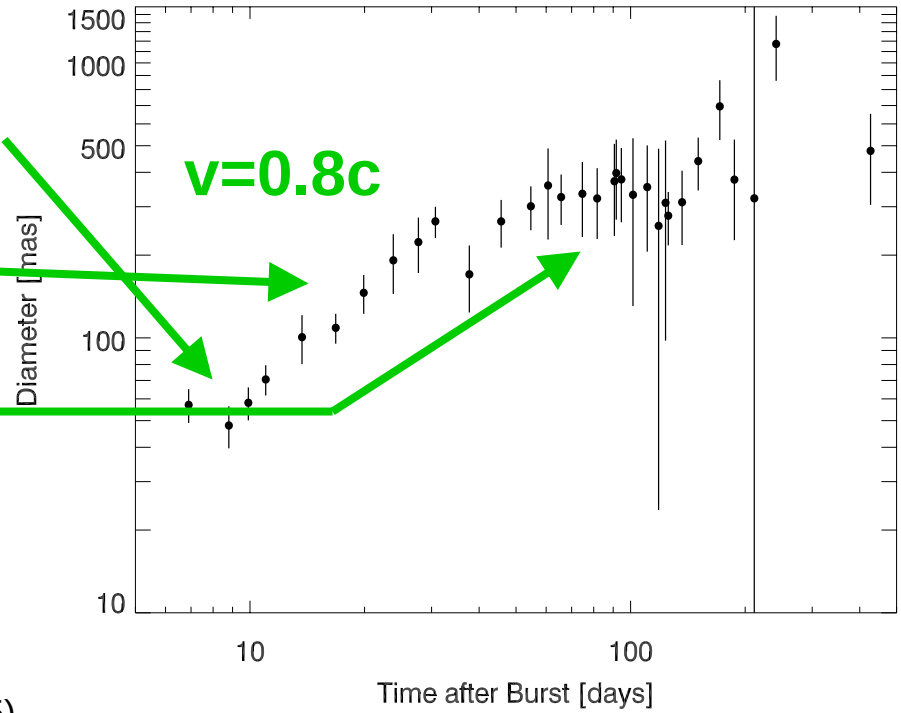
- Proper motion detected along elongation axis
- Three phases:
  - Initially little movement
  - Between days ~9 and ~30, steady change.
  - After Day ~30, no/little movement



(Taylor et al. 2005)

Size of the Radio Source

- Significant changes observed:
  - Before day 9, little growth
  - Between days 9 and 30, constant expansion
  - After day 30, little growth
- Size and proper motion results imply one-sided expansion.

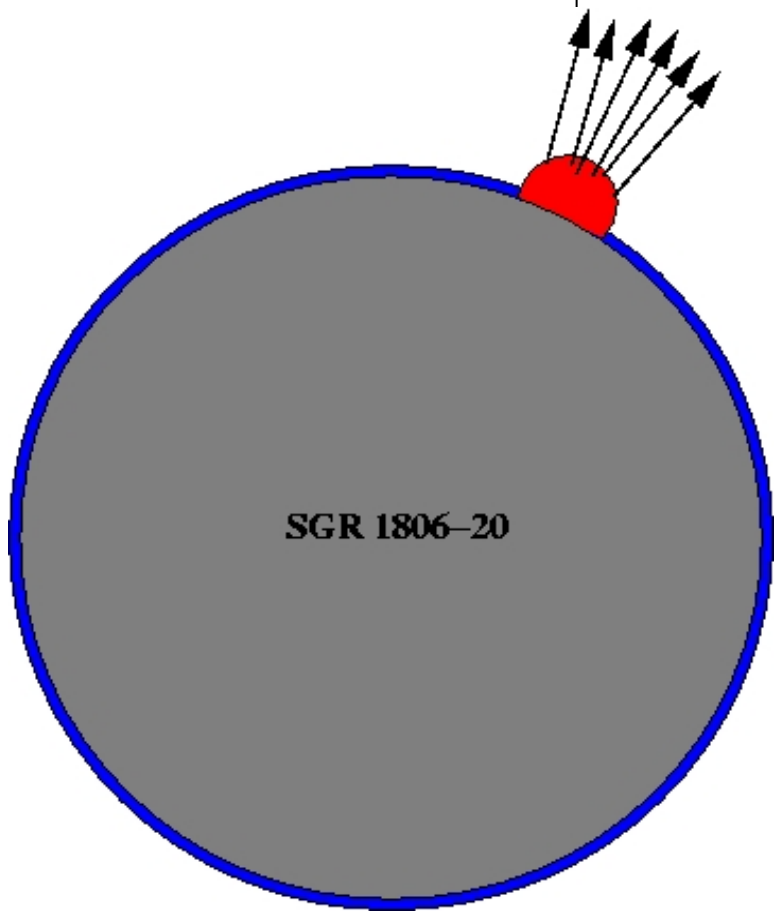


(Taylor et al. 2005)

Ejecta from the Neutron Star Model for the Radio Emission

- **Giant Flare ejected material from neutron star.**
- Collision with existing shell in the ISM.
- Shell of ejecta expands into surrounding ISM.
- Ejecta decelerated by swept-up ISM.

(Gelfand et al. 2005, Granot et al. 2006)



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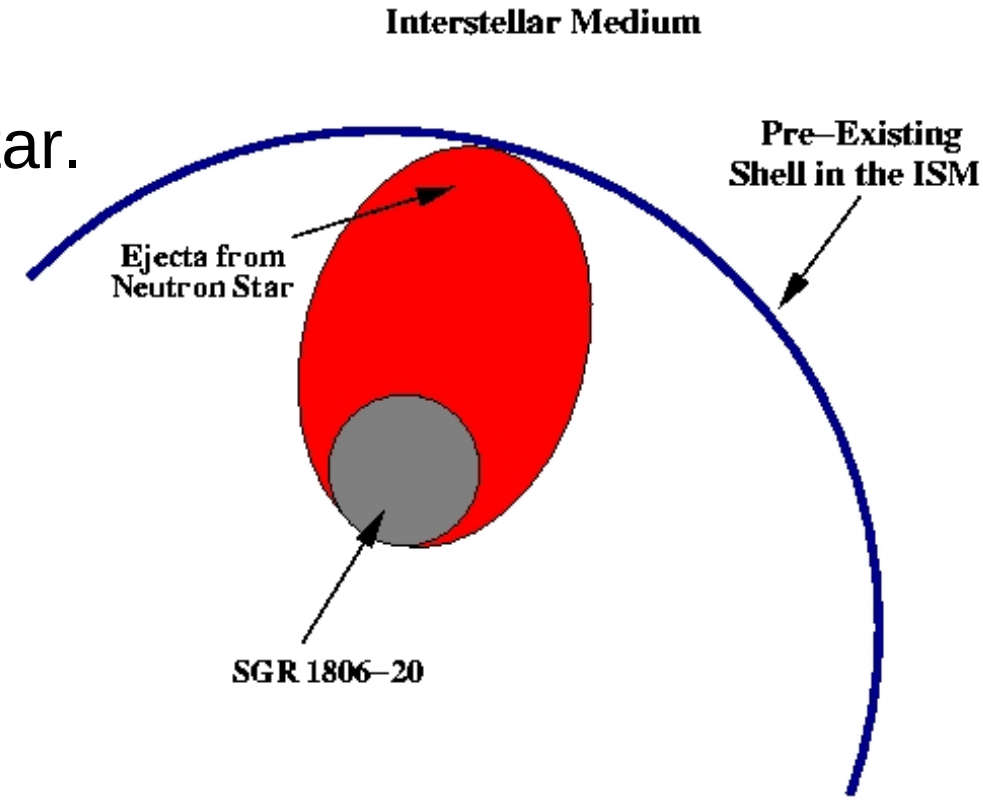

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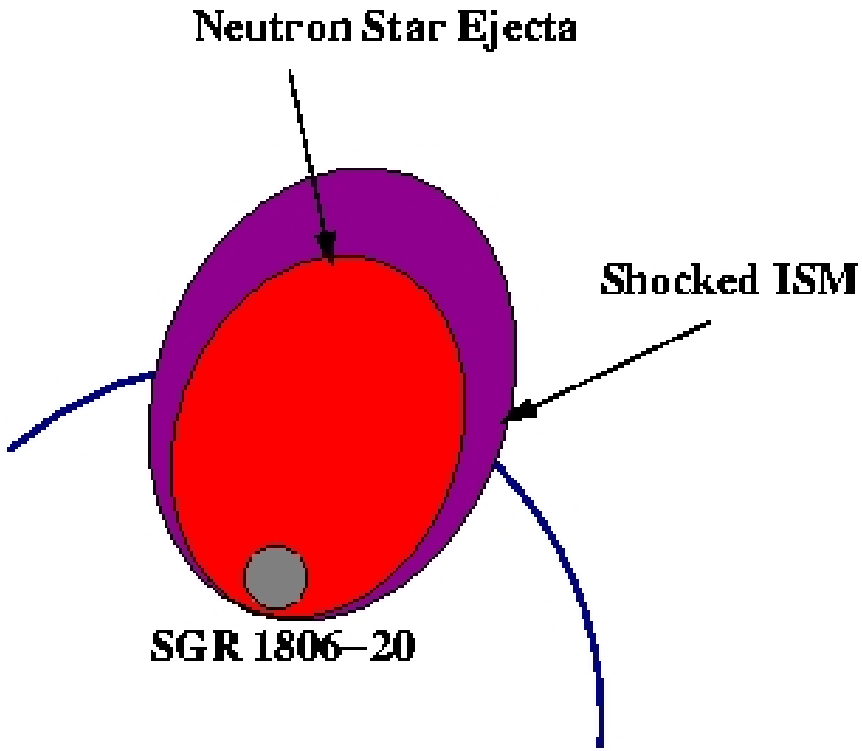

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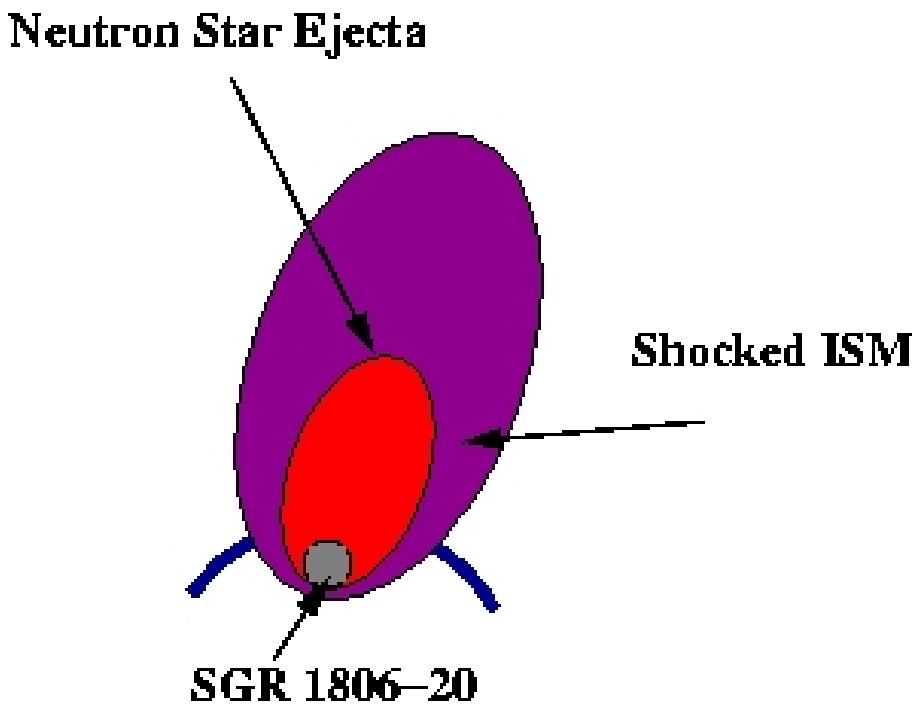


(Gelfand et al. 2005, Granot et al. 2006)

Ejecta from the Neutron Star Model for the Radio Emission

- Explains observed elongation, proper motion, growth, light curve.
- Reproduces “bump” in the light curve.
- Implies $M_{ej}>10^{24.5}$ g and $E_{ej}>10^{44.5}$ ergs

(Gelfand et al. 2005)

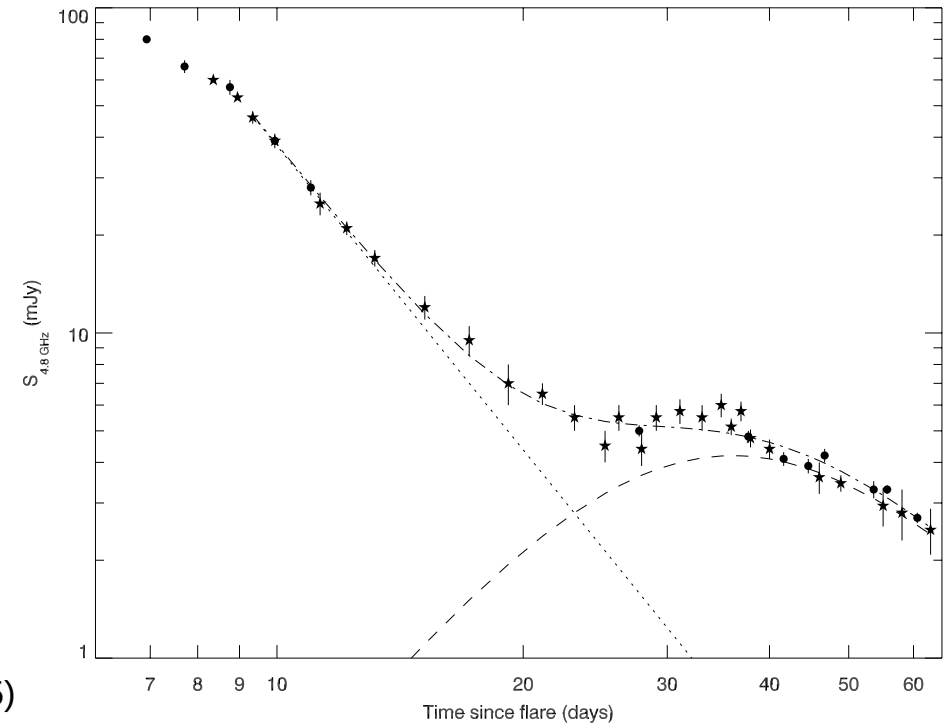
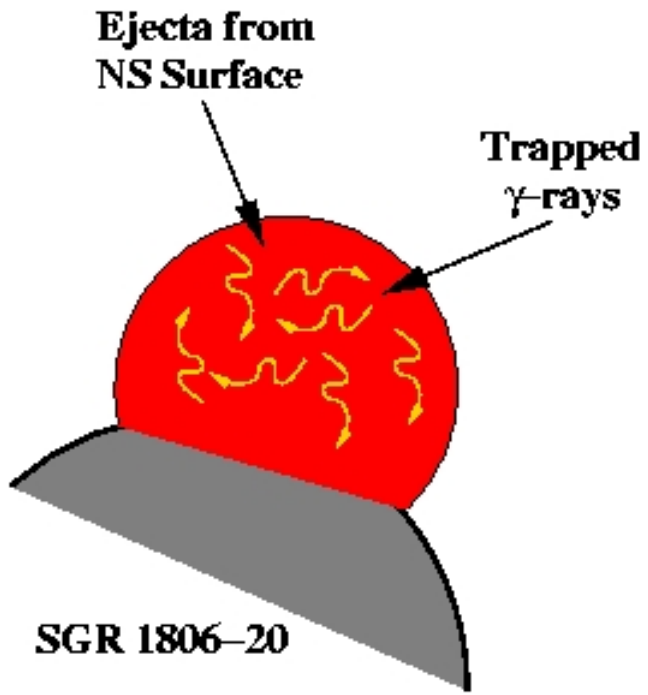


Figure 1 from Gelfand et al. 2005

Ejecta from the Neutron Star Model for the Radio Emission

- Compactness Problem
  - **Mass outflow opaque to γ-rays at early times.**
- Solutions:
  - Mass and γ-rays originate from different regions of the neutron star. (Gelfand et al. 2005, Granot et al. 2006)
  - Outflow not dominated by baryons.



(Lyutikov 2006)

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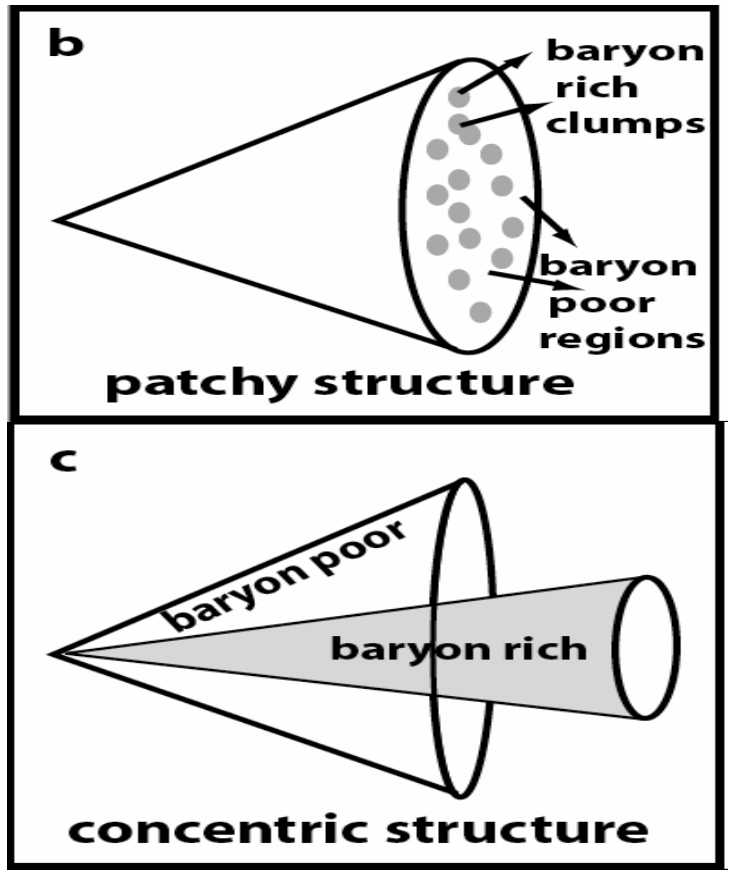

Figures 1b and 1c from Granot et al. 2006

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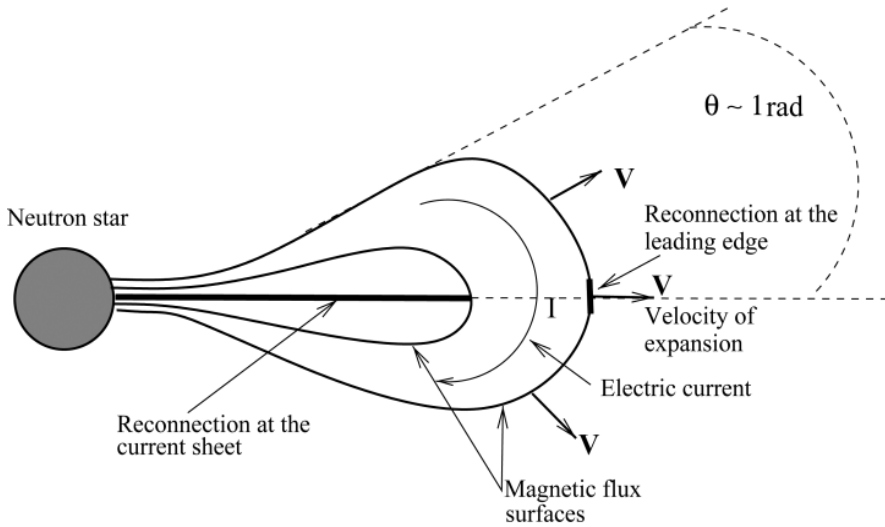

Figure 1 from Lyutikov 2006

VLA + Pie Town Observation

- 8 hour observation on 4 February 2006.
- Resolved radio emission:
  - Confirmed proper motion
  - Confirmed one-sided morphology
  - Compact and Diffuse emission?

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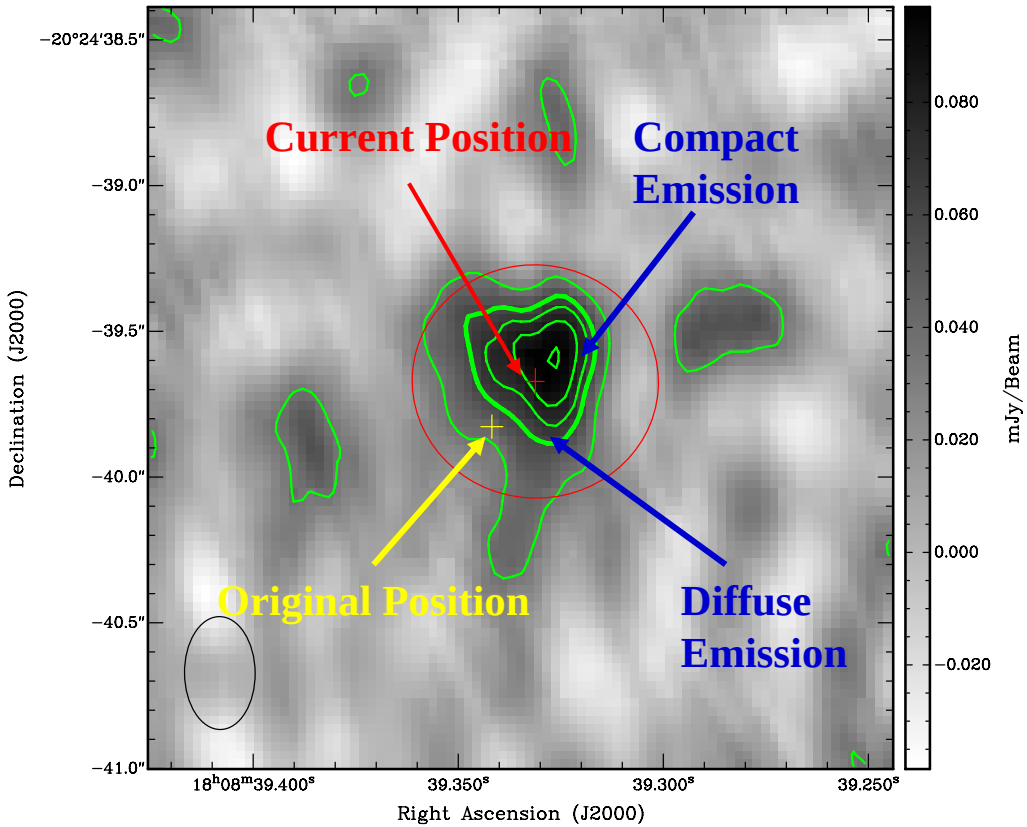
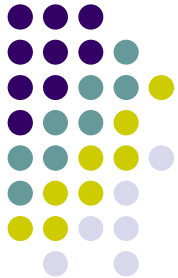


Conclusions and Future Work

- 2004 Dec. 27th Giant Flare created a one-sided, expanding outflow
- If baryon dominated, **$M_{ej}>10^{24.5}$ g**
- On-going theoretical modeling of ejecta model
- Further observations scheduled

New results (hopefully) soon!

Published Papers on the Radio Emission



- Gaensler et al. 2005, *Nature*, 434, 1104
  - Describes initial radio observations.
- Cameron et al. 2005, *Nature*, 434, 1112
  - Describes initial radio observations, argues for a smaller distance, d~7 – 10 kpc.
- Dai et al. 2005, *ApJL*, 629, L81
  - Relativistic narrow + wide jet model for the radio emission
- McClure-Griffiths & Gaensler 2005, *ApJL*, 630,161
  - Refutes arguments of Cameron et al. 2005 for a smaller distance.
- Wang et al. 2005, *ApJL*, 623, L29
  - Relativistic Fireball Model for the radio emission
- Gelfand et al. 2005, *ApJL*, 634, L89
  - Discusses the observed re-brightening and presents the Neutron Star ejecta model.
- Taylor et al. 2005, *ApJL*, 634, L93
  - Presents initial proper motion, expansion, and polarization results.
- Granot et al. 2006, *ApJL*, 638, 391
  - More detailed explanation of the Neutron Star ejecta model.
- Fender et al. 2006, *MNRAS*, 367, L6
  - Early time VLBA and MERLIN observations.
- Lyutikov 2006, *MNRAS*, 367, L1594
  - Spheromac/magnetic flux rope theory for the radio emission.