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

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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 \( t \sim 30 \) 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)
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

\( v = 0.3c \)

(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.

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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 $M_{ej} > 10^{24.5} \text{ g}$ and $E_{ej} > 10^{44.5} \text{ ergs}$

(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 $\gamma$-rays at early times.

- Solutions:
  - Mass and $\gamma$-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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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

  - Describes initial radio observations.
  - Describes initial radio observations, argues for a smaller distance, d~7 – 10 kpc.
  - Relativistic narrow + wide jet model for the radio emission
  - Refutes arguments of Cameron et al. 2005 for a smaller distance.
  - Relativistic Fireball Model for the radio emission
  - Discusses the observed re-brightening and presents the Neutron Star ejecta model.
  - Presents initial proper motion, expansion, and polarization results.
  - More detailed explanation of the Neutron Star ejecta model.
  - Early time VLBA and MERLIN observations.
  - Spheromac/magnetic flux rope theory for the radio emission.