A Radio Search for Hyper-Energetic SNe and Sub-Energetic GRBs

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Motivated by the peculiar event of SN1998bw/GRB 980425

Radio emission requires

• copious relativistic ejecta \((10^{50}\ \text{erg})\) &

• energy injection

\[\text{central engine}\]

\((\text{Kulkarni et al. 1998; Li & Chevalier 1999})\)
SN1998bw – an engine-driven SN

What fraction of local Ibc’s are 98bw-like?

Case 1: off-axis 0.5%
Gradual energy increase

Case 2: quasi-spherical relativistic ejecta
Unknown %
Why Radio Observations of Ibc SNe?

i. Radio emission traces the *relativistic ejecta*, which can be used as a proxy for a *central engine*.

ii. Radio is less sensitive to *geometrical effects*.

We observe *every* Ibc within 100 Mpc with the VLA/ATCA.
Radio Light-curves of Type Ibc SNe

Ibc Survey:
7 detections
55 upper limits
None like GRBs

< 1.6% GRB/SN

Equipartition Energy and Velocity

Optically Fast? (v \sim 20,000 \text{ km/s})

Broad optical lines do NOT imply \textit{relativistic} or \textit{energetic} ejecta.
The Next Chapter: Detailed Studies

I. Late-Time Observations and Off-axis GRB Jets

Local Ibc SNe associated with re-brightening of the ejecta –

*Observed Signature* = flu

**SN1998bw** – NO re-brightening after 6 yrs: NO jet or very low density CSM

**SN2001em** – optical spectra imply CSM hydrogen interaction

The Next Chapter: Detailed Studies

II. Energy Injection

Some local Ibc SNe ex
Caused by a central en

*Same Signature* as off

**SN 2004C**

optical spectra show *no sign of CSM interaction*
The Next Chapter: Detailed Studies

III. Palomar SN & SN Host Galaxy Program
The Next Chapter: Detailed Studies
IV. Gamma-ray Triggered Supernovae

VLA Observations of GRB 031203:
No collimation of ejecta
Energy $\sim 2 \times 10^{49}$ erg
CSM density $\sim 1 \text{ cm}^{-3}$
NR transition at $t \sim 23$ days
No rebrightening $t < 0.5$ yr

Soderberg et al., Nature (accepted)
Putting it all Together: Radio Observations of Cosmic Explosions
Summary & Conclusions

- Caltech/NRAO VLA/ATCA SN survey is monitoring radio emission from Ibc SNe through the *first systematic survey*.

- We constrain the fraction of local Ibc SN with *relativistic ejecta* to $< 1.6 \%$, the fraction with *off-axis relativistic jets* to $< 6 \%$.

- Broad optical lines are **NOT** a proxy for bright radio emission OR large ejecta energies.

- “Unusual” radio SN behavior: *Energy Injection*?

- Synergistic Palomar 60-inch optical program to study SN Ibc light-curves and host galaxy properties. *Full catalog will be published in late 2005.*