Gamma-Ray Burst Radio View From All Angles

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7 Years of MAXI Workshop

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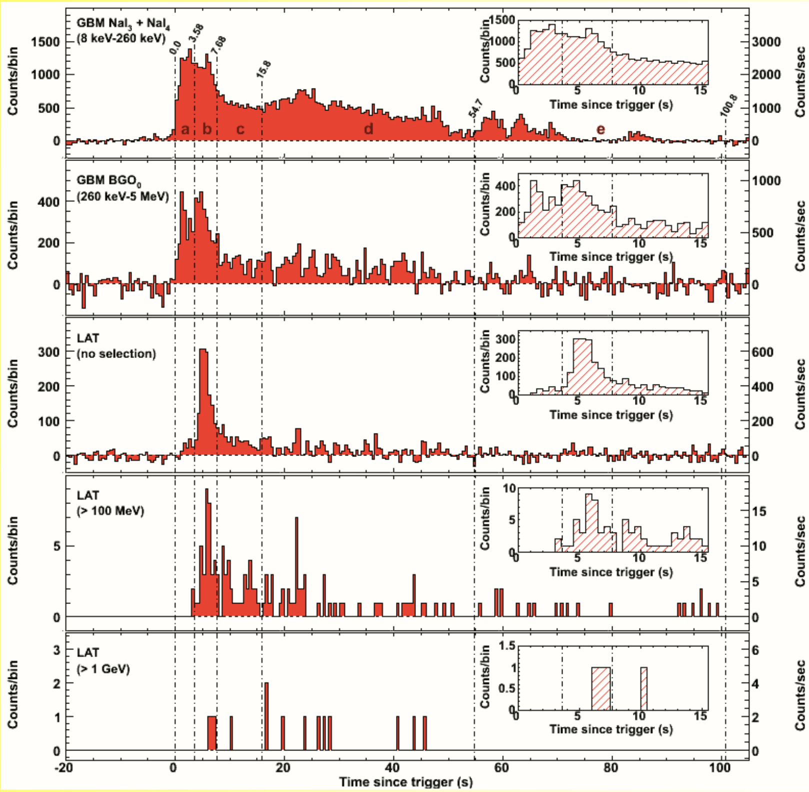
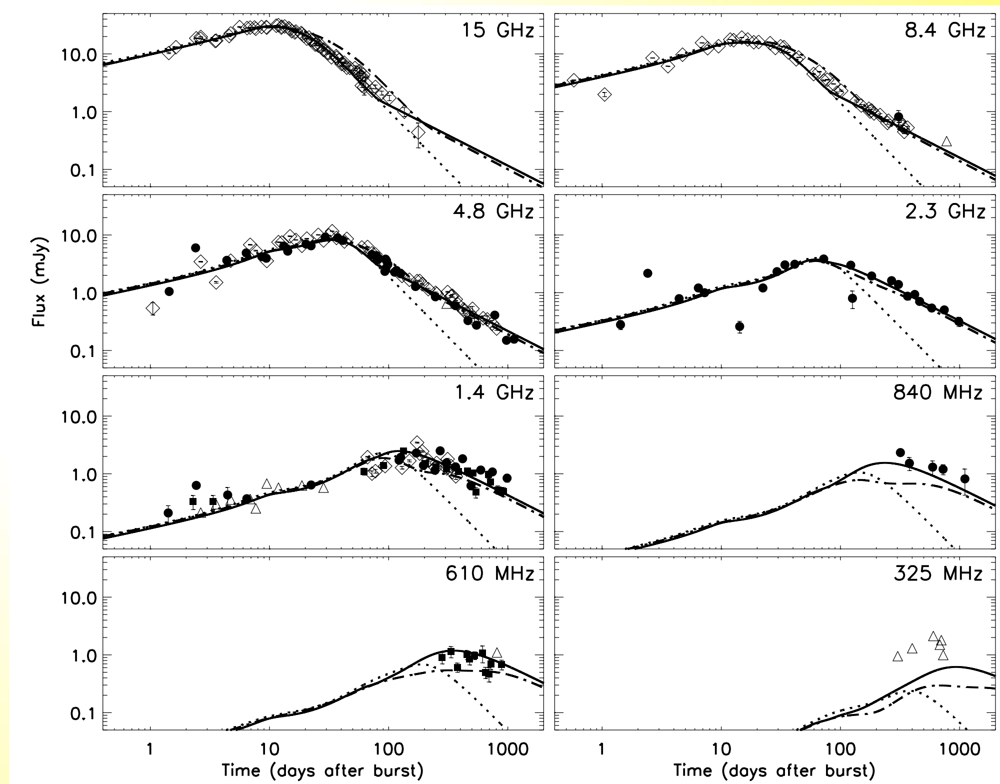
Multi-Wavelength & Multi-Timescale

GRB 080916C (Abdo et al. 2009)



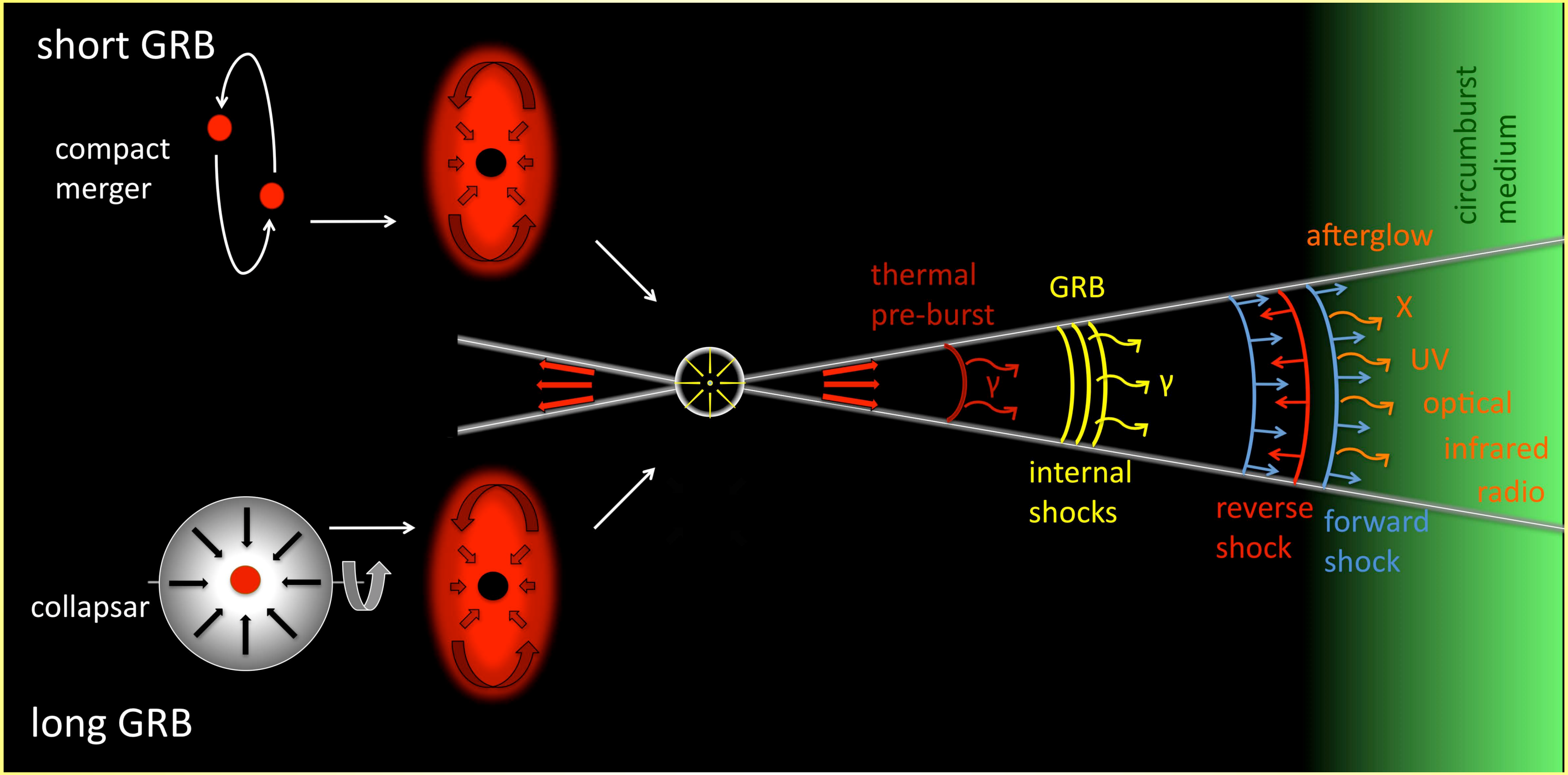
← Seconds – Years

GeV – GHz →



GRB 030329 (van der Horst et al. 2008)

Relativistic Blast Wave Model

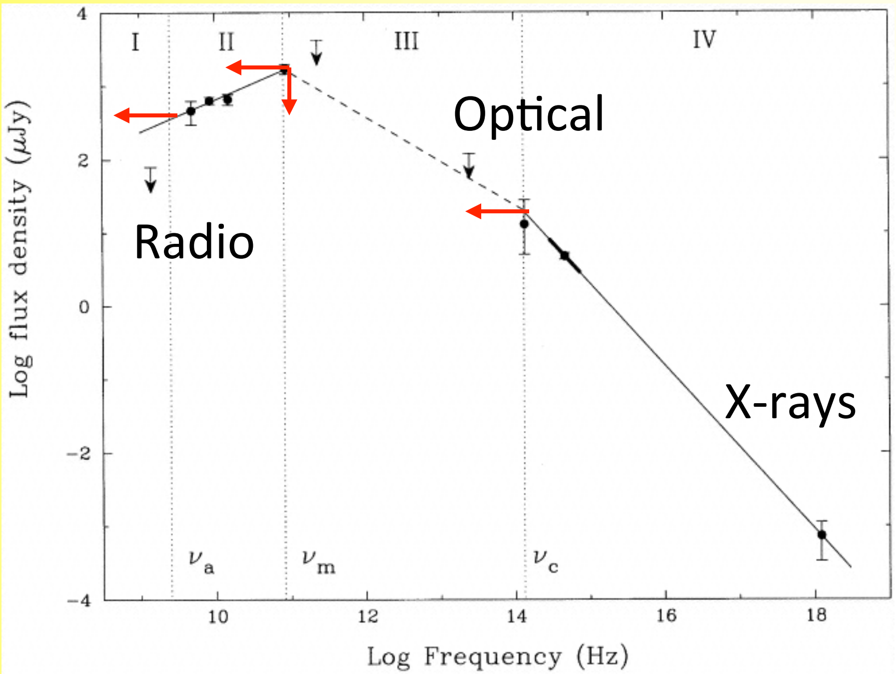


Gomboc 2012

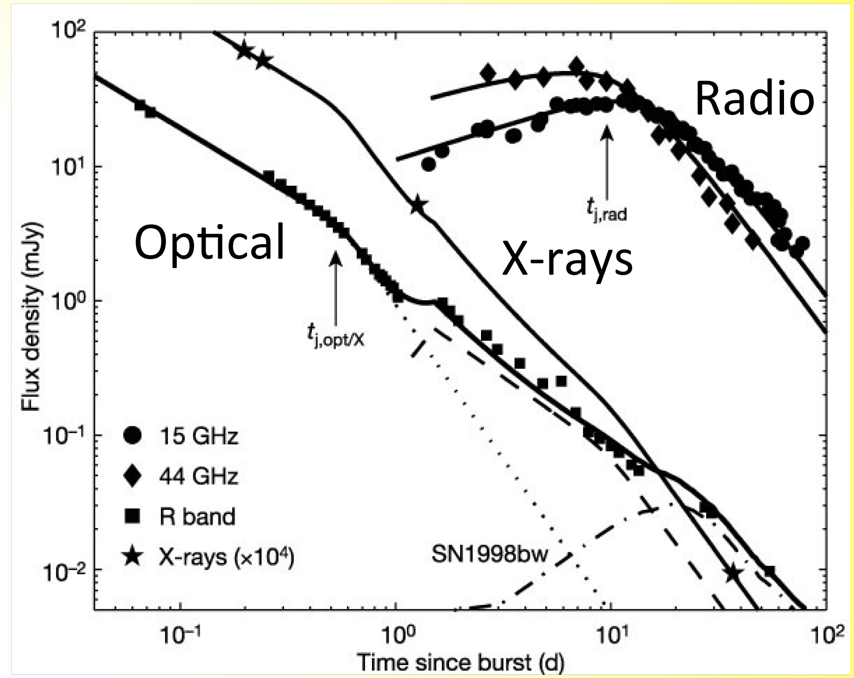
- Collimated relativistic outflow → jet opening angle: θ_0
- Afterglow synchrotron emission → relativistic beaming: $\theta_{rel} = 1/\Gamma$
- Initially $\theta_{rel} << \theta_0$, but blast wave decelerating

Modeling Spectra & Light Curves

Evolving spectrum → Light curves



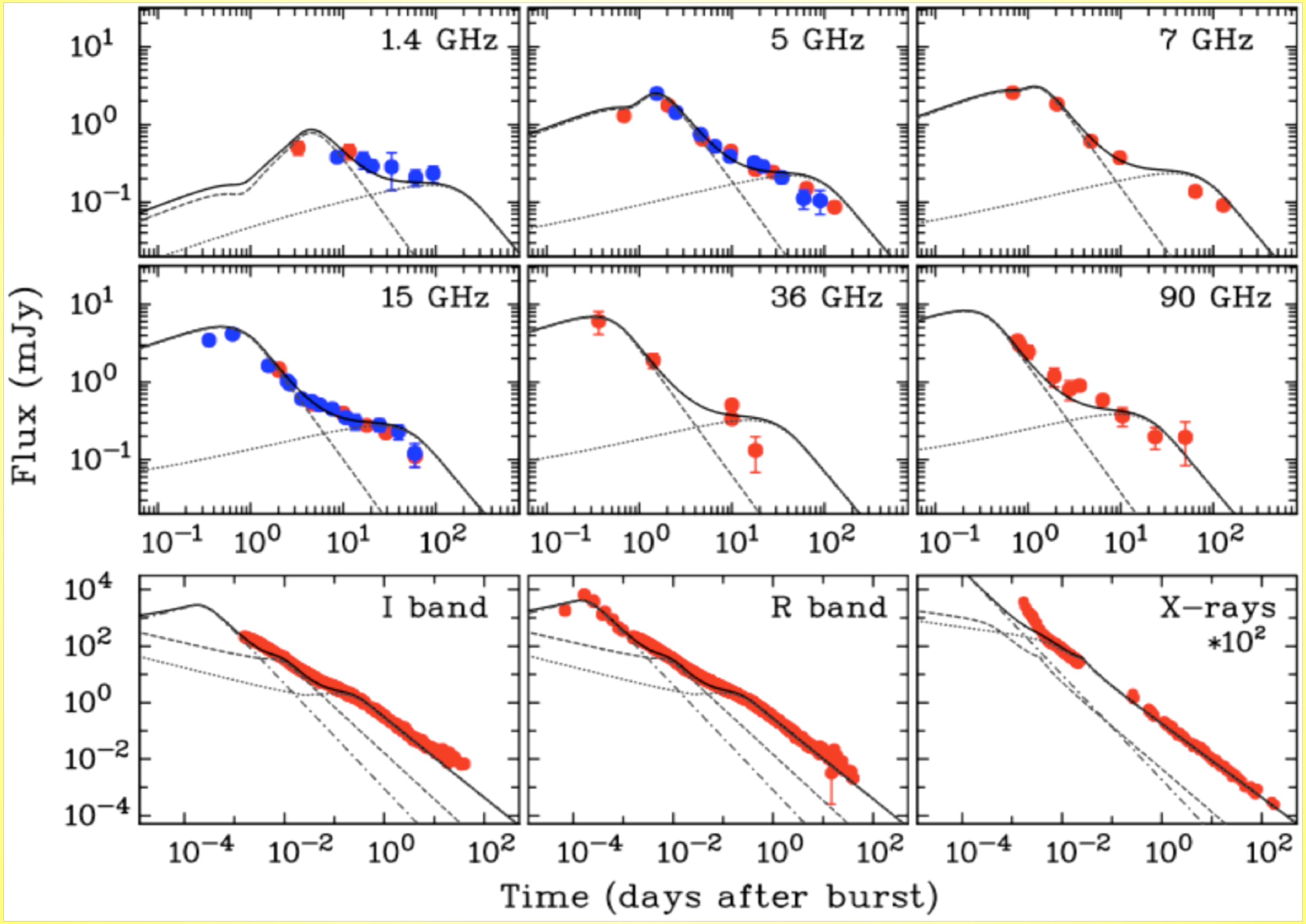
GRB 970508 (Wijers & Galama 1999)



GRB 030329 (Berger et al. 2003)

- Explosion parameters: blast wave energy, density and structure of ambient medium, jet opening angle
- Radiation parameters: electron energy distribution, energy in electrons and magnetic field

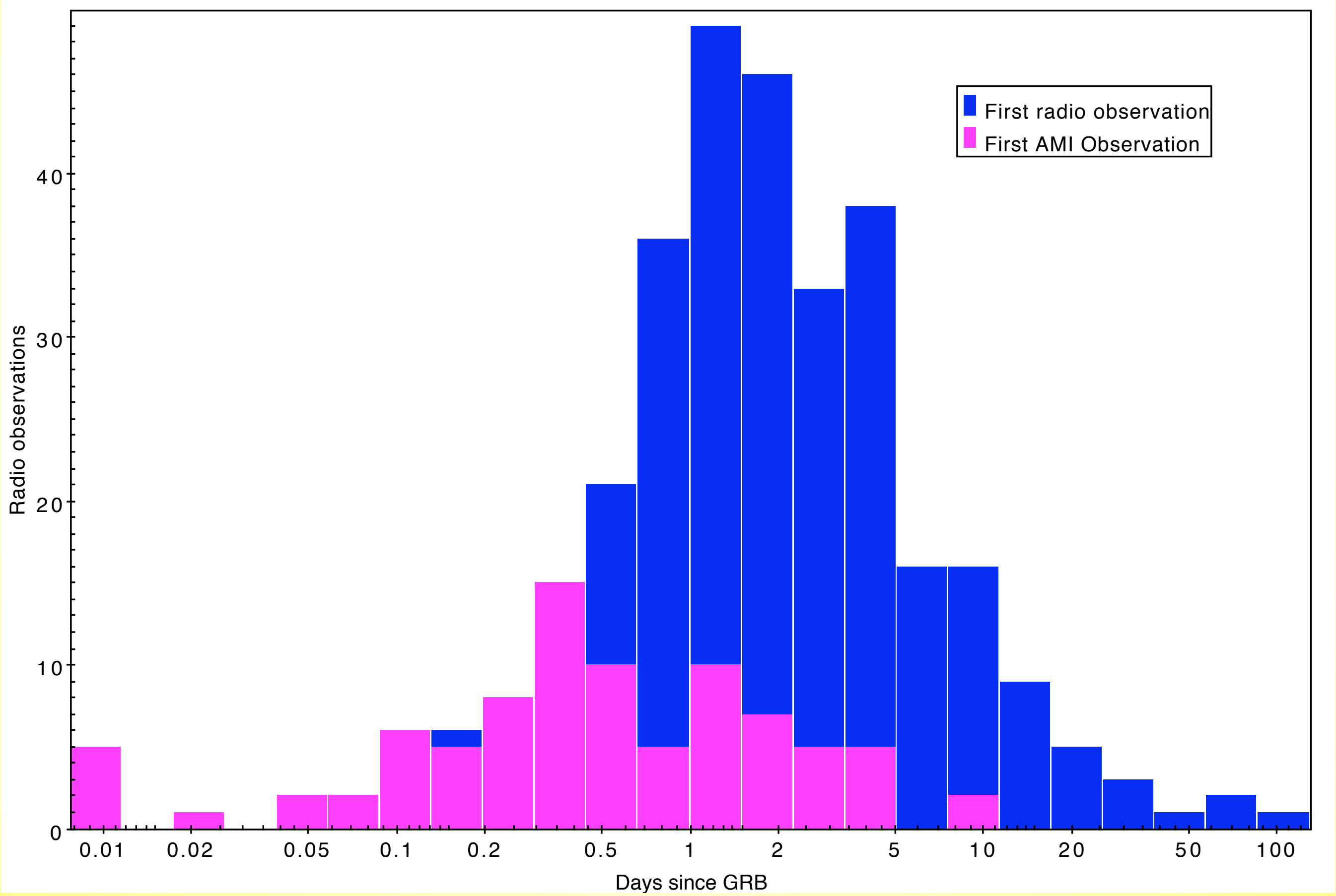
GRB 130427A: Early GRB Observations



Anderson et al. 2014; van der Horst et al. 2014; Perley et al. 2014; Laskar et al. 2013

Fast Radio Follow-Up

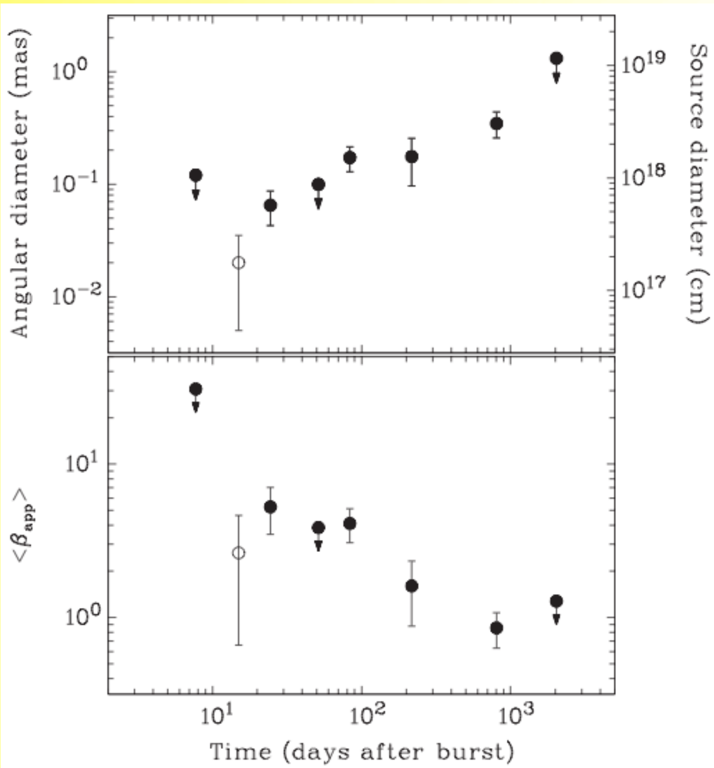
- AMI Large Array at 15 GHz → first responses: 4-5 min.
- System developed for other (new) radio observatories



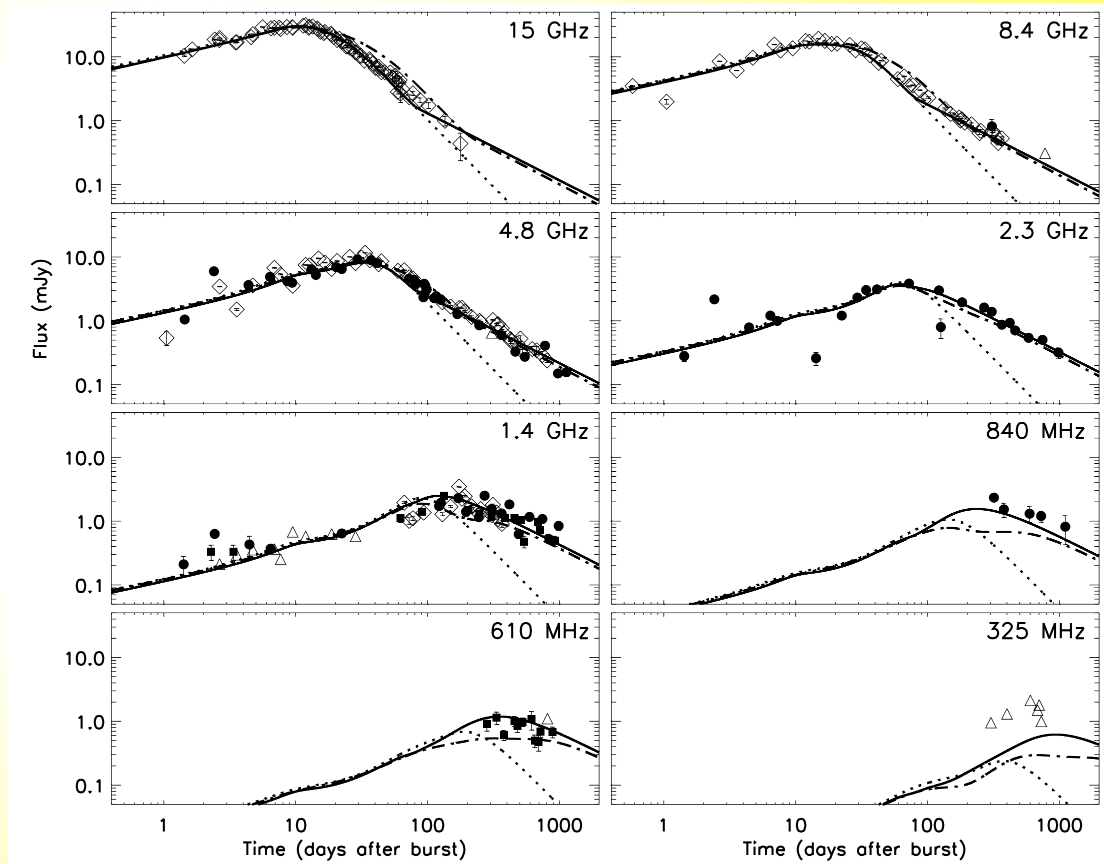
Chandra & Frail 2012; Staley et al. 2013; Anderson et al. 2016

GRB 030329: Long Radio Follow-Up

- Blast wave evolution: from relativistic to non-relativistic
- Sideways spreading → (quasi-)spherical at late(?) times



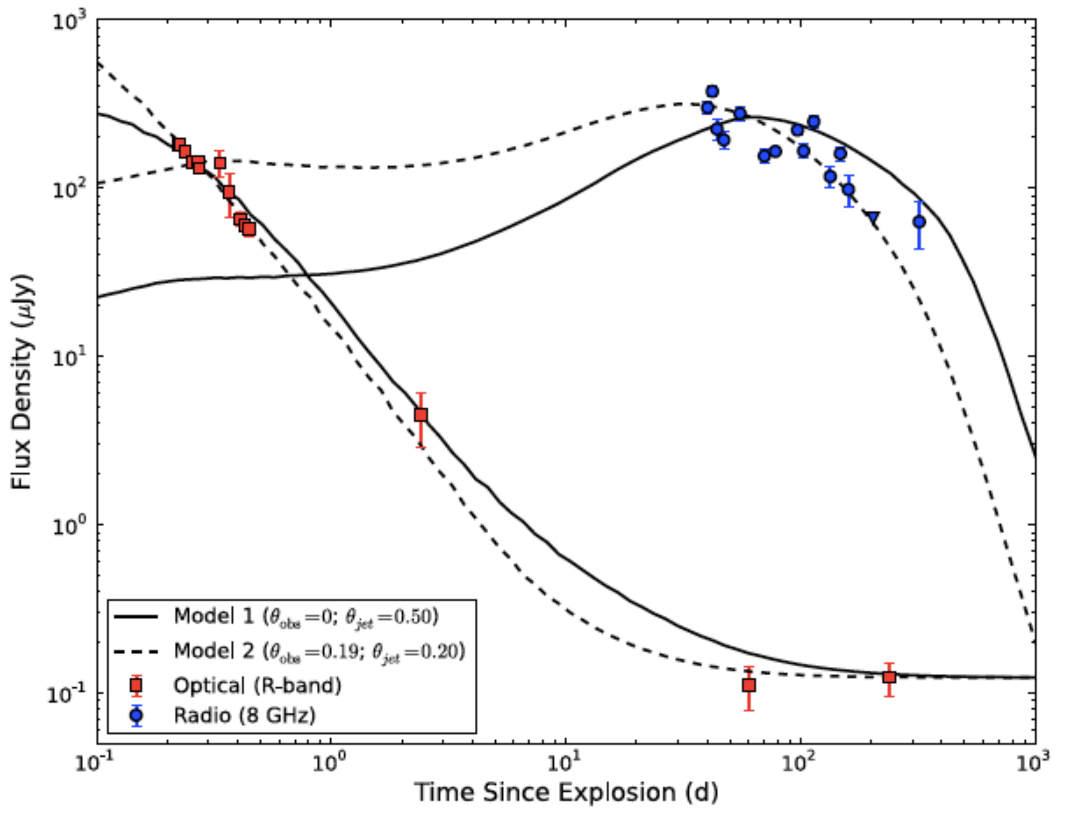
Taylor et al. 2004, 2005;
Pihlstrom et al. 2007;
Granot & van der Horst 2014



Frail et al. 2005; van der Horst et al. 2005, 2008

Orphan Afterglows

- Types of orphan afterglows:
  - On-axis jet but lack of high-energy observations
  - On-axis jet but suppressed high-energy emission
  - Off-axis jet → 'classical' orphan afterglow

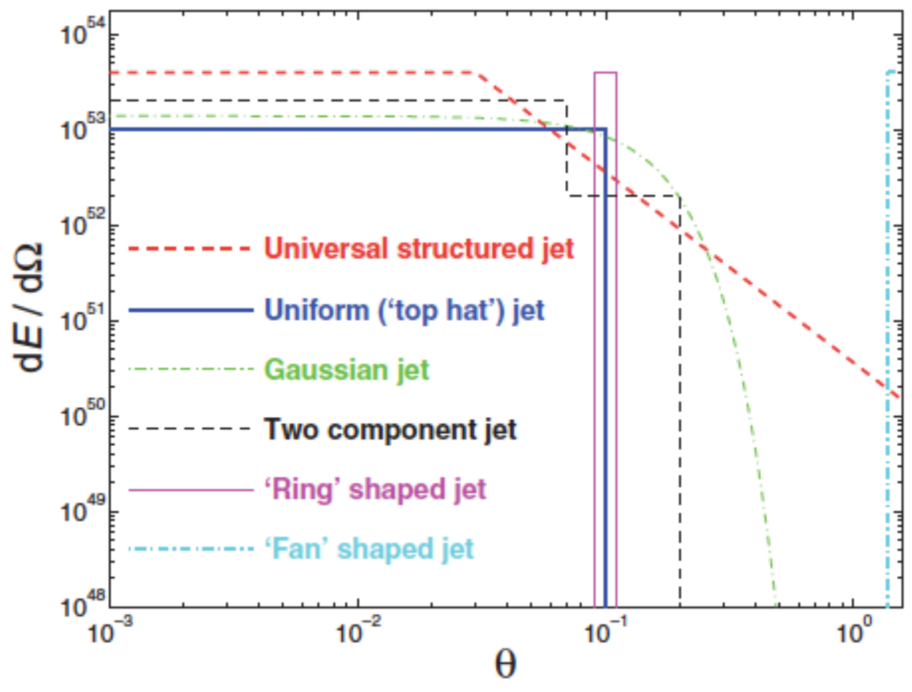


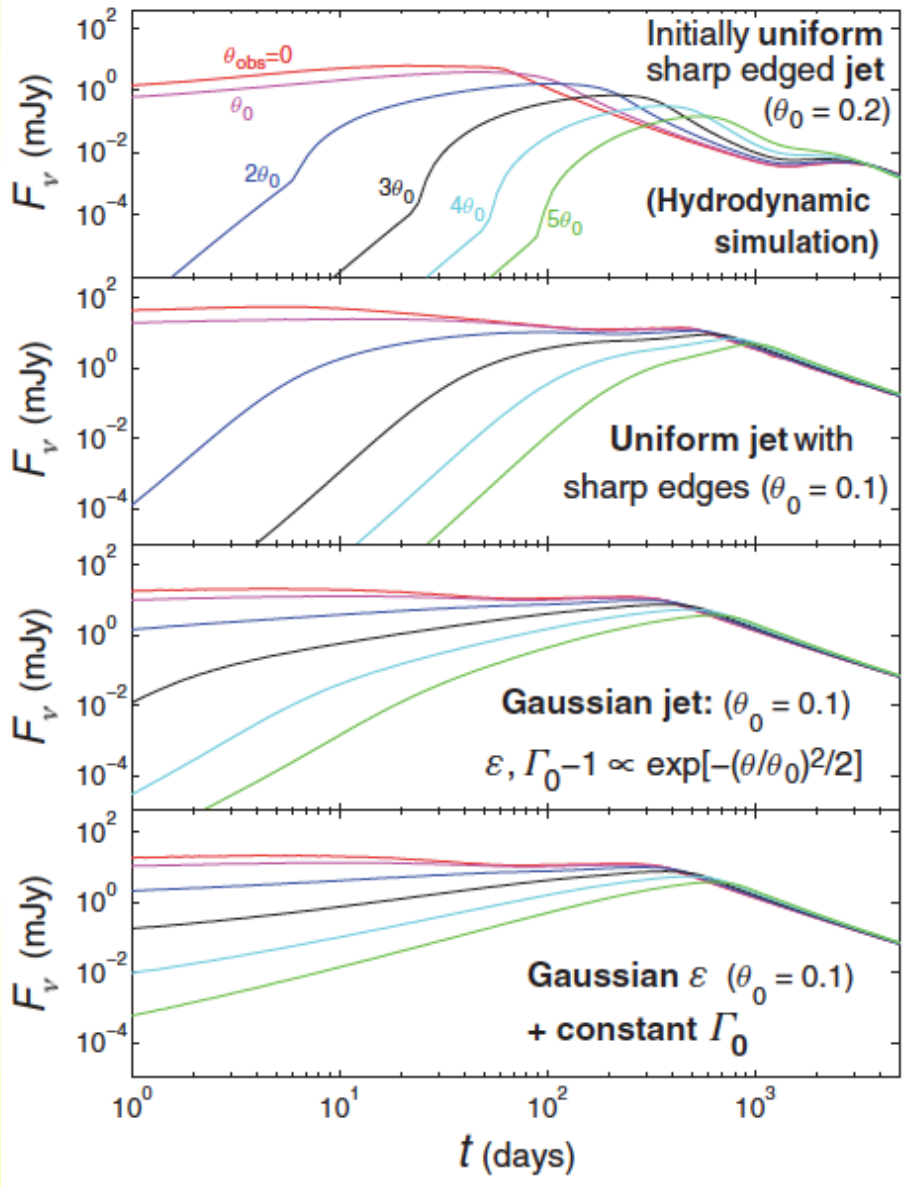
PTF11agg

(Cenko et al. 2013)

On-/Off-Axis Jets & Jet Structure

Granot & van der Horst 2014

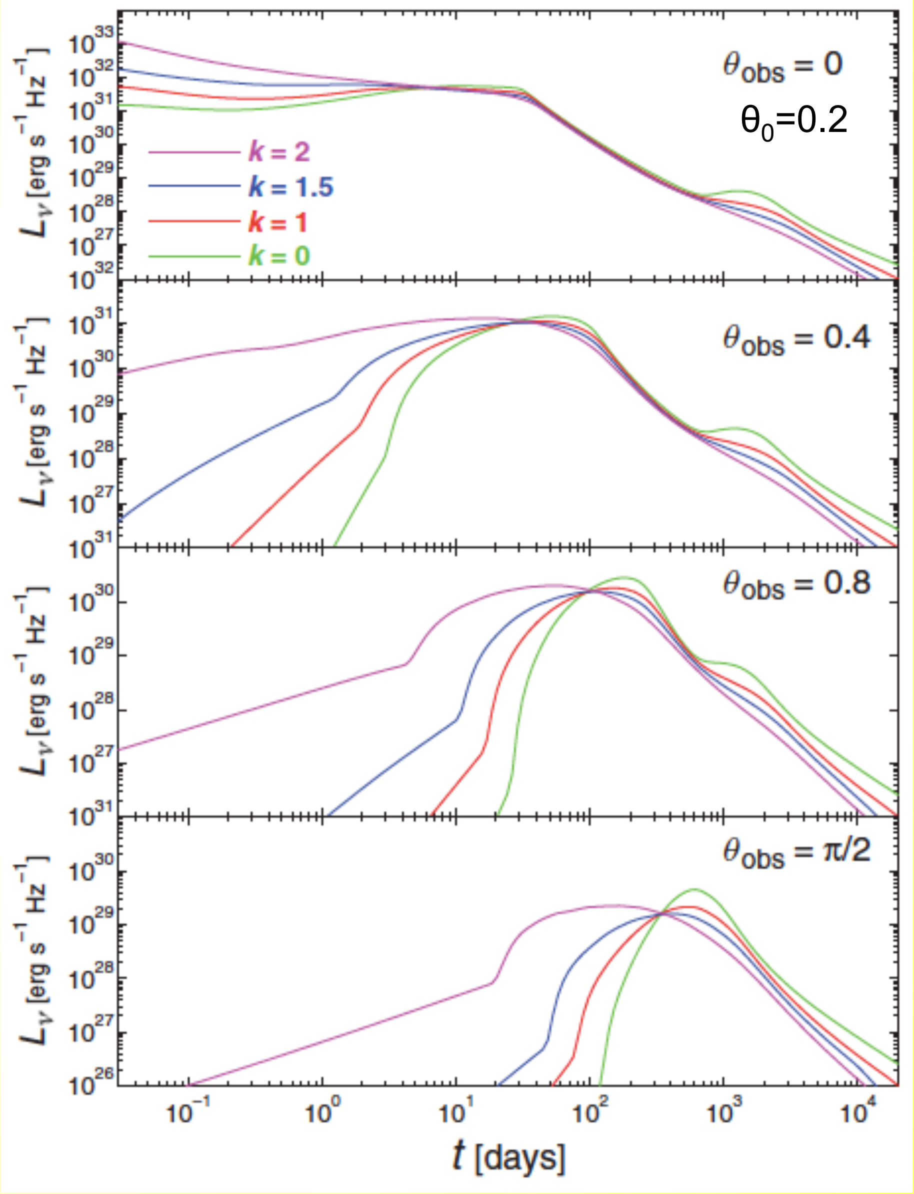




- Jet structure not known
- Structure + observer angle θ_{obs} → light curve variety

Circumburst Medium Structure

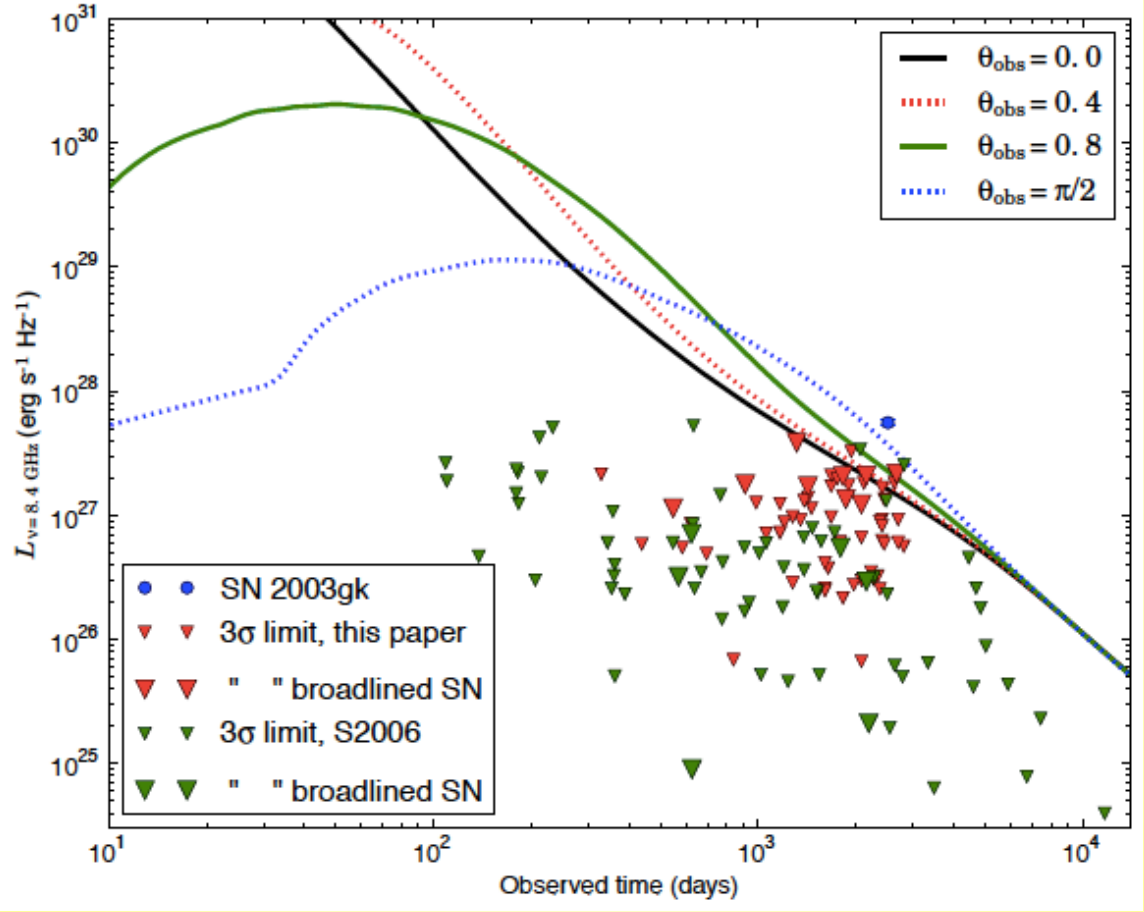
- Ambient medium density proportional to R^{-k}
  - k=0 → homogeneous
  - k=2 → 'simple' stellar wind
- Ambient medium structure determines:
  - Light curve slopes
  - Onset of light curves
  - Strength of counter-jet



Granot & van der Horst 2014

Off-Axis GRB Searches

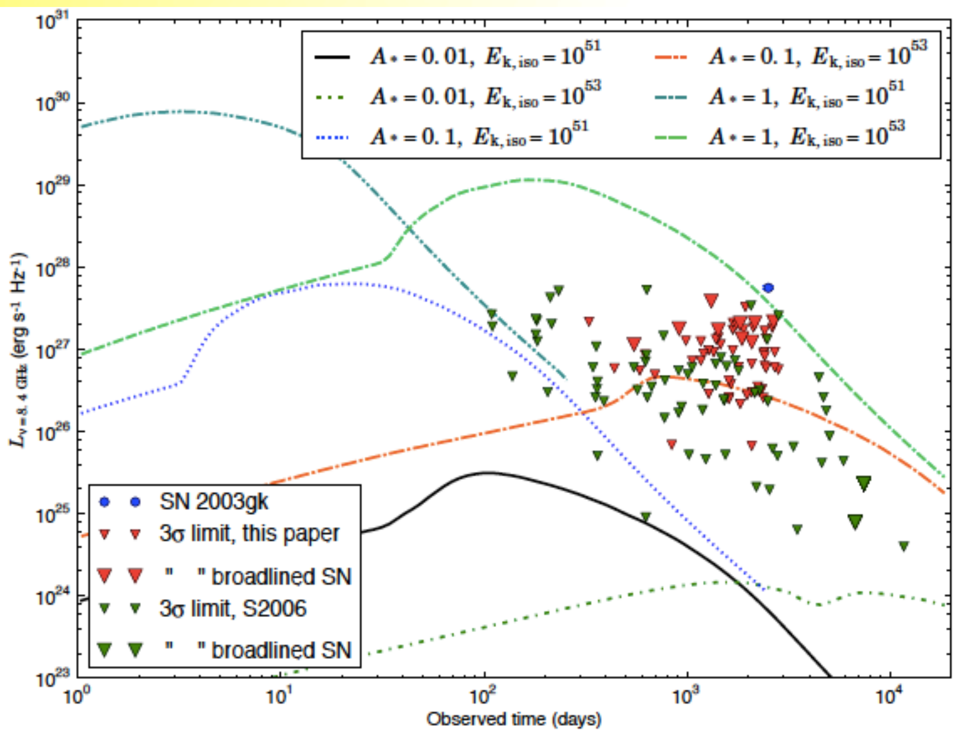
- Searches focused on (broad-lined) Type Ib/c supernovae
- Detections: relativistic jet excluded by VLBI or modeling

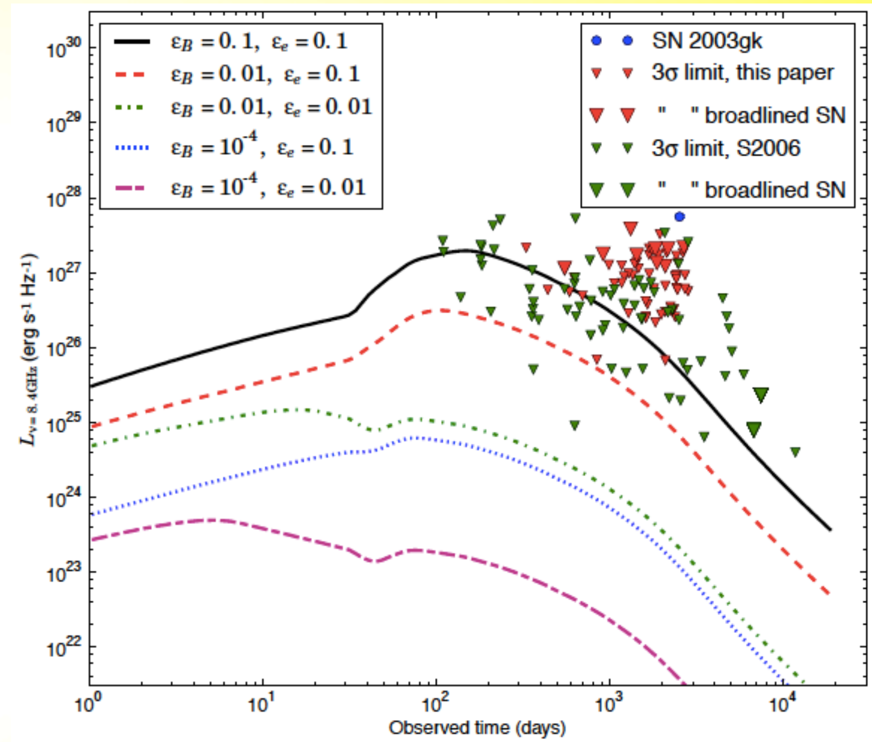


Soderberg et al. 2006; Bietenholz et al. 2014

Off-Axis GRB Limits

- Uncertainty in parameters → limits not constraining yet
- <5% of Ib/c SNe have jets with ‘canonical parameters’
- <33% of broadlined Ib/c SNe have ‘canonical jets’



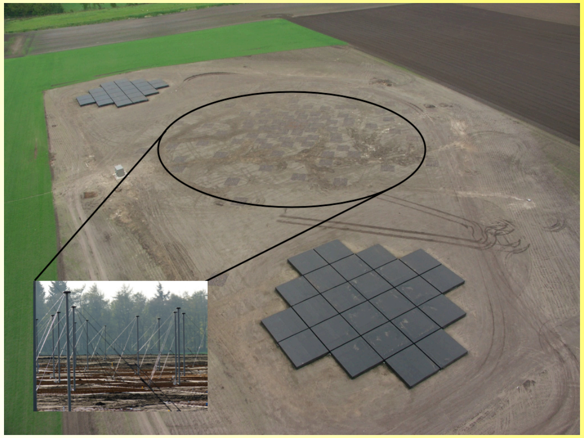


- ‘Canonical parameters’ based on brightest radio-detected GRBs

Bietenholz et al. 2014; Corsi et al. 2016

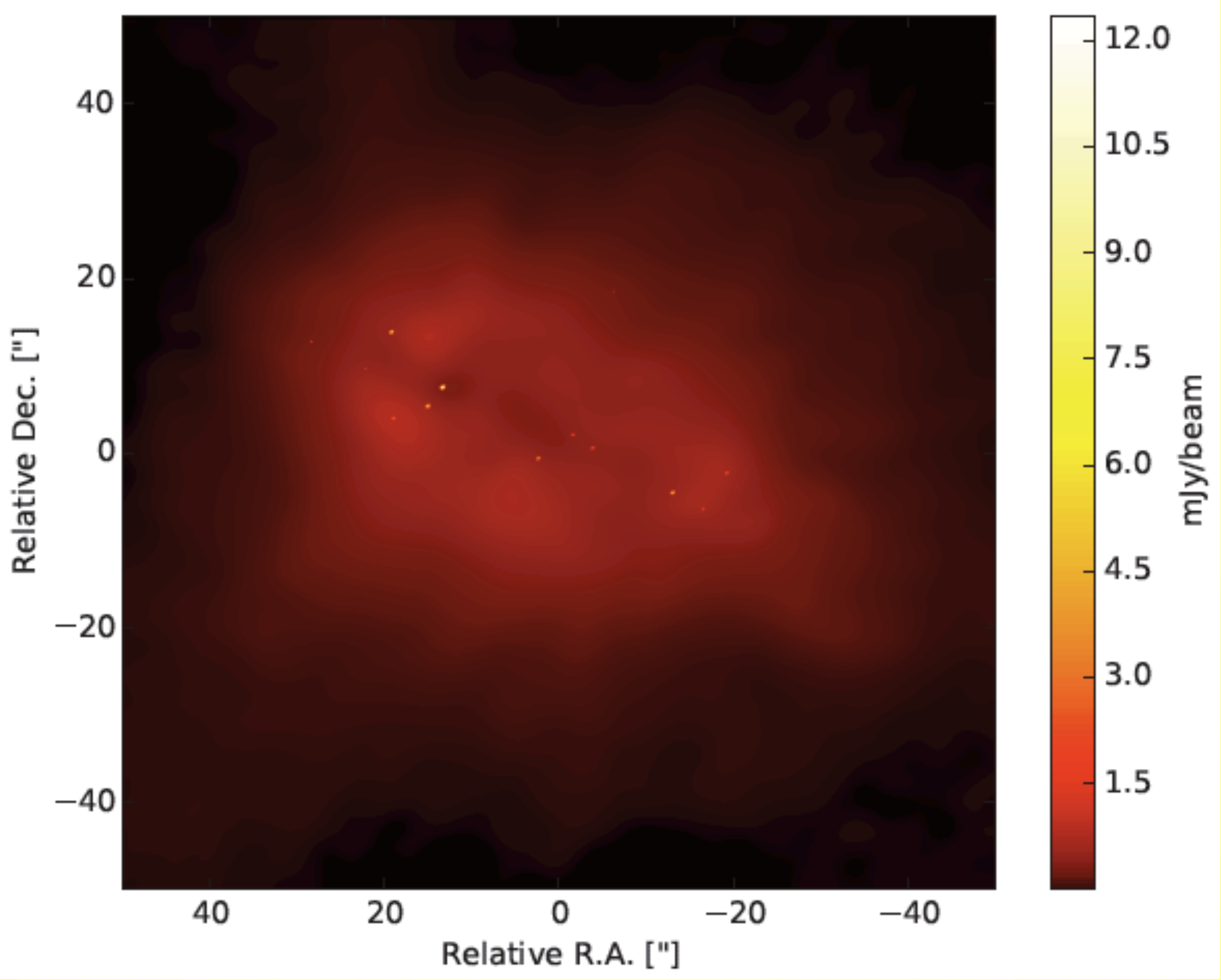
New Era in Radio Astronomy

- New & upgraded radio facilities
- Improvements:
  - Sensitivity & bandwidth
  - Spatial, spectral & temporal resolution
  - Low-frequency radio sky
  - Wide field of view
- GRB opportunities:
  - Fast follow-up & broadband evolution
  - High-resolution VLBI
  - Systematic off-axis GRB searches



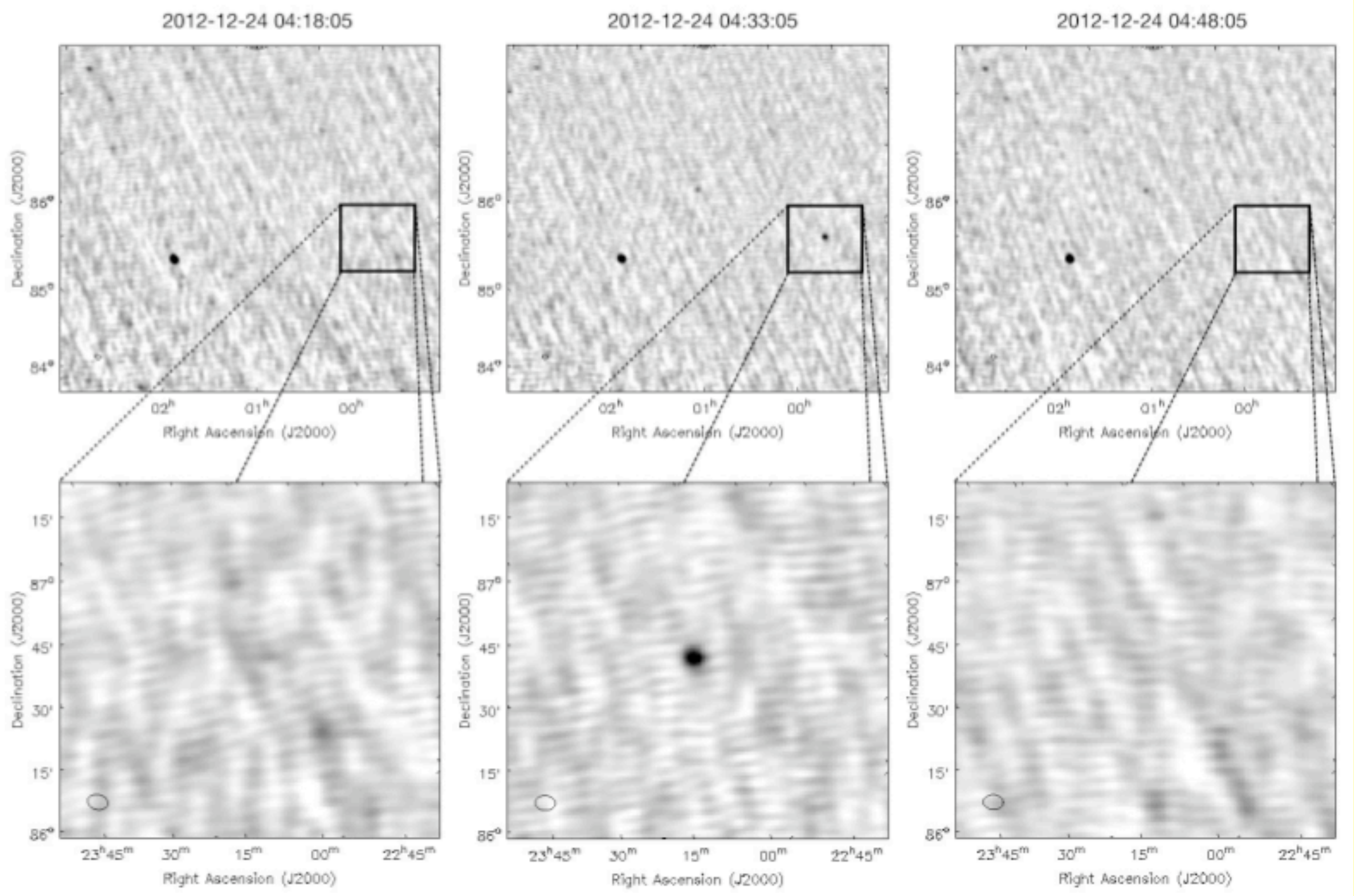
International LOFAR Telescope

M82: 146-162 MHz, 0.3”, 0.15 mJy/beam



Varenius et al. 2015

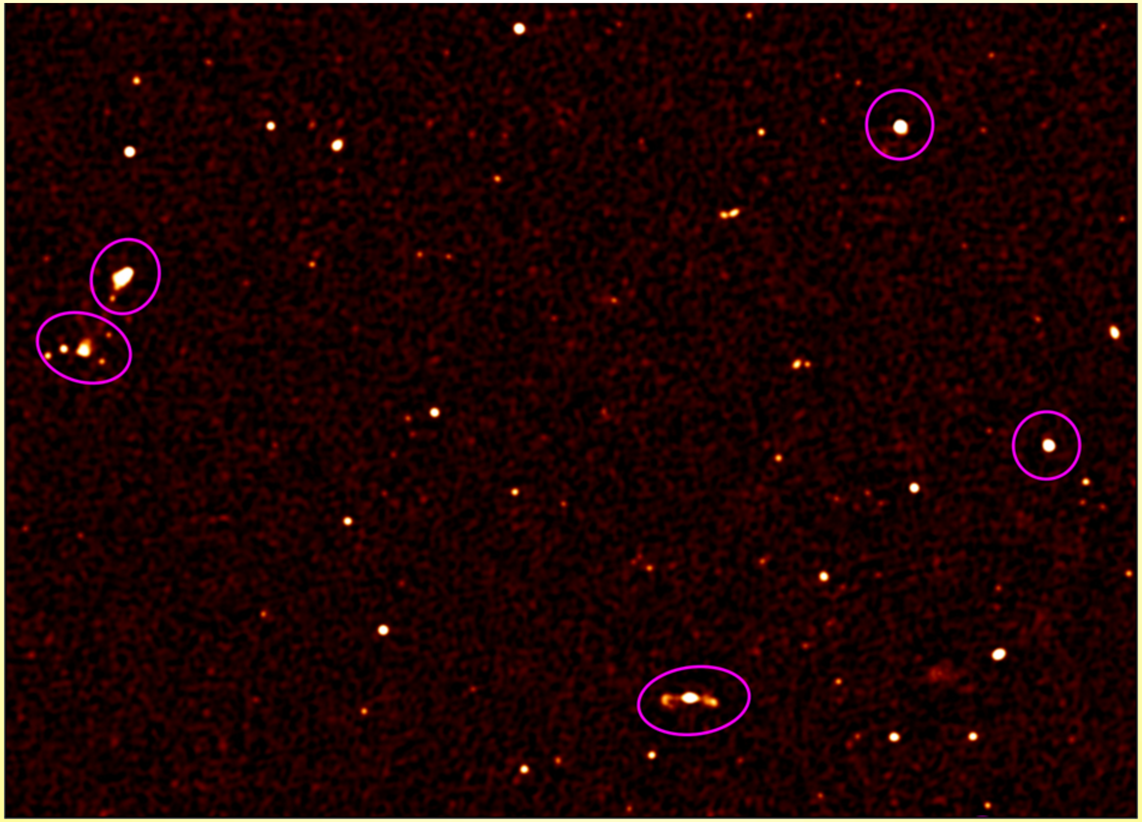
LOFAR North Celestial Pole Transient



Stewart et al. 2016

MeerKAT & ThunderKAT

- MeerKAT in South Africa: 1-1.75 GHz; part of SKA1-MID
- ThunderKAT: transient searches & follow-up (PIs: Fender, Woudt); 2630 hours / 5 years, incl. GRBs & SNe



First light: 16 of 64 final dishes: 200 sources, only 5 known before

Conclusions

- GRBs: multi-wavelength & multi-timescale
- Crucial role for radio observations
  - Physical parameters
  - Jet size measurements
  - Searches for orphan afterglows
- ‘Canonical’ GRB jets are not common in Ib/c Sne
  - Not clear yet how canonical GRBs are
- New era in radio astronomy
  - Opportunities for GRBs viewed from all angles