Type Ib/c supernovae with the EVN

Zsolt Paragi (JIVE), various projects in collaboration with a random selection of the following people:

C. Kouveliotou (NASA/MFSC), E. Ramirez-Ruiz (Univ. Santa Cruz),
A.J. van der Horst (NASA/ORAU), M. Garrett (Astron),
H.J. van Langevelde (JIVE), A. Szomoru (JIVE), M. Argo (Jodrell Bank),
M. Bietenholz (Hartebeesthoek, South Africa/York Univ., Toronto, Canada)
Y. Pridopryhora (JIVE), R. Strom (Astron), J. Granot (Hertfordshire)
R. Wijers (UvA) …

Energetic Supernovae ...

Energetic SN type Ic explosions:

-smooth spectrum, hard to classify, but no H lines (not type II)

-spectrum lines broadened, indicating ~0.1c ejecta velocity
=>very energetic explosions

-high mass loss indicates massive star progenitor

-asymmetric explosions

-some (maybe all) related to GRBs?

...and GRBs

SN1997ef

v_{ej}~20-30000 km/s the first week
M_{ej} ~9.7 M_{sun} (Mazzali et al. 2005)
GRB 970514? (Turatto et al. 2000)

SN1998bw/GRB980425

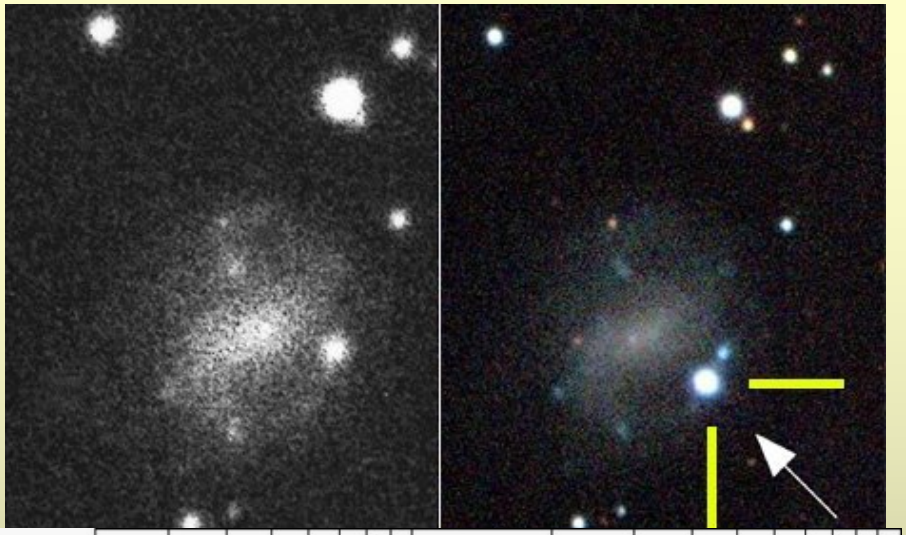
first GRB/SN ID (Galama et al. 1998)
E_{kin}~5x10^{52} erg – hypernova Iwamoto et al. (1998)

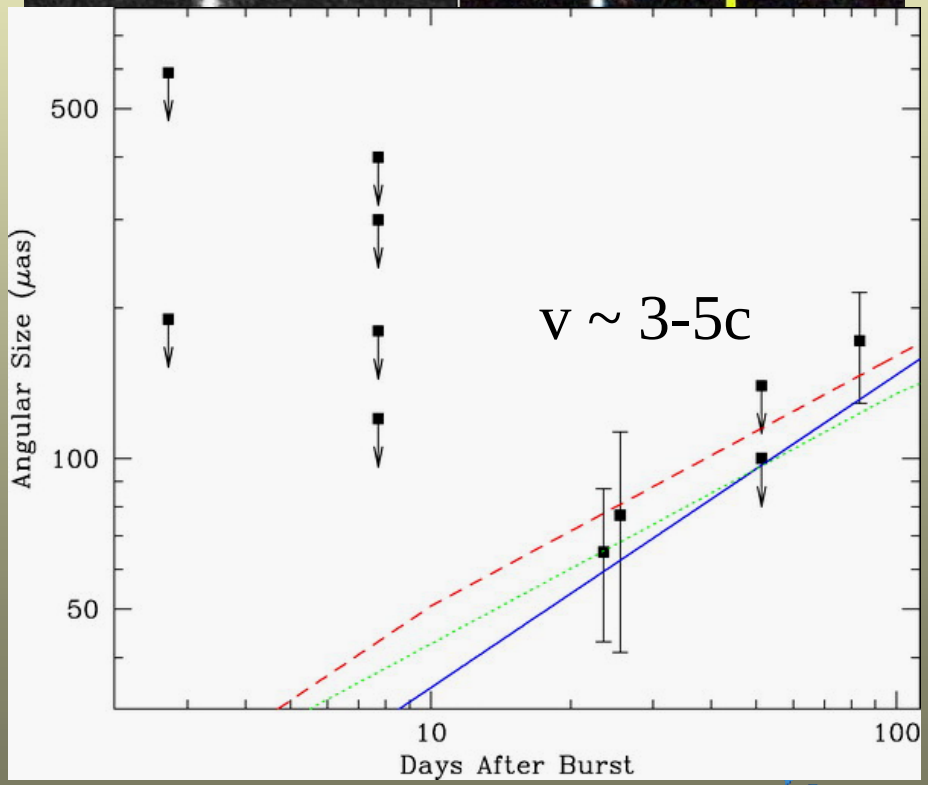
SN2003dh/GRB030329

E_{kin}~5x10^{52} erg, M_{ej} ~9.7 M_{sun} Stanek et al. (2003), Mazzali et al. (2003)
VLBI monitoring (Taylor et al. 2004)

SN2003lw/GRB031202

again, similar spectrum Malesani et al. (2004), Mazzali et al. (2005)





Open questions

Long-duration GRBs are thought to be related to core-collapse SNe (Woosley 1993).

These are assumed to produce highly relativistic jets ($\Gamma>100$) – where are these jets/bipolar structures? (no direct evidence yet, maybe Taylor et al. 2004; M82 41.95+575, a historical GRB? Muxlow et al.)

Are there – and what is the fraction of – mildly relativistic jets ($\Gamma>2$) in SN Ibc? These should be 100x more frequent than the highly relativistic ones (Granot & Ramirez-Ruiz 2005).

If there are, can we see orphan radio afterglows without GRB? These maybe related to X-ray afterglows/flashes.

A detection of such a radio afterglow would strongly support the idea that core-collapse SNe are triggered by jets. These should be resolvable by VLBI at low redshifts (Paczynski 2001).

SN 2007gr ToO observations

• SN 2007gr was discovered on 15 Aug 2007 with KAIT (CBET 1034); identified as Type Ib/c.

• Distance is about 7.3 Mpc, 10x closer than SN 2001em was.

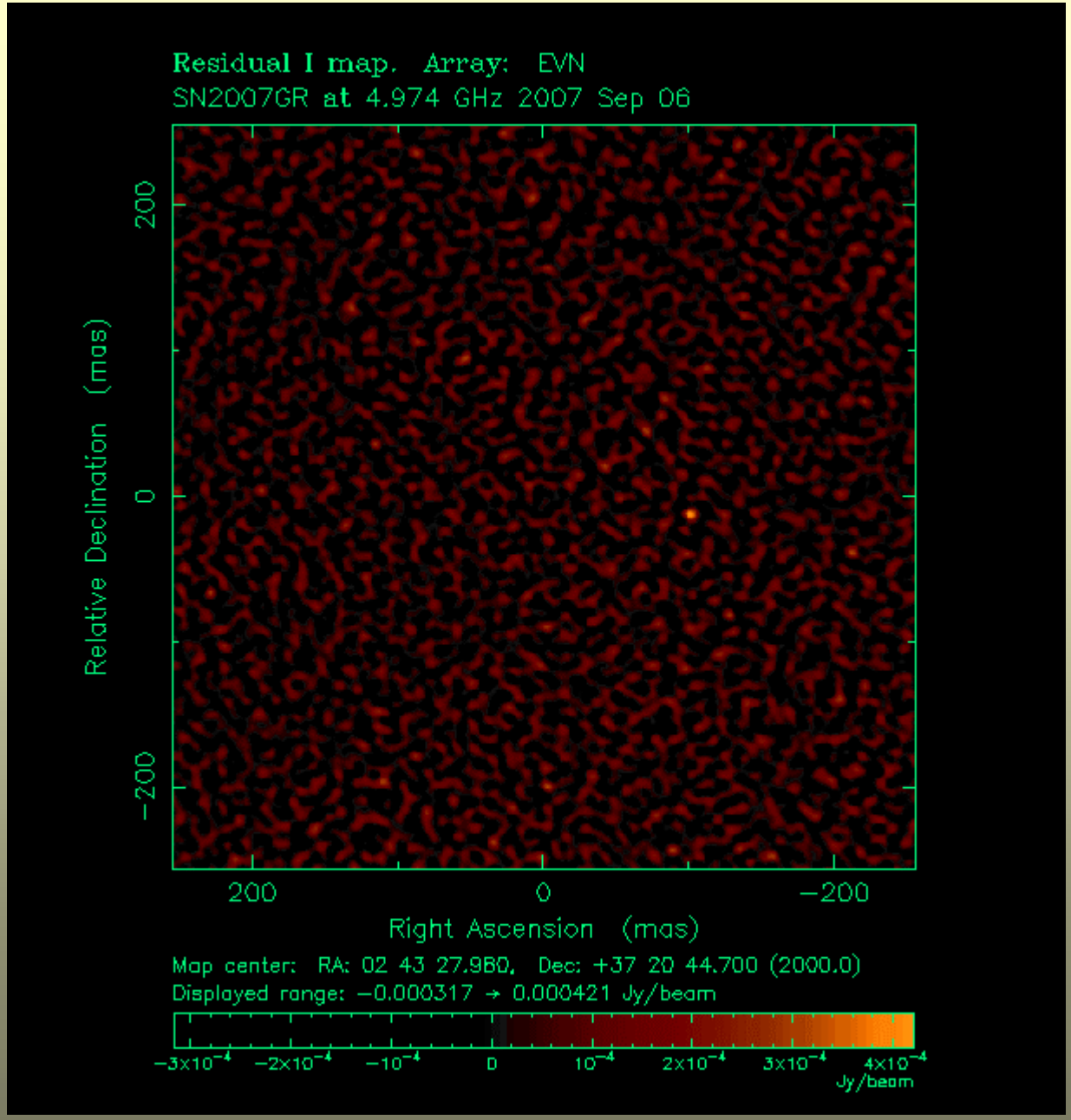
• VLA discovers 610 microJy radio source (Soderberg 2007)

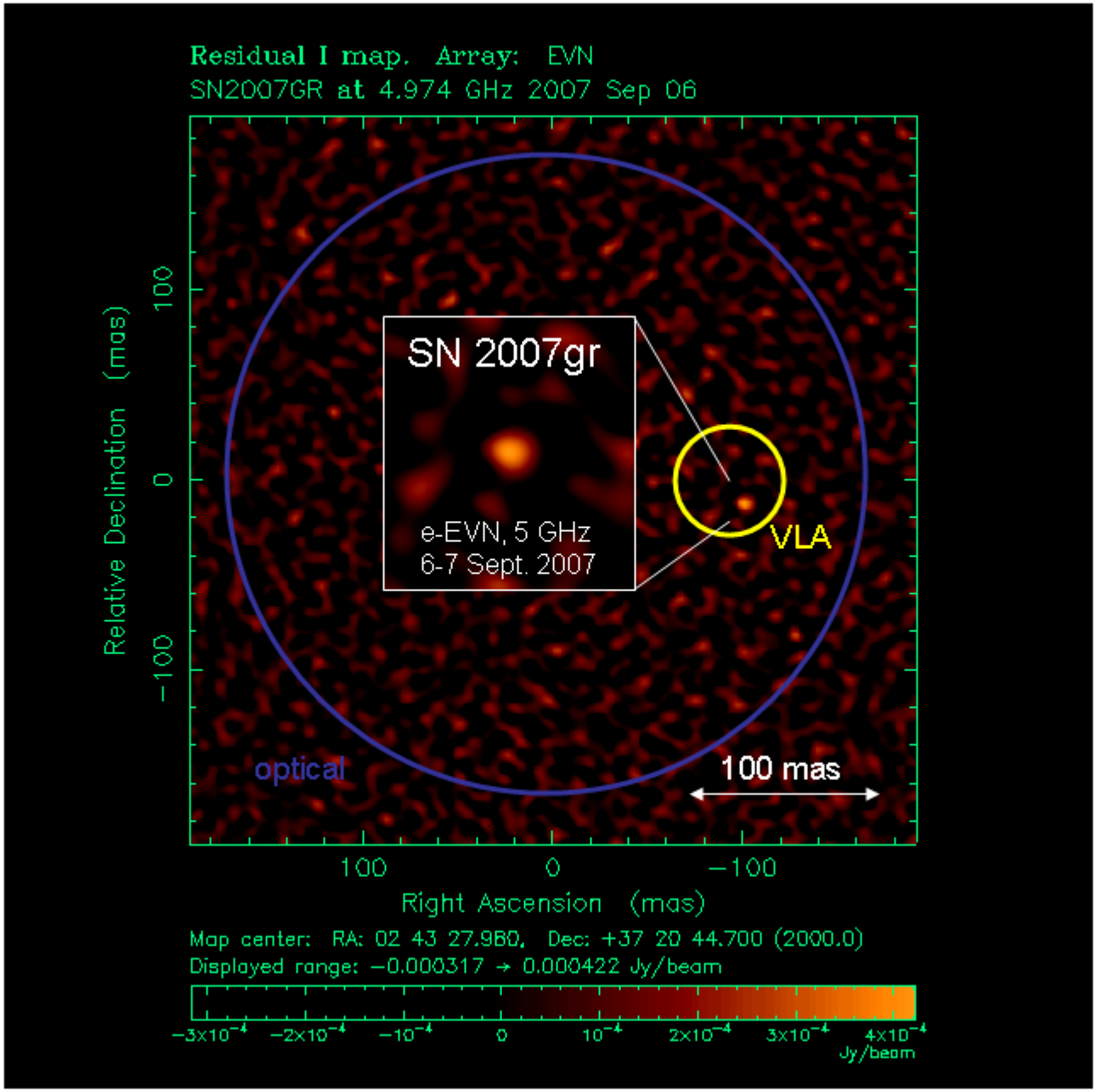
• No detection with GMRT so far at 1.4 GHz; neither MERLIN detection at 1.6 and 5 GHz

• e-EVN observations: Da, Jb2, On, Tr, Wb (256 Mbps), at 5 GHz, on 2007 Sep 6-7

• Firm detection (5.6 σ) of the supernova within the VLA error box

Paragi et al. (2007), ATel #1215


Residual I map. Array: EVN
SN2007GR at 4.974 GHz 2007 Sep 06
Relative Declination (mas)
200
0
−200
200
0
−200
Right Ascension (mas)
Map center: RA: 02 43 27.980, Dec: +37 20 44.700 (2000.0)
Displayed range: −0.000317 → 0.000421 Jy/beam
−3x10−4
−2x10−4
−10−4
0
10−4
2x10−4
3x10−4
4x10−4
Jy/beam


Residual I map. Array: EVN
SN2007GR at 4.974 GHz 2007 Sep 06
SN 2007gr
e-EVN, 5 GHz
6-7 Sept. 2007
VLA
optical
100 mas
Relative Declination (mas)
100
0
−100
100
0
−100
Right Ascension (mas)
Map center: RA: 02 43 27.980, Dec: +37 20 44.700 (2000.0)
Displayed range: −0.000317 → 0.000422 Jy/beam
−3x10−4
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10−4
2x10−4
3x10−4
4x10−4
Jy/beam

e-VLBI detection of SN2007gr

ATel #1215; Z. Paragi (JIVE), C. Kouveliotou (NASA/MFSC), M.A. Garrett (Astron), E. Ramirez-Ruiz (Univ. Santa Cruz), H.J. van Langevelde (JIVE/Leiden), A. Szomoru (JIVE), M. Argo (JBO)
on 12 Sep 2007; 20:22 UT
Password Certification: Zsolt Paragi (zparagi@jive.nl)

Subjects: Radio, Novae, Supernovae

We observed the Type Ibc SN2007gr on 6-7 September for 12 hours (21:00-09:00 UTC) at 4.9 GHz with the the European VLBI Network (EVN) using the e-VLBI technique. Participating telescopes were Darnhall, Jodrell Bank (MkII), Medicina, Onsala, Torun and Westerbork (phased array of 14 telescopes). The aggregate bitrate was 256 Mbps, except for Darnhall whic contributed with an effective data rate of 128 Mbps due to analog bandwidth restrictions. There were 4*8 MHz subbands observed in both RCP and LCP polarizations. The target was phase-referenced to the nearby calibrator J0253+3835. The achieved rms noise level was 75 microJy/beam.

There is an unresolved source (beamsize 7 milliarcsecond) with a flux density of 422+-21 microJy (5.6 sigma) at coordinates RA 02 43 27.97151 DEC +37 20 44.6873 (J2000). This position is within 102 milliarcseconds of the reported optical counterpart of SN2007gr (CBET 1034), and is in agreement with the VLA position of RA=02 43 27.9725 Dec=+37 20 44.702 (Soderberg et al., in prep.). There are no other spurious sources exceeding the 5-sigma level within 1 arcsecond. We consider, therefore, our result as a VLBI detection of the supernova. Further observations are planned.

The VLBI position error is likely dominated by the position accuracy of the reference source J0253+3835 which is given as 0.55 mas in the VLBA Calibrator List. We used the Westerbork synthesis array data to calibrate the flux scale of our VLBI dataset. As a result, the VLBI flux scale is accurate to within 5%. Note that the VLBI amplitudes may be ~10% low due to coherence losses in phase-referencing.

e-VLBI is a technique where the signals from far away radio telescopes are directly streamed t the central data processor for real-time correlation, instead of recording. The data are immediately available to the astronomers for further processing.

e-VLBI developments in Europe are supported by the EC DG-INFSO funded Communication Network Developments project 'EXPReS', Contract No. 02662 The European VLBI Network i a joint facility of European, Chinese, South African and other radio astronomy institutes funde by their national research councils.

[Telegram Index]

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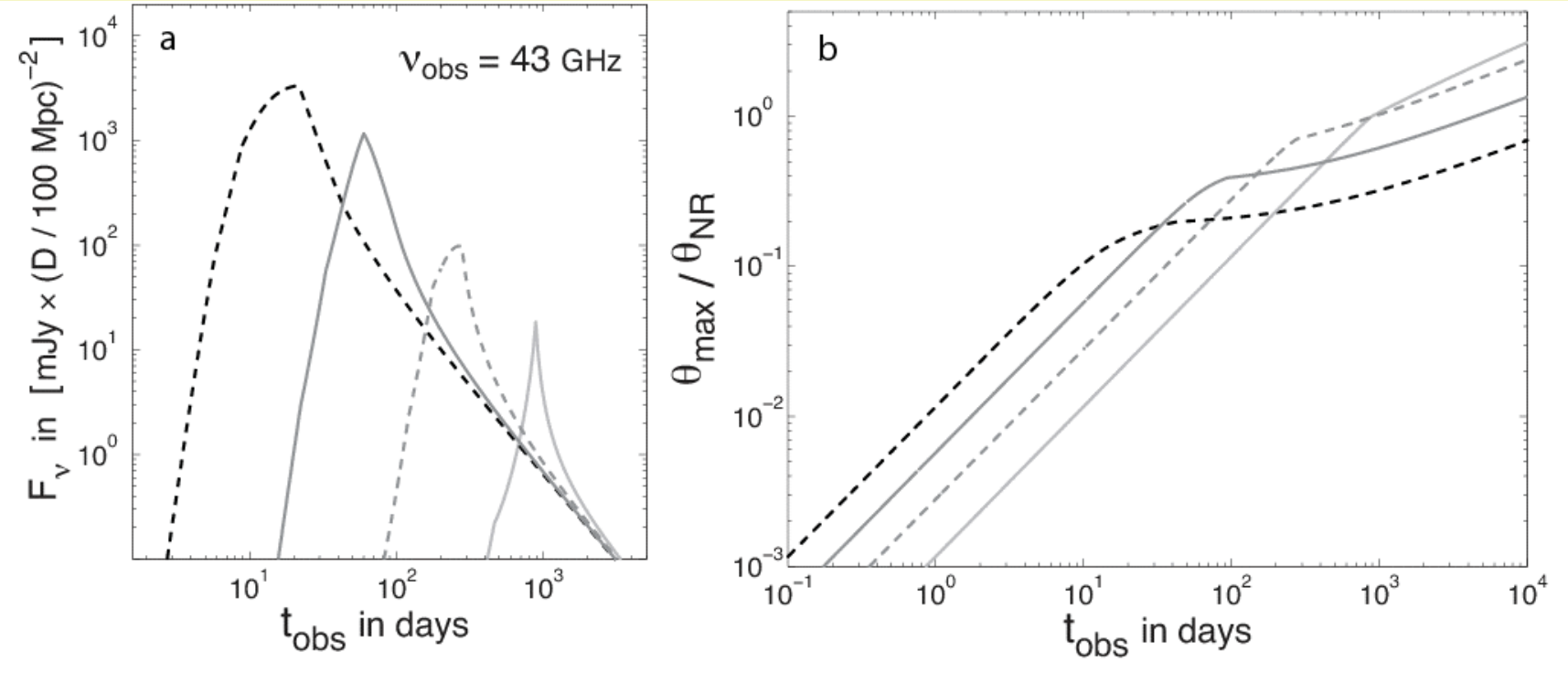
The first ATel message from the e-EVN

GRB-SN jet evolution

Granot & Ramirez-Ruiz (2005)



Various line of sights from 0 to 90 degrees.
Θ_{NR} ~ (D/100 Mpc), in case of SN 2007gr 13.7 mas

Follow-up global VLBI observations: EVN incl. Hh, plus the GBT

Global VLBI results

SN2007gr below ~60 μJy/beam (5σ)

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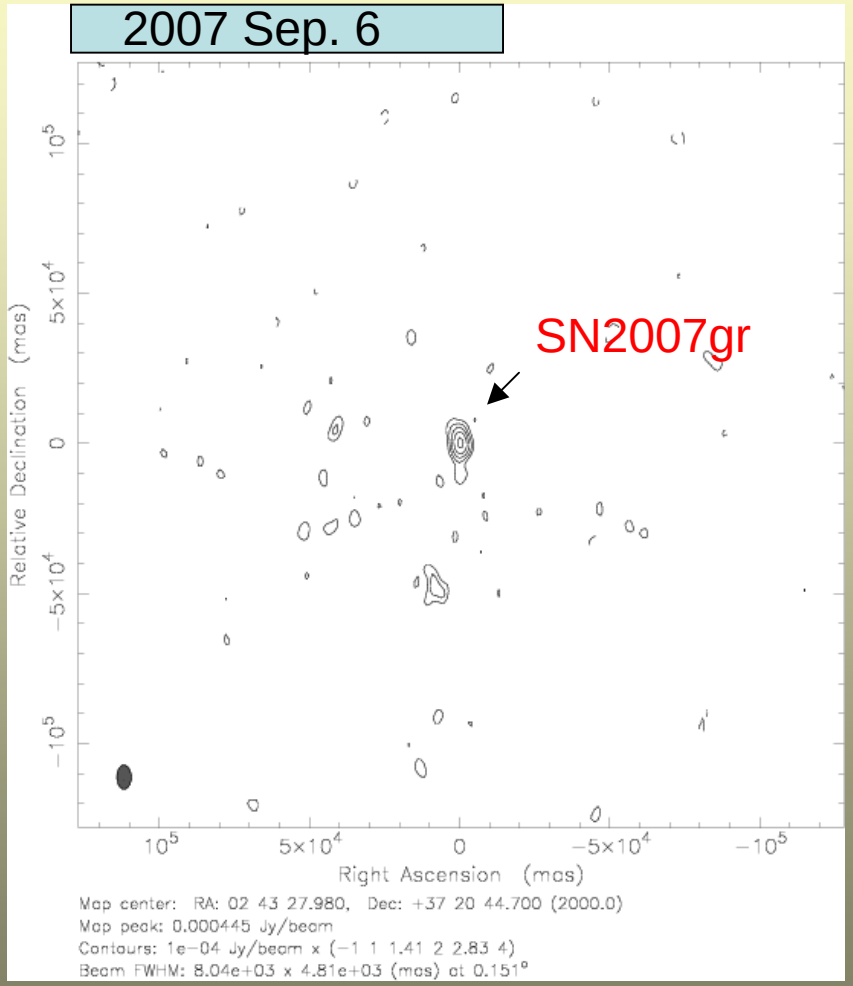
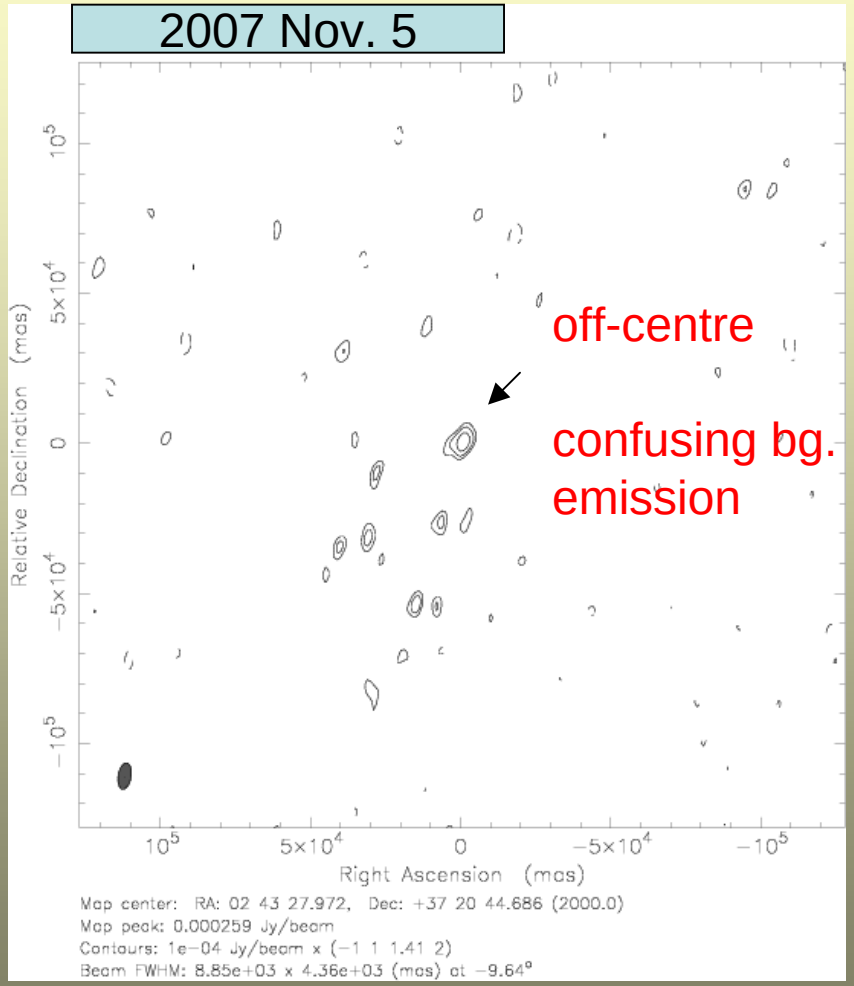
WSRT data from the VLBI runs

2007 Sep. 6



2007 Nov. 5



Work by Yurii Pridopryhora

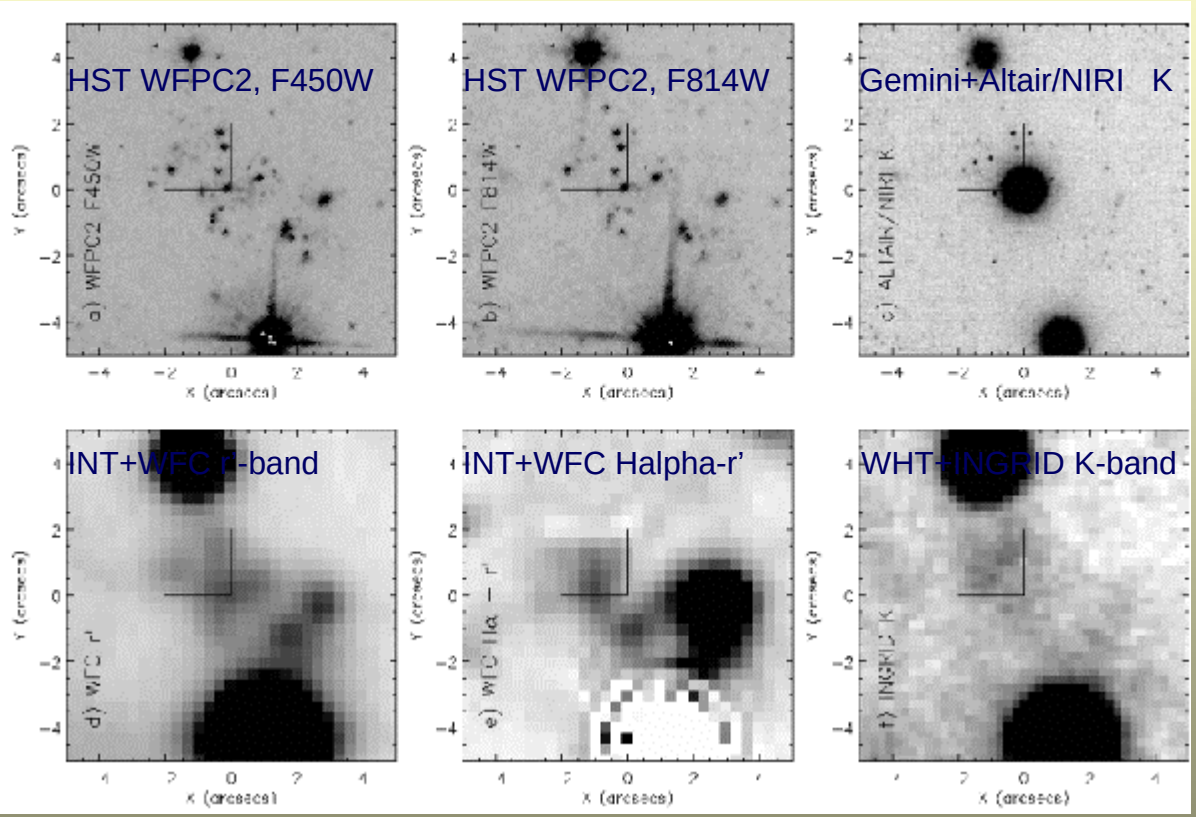
Looking for the progenitor of SN 2007gr

Gemini Altair/NIRI adaptive optics positions ±20 mas.

SN at the edge (~130 mas) of a bright source, likely cluster. SN could have been a member.

From its colors, two solutions for thew age and turnoff mass of the assumed cluster.

K-band and Halpha images favour ~7 My and 28±4 Msun. Good estimate for SN initial mass; wait for fading…



Crockett et al. (2007)

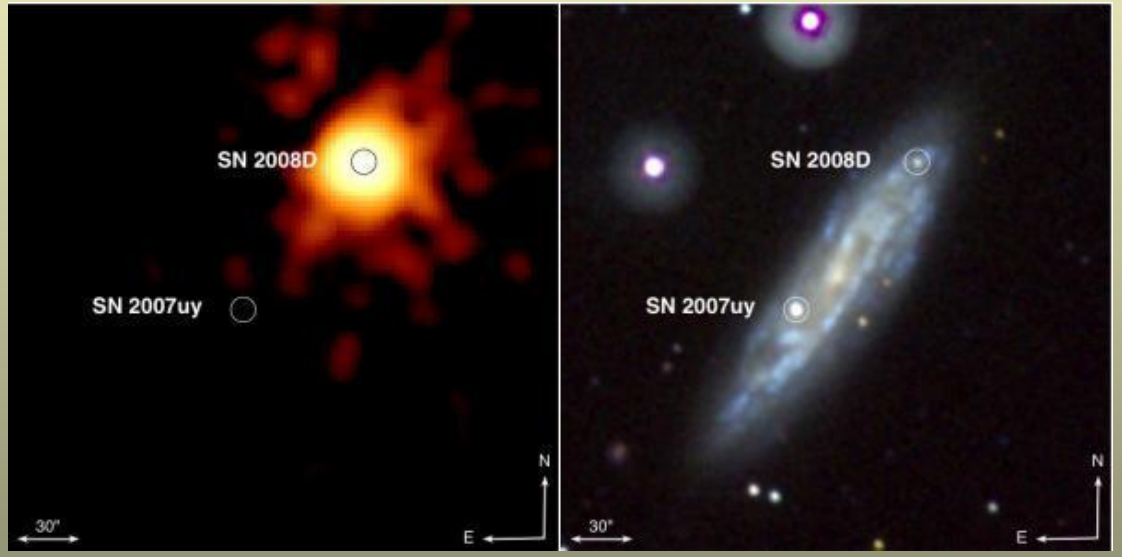
With VLBI one could do progenitor search of SN Ib/c, if the host gx core is detected as well –for alignment with pre-discovery HST images.

SN2008D discovery

• Serendipitous discovery by Swift's XRT on 9 Jan. 2008 (Soderberg et al. 2008). Host galaxy is NGC2770, 27 Mpc away.

Soderberg et al. (2008)
Sciencedaily.com;
NASA/Swift

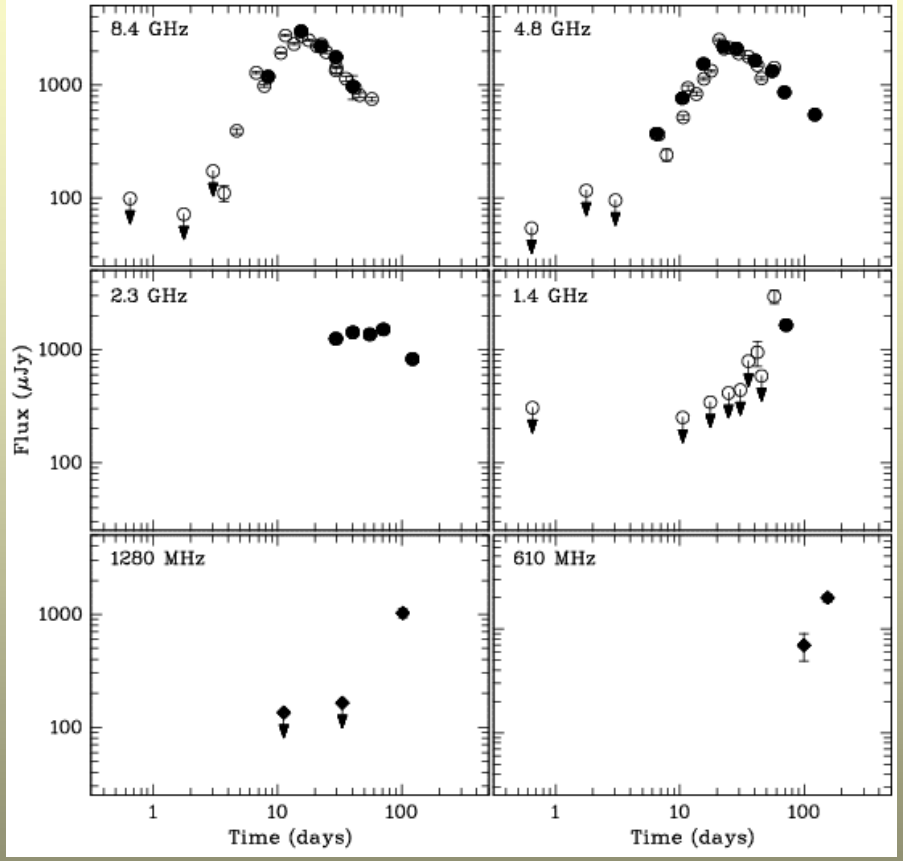
• Extreme luminous outburst (L_X=10^{44}erg/s), just for a few mins. Swift's UVOT detected optical counterpart two hours later.



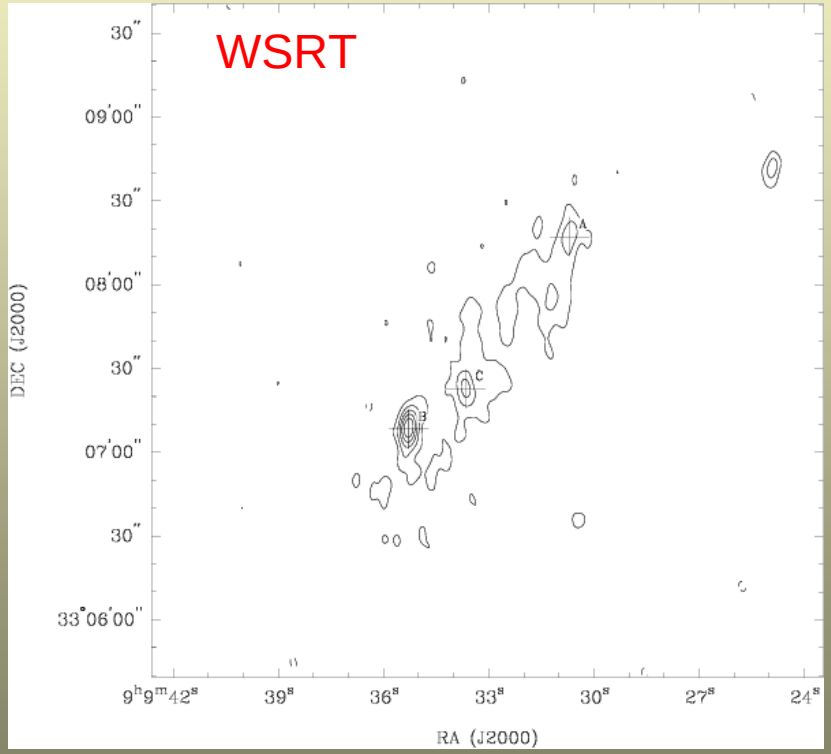
• Optical spectroscopy follow-up: characteristics of a young SN; lack of H and Si lines indicated SN type Ib/c.

• Long-awaited "shock-breakout" emission was detected the first time (Soderberg et al. 2008, Nat. 453, 469)

WSRT monitoring



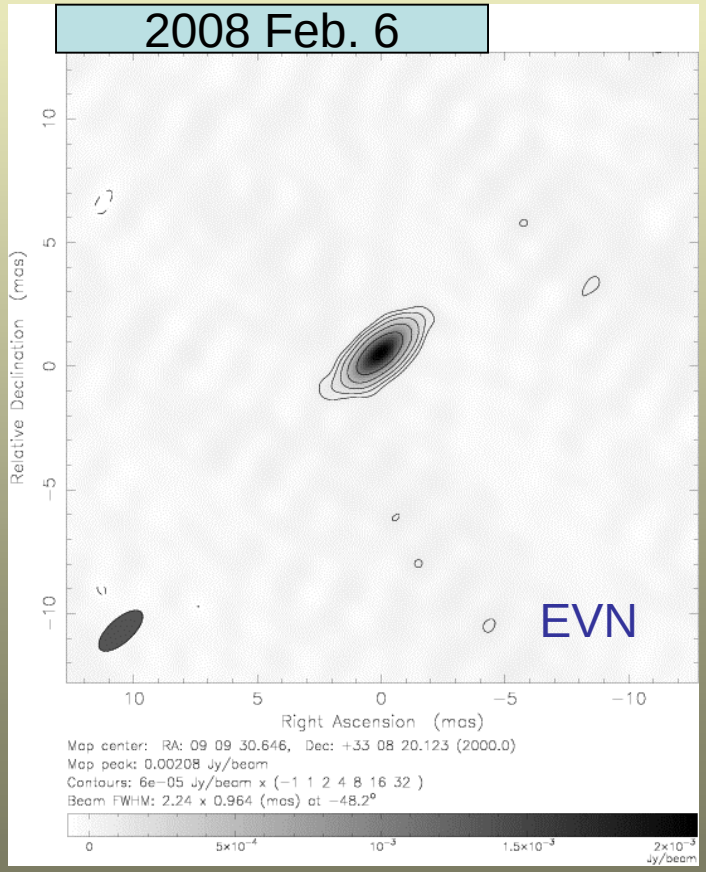
Work by Alexander van der Horst

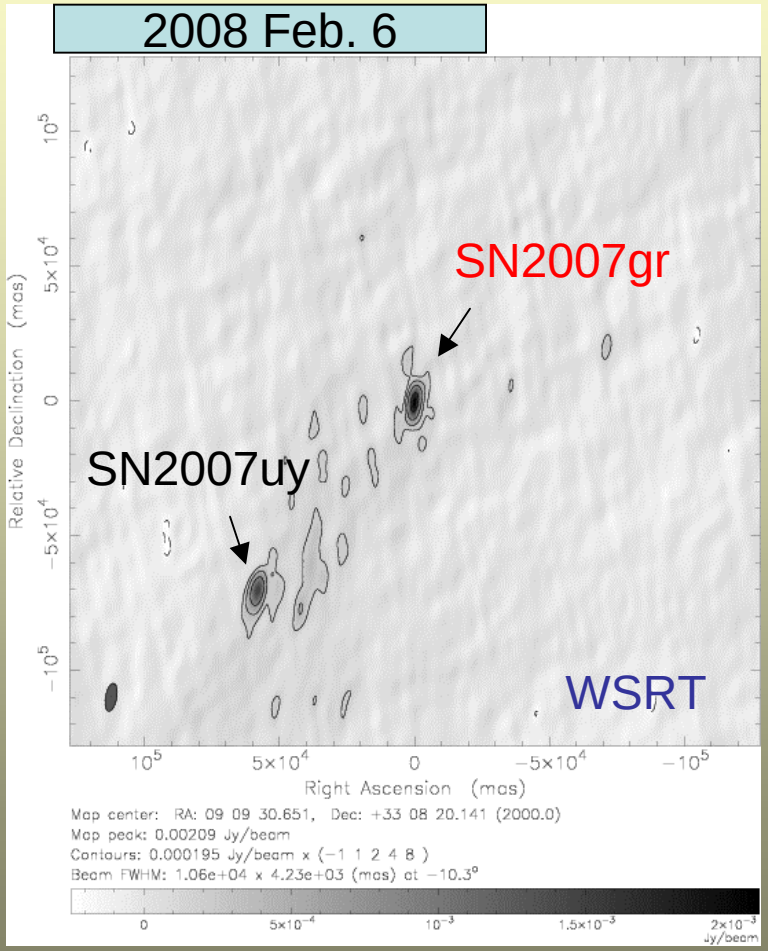


… no evidence for very relativistic outflow.

Global VLBI observations

Two epochs, EVN with Ar plus Hn, Sc @ 5GHz
Work in progress…





Conclusions

• EVN with the phased array WSRT is a great combination for SN type Ib/c studies.

• Urgency justified, some sources fade very quickly.

• Yet, within this short time in principle there is the possibility to distinguish between mildy or non-relativistic cases vs. relativistic outflows.

• We need very sensitive long baselines for that…

• e-MERLIN will certainly be an extremely valuable addition.

“Hypernovae” slide
Open questions
What can VLBI do (jet speeds and detectability)
(e-)EVN and Westerbork
SN2007gr intro
SN2007gr e-EVN obs and results (EVN/WSRT)
SN2007gr global follow up results (EVN/WSRT)
Searching for the progenitor in SN2007gr (aligning frames)
SN2008D story
SN2008D obs (EVN/WSRT –any results from Alexander???)
SN2008D size and speed upper limits
Concluding remarks and e-MERLIN collaboration