Follow up of gamma-ray burst afterglows at the highest resolution

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CTAO/KM3NeT community day

JIVE Joint Institute for VLBI ERIC · ASTRON · ASTROFLASH · erc European Research Council · PANTERA Stars

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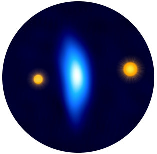
JIVE & ASTRON at Dwingeloo

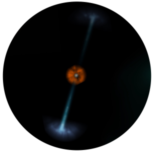
Guest researcher at API/UvA

Observational radio astronomer

Follow up of high-energy transients

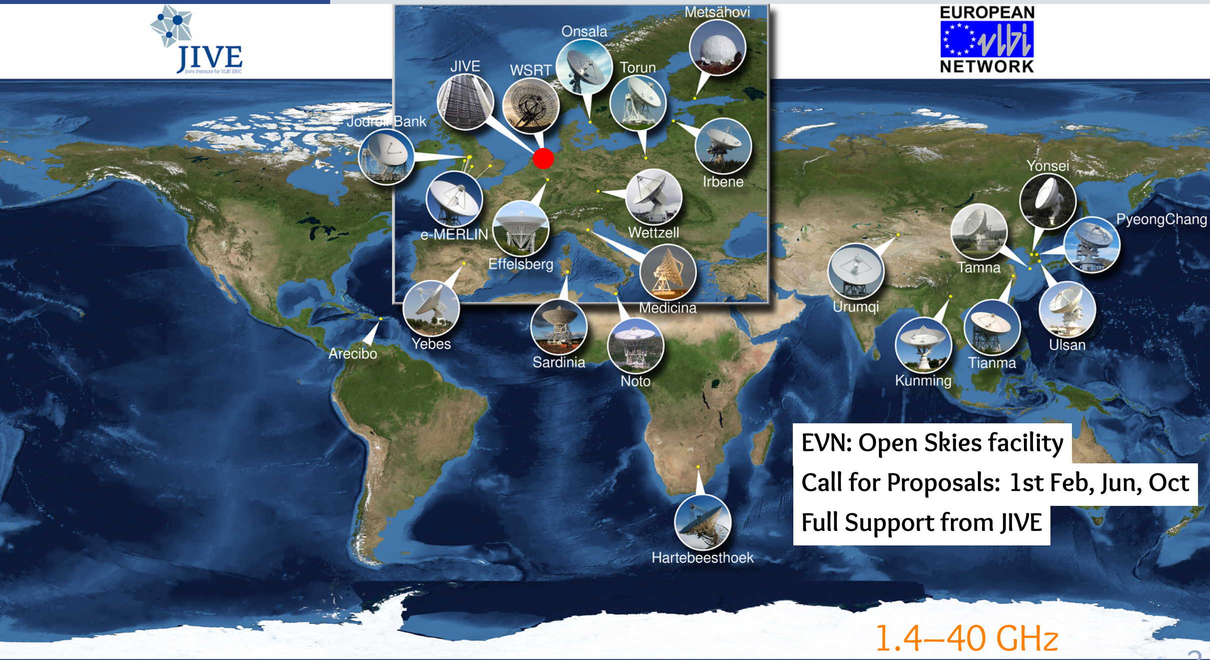


High-Energy Binaries



Gamma-Ray Bursts

Fast Radio Bursts



EVN: Open Skies facility

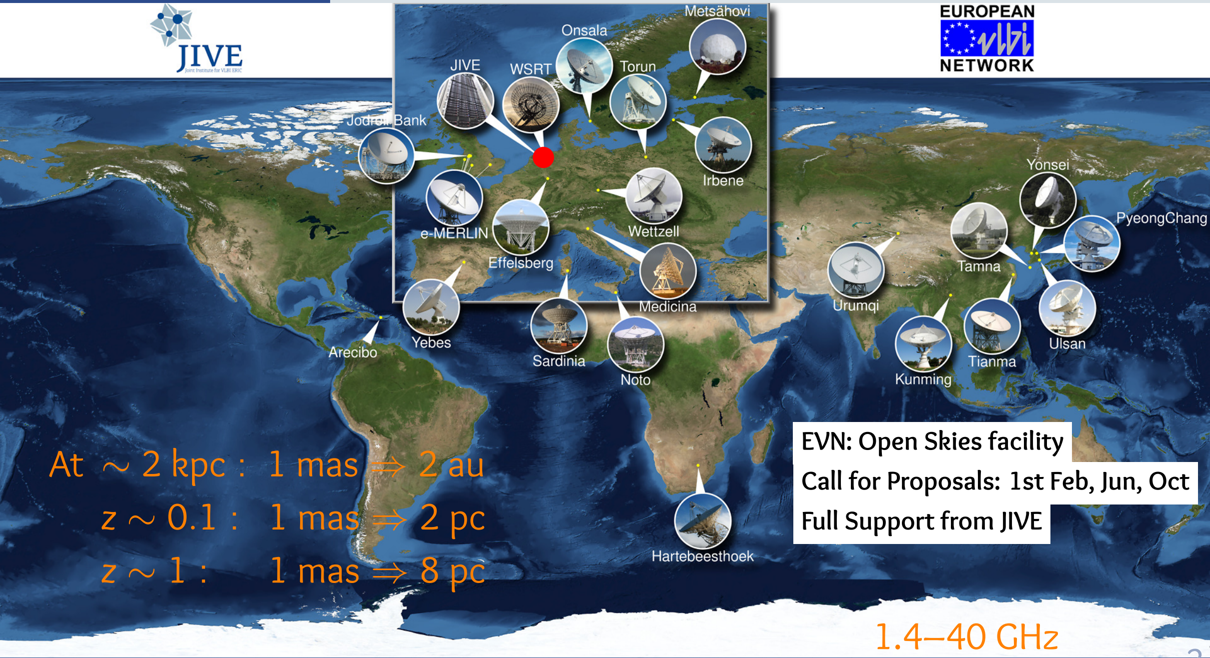
Call for Proposals: 1st Feb, Jun, Oct

Full Support from JIVE

1.4–40 GHz

JIVE
Joint Institute for VLBI ERIC

EUROPEAN vlbi NETWORK



At ~ 2 kpc : 1 mas $\Rightarrow$ 2 au

$z \sim 0.1$: 1 mas $\Rightarrow$ 2 pc

$z \sim 1$: 1 mas $\Rightarrow$ 8 pc

EVN: Open Skies facility

Call for Proposals: 1st Feb, Jun, Oct

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1.4–40 GHz

RS Oph Novae — 2021's outburst

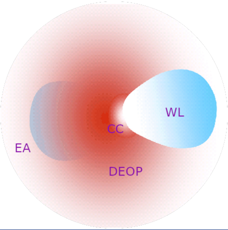
Proton acceleration in the nova shock
MAGIC Collaboration et al. (2022)

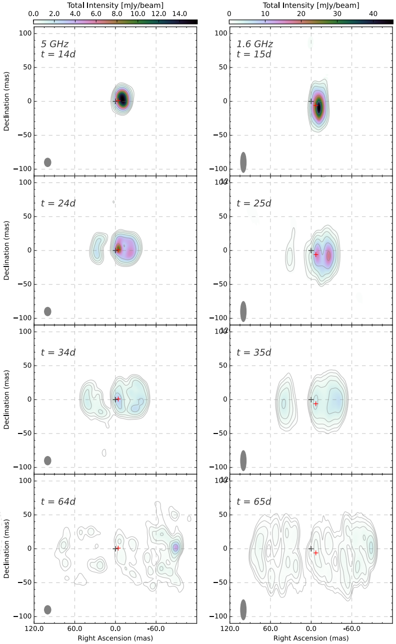
Radio campaign 14–320 d post-outburst.
Munari, Giroletti, Marcote et al. (2022),
Rocco et al. (2024)

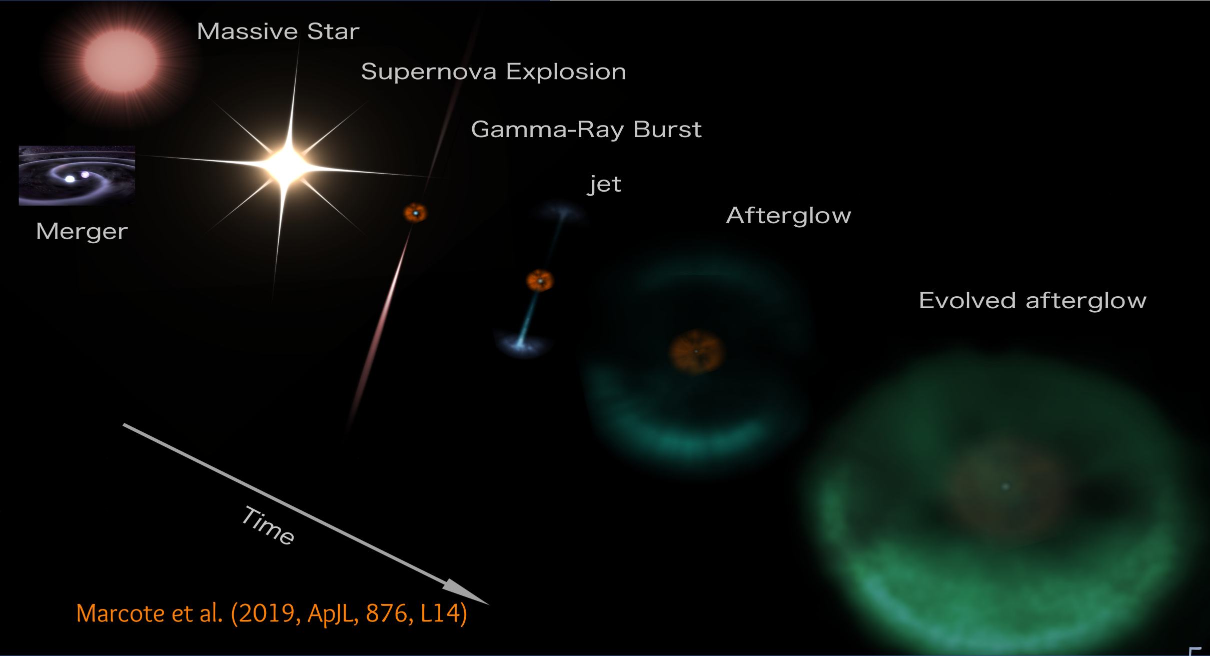
Expansion velocity of $\sim 7\,000$ km s^{-1}

Central and compact core
Bipolar outflow up to ~ 540 AU (+65 d).

$\sim 4.3 \times 10^{-6}$ $M_\odot$ at the DEOP,
$\sim 10\%$ accreted by the white dwarf.

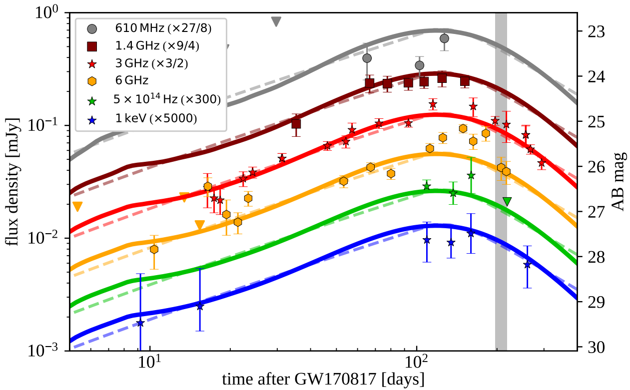






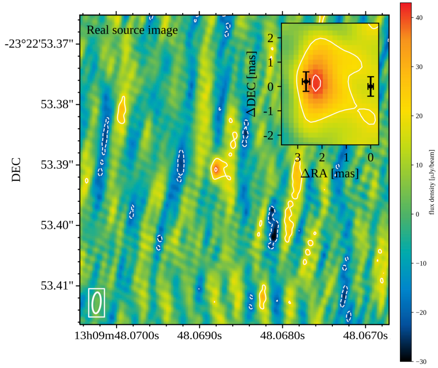
Marcote et al. (2019, ApJL, 876, L14)

The first NSB merger: GW 170817



Ghirlanda et al. (2019, Science, 363, 968)

Structured jet successfully broke through the ejecta



Narrow ($\theta_c = 3.4 \pm 1^\circ$), and energetic ($E_{iso} \approx 2.5 \times 10^{52}$ erg) jet, with a viewing angle of $\sim 15^\circ$.

The BOAT: GRB 221009A

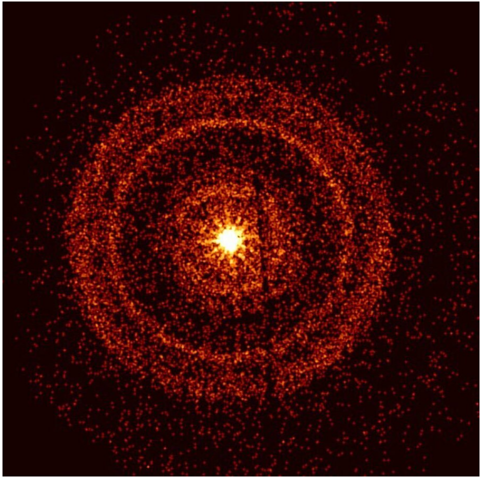
The **B**rightest **O**f **A**ll **T**ime

Detected > 1 TeV.

First clear evidence for a (IC) component beyond synchrotron emission in the GRB afterglow, with comparable power.

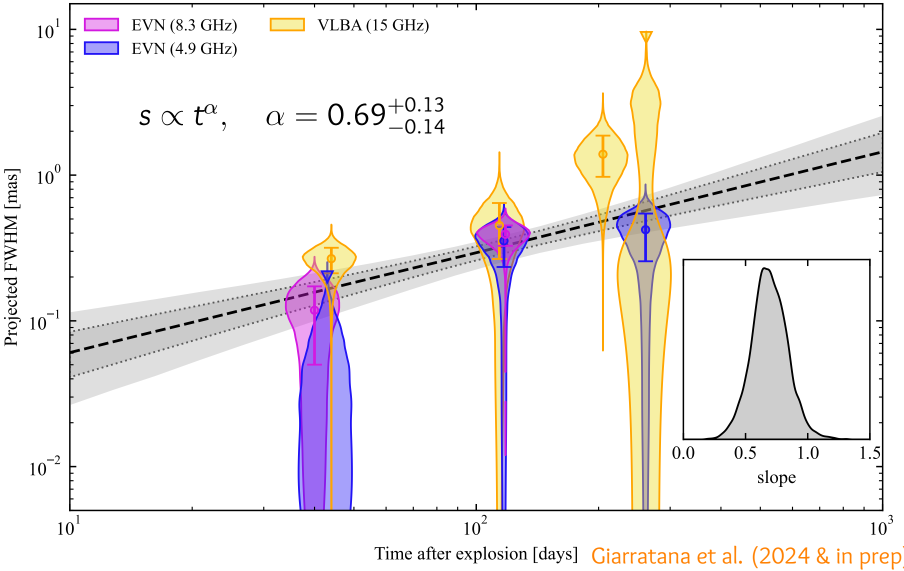
Reverse and forward shock contribution in the early radio afterglow.

We observed 40–261 d post-burst.



Swift's scattered rings (Tiengo et al. 2022)

The BOAT: GRB 221009A



Giarratana et al. (2024 & in prep)

SKA-LOW

THE SKA'S LOW-FREQUENCY TELESCOPE

LOCATION:
AUSTRALIA

FREQUENCY RANGE:
50 MHz–
350 MHz

131,072
ANTENNAS
SPREAD ACROSS **512** STATIONS

MAXIMUM BASELINE:
~65km

SKA-MID

THE SKA'S MID-FREQUENCY TELESCOPE

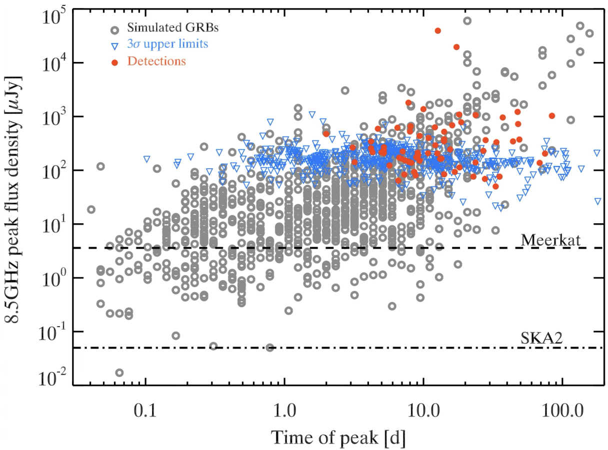
LOCATION:
SOUTH AFRICA

FREQUENCY RANGE:
350 MHz–
15.4 GHz
WITH A GOAL OF 24 GHz

197 DISHES
(INCLUDING 64 MEERKAT DISHES)

MAXIMUM BASELINE:
150km

GRBs in the SKA era



From ∼ 30% of radio detections to almost 100%. Plus constraints on expansion and proper motion (structure and geometry) with SKA-VLBI

Giarratana et al. (in prep) & adapted from Ghirlanda et al. (2013)

Take home messages

The **radio domain** can significantly contribute to the high energies and particle physics!

VLBI at gigahertz frequencies is key to characterize a significant fraction of transient events.

With **SKA** we will be able to detect and follow up most of the reported GRBs

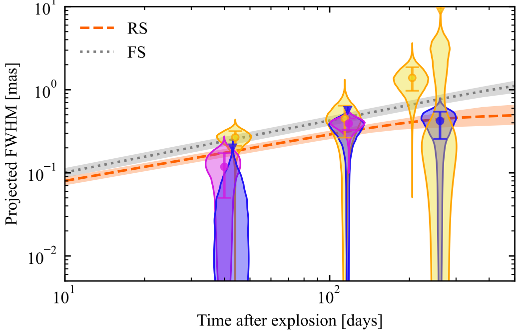
Measuring the afterglows would allow us to have a detailed and direct evolution of their reverse and forward shocks, plus the cocoon/jet interaction.

The BOAT: GRB 221009A

ISM

$k = 0$

15 GHz: FS-dominated
4.9-8.3 GHz: RS-dominated

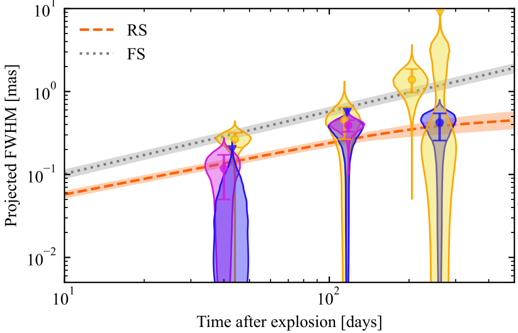


$\theta_j \approx 21^\circ, \quad E/A \approx 10^{57}$ erg cm^3

Wind

$k = 2$

15 GHz: FS-dominated
4.9-8.3 GHz: RS-dominated



$\theta_j \approx 23^\circ, \quad E/A \approx 10^{55}$ erg cm^3

(Giarratana et al. 2024, Giarratana et al. in prep)