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EUROPEAN VLBI NETWORK

How to use the European VLBI Network

-

EVN User Support

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ACME
Astrophysics Centre for Multimessenger studies in Europe

JIVE
Joint Institute for VLBI ERIC

The European VLBI Network

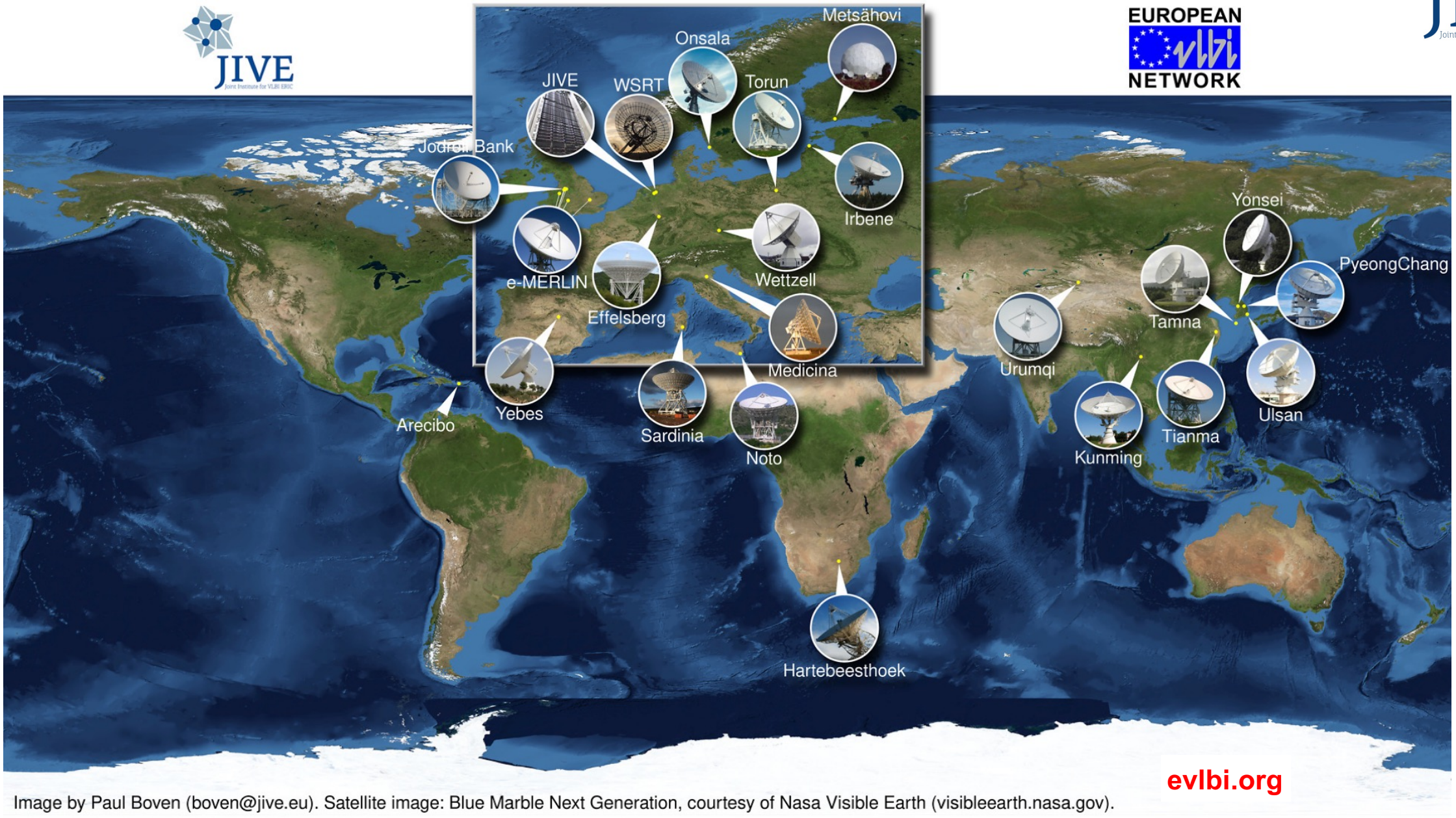
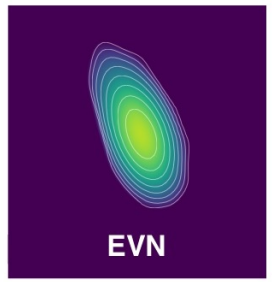


Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

EVN Update: new telescopes



Recently joined:

- uGMRT (India)
- MeerKAT (South Africa)

Added value:

- Robust calibration
- Emission on kpc scales (for extragalactic sources)
- Increasing resolution and sensitivity in the 18-21cm bands!
- SKA-VLBI connection

JIVE-SARAO Press release:
https://www.jive.eu/news/earth-sized-radio-observatory-just-got-better-south-africas-meerkat-telescope-joins-forces

The European VLBI Network

- **Comprises 20+ radio telescopes**
  - Generally larger (32m - 100m): more sensitive
    - Telescopes: Effelsberg (100m), JodrellBank (Lovell-76 m/MarkII-38m), Sardinia (65 m), Tianma (65m), Yebes, Kunming [40m], Svetloe, Badary, Zelenchukskaya, Medicina, Noto, Torun, Irbene [32m], Hartebeesthoek (26m), Onsala (25/20m), Westerbork, Sheshan, Urumqi[25m], Korean VLBI Network (Kt, Ky, Ku - 21 m, limited <= 1.3 cm), Wettzel (20m), Metasähovi (14 m) ran by 14 different observatories
    - + e-MERLIN out-stations (Cambridge (32m), Darnhall, Pickmere, Defford, Knockin [25 m]), Robledo (70/34m)
- **The most sensitive very-long-baseline interferometry (VLBI) array**
- **Frequency coverage: 1.4 — 43.0 GHz**
  - workhorses - 1.4/1.6 , 5 , 6.0/6.7, 2.3/8.4, 22, +43 & 0.3 (limited in global) (in GHz)

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  - workhorses - 1.4/1.6 , 5 , 6.0/6.7, 2.3/8.4, 22, +43 & 0.3 (limited in global) (in GHz)

- **Baselines up to 10,000 km**
  - e.g. Hh (S.Africa) to T6 (China), Hh (S.Africa) to KVN (S.Korea)
  - ~10s of km short baselines Jb2-Pi (UK)
- **Resolution ~ λ/B ~6 mas (1.4 GHz) – 0.3 mas (22 GHz)** with European, African, or Asian baselines.
- **Observing declination limit is -30 degrees**
- **Maximum data rate of 4 Gbps (for 5GHz and higher)**
  - Practical limit of 1 Gbps for 1.6 GHz and below because of stations' front-end limitations
- **Sensitivity ~ 6 μJy** (1.7 GHz, 1 Gbps bandwidth, 12 hr observations)

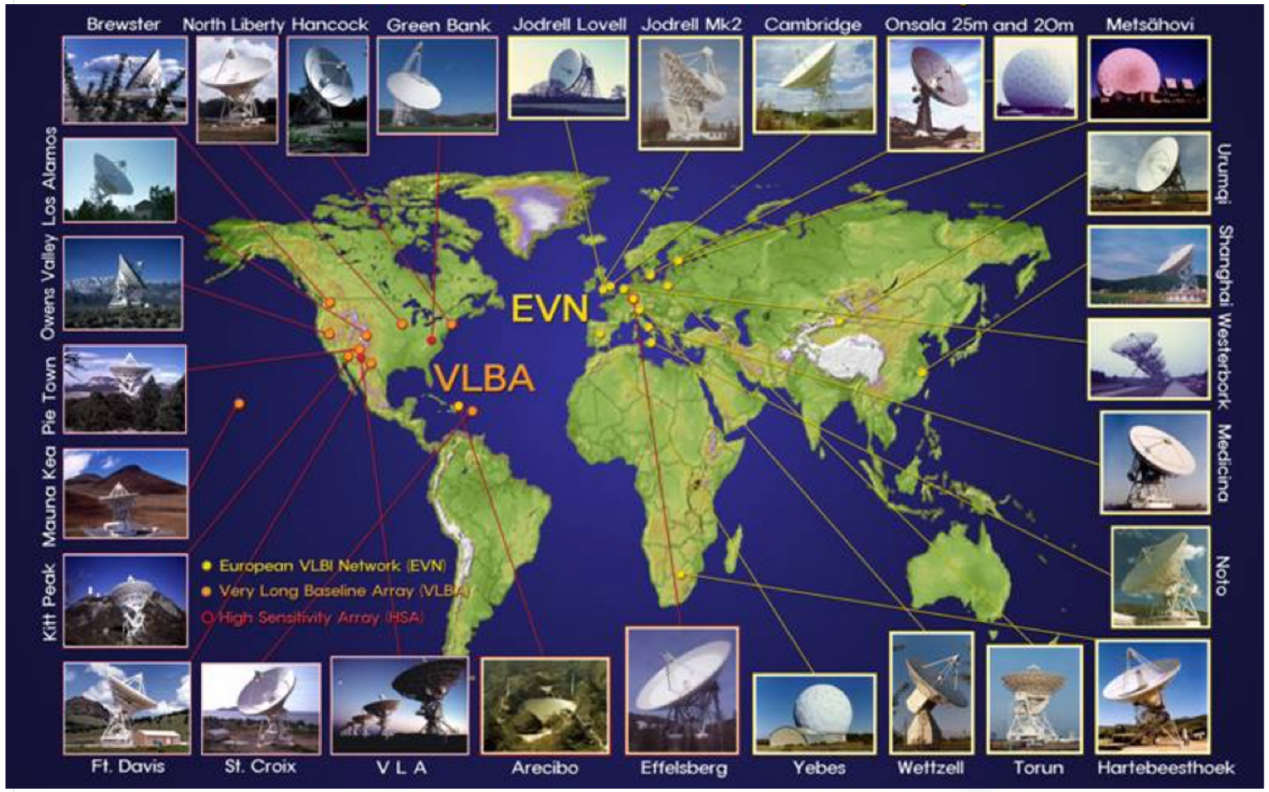
EVN Software Correlator at JIVE

- **Joint Institute for VLBI ERIC (JIVE)** is the central organisation of the EVN, founded in 1993 and located in Dwingeloo
- JIVE operate the EVN VLBI Data Processor
- **The EVN Software (SFXC) Correlator:** flexible operations: real-time e-VLBI, pulsar gating/binning, multiple phase-centres, fast transients

(Keimpema et al. 2015, https://arxiv.org/abs/1502.00467)

Photo: Zsolt Paragi

The Global VLBI Array



Global observations: EVN

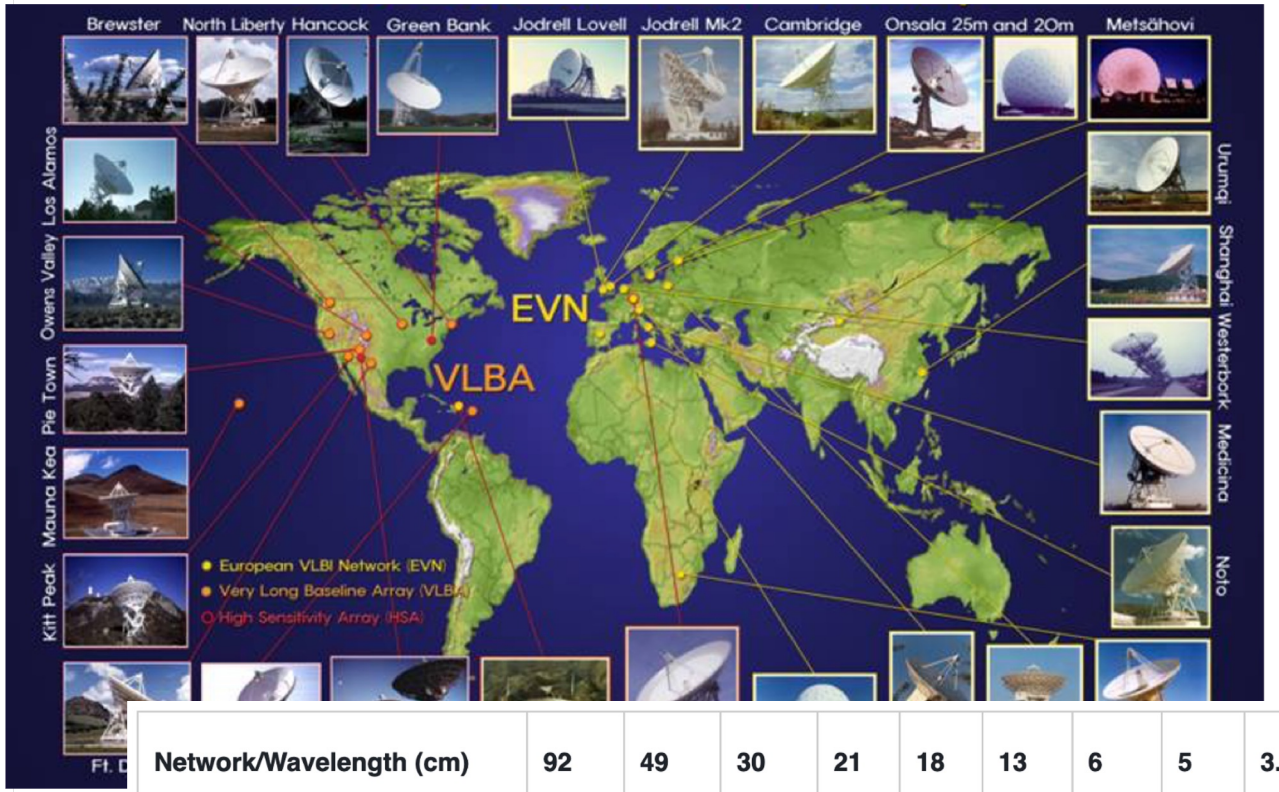
+ Very Long Baseline Array (VLBA)

+ Very Large Array (VLA)

+ Green Bank Telescope

→ More sensitivity and resolution

The Global VLBI Array



Global observations: EVN

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→ More sensitivity and resolution

Network/Wavelength (cm)	92	49	30	21	18	13	6	5	3.6	1.3	0.7		Longest baseline	
EVN-Europe	32.43	17.27	10.57	7.40	6.34	4.58	2.11	1.76	1.27	0.46	0.25		7139	Bd/Ro
EVN-Europe-Africa	24.91	13.27	8.12	5.69	4.87	3.52	1.62	1.35	0.97	0.35	0.19		9833	Bd/Hh
EVN-Europe-Asia	23.54	12.54	7.68	5.37	4.61	3.33	1.54	1.28	0.92	0.33	0.18		9294	Kt/Ro
EVN+VLBA	18.18	9.68	5.93	4.15	3.56	2.57	1.19	0.99	0.71	0.26	0.14		12733	Hh/Mk

EVN Observing Sessions

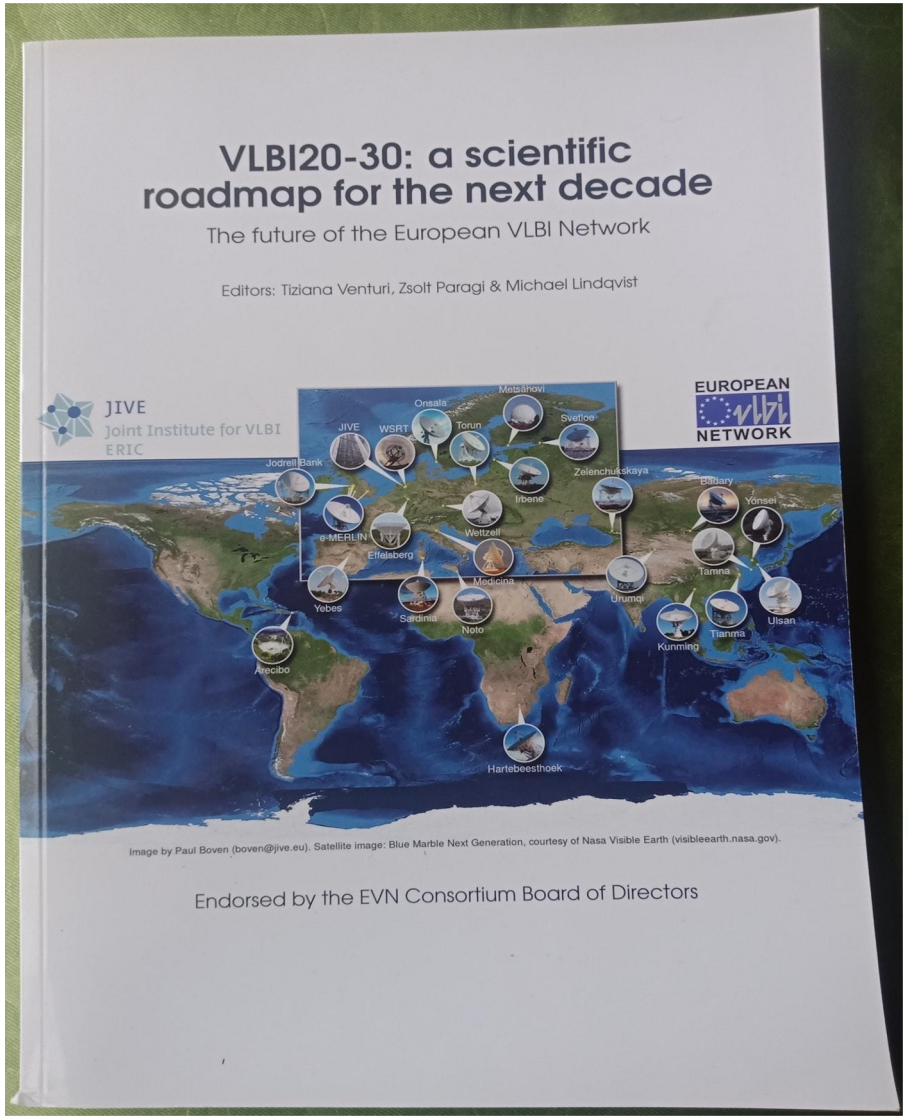
- **Three regular sessions per year**
  - ~ 3 weeks (Feb-Mar, May-June & Oct-Nov)
  - Disk-recorded at the stations, transported to JIVE later (either e-shipping from Mark6/FlexBuff to FlexBuffs at JIVE or physically shipping Mark5 packs)
  - Correlated at EVN SFXC correlator
- **Real time e-VLBI observations**
  - Data transmitted from stations to JIVE over fiber during the observations
  - Correlation proceeds in real time at the SFXC correlator and data distributed to PI within days
  - ~ 10 scheduled 24-hour e-VLBI sessions per year
- **Target of Opportunity observations**
  - *“When there is a rare and/or unpredictable event where there is a limited opportunity to make scientifically important observations”* e.g. just exploded supernovae, gamma-ray bursts etc.
  - in e-VLBI/regular sessions or out-of-session observation
- **EVN-lite**
  - *Out-of-session observations with ad-hoc EVN-subarrays (background program + occasional overrides)*
  - *Providing 5-600h of special observing, correlating only a small fraction of that (conditional; depending on science case)*
  - Strictly on a best-effort basis

EVN Science

Covers a broad range of topics ….

- AGNs - jet evolution, HI absorption studies
- Gravitational lenses
- Transients
- Galactic and extra-galactic masers
- Starburst galaxies
- Astrometry
- Radio jets and black hole physics
- Supernovae, novae and gamma-ray-bursts
- X-ray binaries
- Space-VLBI

The EVN Vision Document



- VLBI20-30: A technological roadmap was derived from the science requirements
- Summarises the science drivers for the EVN and the future activities of EVN

arxiv.org/abs/2007.0234

EVN Science: Blazar Jets

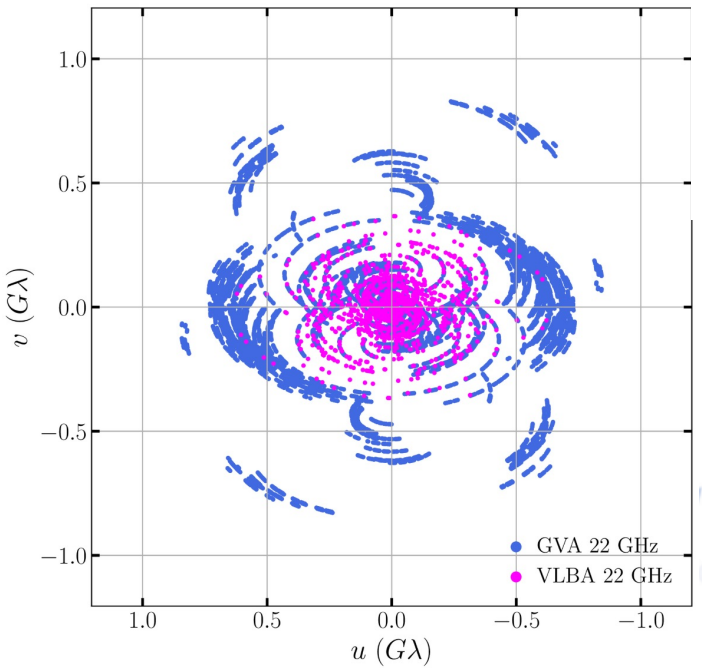
Limb-brightening in the parsec-scale jet of NGC 315

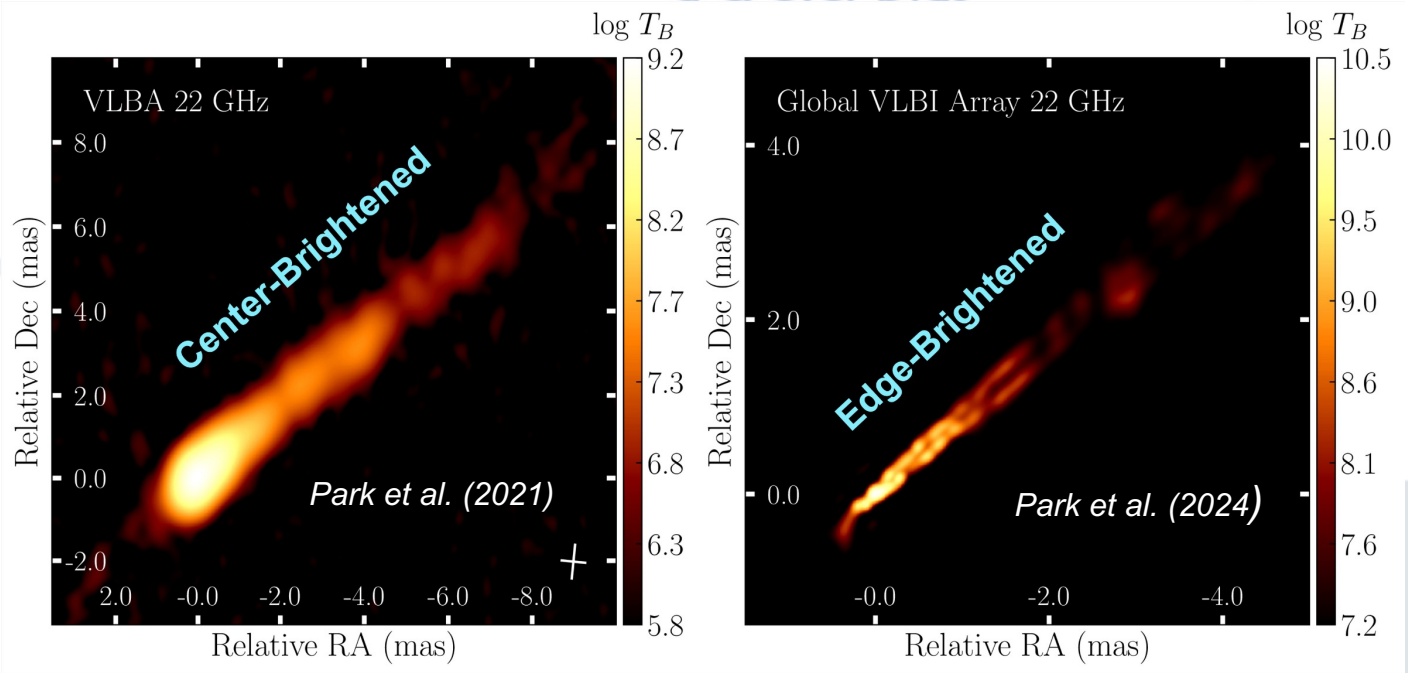
- NGC 315 “uv-coverages” with the VLBA (pink) & including EVN and the KVN (blue) (**GP060**)
- Previous VLBA study revealed a regular, centre-brightened jet
- New study with global baselines and Bayesian imaging techniques reveals an edge-brightened jet
- Results indicating either a structured jet as a (fast spine/slow sheath) or transverse variation in emissivity

Park et al. 2024, ApJ 973, L45

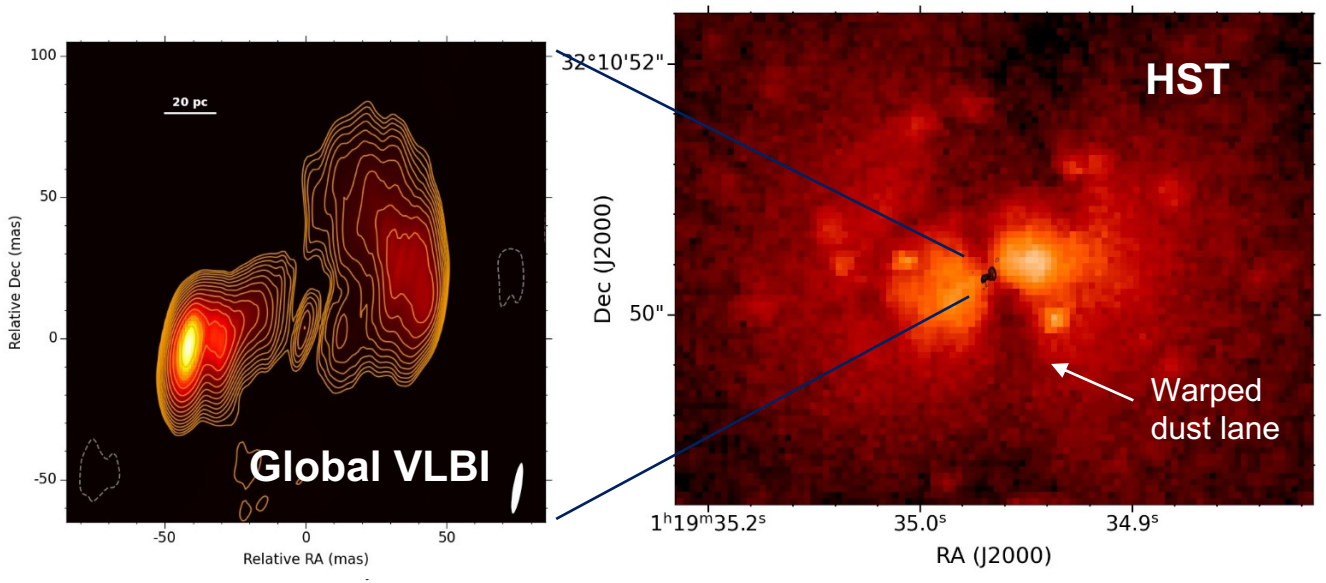
The true power of Global VLBI

The GVA offers not just gradual increase in sensitivity and slightly better resolution! Redistributing the baselines + using modern imaging techniques is a game changer for cm-VLBI!

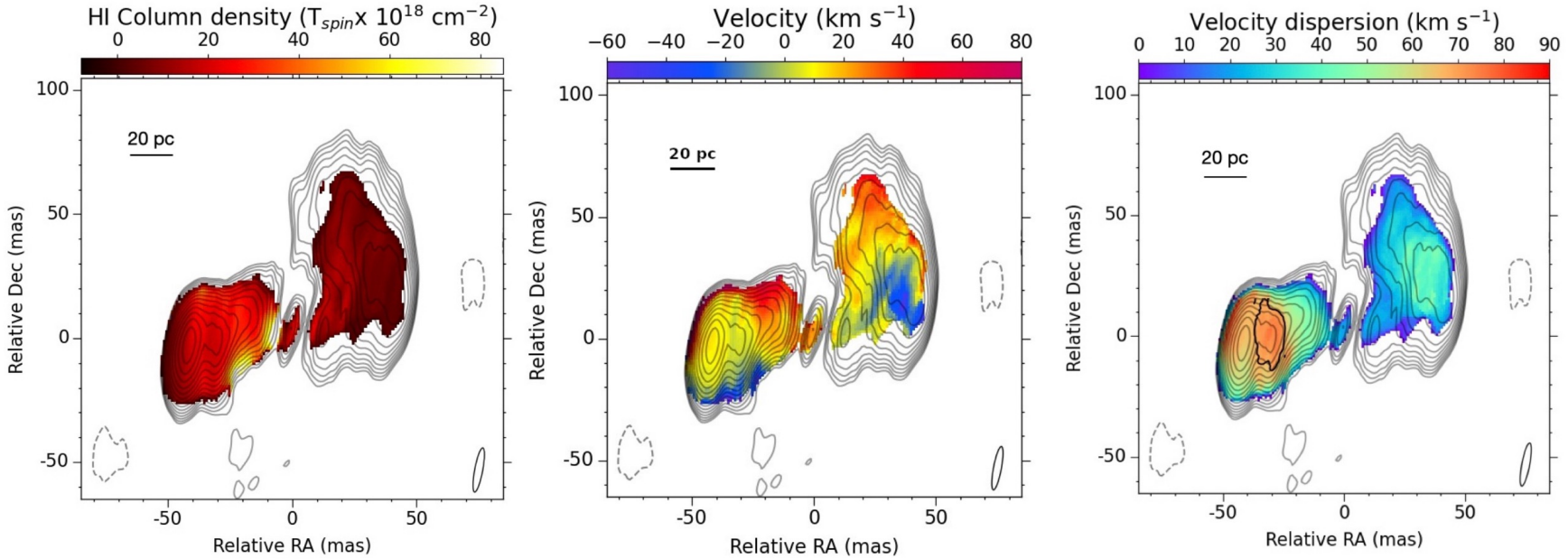




EVN Science: Feeding and feedback

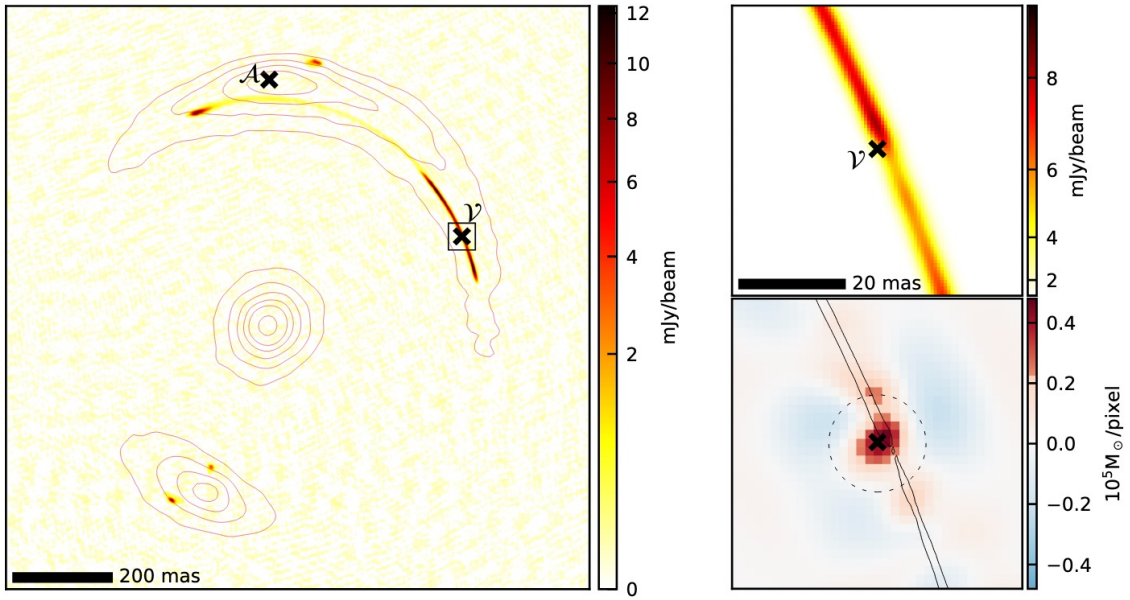


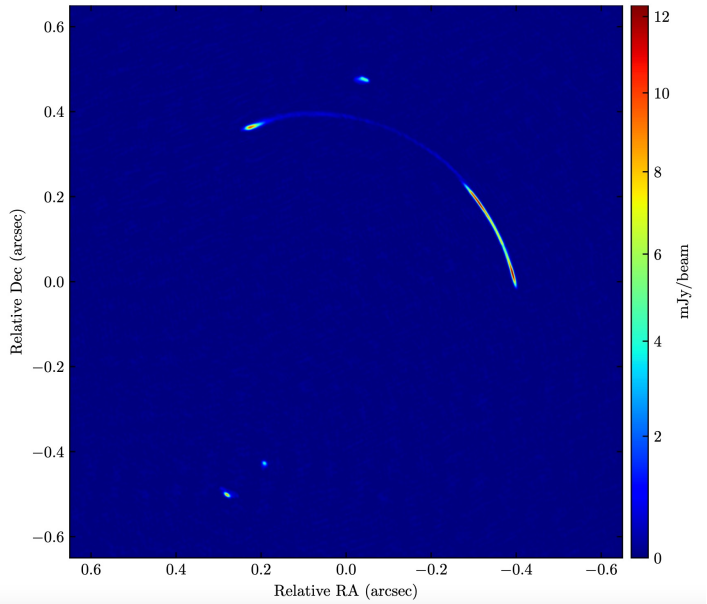
- Young radio source 4C31.04 (<5000yr) Spectral line Global VLBI observations in the 21cm band (**GS045**)
- Radio lobes expand to circumnuclear disc, perturbing the gas
- Eastern lobe shows signs of strong interaction, driving a large-scale outflow



Murthy et al. (2024)

EVN Science: Gravitational Lensing



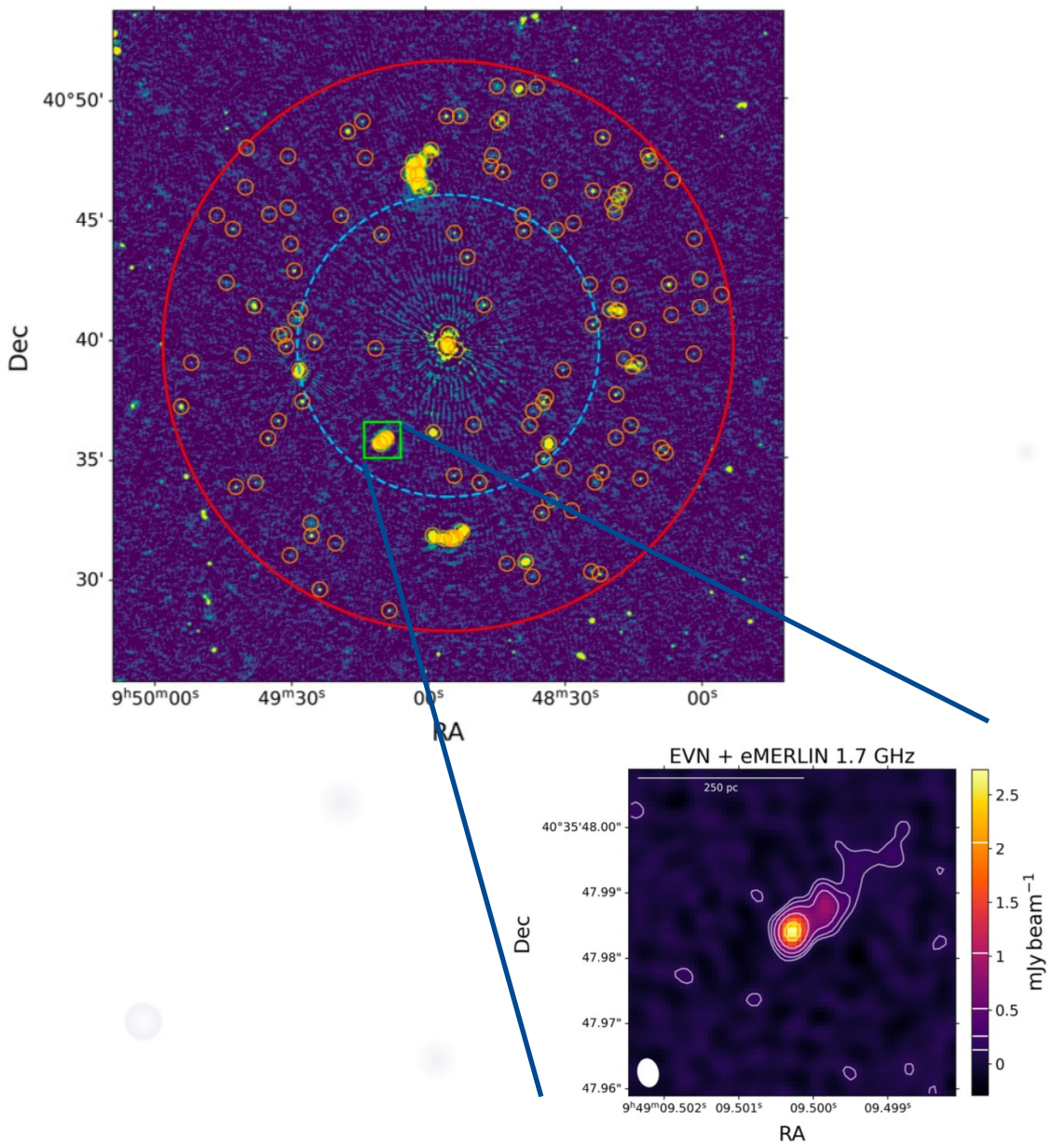


Extremely thin gravitational arc from a lensed CSO at z~2

- Global VLBI observations (GM068) of JVAS B1938+666 in 2011;
- Advanced Bayesian forward modelling deconvolution (not available at the time!)
- Found a million-Solar-mass object (z~0.88) of unknown origin perturbing the image
- This is by far the lowest-mass detected at a cosmological distance by its gravitational effect

Powell et al. 2025, Nature Astronomy, 9, 1714
McKean et al. 2025, MNRAS, 544, L24

EVN Science: Wide-field VLBI

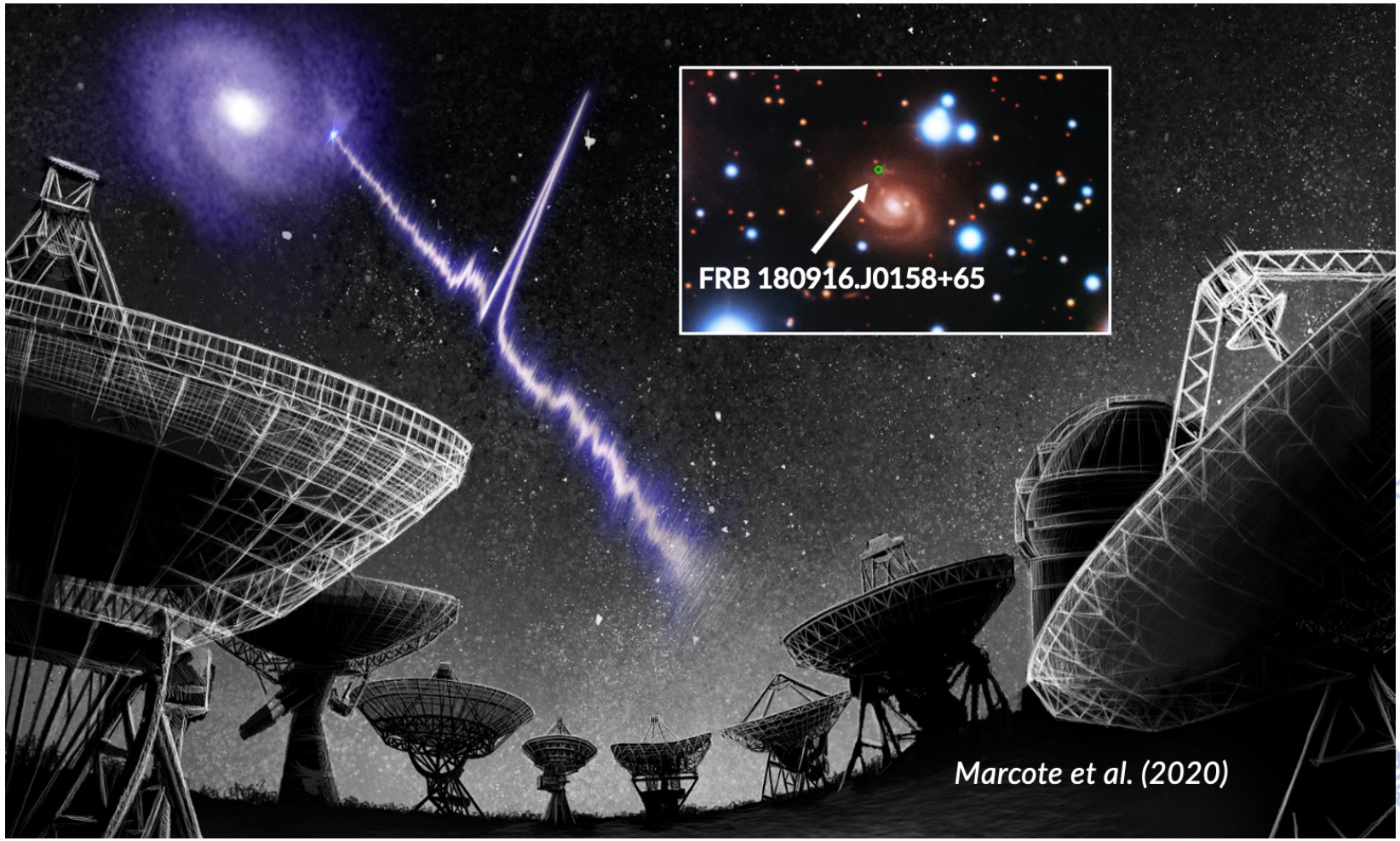


VLBI is a unique tool to study AGN and star-formation across cosmic time

- VLBI surveys so far focused on either a few deep fields, or very shallow wide-field observations
- Wide-fields of view: Multi-phase-centre correlation with the ***EVN Software Correlator at JIVE (SFXC)***
- SWEEPS idea: wide-field recorrelation (12') of all L-band EVN+e-MERLIN user projects
- Pilot: detected a field source in a user project (EM160; PI J. McKean)

Herbé-George et al. 2025, MNRAS 537, L49

EVN Science: short transients

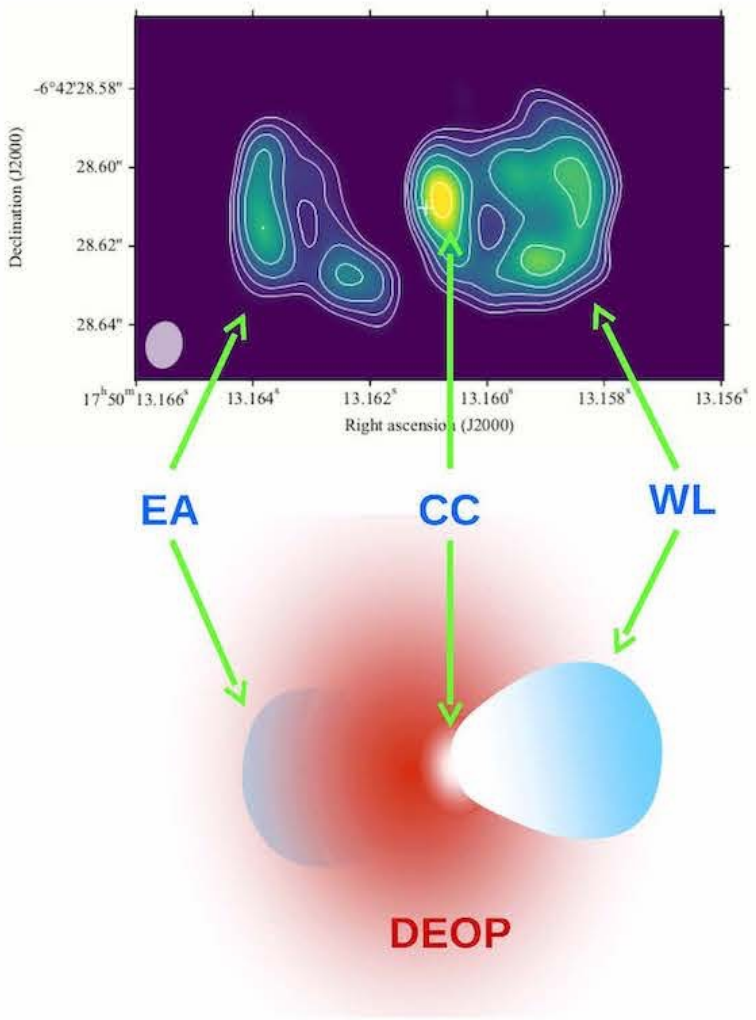


FRB localization on milliarcsecond scales with the EVN

- Fast Radio Burst (FRB): mysterious radio flashes of millisecond duration
- FRB 180916.J0158+65: The second FRB repeater associated to a star-forming region in a spiral galaxy (**EM135C**)
- FRBs occur in a range of environments

Marcote et al. 2020, Nature, 577, 190

EVN Science: Transients – Novae

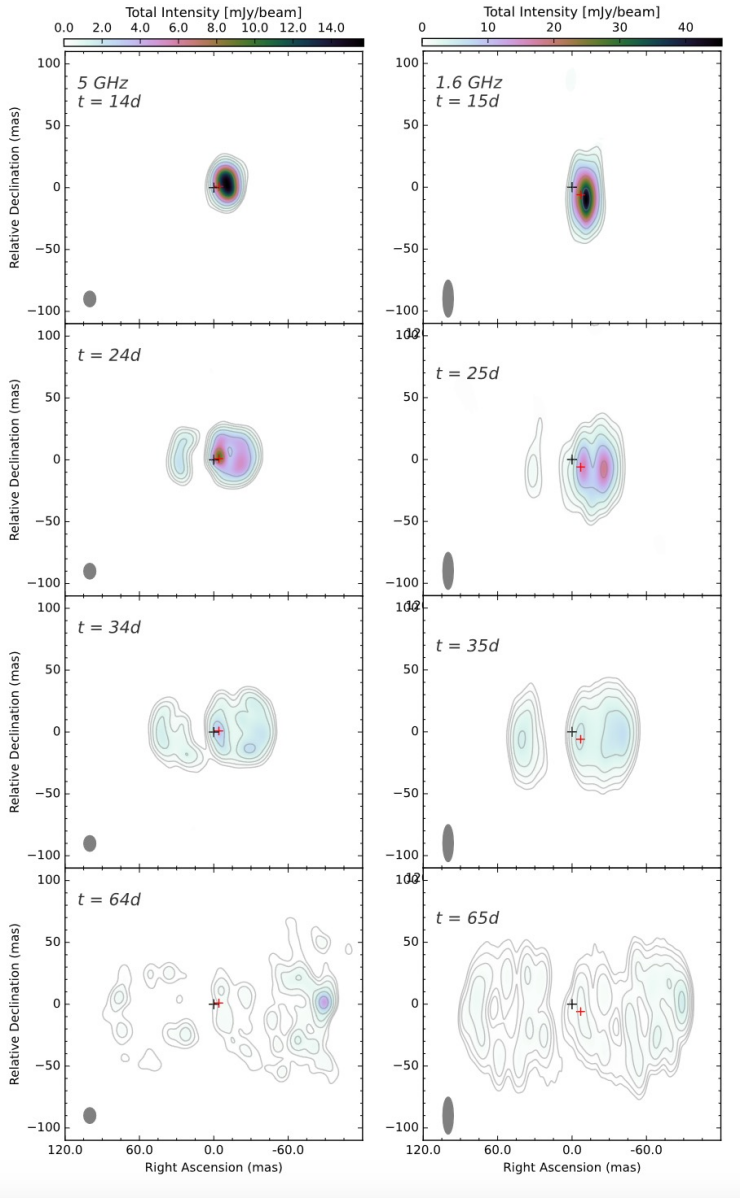


RS Oph: the fastest recurring symbiotic nova

- Novae are cataclysmic variables in close binaries; accretion-induced runaway thermonuclear flares in White Dwarfs
- Thermal and non-thermal processes: bright flaring on timescales of days to months, covering a range of spatial scales (~AU to 100s of AU)
- RS Oph: EVN monitoring through the 2021 outburst; EVN 5 GHz observations on day 34 presented (RG012E)
- Used optical spectroscopy, Gaia astrometry and EVN imaging to reconstruct an unprecedented 3D view of the pre-existing circumstellar environment and the expanding nova ejecta

Munari et al. 2022, Astron. Astrophys., 666, L6

EVN Science: RS Oph 2021 monitoring



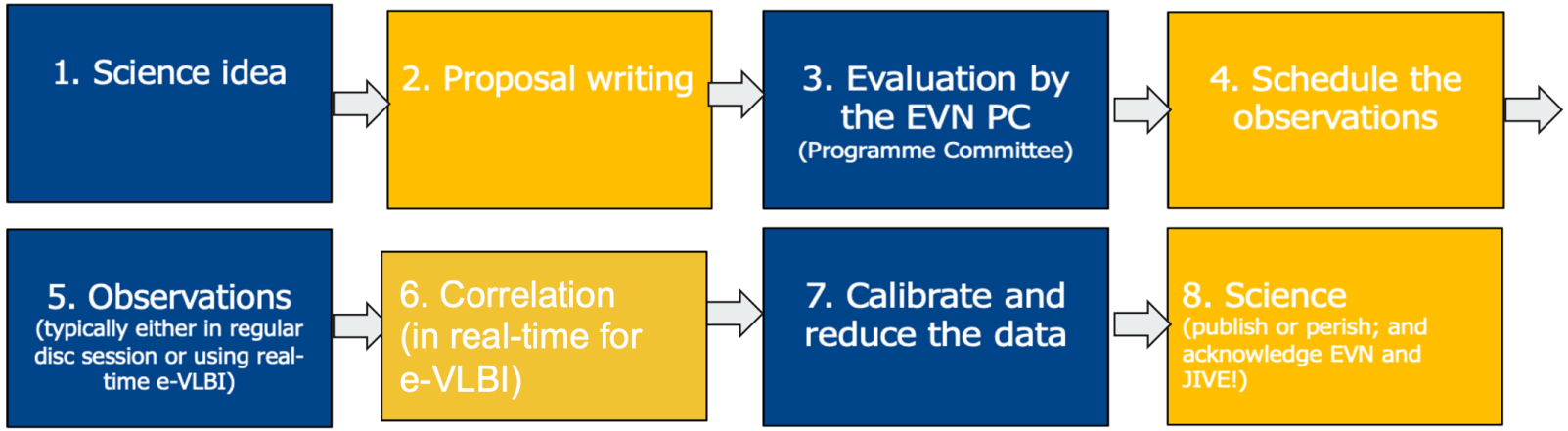
RS Oph: the fastest recurring symbiotic nova

- RS Oph 2021 outburst phase: first ever VHE detection (E>100 GeV); coordinated multi-band follow-up
- EVN+e-MERLIN monitoring through day 14-65, 1.6 – 5 GHz (18cm, 6cm; RG012)
- Clear evidence for density enhancement in the orbital plane, most mass-loss observed there
- Estimated 6x1e-6 $M_\odot$ total mass loss from red giant, of which only ~10% is accreted to the WD

Lico et al. 2024, Astron. Astrophys., 692, A107

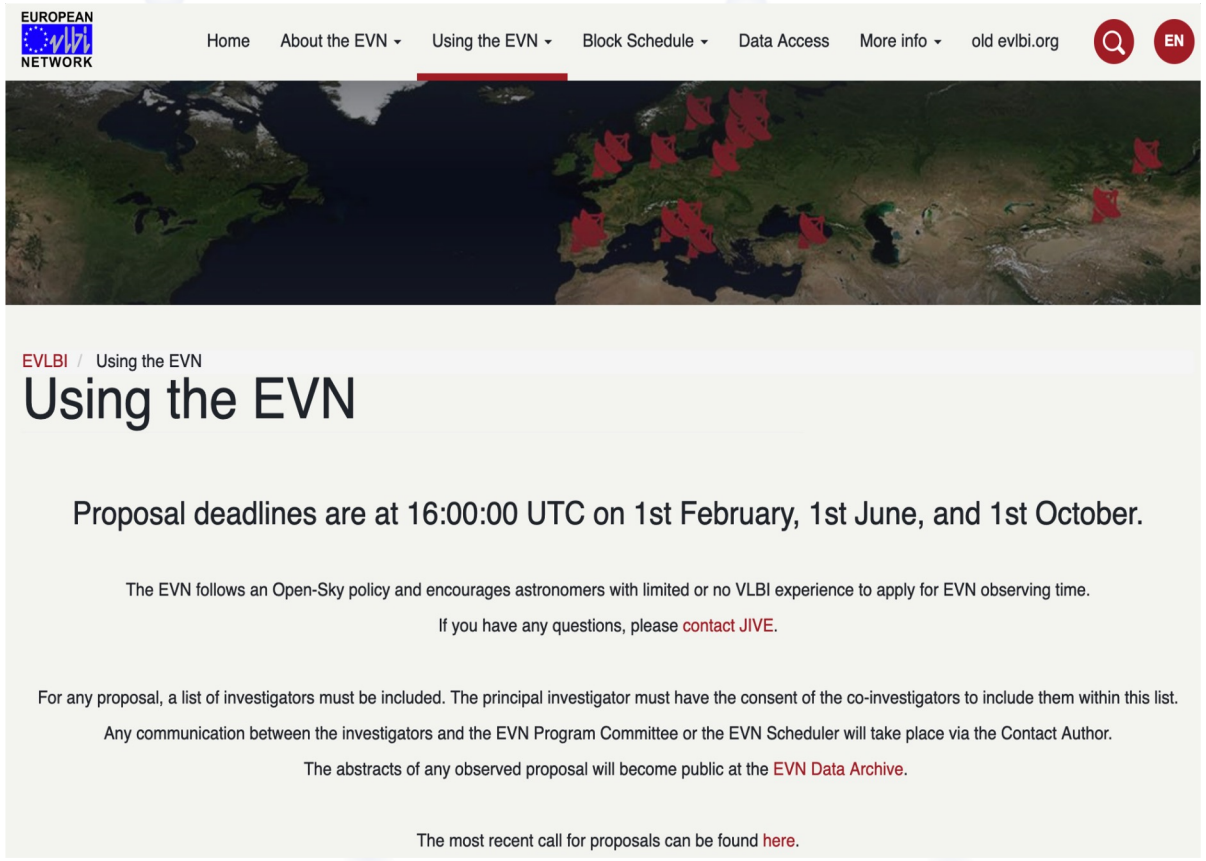
*See also the recent **EVN Seminar presentation**:*
https://www.youtube.com/live/bK1qFsFdyTE

The EVN workflow & User Support



- For support, contact us online: **usersupport@jive.eu**
  https://www.evlbi.org/article/evn-user-support-now-mattermost
- Or at JIVE – visit us!
  - **EVN Support+ programme** - support to groups with no experience with VLBI, and for strong science cases evaluated by the EVN PC
    - **evlbi.org/newsletter**
    - **evlbi.org/call-proposals**
  - **EVN Travel Support**
    - **evlbi.org/travel-support**

Proposal submission using NorthStar



- EVN proposal deadline for regular, e-VLBI, and joint EVN+NRAO global observations
  - Feb 1, June 1 and Oct 1 (at 16:00 UTC).

evlbi.org/using-evn

- NorthStar Tool:
  - All EVN+e-MERLIN & Global (EVN+NRAO) proposals
  - e-EVN proposals

proposal.jive.eu

- ToO proposals and short requests to be sent to the EVN program committee chair

The proposal

What makes a proposal successful?

- **The Science case**

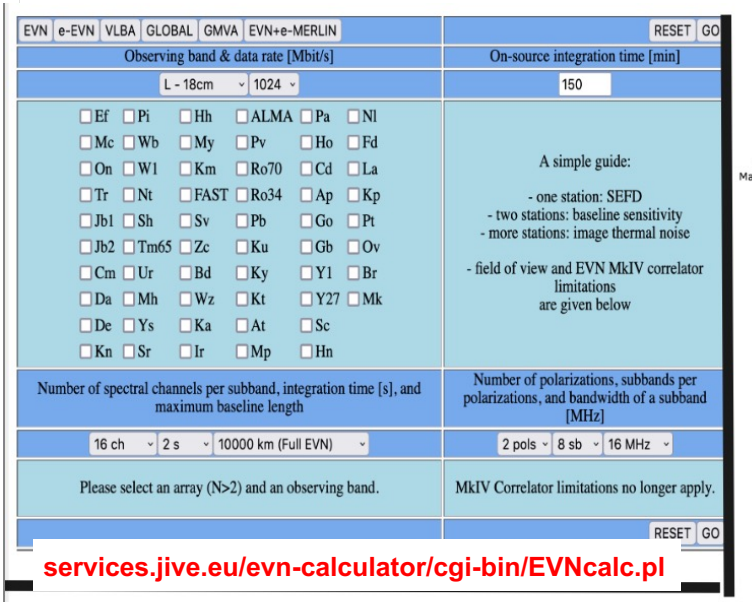
  - Pick a topical science case; provide a concise background
  - Have a very well-defined science goal! (was this done before?)
  - Clearly explain how the results will be achieved
  - Explain how the results will advance the field
    (in the context of the broader science case)

- **Technical justification**

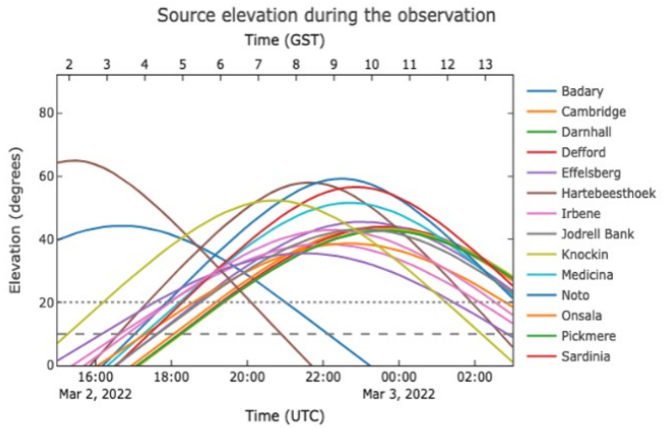
  - Can the results be achieved with the EVN?
    (technical feasibility!)
  - Is the EVN the best instrument to do this?
  - If e-MERLIN is requested: justify the addition of short spacings!
    (how will e-MERLIN contribute to achieving the science goals?)

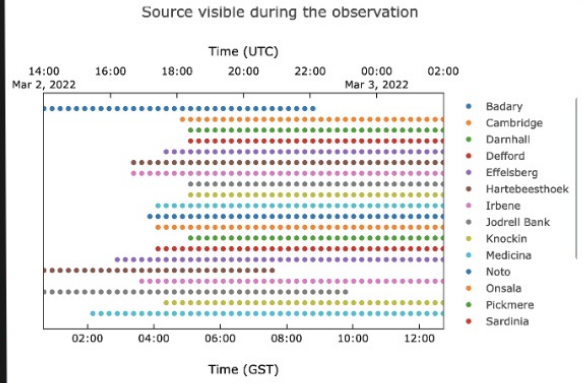
NO MORE THAN 2 PAGES OF TEXT OPTIONAL 2 PAGES FIGURES/TABLES!

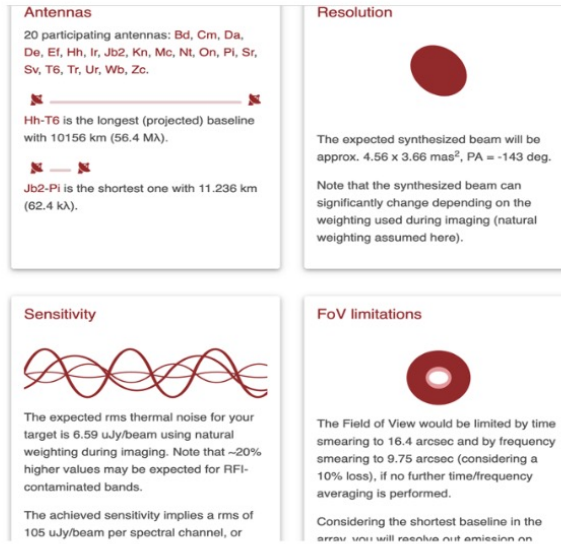
EVN Calculator and Observation Planner



services.jive.eu/evn-calculator/cgi-bin/EVNcalc.pl







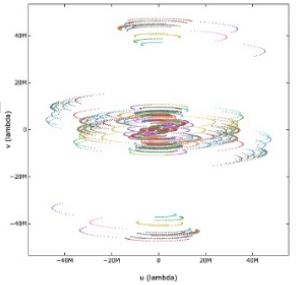
EUROPEAN VLBI NETWORK

EVN Observation Planner

JIVE Joint Institute for VLBI ERIC

planobs.jive.eu

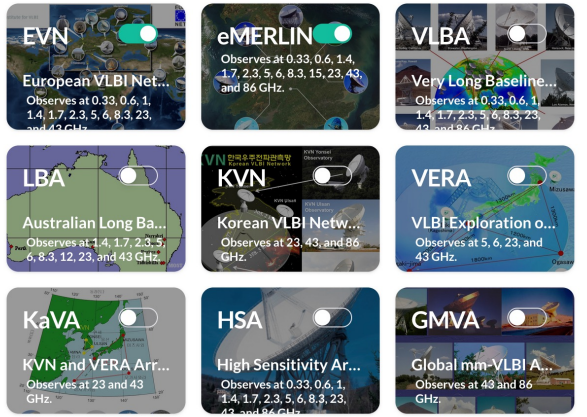
The EVN Observation Planner allows you to plan observations with the European VLBI Network (EVN) and other Very Long Baseline Interferometry (VLBI) networks. The EVN Observation Planner helps you to determine when your source can be observed by the different antennas, and provides the expected outcome of these observations, like the expected sensitivity or resolution.



Observing band — Show wavelenths

ν (GHz) 0.33 0.6 1 1.4 1.7 2.3 5 6 8.3 12 15 23 43 86 230 345

Select default VLBI Network(s)



More extensive help to plan an observation or to prepare for proposal submission, including array selection, target visibility at telescopes, uv-coverage, resolution, etc.

evlbi.org/evn-scheduling

The EVN Data Archive

JIVE
Joint Institute for VLBI ERIC

EVN Data Archive at JIVE

Availability of standard plots, pipeline and fitsfiles.

Select Sort order: Experiment Observation period: 2020 - 2021 Submit Query

Experiment	Stnd	Pipe	Fits	P.Investigator	Stations	Obs. Date	Distr. Date	Publ. Date	Support Scientist
EA065A	x	x	x	Atri	JbWbEfMcO8TrHhIrCmDaDeKnPi	210921	210924	230204	Marcote
EA065B	x	x	x	Atri	JbWbEfMcNtO8TrHhSvZcBdIrCmDaDeKnPi	211116	220204	230204	Marcote/Orosz
EA065C				Atri	JbWbEfMcNtO8TrHhIrCmDaKnPiDe	211207			Marcote/Orosz
EB064G	x	x	x	Bach	JbEfMcNtO6UrTrYsHhSvZcBdSrMhT6KtKyKu	200605	200905	220518	Nair
EB064H	x	x	x	Bach	JbEfMcNtO6UrTrYsHhSvZcBdSrMh	200607	200805	220518	Nair
EB064I	x	x	x	Bach	JbEfMcO6UrTrYsSvZcBdHhMhSrT6KtKyKu	210317	210518	220518	Nair
EB064J	x	x	x	Bach	JbEfMcO6UrTrYsSvZcBdHhMhSr	210318	210512	220518	Nair
EB074C	x	x	x	Bruni	WbEfMcNtO6T6UrYsHhSvZcBdIr	201019	210112	220204	Bayandina
EB074D	x	x	x	Bruni	WbEfMcNtO6T6UrYsHhSvZcBdIr	201020	210113	220204	Bayandina
EB074E	x	x	x	Bruni	JbEfMcO6T6UrTrYsHhSvZcBdSrMhKtKyKu	201026	210121	220204	Bayandina
EB074F	x	x	x	Bruni	JbEfMcO6T6UrTrYsHhSvZcBdSrMhKtKyKu	201026	210122	220204	Bayandina
EB079	x	x	x	Bartkiewicz	JbEfMcNtO8TrWbYsIrT6SrKmCmDaDeKnPi	201016	201222	211222	Bayandina
EB080	x	x	x	Bartkiewicz	JbEfMcO8TrNtWbYsT6HhIrSr	200602	200810	210810	Bayandina
EB081A	x	x	x	Boven	JbWbEfO8T6UrHhSvZcBdIrPi	200609	200925	220722	Marcote
EB081B	x	x	x	Boven	JlJbWbEfMcNtO8T6UrTrHhSvZcBdIrSr	201104	210305	220722	Nair
EB081C	x	x	x	Boven	JlJbWbEfMcNtO8T6UrTrHhSvZcBdIrSr	210303	210722	220722	Nair
EB082	x	x	x	Boven	JbWbEfMcNtO8T6UrTrHhSvZcBdIrSr	201104	210318	220318	Bayandina
EB084	x	x	x	Bayandina	BdKuKyKtT6UrHhZcSrMcTrYsCmJbEfDaKnPiO6	210311	210607	220607	Bayandina
EB085B				Bietenholz	WbEfMcNtO6ShUrTrYsSvZcBdIrKmHh	211107			Paragi
EB085	x		x	Bietenholz	WbEfMcNtO6T6UrSvZcIrBdKmYsHh	210313	210520	220520	Paragi
EB087				Burns	JbWbEfMcNtO8TrYsHhIrShKm	211103			Bayandina
EB088	x	x	x	Bright	JbWbEfMcNtO8UrTrHhSvZcBdIr	211026	220204	230204	Marcote
EB089A				Boven	JbWbEfMcNtO8UrTrHhSvZcBdIrCmDaKnPiDeJl	211102			
EB090A				Boccardi	JbWbEfMcNtO8UrTrHhSvZcBdIrCmDaDeKnPi	211028			
EB090B				Boccardi	JbWbEfMcNtO8UrTrHhSvZcBdIrCmDaDeKnPi	211102			
EC070E	x	x	x	Chiaraluce	WbEfO6T6UrHhYsSvZcBdIr	200220	200508	210909	Nair
EC070F	x	x	x	Chiaraluce	WbO6UrHhYsSvZcIrEf	200222	200508	210909	Nair
EC070G	x	x	x	Chiaraluce	WbEfO6T6UrHhYsSvZcBdIr	200222	200508	210909	Nair
EC070H	x	x	x	Chiaraluce	WbEfO6T6UrHhYsSvZcBdIr	200223	200514	210909	Nair
EC070I	x	x	x	Chiaraluce	JbWbEfO8UrTrHhYsSvZcIr	200226	200514	210909	Nair
EC070J	x	x	x	Chiaraluce	JbWbEfO8T6UrTrHhYsSvZcBdIr	200226	200519	210909	Nair

Correlation

↓

post-correlation processing by support scientists

↓

prepare FITS files, calibration metadata and run a pipeline

↓

EVN Data Archive

Proprietary period of 1 year for regular proposals and 6 months for ToO

archive.jive.eu/scripts/listarch.php

The EVN Data Reduction Guide

JIVE
Joint Institute for VLBI ERIC

evlbi.org/evn-data-reduction-guide

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EVN Data Reduction Guide

Become familiar with EVN data reduction in AIPS or CASA. Here you can find the basic commands to calibrate your EVN data using any of the two packages (AIPS instructions on the left column, CASA instructions on the right column). **Hover your mouse over the different parameters to know their meaning and the explanation about the chosen values.** Note that VLBI data reduction under CASA is still under heavy development, and thus several options available in AIPS may still be missing in CASA.
You can also access the EVN Data Reduction Tutorials to follow a hands on calibration.

- First steps.
- Inspecting the data.
- Calibration:
  - Atmospheric corrections.
  - Bandpass calibration.
  - Instrumental delay correction.
  - Delay and rate calibration (fringe).
- Split the data.
- Imaging.
- Post-imaging steps:
  - Image fitting and statistics.
  - Self-calibration.
- Specific observing modes:
  - Multi phase-center observations.
  - Primary beam corrections.
- Frequently Asked Questions (FAQ).

Obtaining the data

The very first step is to obtain your EVN data, that can be retrieved from the EVN Data Archive. See the detailed instructions from the EVN Data Access page.

At this point you should have several FITS IDI files containing the visibility data from your observation and a `tasav.FITS` file containing the calibration tables generated by the EVN Pipeline.

AIPS

Start AIPS and load the data

AIPS can be started by typing (you may need to initialize the environment before hand): `aips tv=local:0`. Introduce the AIPS user number that you wish to use for the session.

The EVN data need to be loaded as:

```
default fitld
datain 'PWD:experiment_1_1.IDI
digicor -1
doconcat 1
ncount n
outname 'exp'
go fitld
recat
```

And the same for the `tasav` FITS file:

```
tget fitld
datain 'PWD:experiment_tasav.FITS
digicor -1
doconcat -1
ncount 1
outname 'exp'
go fitld
```

The useful calibration tables from the EVN Pipeline must be transfered from the tasav file to the data. In the case of EVN data, this means the CL table no. 2 (calibration table containing the parallactic angle and a-priori gain corrections), the a-priori flagging (FG) table, and, optionally, the bandpass (BP) calibration.

```
default tacop
getn 2
geton 1
inext 'CL'
invers 2
ncount 1
go tacop
```

```
tget tacop
inext 'FG'
invers 1
ncount 1
go tacop
```

CASA

Start CASA and load the data

Before starting CASA it is required to download some external Python scripts located under this link (`append_tsys.py, flag.py, key.py, gc.py`). A new environmental variable `$PYCAPATH` needs to be set, pointing to the directory where these scripts are located, and `$PYTHONPATH` also needs to be set/updated to include the same directory.
Additionally to the previous downloaded files, another two files from the EVN Data Archive are required. Under the "Pipeline" tab, download both the *Associated EVN calibration* (`antab file`) and the *UVFLG flagged data* (`uvflg file`).

First, the a-priori flag commands will be converted into a CASA-compatible format:

```
python $PYCAPATH/flag.py experiment.uvflg experiment_1_1.IDI1 > exper
iment.flag
```

Second, the a-priori gain calibration (system temperature measurements) will be incorporated into the IDI FITS files:

```
casa --nogui -c $PYCAPATH/append_tsys.py experiment.antab experiment_
1_1.IDI*
```

Note that this step can only be run once. Multiple runs will cause problems later and it cannot be undone.
Finally, the gain curve calibration table (how the system temperature values are converted to Jansky units) must be generated with:

```
casa --nogui -c $PYCAPATH/gc.py experiment.antab EVN.gc
```

In some cases a restricted range for the aceptable elevation values must be set with the options , as some extreme values may cause the gain curves to fail.

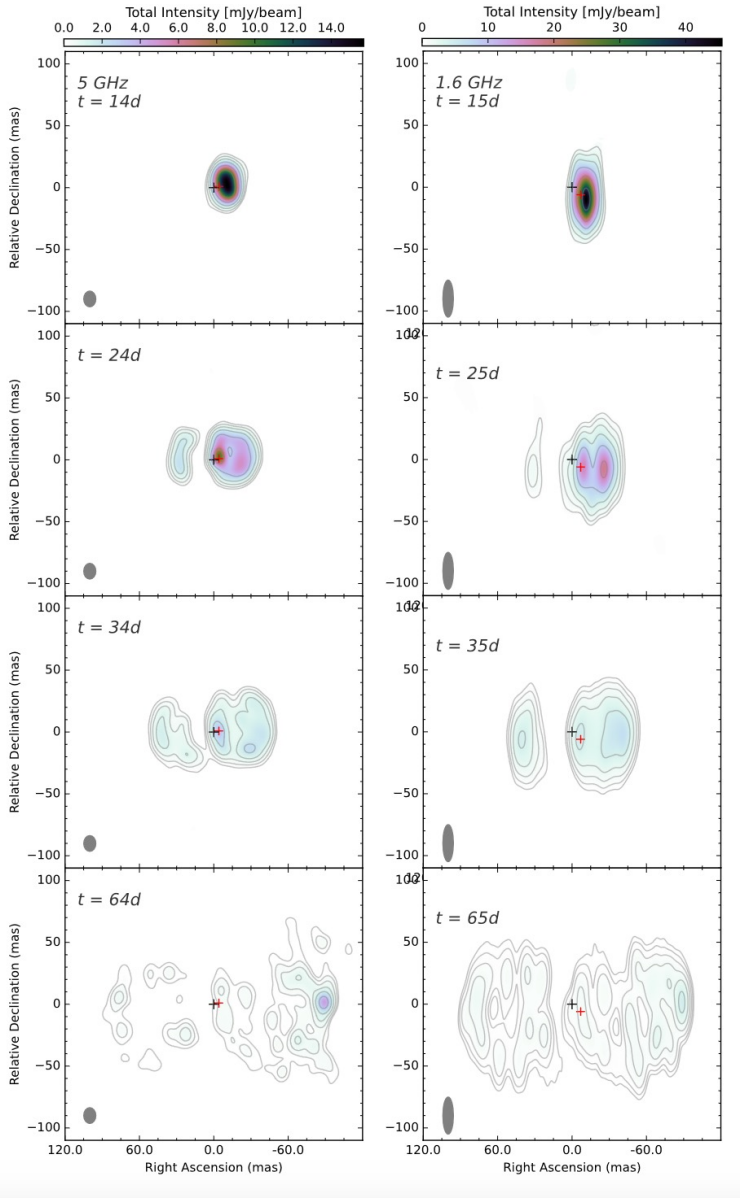
CASA can be started by typing `casa` . The IDI FITS files may be converted to a Measurement Set (MS) file, the native format for CASA:

```
import glob
myidifiles = sorted(glob.glob('experiment*IDI*'))
importfitsidi(vis='experiment.ms',
    fitsidifile=myidifiles,
    constobsid=True,
    scanreindexgap_s=15.0)
```

For data reduction training join a future ERIS and JIVE/EVN schools!

usersupport@jive.eu

This training: make an EVN proposal



RS Oph, T CrB…: Prepare for an imminent nova outburst

- In this example we prepare for a **triggered proposal**: we describe the science case for a future event! (Note in many cases **ToO proposals** work better, but the triggered proposal class is suitable for expected future events where the science case can be described well in advance)
- Must define exact **triggering conditions**, based on multi-band flaring source properties!
- Describe **array configuration** (EVN+e-MERLIN!), **observing frequencies** (spectral indeces needed?), observing **time ranges and cadence** – motivated by the science goals!
- We will use **PlanObs** and **Northstar** to prepare the proposal (for the following steps of preparing for the observations, join the 29 April online training!)

Astrophysics Centre for Multimessenger studies in Europe

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ACME
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Broaden access to infrastructures, data, expertise, tools… for multi-messenger science.

- Open calls for data sharing and visiting institutes.
- Organisation of schools and workshops.
- …

Funded by the European Union

The ACME project has received funding from the European Union's Horizon Europe Research and innovation programme under Grant Agreement No 101131928.

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