# The EVN and JIVE

By

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*Joint Institute for VLBI ERIC (JIVE)*

# Contents

- The European VLBI Network (EVN)
- The Joint Institute for VLBI ERIC (JIVE)
- (A few) recent VLBI results
- Globalization of VLBI

# European VLBI Network (EVN)

- The EVN is a network of radio telescopes located primarily in Europe and Asia, with additional antennas in South Africa and Puerto Rico, which performs high angular resolution observations of cosmic radio sources.
- It is **the most sensitive VLBI array in the world**, thanks to the collection of extremely large telescopes that contribute to the network, operating from 1.4 GHz to 45 GHz (some up to 90 GHz), also in **real-time** (*e*EVN).
- The **Joint Institute for VLBI ERIC (JIVE)** correlates the EVN data and **provides expert support to EVN users**.

**http://www.evlbi.org/**

JIVE

JIVE
Joint Institute for VLBI ERIC

EUROPEAN VLBI NETWORK

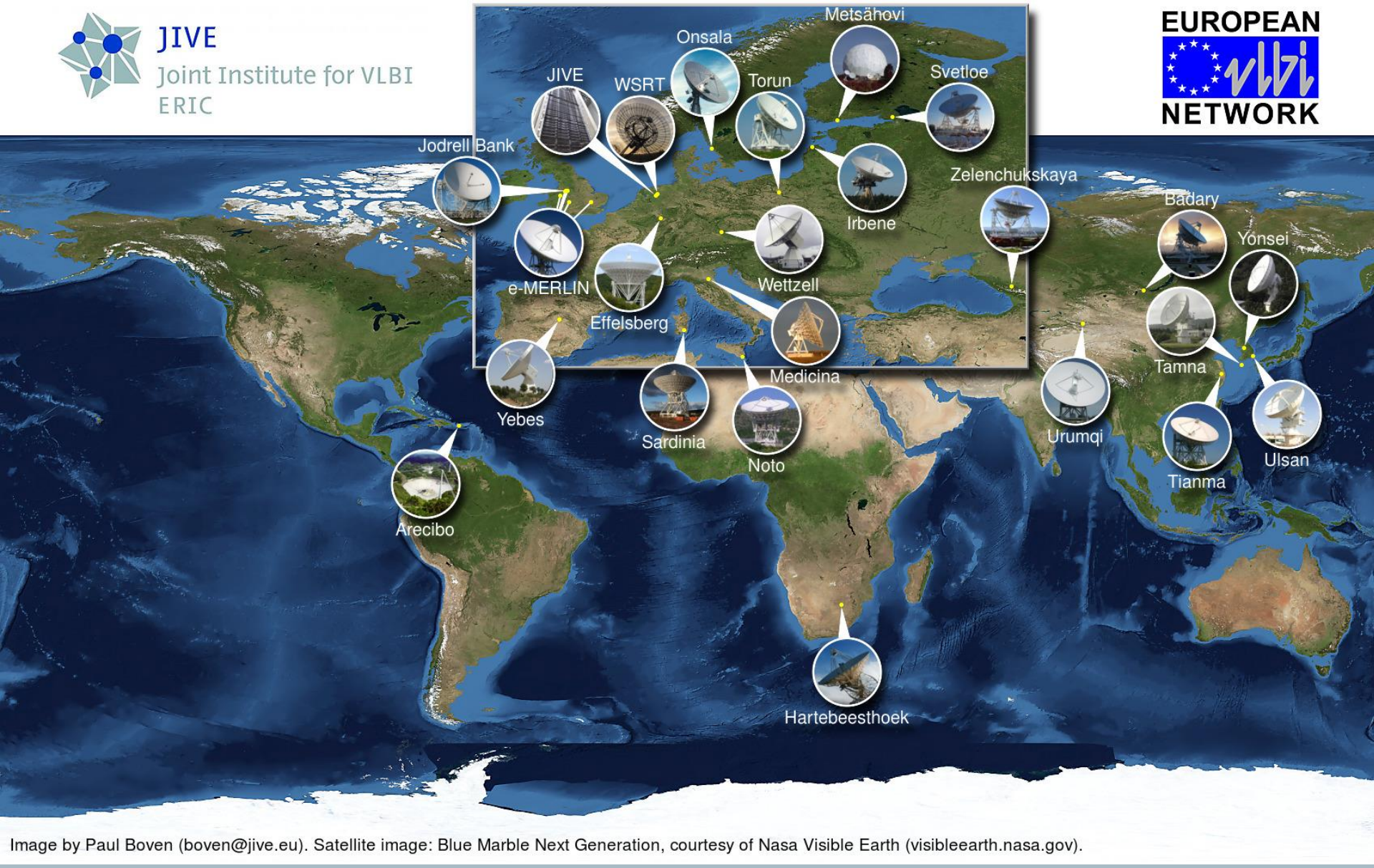


Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

www.jive.eu / www.evlbi.org

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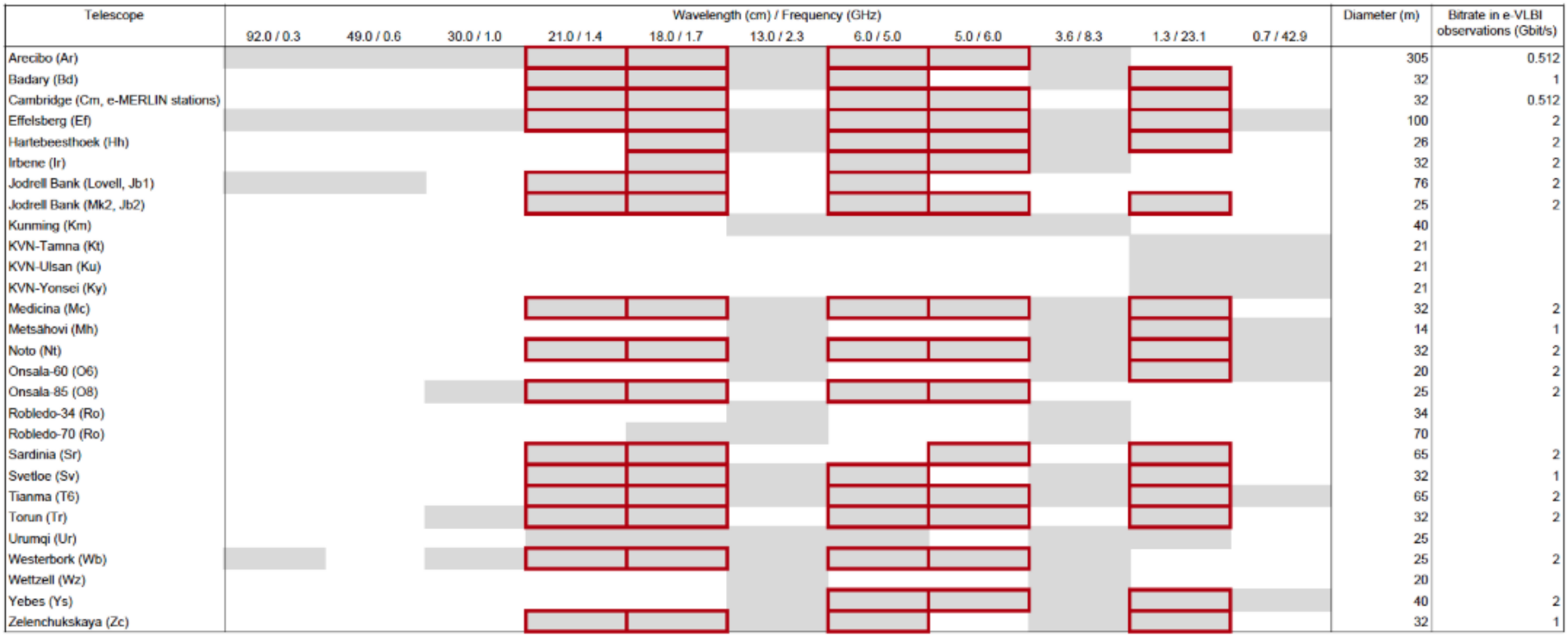
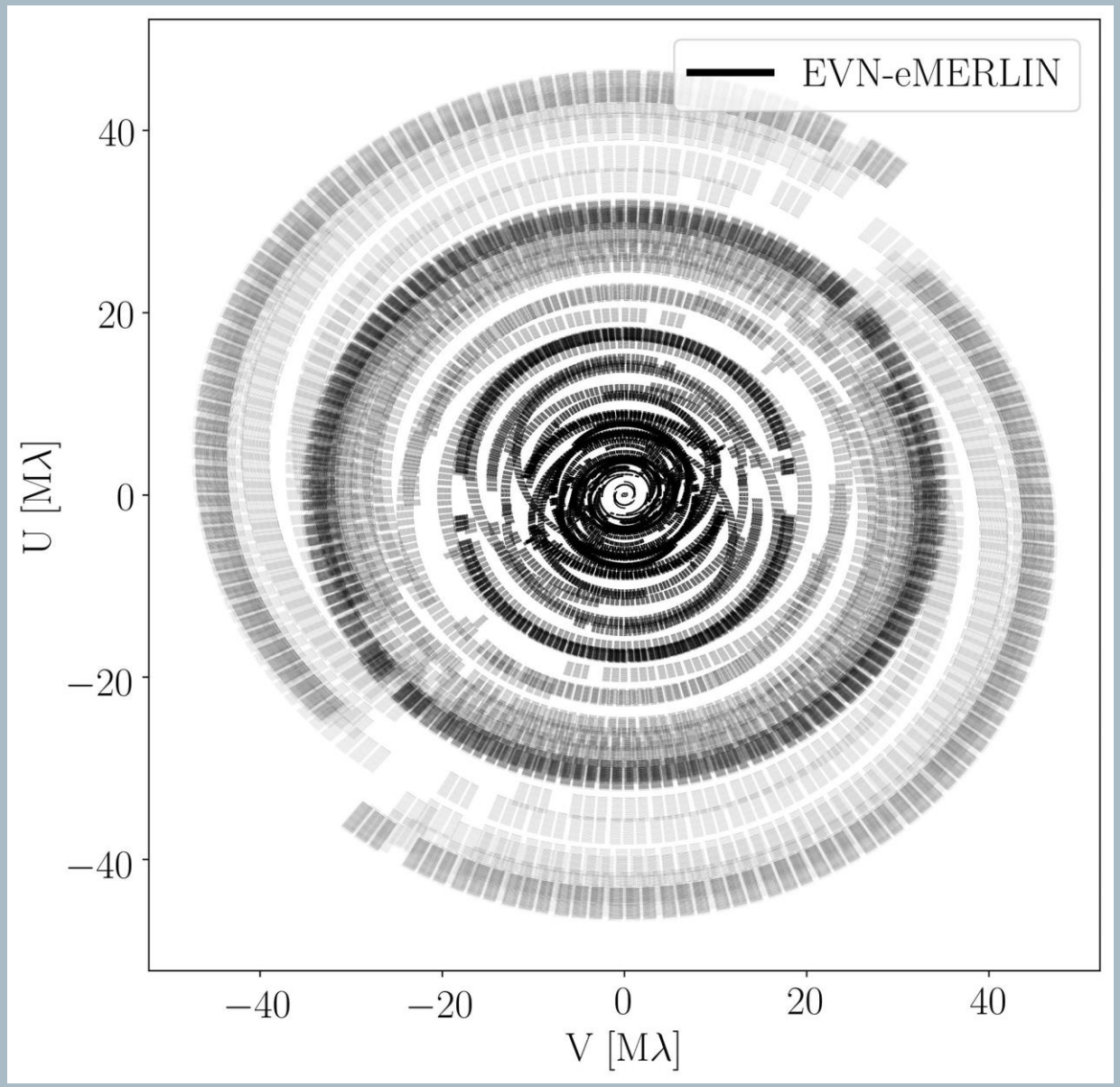
# EVN frequencies



| Telescope | Wavelength (cm) / Frequency (GHz) | | | | | | | | | | | Diameter (m) | Bitrate in e-VLBI observations (Gbit/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 92.0 / 0.3 | 49.0 / 0.6 | 30.0 / 1.0 | 21.0 / 1.4 | 18.0 / 1.7 | 13.0 / 2.3 | 6.0 / 5.0 | 5.0 / 6.0 | 3.6 / 8.3 | 1.3 / 23.1 | 0.7 / 42.9 | | |
| Arecibo (Ar) | | | | ■ | ■ | | ■ | ■ | | | | 305 | 0.512 |
| Badary (Bd) | | | | ■ | ■ | | ■ | | | ■ | | 32 | 1 |
| Cambridge (Cm, e-MERLIN stations) | | | | ■ | ■ | | ■ | ■ | | ■ | | 32 | 0.512 |
| Effelsberg (Ef) | | | | ■ | ■ | | ■ | ■ | | ■ | | 100 | 2 |
| Hartebeesthoek (Hh) | | | | | ■ | | ■ | ■ | | ■ | | 26 | 2 |
| Irbene (Ir) | | | | | ■ | | ■ | ■ | | | | 32 | 2 |
| Jodrell Bank (Lovell, Jb1) | | | | ■ | ■ | | ■ | | | | | 76 | 2 |
| Jodrell Bank (Mk2, Jb2) | | | | ■ | ■ | | ■ | ■ | | ■ | | 25 | 2 |
| Kunming (Km) | | | | | | | | | | | | 40 | |
| KVN-Tamna (Kt) | | | | | | | | | | | | 21 | |
| KVN-Ulsan (Ku) | | | | | | | | | | | | 21 | |
| KVN-Yonsei (Ky) | | | | | | | | | | | | 21 | |
| Medicina (Mc) | | | | ■ | ■ | | ■ | ■ | | ■ | | 32 | 2 |
| Metsähovi (Mh) | | | | | | | | | | ■ | | 14 | 1 |
| Noto (Nt) | | | | ■ | ■ | | ■ | ■ | | ■ | | 32 | 2 |
| Onsala-60 (O6) | | | | | | | | | | ■ | | 20 | 2 |
| Onsala-85 (O8) | | | | ■ | ■ | | ■ | ■ | | | | 25 | 2 |
| Robledo-34 (Ro) | | | | | | | | | | | | 34 | |
| Robledo-70 (Ro) | | | | | | | | | | | | 70 | |
| Sardinia (Sr) | | | | ■ | ■ | | | ■ | | ■ | | 65 | 2 |
| Svetloe (Sv) | | | | ■ | ■ | | ■ | | | ■ | | 32 | 1 |
| Tianma (T6) | | | | ■ | ■ | | ■ | ■ | | ■ | | 65 | 2 |
| Torun (Tr) | | | | ■ | ■ | | ■ | ■ | | ■ | | 32 | 2 |
| Urumqi (Ur) | | | | | | | | | | | | 25 | |
| Westerbork (Wb) | | | | ■ | ■ | | ■ | ■ | | | | 25 | 2 |
| Wettzell (Wz) | | | | | | | | | | | | 20 | |
| Yebes (Ys) | | | | | | | ■ | ■ | | ■ | | 40 | 2 |
| Zelenchukskaya (Zc) | | | | ■ | ■ | | ■ | | | ■ | | 32 | 1 |

# EVN+MERLIN



# Joint Institute for VLBI ERIC (JIVE)

- **Supports the European VLBI Network**
  - Radio astronomy at its highest angular resolution
  - operations
  - correlation
  - data acquisition
- **Research & development**
  - Software (CASA 5.3)
  - hardware
  - e-VLBI
- **Science support**
- **Training**

JIVE headquarters in Dwingeloo, the Netherlands.



[http://www.jive.eu/](http://www.jive.eu/)

# Joint Institute for VLBI ERIC (JIVE)

An **European Research Infrastructure Consortium (ERIC)**

- 6 partner countries: NL (host), FR, ES, UK, SE, LV
- 4 associated institutions: INAF (IT), NRF (SA), MPIfR (DE), NAOC (Cn)
- Expected: PL, Fi, Kr, Th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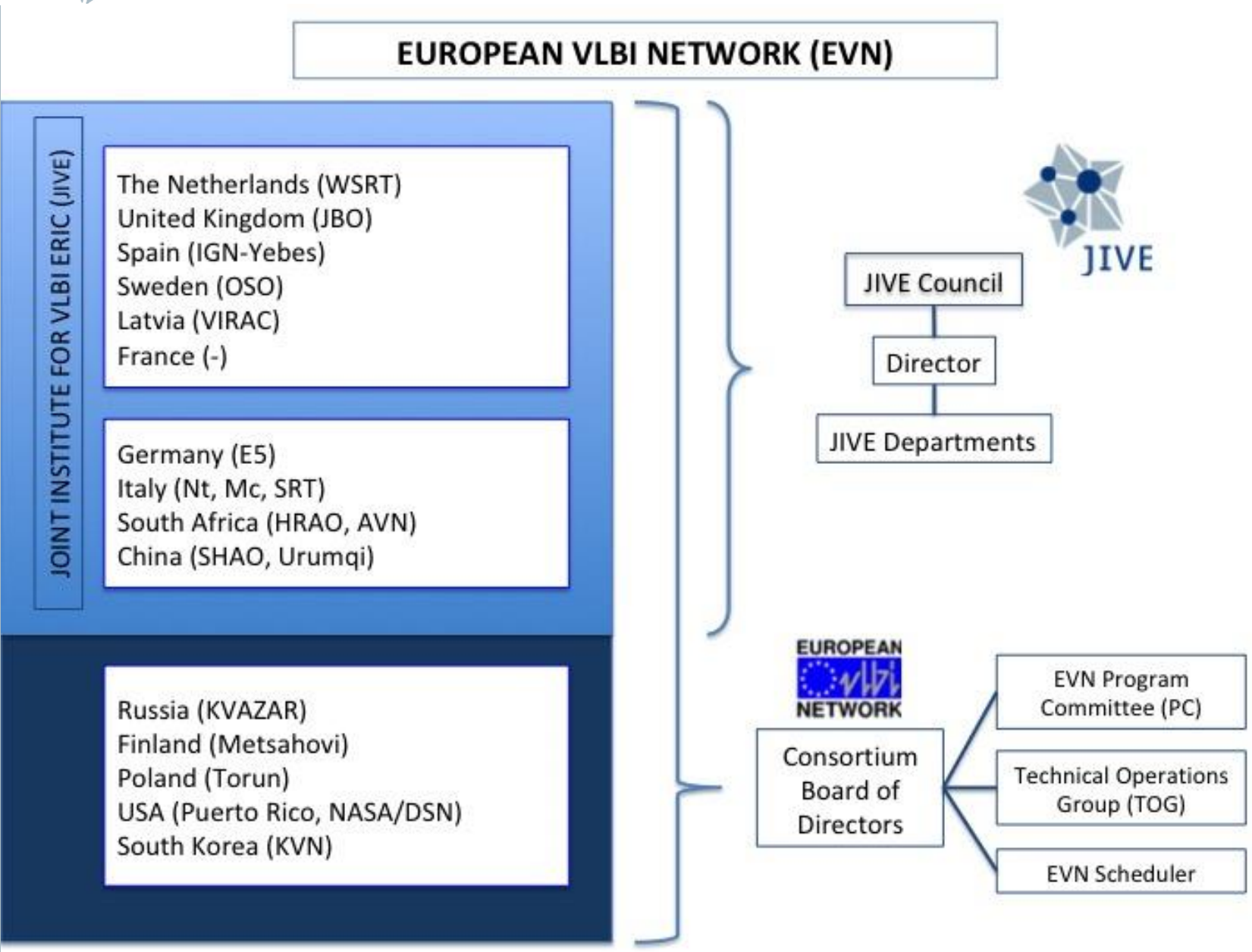
# JIVE and EVN

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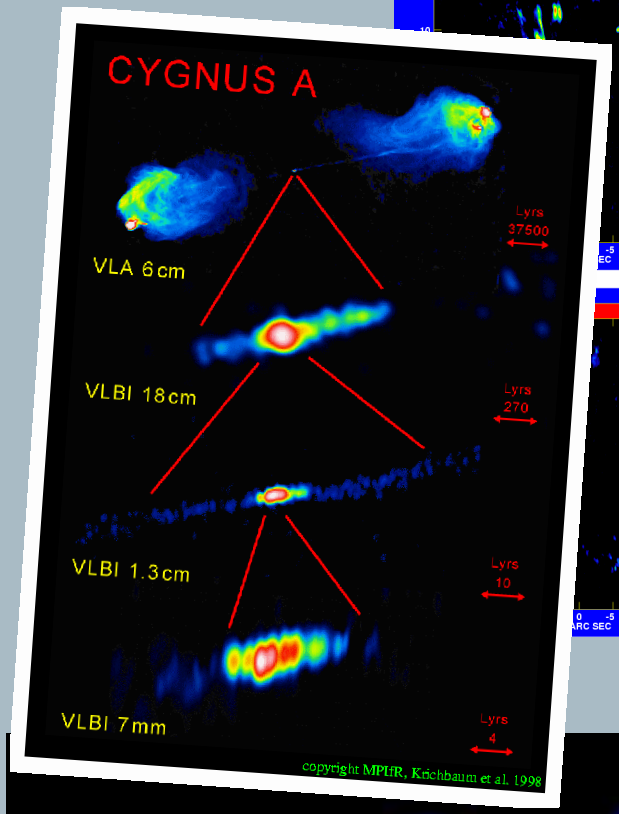
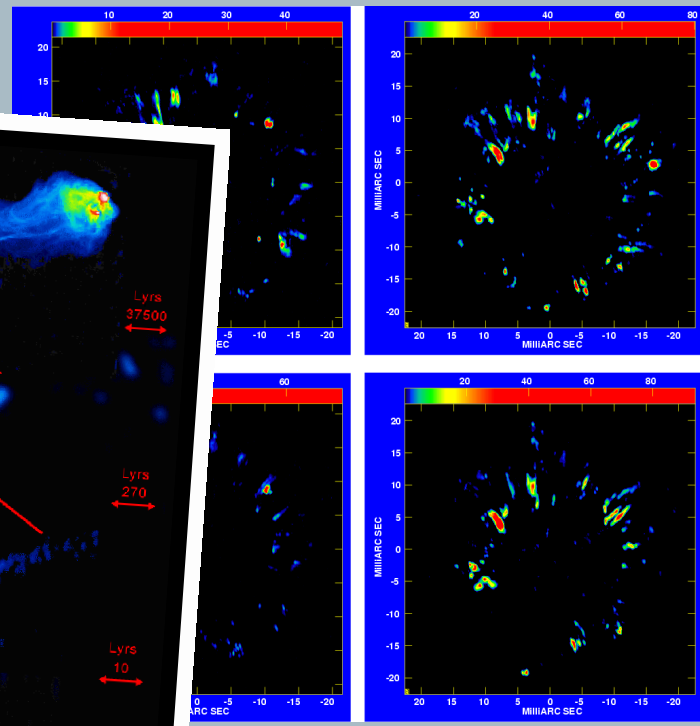
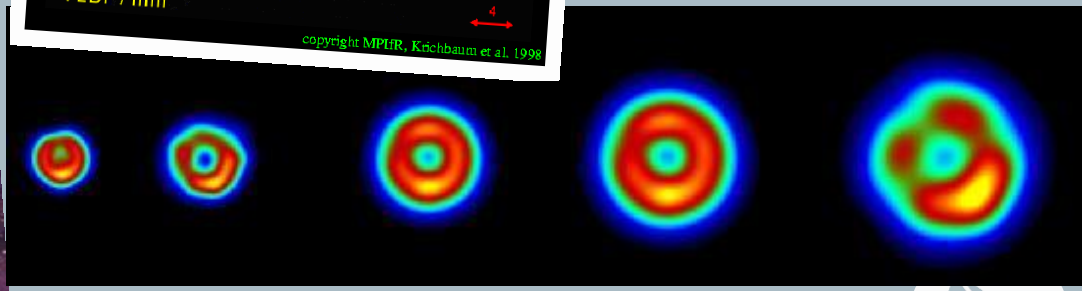
# VLBI science highlights

- AGN, galaxies
- Star formation
- Evolved stars
- The transient Universe
- Astrometry
- Reference frames
- Space and planetary science

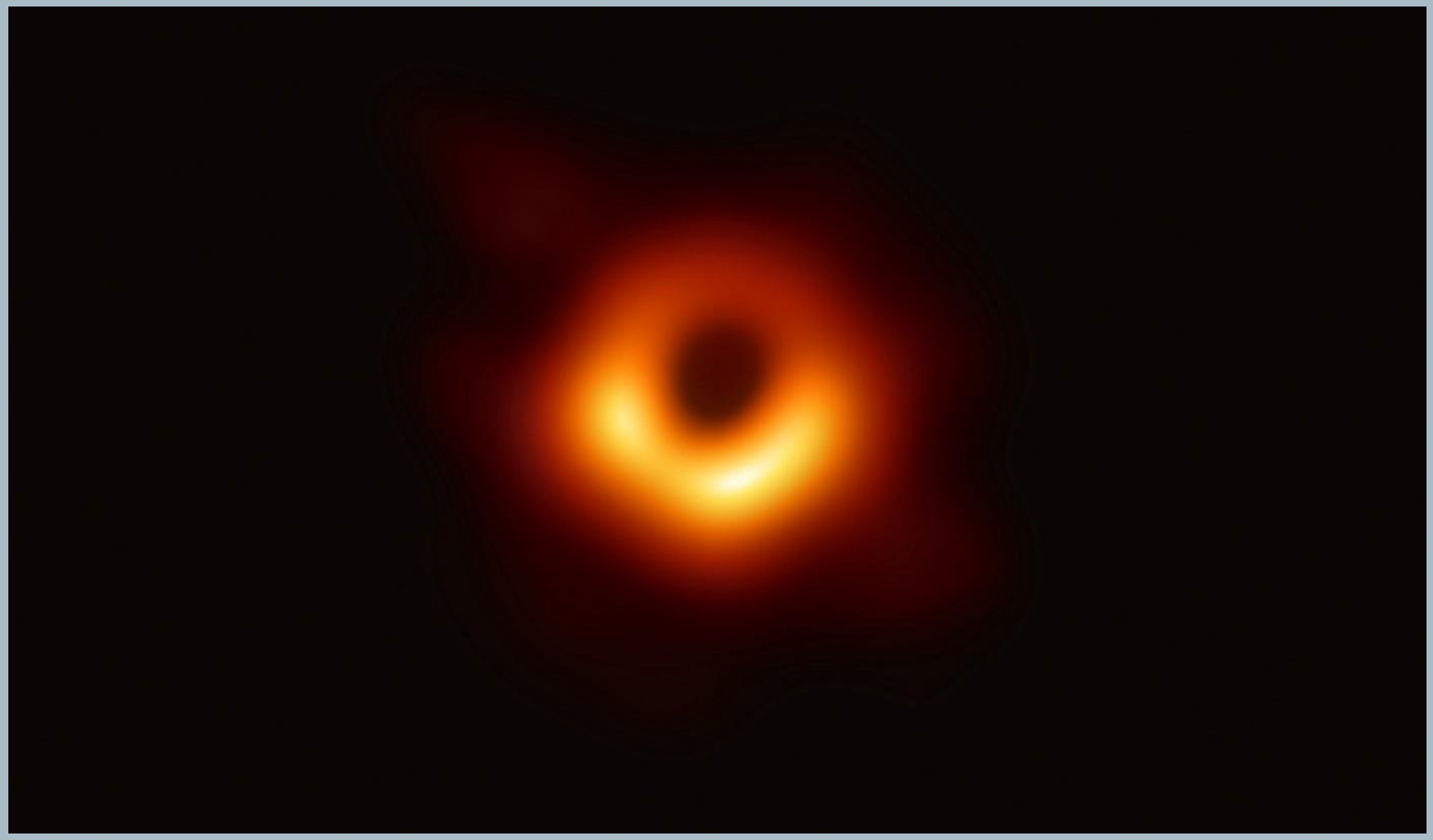


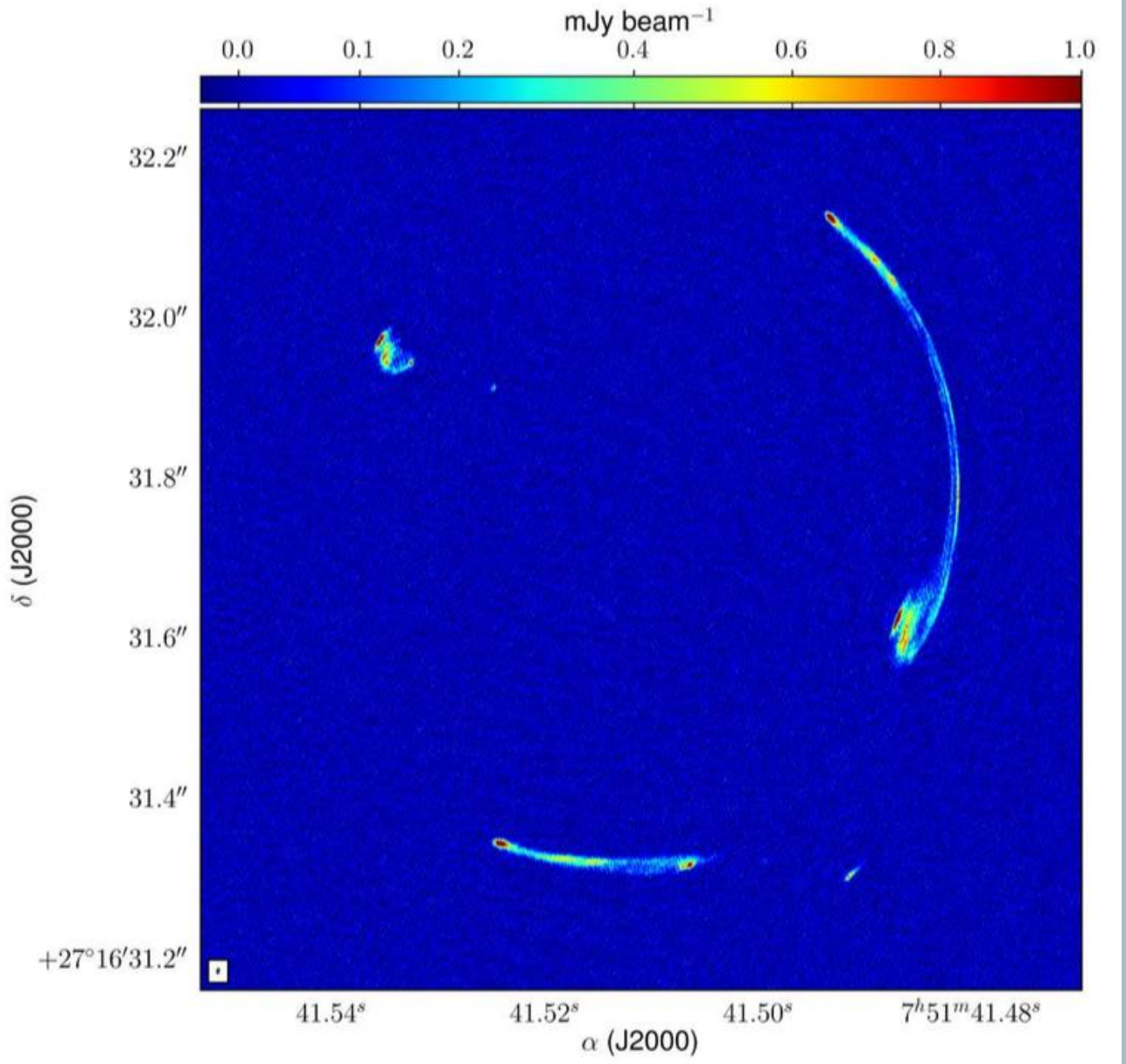



# The shadow of the SMBH in M87

- By the Event Horizon Telescope collaboration (EHT)
- JIVE participated in the CASA VLBI analysis pipeline



# Gravitational lenses and dark matter




"SHARP – V. Modelling gravitationally-lensed radio arcs imaged with global VLBI observations".

C. Spingola et al.

Monthly Notices of the Royal Astronomical Society, Volume 478, Issue 4, 21 August 2018, Pages 4816–4829, https://doi.org/10.1093/mnras/sty1326

JIVE PR:

http://www.jive.eu/new-images-super-telescope-bring-astronomers-step-closer-understanding-dark-matter

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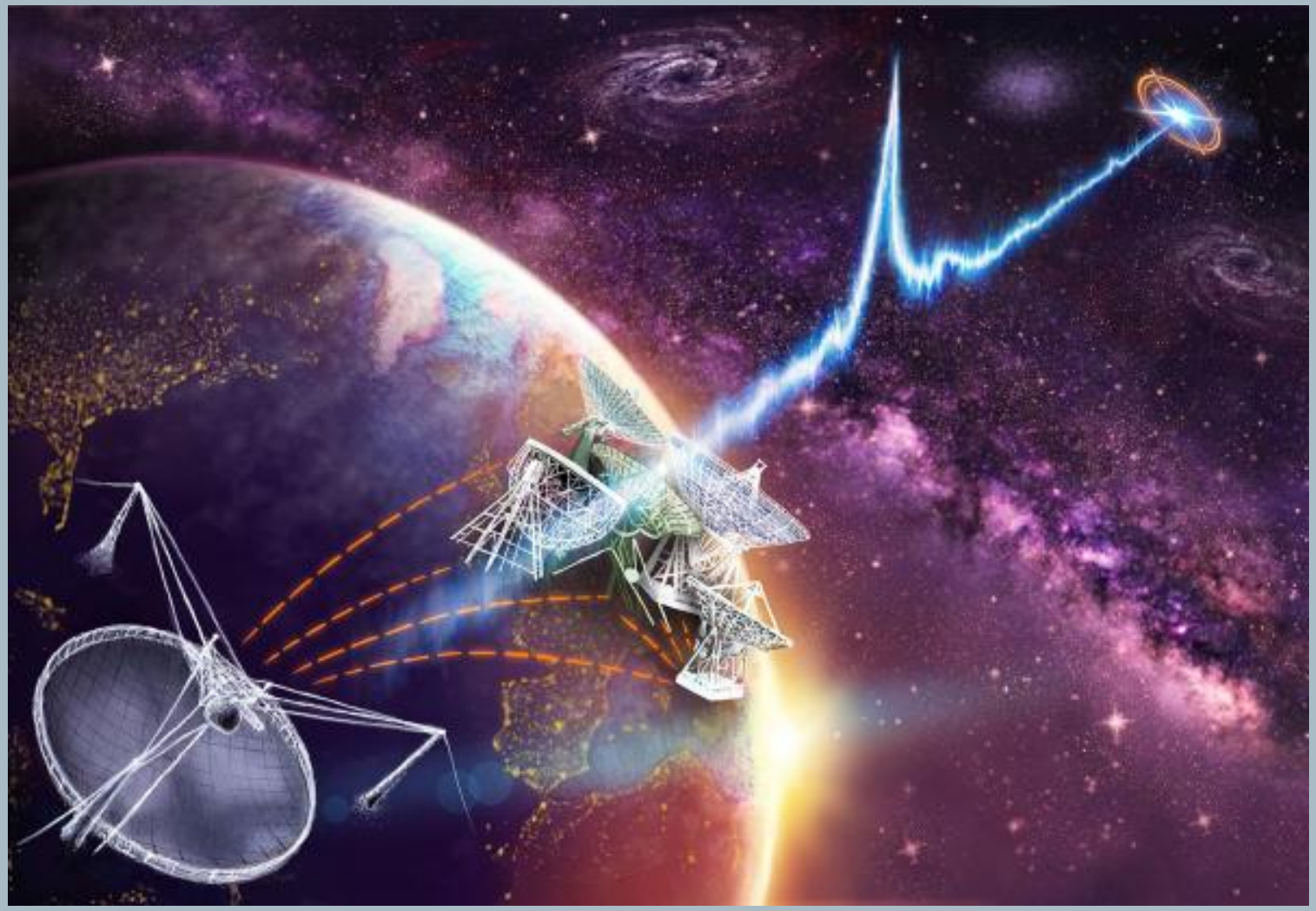
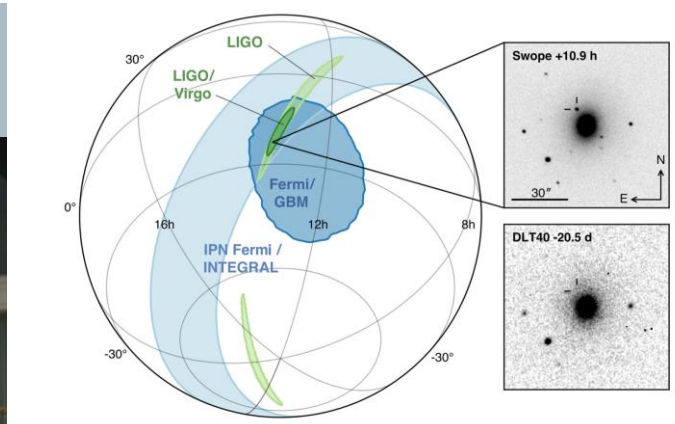
# Locating mysterious Fast Radio Bursts

EVN enables the identification of the host galaxy.

http://jive.eu/astronomers-pinpoint-radio-flashes-long-long-ago-galaxy-far-far-away



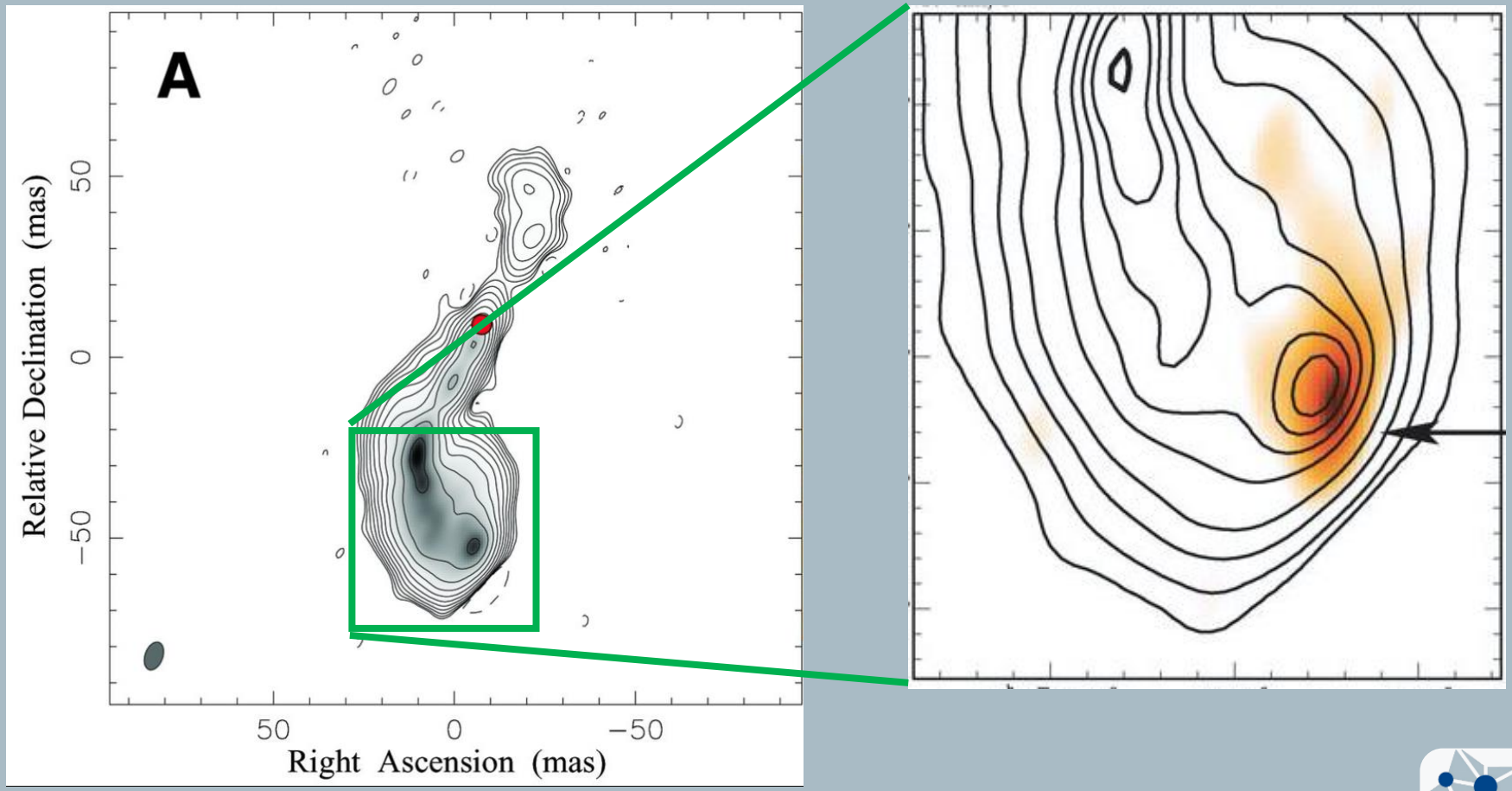
# First EVN observation of a Gravitational Wave counterpart

# Feeding monsters

Material ejected from (or falling into) black holes.

http://science.sciencemag.org/content/341/6150/1082



# Tidal Disruption Event (TDE)

A supernova explosion was actually a star being pulled apart by a supermassive black hole: the powerful gravity of SMBH rips apart a star that has wandered too close.

Mattila, S., Pérez-Torres, M., et al. 2018. A dust enshrouded tidal disruption event with a resolved radio jet in a galaxy merger. Science. DOI: 10.1126/science.aao4669

http://www.jive.eu/surprise-discovery-provides-new-insights-stellar-deaths

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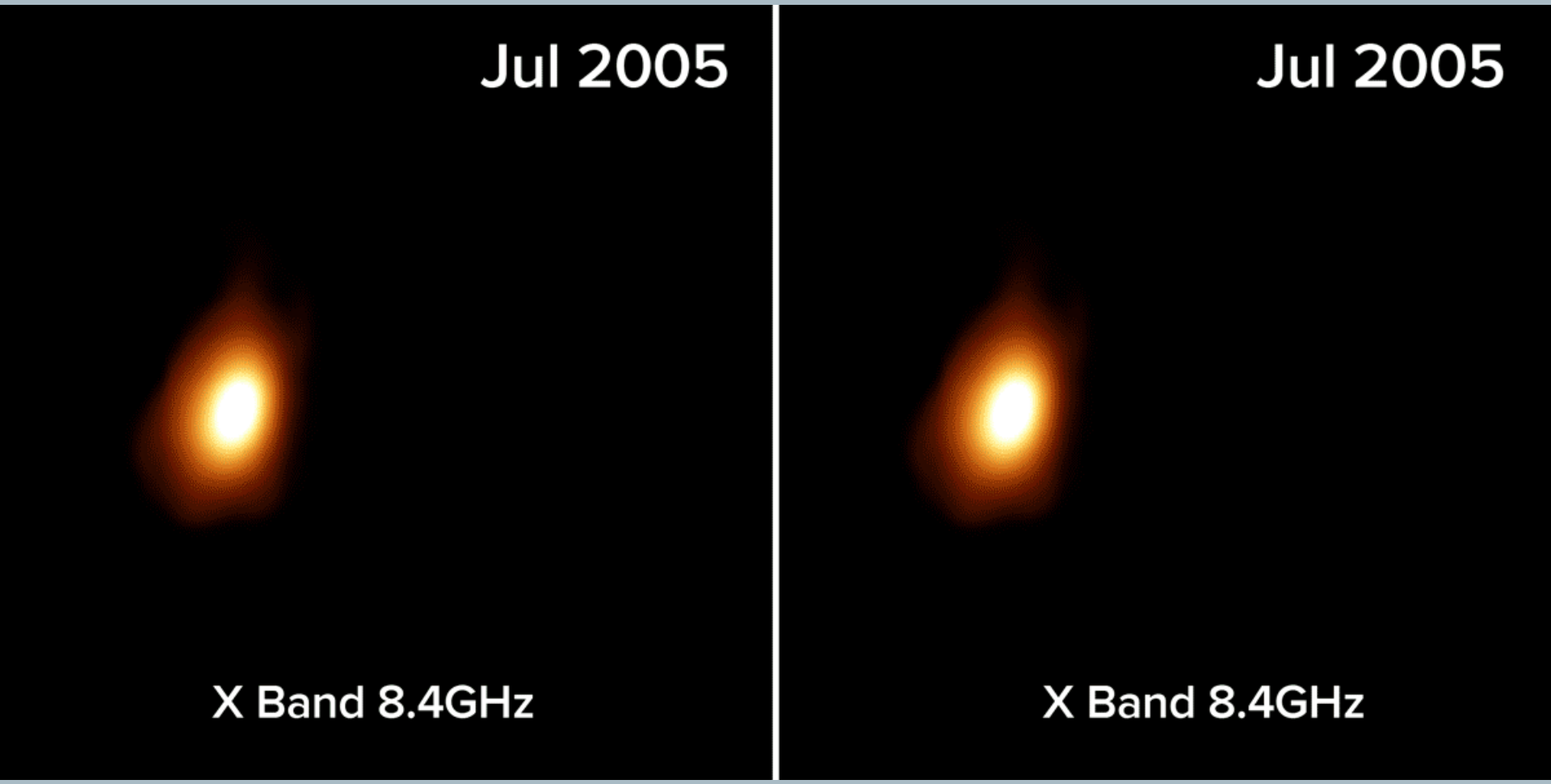
# Tidal Disruption Event (TDE)




http://www.jive.eu/surprise-discovery-provides-new-insights-stellar-deaths

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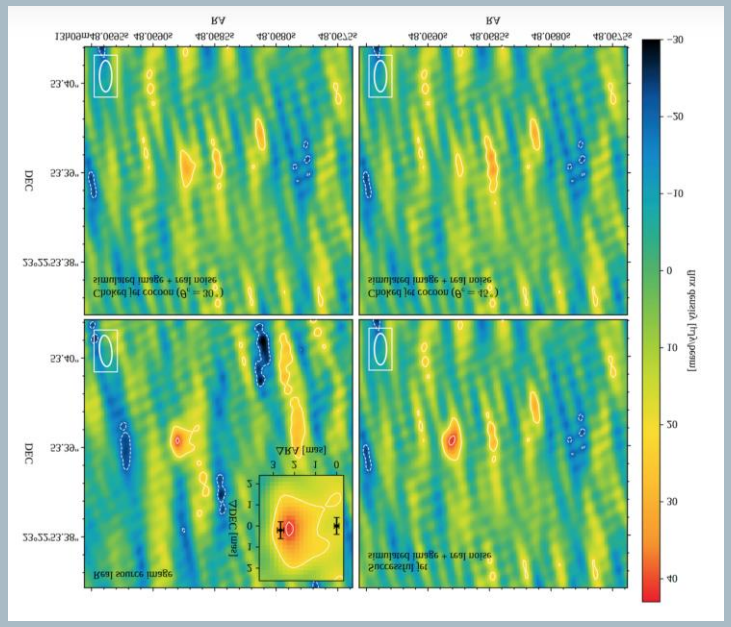
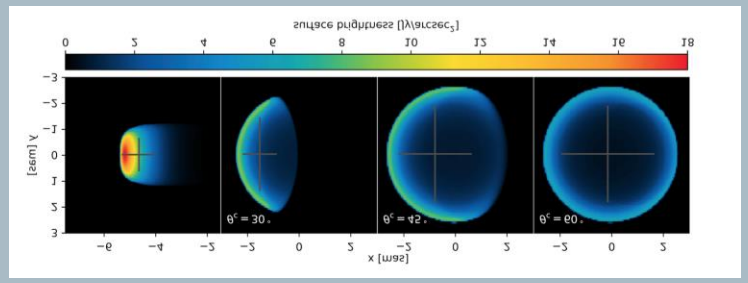
# First EVN observation of a Gravitational Wave counterpart

The BNS merger EM counterpart EVN paper has been published in *Science*



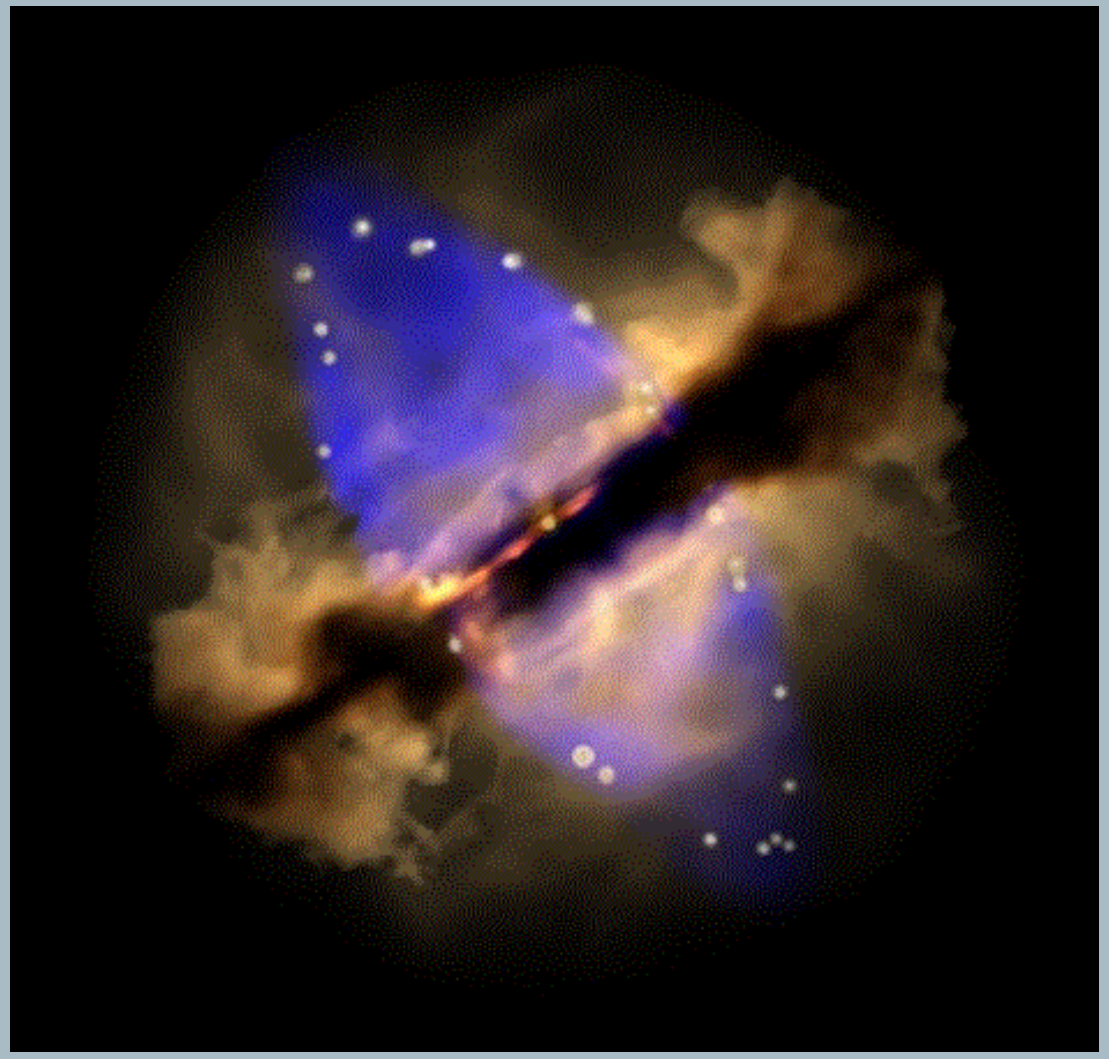


*Ghirlanda et al. (2019)*

# Birth of massive stars

EVN can trace gas motions around birth place.

http://jive.eu/w75n-outflow-onset



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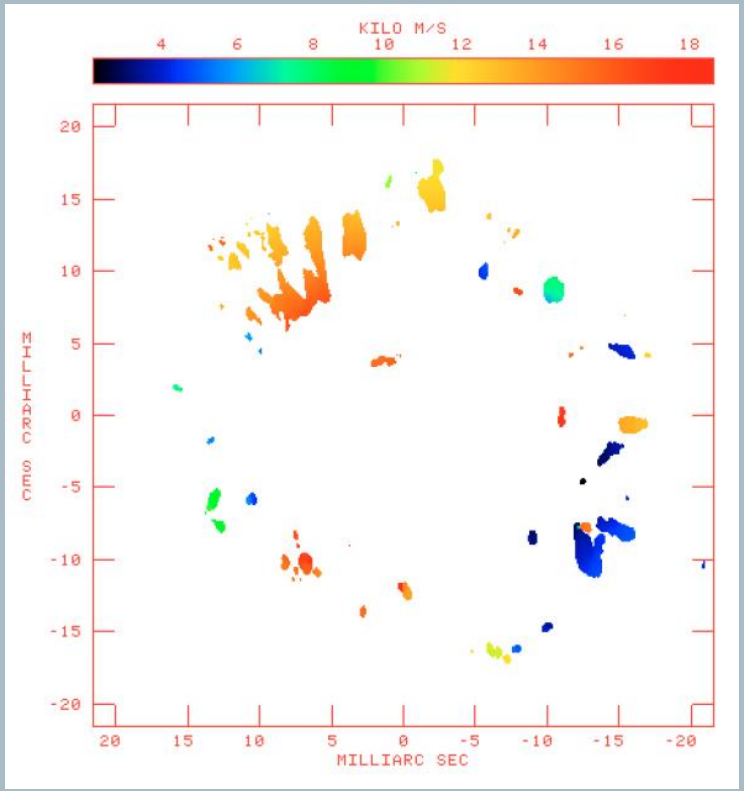
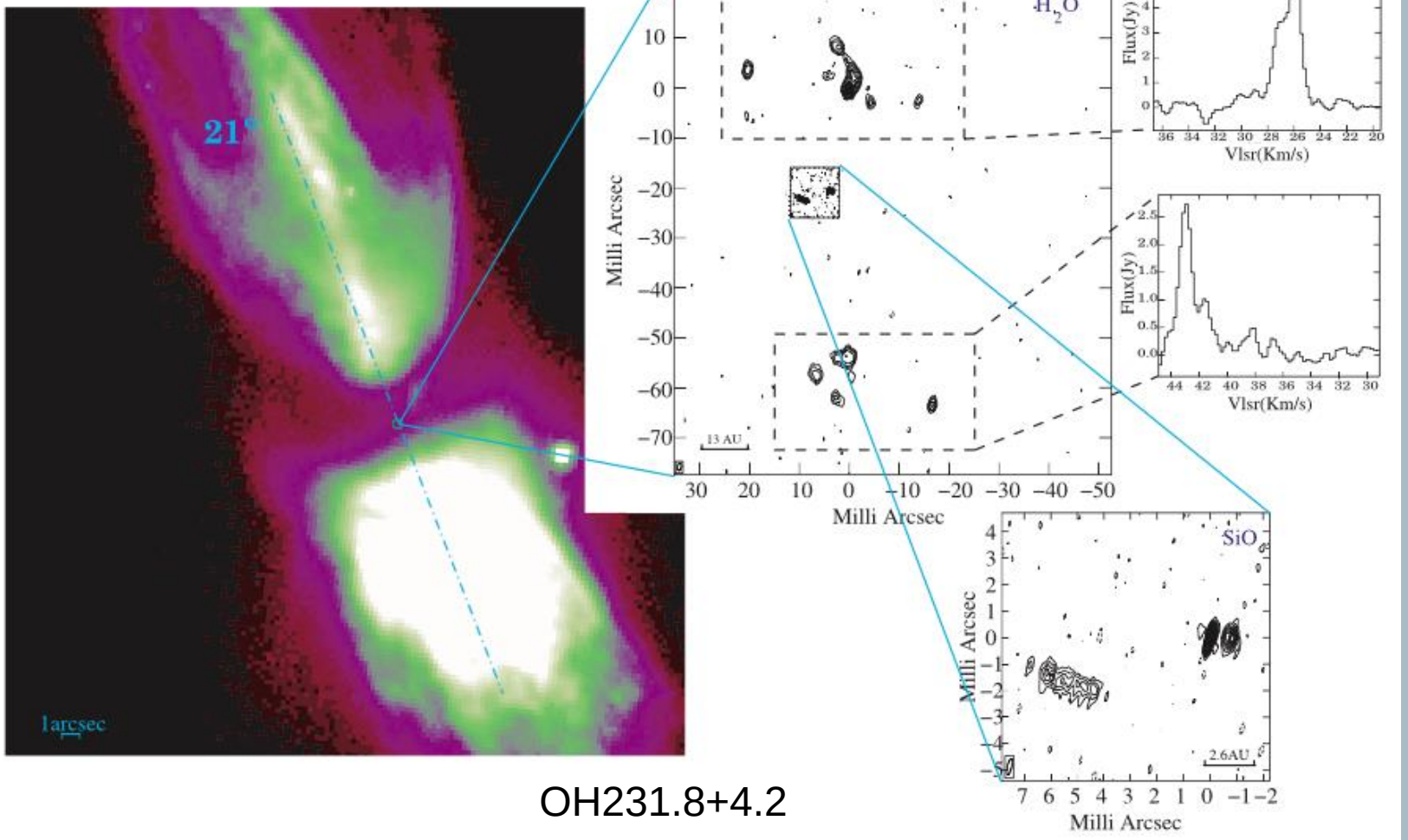
# Envelopes of evolved stars

VLBI displays the star CSE evolution in real time.




# How does axial asymmetry appears?




OH231.8+4.2

Desmurs et al. (2007), A&A 468, 189

*Absolute positions are needed !*

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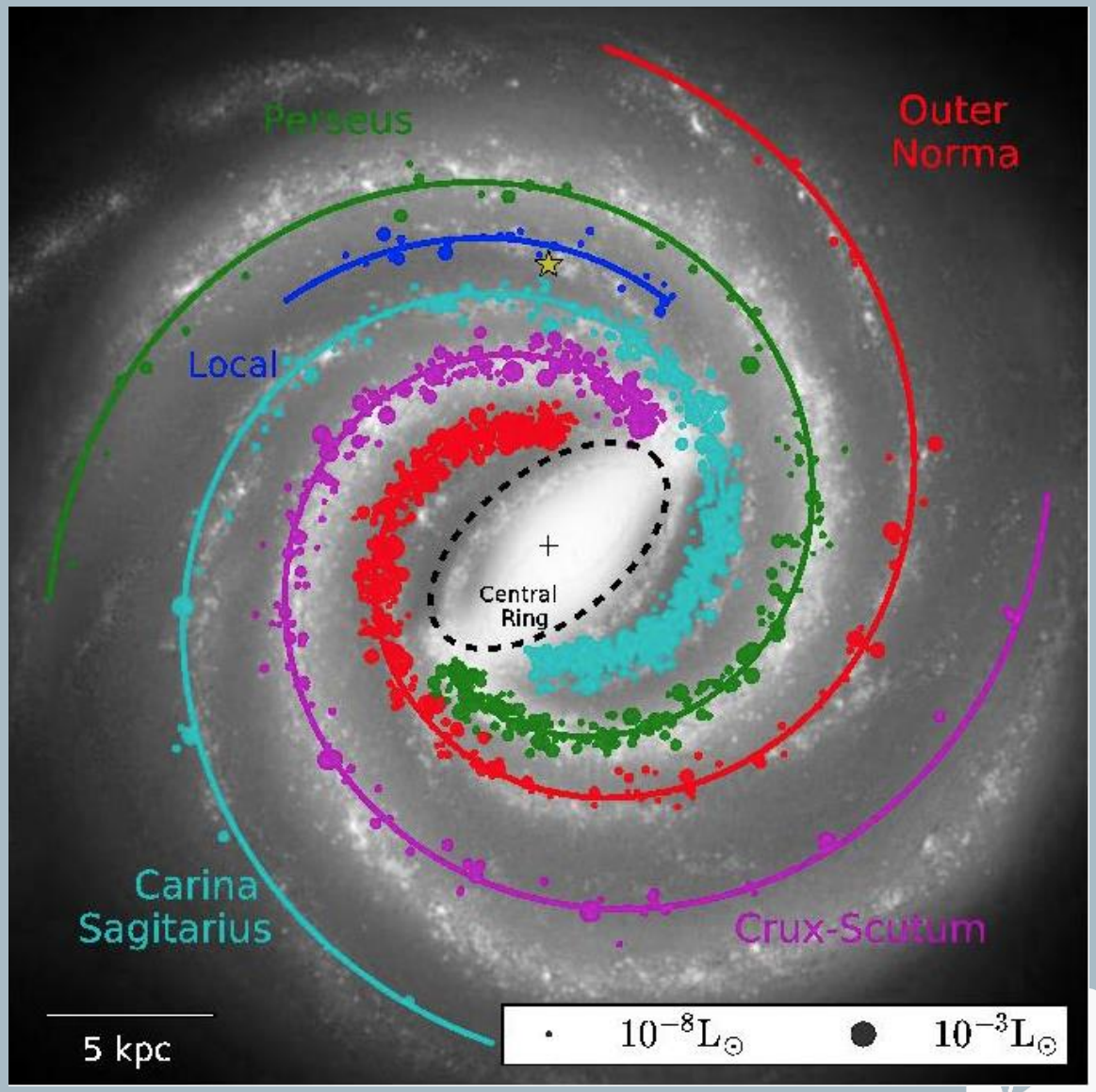
# Understanding our Galaxy

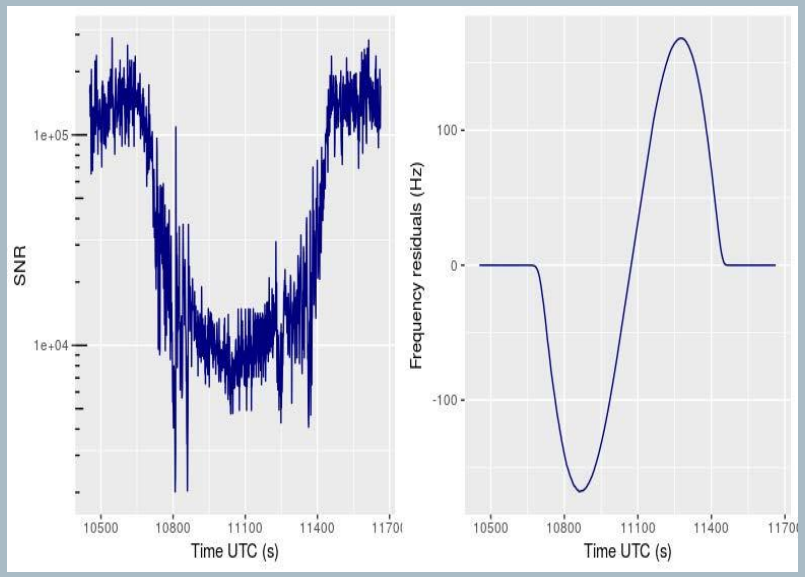
- Study our own galaxy in intricate detail
- VLBI with SKA.

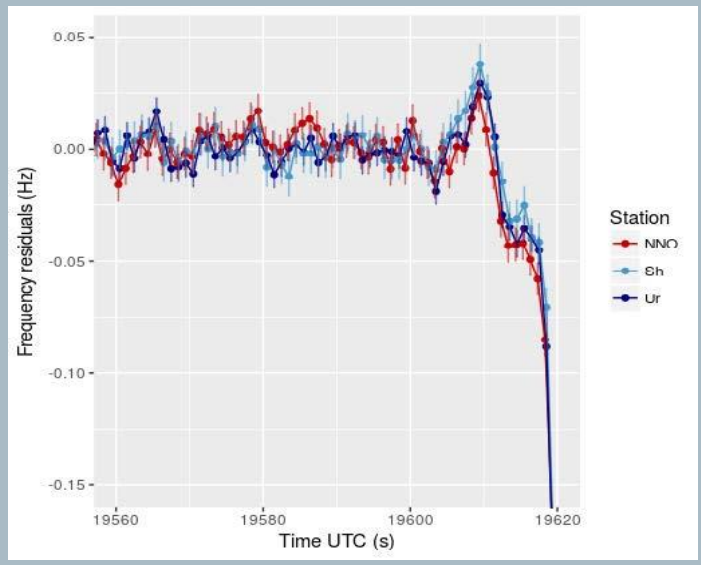
http://esoads.eso.org/abs/2017A%26A...604A..72Q



# Space and planetary science

- *PRIDE* project applied to space missions (JUICE)
- Tested on Venus Express, ExoMars, BeppiColombo




The S/N throughout the radio occultation detection of Venus Express by the Tianma 65-m radio telescope (China) on 2014.03.23, showing no loss of detection during the whole occultation. Right panel: shows the frequency residuals, which show from 10650 to 11100 s (ingress) followed by the egress from 11100 to 11450 s. The Tianma telescope was able to detect the signal while the planetary disk was completely occulting Venus Express.

*Bocanegra-Bahamon et al. (2019)*

# Geodetic VLBI

- JIVE SFXC correlator ready to process geovlbi data of the International VLBI Service (IVS) for Geodesy and Astrometry.
- Now tested on EVN data.
- And ***VGOS*** is coming…

# VLBI in the era of SKA

- The Square Kilometer Array (SKA) will be built in two phases.
- SKA-1 is 10% of the full SKA, and will lack very long baselines, which are provided by VLBI.

# VLBI in the era of SKA (II)

## WP10: SKA-VLBI

- Explores the synergies between VLBI and SKA
- **SKA1-MID shares frequencies with EVN**; combined observations will provide unprecedented sensitivity.
- To develop a **global VLBI** Science Case including precision astrometry, large field-of-view VLBI, VLBI surveys and transients, etc.


https://www.skatelescope.org/precursors-pathfinders-design-studies/

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# VLBI in the era of SKA (III)


## WP10: SKA-VLBI

- Workshop to develop the Key Science Program
- Manchester, October 14-17 2019

https://indico.skatelescope.org/event/539/

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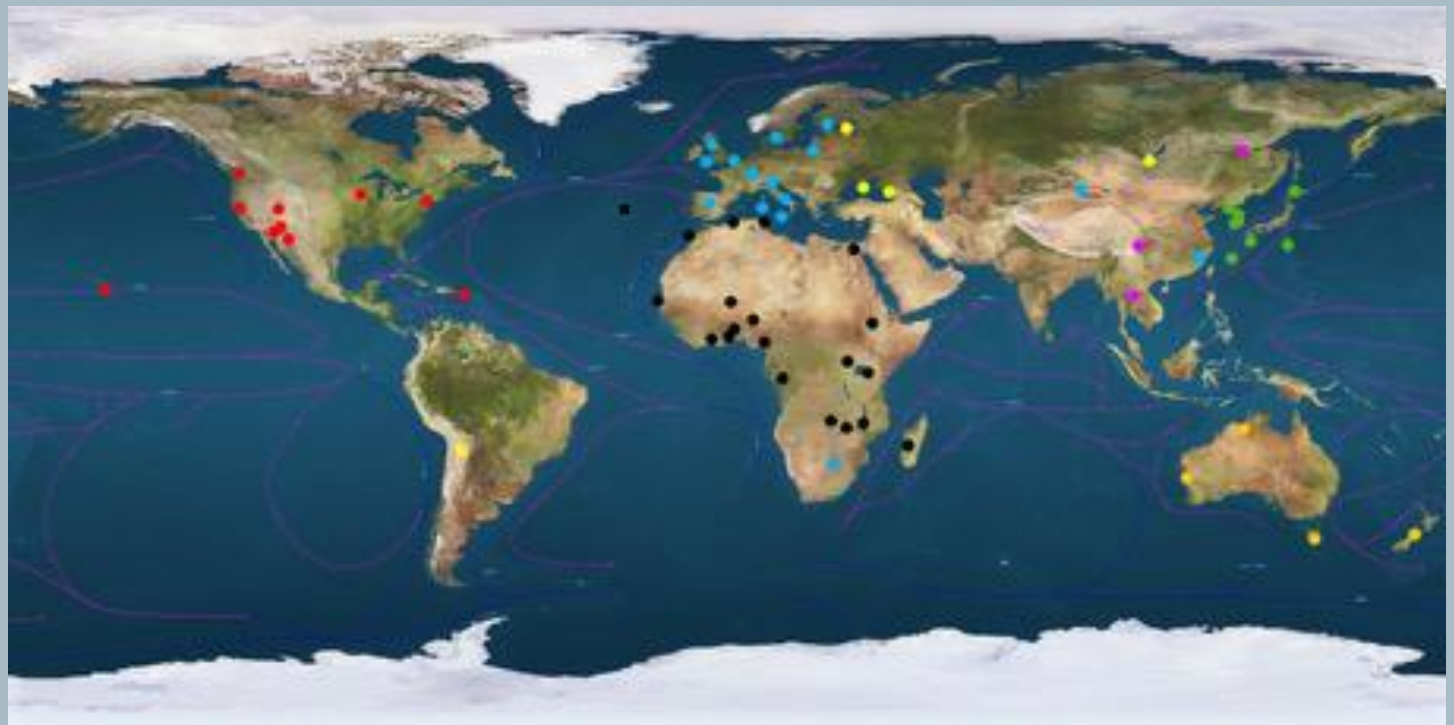
# Towards global VLBI

- "Global VLBI alliance" concept being developed
  - EVN, VLBA, LBA, GMVA, EAVN, KVN, VERA, AVN…
  - Setting a Global VLBI Alliance (GVA) for coordination
- When SKA_1 is built, long baselines and northern hemisphere sky coverage will be needed!



# New potential EVN partners

Haopin, 40 m, China

Usuda, 64 m, Japan

MeerKAT

Aragats, 50 m, Armenia

Azores, 32 m, Portugal

Thailand, 40 m, NRT

Thermopílai, 32 m, Greece

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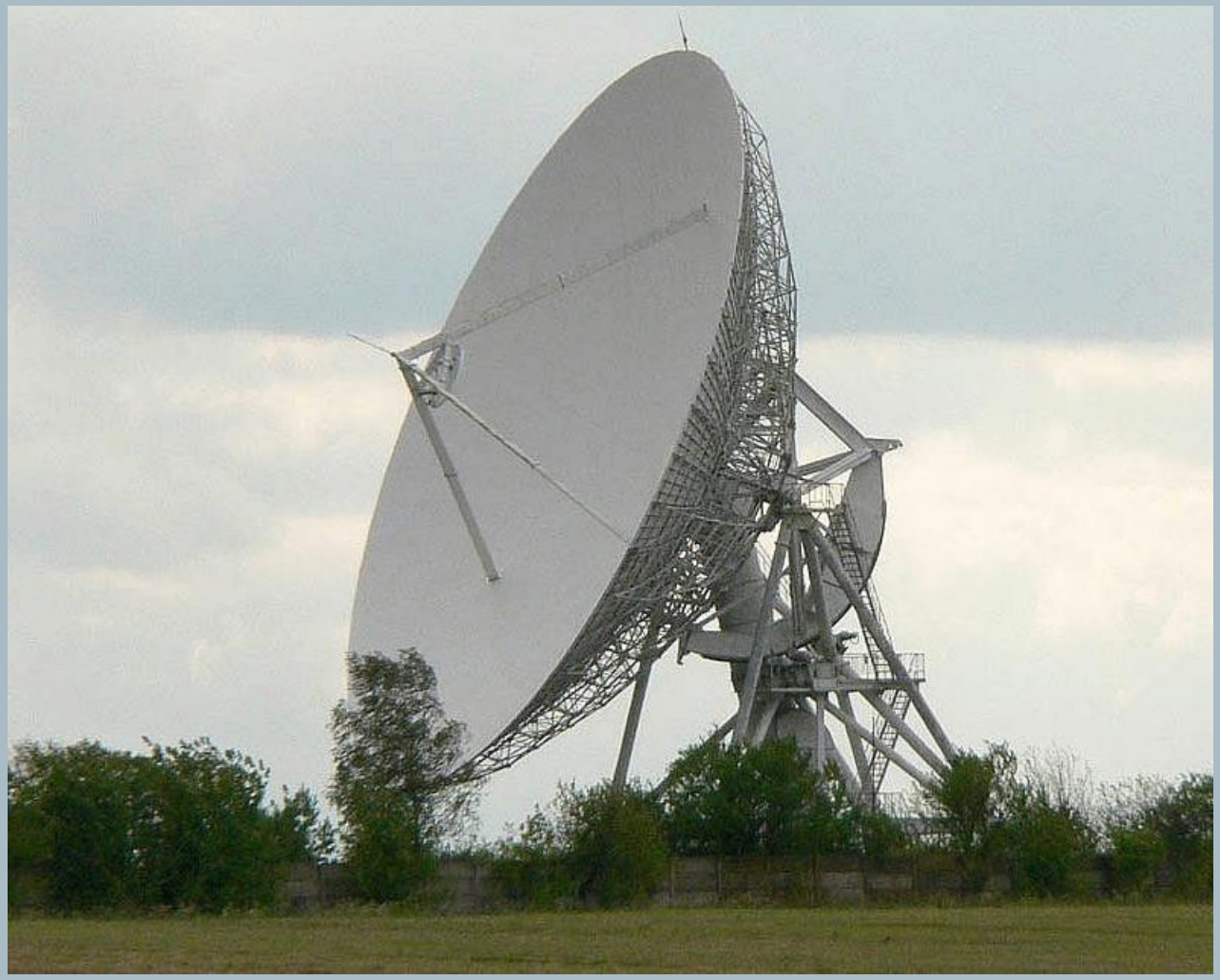
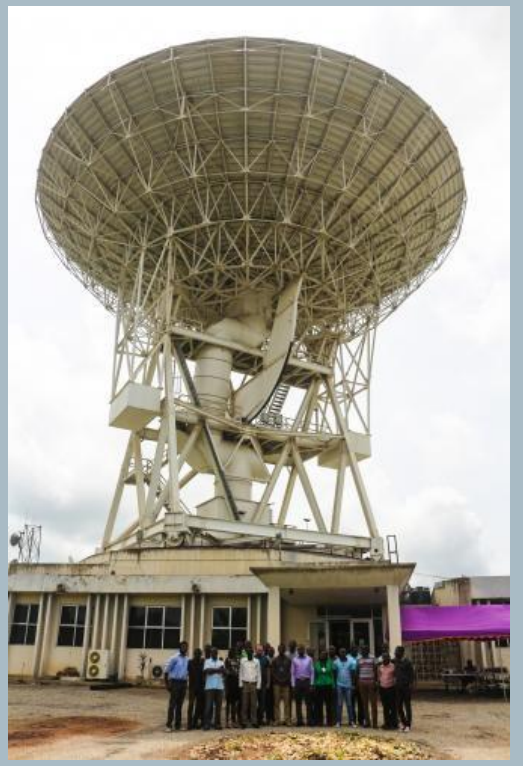
# New potential EVN partners



Zolochiv, 32 m, Ukraine

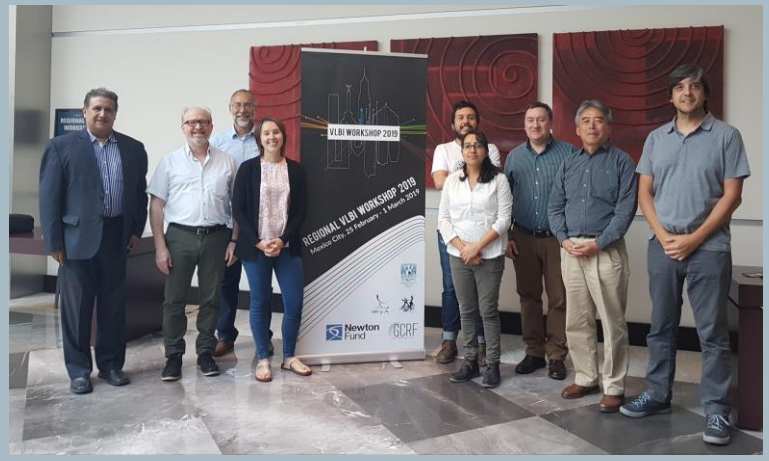
# Refurbishing antennas into radio telescopes?

- Success cases in New Zealand (2000), Japan (2010), Ghana (2017), Mexico (2020)



# Iniciativa VLBI IberoAmericana (IVIA)

- México, Costa Rica, Colombia, Ecuador, Perú, Brasil, Uruguay, Argentina, Portugal, Spain, and other international partners (incl. JIVE)




http://www.ivia-net.org/

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# Upcoming meetings of interest

- EVN Technical and Operations Group (TOG): Bonn (Germany) on March 2020

  https://www3.mpifr-bonn.mpg.de/EVN/TOG/tog.html

- EVN Symposium and users' meeting: Cork (Ireland) on July 6-10 2020

  http://www.evlbi.org/

- IVS General Meeting: Annapolis (USA), March 22-27 2020

  http://ivscc.gsfc.nasa.gov/

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# Summary

- VLBI is the astronomical technique with **highest angular resolution**
- VLBI provides a huge add-on value to national RA facilities
- **EVN** is the **most sensitive** VLBI network in the world, **open** to all astronomers
- Members of EVN/JIVE are involved in **cutting-edge research and development**
- Development of **new VLBI stations** will improve image quality, and create local expert communities (building **human capacity**)
- JUMPING JIVE fosters **global VLBI** – need to set a *Global VLBI Alliance (GVA)*
- e-VLBI networks are **pathfinders to SKA**

JIVE

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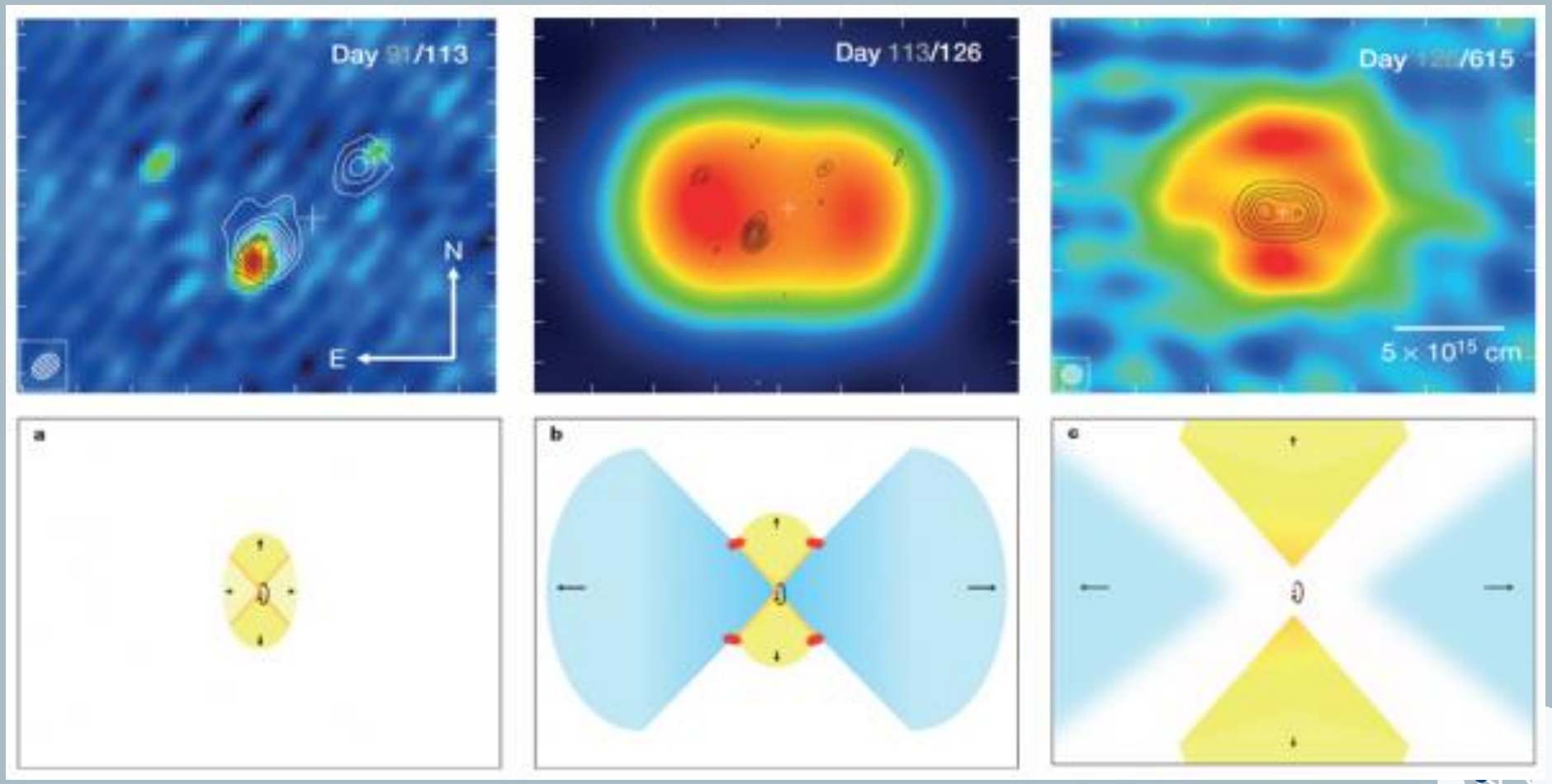
# EXTRA SLIDES

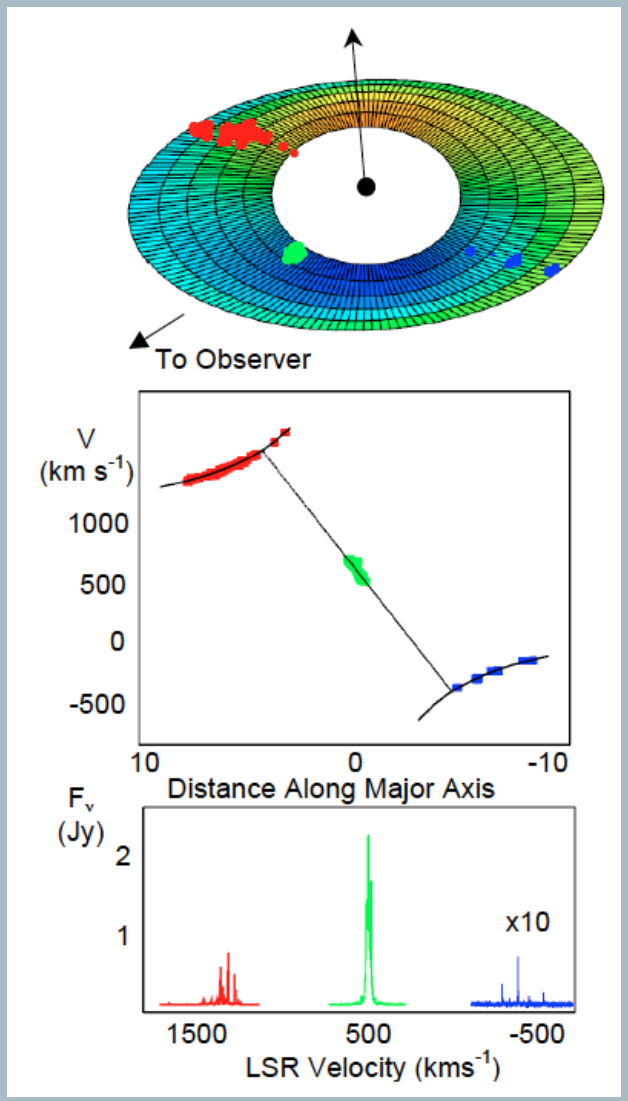
# Nova Mon: stellar evolution

EVN solves riddle on gamma ray production.

http://jive.eu/sharp-radio-images-unravel-mystery-gamma-rays-stellar-explosions



# Cosmology and determination of $H_o$




For distant AGN (> 50 Mpc), water maser geometric distances can yield a high accuracy $H_0$ and constrain Dark Energy.

Humphreys et al. (2013)

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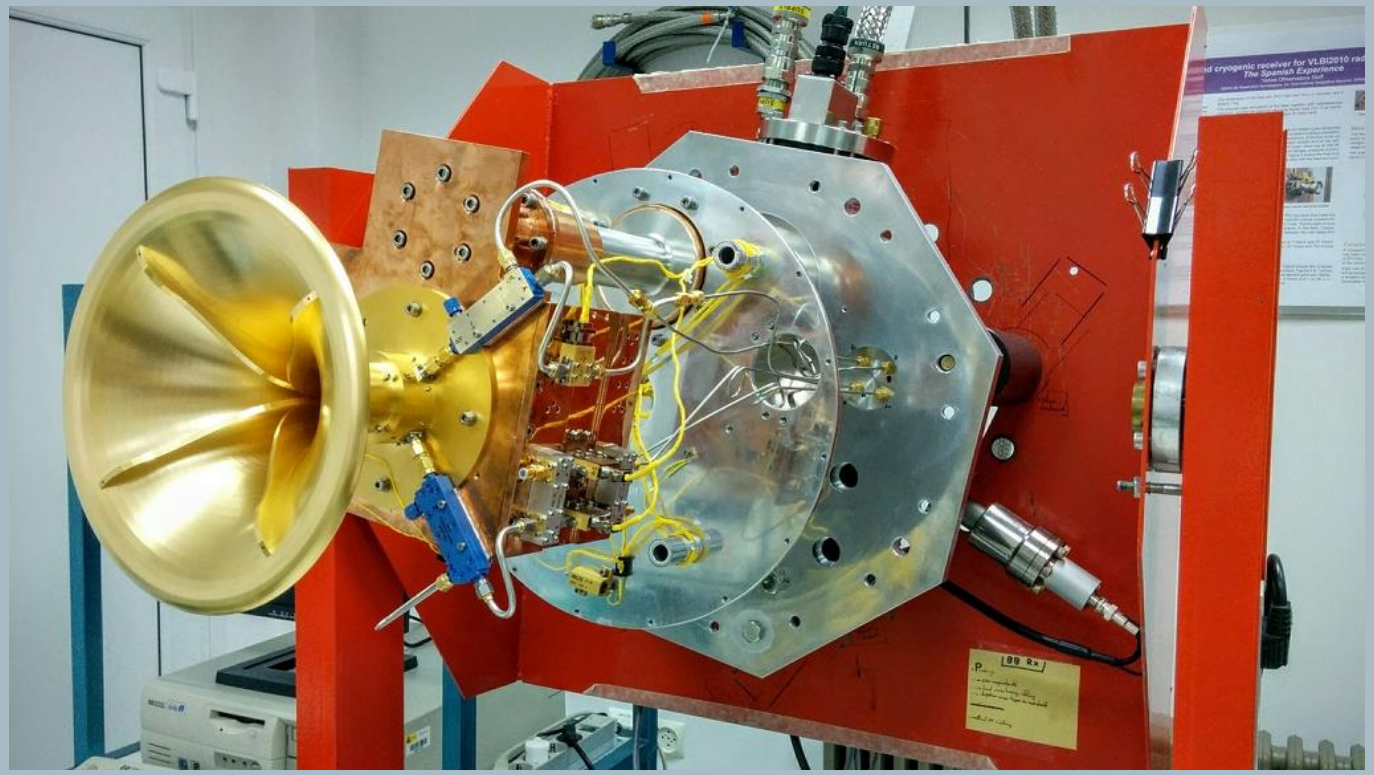
# What can VLBI do for you?

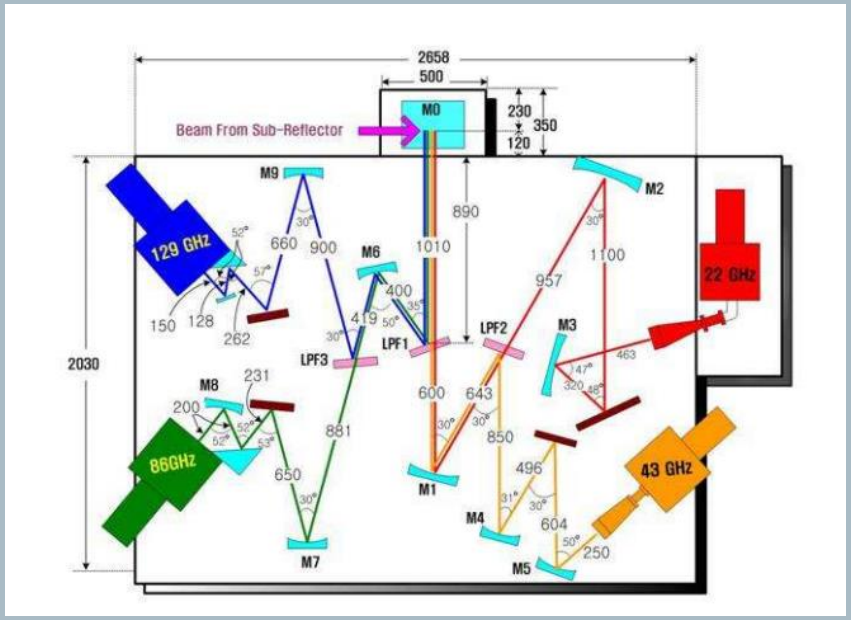
FUTURE PROSPECTS

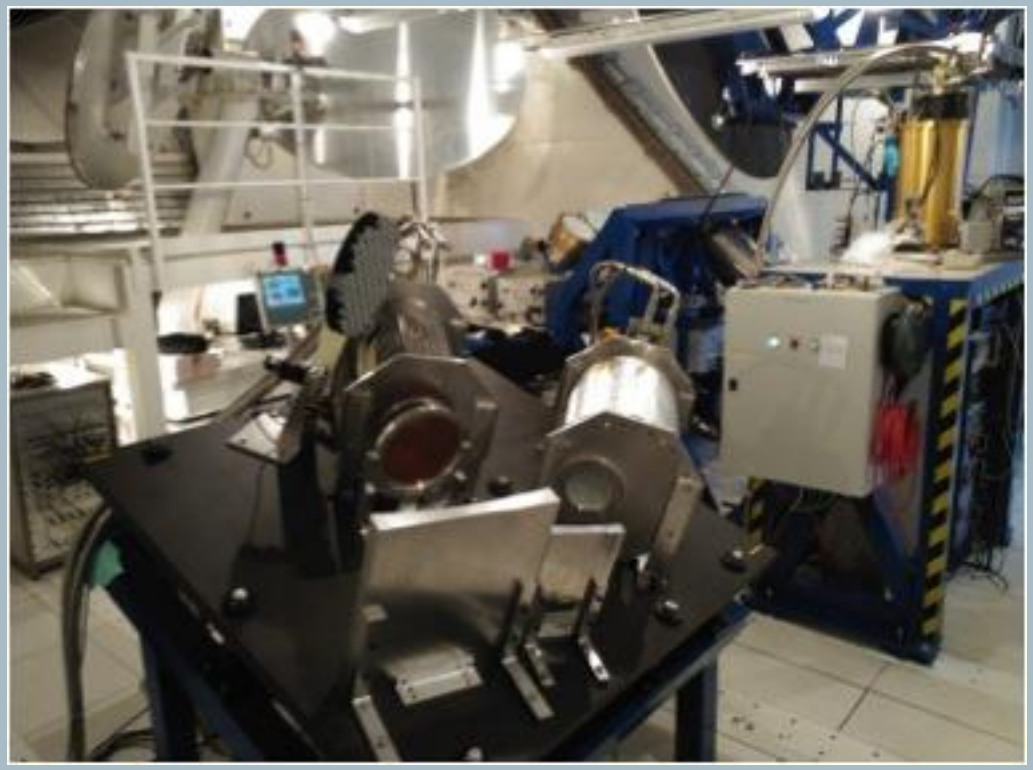
# RADIONET BRAND receiver for EVN

- Broadband receiver to cover 1.5-15.5 GHz.
- Allows simultaneous registration of masers of OH (1.6, 1.7, 4.7 and 6.0 GHz), and $CH_3OH$ (6.7 and 12.2 GHz).



# Simultaneous multi-frequency observations



K band (21-26 GHz)
Q band (41-49 GHz)
W band (76-100 GHz)

Water masers
SiO masers
HCN masers
Some methanol masers

***Allows alignment of maser maps !***

K/Q/W at IGN-Yebes 40-m RT

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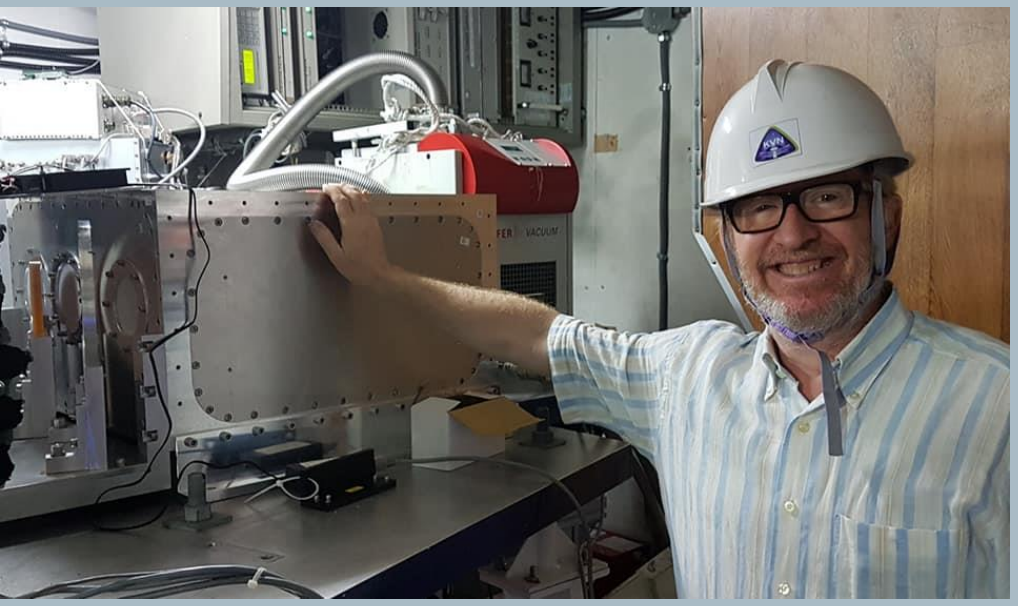
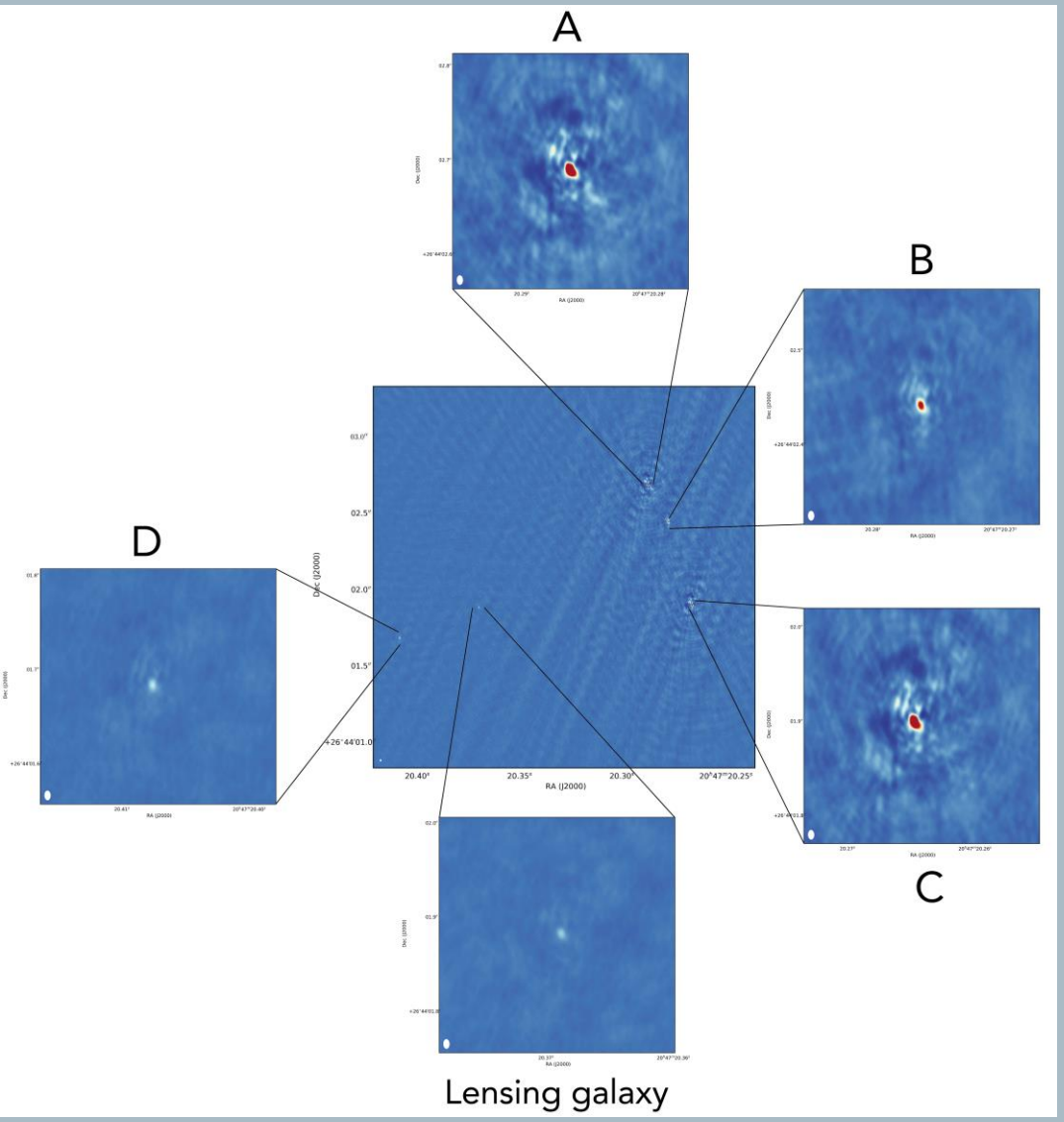
# Compact K/Q/W bands receiver




Also allows calibration of high frequency data (up to W band) using lower frequency (Q, K) simultaneous observations

# Software highlights




## Fringe Fitting for VLBI in CASA reaches maturity

- Two very successful workshops to exercise new capability
- First image of a VLBI science target fully processed with the new CASA tools

Cristiana Spingola (Kapteyn Institute, University of Groningen)

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