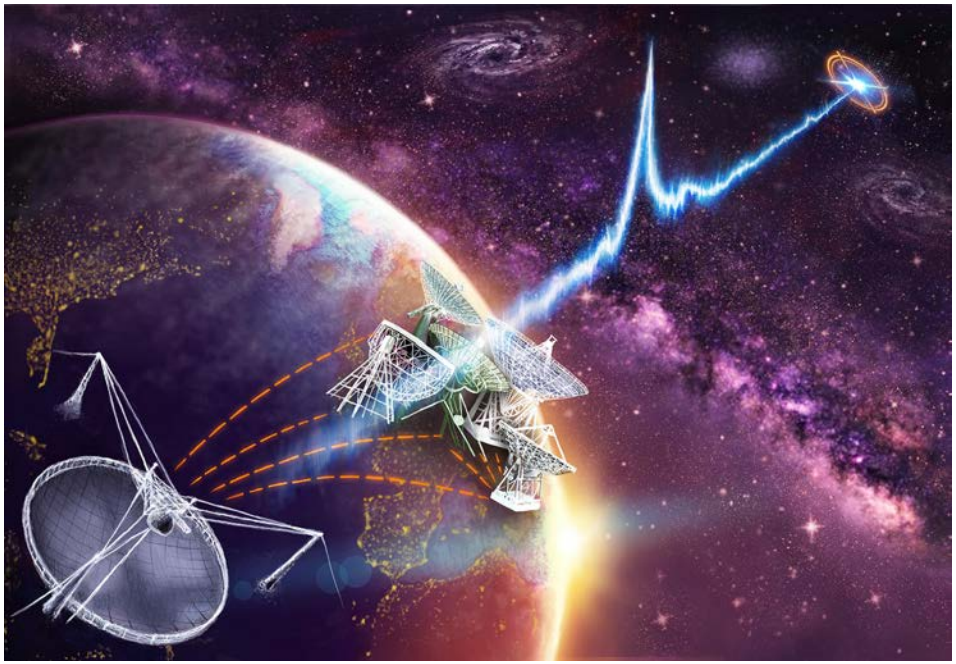
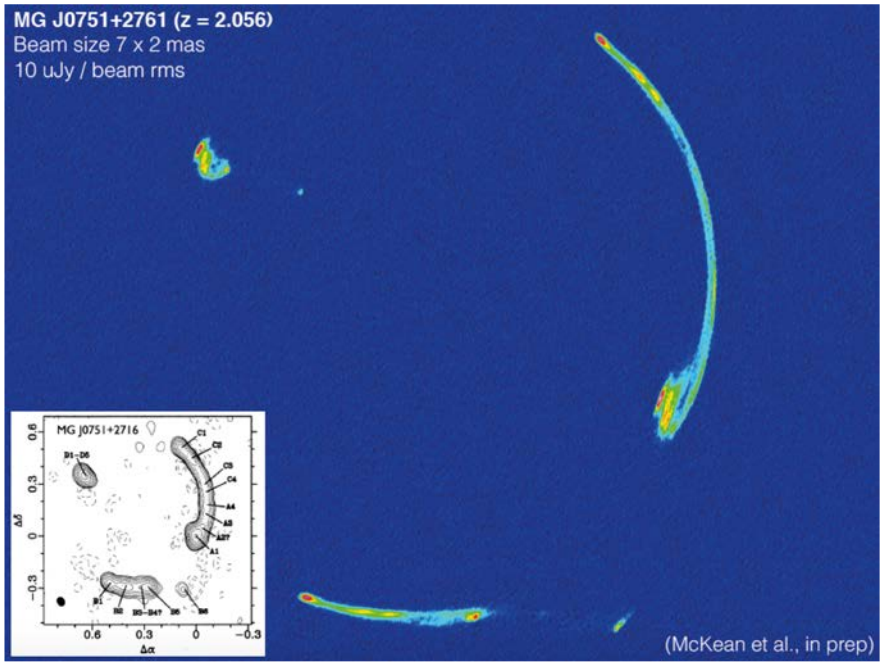
A Vision for the Future of the European VLBI Network





Michael Lindqvist, Onsala Space Observatory

Tiziana Venturi, INAF

Zsolt Paragi, JIVE

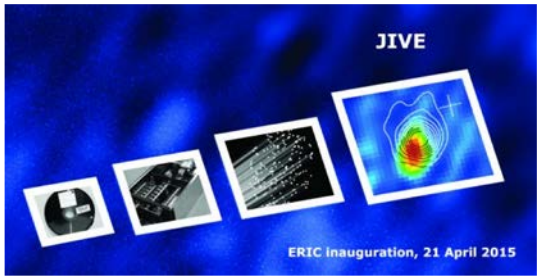
Contents

- EVN
- JUMPING JIVE
- JUMPING JIVE: WP7 – The VLBI future
- Voices from the community
- Input from you!

Description of the EVN

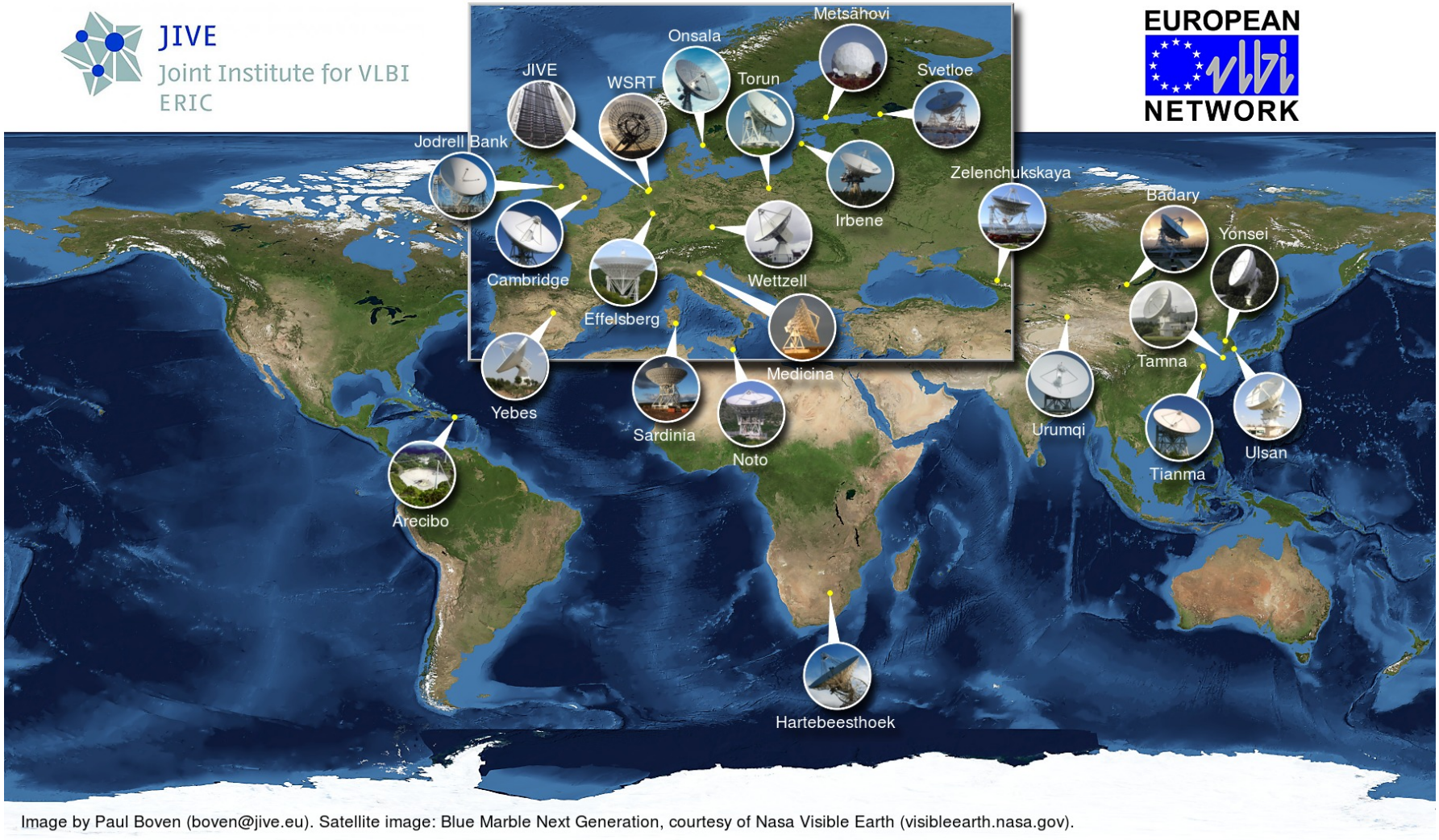
- The European VLBI Network (EVN) was formed in 1980. Today it includes 15 major institutes, including the Joint Institute for VLBI ERIC, JIVE

- JIVE operates EVN correlator. JIVE is also involved in supporting EVN users and operations of EVN as a facility. JIVE has officially been established as an European Research Infrastructure Consortium (ERIC).



- No standing centralised budget for the EVN - distributed facility
- The general policy of the EVN is set by the EVN Consortium Board of Directors (CBD). Members of this board are the directors of the individual EVN member institutes.

The network


JIVE
Joint Institute for VLBI ERIC
EUROPEAN VLBI NETWORK
Metsähovi
Onsala
JIVE
WSRT
Torun
Svetloe
Jodrell Bank
Irbene
Zelenchukskaya
Badary
Yonsei
Cambridge
Wettzell
Effelsberg
Tamna
Medicina
Yebes
Urumqi
Sardinia
Noto
Ulsan
Tianma
Arecibo
Hartebeesthoek
Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

EVN - current status

- **Call for proposals:** 3 times per year: (February 1, June 1, October 1)
- **Wavebands:** 90, 18, 6, 5, 3.6, 1.3, 0.7 cm
- **Maximum Angular Resolution in milliarcseconds:** 5 mas (18 cm), 1.5 mas (6cm)
- **Not a full time array, the EVN observes during "sessions":**
  - **3 EVN disk sessions (3x3 weeks)**
  - **10 e-VLBI sessions (10x24 hours)**
  - **Target of Opportunity and Out-of-Session**
- **Disk recording and e-VLBI simultaneously**
- **Automated trigger e-VLBI**
- **Most data correlated at JIVE**
- **Collaborations:** NRAO/GBO/LBO, RadioAstron, LBA, EAVN, AVN

JUMPING JIVE

JUMPING JIVE: Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE

- 12 institutes from 8 different European countries have teamed up in the JIVE lead project JUMPING JIVE.
- The program was awarded nearly 3 million euros from the Horizon 2020 Framework Programme.
- Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020).

JUMPING JIVE

JUMPING JIVE: Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE

- JUMPING JIVE started December 2016 and will run for 4 years
- **Goal:** take VLBI into the next decade, with JIVE and the EVN as globally recognized centres of excellence in radio astronomy.

JUMPING JIVE

WP1 Management	WP2 Outreach & advocacy	WP3 Building new partnerships	WP4 ERIC scope: LOFAR
WP5 Integrating New elements	WP6 Geodetic capabilities	WP7 The VLBI future	WP8 Global VLBI interfaces
WP9 Capacity for VLBI in Africa	WP10 VLBI with the SKA		

JUMPING JIVE

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- Tiziana Venturi, INAF
- Zsolt Paragi, JIVE
- Michael Lindqvist, OSO

JUMPING JIVE

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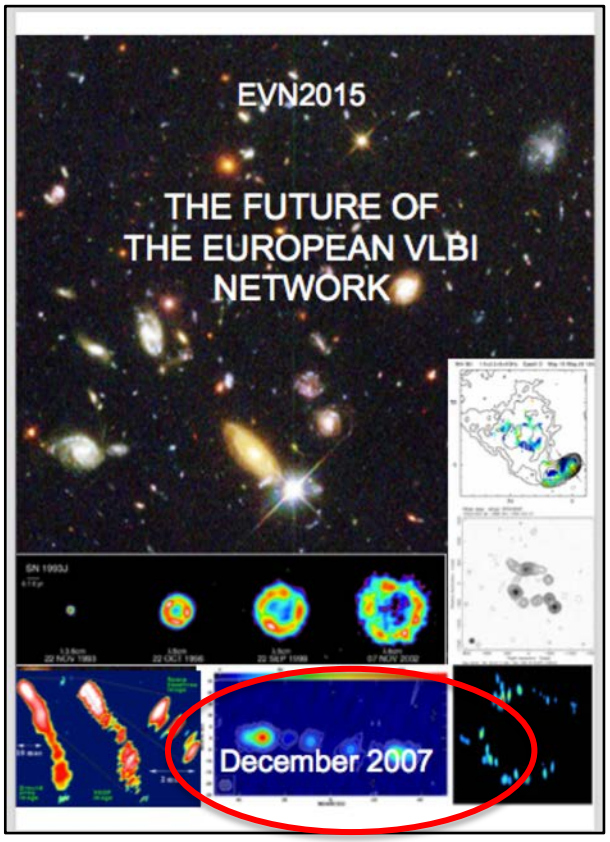
Background and actors



As highlighted by the EVN CBD in 2016: it is time to revise the VLBI Science case for several reasons

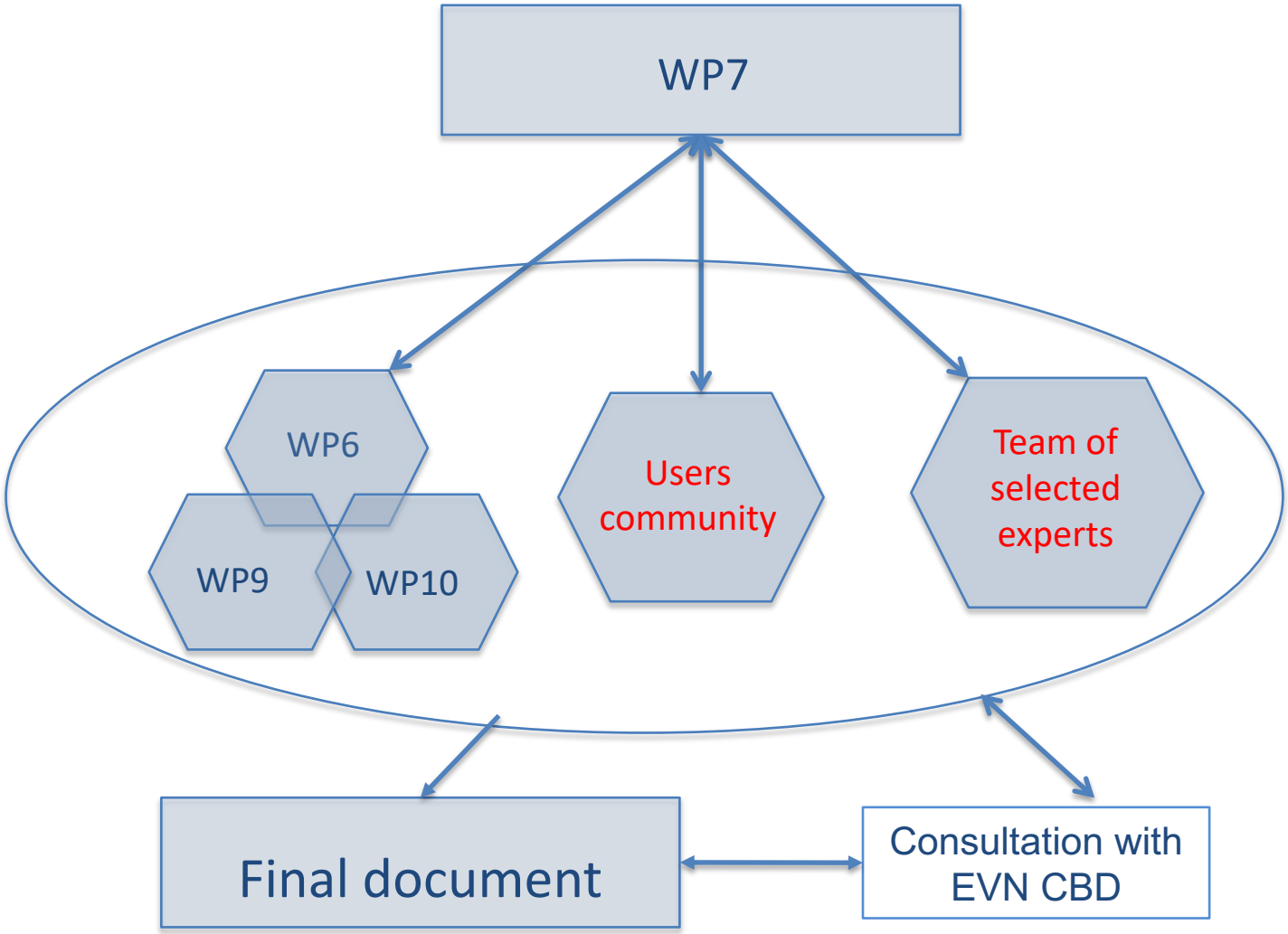
- EVN2015 more than 10 years old
- Role and potentials of VLBI in the new astrophysical landscape
- Role, potentials and added value of VLBI in the SKA era
- Define key science areas and observational needs for the technological development
- White book in support of funding requests to national agencies and ministries

Objectives for WP7

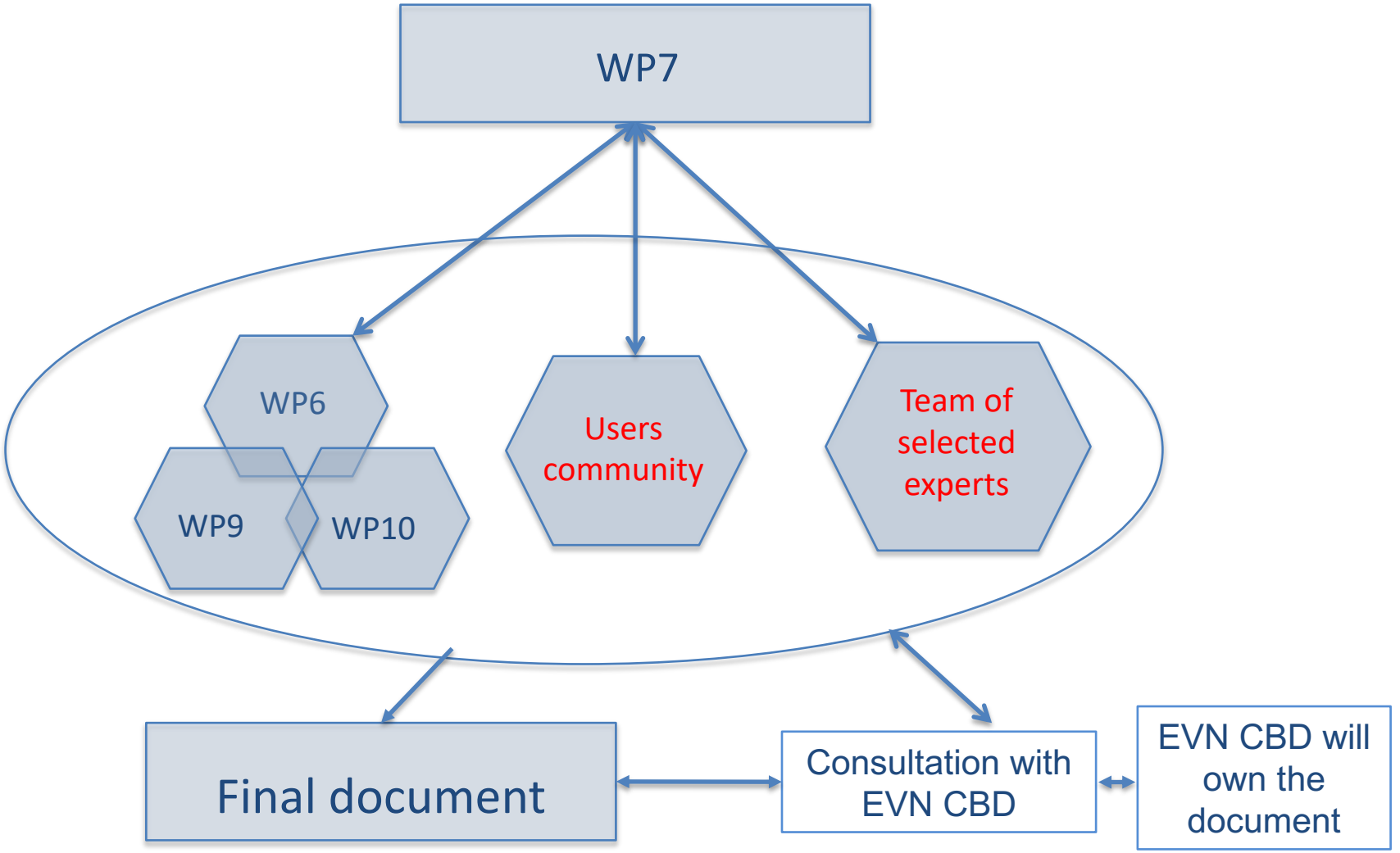
In consultation with the user community and global partners we will try to define the most important science areas for future VLBI array.

- One task: VLBI Science case
- One main deliverable: a white paper setting the future priorities of VLBI science capabilities

The process


WP7
WP6
WP9
WP10
Users community
Team of selected experts
Final document
Consultation with EVN CBD

The process


WP7
WP6
WP9
WP10
Users community
Team of selected experts
Final document
Consultation with EVN CBD
EVN CBD will own the document

Implementation plan and status

Core team of max 10 experts identifies key science areas and **experts** for the various sections/chapters

R. Beswick, T. Bogdanovic, W. Brisken, P. Charlot, M. Lindqvist, A. Lobanov, Z. Paragi, A. Szomoru, L. Testi, T. Venturi

Core team and **experts** meet in a 1-2 day brainstorming meeting:

- to discuss key science areas and technological developments;
- to discuss how to involve the community at large

✓ DONE

The write up of the document starts

✓ DONE

eMERLIN and EVN in the SKA era, Jodrell Bank, September 2017

Meeting part 2 : The future of VLBI

(Organisers: Tiziana Venturi (INAF) /Michael Lindqvist (Onsala) /Zsolt Paragi (JIVE)
12:00 - Introduction, welcome and overall vision - Tiziana Venturi (INAF, Italy)
12:15 - EVN present status and future direction - Michael Lindqvist (Onsala Space Observatory, Sweden)
12:30 - VLBA technical roadmap : 2020-2035 - Walter Brisken(LBO, USA)
12:45 - Wide-Band single pixel feeds and EVN technical upgrades - John Conway (Onsala Space Observatory, Sweden)

13:00 - Lunch

14:15 - VLBI and the SKA (an update from the SKA-VLBI SWG) - Zsolt Paragi (JIVE)
14:15 - Invesigating radio quiet quasars using e-MERLIN and EVN observations of strong gravitational lensing - Philippa Hartley (JBCA)
14:15 - Probing circumstellar structures through masers with the EVN and e-MERLIN - Sandra Etoka (JBCA)
14:30 onwards - Discussion and Wrap-up

Figure 1: e-MERLIN & VLBI Community Workshop (Jodrell Bank Observatory, September 2017)

The F2F Meeting
Zaandam (NL), February 2018

- Scientific presentations on: cosmology, galaxy formation & AGN feedback, AGN and inner jets, stellar evolution, astrometry and geodesy, transient science
- Lively and productive discussion
- Chapter coordinators identified

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- Presentations online!

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Zaandam (NL), February 2018

- Learn from history (H. Langevelde):
  - Could have looked more ‘glossy’
  - Science part could have been more
  - concise?
  - Technical part was a vision, not a plan endorsed by EVN
  - Should have been translated in a project

- Besides GRB & FRB we now have GW events! What are we missing today?

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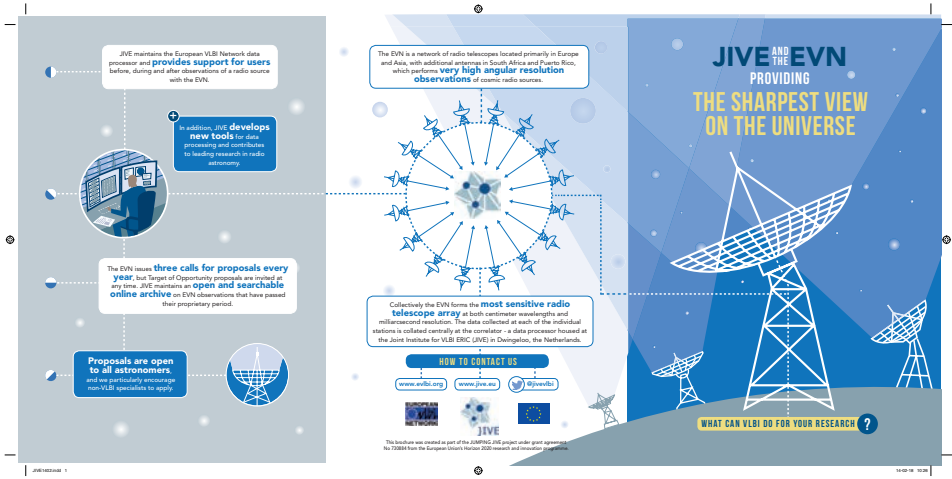

- Besides GRB & FRB we now have GW events! What are we missing today?

We will….

- Make a glossy document ☺
- Make a handy brochure
- And distribute WIDELY!

European Week of Astronomy and Space Science

- Session by invitation
- A few posters presented
- Very good attendance (40-50 people throughout the day)
- Excellent presentation (all available online) highlighting the potentials of VLBI over a very broad range of science
- Very successful engagement of experts outside the radio domain for the development of the EVN Science case

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European Week of Astronomy and Space Science

- **A. Williamson:** Gravitational waves: potential contribution of VLBI
- **C. Spingola:** Gravitational Lensing with the next generation of VLBI arrays
- **A. Merloni:** Coevolution of Supermassive Black Holes and their host galaxies:
- **T. Muxlow:** The Impact of VLBI Observations on our Understanding of Star-formation Activity and Low-Luminosity AGN Systems
- **H. Falcke:** Imaging black holes with mm-VLBI: past, present and future
- **T. Sbarrato:** Big and young SMBHs in the early Universe: how can we observe jetted AGN?
- **J. Hessels:** Zooming in on fast radio bursts
- **M. Perez Torres:** Extragalactic Synchrotron Transients with VLBI: from Supernovae to TDEs
- **A. Brunthaler:** Stellar masers and the structure of the Galaxy
- **H. Olofsson:** VLBI and the life-cycles of stars
- **J. Conway:** The Future of VLBI
- **T. Venturi:** Summary and concluding remarks

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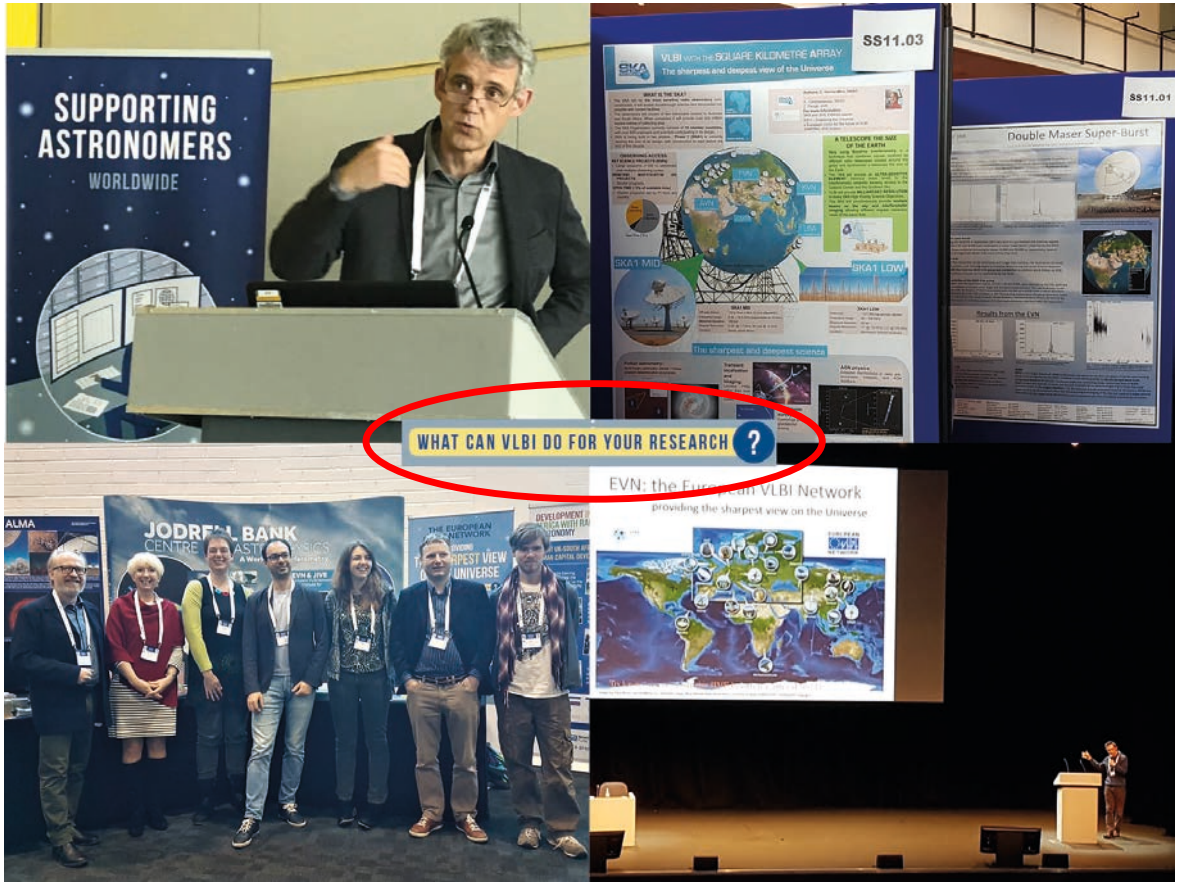


The VLBI Science Vision Document

Approach - The document is not a wishlist, but rather includes:

- ✓ a selection of open questions in astrophysics where VLBI can provide unique answers
- ✓ a selection of science areas which can make considerable progress thanks to VLBI
- ✓ feasible developments to address the science

Chapters and coordinators

Coordinator W. Brisken:

Present and future VLBI arrays and other radio facilities - EVN and JIVE; eMERLIN; CVN; EAVN; JVLA; VLBA; LBA; LOFAR

The multi-messenger landscape – ALMA and E-ELT; CTA

Coordinator J. McKean

Cosmology – Review of current state-of-play; Dark matter: lensing on various scales; Dark energy; Masers: geometric distance and high-z; Lenses: time-delay distances; FRBs: geometric distances

Coordinators: T. Muxlow & R. Morganti

Galaxy Formation and AGN Feedback – Galaxy formation; Faint radio population; AGN vs star formation; faint radio-loud AGN; star formation and accretion in the local Universe; signposts of accretion and feedback; star formation processes; feedback through spectral line VLBI of HI

Coordinator: S. Frey

High-redshift AGNs and SMBH – AGNs in the early Universe; Blazars as tracers of high-z jetted AGNs; High-z observations with VLBI

Chapters and coordinators

Coordinator: A. Lobanov

The inner core regions and mm-VLBI

Coordinators: M. Perez-Torres & Z. Paragi

Transient Phenomena – Slow transients: BHs and neutron X-ray binary stars, thermonucear runaway supernovae, CCSNs and long GRBs, TDEs, NS and black home mergers, GW; Fast transients: FRBs, NS and pulsars

Coordinators: A. Bartkiewicz & K. Rygl

Galactic Masers – Masers in star forming regions; Masers around evolved stars; Maser astrometry

Coordinator: J.C. Guirado

Stellar evolution and planetary systems – VLBI astrometry; Pre-main sequence stars: protoplanetary disks, clusters and star forming regions, calibration of PMS evolutionary; Main sequence stars: Flares/coronal mass ejection, ultracool dwarfs, exoplanets; Evolved stars: mass loss/stellar winds, star spots, colliding winds

Chapters and coordinators

Coordinator: P. Charlot
Astrometry, Earth and Celestrial Reference Frames

Coordinator: L. Gurvits
Space Science– Spacecraft as a VLBI target; near-field VLBI

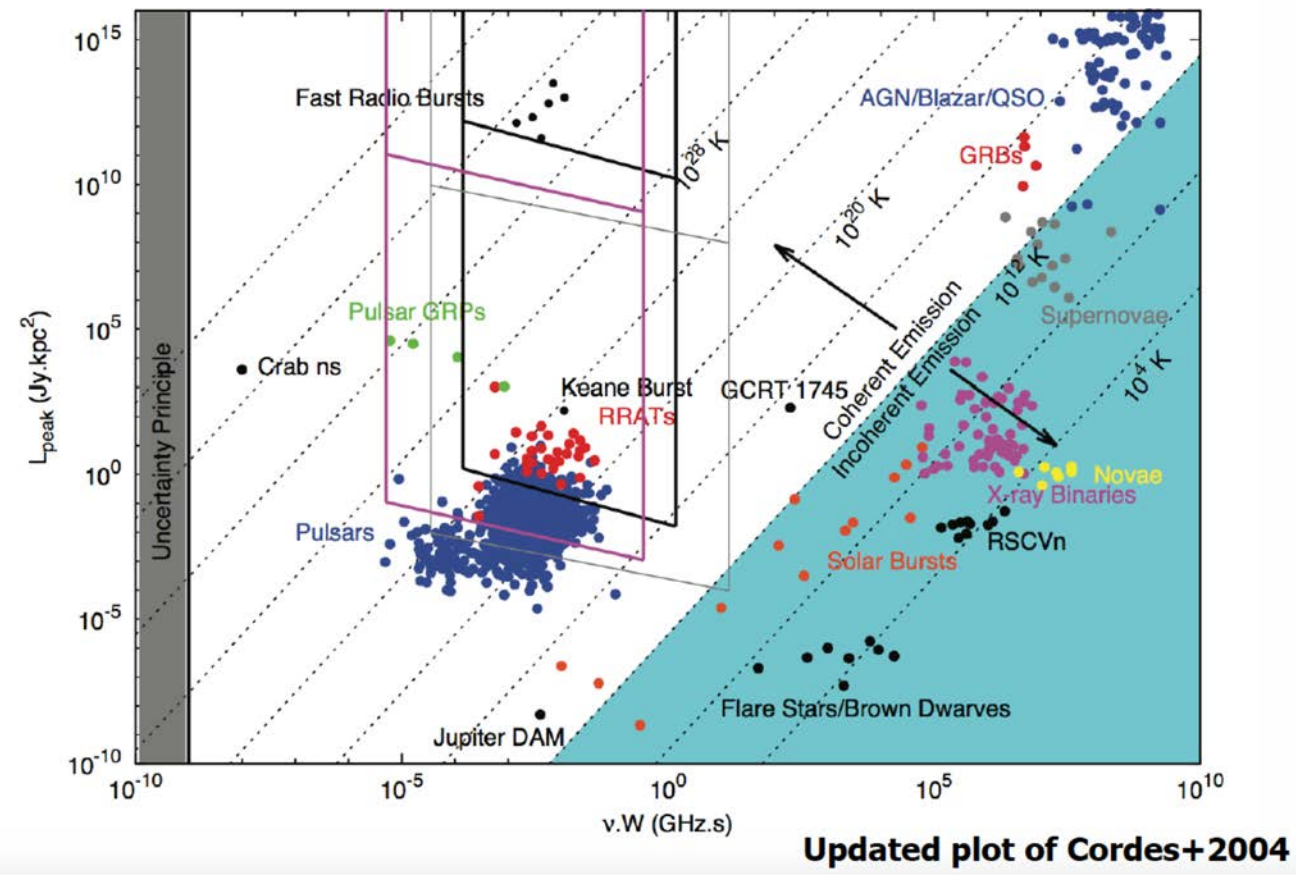
Coordinators: A. Szomoru & P. de Vicente
Technological developments

Coordinator: H. Langevelde
VLBI & synergies in the next decade

Extragalactic Synchrotron Transients with the EVN

M. Pérez-Torres

The transient parameter space



Updated plot of Cordes+2004

Extragalactic Synchrotron Transients with the EVN

M. Pérez-Torres

The EVN challenge for the next decade

Towards a 1 microJy/b sensitivity, frequency agile, multi-scale, prompt-response VLBI array

Gravitational wave astrophysics: the role of VLBI from A. Williamson, EWASS 2018

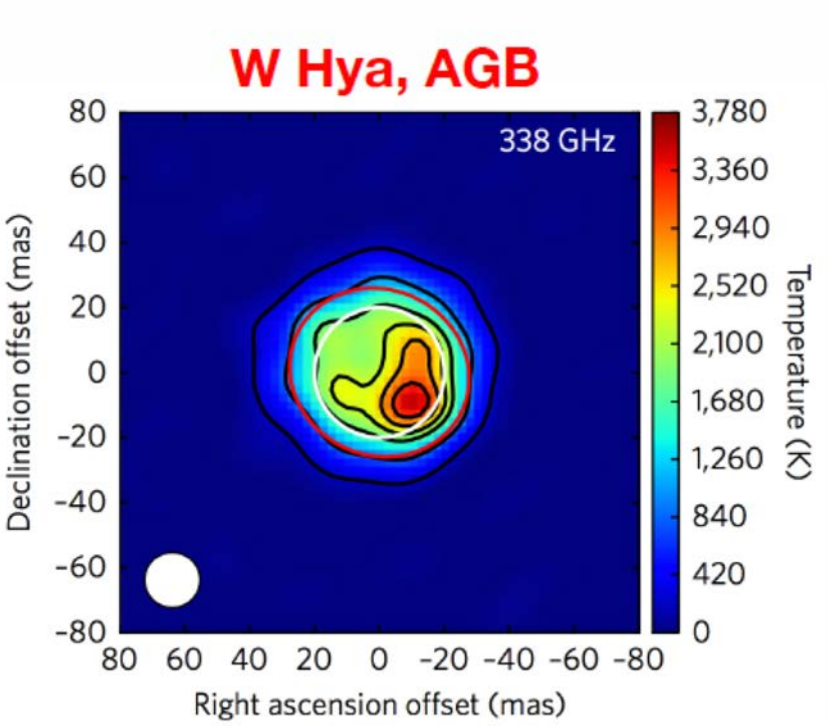
- VLBI imaging can help clarify the astrophysics behind e.g. neutron star mergers.
- There are likely to be many similarly exciting events! O3 starts 2019!
- VLBI can probe the stochastic GW background between ~10^{-16} - ~10^{-9} Hz.
- VLBI astrometry will also aid pulsar timing measurements for supermassive GW sources.

Image credit: University of Warwick / Mark Garlick.

The life cycles of stars: What VLBI can tell us

from H. Olofsson, EWASS, 2018

- Astrometric measurements: crucial for a wide variety of studies.
- Radiation mechanism identification, Turn-over frequencies of free-free, gyro-synchrotron, …
- Source imaging: non-thermal components at mas-scales
- Very high sensitivity
  - Even thermal emission?
  - Surface structures
  - Wind clumpiness
  - Coronal winds
  - Flares, CMEs



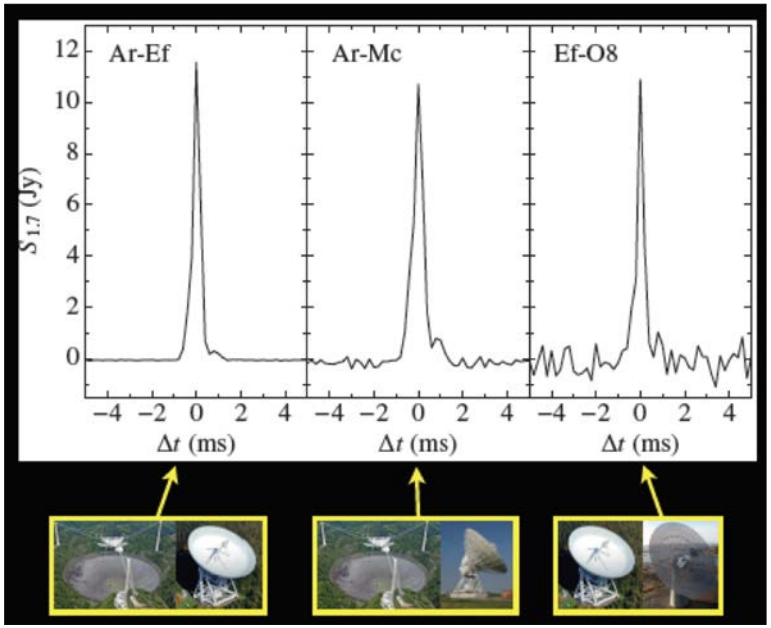
T_b > 53000 K, size < 3 mas

Vlemmings et al. (2017), ALMA

FRB follow-up with EVN

from J. Hessels, EWASS, 2018

- FRB 121102 demonstrates the importance of VLBI for understanding FRBs
- CHIME, ASKAP, Apertif, UTMOST, etc.
- Precision localizations remains critical.
- The EVN can be an important follow-up machine and enable precision burst localizations and identify potential persistent radio counterparts.
- Discovering new FRBs with EVN would require a major investment and effort.

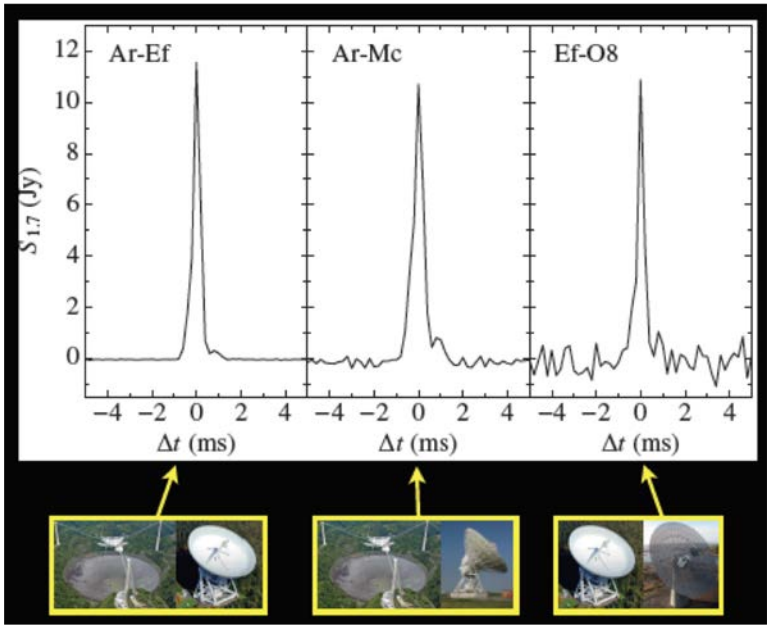


Marcote et al. 2017

FRB follow-up with EVN

from J. Hessels, EWASS, 2018

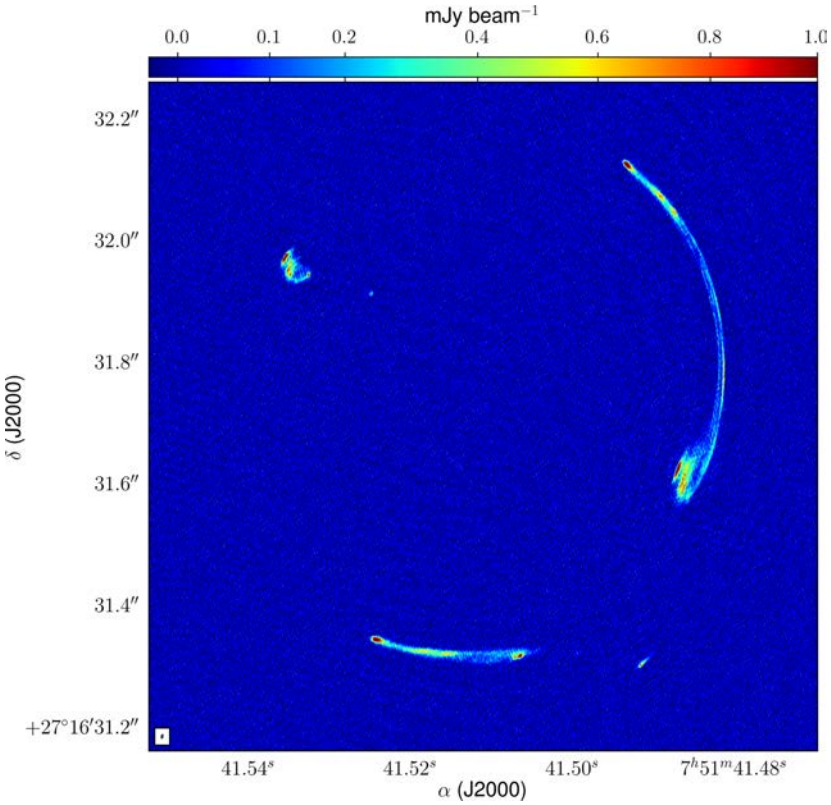
- Greatly expand the capacity for buffering individual telescope data and imaging a large fraction of the primary field-of-view.
- Use the small dishes to continuously shadow an instrument capable of discovering FRBs at a reasonable rate. EVN lite



Marcote et al. 2017

Gravitational lensing with the next generation of VLBI arrays from C. Spingola, EWASS, 2018

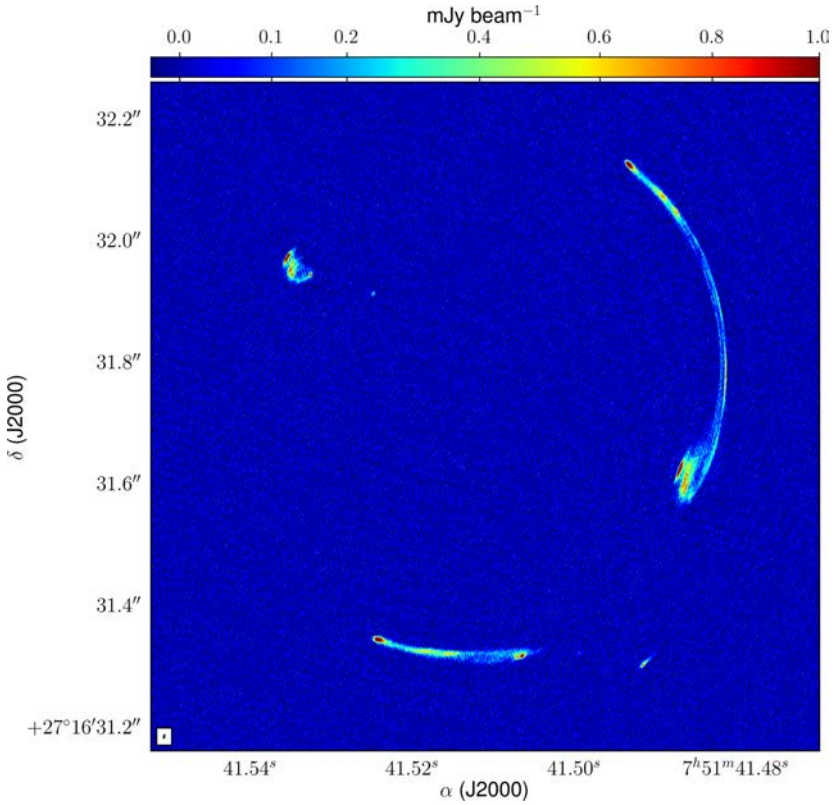
- What is dark energy? (can we constrain the equation of state?)
- What is dark matter? (can we constrain the dark matter particle?)
- Gravitational lensing
- VLBI observations allows to resolve lensed images -> quantify mass of perturbation
- SKA1-MID will find many lenses
- VLBI follow up



Spingola et al. 2018

Gravitational lensing with the next generation of VLBI arrays from C. Spingola, EWASS, 2018

- What do we need:
  - Improved sensitivity
  - Wide-field surveys + matched sky areas with optical surveys
  - Flexibility in observing frequency
  - VLBI mode for SKA

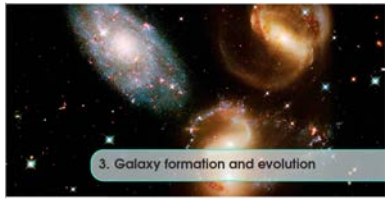


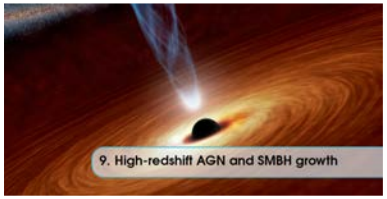
Spingola et al. 2018

14th EVN Symposium & Users Meeting
Granada, October 2018

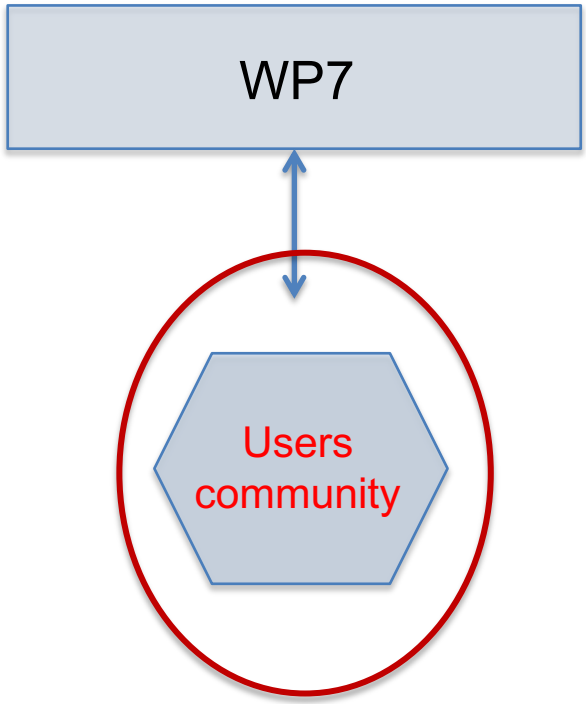
Next steps and deadlines

- Updated report to the CBD in Autumn 2018 (November 28)
- WP leaders meeting, January 2019
- Meeting among WP leaders, chapter coordinators and writing team, 2019
- Advanced draft to be delivered to the EVN CBD by autumn 2019 as requested
- EVN - Quo vadis?





Input from you!



Discussion with the EVN/VLBI users community at large

Input from you!

- Comments/suggestions?
- Is there anything major missing from the broad list of topics we have selected?

- Contributions are welcome!
- Get in touch with the chapter coordinator of the topic you may wish to contribute to!

http://jumping.jive.eu/