

Scientific prospects for joint EVN and uGMRT observations

Tiziana Venturi (IRA-INAF, chair EVN CBD)

Outline

- Overview of the EVN
- The VLBI Science Vision Document and the technological roadmap
- The inclusion of uGMRT in EVN operations
- Scientific potentials

The European VLBI Network is much broader than geographical Europe

- 18 European partners + China + Russia + South Africa + Korea
- eMERLIN routinely part of the array
- Arecibo lost – but 12m in progress
- 3 sessions (x 3 weeks) per year
- + 10 e-VLBI days, + ToO + OoS
- 3 calls for proposals (Feb, Jun, Oct 1)
- Operates at L,S,C,X,K bands
- Routinely @2Gbps
- Moving towards 4 Gbps

<https://www.evlbi.org/>



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• Organisation:

- EVN Consortium Board of Directors (EVN CBD)
- EVN time allocation Program Committee (EVN PC)
- EVN Technical and Operations Group (EVN TOG)
- EVN scheduler

Officers

• Central institute is JIVE

- Correlation, R&D, outreach
- Expert user support
- EVN tech exploder (evntech@jive.eu)



$\mu\text{Jy/b}$ sensitivity at mas to sub-mas angular scales

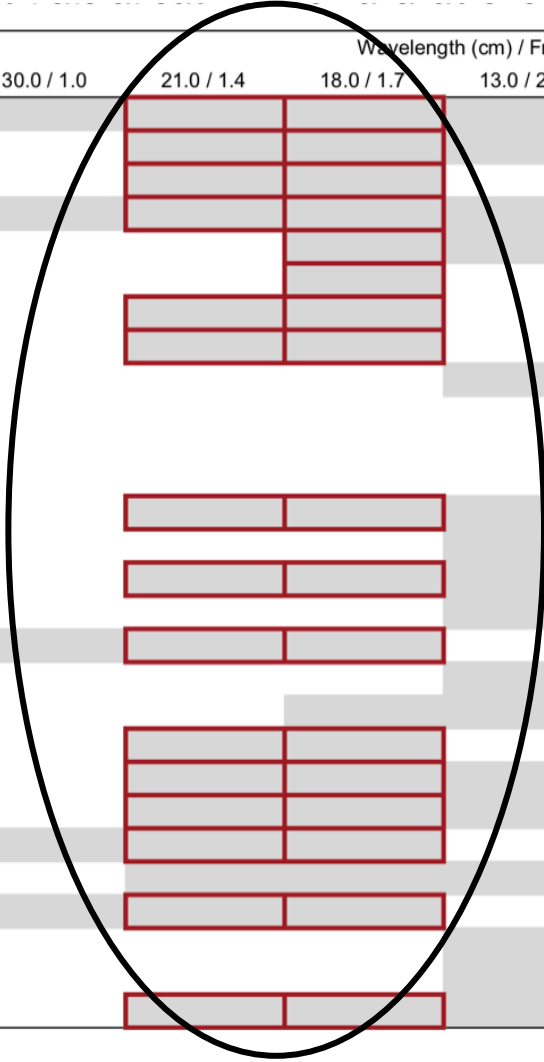
Network/Wavelength (cm)	92	49	30	21	18	13	6	5	3.6	1.3	0.7		Longest baseline	
EVN-Europe	32.43	17.27	10.57	7.40	6.34	4.58	2.11	1.76	1.27	0.46	0.25		7139	Bd/Ro
EVN-Europe-Africa	24.91	13.27	8.12	5.69	4.87	3.52	1.62	1.35	0.97	0.35	0.19		9833	Bd/Hh
EVN-Europe-Asia	23.54	12.54	7.68	5.37	4.61	3.33	1.54	1.28	0.92	0.33	0.18		9294	Kt/Ro
EVN-Europe-North America	22.24	11.85	7.25	5.08	4.35	3.14	1.45	1.21	0.87	0.31	0.17		10408	Ar/Bd
EVN-Full	19.60	10.44	6.39	4.47	3.83	2.77	1.28	1.07	0.77	0.28	0.15		11812	Ar/Km
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

Frequency coverage

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
Zelenchuskaya (Zc)												32	1

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Metsähovi (Mh)				█	█		█	█		█		14	1
Noto (Nt)				█	█		█	█		█		32	2
Onsala-60 (O6)				█	█		█	█		█		20	2
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VLBI20-30: a scientific roadmap for the next decade

The future of the European VLBI Network

Editors: Tiziana Venturi, Zsolt Paragi & Michael Lindqvist



Endorsed by the EVN Consortium Board of Directors

Main purpose: define the role of VLBI in the scientific framework of the next decade, with the new observational facilities in the radio, optical, X- and gamma-ray domains

- Great community effort, facilitated by H2020 JUMPING JIVE.

<https://arxiv.org/abs/2007.02347>

- Main topics:
 1. Cosmology
 2. Galaxy formation and evolution
 3. Innermost regions of AGN
 4. Explosive phenomena, transients
 5. Stars and stellar masers in the Milky Way
 6. Earth and Space

An amazing broadening of the science where VLBI plays a unique role compared to 15 years ago

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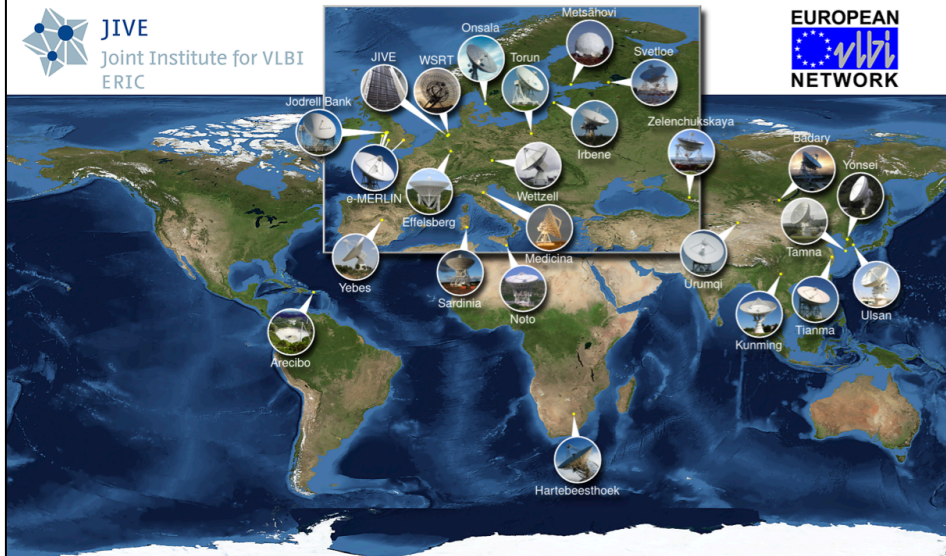


Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Endorsed by the EVN Consortium Board of Directors

Directions for a technological roadmap

Improved performances:

- Higher sensitivity
- Broader frequency range
- Extension to the Southern Sky

Improved operations:

- More flexibility

Improved tools



Value of joint EVN-uGMRT observations

Improved performances:

- Higher sensitivity
- Broader frequency range
- Extension to the Southern Sky

Improved operations:

- More flexibility

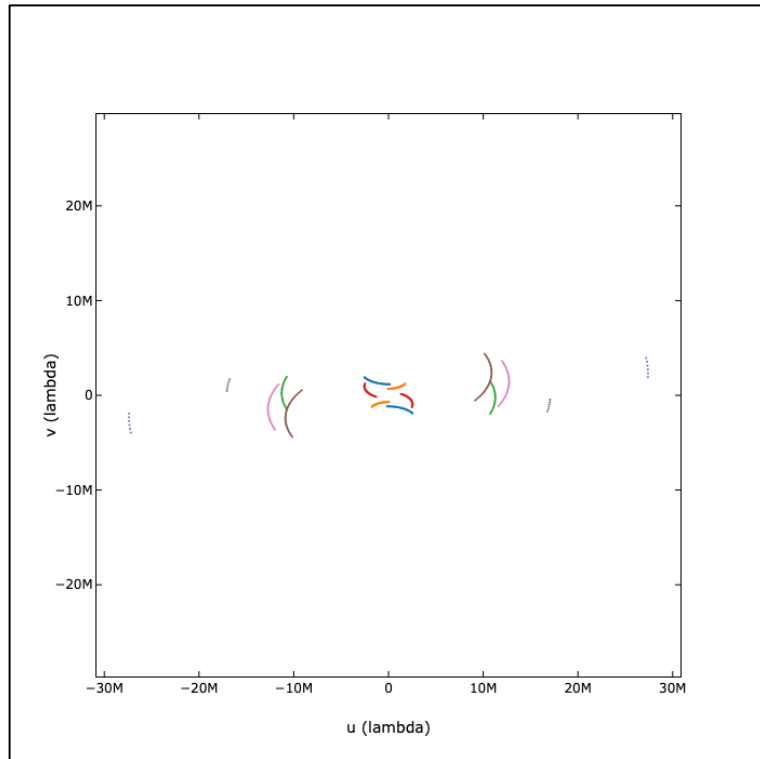
Improved tools

Jump in collecting area

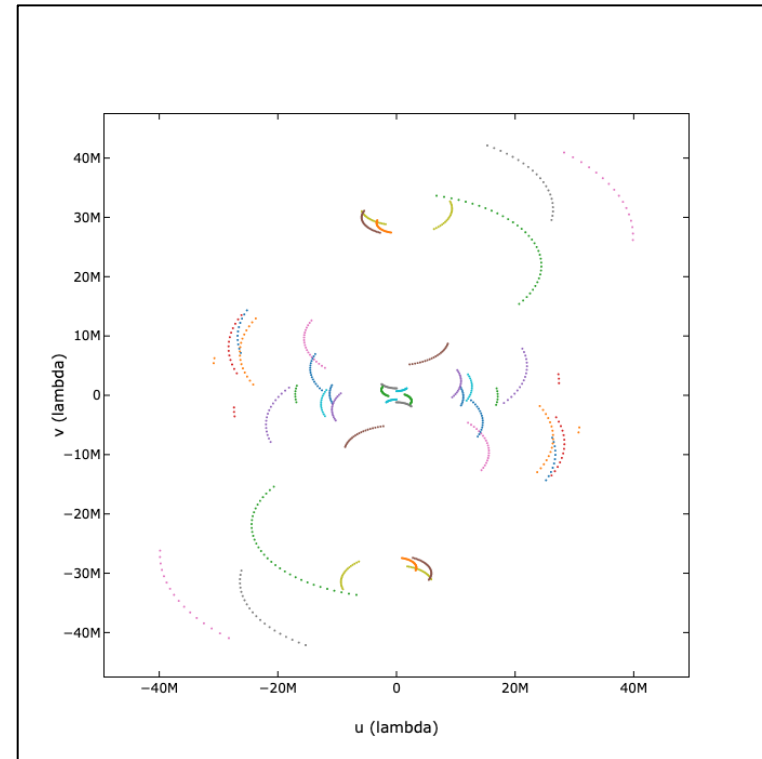
Improvement of the u-v
plane especially at low
declinations



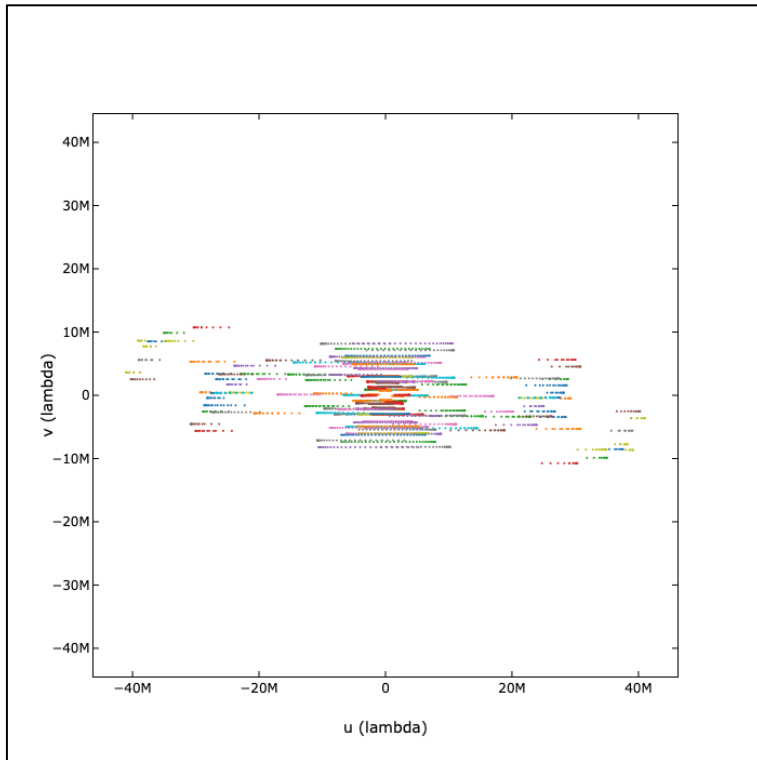
EVN-only at -30°



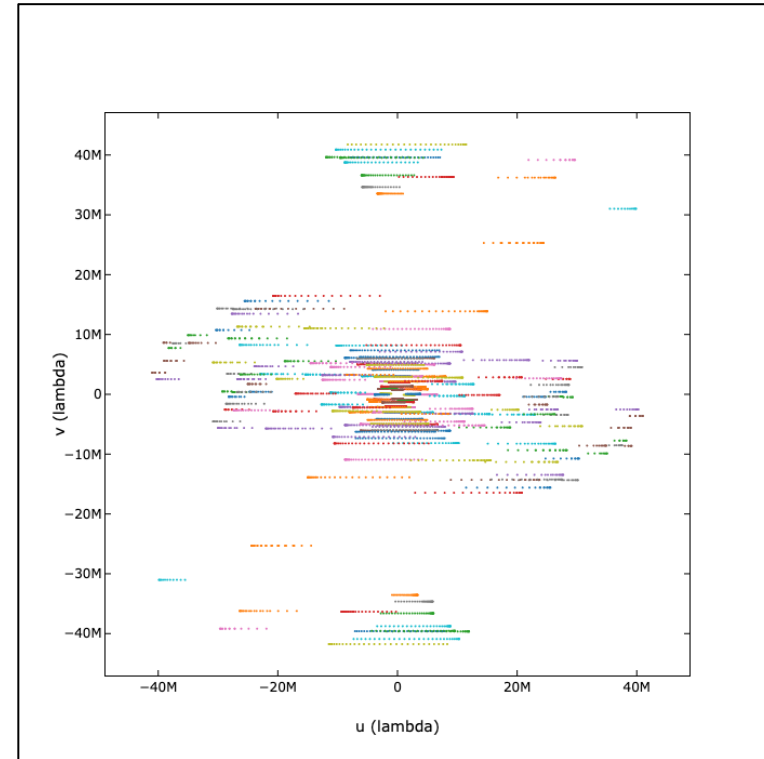
EVN+uGMRT+South Africa at -30°



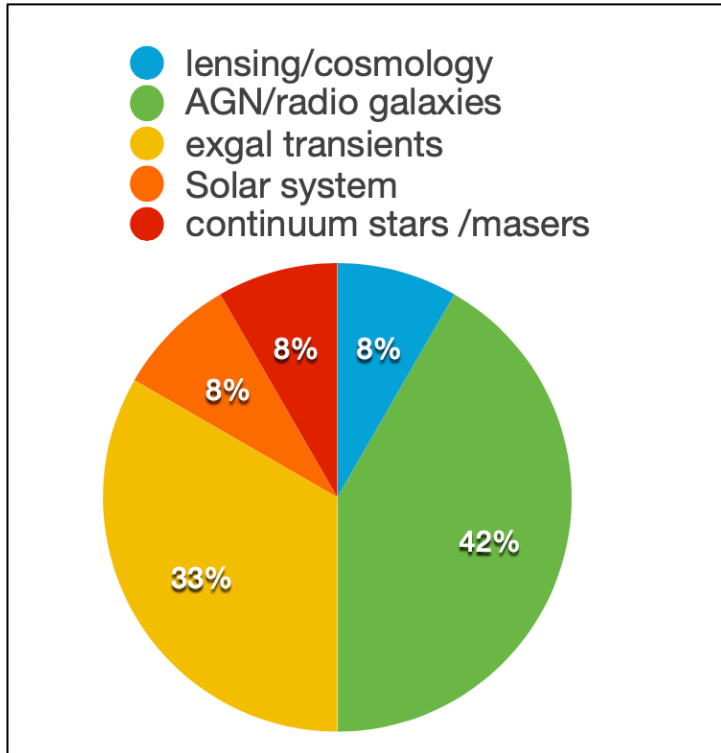
EVN-only at 0°



EVN+uGMRT+South Africa at 0°



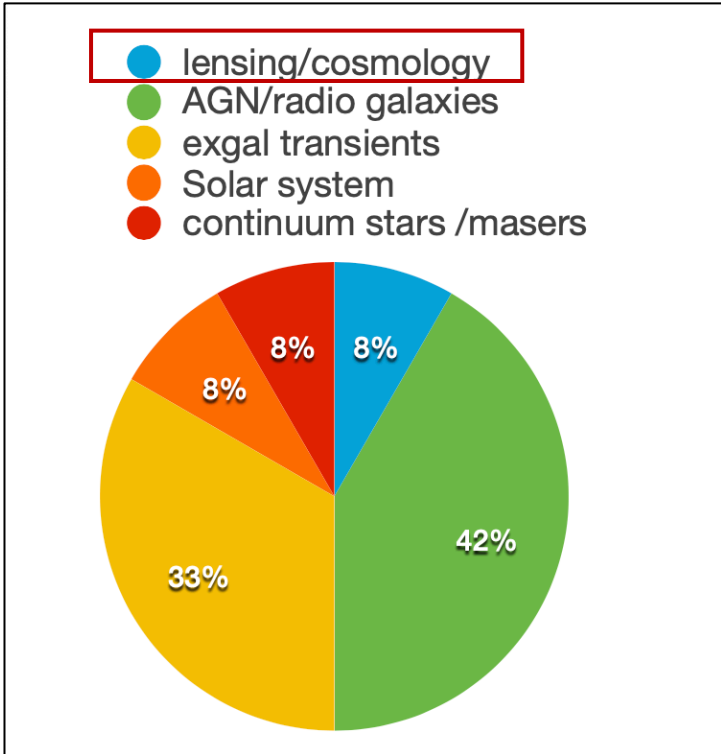
VLBI Science in the next decade



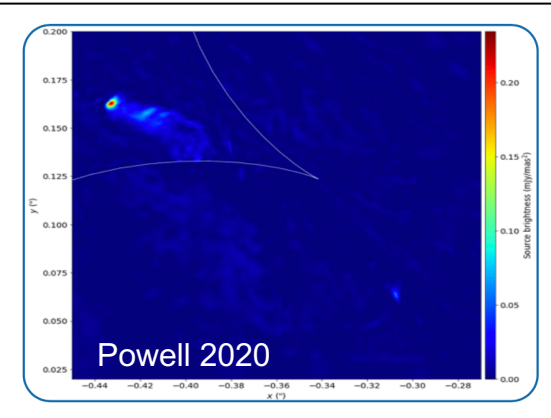
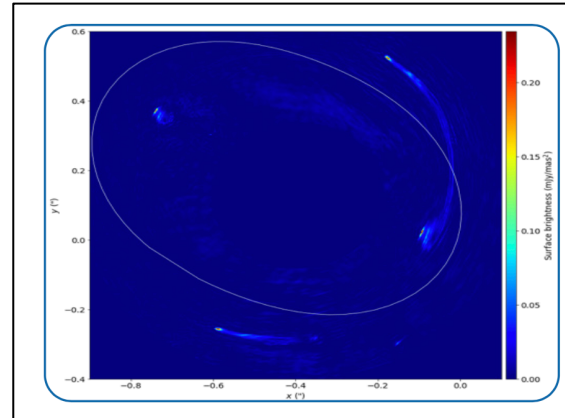
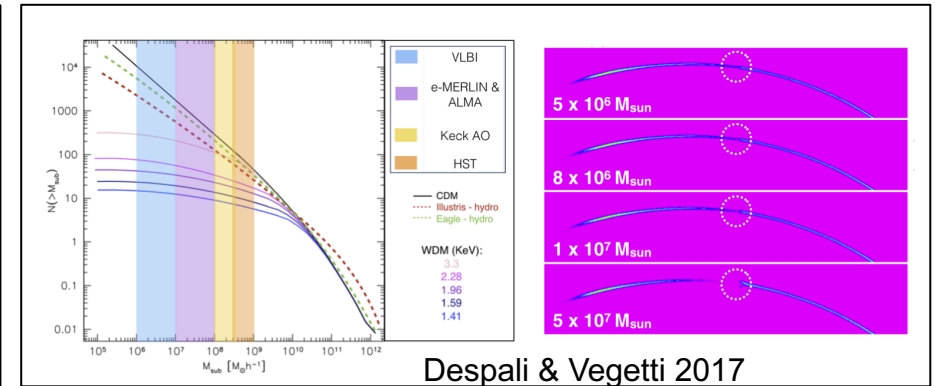
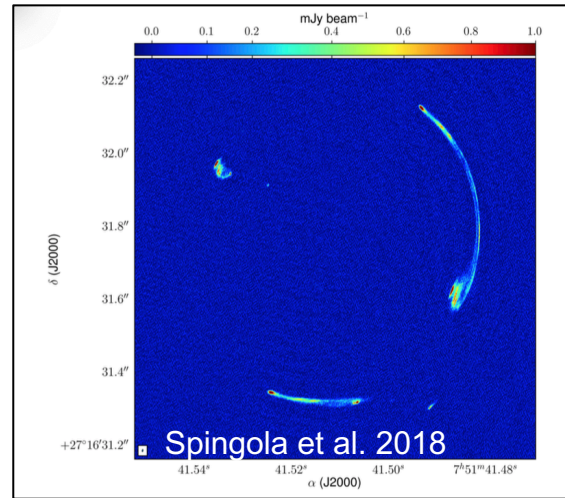
AGN/radio galaxies are still dominant, but many new areas are now part of the scientific coverage of VLBI

Science distribution of EVN proposals in 2019C. *Courtesy of the EVN PC Chair (Rygl)*

VLBI Science in the next decade

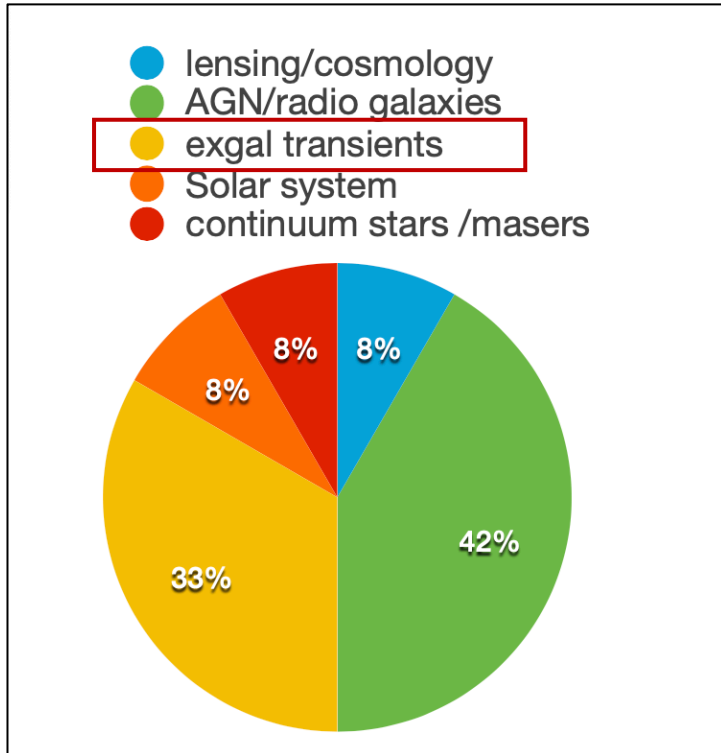


Science distribution of EVN proposals in 2019C. *Courtesy of the EVN PC Chair (Rygl)*

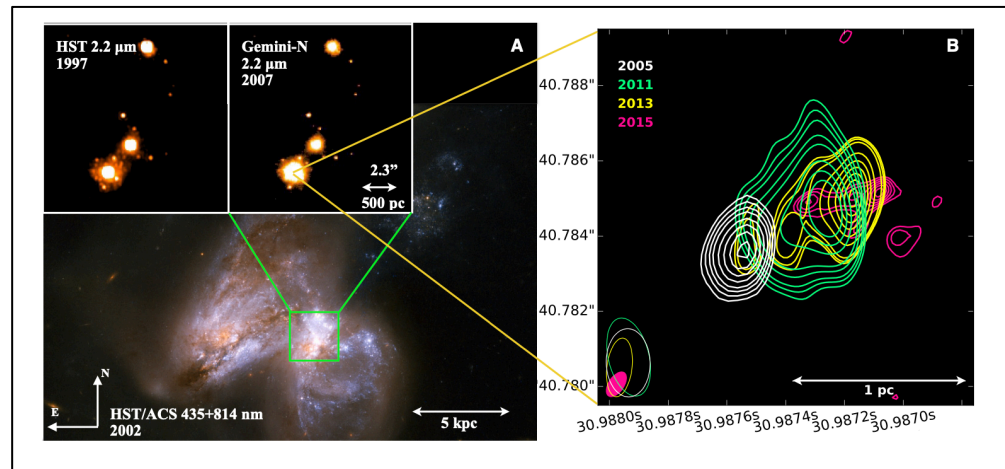


VLBI imaging of gravitational lenses covers the mass range of $\sim 10^6$ - $10^7 M_{\text{sun}}$ dark matter halos

VLBI Science in the next decade

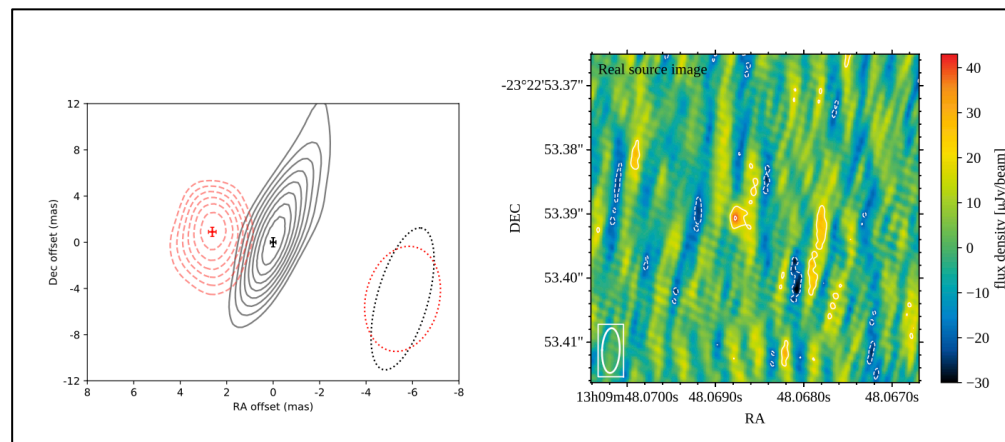


Science distribution of EVN proposals in 2019C. *Courtesy of the EVN PC Chair (Rygl)*



A Tidal Disruption Event in Arp-299 B

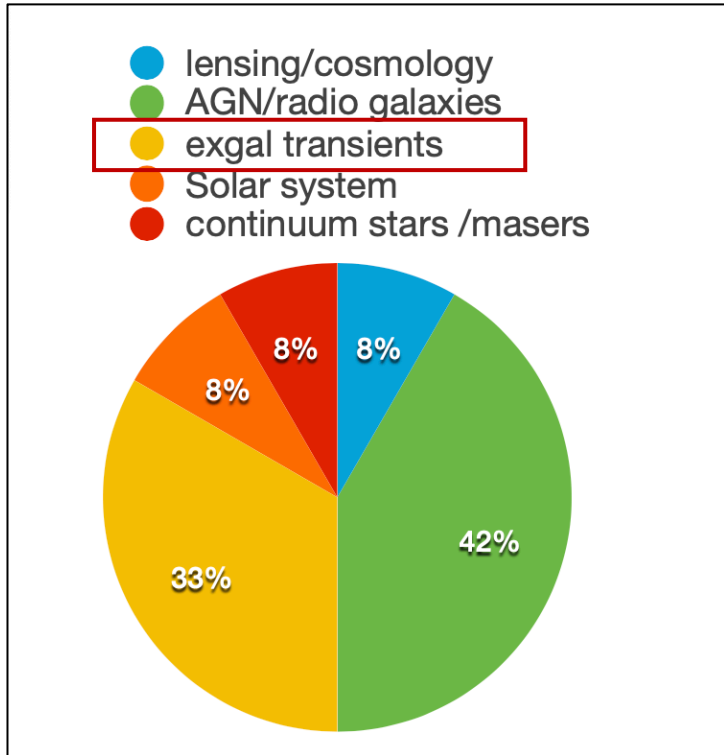
Mattila et al. 2018



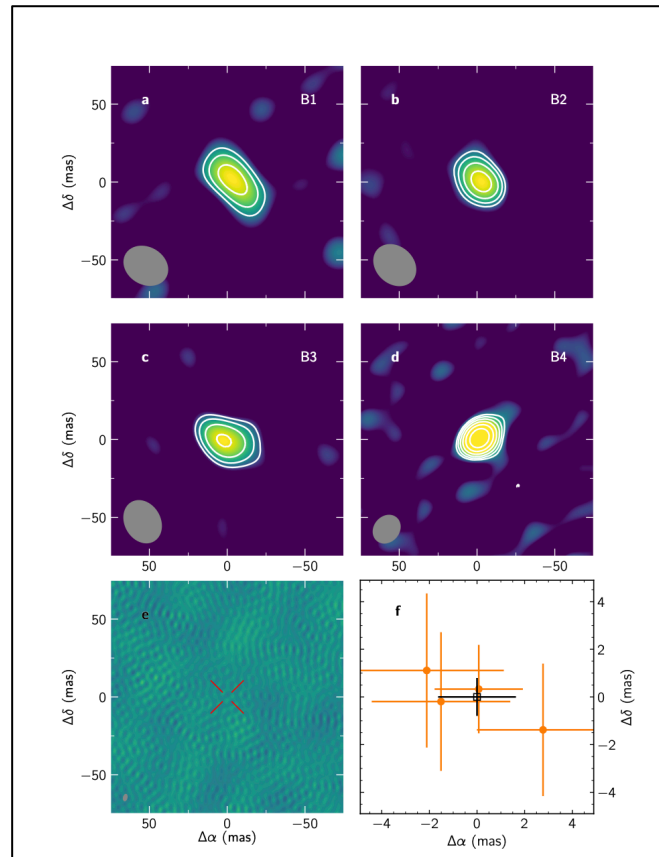
Non-thermal counterpart of GW170817
Jet vs cocoon

Ghirlanda et al. 2019

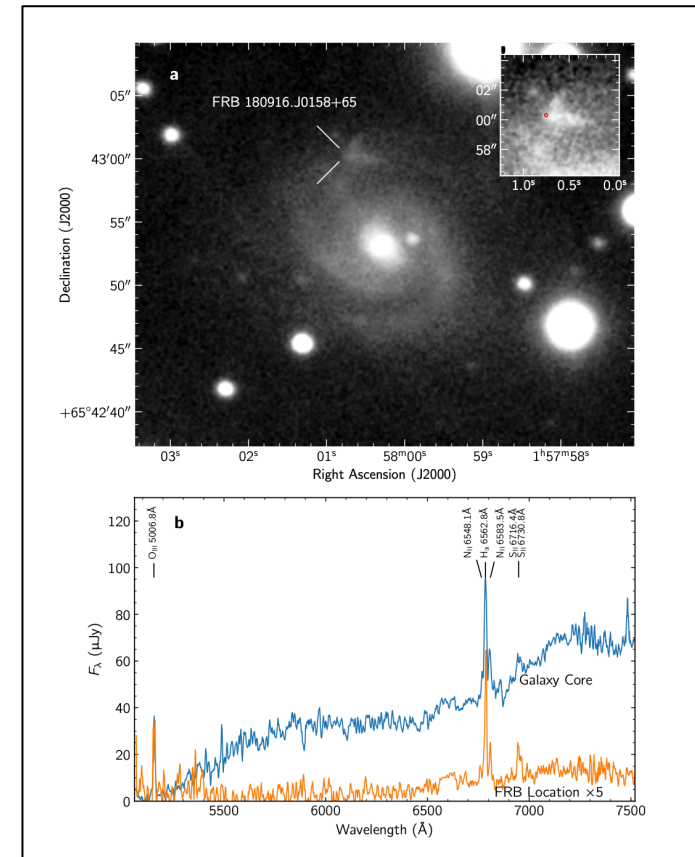
VLBI Science in the next decade



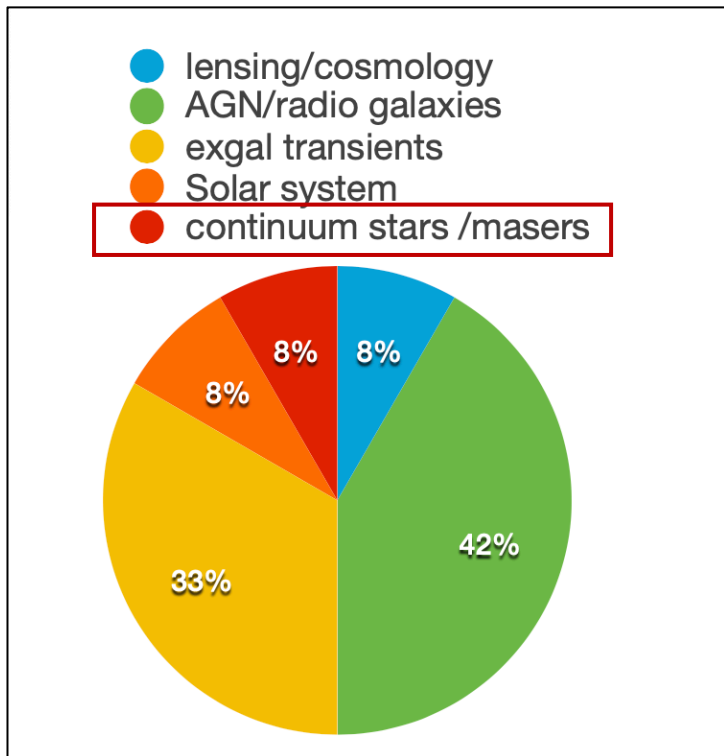
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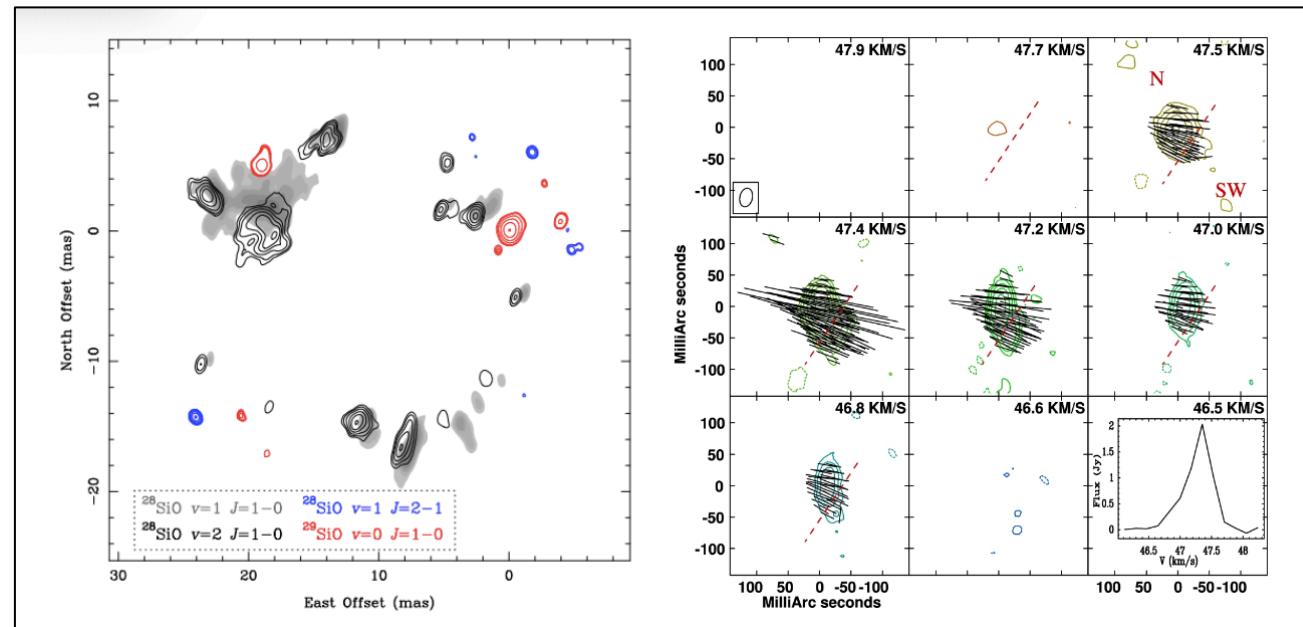
Localization of FRBs – Marcote et al. 2020



VLBI Science in the next decade



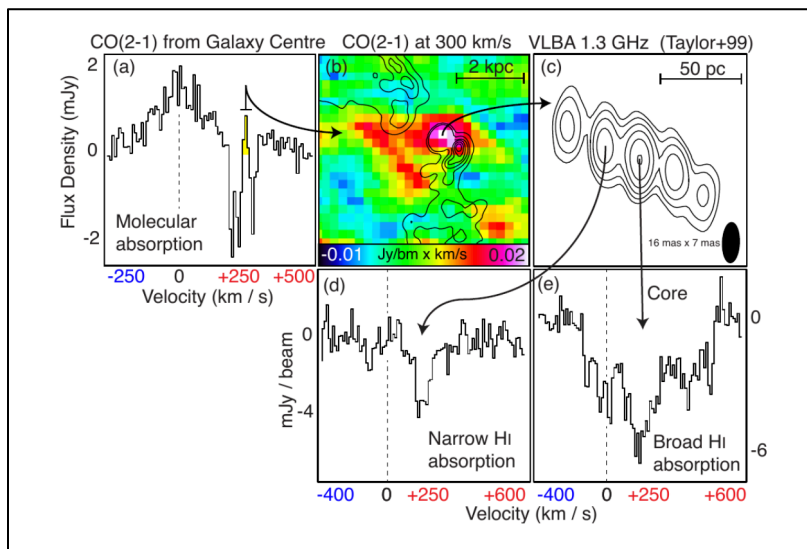
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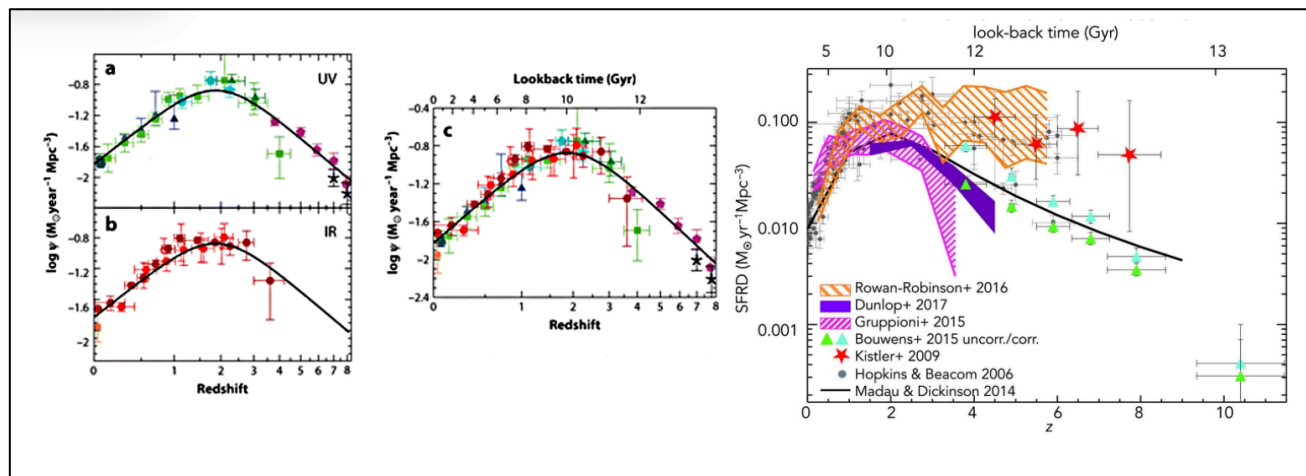
Maser species around stars in late evolutionary stages

Etoka et al. 2017

VLBI Science in the next decade

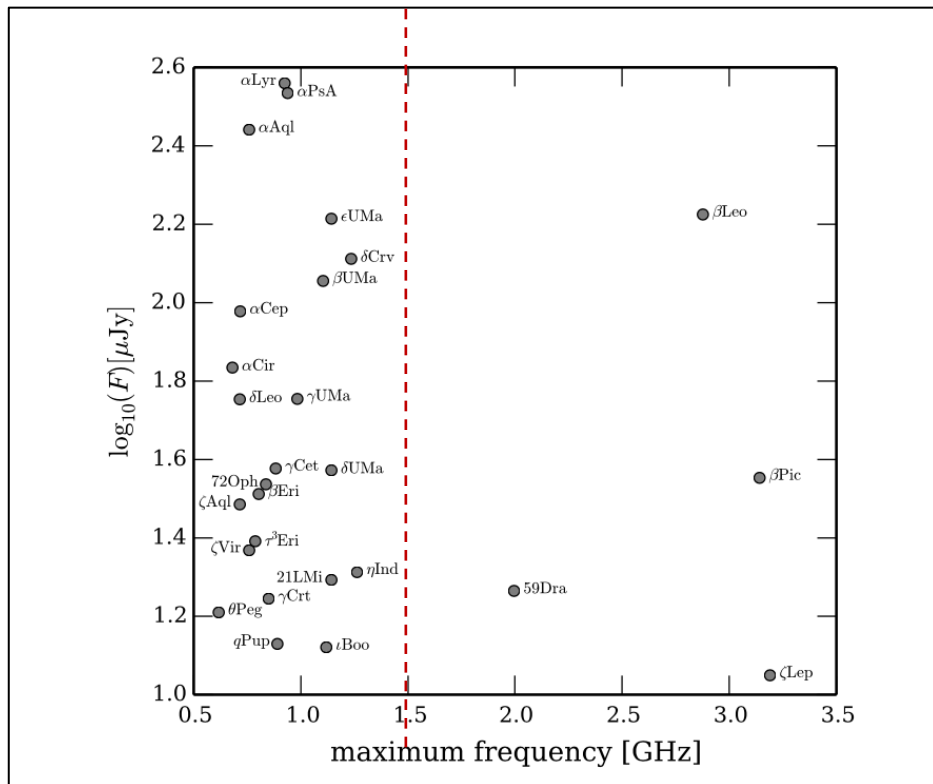


AGN Feedback with HI – A2597
Tremblay et al. 2016

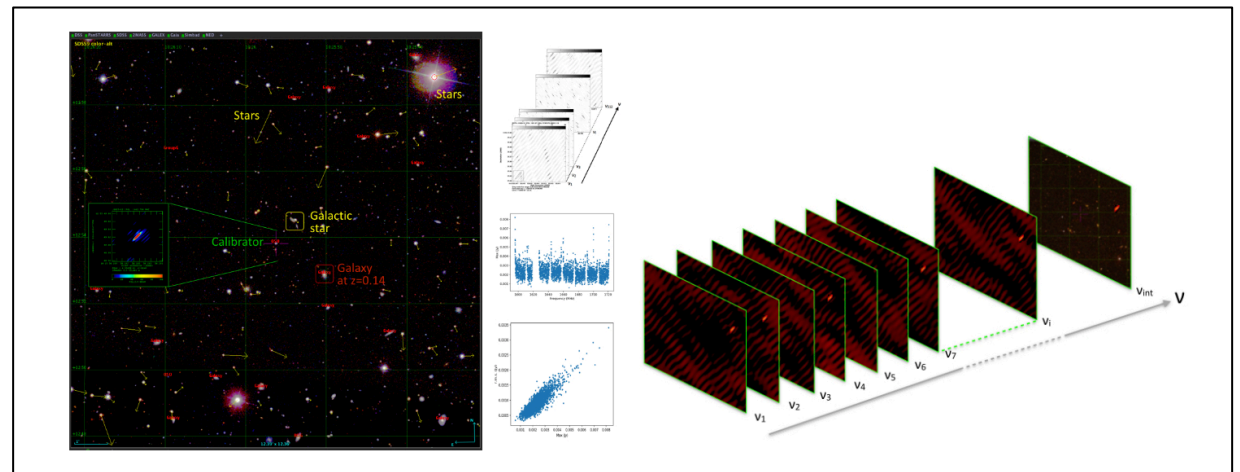


Galaxy evolution - Resolving AGN and starburst at high z
Gruppioni et al. 2017

VLBI Science in the next decade



Expected radio emission from massive exoplanets
at 1 AU around A-type stars
Katarzynski et al. 2016



SETI – Courtesy of M.A. Garrett

Concluding Remarks

- The scientific potentials of VLBI have broadened enormously over the past decade
- High-sensitivity mas-scale angular resolution facilities are mandatory in the observational landscape of the present decade and beyond
- Joint operations between the EVN, uGMRT and radio telescopes in Africa (Ghana, MeerKAT) at 1.4 GHz would considerably increase the portion of sky accessible to mas-scale resolution, most remarkably the Galactic Plane and further south

Concluding Remarks

- The Global VLBI Alliance offers uGMRT a unique chance to join not just the EVN but any other VLBI array operating at L band
- Compatibility of recording modes and correlation will need to be addressed

Scientific prospects for joint EVN and uGMRT observations