

The Future of the EVN and VLBI with the SKA

Zsolt Paragi
JIVE

The European VLBI Network

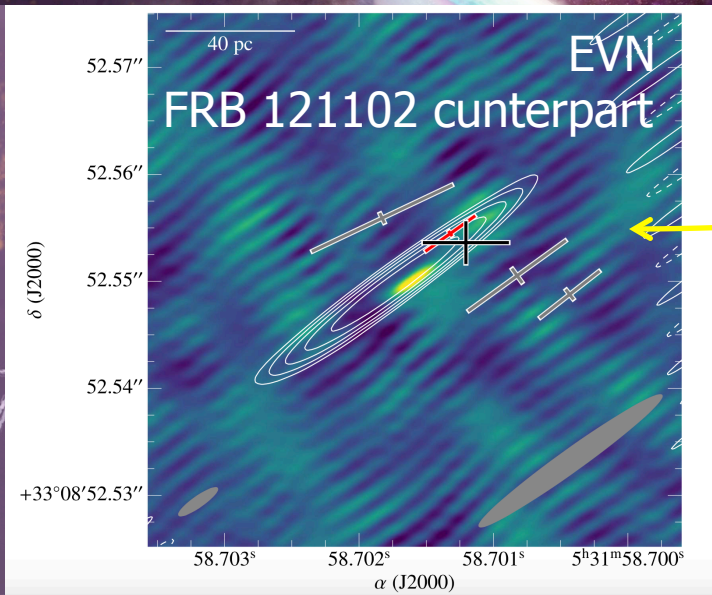


Science Highlights

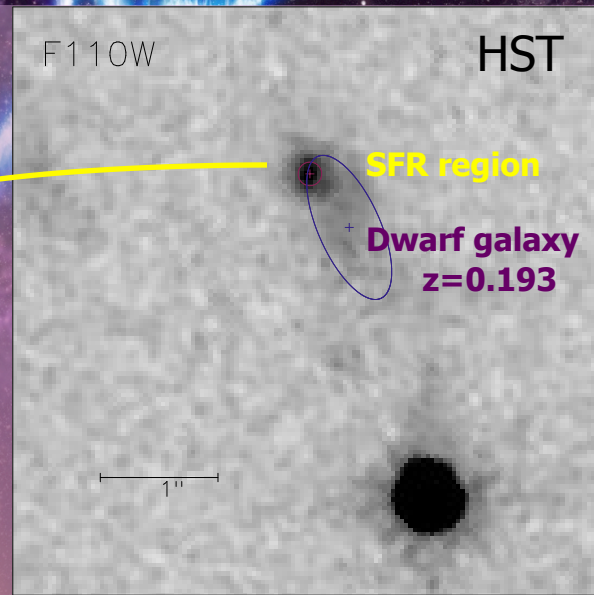


Dana Berry/NASA/Skyworks Digital

Fast Radio Bursts: EVN localization of the repeater FRB 121102



Marcote et al. (2017)
Chatterjee et al. (2017)

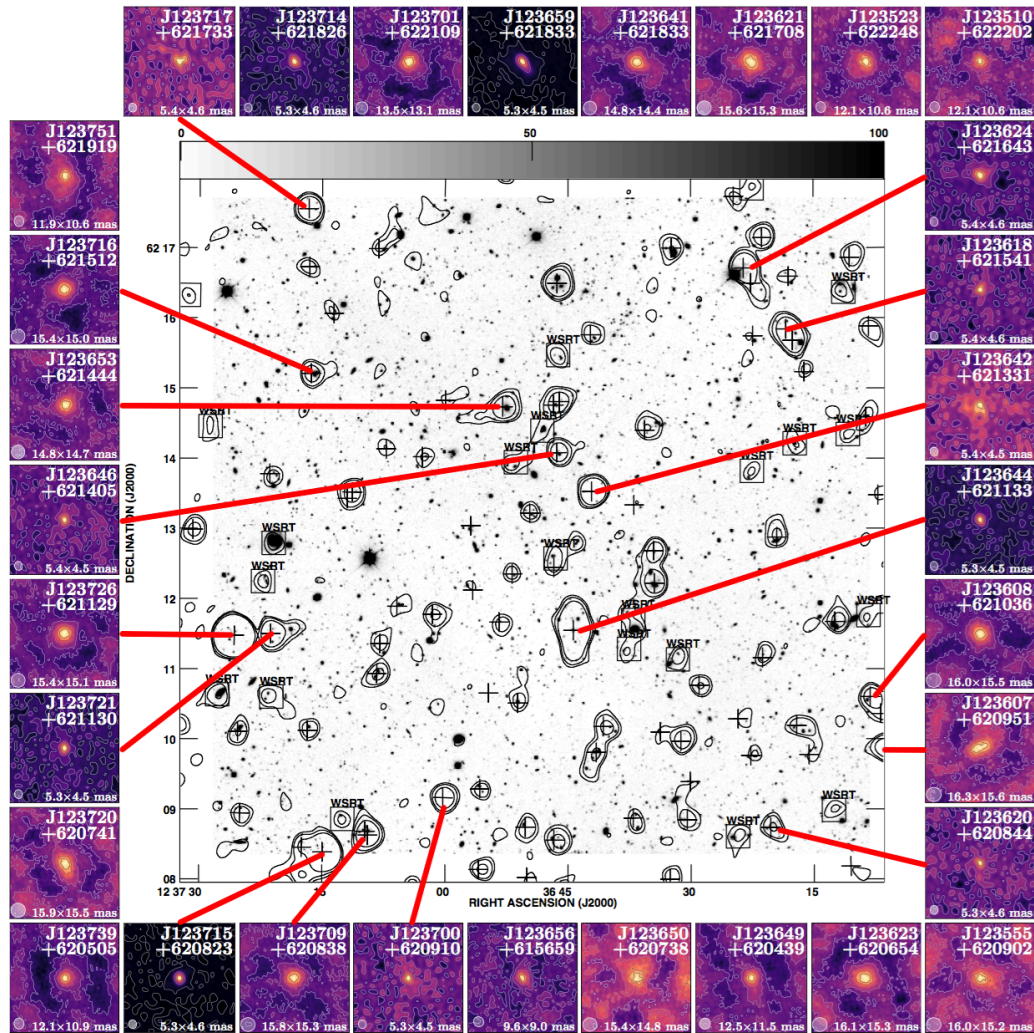


Bassa et al. (2017)
Tendulkar et al. (2017)

- **First ever VLBI detection of a millisecond-duration transient signal**
- **Required advanced features in the EVN Software Correlator at JIVE (SFXC)**

Artist's impression: Danielle Futselaar

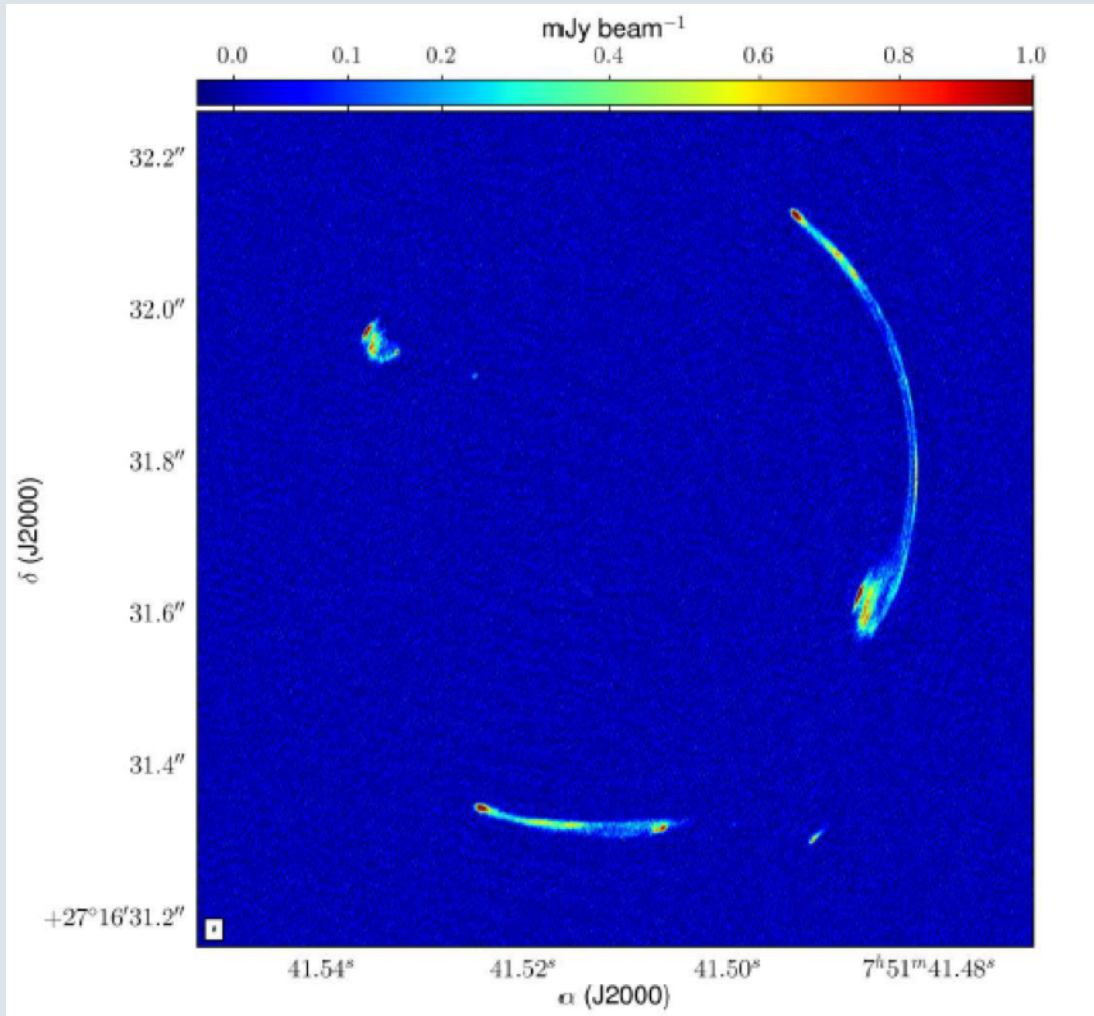
Wide-field VLBI of the HDF



Radcliffe et al. (2018)

- Sensitive wide-field VLBI fully operational in the EVN (beam-correction applied)
- Made possible by multi-phase center correlation capability of SFXC

The hunt for DM halos using gravitational lensing as a tool



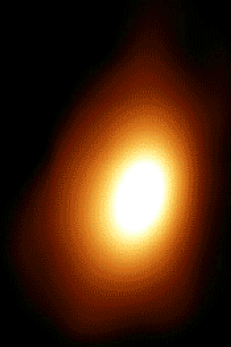
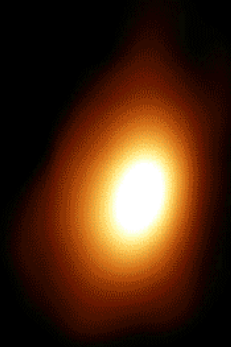
- **One of the sharpest images of a gravitationally lensed radio source: MG J0751+2716 ($z = 3.2$)**
- **Mass distribution of the foreground $z = 0.35$ gravitational lens is not smooth**
- **It is not clear yet whether this extra mass is in the form of sub-haloes within the lens or along the line of sight, or from a more complex halo of the galaxy group**

Spingola et al. (2018)

Stellar death near SMBH in Arp299B

Jul 2005

Jul 2005



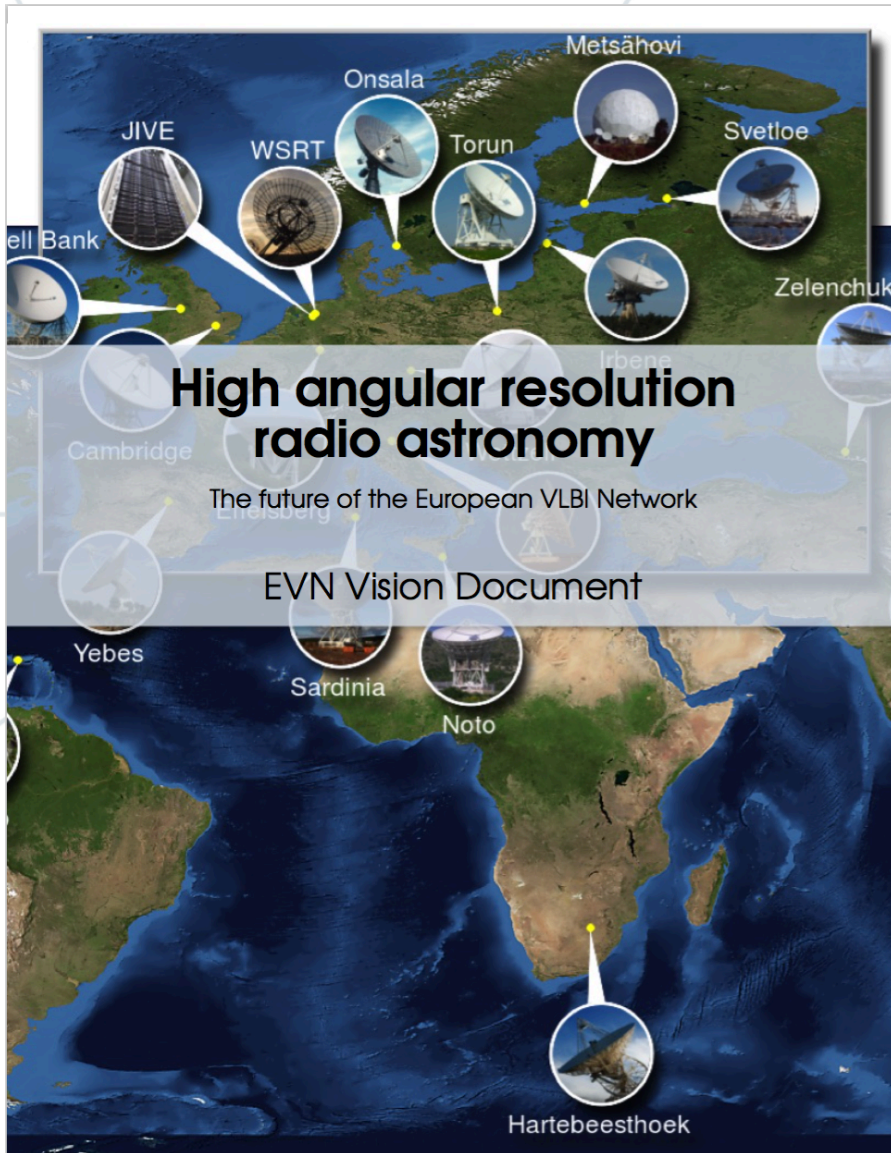
X Band 8.4GHz

X Band 8.4GHz

Mattila et al. (2018)

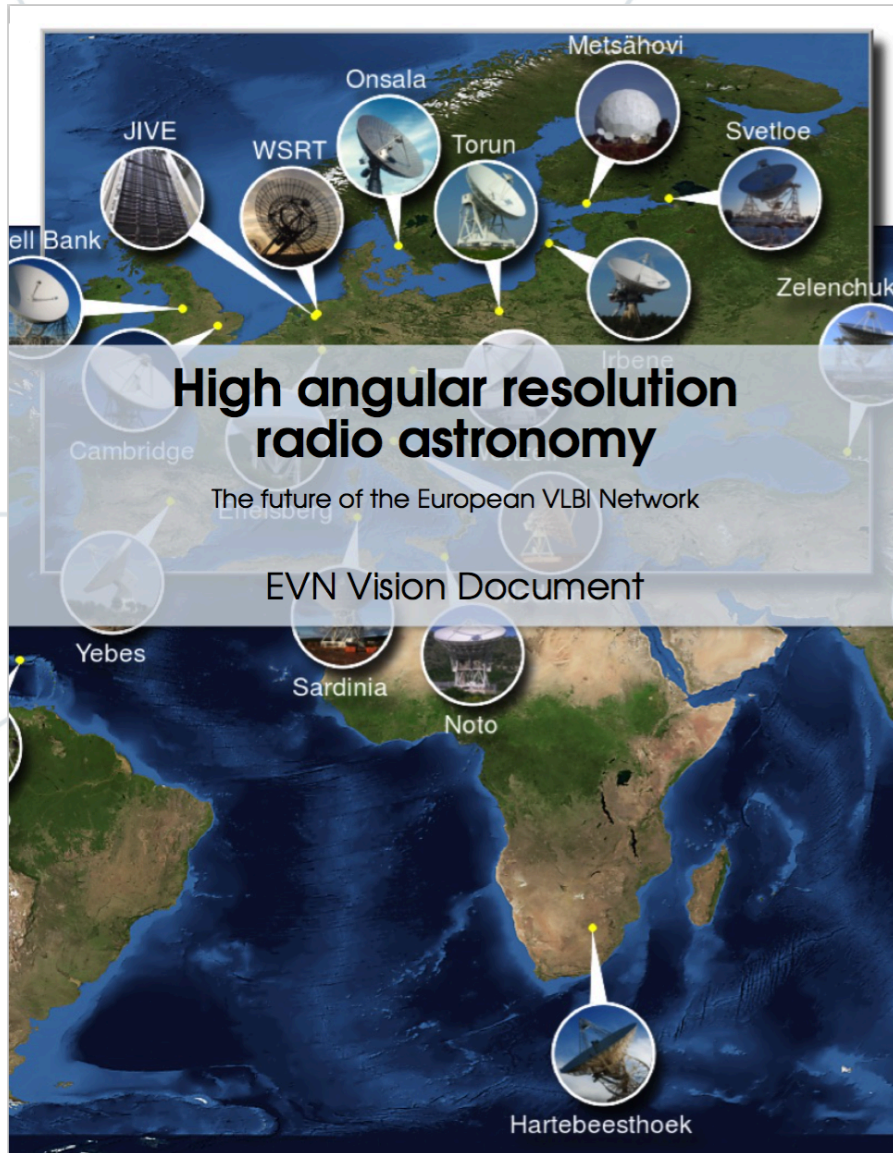
- **First detection of resolved ejecta from a jetted Tidal Disruption Event**
- **TDE detected in IR rather than in X-rays: thick torus absorbing/re-radiating X-ray flare?**

EVN: future directions



- **Jumping JIVE project WP7 "Future of VLBI"**

EVN Vision Document



SECTION I - THE LANDSCAPE OF THE PRESENT AND FUTURE OBSERVING FACILITIES

- I.1 Present and future VLBI arrays and radio facilities
- I.2 Present and future space and ground observatories at other wavelengths

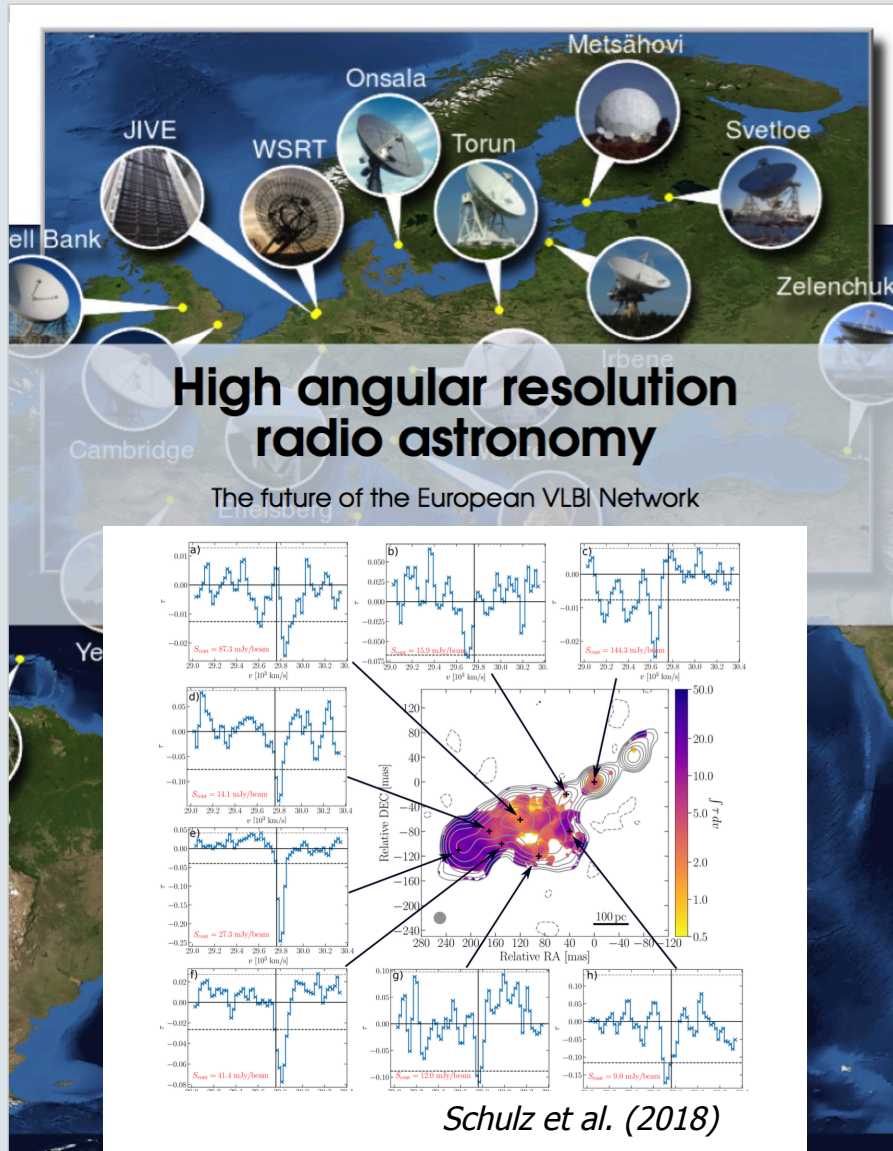
SECTION II - SCIENTIFIC ROADMAP FOR THE NEXT DECADES

- II.1 And there was light (cosmology)
 - II.2.1 When monsters were born (galaxy formation; AGN feedback)
 - II.2.2 AGN/BH evolution through cosmic time
- II.3 Towards the Horizon (mm-VLBI, jet formation)
- II.4 Inferno (explosive phenomena/transients)
- II.5 Stars and life (stars, stellar evolution and planetary systems formation)
 - II.5.1 Stellar maser
 - II.5.2 Stellar radio continuum and planetary systems
- II. 6 Innovative applications
 - II.6.1 Astrometry, Earth and Celestial Reference Frames
 - II.6.2 Space Science developments

SECTION III - The future of VLBI and the EVN

- III.1 New technological developments
- III.2 VLBI & synergies in the next decade

EVN Vision Document



SECTION II - SCIENTIFIC ROADMAP FOR THE NEXT DECADES

II.1 And there was light (cosmology)

II.2.1 When monsters were born (galaxy formation; AGN feedback)

II.2.2 AGN/BH evolution through cosmic time

...

Any contribution to the science case is welcome:

- **What are the major science drivers of HI absorption VLBI science in the coming decades?**
- **How shall we address these?**

Contact:

Raffaella Morganti, Robert Schulz (ASTRON)

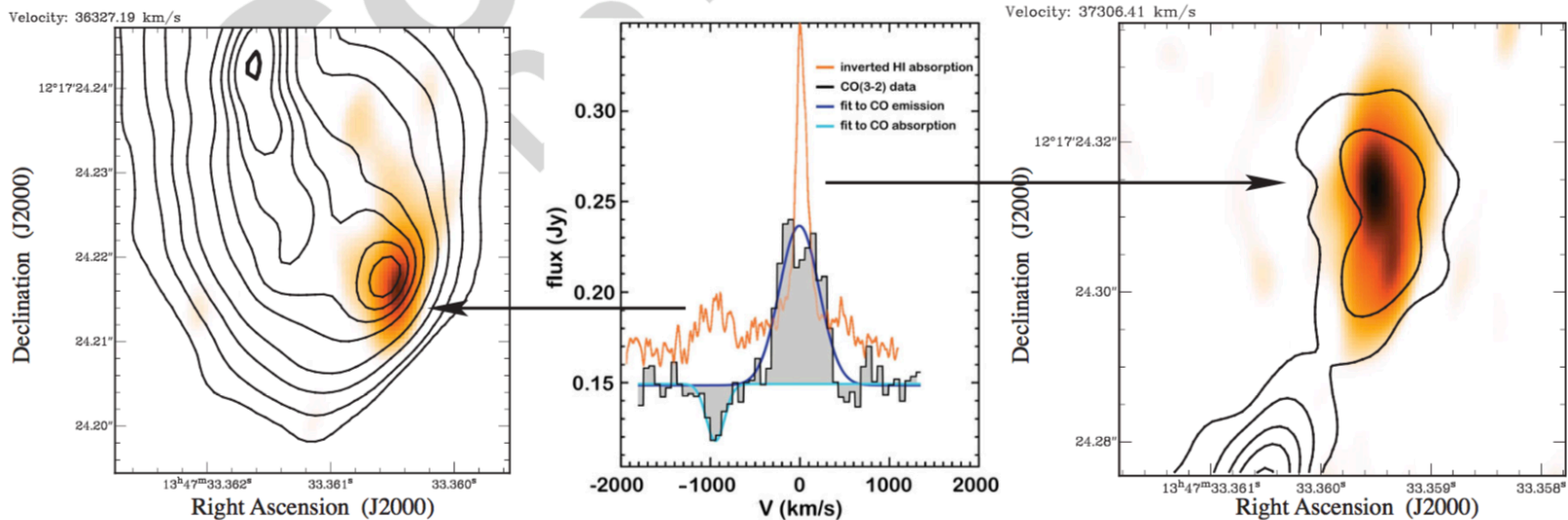
HI VLBI: pushing the limits

$$N_{\text{HI}} = 1.8 \times 10^{18} T_{\text{spin}} \tau_{\text{peak}} \text{FWHM}_{\text{line}}$$

(100 K; 0.02-0.05; 100 km/s)

→ few $10^{20} - 10^{21} \text{ cm}^{-2}$
($4.6 \times 10^{21} \text{ cm}^{-2}$ in 4C 12.50)

[N_{HI} detection limit presented here last year, using sensitivities of EVN and EVN+FAST or EVN+SKA1-MID]



Young radio source in an ULIRG, 4C12.50 at $z=0.1217$ Morganti et al., Science, 341, 1082, 2013

- **Need additional big dishes to reach beyond N_{HI} limit of $\sim 10^{20} \text{ cm}^{-2}$**
- **Must improve $\nu < 1.2-1.3 \text{ GHz}$ coverage to reach beyond $z \sim 0.1-0.2$**
- **Combine with e-MERLIN/MeerKAT short spacings to map extended outflows**

MeerKAT - EVN fringes

N18L1

amplitude versus channel

unique: sess118.L512nme/15:30:00.00/J0530+1331

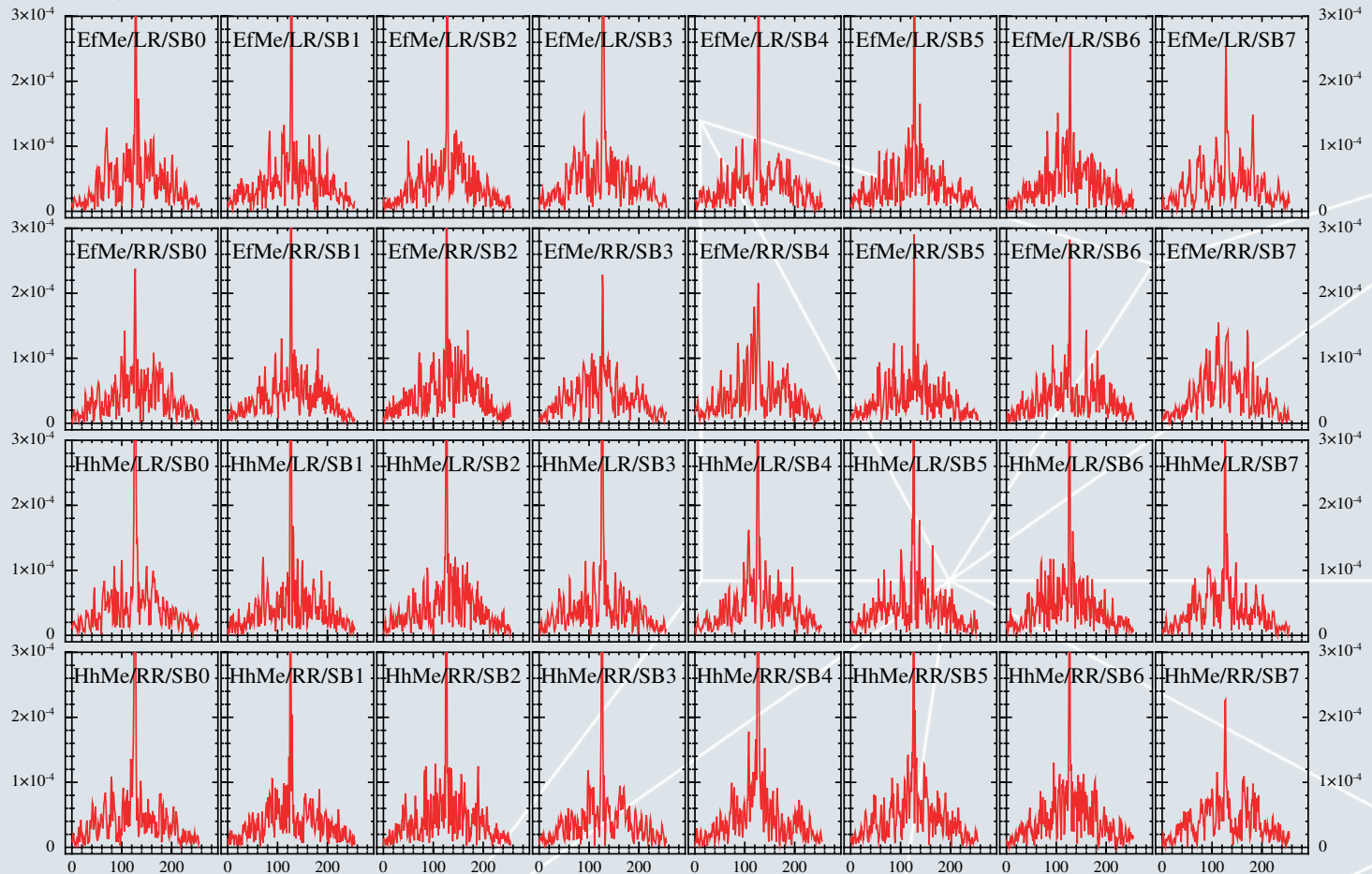
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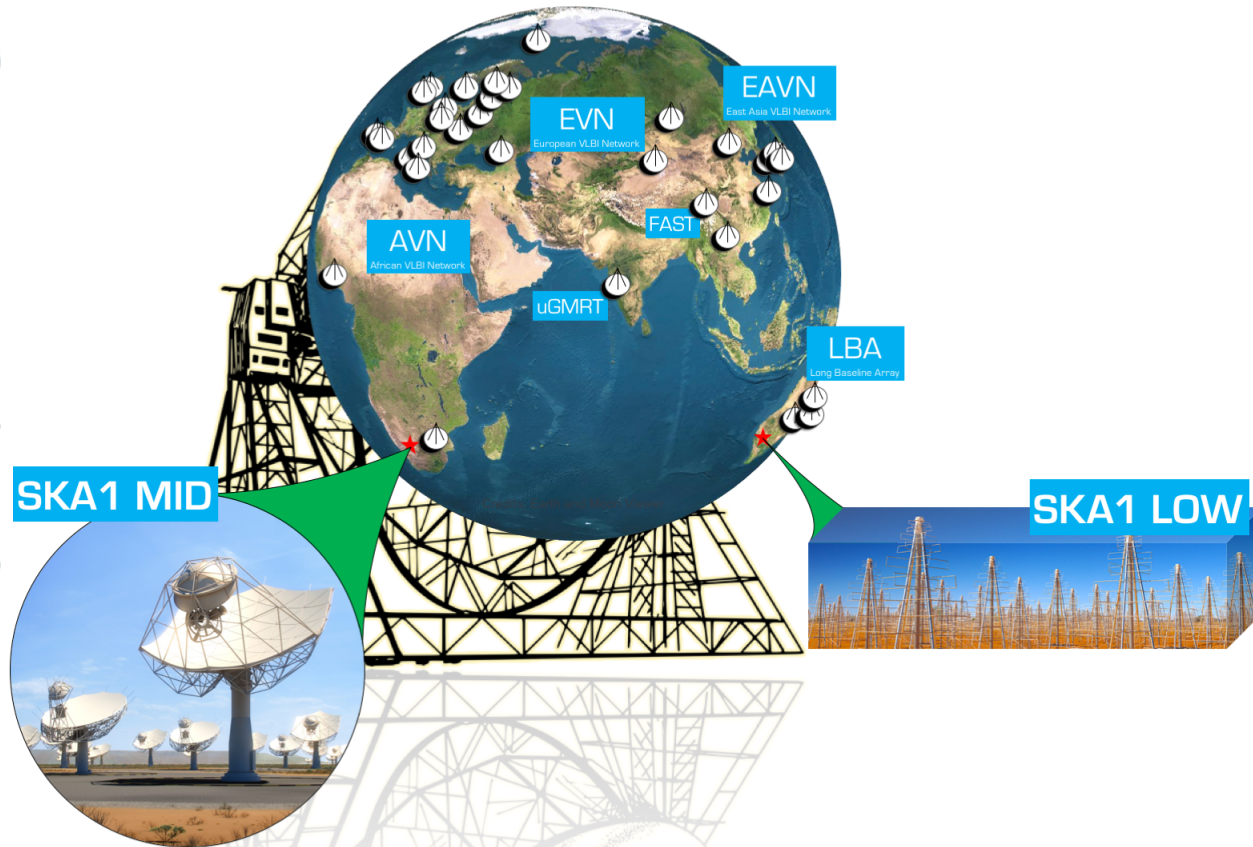
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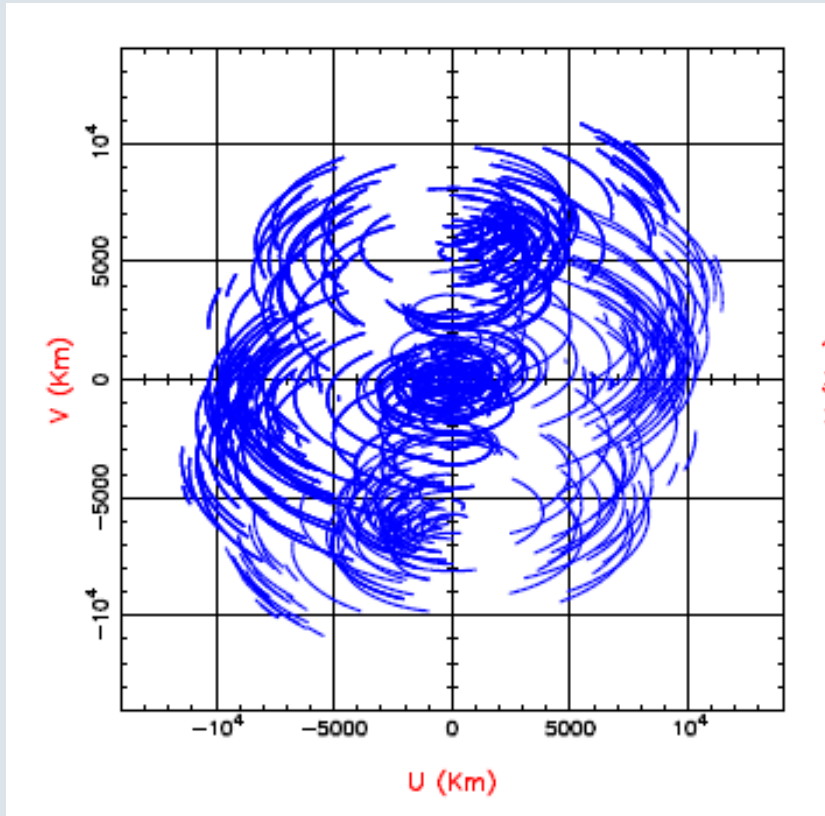


➤ **JJ WP5/9 "Integrating New Elements/Capacity for VLBI in Africa"**

SKA-VLBI



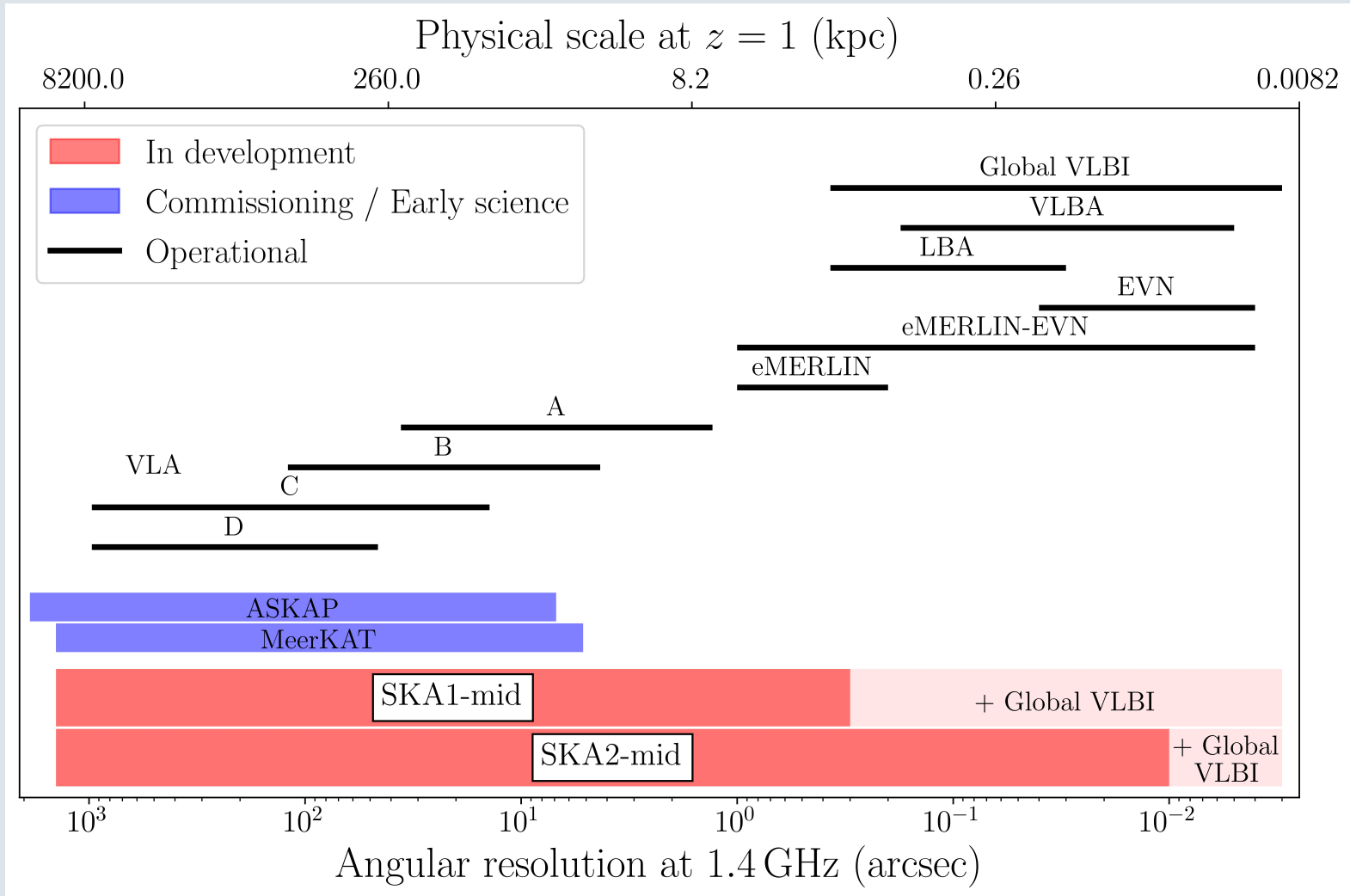
VLBI with the Square Kilometre Array



- **Ultra-sensitive VLBI allowing access to the Galactic Centre and the Souther Sky**

"Very Long Baseline Interferometry with the SKA", Paragi et al. 2015, SKA Science book (Mainly focusing on SKA1-MID)

VLBI with the Square Kilometre Array



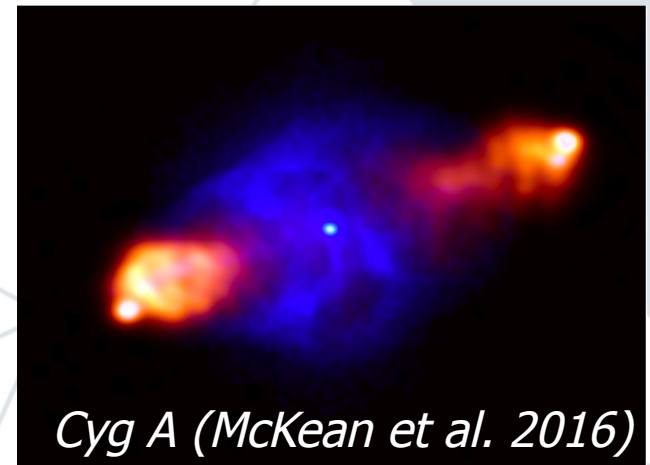
VLBI Scientist at the SKA HQ



- **Jumping JIVE project WP10 "SKA-VLBI" funded position**
- **Cristina Garcia-Miro started 1 August 2017**

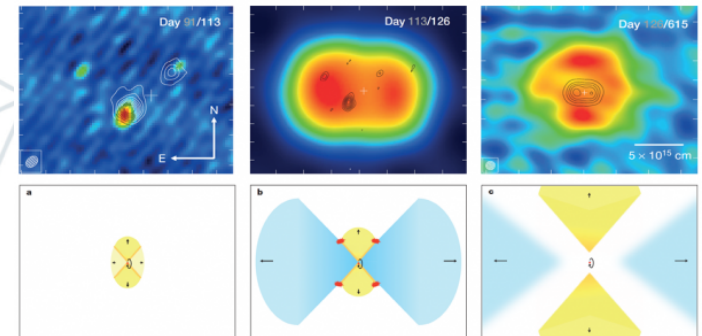
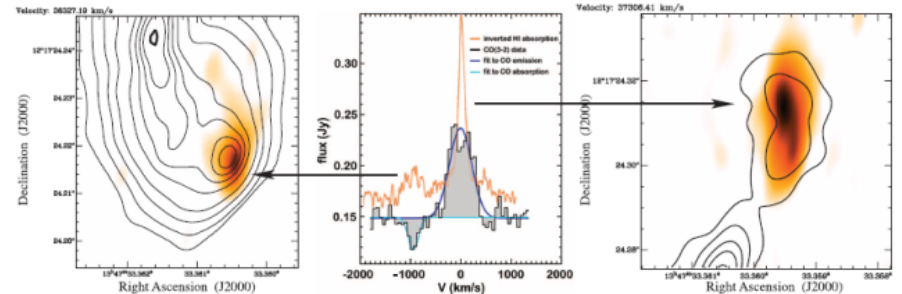
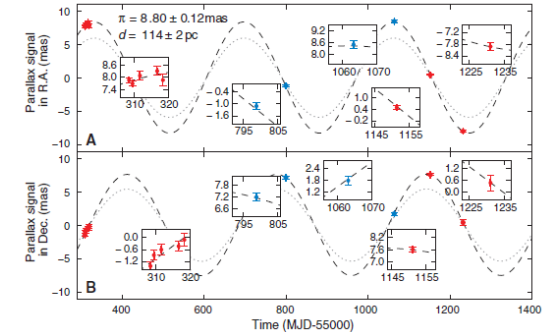
VLBI with SKA1-LOW

- **HI absorption systems at high redshift**
 - To resolve background source or absorber
 - **HPSO#13** for MID; complementary work on LOW
- **Pulsar scintillometry**
 - ISM as 10-50 AU scale interferometer (picoarcsec resolution)
 - Parallax distance (related to **HPSO#4** on pulsar timing)
- **AGN jet termination hot-spots with VLBI to reveal their physics**
- **Transient localization**
 - Localize FRB within the host galaxy with ~ 40 mas resolution (**HPSO#18**)

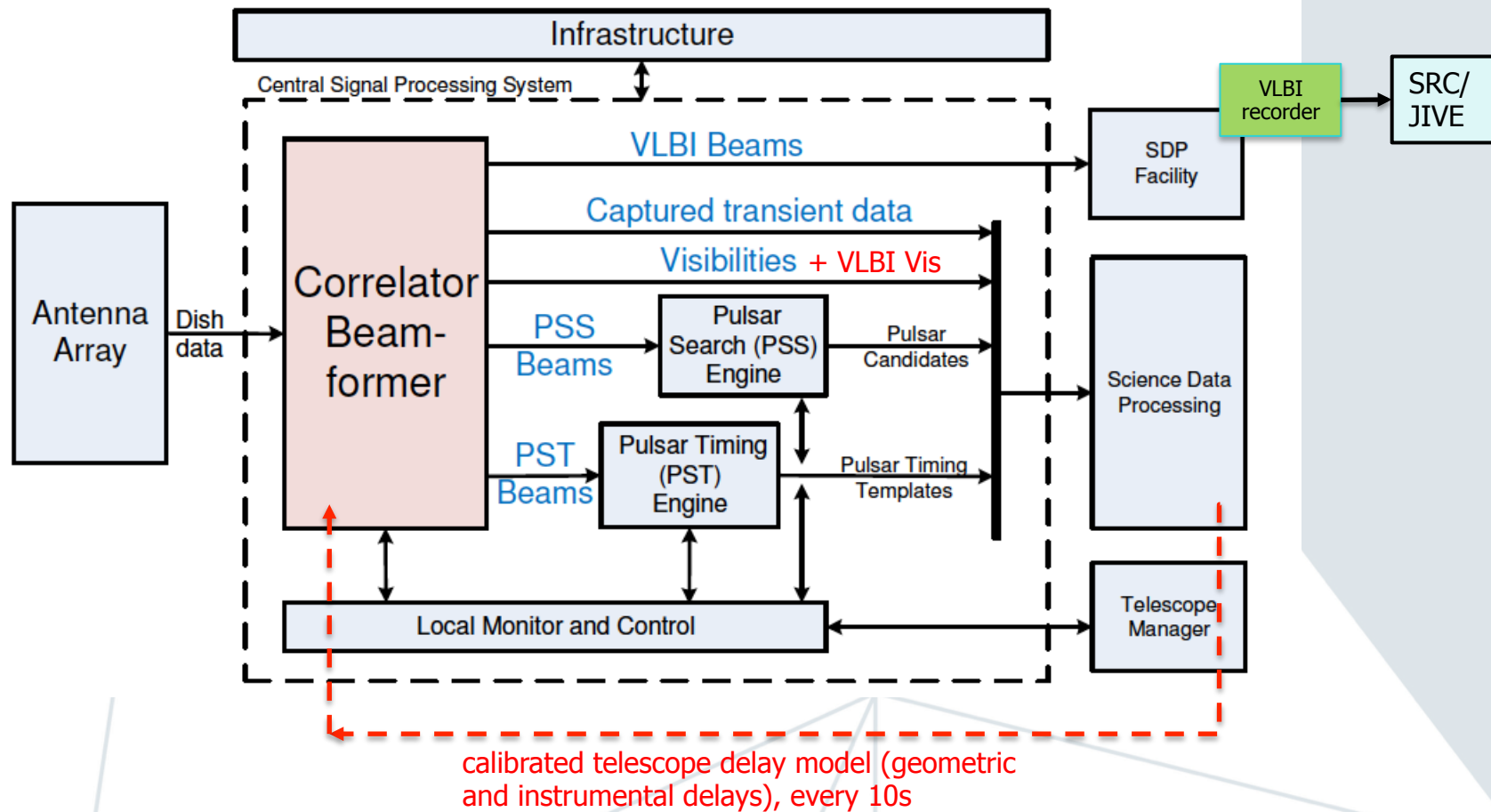


VLBI with SKA1-MID










- **Pulsar astrometry: HPSO#5**
 - Multi-beam calibration, precision $\sim 10 \mu\text{as}$ and below!
 - Requires Band 5 for GC pulsars
- **Proper motion and parallax of stars/clusters: HPSO#26**
 - Methanol maser for high-mass, continuum for low-mass
 - 6D tomography of spiral arms
- **HI absorption: HPSO#16**
 - AGN feedback, Band 2, 1
- **Continuum surveys**
 - AGN vs. (nuclear) SF beyond $z > 0.1$
 - Cosmology with gravitational lensing
- **Transient localization and imaging, HPSOs#18-19**
 - Synchrotron (galactic/extragal), ToO, trigger
 - Localize FRB within their host on sub-pc scales



VLBI with SKA1-MID



Commensal modes and VLBI with SKA1-MID

Band	VLBI + coarse Vis	Imaging	PSS	PST	Zoom
Band 1 (0.35-1.05GHz)	4b full (8 FSP)	Full (4 FSP)	1500b 300MHz (8 FSP)	16b (4 FSP)	2 (2 FSP)
	4b 512MHz (6 FSP)	Full (4 FSP)	1500b 300MHz (8 FSP)	16b (4 FSP)	4 (4 FSP)
Band 2 (0.95-1.76GHz)	4b full (10 FSP)	Full (5 FSP)	1500b 300MHz (8 FSP)	16b 600 MHz (3 FSP)	
	4b 512MHz (6 FSP)	Full (5 FSP)	1500b 300MHz (8 FSP)	16b (5 FSP)	2 (2 FSP)
Band 5a/b (4.6-8.5 GHz & 8.3-15.3 GHz)	2b 5GHz (26 FSP)				
	4b 2.5GHz (26 FSP)				
	4b 512MHz (6 FSP)	512MHz (3 FSP)	1500b 300MHz (8 FSP)	16b 512 MHz (3 FSP)	6 (6 FSP)

- Since time for VLBI with SKA1 will be limited, commensal options have to be explored
- Frequency slice architecture allows for full commensality in Band 1—2 for HI VLBI

Final notes

- **EVN is an excellent instrument for spectral line VLBI research, but the low-frequency coverage for $z > 0.1$ observations must be improved**
- **JIVE supports your research in all steps from putting together the proposal to get the data reduced (and even with the PR, following the publication)**
- **Prospects for H_I VLBI with SKA1-MID look good. Jumping JIVE WP10 supports the realization of VLBI modes and helps the community to define VLBI-related Key Science Programmes:**
- **We plan to organize dedicated SKA-VLBI KSP workshop in the fall of 2019 at the SKA HQ**