

SKA-VLBI Update

**Zsolt Paragi (JIVE)
SKA VLBI Working/Focus Group**

SKA-VLBI Working/Focus Group



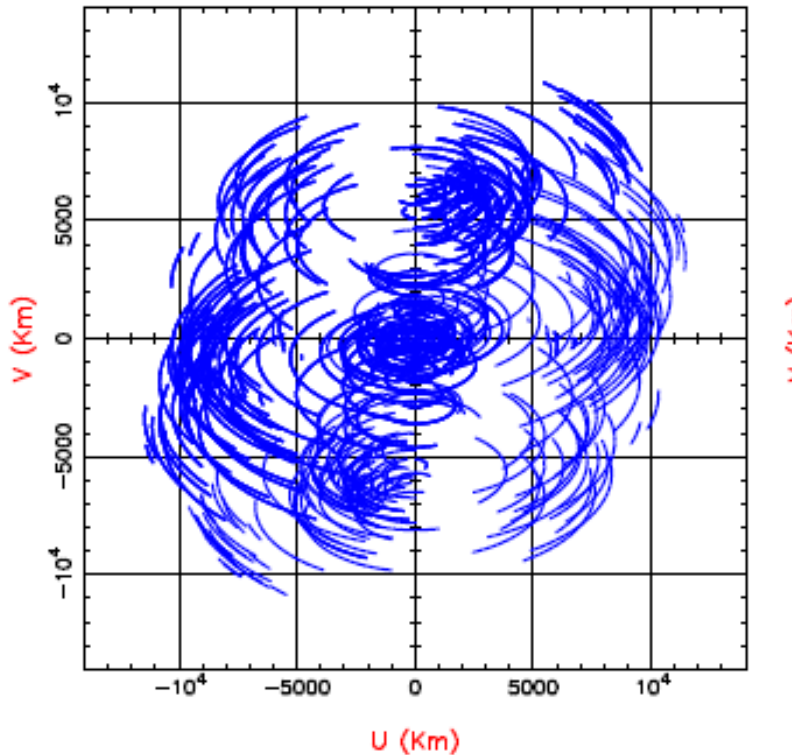
- **Technical definition of VLBI for phase-I SKA components**
- **Science priorities for SKA-VLBI: *We are fully science driven!***
- **Formal WG since 2015 (co-chairs: Cormac Reynolds CSIRO, Zsolt Paragi JIVE)**

VLBI Scientist at the SKA HQ



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

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)

Highest Priority Science Objectives & VLBI

Science Goal	SWG	Objective	SWG Rank
1	CD/EoR	Physics of the early universe IGM - I. Imaging	1/3
2	CD/EoR	Physics of the early universe IGM - II. Power spectrum	2/3
4	Pulsars	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection	1/3
→ 5	Pulsars	High precision timing for testing gravity and GW detection	1/3
(→) 13	HI	Resolved HI kinematics and morphology of $\sim 10^{10} M_{\odot}$ mass galaxies out to $z \sim 0.8$	1/5
14	HI	High spatial resolution studies of the ISM in the nearby Universe.	2/5
15	HI	Multi-resolution mapping studies of the ISM in our Galaxy	3/5
→ 18	Transients	Solve missing baryon problem at $z \sim 2$ and determine the Dark Energy Equation of State	=1/4
(→) 22	Cradle of Life	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc	1/5
27	Magnetism	The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields	1/5
32	Cosmology	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.	1/5
33	Cosmology	Angular correlation functions to probe non-Gaussianity and the matter dipole	2/5
→ 37 + 38	Continuum	Star formation history of the Universe (SFHU) – I+II. Non-thermal & Thermal processes	1+2/8

VLBI with:

LOW/MID
LOW/MID

MID
MID

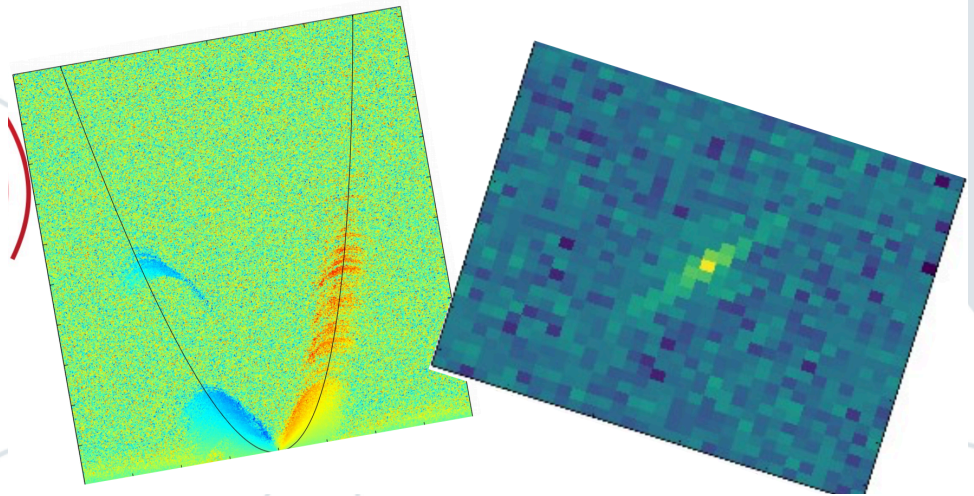
MID

- While not directly visible, VLBI is fundamental to some of the SKA HPSOs
- Also note: VLBI Science = SKA2 Science!

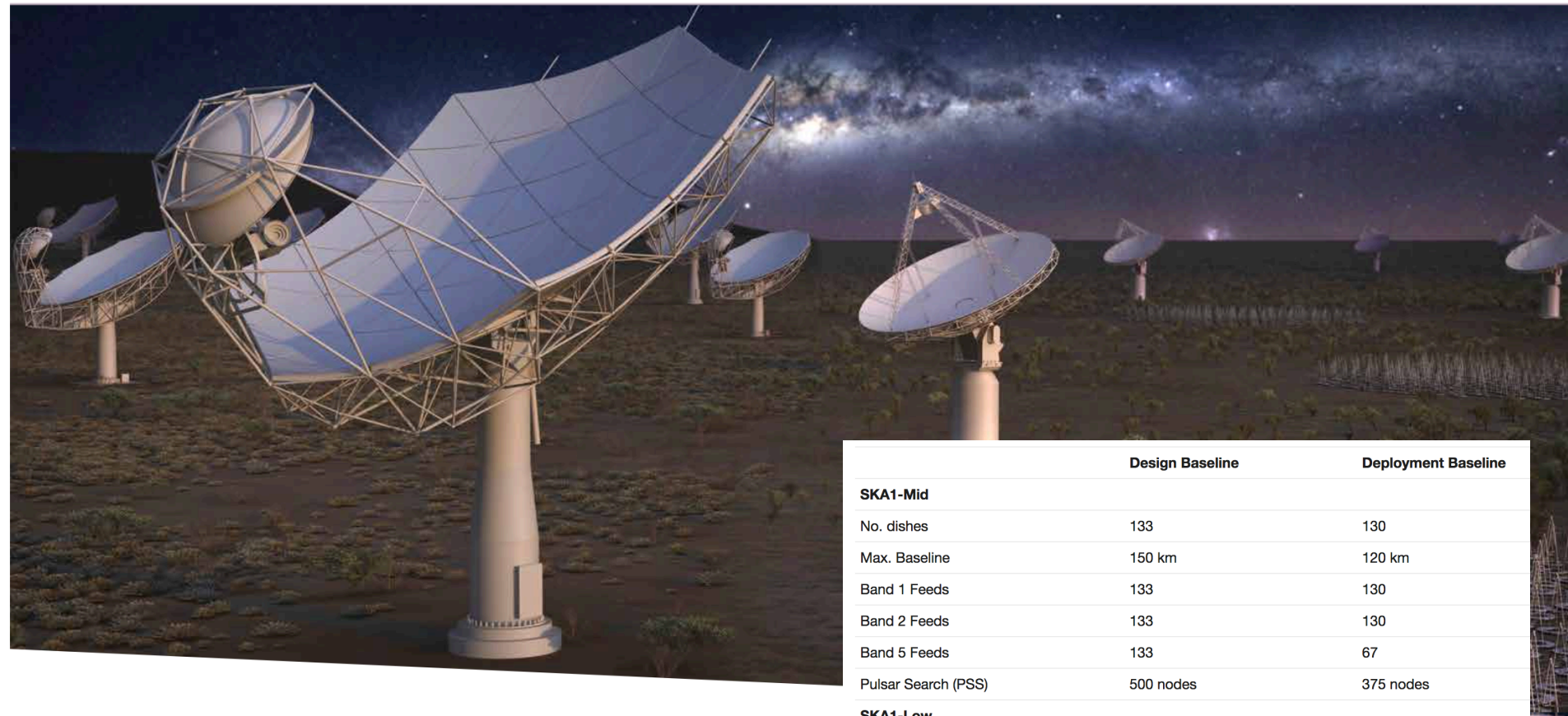
Working Group progress so far

- **Input to L0 Science Requirements, Baseline Design, L1 Technical Requirements**
- **Science priorities: pushing for Band 5 ($\sim 4.6\text{-}12$ GHz)**
- **Engineering Change Request Proposal:
VLBI capability for LOW (Evan Keane et al. 2016, ECP160040)**

*Fringes between GMRT and MWA
Franz Kirsten, SKA 2016 meeting, Goa*



Cost Control Project



	Design Baseline	Deployment Baseline
SKA1-Mid		
No. dishes	133	130
Max. Baseline	150 km	120 km
Band 1 Feeds	133	130
Band 2 Feeds	133	130
Band 5 Feeds	133	67
Pulsar Search (PSS)	500 nodes	375 nodes
SKA1-Low		
No. stations	512	476
Max. Baseline	65 km	40 km
Pulsar Search	167 nodes	125 nodes
Common		
Compute Power	260 PFLOPs	50 PFLOPs

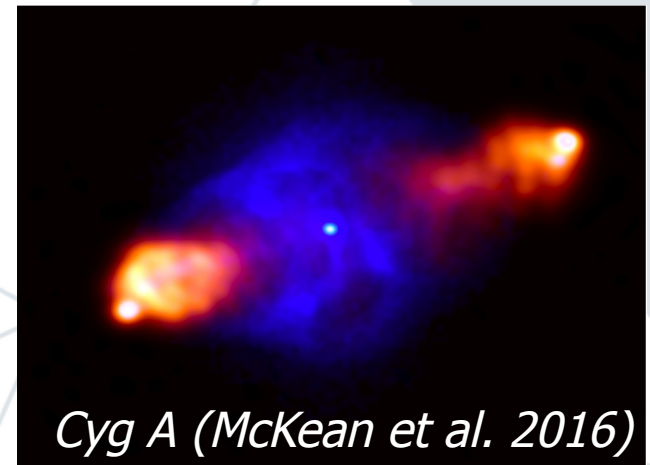
SKA Board 18-19 July 2017:

- **Deployment Baseline vs. Design Baseline**
- **Band 5: deploy half of the receivers initially**

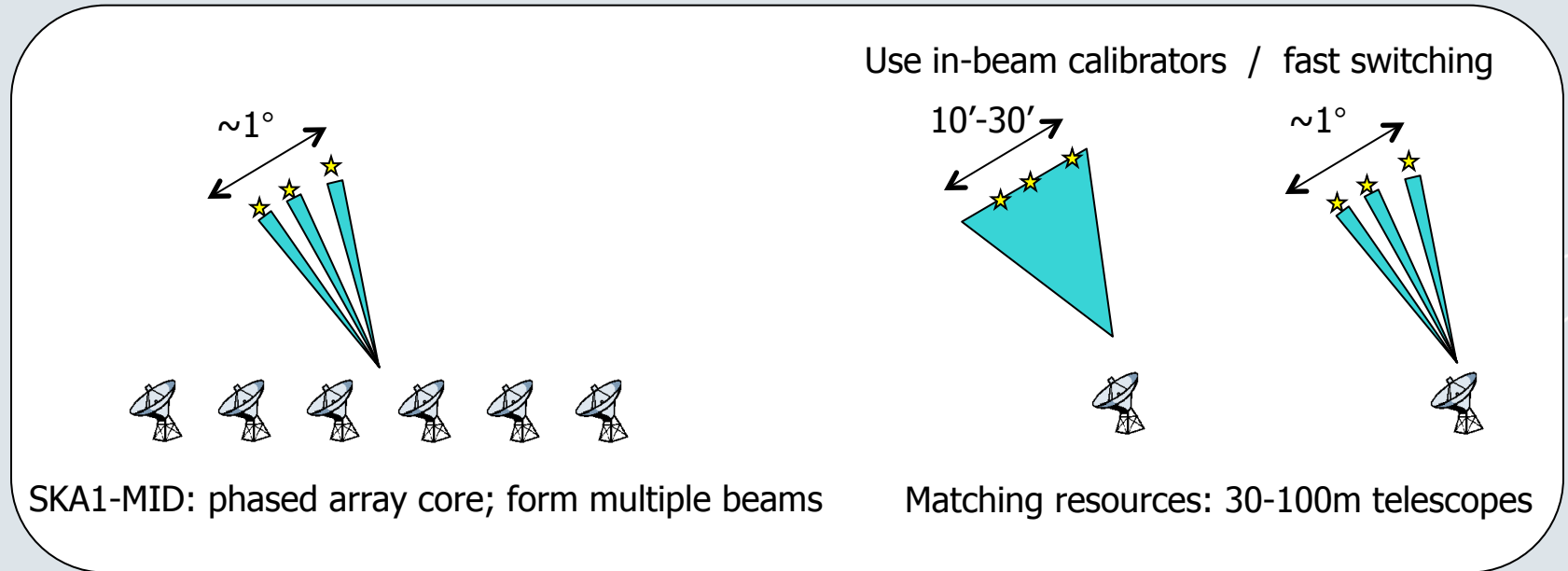
VLBI with SKA1-LOW

- **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)

NO SIGNIFICANT CCP IMPACT



VLBI with SKA1-MID



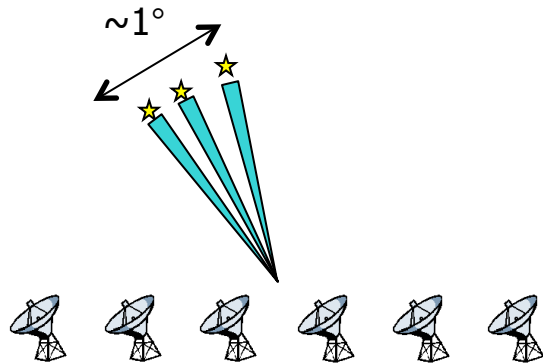
➤ Real-time or “e-shipping” transfer to data processor centre (e.g. JIVE)

- SKA1-MID baselines up to 120-150 km
- SKA-VLBI baselines up to ~10000 km
- Full SKA goal: all angular scales, mas imaging of the full FoV



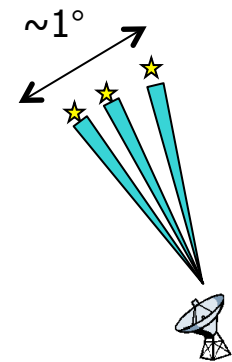
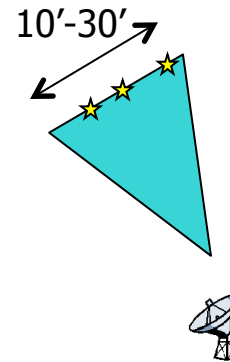
a range of angular scales,
but, a limited number
VLBI phase-centres

VLBI with SKA1-MID



SKA1-MID: phased array core; form multiple beams

Use in-beam calibrators / fast switching



Matching resources: 30-100m telescopes

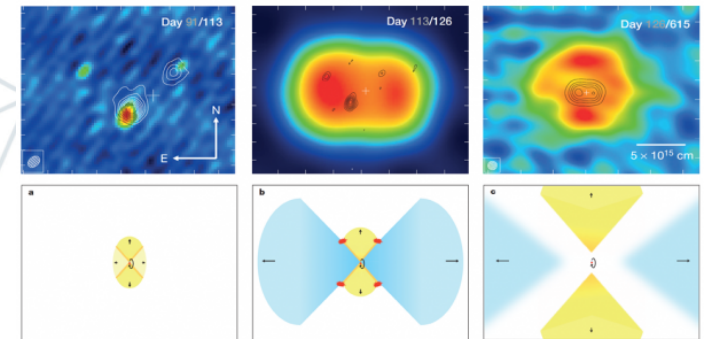
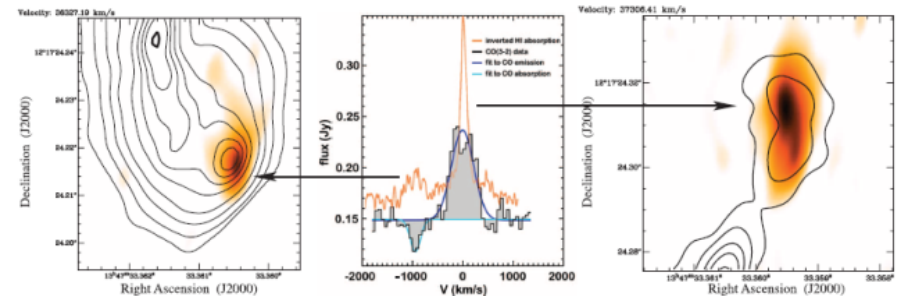
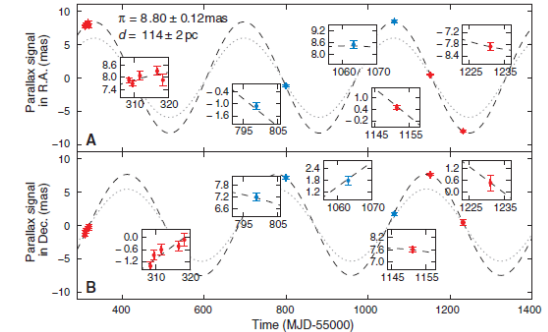
- **Phase-up inner 4km core ($\sim 70\%$ of collecting area)**
 - Phasing-up longer baselines (> 10 km) will have difficulties (coherence loss)
 - It will also severely limit the FoV of a single beam

Besides basic beam-forming and other basic technical requirements:

- **Requires simultaneous beam-formed and SKA1-MID products**
 - Range of angular scales – for transformational science!
 - For excellent calibration of the VLBI products

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

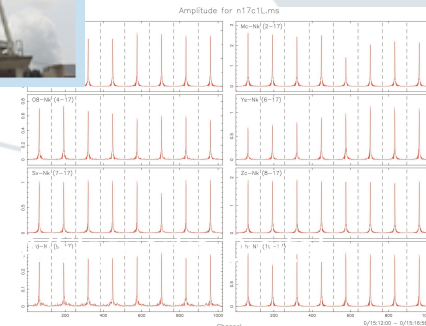


BAND 5 REDUCTION SIGNIFICANT IMPACT

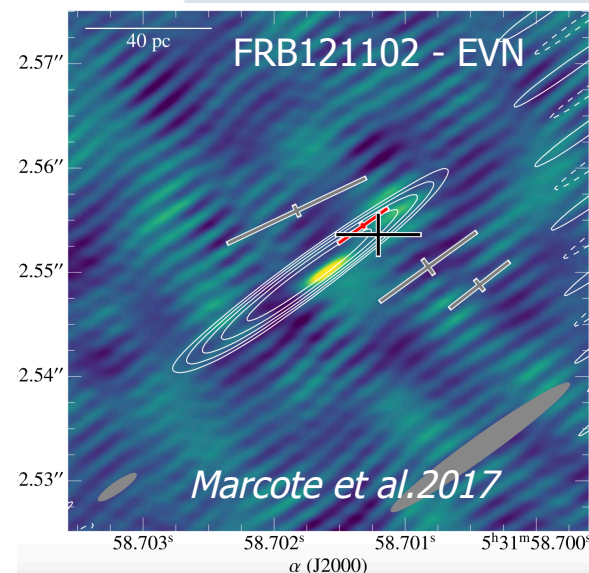
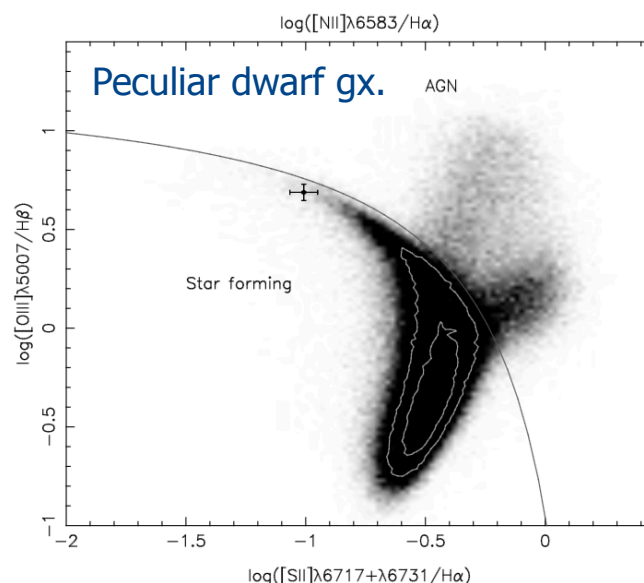
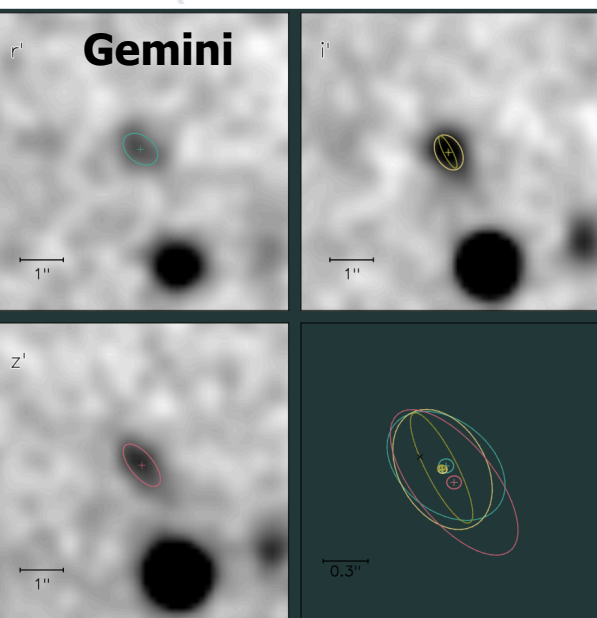
Towards a VLBI Network in Africa



- **Jumping JIVE supports AVN telescope fringe tests and training in AVN countries**
- **Kuntunse in Ghana produced first fringes this summer**



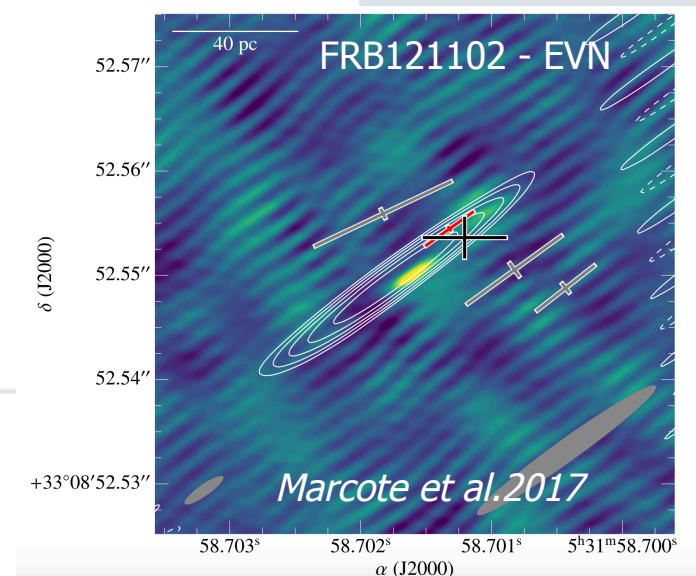
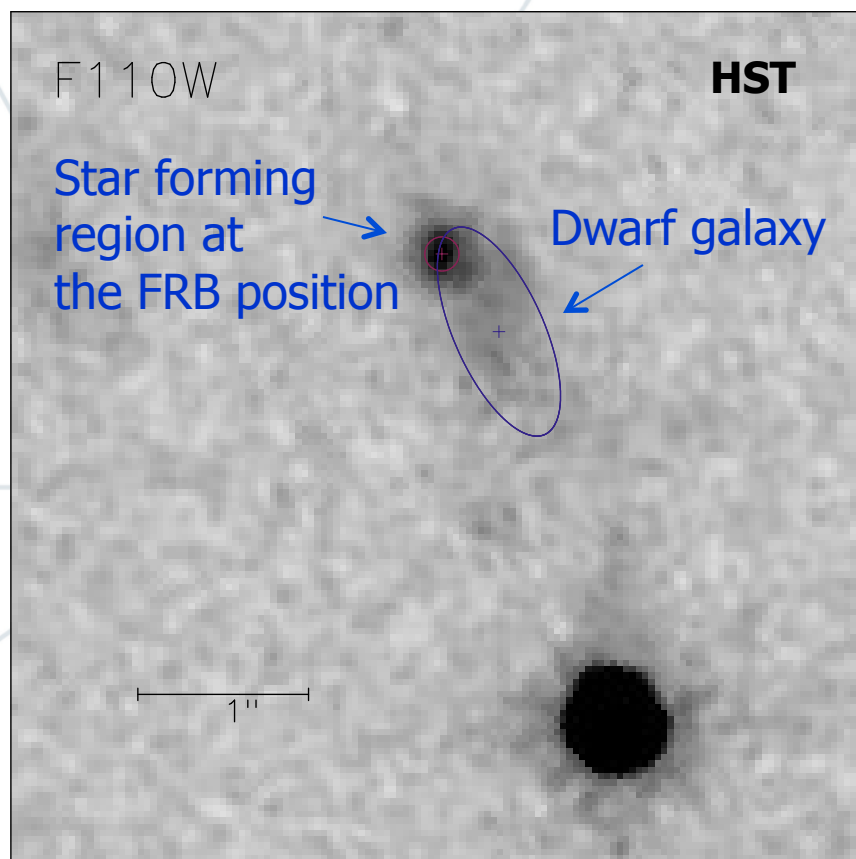
Transformational Science: Fast Radio Bursts



Chatterjee et al. 2017, Tendulkar et al. 2017, Marcote et al. 2017

- **One of the highest priority science cases for the SKA: FRB localization**
- **VLA and EVN breakthrough result open up a new era in fast transient research**
- **Persistent radio source: young SLSN hiding a magnetar? Metal-poor host – would not be unexpected**

Transformational Science: Fast Radio Bursts

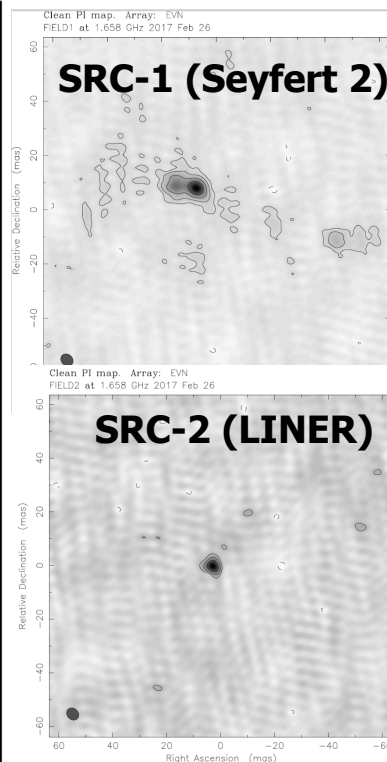
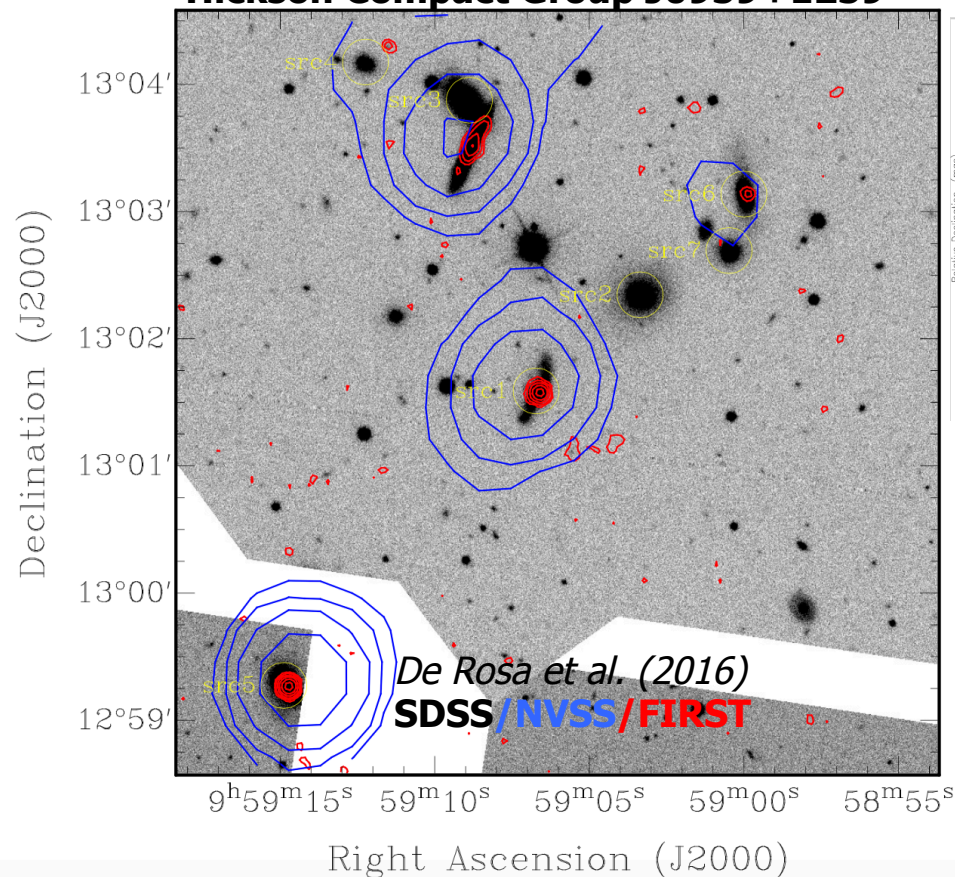


Bassa et al. 2017

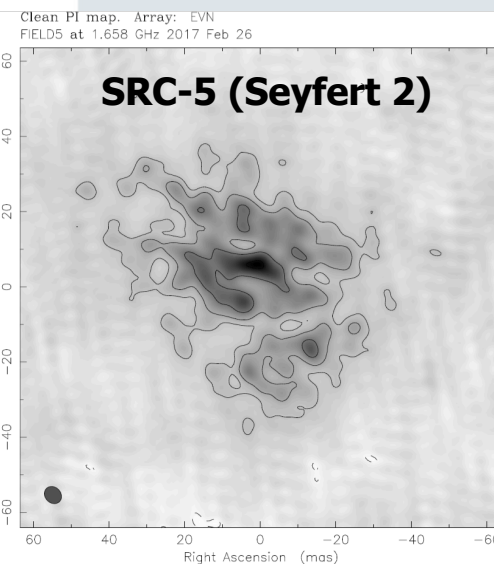
- **Super-SKA resolution:** Great potentials for e-MERLIN (with the LT!) and EVN!
- **Note also e-MERLIN surveys may reveal a great number of peculiar objects: It is not just SF/AGN out there in the sub-mJy source population!**

The need for e-MERLIN – EVN integration

Hickson Compact Group J0959+1259



Paragi et al. (in prep.) European VLBI Network



- **EVN can survey ~large FoV; but misses short spacings to get the full picture**
- **EVN-e-MERLIN would offer a unique range of uv-spacings to study Low-Luminosity AGN and their feedback on their hosts**

Conclusions

- **SKA-VLBI is fundamental to a number of high priority SKA science objectives**
- **Simultaneous SKA1-MID data provide short spacings to calibrate SKA-VLBI data**
- **e-MERLIN can do the same + forming baselines across the two arrays will allow unique science (even in the SKA era)**
- **I propose we dedicate significant time to joint EVN-e-MERLIN operations, to complement shallow/deep SKA1-MID surveys, and to do transformational transient science**