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VLBI observations with the SKA-Mid at 12/15 GHz

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Collaborators

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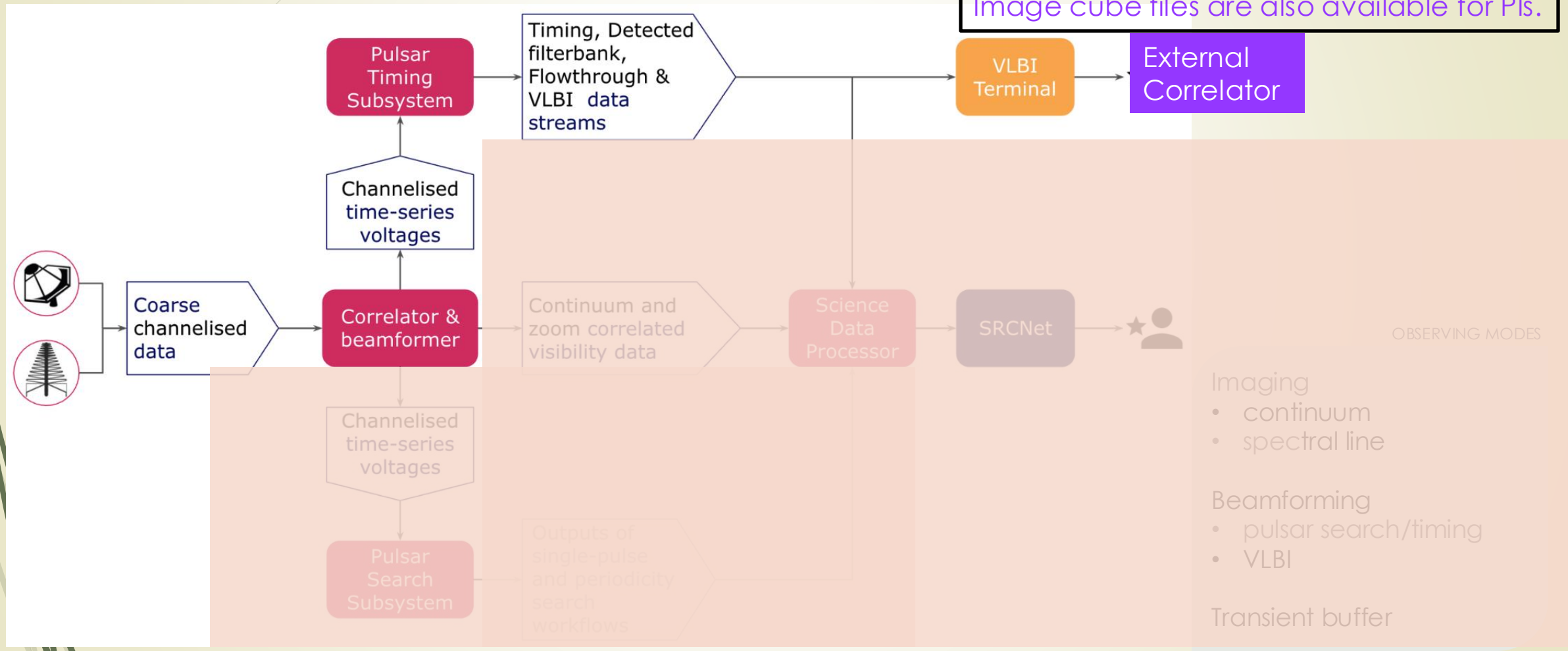
1. VLBI observing mode

1.1 Signal path

VLBI Control: VEX files.
Output: multi-beam (<=4) and multi-thread VDIF data for VLBI correlation
Note: Low-resolution and wide-field SKA Image cube files are also available for PIs.



1.2 Sensitivity for the tied arrays

	System Equivalent Flux Densities (SEFDs) for phased-up VLBI beams								
Array	**SKA-Low (Core<1km)** **AA* Core**: 199 st **AA4 Core**: 224 st	**SKA-Low (Inner 10 km)** **AA*** : 271 st **AA4 Core**: 404 st	**SKA-Mid: inner 20 km diameter** **AA2** (64x15-m dishes, No MeerKAT dishes) **AA*** (**77x15-m** dishes at 0.3-15 GHz & **64x13.5 m** dishes at 1.4 GHz) **AA4** (**110x15-m** dishes at 0.3-15 GHz & **64x13.5 m** dishes at 1.4 GHz)							
Band	**50-350 MHz**		**1** (0.35-1.05 GHz)	**2** (0.95-1.76 GHz)		**5a** (4.6-8.5 GHz)			**5b** (8.3-15.4 GHz)	
Freq. (GHz)	**0.3**		**0.6**	**1.4**	**1.6**	**4.8**	**6.7**	**8.4**	**12.2**	**15.0**
AA2 (Jy)	No VLBI beam available		12.5	5.5	5.5	5.6	6.2	6.8	**8.5**	**10.2**
AA* (Jy)	18.3	13.5	6.3	2.7	4.4	4.6	5.1	5.6	**7.0**	**8.5**
AA4 (Jy)	16.3	9.0	4.6	2.2	3.1	2.7	3.0	3.3	**4.1**	**4.9**

Numerically, they are also the weighted continuum sensitivity (in uJy/beam) from **the SKA Sensitivity Calculator** using BW: 0.05 GHz, Time:10000 s, Natural weighting, EL: 45 deg, system efficiency: 0.9.

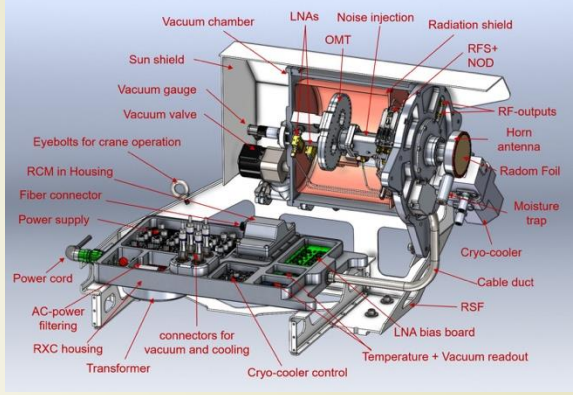
References: (1) SKA-MID Sensitivity Calculator User Guide, (2) Anticipated SKA1 Science Performance

2. VLBI with the SKA-Mid at Ku band

2.1 Unique advantages

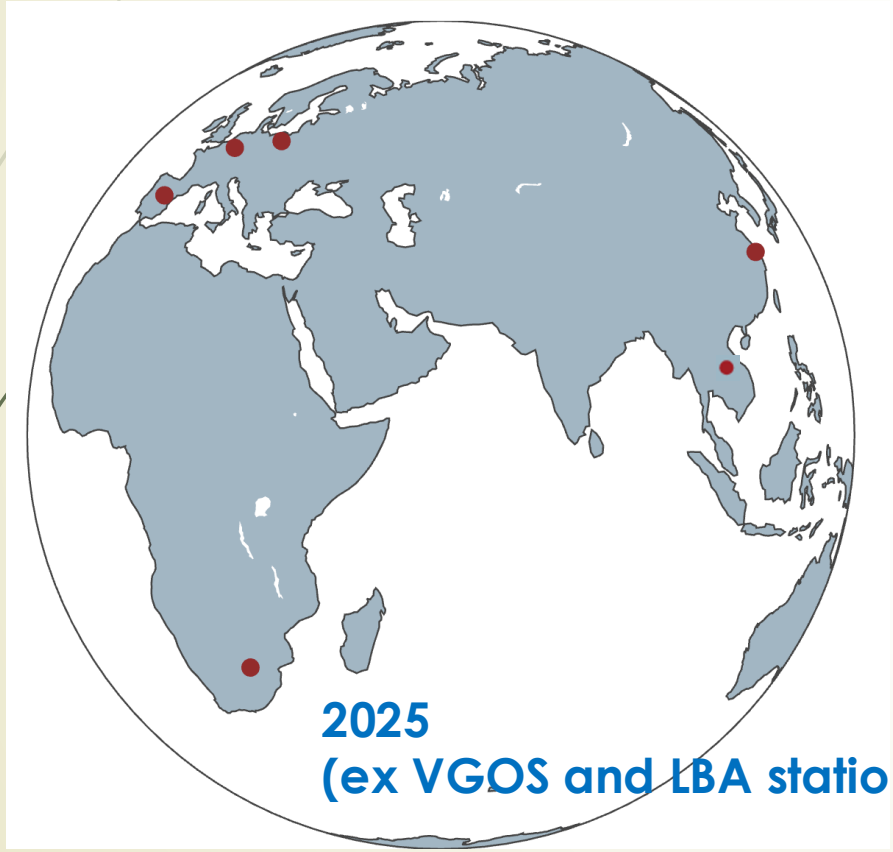
- Providing the highest resolution (up to ~1 mas) for SKA-VLBI users to study innermost jets, cosmic transients, etc. (Paragi et al. 2015)
  - The longest baseline: **10610 km between SKA-Mid and Tianma65**.
- Having very wide observing bandwidth available for deep imaging observations up to 64 Gbps (8 GHz bandwidth per pol.) and powerful self-calibration on sources of a few mJy.
  - VLBI image sensitivity is also dominated by the SKA-Mid and a few big dishes.
- Best observing band for the target sources close to the Galactic plane because of significantly less scattering broadening effect, i.e. $\theta_{\mathrm{scatter}} \propto \lambda^2$ and $\theta_{\mathrm{obs}} \approx sqrt(\theta^2{}_{\mathrm{scatter}} + \theta^2{}_{\mathrm{source}})$, for point-like sources.
  - Example: SKA-VLBI astrometry on Galactic radio stars or masers at 12.2 GHz (e.g. Green et al. 2015).
  - Note that SKA Band 6 (15.3–50 GHz) receivers (Conway et al. Memo 20-01) are not funded for the SKA-Mid AA*.

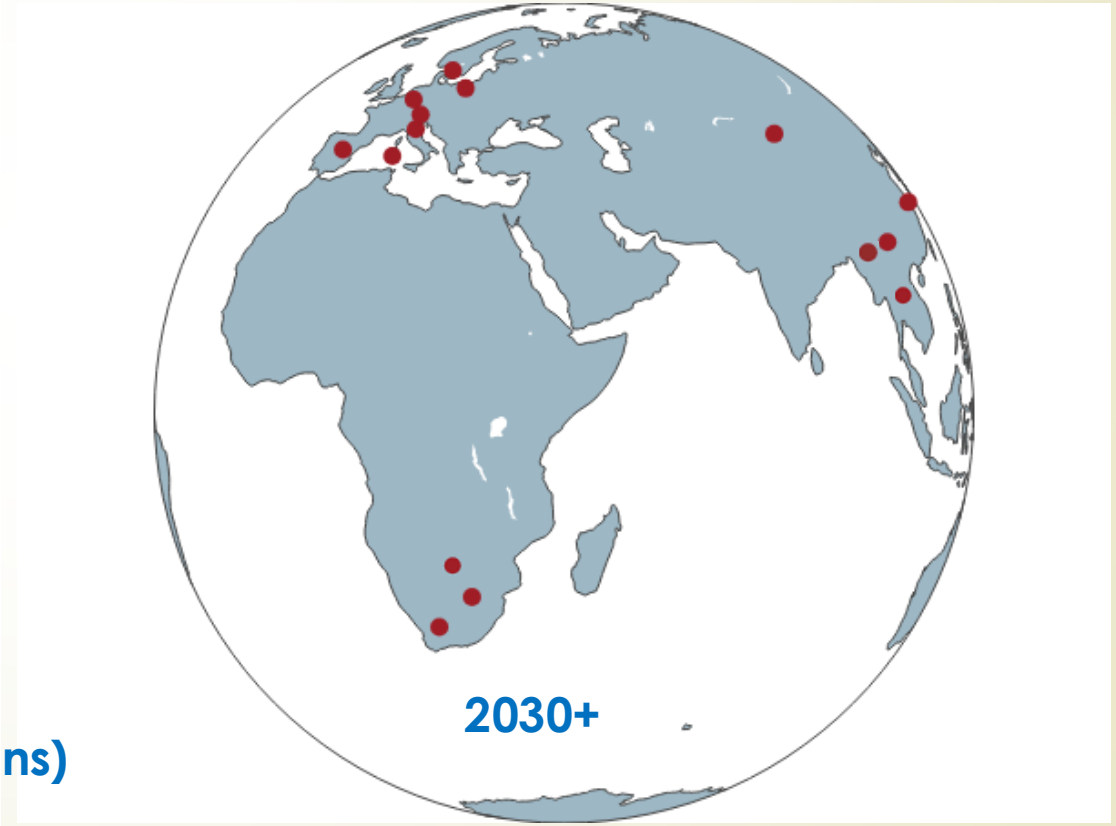
2.2 Current status and future expansion



- **Europe, Asia and Africa**
  - EVN and EAVN: Not available because of limited stations.
  - VLBI stations available at Ku band
    - **Effelsberg** (100 m), **Tianma** (65 m) & **Yebes** (40 m).
    - **Torun** (32 m), **Hartebeesthoek** (25 m), **Ibaraki** (32 m) **& Yamaguchi** (32 m)at 12.2 GHz only.
    - **VGOS** (VLBI Global Observing System) telescopes (13 m), e.g. Onsala Twin telescope.
  - Upcoming stations
    - **Kunming** (40 m): Installing a Ku-band receiver this year.
    - **Thai National Radio Telescope** (TNRT 40 m): Installing a 4.6–13.7 GHz receiver in 2026.
    - **VLBI Exploration of Radio Astrometry** (**VERA**): Developing 6-18 GHz receivers.
    - **MeerKAT** (64 x 13 m dishes): Ordered 66 Band 5b receivers from MPIfR.
    - Intend to develop Ku-band receivers: **Sardinia** (64 m), **Medicina** (32 m), & **Onsala** (20 m).
  - Available new telescopes over next 5 years
    - **Qitai 110-m** and **Jingdong 120-m** radio telescopes in China.
    - **Wetterstein** Millimeter Telescope (WMT, 18 m), **Botswana DZA** and **SKA-MPI** dishes (15 m).
- **Long Baseline Array** (LBA) in the southern hemisphere
  - Parkes (64 m): Started a 4-16 GHz receiver project and available in 2027+. Ceduna at 12.2 GHz.
- **VLBA+VLA+GBT**: Available and installing 8–40 GHz receivers for the VLBA.

- Currently, 5 stations available at 12.2 GHz in the EVN.
- **~15 stations available** for EVN+SKA-Mid observations at 12.2 GHz in 2030+.
- More stations available in Japan, Australia. **10+ VGOS stations** might be also included in the EVN, the EAVN, the LBA, and the SKA-VLBI observations.





Major concern: As the NRAO did, it requires an agreement with Starlink to get a radio-quiet sky at **10.7–12.7 GHz.**

3. Summary and outlook

- SKA-Mid and more new radio facilities would provide an unprecedented opportunity for us to perform the EVN and Global VLBI observations at Ku band.
- SKA-VLBI observations at Ku band allow astronomers to achieve high-sensitivity (~1 uJy/beam) and high-resolution (~1 mas) images, and extremely high astrometric precision (~1 uas).
- Welcome more stations to develop receivers at Ku band. Short VLBI tests will be organized to gain a complete view of the VLBI network performance at 12/15 GHz.