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Pillar 8:
R&D and Next-Generation
Supply Chain: Innovation
Without Borders

Making \leq sure $\left(\frac{\text{it's}}{\text{possible}} \right)$



science, technology
& innovation

Department:
Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA

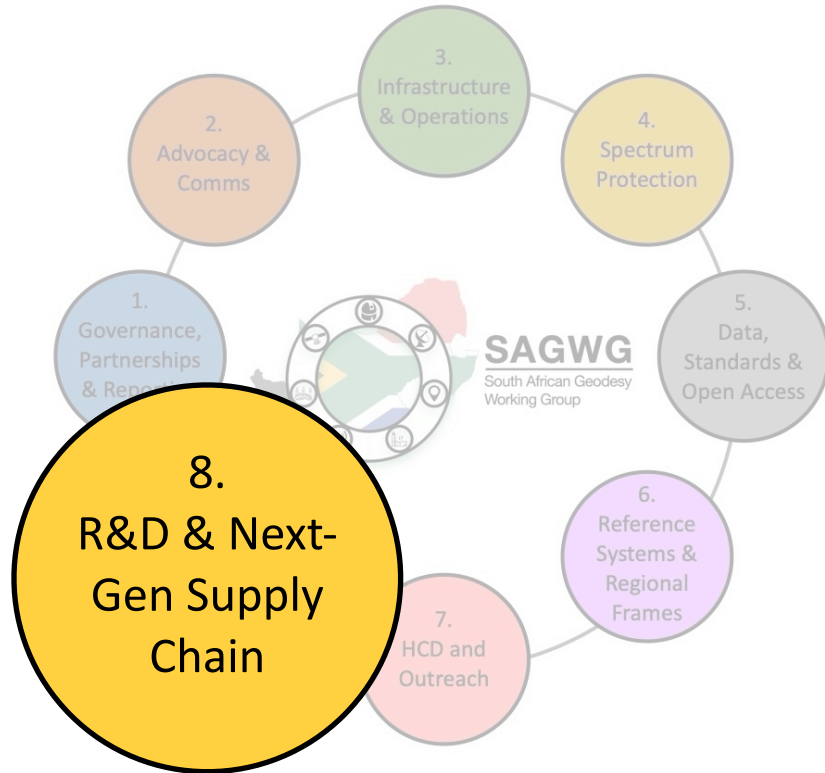
South African Geodesy Workshop
1-2 October 2025, SAAO, Cape Town



SAGWG
South African Geodesy
Working Group



Shaping Tomorrow's Geodesy, Today



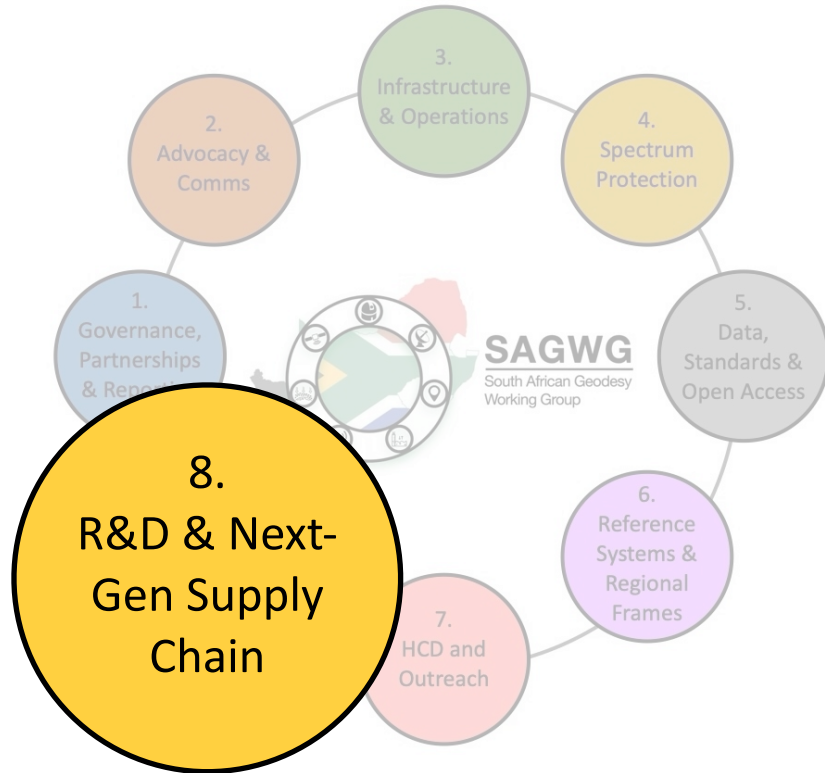
Support and advance geodetic research, development, and innovation, adopt emerging technologies, align with global initiatives, and build next-generation capacity for Africa's leadership in the geodesy supply chain

Development Plan Activities

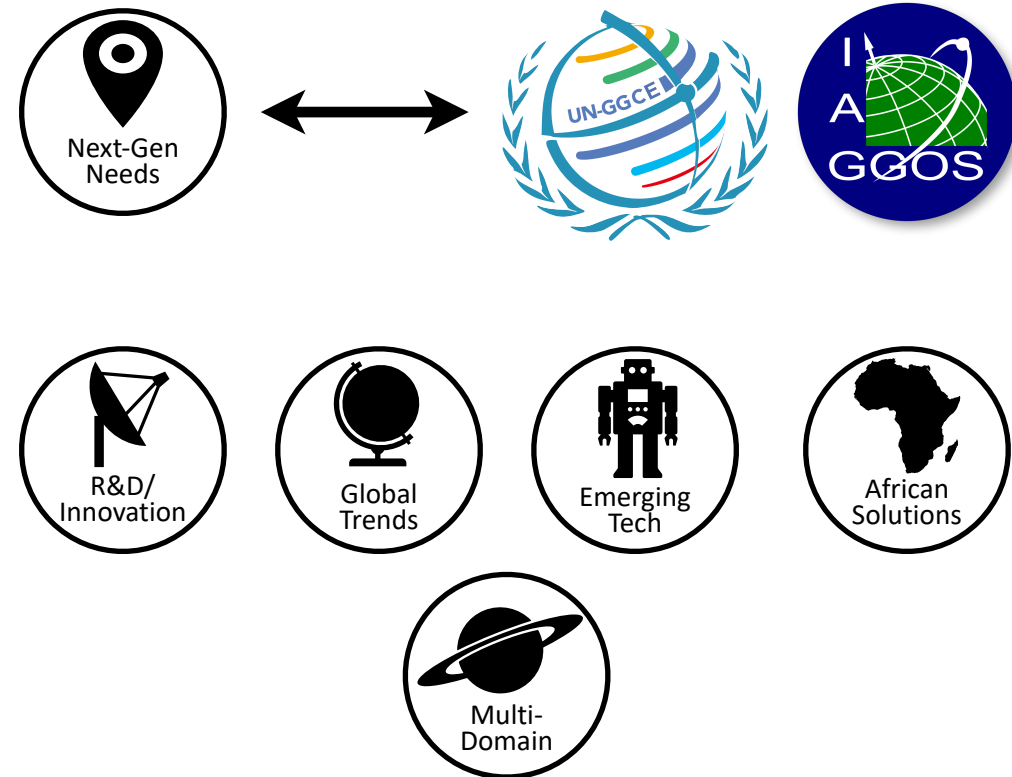
Phase 3: A next-generation global geodesy supply chain

- Provide information to UN-GGCE regarding what are the operational requirements constituting a next-generation global geodesy supply chain
- Undertake the geodetic research and development required to sustain and enhance the global geodesy supply chain
- Where appropriate, support space missions relevant to geodesy such as the ESA Genesis mission or the NASA/ESA joint missions on satellite gravimetry
- Support projects where South Africa is already leading globally in developing new techniques and solutions
- Strengthen current SA-led geodetic R&D projects and encourage innovation, commercialisation, and multi-domain collaborations
- Adopt and implement emerging technologies — including machine learning and AI applications (e.g. in ionospheric modelling) — and ensure national infrastructure (e.g. VLBI receivers, HPC capacity) keeps pace with international developments
- Ensure geodesists have access to national HPC infrastructure for data-intensive research, modelling, and analysis
- Develop and support innovative infrastructure solutions for African capacity-building (e.g. remote stations, shared infrastructure models)

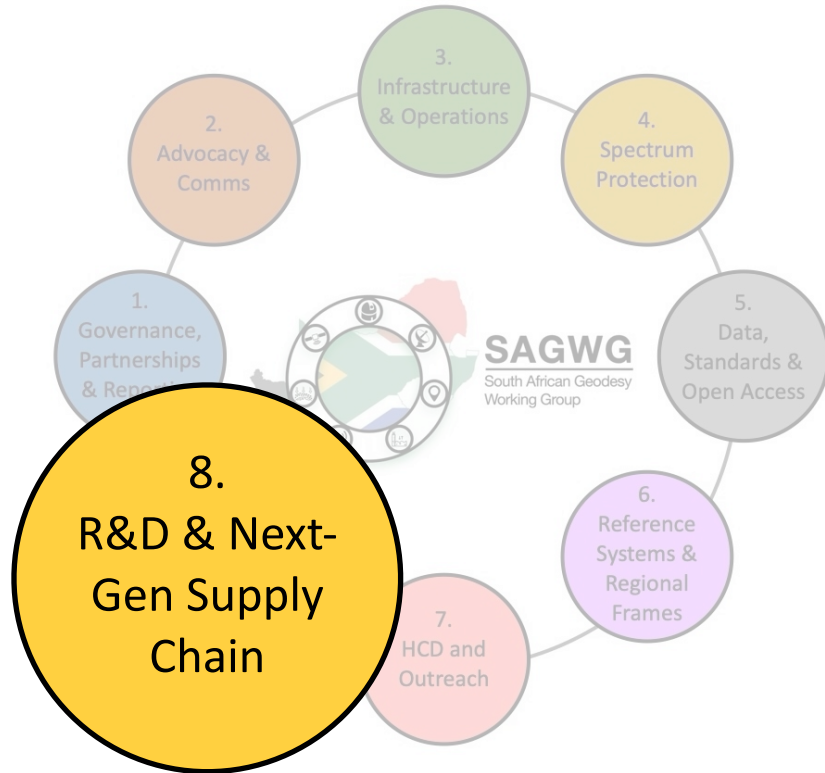
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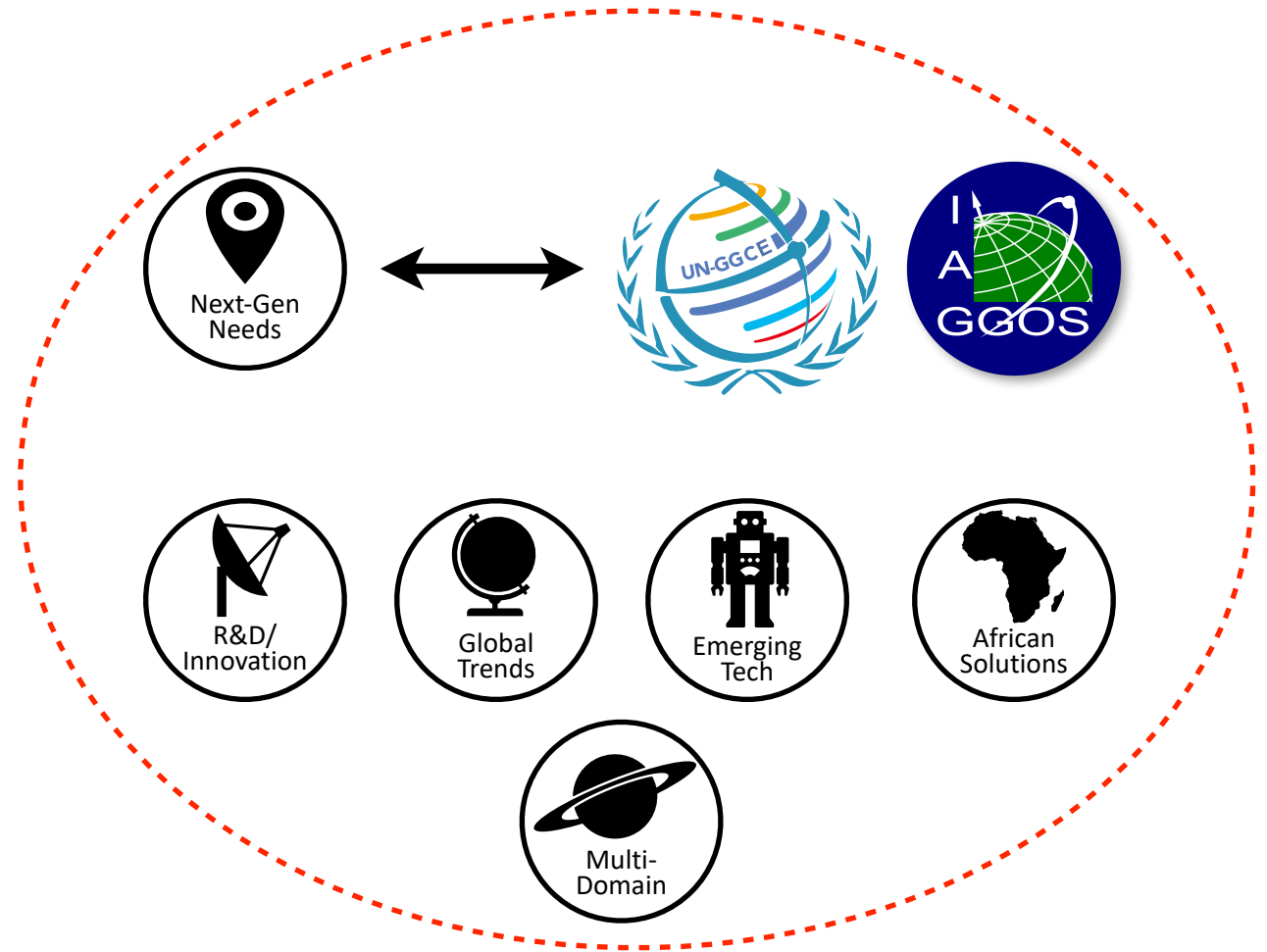
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Shaping Tomorrow's Geodesy, Today



Support and advance geodetic research, development, and innovation, adopt emerging technologies, align with global initiatives, and build next-generation capacity for Africa's leadership in the geodesy supply chain



Astro2Geo K-Band Project: Ticking All the Boxes

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Experimental plan for improving the K-band Celestial Frame

ABSTRACT

A new K-band collaboration has been formed to reduce astrometric systematics and to complete sky coverage at K-band. Phase I will demonstrate fringes. The first observations were carried out on 23 August 2013 between telescopes in Australia, Korea and South Africa. From our initial observations we successfully detected fringes which demonstrates the feasibility of our experimental approach. Phase II of our plan will include 24 hour observations and a bigger network of telescopes to observe a larger number of sources and for imaging of source structure. The Korea South Africa baselines will extend K-band celestial reference frame (CRF) coverage down to about -45° declination. Observations between Australia and South Africa will extend coverage to the south polar cap and thus gain full sky coverage for the K-band CRF. We discuss the potential baselines, their mutual spatial and frequency coverages and the implications for K-band CRF work.

BACKGROUND

We present a new collaboration to densify the CRF at 22 GHz (K-band), with specific emphasis on the Southern hemisphere where K-band CRF coverage is weak.

TELESCOPES

Fig. 1 The distribution of CRF sources at 24 GHz, showing a rapid drop in source density at declinations south of -30° .

Fig. 2 Relative to the standard S/X observing bands, at K-band sources are expected to exhibit more compact source morphology (see e.g. Figure 2) and reduced optical depth.

Fig. 3 This reduction of astrophysical systematics should be advantageous in tying the VLBI radio frame to the Gaia optical frame.

Fig. 3 Source structure (morphology) of source vs. frequency. Image credit: P. Charlot et al. A&S, 136, 5, 2010

Observational plan for extending the K-band celestial reference frame.

> We have developed a collaboration amongst the telescopes of the Korea VLBI Network (KVN), HartRAO, South Africa and Tdbinilla and Hobart in Australia (see Figure 5).

Phase I observations:

- > Demonstrate fringes.
- > Succeeded 23 August 2013.

Phase II observations:

- > 24 hour K-band observations to observe a larger number of sources.
- > Goal: more than 500 sources within the next year, with precision of $< 70 \mu\text{as}$.
- > A bigger network of telescopes for imaging of source structure.

MUTUAL VISIBILITY

Fig. 3 Sky coverage plots for a source at -30° declination. Observations between the KVN telescopes and HartRAO is limited to about 40° declination, and less than 4 hours of mutual visibility. Hobart and Tdbinilla will not be able to observe higher than about -30° declination.

Fig. 4 Sky coverage plots for a source at -70° declination. The gap in the HartRAO sky coverage is due to the polar mount of the telescope.

TELESCOPES

Fig. 5 A map showing the proposed telescopes for the K-band project. HartRAO in South Africa, Hobart and Tdbinilla in Australia and the KVN telescopes (Tama, Yonsei and Ulsan) in Korea. Phase I observations included HartRAO, Hobart and Tama.

Telescope	Diameter	Latitude	Longitude	Slew rate	K-band receiver	K-band SFD	Frequency range
HartRAO	26 m	25.89° S	27.69° E	0.50 deg/sec	uncooled *	5000 Jy	22 - 24 GHz
Hobart	26 m	42.81° S	147.44° E	0.67 deg/sec	cryogenically cooled	3400 Jy	18 - 25 GHz
KVN	21 m	26.29° N	126.49° E	3.00 deg/sec	cryogenically cooled	1200 Jy	21.25 - 22.25 GHz
Tdbinilla	70 m	35.40° S	148.98° E	0.25 deg/sec	cryogenically cooled	60 Jy	18 - 26.5 GHz

* Replacement of the HartRAO test receiver at K-band with a cryogenic receiver is in progress.

PHASE I OBSERVATIONS

Observational Details

- > **Date & Time:** 23 August 2013, 06:30 - 10:30 UT
- > **Stations:**
 - HartRAO => recorded with Mk5 & DBBC
 - Hobart => recorded with Mk5
 - Tama => recorded with KVN digital backend
- > **Recorded bandwidth:** 256 MHz
8 channels x 16 MHz x 2 sidebands, RCP only
- > **Spanned bandwidth:** 350 MHz, centered on 22304 MHz
- > **Rates:** Bits/sample = 2, Data rate = 1024 Mbit/s
- > **Data correlation:** DFX software correlator in Bonn. The data was electronically transferred from HartRAO and Hobart and via courier from Tama.

Source Selection

- > 23 compact sources from VLBI global solution rfc_2013c catalogue (<http://astrogeo.org>).
- > X-band flux > 600mJy
- > Goal SNR ≥ 20 in 2 min integration

Fig. 4 Distribution of the 23 sources selected for the fringe demonstration on 23 August 2013. Sources in blue have been observed with HartRAO, Tama and Hobart. Sources in red have been observed with HartRAO and Hobart only.

Results from Phase I observations

Baseline: HartRAO - Hobart26
Source: PKS J1427-4206
Flux density: 1.6 to 2.8 Jy at K-band

SNR ~ 78 in 120 seconds

The data has been fringe fitted and manual phase calibration applied.

Multi-band delay (MBD) in μs : The location of the peak of the MBD spectrum gives the residual MBD solution

Single-band delay (SBD) in μs

Fig. 7 MxGDFF correlator fringe fit output from the Phase I, K-band observations between HartRAO and Hobart for source J1427-4206.

- South Africa leads an international effort to improve the ICRF
- Concept of moving to higher radio frequencies (K-band, 24 GHz) was conceived in 2012 during a snowstorm in Helsinki
- First observational results were presented at the IVS General Meeting in 2013
- In 2018, the K-band CRF was officially adopted by the IAU as part of ICRF3, alongside the traditional S/X-band (2.3/8.4 GHz) frame
- The Astro2Geo K-band Project and website were launched in 2023
- By July 2025, K-band achieved higher precision than the S/X frame



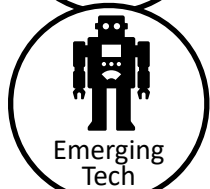
Astro2Geo K-Band Project: Ticking All the Boxes



- Higher precision CRF through reduced source structure effects and improved resolution. Operating at 24 GHz avoids much of the RFI plaguing lower bands.



- Tackling challenges in scheduling, correlation, and atmospheric modelling. Receiver development —> also higher frequencies and tri-band (K/Q/W) receivers



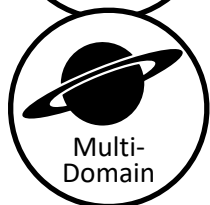
- Applying machine learning/AI for improved ionospheric calibration in single-band mode. Advances in high-frequency receivers and in recording & network systems that now enable higher data rates



- VLBI networks worldwide are moving to higher frequencies (K, Q, W) & multi/broadband receivers

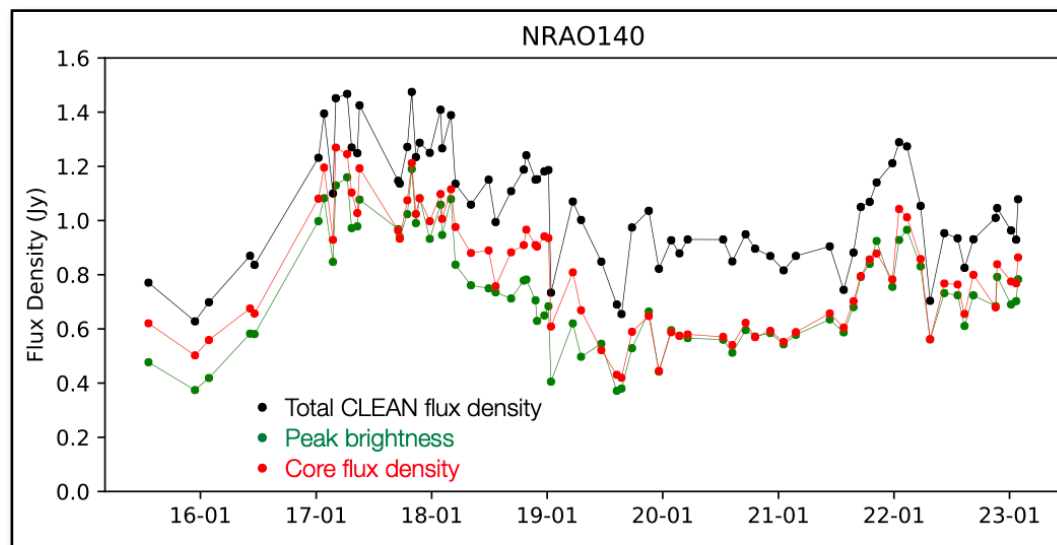
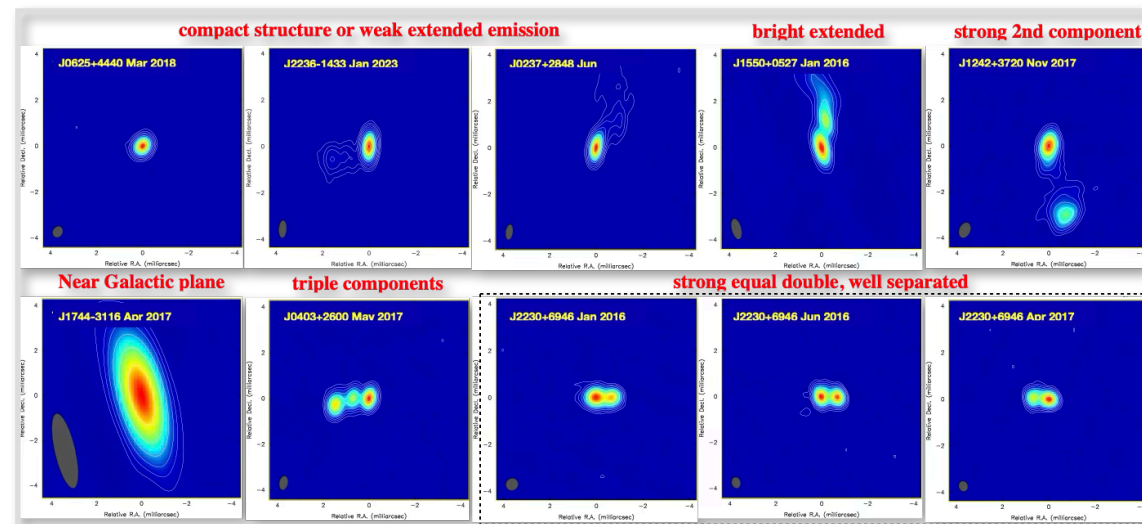
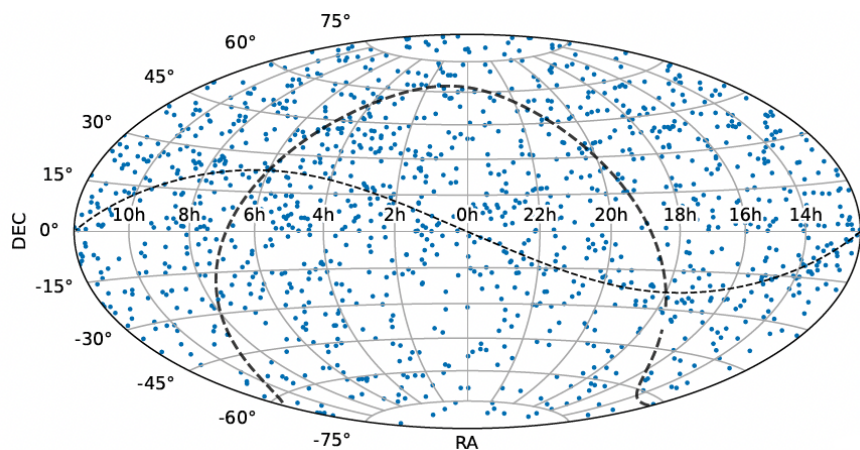
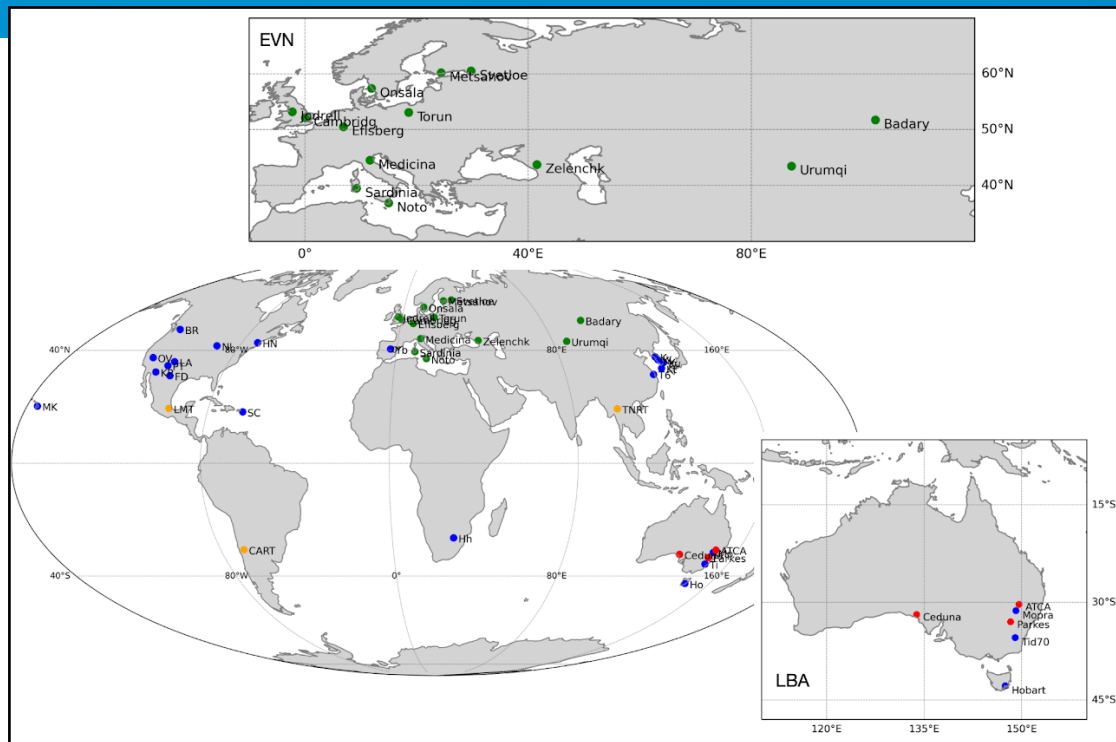


- Planning K-band receivers for new African telescopes (e.g., AMT in Namibia)



- ICRF K-band adopted by the IAU in 2018. K-band data submitted for the next ITRF solution (station positions, EOP). VLBI monitoring and imaging of AGN contributes to many astronomy projects

Astro2Geo K-Band Project: Ticking All the Boxes



*Dankie
Enkosi
Ha khensa
Re a leboga
Ro livhuwa
Siyabonga
Siyathokoza
Thank you*

M $\overline{\text{Making}}$ < sure $\left(\frac{\text{it's}}{\text{possible}} \right)$



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