

(TRANSIENTS) VLBI WITH SKA1

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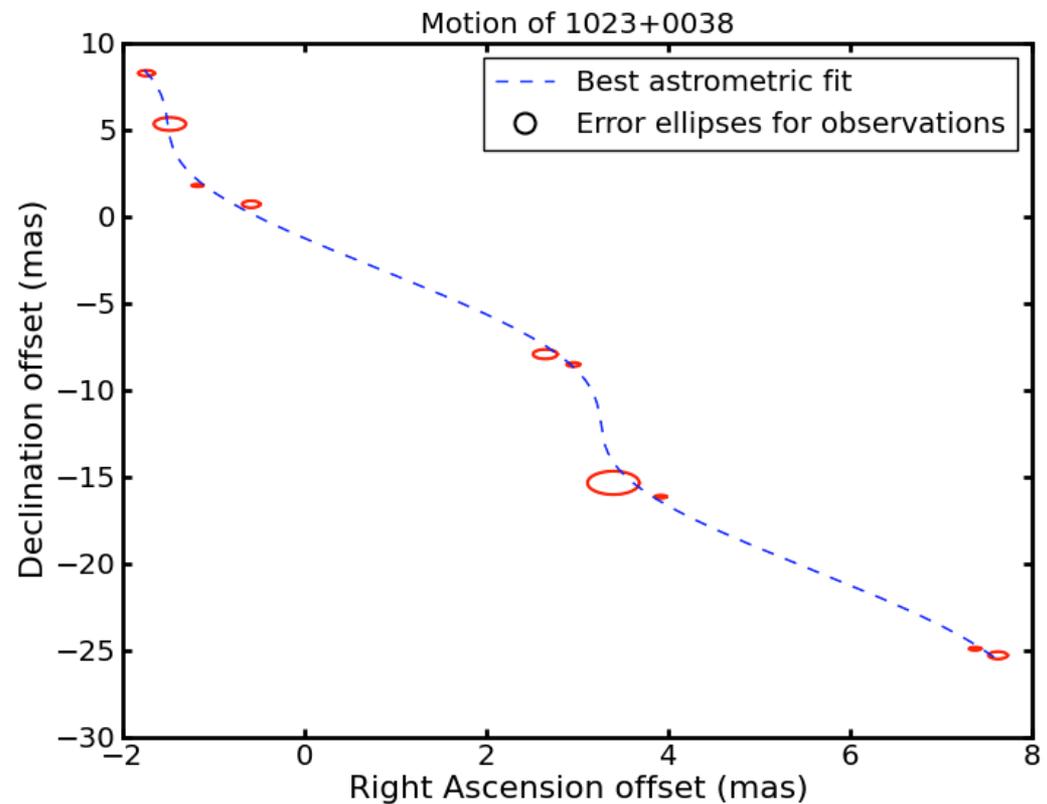
VLBI with SKA

- Pulsars (high priority) **need** better VLBI. Transients and all other VLBI users can leverage off their requirements
- **How can we (cheaply) do VLBI better using SKA1?**



VLBI astrometry

- Astrometry is needed for pulsar distances, velocities, associations, timing improvements, frame ties... SKA1 alone is no use (insufficient ang. resolution)
- Want $\sim 2\text{-}3 \mu\text{as}$ parallax accuracy for PTA pulsar distances
- Astrometry is also required by transients
- **Meeting the (high priority) astrometry spec will cover almost all transient VLBI science cases**



“Ideal VLBI” vs current VLBI arrays

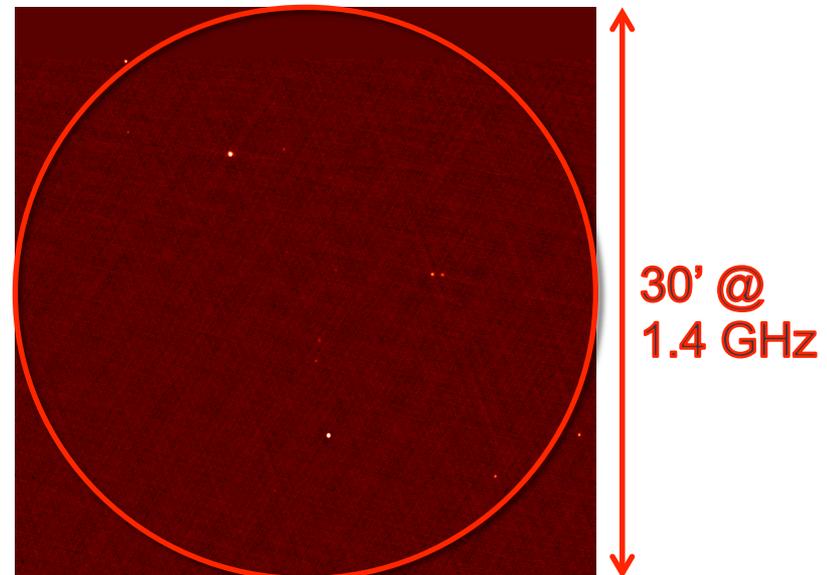
- Ideally, VLBI would have very high sensitivity over a very large (complete) FOV. Difficult/expensive for SKA1.

“Ideal VLBI” vs current VLBI arrays

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Northern Hemisphere 1:
VLBA has moderate sensitivity
over a **large** FOV



“Ideal VLBI” vs current VLBI arrays

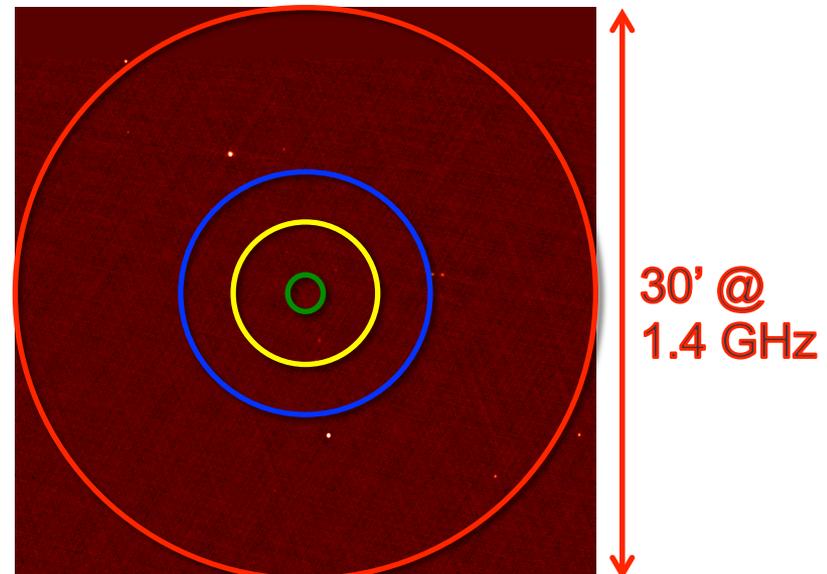
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Northern Hemisphere 2:

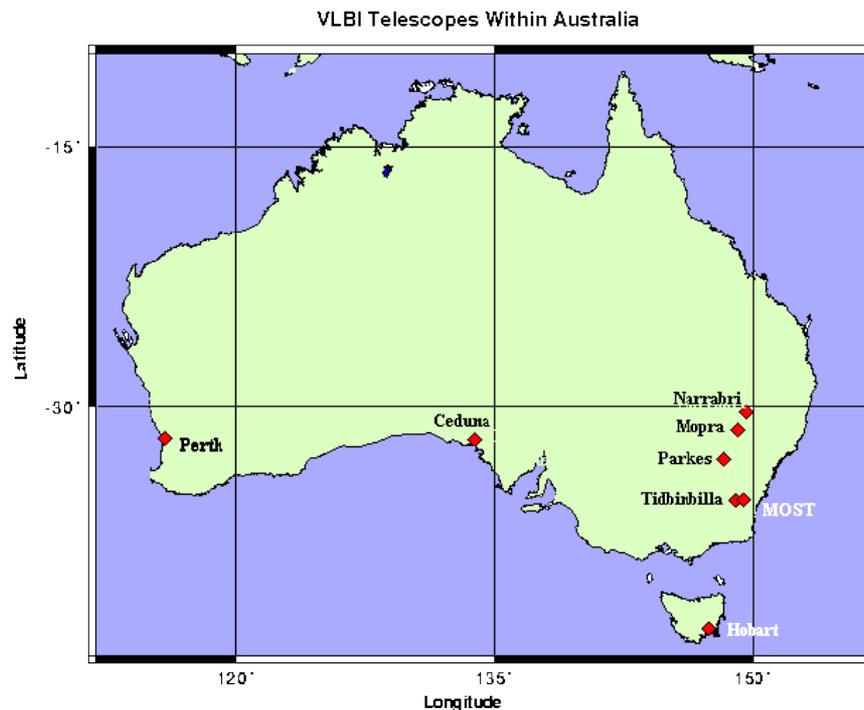
EVN has **high** sensitivity over a small FOV

(HSA = VLBA + GBT + phased VLA
[+Effelsberg] [+Arecibo] has basically the same capabilities)

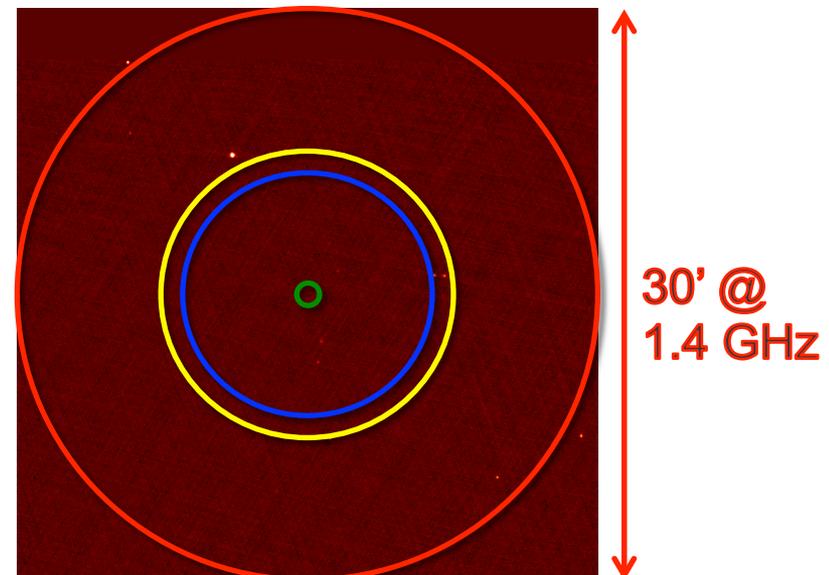


“Ideal VLBI” vs current VLBI arrays

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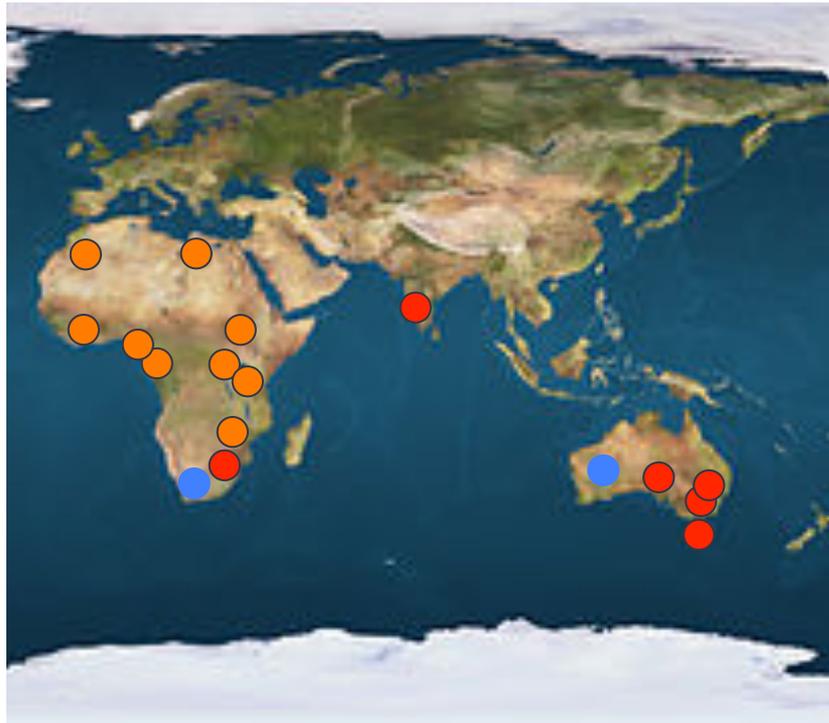
Southern Hemisphere:
LBA has moderate sensitivity over
a small FOV



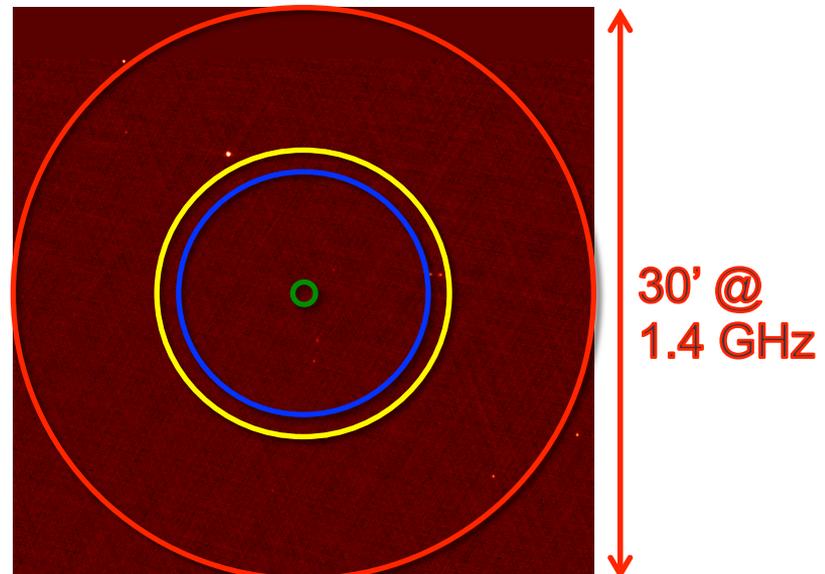
“Ideal VLBI” vs current VLBI arrays

- Ideally, VLBI would have very high sensitivity over a very large (complete) FOV. Difficult/expensive for SKA1.

- SKA
- Existing
- Potential



Southern Hemisphere future:
SKA1-mid + SKA1-survey + other
telescopes; very high sensitivity
over very small FOV; *uv* coverage?



Even by VLBI standards, this will be very sparse unless more new antennas are made available!

Observing with phased-SKA VLBI

- Current VLBA point source sensitivity in 2 hours (@ max bandwidth of 256 MHz): **27 μ Jy**
- Current EVN point source sensitivity in 2 hours (@ max bandwidth of 128 MHz, inc. Arecibo): **4 μ Jy**
- Current LBA point source sensitivity in 2 hours (@ max bandwidth of 64/128 MHz, inc. 70m Tidbinbilla): **22 μ Jy**
- Hypothetical array of phased SKA1-mid, phased SKA1-survey, LBA + Hartebeestok in 2 hours @ 512 MHz bandwidth: **\sim 1.5 μ Jy**
- So we can get **super-EVN sensitivity in the South, albeit with probably very sparse *uv* coverage.**

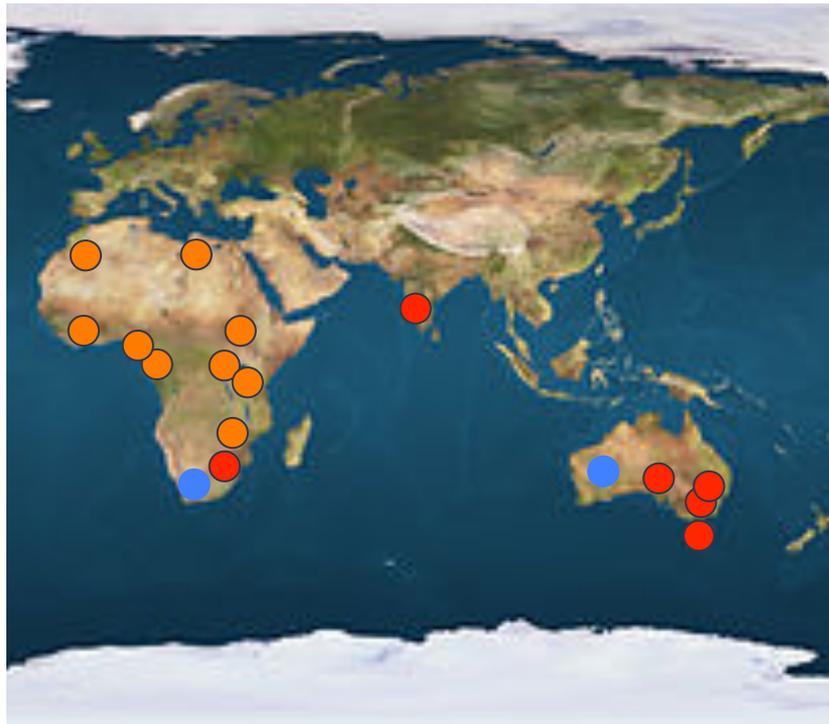
What is important for astrometry?

- Of the ~80 VLBI pulsar parallaxes currently available (including preliminary PSRPI results), >90% were obtained with the VLBA, **including the ~30 most precise ones**
 - Despite the fact that the EVN can be 5x more sensitive!
 - The large (uniform) FOV of the VLBA makes simultaneous in-beam calibration routine, rather than extremely difficult.
 - Inbeams are **absolute must have** for precision 1.6 GHz astrometry
 - Better sensitivity makes fainter calibrators usable and reduces required FOV, but FOV of arcseconds will never suffice
 - **For precision astrometry, SKA1 must have multiple beams for simultaneous access to calibrators at moderate separations**
 - **All observations benefit from contemporaneous calibration**

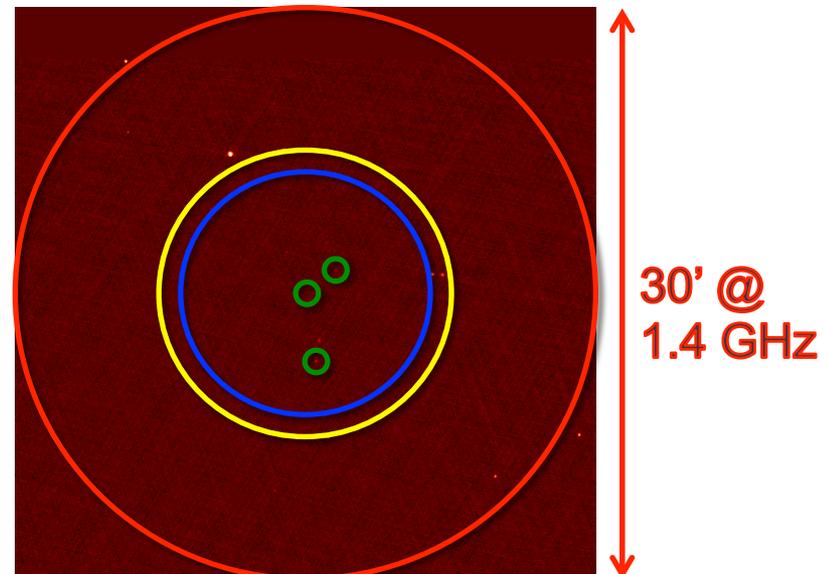
“Very good” VLBI with SKA1

- To get the necessary FOV, multiple beams are crucial. Flexible subarrays could trade sensitivity for SKA1 FOV.

- SKA
- Existing
- Potential



Southern Hemisphere future:
SKA1-mid + SKA1-survey + other
telescopes; **very high** sensitivity
over multiple (very small) FOVs



VLBI in the Baseline Design

- Extension to SKA2: very long baseline extensions:
 - **“...little impact on the design of SKA1, and will not be considered further.”**
- Figure 25 Block Diagram for SKA1-survey:
 - **“VLBI TBC”**
- Data transport for SKA1 survey
 - **“No provision has been made in this budget for concurrent VLBI transmission.”**
- Synchronisation: timing
 - **“VLBI obs. may require high-precision reference to IAT.”**
 - **“VLBI and transient detection equipment, where present, will have access to time services...”**

VLBI in the Level 1 Requirements

- VLBI now appears in a number of places, but there are still many shortcomings. The most serious:
 - Section 7.21.10: **Only 1 VLBI beam for SKA1mid**
 - Section 8.2.4: **Only 1 VLBI beam for SKA1survey**
- Other significant points of concern:
 - Beams are produced “for use by a VLBI terminal”: **but the terminal is neither included nor requested from a partner**
 - Section 4.6: “**VLBI ... will initially be treated as a subclass of custom experiments**”; Undesirable. How long is initially?
 - Section 4.8.1: “**...1-16 (TBC) subarrays...**”; subarrays highly desirable for efficient VLBI; ability for different modes crucial
 - Section 6.18: **Elevation limit 15 degrees**; desire lower limit (degradation of sensitivity due to pointing/shadowing acceptable)

Key changes required to Level 1 Reqs

- Flexible beamforming for both SKA1-mid and SKA1-survey:
 - Selectable number of independently steerable core beams (min. 2, preferably 4+) **particularly crucial for astrometry.**
 - Ideally also: 4+ tied array beams from 1 or 2 remote SKA1-mid stations.
 - For each beam: selectable subarray, flexible calibration (e.g., don't want to have to have a dominant source at the pointing centre).
- No hard limit on elevation.
- Clarity on the operational use of VLBI; ideally a more positive approach.

VLBI in the Concept of Operations

- Section 8.6: “VLBI will initially be considered a subclass of custom observing”:
 - Like Level 1 Reqs, this needs clarity, ideally a more positive approach
- Section 8.8: “The scientific need for subarrays will be determined as a result of an analysis of use cases”, footnote “Position paper needed from SWG”:
 - Subarrays are really essential, for many science cases. Here ConOps conflicts with Level 1 Requirements. This should be updated.