



# (PULSAR) VLBI WITH SKA1

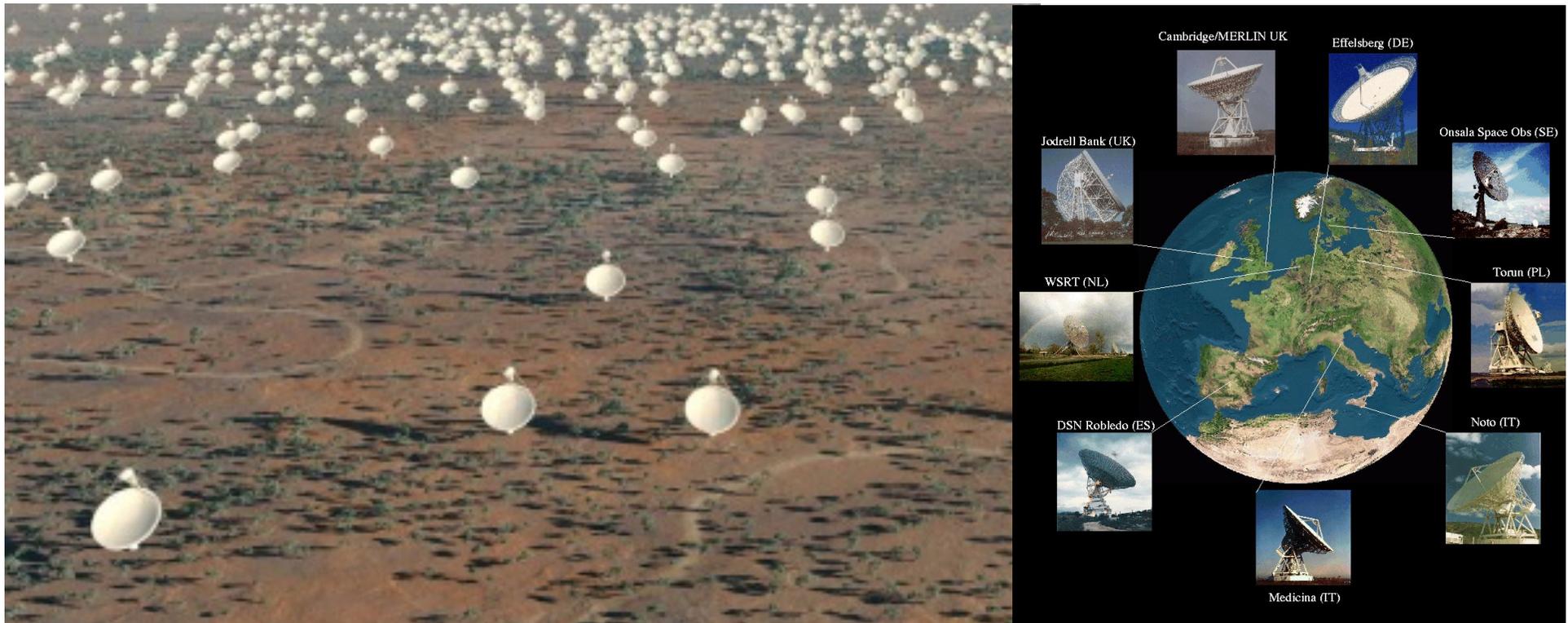
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Adam Deller

SKA Pulsar Science Working Group meeting  
17 July 2013  
SKA HQ, JBO

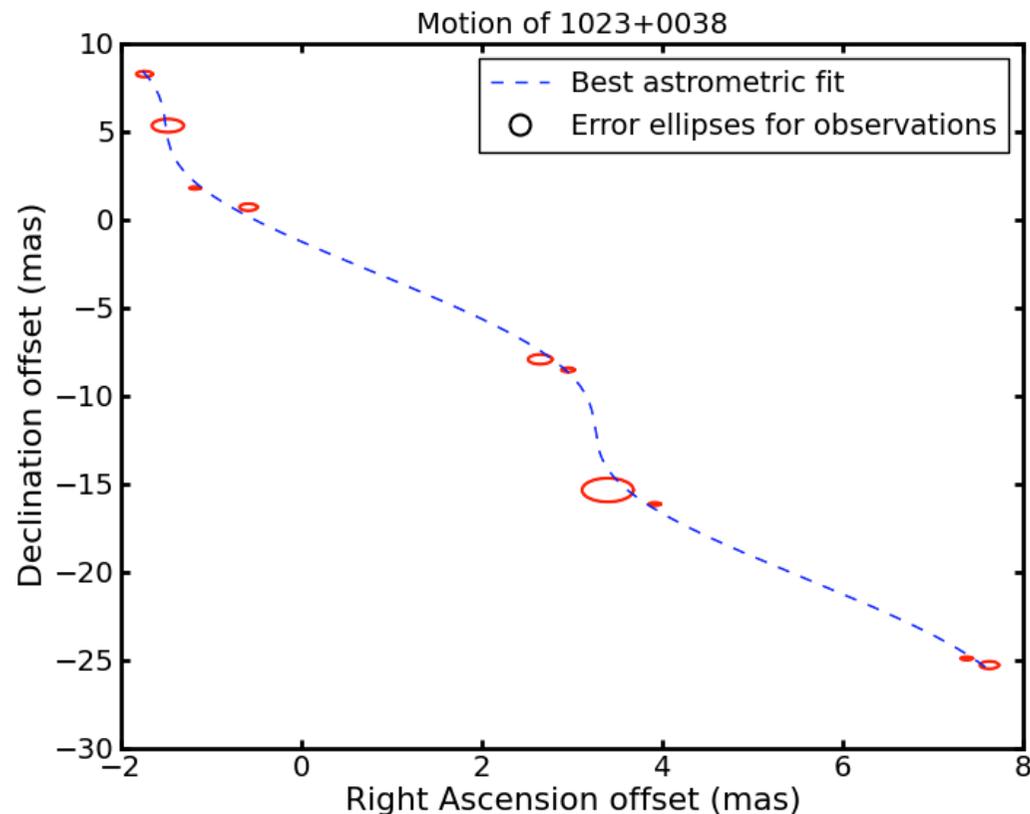
# VLBI with SKA

- How can we use SKA1 to do VLBI better than we do currently?
- Focus on pulsars, but all these points are relevant to generic use of the SKA for VLBI



# Science for SKA1-VLBI pulsars obs.

- **Most important:** astrometry 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
- Also: angular broadening for scattering studies
- Speculative: SKA1-low for scintillation imaging



# 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...”**

# What can SKA1 provide?

- **SKA1-mid 1.4 GHz SEFD: 1.7 Jy**
- **SKA1-survey 1.4 GHz SEFD: 7.1 Jy**
- C.f. Arecibo 1.4 GHz SEFD: 2.4 Jy  
or phased EVLA SEFD: 10 Jy  
or 25m dish like VLBA SEFD: 300 Jy

But: consider FoV:

- Phased SKA1-mid/SKA1-survey to 1km: 4"
- Arecibo: 20"
- 25m dish like VLBA: 1800"

# Current VLBI arrays and “ideal VLBI”

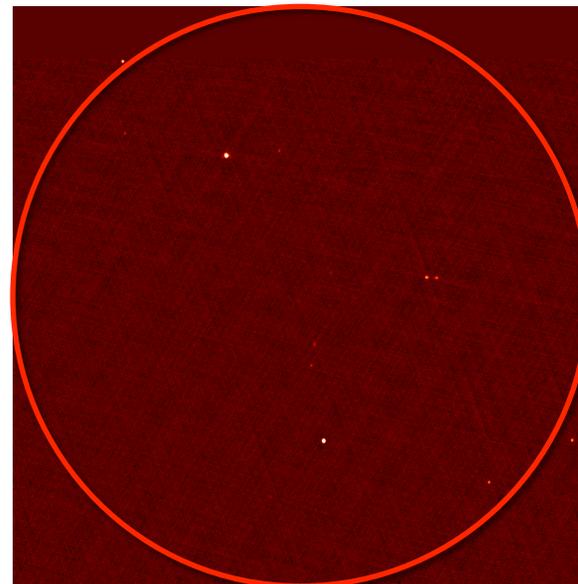
- Ideally, VLBI would have very high sensitivity over a very large FOV. This is SKA2 territory.

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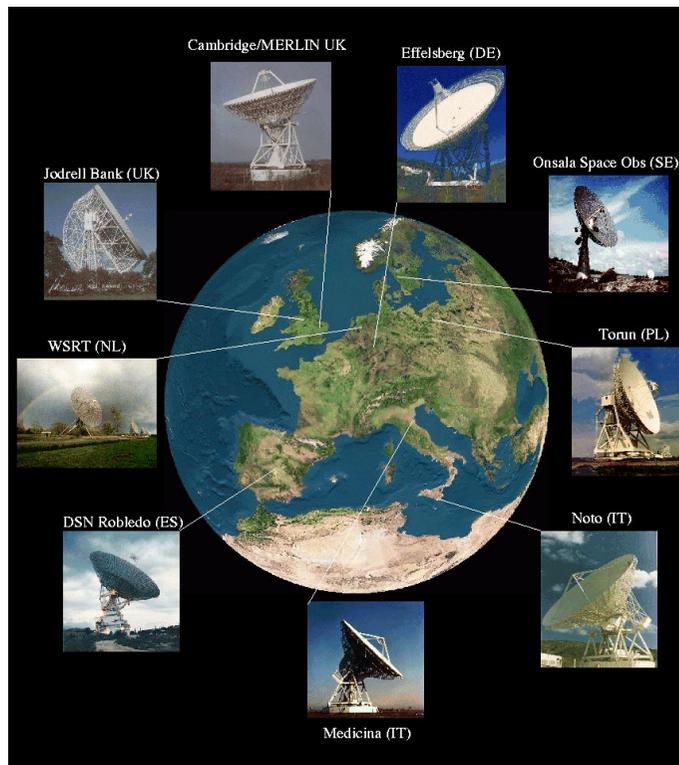


Northern Hemisphere 1:  
VLBA has moderate sensitivity  
over a **large** FOV



# Current VLBI arrays and “ideal VLBI”

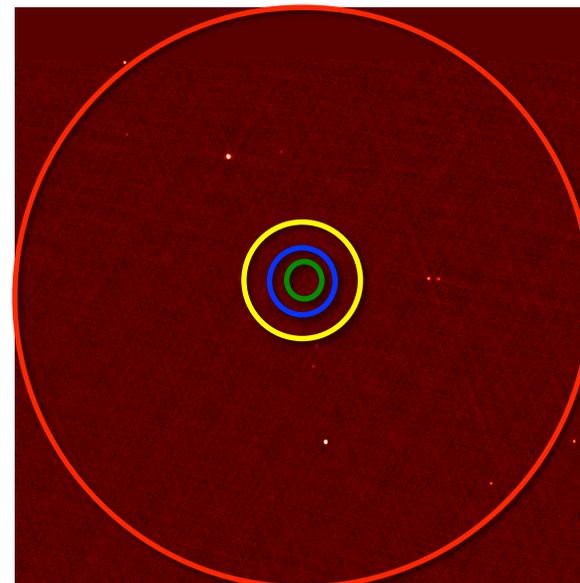
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Northern Hemisphere 2:

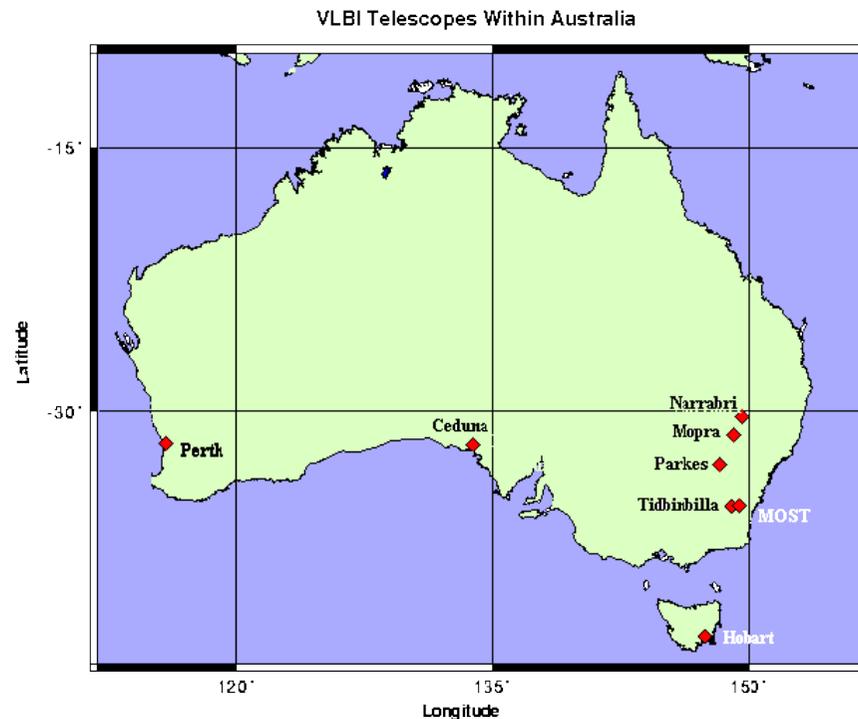
EVN has **high** sensitivity over a small FOV

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

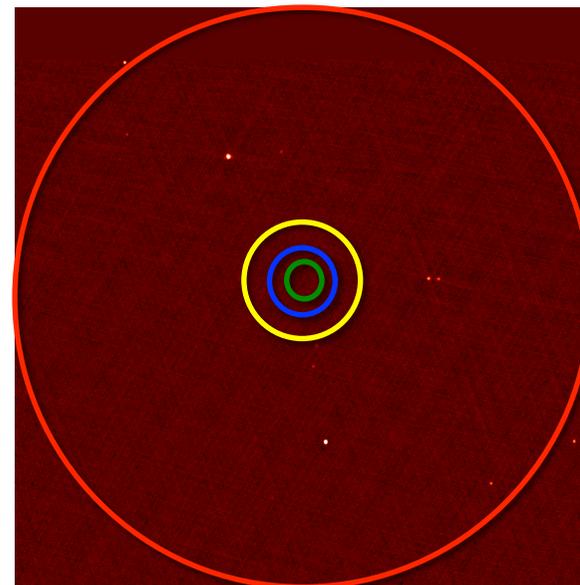


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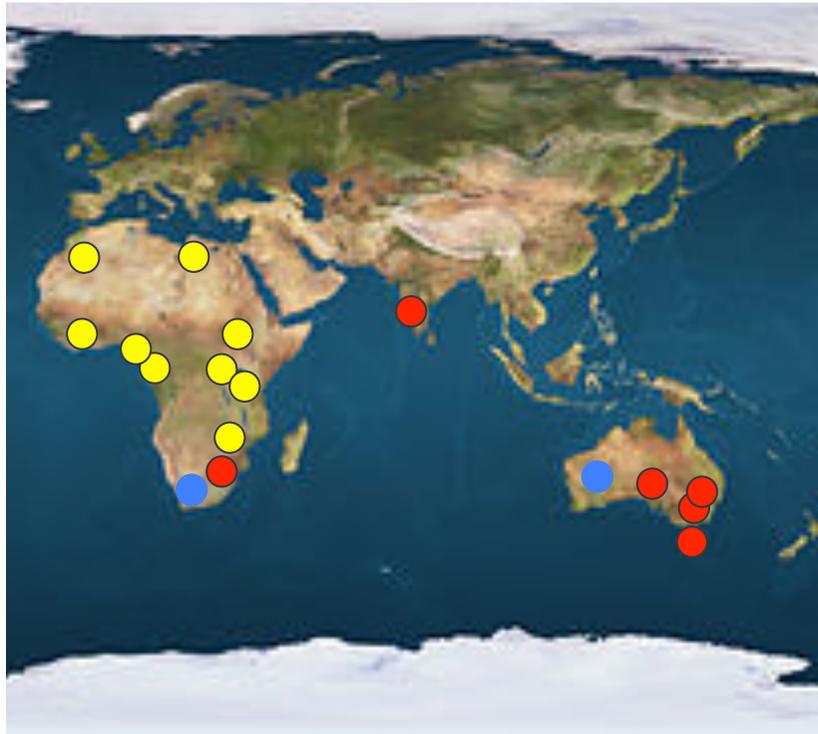
Southern Hemisphere:  
LBA has moderate sensitivity over  
a small FOV



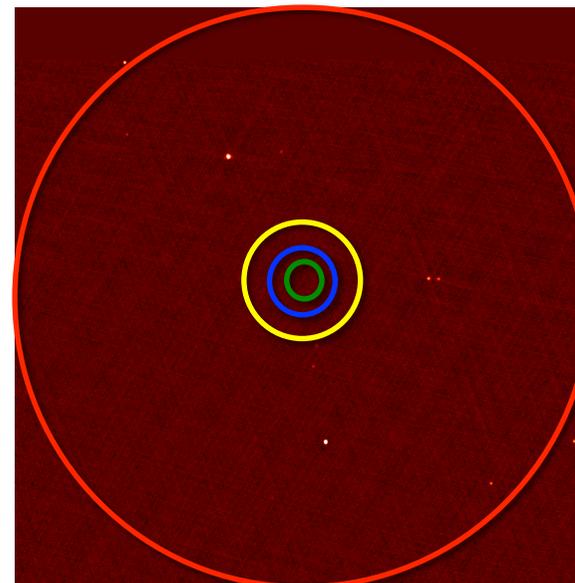
# Current VLBI arrays and “ideal VLBI”

- Ideally, VLBI would have very high sensitivity over a very large FOV. This is SKA2 territory.

● SKA  
● Existing  
● Potential



Southern Hemisphere future:  
SKA1-mid + 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  $\mu$ Jy**
- Current EVN point source sensitivity in 2 hours (@ max bandwidth of 128 MHz, inc. Arecibo): **4  $\mu$ Jy**
- Current LBA point source sensitivity in 2 hours (@ max bandwidth of 64/128 MHz, inc. 70m Tidbinbilla): **22  $\mu$ Jy**
- Hypothetical array of phased SKA1-mid, phased SKA1-survey, LBA + Hartebeestok in 2 hours @ 512 MHz bandwidth:  **$\sim$ 1.5  $\mu$ 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 is >2x more sensitive!
  - The VLBA is the only array to date which has been able to use simultaneous “in-beam” calibration due to its large FOV
  - This is an **absolute must have** for precision astrometry at 1.6 GHz
  - Better sensitivity means fainter calibrators usable and hence smaller FOV necessary, but a FOV of arcseconds is never going to have sufficient calibrators
  - **If precision astrometry is required, SKA1 must have multiple beams to allow simultaneous access to calibrators at moderate separations**

# What do we need from SKA1?

- Flexible beamforming for both SKA1-mid and SKA1-survey:
  - Selectable number of stations in a core tied array beam
  - Selectable number of independently steerable core beams (min. 2, preferably 4+) **particularly crucial for astrometry**
  - Sensibly formatted tied array output (e.g., VLBI Data Interchange Format - VDIF)
  - Ideally also: 4+ tied array beams from 1 or 2 remote SKA1-mid stations
- The means to “do” VLBI:
  - A maser / high precision time standard
  - Data recording (local disks) or transport (fibre connection).
- Also would be nice: 1 beam VLBI capability for SKA1-low

# Other considerations

- VLBI astrometry needs observations at a fixed time (depends on RA) to get good sensitivity to parallax
- Need to coordinate with the other telescopes in the VLBI array (proposals as well as scheduling!)
- Should think ahead of time who is going to take responsibility for what aspects of VLBI observations with SKA
  - i.e., who pays for the masers / disks / fibre links?
  - who commissions the VLBI capability?
  - ...?