VLBI:
The very high resolution component of ASKAP

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LBA

• LBA VLBI array operated by CSIRO
  • University of Tasmania, Auckland University of Auckland and Hartebeesthoek Radio Observatory

• Five core telescopes
  • Parkes (64m), ATCA (5x22m), Mopra (22m), Hobart (26m), Ceduna (30m)

• Warkworth (14m/30m), Hartebeesthoek (26m/15m), Tidbinbilla (70m/34m), Auscope (12m)

• Some Asian & EVN involvement
• 1-100 GHz frequency range
• ~30 days/year observing
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<th>Frequency (GHz)</th>
<th>Baseline (km)</th>
<th>Resolution (mas)</th>
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<td>Full LBA</td>
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Aus LBA: Parkes, ATCA, Mopra, Hobart & Ceduna
Full LBA: Also Warkworth, Hartebeesthoek
The High Resolution Components of ASKAP: Meeting the Long Baseline Specifications for the SKA (VLBI)

• Use ASKAP as an element of the LBA
• Accepted as “technology demonstrator” rather than full on survey
• Main requirement ASKAP tied array
  • ~35m equivalent single dish
• Doubles maximum Australia only baseline
  • 1.5x longer which including New Zealand
• Fills in uv coverage to South Africa
• Explore “multi-view” VLBI
  – Multibeam VLBI
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Project Update

• Installed single pixel feeds at 1.6 and 8.4 GHz on two antenna
• Supplied Hydrogen maser for observatory
• Installed own VLBI backend
  • First ASKAP fringes 22 April 2010
  • First eVLBI fringes 27 June 2011
  • Determined absolute position for AK29
    – Original survey position 17m off
• Demonstrated PAF VLBI with single dish beta system
• No tied array developed for beta
• Tied array for full ASKAP spun off as separate project
• Exploring ASKAP PAF-PARKES PAF VLBI
ASKAP VLBI Science

• Regular inclusion in regular LBA observations since
  • 69 user experiments
  • 1000 hours observing (including June 2016 session)
• First science - 1934-638 - Tzioumis *et. al.* 2010
  – Higher resolution low frequency observations reinterpreted evolution changes as optical depth effect
• Pulsar astrometry (Miller Jones *et. al.*)
• PKS B1424–418
  – Possible radio association with extraterrestrial very-high-energy neutrinos discovered by IceCube
VLBI with ASKAP/VLBI for ASKAP

• ASKAP will enhance all low frequency LBA observations
  – Better resolution matching for higher frequency observations
  – Benefits a range of science
• ASKAP SSPs need VLBI for follow up
  – LBA is only Southern Hemisphere LBA array
  – ASKAP has unique frequency coverage
• Call for 1 GHz LBA observations will increase
Pulsar Astrometry

• Accurate astrometry give parallax and proper motion independent of timing
  – Good to break some degeneracies in timing model
  – Improved GR tests

• Independent parallax measurement anchors electron density distribution of Milky Way
  – Improved distance estimate for other pulsars, Galactic formation models

• Calibrate pulsar 2D velocity distribution – kick physics

• Pulsar timing arrays have underestimated errors on parallax and pm (Deller et al, 2016, ApJ submitted)
EMU

- EMU is a deep (10 μJy/beam rms) radio continuum survey of 75% of the sky
- Will detect 70 million radio galaxies
- Need VLBI to distinguish between AGN and Star forming galaxy
  - Ideally VLBI on all sources....
- High quality VLBI on a sample of sources, high resolution
- Widefield VLBI of 1000 square degrees
- Single baseline survey of large fraction of EMU sources
  - Parkes-ATCA. Would include ASKAP if practical but resolve out some sources
- Want 1 GHz VLBI
FLASH

• A blind HI absorption-line survey using background radio continuum sources to identify and characterize foreground neutral hydrogen
• Want VLBI to interpret results based on shape of background radio source
• Also VLBI follow up of actual HI detections
  – 700-1000 MHz (need ASKAP & Parkes PAF)
  – Estimate size of absorbing clouds
  – Figure out where absorption is coming from
  – E.g. fast jet-driven outflows of neutral gas in nearby radio galaxies
GASKAP

• High spectral resolution survey of HI and OH lines in the Milky Way and Magellanic Systems
• VLBI follow up of OH masers:
  – Structure and dynamics of individual sources
  – Astrometry – distance and Galactic dynamics
  – Zeeman pair polarisation
    – Need high resolution to match pairs and overcome spatial depolarisation
• Required VLBI at 1.6 GHz
Transients

- VAST and CRAFT investigate the radio sky looking for transients at a range of timescales
- Fast transients must be small
  - Need VLBI to resolve
- VLBI crucial for interpreting many of the detections
  - ESE (Extreme Scattering Events)
    - Image while on progress – infer geometry of the lens
  - FRBs (Fast Radio Bursts)
    - Location of afterglow associated with blackhole core or elsewhere
  - Gamma-ray bursts and supernova
    - Measure expansion rate and discriminate between different sources for the radio emission
• Measure the Faraday rotation of three million extragalactic radio sources
• Significant population of de- (or un-) polarized compact steep spectrum sources, as well as a smaller population of higher polarization compact sources
• VLBI to see if they are structurally different, are embedded in different types of media, etc
  – Including polarimetry
  – 1 GHz LBA plus at a higher frequency (with ~matched resolution) to get rough spectral indices for the resolved components (to help distinguish between CSOs and blazars).
SETI

• SETI with ASKAP would require tied array
  – Untargeted search would require prohibitive compute
• Multiple tied array beams with dedicated SETI backend per beam
  – Presumably would want many tied array beams
RFOF
188 elements

1 MHz channels
Oversampled

18.5 kHz
Nyquist sampled

Correlator
Tied Array Strawman

• Develop oversampled fine filterbank
  – Beamformer ➔ Correlator link at capacity
• Add tied array functionality in correlator
  – Maybe linear ➔ circular conversion
• Add Ethernet packetisor
• Purchase “large” switch and add *lots* of Ethernet cables
• Develop GPU based synthesis (inverse) filterbank
  – GPU server with 4 GPUs can probably handle 4 beams
  – Purchase 1 or 2 GPU servers initially
• Feedback for array calibration
Conclusion

• ASKAP tied array functionality would be a major benefit for a range of science using the LBA
• VLBI is critical for the follow up of a lot of ASKAP science
  – Much of this needs to be at ASKAP frequencies
• The tied array project is still being planned
Acknowledgements

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Thank you

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