VLBI Developments

“Down under”

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Talk Outline

• Introduction to the LBA
• Telescope Developments – more antennas
  • AuScope; ASKAP; Ww; South Africa
• DAS/Recorder developments
  • ASKAP DAS/recorder
  • CABB/DFB3
  • Xcube recorder + DAS
• Correlation – DiFX
• Networks
• E-VLBI
• NTFN
• Summary
Long Baseline Array (LBA)

- Telescopes in Australia / Asia-Pacific / Southern hemisphere
  - CSIRO (ATCA, Mopra, Parkes); U.Tasmania (Hobart, Ceduna)
  - NASA (Tidbinbilla)
  - ASKAP; + NZ; AuScope
  - + South Africa (9000 km baselines) – Hart (& KAT-7)
  - + Telescopes in Asia Pacific: Japan, China, Hawaii, VLBA,…

- Frequency range: 1-22 GHz
- Disks (XRAIDs) & eVLBI - up to 1Gbps (4 x 64 MHz)
  - All (almost) data transfers electronically – Petabyte store

- Software correlator(s) - DiFX
  - Curtin University Supercomputer cluster - CUPPA
    - “Real time” correlation from disks & eVLBI
  - e-VLBI correlators at ATNF (Parkes; ATCA)

- Open VLBI network - proposals 15 June & December
  - ** Includes e-VLBI proposals **
LBA Sensitivity calculator (Java online)
Long Baseline Array (LBA)

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Development #1: New Antennas

- **Australian SKA Pathfinder (ASKAP)**
  - 36 x 12m antennas + Phased-Array feeds and multiple beams
  - VLBI with single antenna + single pixel feeds (L & X bands)
  - Recorded-VLBI & e-VLBI (at 512 Mbps)
- **AuScope** for IVS (geodesy)
  - 3 x 12m antennas; Hobart, Katherine, Yarragadee
  - S/X geodetic systems + DBBC + MK5B
- **NZ Warkworth** antenna – IVS (see Tim’s talk)
  - 12m dish + DBBC + MK5B
- **South Africa** (Jonathan’s talk)
  - Hart 26m + 15m SKA prototype (used in 2012)
  - KAT 7 (7 x 12m) – tests scheduled
  - MeerKat
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LBA Imaging capability improvements

- “LBA” 6 ant 1700km 40 uJy/beam (Ceduna)
- +Auscope +ASKAP 9 ant 3450km 110 uJy/beam
- +NZ 10 ant 5360km 110 uJy/beam
- +South Africa 11 ant 10440km 110 uJy/beam

Enhanced imaging; “zoomed arrays”; very high resolution
Future telescope developments - sensitivity

• ASKAP tied array beams
  • Multiple synthesised beams (4+)
  • Up to 36 antennas $\rightarrow$ equivalent to $\sqrt{36 \times 12m} = 72m$ antenna
• NZ 30m antenna – existing coms antenna (see Tim’s talk)
• GMRT VLBI
  • Inner 16 antennas $\rightarrow$ $4 \times 45m = 180m$ antenna!!!
• South Africa
  • Tied array KAT 7 ? $\rightarrow$ 23m equivalent
  • Tied MeerKat ? $\rightarrow$ $\sqrt{64 \times 13m} = 104m$ equivalent!
• SKA VLBI ??
  • Southern hemisphere arrays...

***Sensitivity key factor $\rightarrow$ at present try BW increases
DAS/Recorder systems - existing

- **LBA DAS** (Developed for S2 VCR system)
  - Digital filtering – 2 x 64 MHz input IFs (2 pols) → 512 Mbps
  - ATNF (At, Mp, Pks) with 2 DAS/station → 1024 Mbps
  - + COTS Computers + Disks (mainly XRAID systems)
  - Remote disk recording + eVLBI

- **Mk4/Mk5/VLBA DAS** + MK5A or MK5B recorders
  - Ho, Pk, Tid (older geodetic systems) – {16 MHz bands}

- **DBBC + Mk5B recorders**
  - IVS systems – AuScope & NZ -- {16 MHz bands}

- **ASKAP system** - (“Bruce” Curtin recorder)
  - COTS computer + Disks
  - Commercial sampler card (Signatec PX1440)
  - 2 x 64 MHz bands → 512 Mbps (could go x2)
DAS/Recorder systems - development

- **DFB3** boards – 1 GHz BW
  - Non-VLBI operation at Parkes → need VLBI mods
  - Initial tests successful BUT no manpower!! (ASKAP) - deferred

- **CABB wideband DAS** - 2 GHz BWs x 2 pols
  - ATCA array – 2 freq chains x 2 GHz BW x 2 pols x 16-bits
  - Up to now using only 64 MHz sub-band → old DAS
  - Tied array in 32 x 64MHz (for full 2 GHz) x 2 pols
  - Output directly on 10 GigE ports
  - Have FPGA engineer and current project!!
  - Mods underway!! Basic functionality already added!!
  - Tests within weeks. Basic system commissioning within months!
  - Outputs into large 10 Gbps switch(already bought) – then record or eVLBI
  - Potentially record full 2 GHz of BW → Need 10 GigE recorders!
Xcube Recorders

• Commercially available and supported systems – 4 acquired
  • **Notable characteristics:**
    • - Ethernet recorder
    • - 4x10 Gbps ethernet inputs
    • - 16 Gbps recording rates advertised
    • - 4x8 disks modules connected externally. Up to 128 TB of spinning storage
    • - Library functions to read the data back off disk
  • **Tests so far:**
    • Streamed data in VDIF/UDP format from existing recorder at ATCA to an Xcube in Sydney at 512 Mbps. Successfully copied the data off the Xcube and correlated in DIFX
    • Sent dummy VDIF data from one Xcube to another with a direct connection at 8 Gbps. For a 10min test we received 94 million packets with 2400 missing packets.
Xcube - StreamX-VLBI

• Digital receiver board based on FPGA commercial digitisers
  • 4 Channels x 512 MHz each
  • polyphase (32 channels) filter bank
  • quantizers to provide 2-bit output stream to recorder
  • Setting and control via the Xcube recorder

• Units yet to be tested
• May replace current generation of LBA DAS systems

• Visit to Xcube this afternoon
Correlation - DiFX

- **DiFX** software correlator - (from Adam Deller at Swinburne)
  - (Ref: Deller et al. 2011, PASP, 123, 275 (DiFX-2))
  - Adopted internationally (NRAO, Bonn, LBA,…)
  - Accepts many formats (LBA, MK5, VDIF) & real or complex samples
  - Very flexible and versatile

- DiFX 2.0 can correlate mixed bands e.g 64 vs 4x16 MHz
  - Extremely important for LBA (many DAS systems)
- Adopted for all e-VLBI or recorded-VLBI correlation in LBA
  - Even real-time fringe testing

- * Data Compatibility no longer an issue!!
- ** Transformed the way we do VLBI
ICRAR-Curtin Correlator Facility

• Primary correlator for the Australian Long Baseline Array

• CUPPA
  – 20 node (160 core) beowulf cluster
  – Gb ethernet
  – >150 TB attached storage
  – Runs DiFX under the Espresso processing pipeline

• Future plans

• Pawsey Centre for SKA Supercomputing
  • Under construction in WA
    – 150 teraflops (currently)
    – scaling up to petaflop in 2 years

• Tests of DiFX on new hardware
  • to be carried out during 2012/13
Networks: AARNet Network

Updates: 40 Gbps 100 Gbps
NTFN - National Time and Frequency Network

• Dissemination of time and frequency via optical fibre
  • Use of existing data networks
  • Need bi-directional amplifiers – special equipment
  • Using AARNet research network

• NTFN collaboration project
  • Funded via government research grants
  • Basic research/development underway
  • Astronomical testing by VLBI observations
    • On CSIRO network between Mopra and ATCA

• Research important for SKA – participation in SKA developments
  • Work-package involvement
e-VLBI

- Continue developments in LBA & Internationally
  - Already part of operational VLBI
  - Up to 1 Gbps

- 10 Gbps connection Parkes – ATCA established
  - Planning eVLBI tests at high data rates (8 Gbps)
  - Need new DAS system(s) to provide data streams

- 10 Gbps astronomy connectivity across Australia
  - Network development underway
  - Need access to HPC – Pawsey computers in Perth

- NEXPReS involvement
  - Bandwidth-on-demand & Distributed correlation
Summary

• The LBA is the main extensive VLBI network in the South
  • Open access; eVLBI capabilities
• Augmented imaging capabilities from new antennas
  • Up to 11 telescopes at some bands
  • Future tied-arrays for sensitivity
• Developments to wide-band (2 GHz BW) and GigE recording
  • ATCA CABB system in active development
  • Xcube recorders for multiple 10 GigE capability
  • Xcube DAS under testing
• DiFX software correlator adopted -
  • Mixed BW correlation
  • Supports many input formats – no compatibility issues
• High speed fibre networks in construction
• Research in time and frequency distribution over fibre
Thank you

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