

e-VLBI Progress in Australia

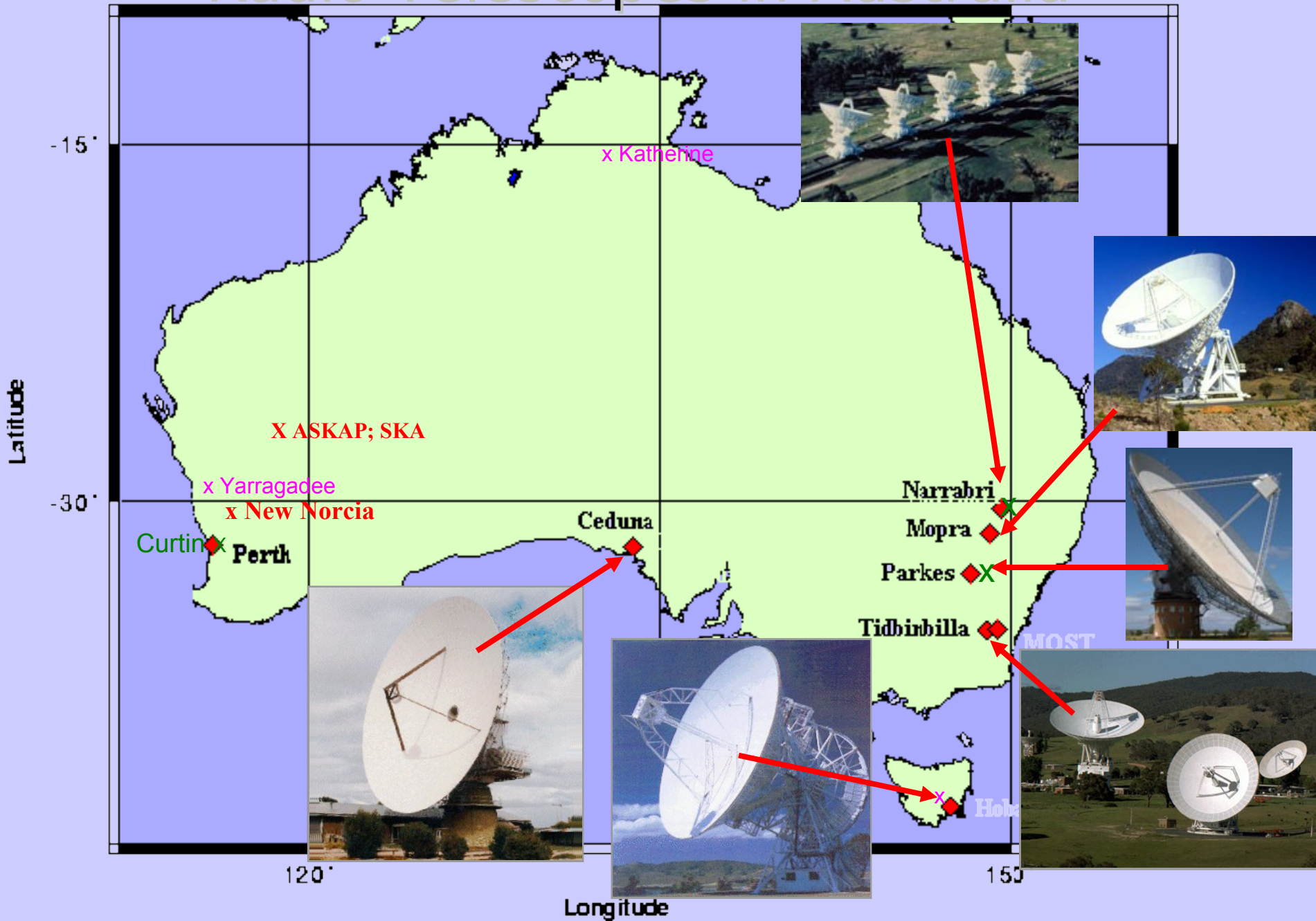
CSIRO ATNF
Tasso Tzioumis, June 2009



Overview

- The LBA
 - Overview of network
 - Brief history
 - Transitions in last 5 years
 - e-VLBI history
 - EXPReS
 - Oz and Asia-Pacific
 - e-VLBI status
 - Plans for the future
-
- *(Technical details in talks by C. Phillips & S. Amy*
 - *Also other approaches by R. Dodson & M. Rioja)*

Radio Telescopes in Australia



Long Baseline Array (LBA)

- Telescopes in Australia /Asia-Pacific / Southern hemisphere
 - ATNF (ATCA, Mopra, Parkes); U.Tasmania (Hobart, Ceduna)
 - NASA (Tidbinbilla)
 - + NZ ; AuScope; New Norcia (ESA); ASKAP
 - + South Africa (9000 km baselines) ????? (+ South America!!)
 - + Telescopes in Asia Pacific: Japan, China, Hawaii, VLBA,...
- Frequency range: 1-22 GHz
- Disks (XRAIDs) & eVLBI - up to 1Gbps (4 x 64 MHz)
- Software correlator(s) - DiFX
 - Curtin University Supercomputer cluster
 - “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 usage statistics 2008

LBA allocated time	26 days (633 hrs)	
Scheduled proposal time	496 hrs	78%
Disk and network tests	82 hrs	13%
Setup and fringe checking	~55 hrs	9%
<i>e-VLBI (part of scheduled time)</i>	<i>~47 hrs</i>	<i>10%</i>

- e-VLBI part of National Facility – no restrictions
- e-VLBI percentage doubled from 2007 & growing
- Niche instrument – proposals accepted for new projects

LBA history – recent transitions – 2004-05

- ~1994-2004:
 - S2 VCR based system and HW correlator
- 2004-2005:
 - First experiments with disks
 - PC-EVN/MRO system → LBADR
 - Huygens probe to Titan – JIVE collaboration
 - **Catalyst** for disk-recorder development
 - First “e-VLBI” from Oz?
 - Disks from observatories
 - Flown to Sydney by charter plane
 - Transferred Sydney-JIVE via network (Mbps)
 - ✂ → **Aggregate data-rate ~20 Mbps!!!**
 - Adopted Apple XRAID disk systems
 - First Swinburne software correlator
 - Real-time fringe system

LBA history – recent transitions - 2006

• Operations

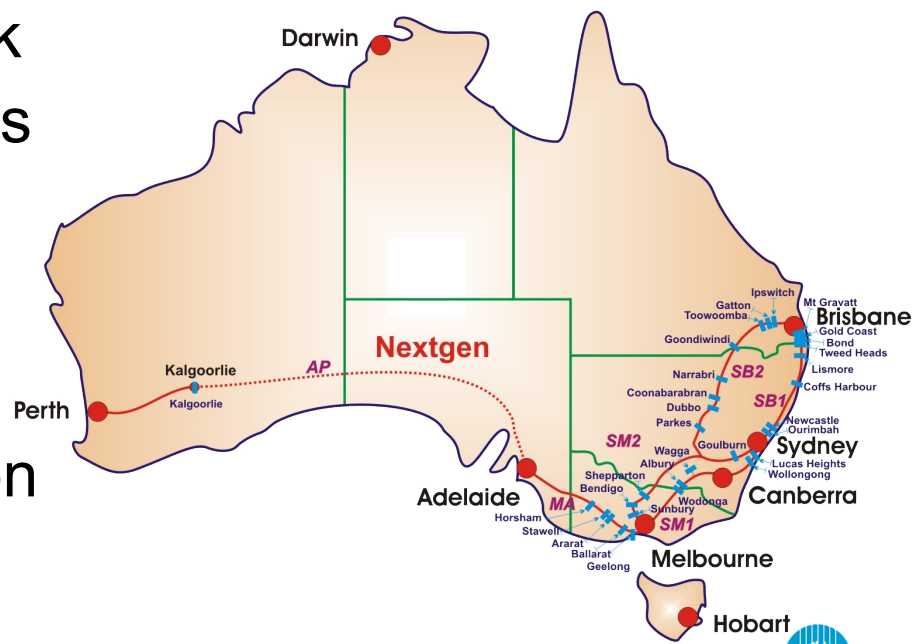
- New Swinburne software correlator → DiFX
- S2 system and HW correlator decommissioned!!
- Contract with Swinburne for all correlation!

• Networking / eVLBI

- AARNet3 Regional network
- Last-mile to ATNF antennas
- 2 x 1 Gbps (Ho 1 Gbps)

• EXPReS !!!

- **Catalyst** for e-VLBI in Oz
- ATNF-AARNet collaboration
- Much faster progress



LBA history – recent transitions - 2007

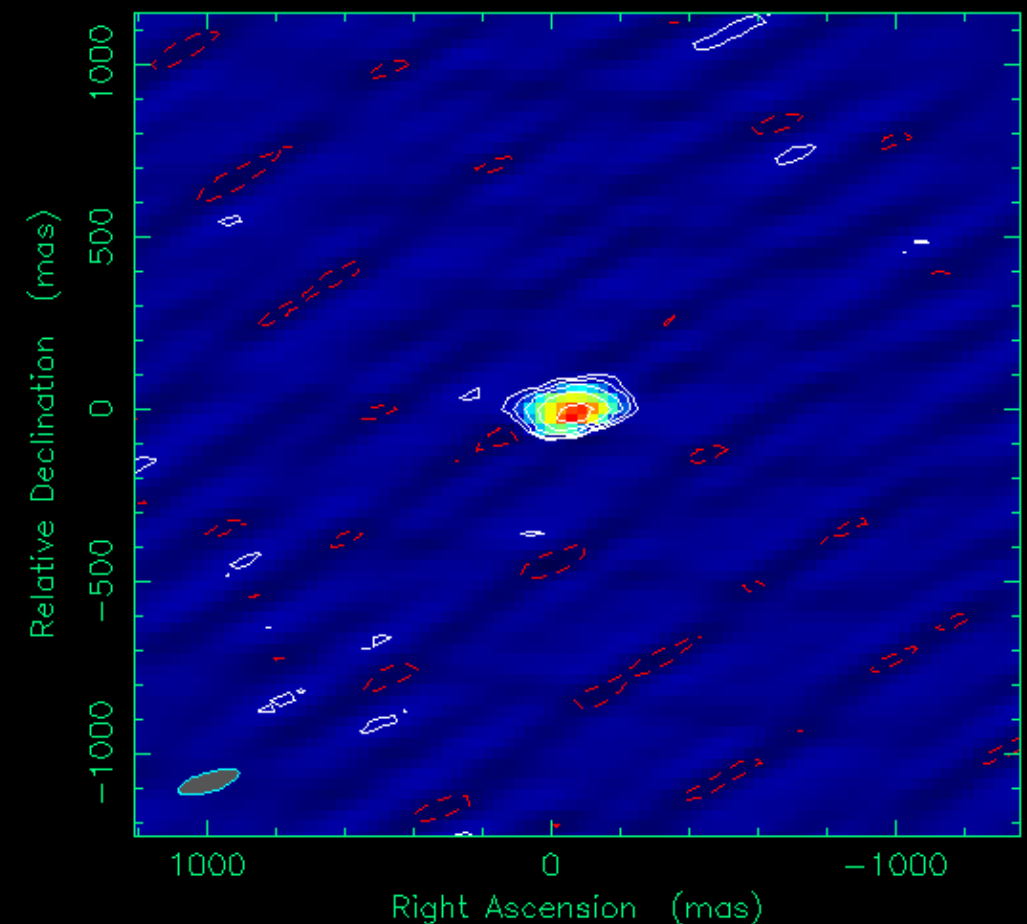
• Networking / eVLBI

- March 2007 – 1st Oz eVLBI
 - Parkes-ATCA-Mopra-(Hobart) → PAM(H)ELA
 - CPSR2 cluster (60 cores) with DiFX correlator
 - 3 x 256 Mbps (+ Ho @ 64-128 Mbps)
 - Cir X-1 image and paper!! (mnras)
- August 2007 – APAN EXPReS demo
 - Oz + Shanghai @ 256 Mbps
 - Wide publicity world-wide!!
- November 2007 – Oz EXPReS demo
 - ATNF → JIVE @ 512 Mbps for 12 hours
 - 3 lightpaths Oz-Europe – critical NREN role!
 - SN1987A image

• Operations

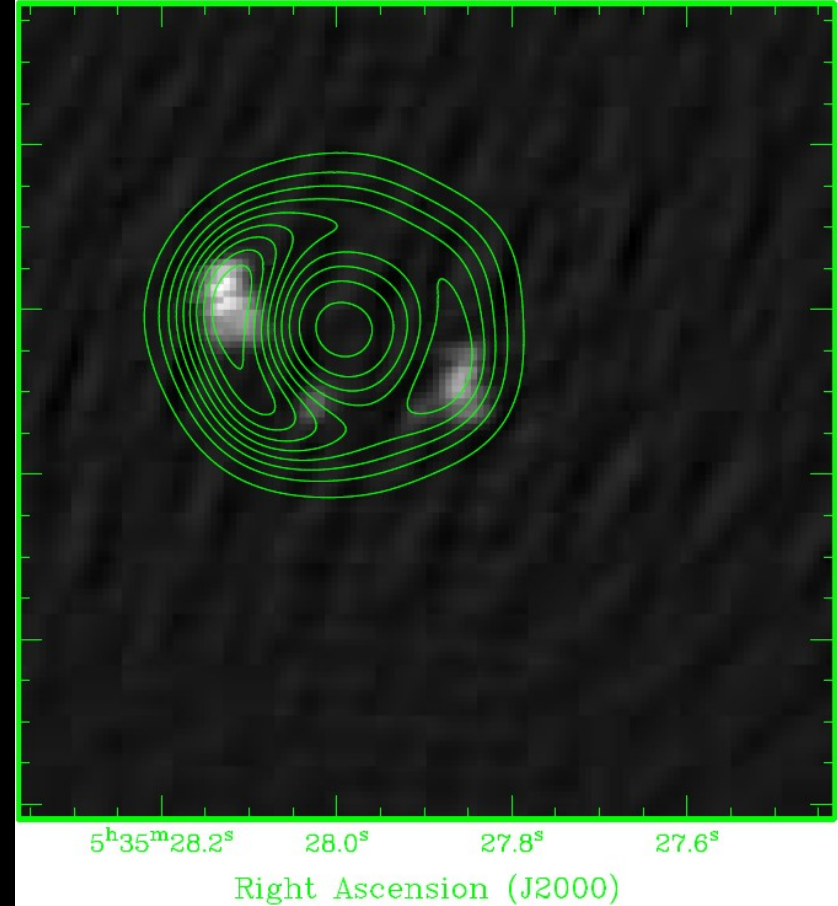
- Offering e-VLBI via LBA proposal system

e-VLBI Images with the LBA



*Circinus X-1, first Australian e-VLBI
(MNRAS, May 2007)*

SN1987A overlaid with sn1987a→10



SN1987A
*Contours ATCA 9 GHz super resolved
image (0.4" FWHM)*

LBA history – recent transitions – 2008-9

- Networking / eVLBI:
- June 2008
 - DiFX on APSR (18 node, dual-processor quad-core)
 - Shanghai eVLBI demonstration
 - 5 x 512 Mbps Pk-At-Mp-Sh-Ks
- March 2009
 - 3 x 1024 Mbps demonstration (+ 128 Mbps Hobart)
 - e-VLBI on Curtin cluster in Perth (CUPPA)
 - 3.2 Gbps sustained across Australia
 - Wide publicity and political support
- IYA international demos – Jan and Apr 09
- Operations
 - No disk shipments from most antennas in 2009
 - Transfers via Australian Research Collaboration Service (ARCS)
 - Intermediate storage in Petabyte store

Current e-VLBI developments

- **CAVE cluster at ATCA (14 nodes)**
 - Installed in 2008; commissioned June 2009
 - Another DiFX e-VLBI correlator
 - → Distributed eVLBI correlation
 - Utilize fibre links in both directions?
- **Parallel e-VLBI & disk-recording demo (June '09)**
 - Quick-look at data e.g. transients
 - Include stations with no eVLBI connections in imaging
 - Will offer to users next round of proposals
- **e-VLBI scheduled observations of Cir X-1 (July'09)**
 - Follow X-ray binary over $>1 \times 16.5$ day orbits
 - 3 hrs of e-VLBI over 3 weeks (9 observations)
- **ToO e-VLBI of Fermi source (JIVE correlation)**
 - 3 scheduled runs May-July 09

Future Oz e-VLBI developments

- **ATNF eVLBI project**

- Funded for next 5 years @ ~ €100k/year
- New developments only
- LBA operation in National Facility Operations

- **ICRAR projects at Western Australia**

- International Centre for Radio Astronomy Research
- Curtin University of Technology & University of Western Australia
- Independent government funding
- Strong VLBI/eVLBI projects

- **Strategic SKA development**

- Support of SKA Pathfinder(s)
- ASKAP proposal

✂ → **Strong support for e-VLBI**

Near Future: CABB – Compact Array Broadband Backend

- ATCA Upgrade: 2 x 2 GHz dual polarisation IFs
 - 160 Gbps/antenna
 - 960 Gbps total
 - 2 Tbps processed - in 2x 12U chassis
- FPGA polyphase filterbank design
- Commissioned April 2009 !! **Operating now!!**
- Usable for VLBI for up to 2 GHz, dual polarisation
 - 16 Gbps of user data/antenna (2 GHz x 2 pol @ 2-bits)
 - Generate up to 80 Gbps!
- Up to 7 Australian sites connecting at these rates

Oz e-VLBI developments -2009-10

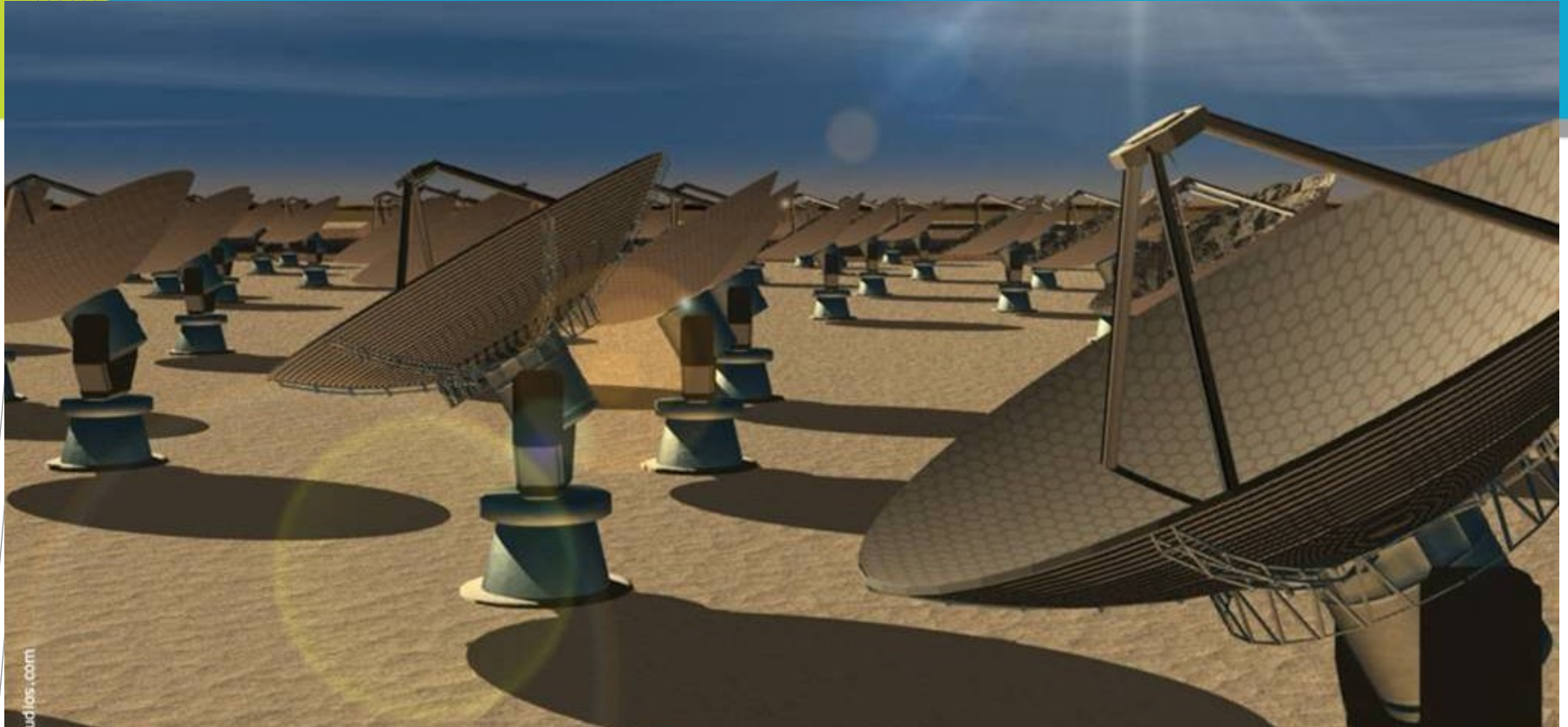
• Technical

- Broadband DBE
 - CABB at ATCA
 - DFB3 at Parkes (& Mopra)
- Broadbanding Receivers
 - ATCA done
 - Parkes (and Mopra) underway
 - Other Oz antennas - new funding needed
- 10 Gbps e-VLBI – planned with AARnet
 - Initially Parkes-ATCA
- CABB as an e-VLBI h/w correlator – demo
- More e-VLBI demos – national + international
 - Asia-Pacific; NZ; Brazil; India;

• Operational

- Implement parallel e-VLBI & disk-recording operation
- Distributed e-VLBI correlation by DiFX

ASKAP

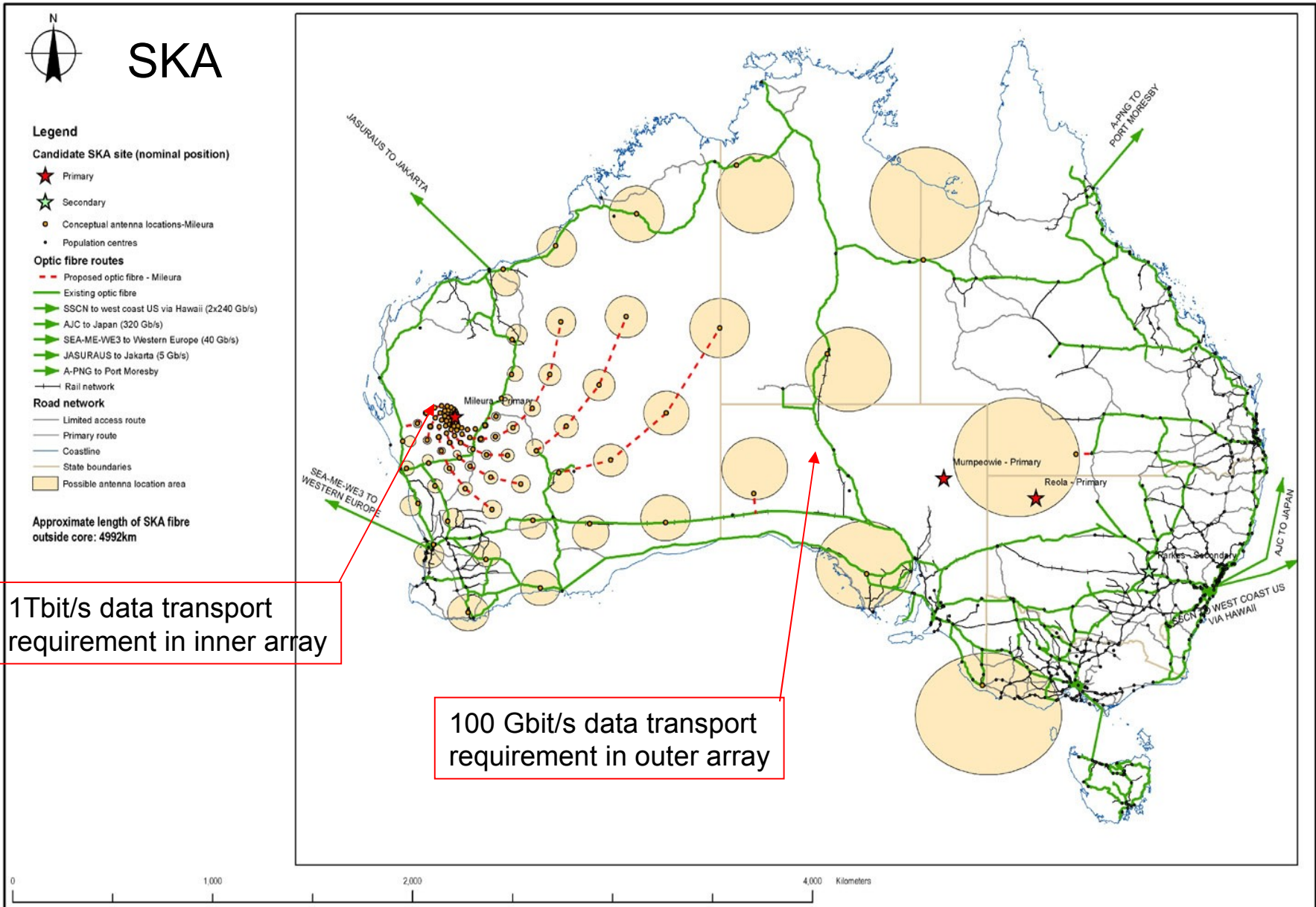


Number dishes	36
Dish diameter	12 m
Max baseline	6 km
Frequency	700 – 1800 MHz
FOV	30 deg²
Bandwidth	300 MHz
Resolution	5 kHz
Channels	16k
PAF	2 x 96 elmts

Oz e-VLBI developments - 2010-13

- **e-VLBI with and in support of ASKAP**
 - Recent EoI proposals for ASKAP survey science
 - ~30% of proposals ask for VLBI follow-up
 - e-VLBI ASKAP proposal also submitted
 - Possible VLBI with multiple beams
 - Cluster-cluster VLBI (Rioja)
 - ASKAP fibre build within next 12 months
 - ASKAP e-VLBI demo by end 2010?
- **Grow and implement user e-VLBI network**
 - Involve all current and developing facilities
- **National Broadband Network (NBN)**
 - Government funded national infrastructure (\$43B)
 - NREN access for Science?...

Future: SKA - an e-VLBI array!!



Rev	Date	Revision Details	By	Chk	App

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Project
SQUARE KILOMETRE ARRAY

Drawn	AD	Signed	Date	Title
Surveyed		Signed	Date	
Checked		Signed	Date	
Approved By		Signed	Date	

MILEURA SITE AUSTRALIA WIDE CONCEPTUAL POSITIONS

Date: 12/05/2003
 Scale: 1:16,000,000
 Job No: 59963_05
 Drawn: []
 Rev: []

FIG F-1

The Oz e-VLBI team

- **ATNF – LBA as National Facility**
 - ATNF telescopes & correlators (Parkes; Mopra; Narrabri)
 - Chris Phillips – technical developments
 - Shaun Amy – network developments
- **AARNet – the Australian NREN ****critical******
- **University of Tasmania**
 - Hobart & Ceduna + AuScope
- **Steven Tingay and his team(s)**
 - Started at Swinburne → DiFX software correlator (Deller)
 - Now at Curtin, Perth
 - Contract for all disk correlation + improved LBA Ops
 - e-VLBI on Curtin cluster already demonstrated
- **New participants @ UWA (Dodson; Rioja)**
- **ICRAR – both Curtin and UWA – new funding**
 - **** Host for eVLBI10 workshop next year ****

ATNF

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Thank you

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