LambdaGammaBI – looking up from down under

Phil Edwards | Head of Science Operations

20 April 2015

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Credit to Leonid Gurvits for suggesting this title…

ΛΓBI — looking up from down under

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…which may be more comprehensible in this format!

Dutch & EU Ambassadors visit to MRO

Earlier this month …

Overview

The LBA – facts and figures

Who's who?

History of development

High impact results

More recent results

Most recent observations

Observing time by year and observing band

Recent developments

Future prospects

The Long Baseline Array (LBA)

Operated as a National Facility by ATNF (which is part of CSIRO Astronomy & Space Science), in close cooperation with the University of Tasmania, Curtin University, and Auckland University of Technology

Core elements: ATCA (5x22m), Mopra (22m), Parkes (64m), Ceduna (30m), Hobart (26m)

+ Tidbinbilla (70m & 34m), Warkworth (12m & 30m), Hartebeesthoek (26m & 15m), ASKAP (12m), AuScope (3x12m), TIGO (6m), O'Higgins (9m), Shanghai (25m), …

Typically ~25 days observing each year in 3~4 sessions

Baseline lengths in km

	Pa	At	Mp	Ho	Cd	Hh	Yg	Ke	Ak	Ww	Ti
Pa	0	322	207	1089	1361	9665	3128	2610	3091	2425	274
At	322	0	114	1396	1508	9847	3266	2493	3202	2409	566
Mp	207	114	0	1286	1448	9783	3213	2530	3159	2411	458
Ho	1089	1396	1286	0	1702	9167	3211	3431	3273	2415	832
Cd	1361	1508	1448	1702	0	8944	1792	1937	1756	3718	1455
Hh	9665	9847	9783	9167	8944	0	7848	9504	8019	10480	9589
Yg	3128	3266	3213	3211	1792	7848	0	2360	290	5362	3196
Ke	2610	2493	2530	3431	1937	9504	2360	0	2102	4752	2849
Ak	3091	3202	3159	3273	1756	8019	290	2102	0	5360	3184
Ww	2425	2409	2411	2415	3718	10480	5362	4752	5360	0	2301
Ti	274	566	458	832	1455	9589	3196	2849	3184	2301	0

The Long Baseline Array (LBA)

Observations in 20, 13, 6, 3, 1cm bands

- (Not all telescopes support all bands)

Disk-based recorders (with most data later streamed to the correlator) or/and eVLBI on a subset of the array

LBA DR, Mk5, COTS ("Bruce DAS") systems

Max. bit-rate 1Gbps

LBA reliability greatly enhanced by real-time fringe checks

Data correlated by Curtin Uni on DiFX software correlator

- Deller et al. 2007, PASP, 119, 318 (DiFX)
- Deller et al. 2011, PASP, 123, 275 (DiFX-2)

Locations & SEFDs (in Jy) of LBA elements

		Lat.	Long.	20cm	13cm	6cm	3cm	1.5cm	9mm
ATCA	5x22m	150 E	30 S	40	40	36	39	106	180
ASKAP	1x12m	117 E	26 S	6000	--	--	3500	--	--
Ceduna	30m	134 E	32 S	1500	400	450	600	2500	--
Hobart	26m	147 E	43 S	450	650	650	560	1800	--
Hart	26m	28 E	26 S	200	210	290	340	1320	--
Mopra	22m	149 E	31 S	340	530	350	430	675	900
Parkes	64m	148 E	33 S	40	30	110	43	810	--
Tid	70m	149 E	35 S	23	16	--	25	60	--
Tid	34m	149 E	35 S	--	165	--	90	--	180
Warkworth	12m	175 E	37 S	7000	3500	--	3500	--	--

Who's who? An incomplete list…

Chris Phillips	LBA Lead Scientist
Phil Edwards	Scheduler
Tasso Tzioumis	Assistant Director
John Reynolds	ASKAP Systems Scientist
Jamie Stevens	ATCA Systems Scientist
Shinji Horiuchi	Tidbinbilla
Steven Tingay, Cormac Reynolds, Hayley Bignall, …	Curtin Uni
Simon Ellingsen, Jim Lovell, Jamie McCallum, …	U. of Tasmania
Richard Dodson, Maria Rioja	UWA
Sergei Gulyaev, Tim Natusch, Stuart Weston…	Auckland UT
Jonathan Quick, …	Hart

History of Development

Late 1960s, 1970s	First VLBI with Tidbinbilla, Parkes
1980s	SHEVE, PTI
Nov 1988	First VLBI with ATCA single dish
Nov 1991	First VLBI with Mopra
1995	S2 recorders replace MKII
1996	Full ATCA Tied array
1997	Hydrogen Masers installed, First VLBI with Ceduna
Oct 2005	Disk based LBADR recorders replace S2
March 2006	First 1 Gbps VLBI recording
Aug 2006	First eVLBI fringes
October 2007	SN1987A eVLBI observations, EXPReS participation
2010	First VLBI with ASKAP (single dish) & Warkworth
2014	First VLBI demonstration with an ASKAP PAF
2015	Development of 8 Gbps Xcube recorders

October 2007: SNR 1987a eVLBI

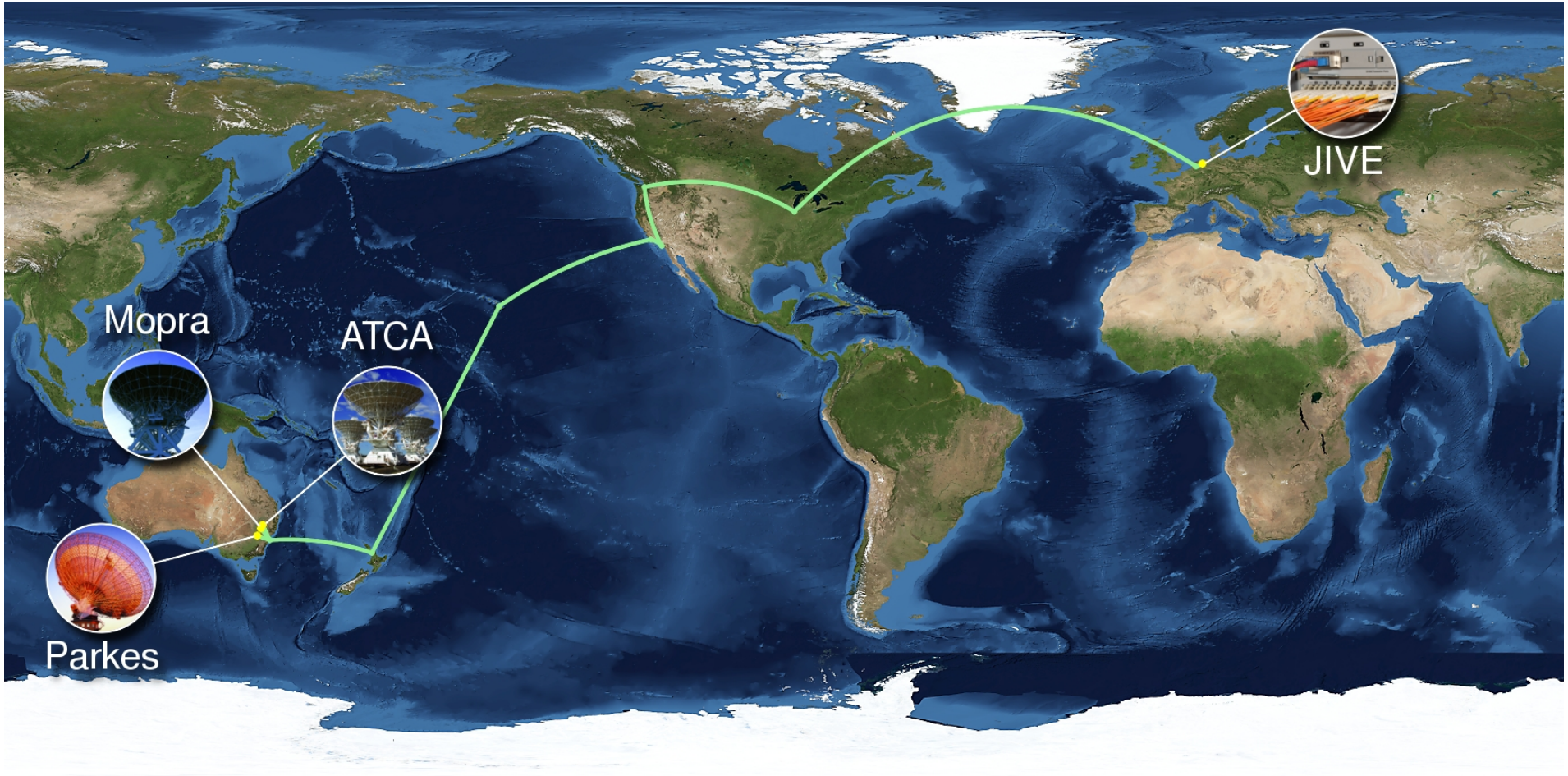


Image created by Paul Boven. Satellite image: Blue Marble Next Generation, courtesy of NASA Visible Earth

High impact results – a top 10

Relativistic motion in a nearby bright X-ray source	(1995)
A Warped Accretion Disk and Wide-Angle Outflow in the Inner Parsec of the Circinus Galaxy	(2003)
Chandra Discovery of a 100 kiloparsec X-Ray Jet in PKS 0637-752	(2000)
A Radio Reference Frame	(1995)
Overview and Initial Results of the VLBI Space Observatory Programme	(1998)
The Subparsec-Scale Structure and Evolution of Centaurus A…	(1998)
The Vela Pulsar's Proper Motion and Parallax Derived from VLBI Observations	(2003)
Parsec-scale Radio Cores in Early Type Galaxies	(1994)
DiFX: A Software Correlator for VLBI Using Multiprocessor Computing Environments	(2007)
Methanol Masers as Tracers of Circumstellar Disks	(1998)

GRO J1655-40 Superluminal motion

Relativistic motion in a nearby bright X-ray source

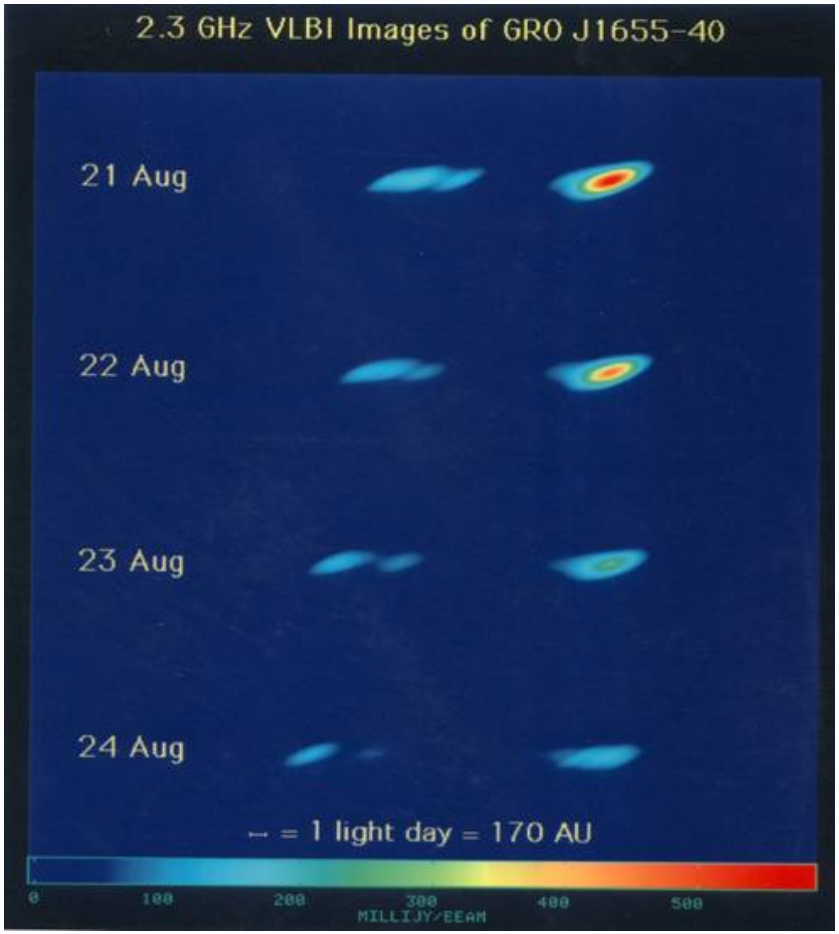
S. J. Tingay*†, D. L. Jauncey‡, R. A. Preston†, J. E. Reynolds‡, D. L. Meier†, D. W. Murphy†, A. K. Tzioumis‡, D. J. McKay‡, M. J. Kesteven‡, J. E. J. Lovell§, D. Campbell-Wilson#, S. P. Ellingsen§, R. Gough‡, R. W. Hunstead#, D. L. Jones†, P. M. McCulloch§, V. Migenes‡, J. Quick‖, M. W. Sinclair‡ & D. Smits‖


THE AUSTRALIAN

SPACE BLAST

BLACK HOLE EATS STAR

FRIDAY AUGUST 19 1994 Printed and published by Nationwide News at Muir Rd, Chullora, 2190



Centaurus A

THE ASTRONOMICAL JOURNAL, 115:960–974, 1998 March

THE SUBPARSEC-SCALE STRUCTURE AND EVOLUTION OF CENTAURUS A: THE NEAREST ACTIVE RADIO GALAXY

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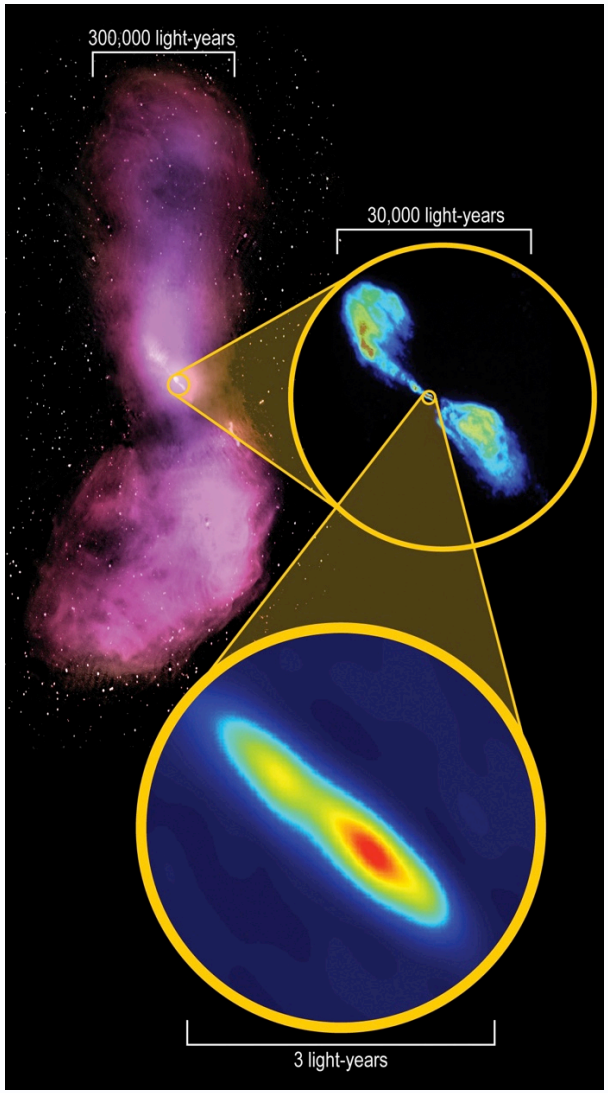
Received 1997 October 15; revised 1997 December 1

ABSTRACT

We present high-resolution VLBI radio images of the closest classical radio galaxy, Centaurus A, including the highest resolution image yet for this source. The images were made from data obtained over a period of approximately 8 yr at the frequencies of 2.3, 4.8, and 8.4 GHz with the Southern Hemisphere VLBI Experiment (SHEVE) array and at 2.3, 8.4, and 22.2 GHz with the Very Long Baseline Array. We give complete details of the data reduction and analysis procedures.



Vela Proper motion

THE ASTROPHYSICAL JOURNAL, 596:1137–1141, 2003 October 20

THE VELA PULSAR'S PROPER MOTION AND PARALLAX DERIVED FROM VLBI OBSERVATIONS

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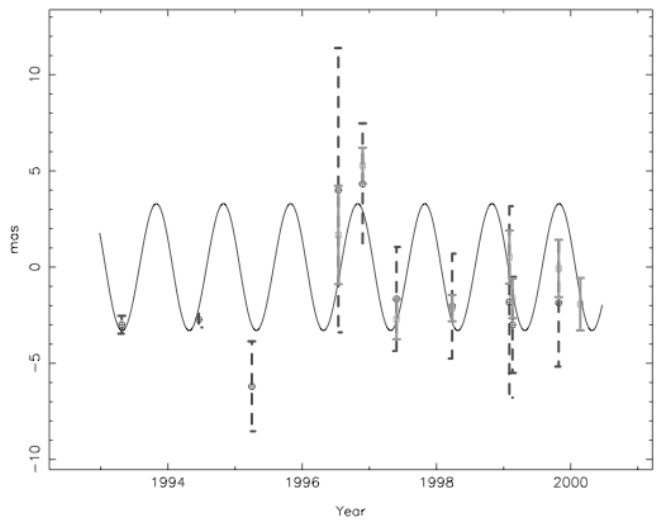
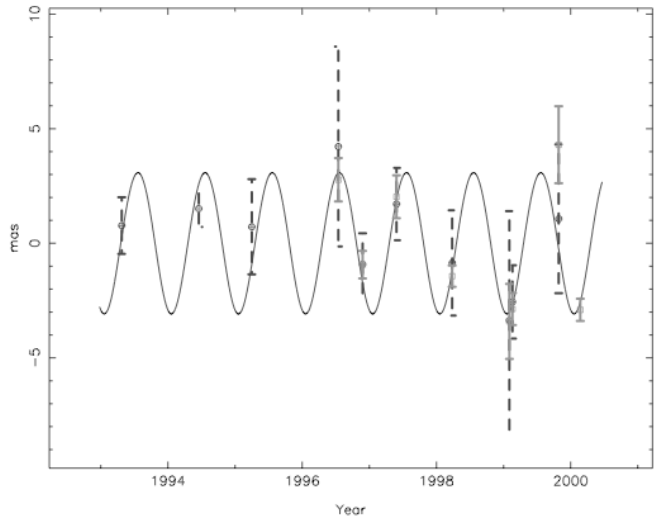
Received 2003 March 16; accepted 2003 June 21

ABSTRACT

The Vela pulsar is the brightest pulsar at radio wavelengths. It was the object that told us (via its glitching) that pulsars were solid rotating bodies not oscillating ones. Along with the Crab pulsar, is it the source of many of the models of pulsar behavior. Therefore it is of vital importance to know how far away it is and its origin. The proper motion and parallax for the Vela pulsar have been derived from 2.3 and 8.4 GHz very long baseline interferometry (VLBI) observations. The data span 6.8 years and consist of 11 epochs. We find a proper motion of $\mu_{\alpha\cos\delta} = -49.68 \pm 0.06$, $\mu_\delta = 29.9 \pm 0.1$ mas yr^{-1} and a parallax of 3.5 ± 0.2 mas, which is equivalent to a distance of 287^{+19}_{-17} pc. When we subtract out the Galactic rotation and solar peculiar velocity, we find $\mu_* = 45 \pm 1.3$ mas yr^{-1} with a position angle of $301° \pm 1.°8$ which implies that the proper motion has a small but significant offset from the X-ray nebula's symmetry axis.

Subject headings: astrometry — pulsars: individual (Vela pulsar) — stars: neutron — techniques: high angular resolution





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'No signal' from targeted ET hunt

Very long baseline interferometry results in an effective antenna of many kilometres in size

The hunt for other intelligent civilisations has a new technique in its arsenal, but its first use has turned up no signs of alien broadcasts.

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Rampadarath et al. 2012 AJ 144, 38

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Recent LBA publications

"Dynamical masses of the low-mass stellar binary AB Doradus B"
Azulay et al., 2015, A&A in press (arXiv:1504.02766)

"First Parallax Measurements Towards a 6.7 GHz Methanol Maser with the Australian Long Baseline Array - Distance to G339.884-1.259"
Krishnan et al., 2015, ApJ, in press (arXiv:1503.05917)

"New Associations of Gamma-Ray Sources from the Fermi Second Source Catalog"
Schinzel et al., 2015, ApJS, 217:4

"TANAMI monitoring of Cen A: The complex dynamics in the inner parsec of an extragalactic jet" Müller et al., 2014, A&A, 569, A115

"Unusual flaring activity in the blazar PKS 1424-418 during 2008-2011"
Buson et al., 2014, A&A, 569, A40

"TANAMI blazars in the IceCube PeV neutrino fields" Krauss et al., 2014, A&A, 566, L7

"The unusual multiwavelength properties of the gamma-ray source PMN J1603-4904"
Müller et al., 2014, A&A, 562, A4

"Multi-epoch VLBI Observations of the Nuclear Starburst Region of NGC 253: Improved Modeling of the Supernova and Star formation Rates" Rampadarath et al., 2014, AJ, 147, 5

Programs in the last (Mar/Apr 2015) session

Assessing the origin of the radio emission in Radio Quiet AGNs (Maini)

RadioAstron AGN Survey (Reynolds/Kovalev)

6.7GHz Maser Parallax of an Interesting High Mass Star Forming Region (Burns)

Astrometry of 6.7 GHz methanol masers (Sugiyama)

Methanol Masers: Galactic Structure and High-Mass star formation (Ellingsen)

LBA Imaging of Supernova 1978K in NGC 1313 (Ryder)

Mapping the orbit of PSR B1259-63 with LBA astrometry (Miller-Jones)

Physics of Gamma Ray Emitting AGN (Ojha)

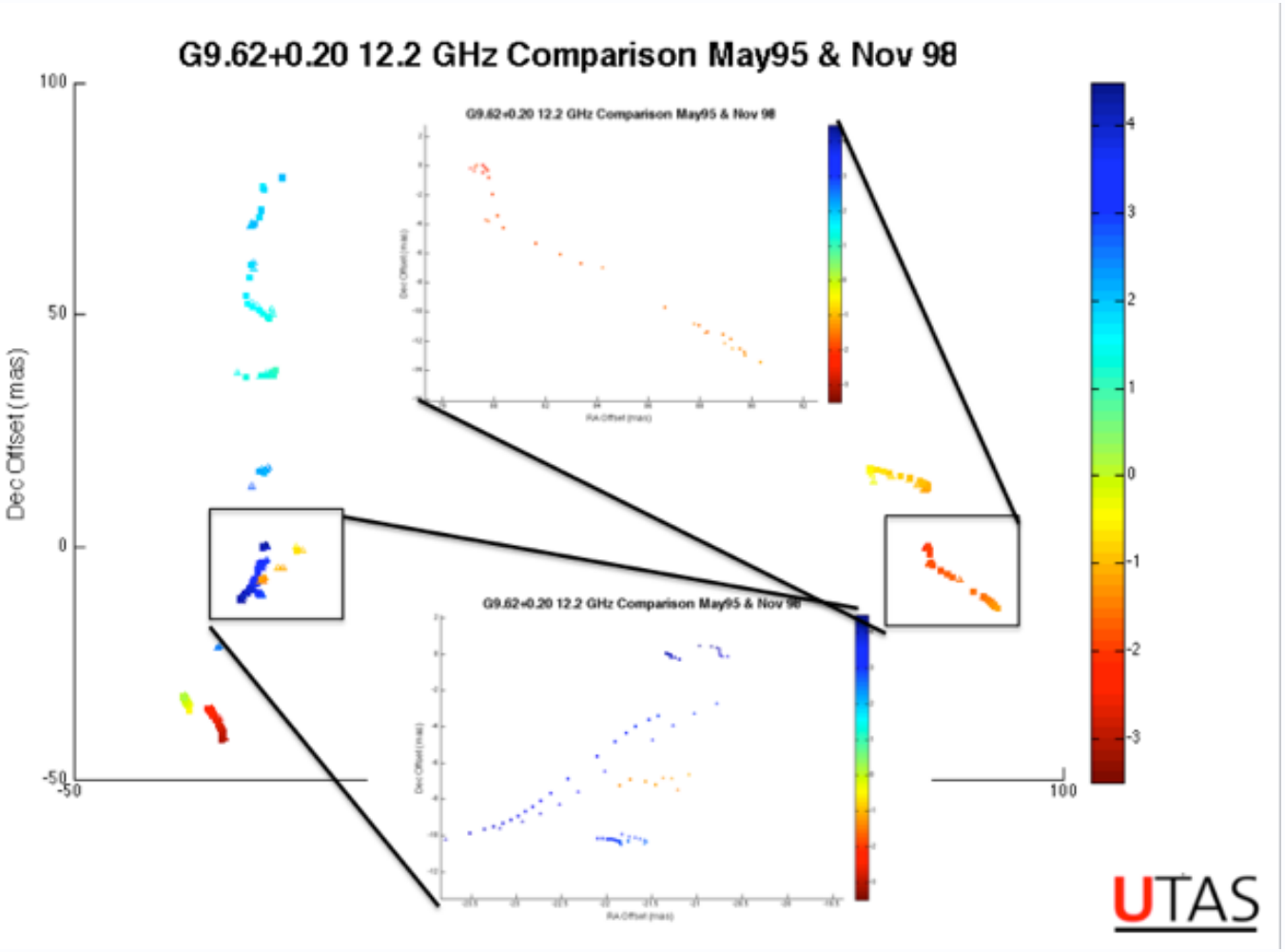
Accurate Alignment of the VLBI Frame and the Future Gaia Frame (de Witt)

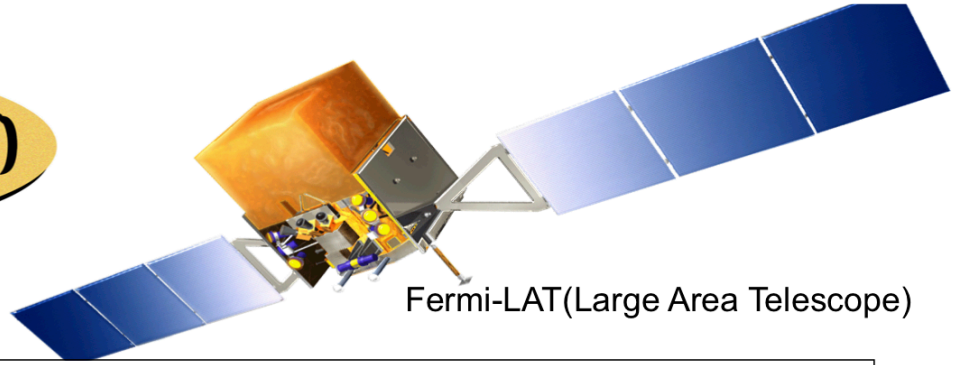
LBA Calibrator Survey 7 (Petrov)

32 GHz Celestial Reference Frame Survey for Dec < -45 deg. (Horiuchi)

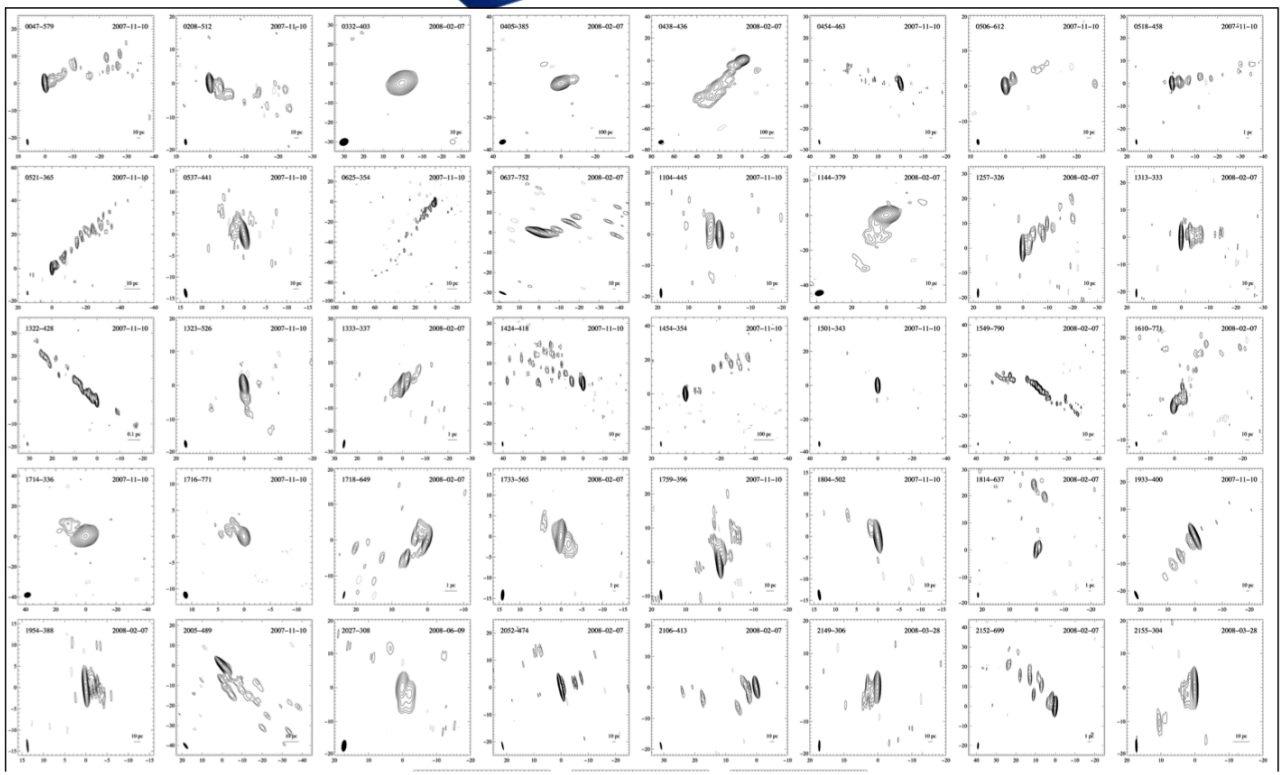
M87 jet at ~10Rs from the black hole with micro-arcsecond astrometry (Dodson)

Methanol Maser Astrometric Parallax



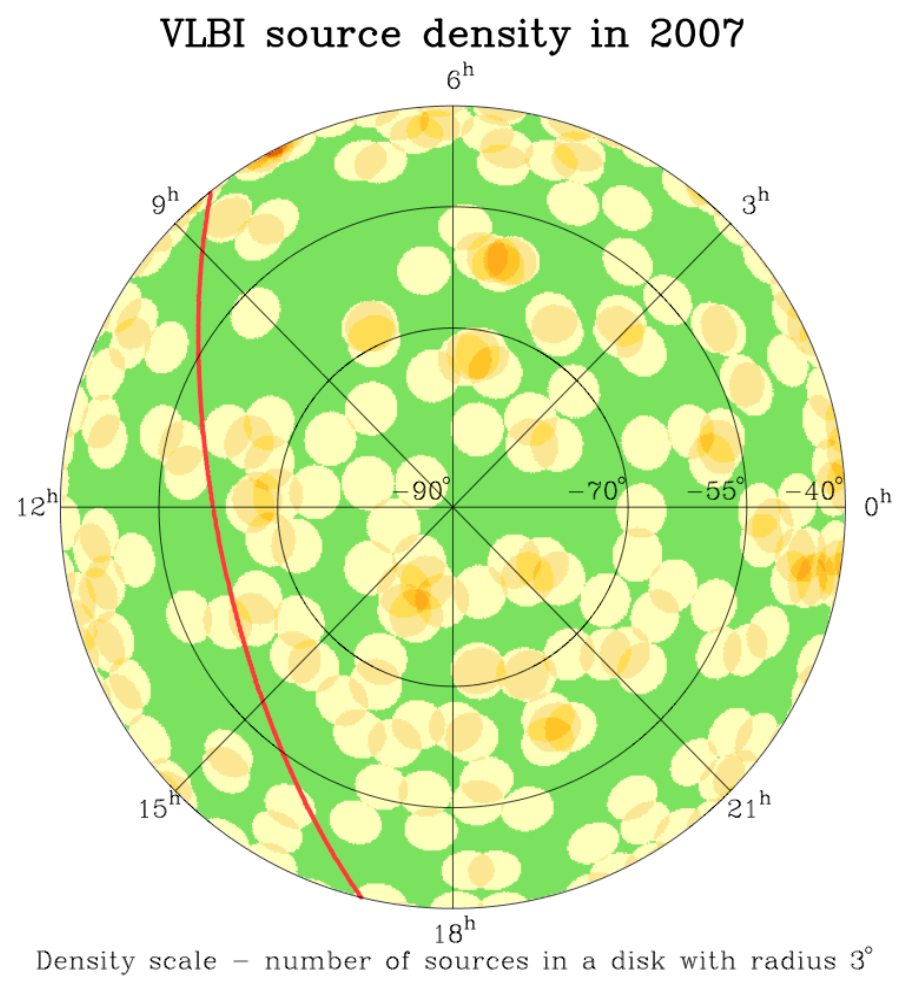


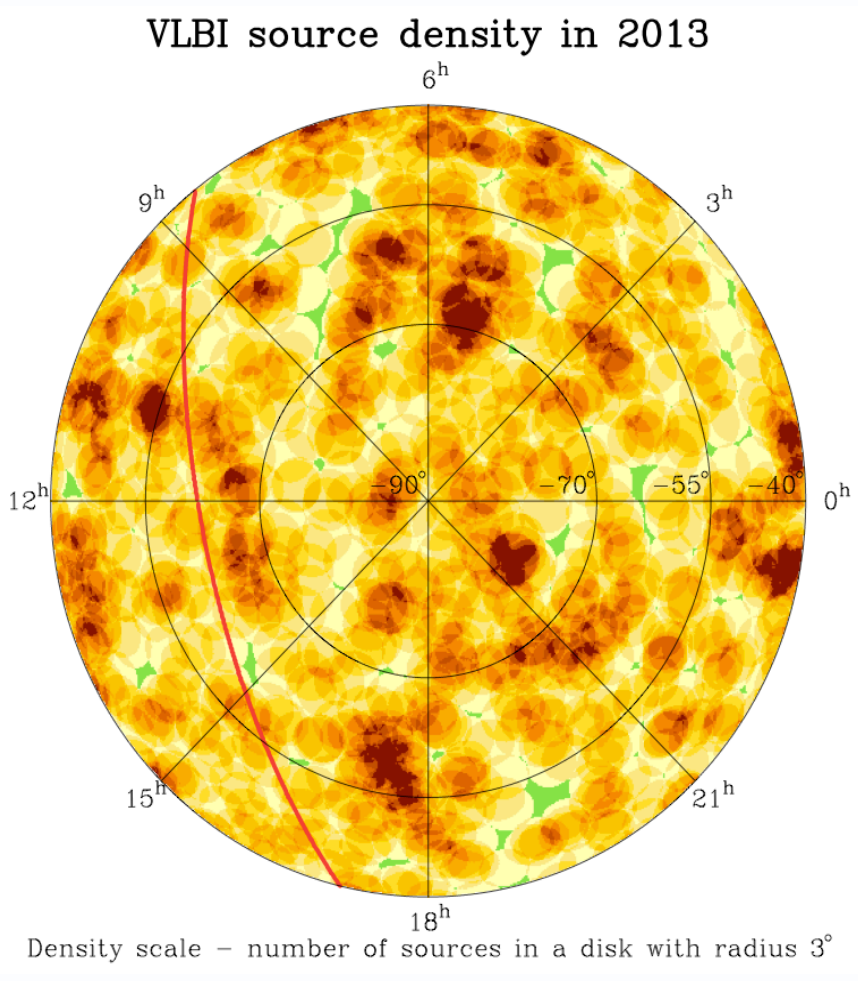
Fermi-LAT(Large Area Telescope)



Ojha et al. 2010 A&A, 519, A45

LBA Calibrator Survey





Petrov et al. 2011 MNRAS, 414, 2528

http://astrogeo.org/lcs/

Observing time (in hrs) by year and band

	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
20cm	36	37	107	142	58	65	44	20	84	64	223
13cm	64	44	54	91	51	11	37	70	75	0	0
6cm	22	60	42	14	65	95	88	72	31	114	48
3cm	98	192	127	99	226	168	290	247	148	210	91
1.5cm	24	0	12	21	105	57	60	54	113	82	106
9mm	0	0	0	0	0	0	0	0	4	3	11
total	244	333	341	366	505	396	519	463	445	473	490

Recent developments

Fewer receiver changes at Parkes

Routine L-band at Ceduna

Mopra bushfire recovery

Reliable 32 GHz fringes ATCA/Mopra/Tid-34m

ATCA split array capability: 7mm/3mm obs with KVN

Ongoing RadioAstron participation

Fringes demonstrated with ASKAP PAF data

Warkworth 30m first fringes

New Tidbinbilla 34 m antenna commissioned (DSS-35), another under construction (DSS-36)

Tidbinbilla DSS-35 “photobombing”

Ceduna L-band capability

Mopra bushfire, January 2013

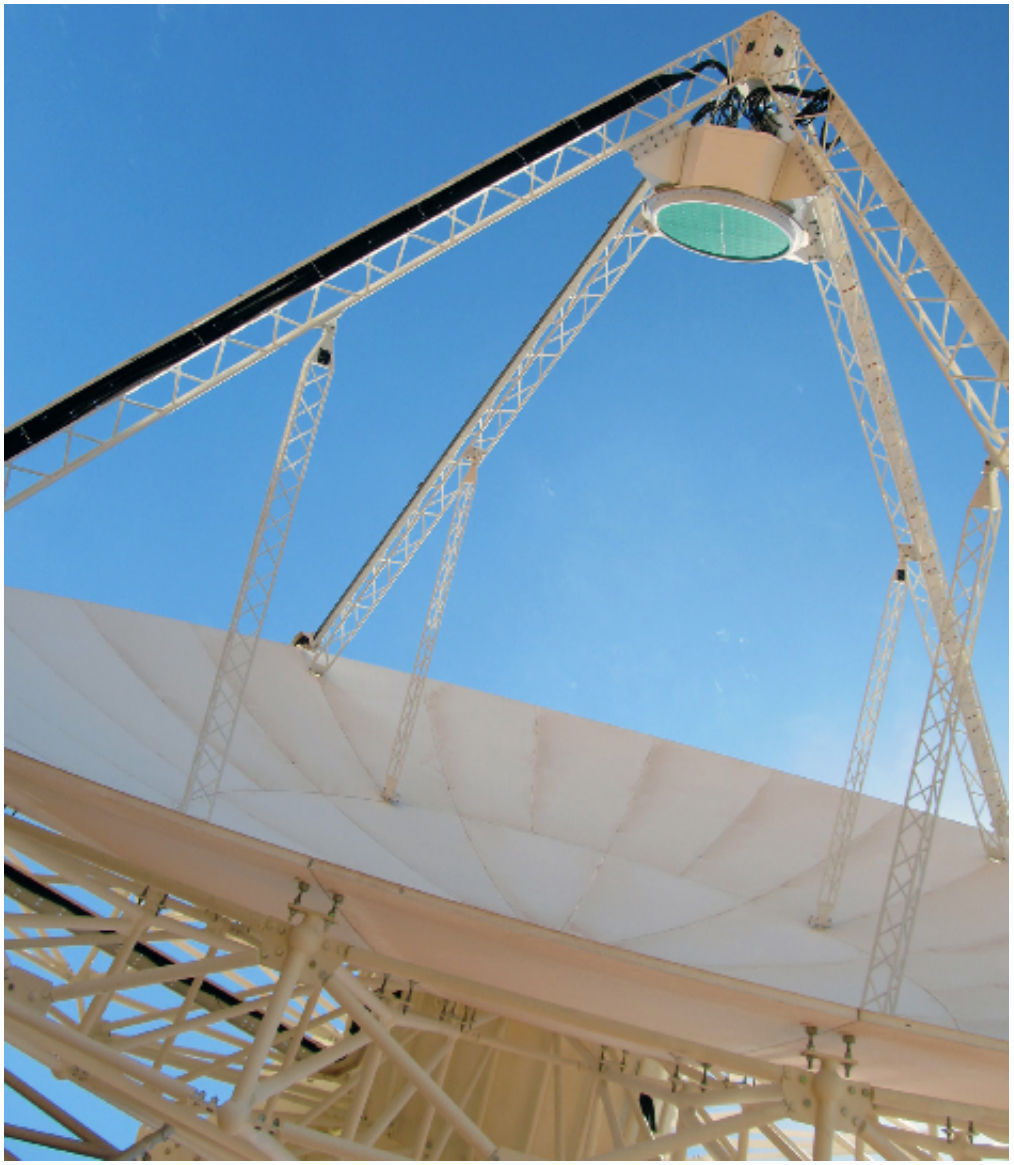
ASKAP

Mk I PAFs on 6 antennas

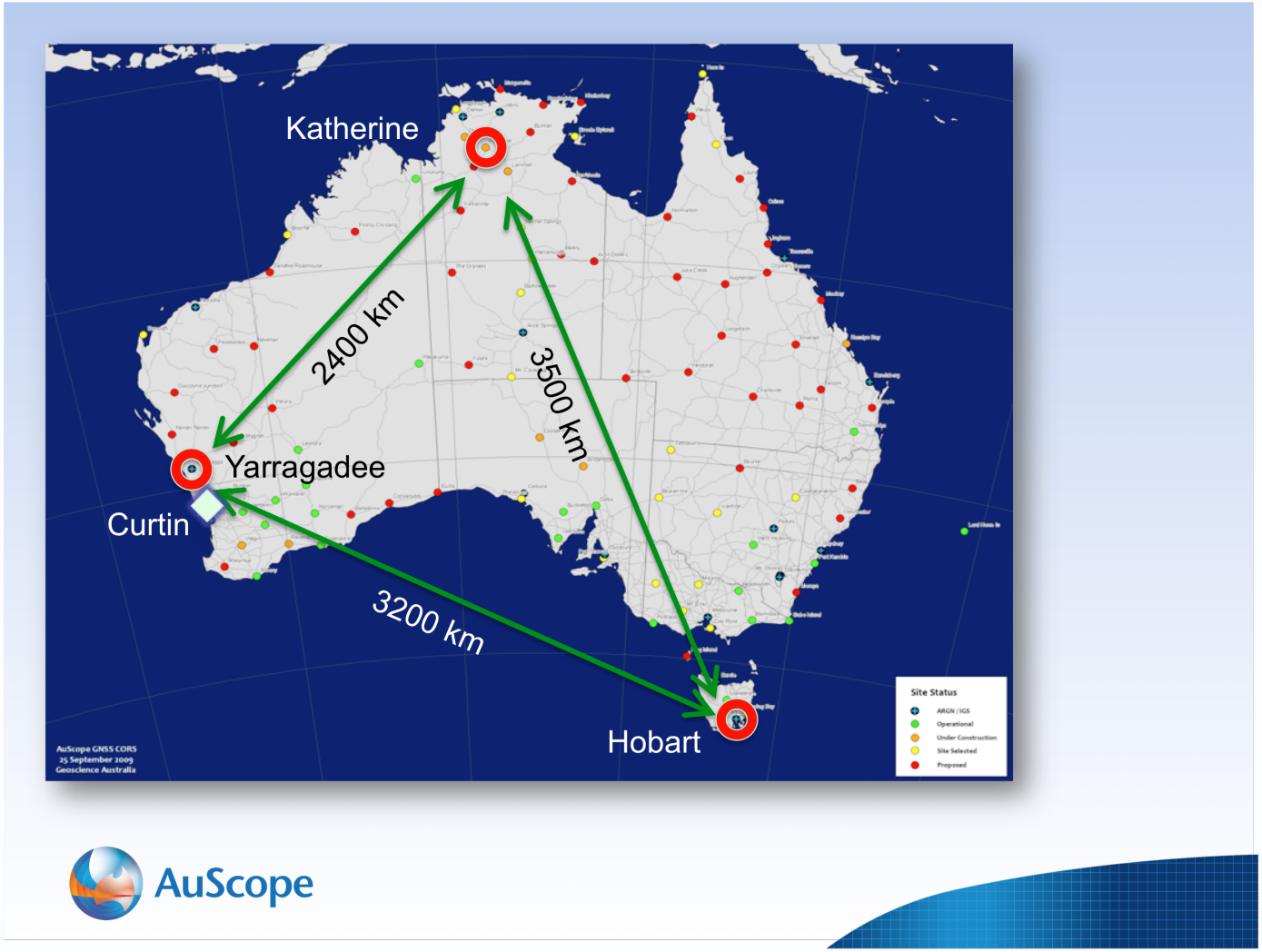
Roll-out of first Mk II PAFs about to commence

One antenna with L-band single pixel feed, and another with X-band single pixel feed, for VLBI

Tzioumis et al. 2010 AJ
Petrov et al. 2011 PASA



AuScope (operated by Uni. of Tasmania)



3 x 12m S/X geodetic array: Lovell et al. 2013, J. Geodesy, 87, 527

Warkworth

First light with 12m S/X antenna in 2010

Handover of ex-telecommunications 30m dish to AUT in 2010

First light with 30m at 6.7 GHz in 2014
(Petrov et al. arXiv:1502.06802)

First light with 30m at 8.4 GHz in March 2015

Future prospects

Fewer receiver changes at Parkes

- 0.7 – 4.0 GHz UWB receiver funded
- improved access to Tid 70m time(?)

Mopra future uncertain

Contract with Curtin U. for correlation to end in Sep 2015

Interest from EVN in greater cooperation

Xcube developments: steps towards 8 Gbps (1 GHz b/w) recording

Next proposal deadline in mid June (for obs from Oct 2015)

- http://www.atnf.csiro.au/vlbi/

Thank you

CASS/ATNF
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