AuScope VLBI Array and Hobart 26-m Antenna

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Abstract This is a report on the activities carried out at the University of Tasmania in support of the three AuScope VLBI observatories and the Hobart 26-m antenna in 2015 and 2016. We describe our operations and research activities which are primarily focused on southern hemisphere priorities in geodesy and astrometry, as well as developing new techniques where a single-institute operated VLBI array such as ours can be used to great advantage.

1 General Information

As part of AuScope (www.auscope.org.au), the University of Tasmania (UTAS) operates the AuScope VLBI Array (Lovell et al., 2013), three 12-m diameter radio telescopes on the Australian continent, located near Hobart (Tasmania), Yarragadee (Western Australia), and Katherine (Northern Territory).

2 Staff

The staff at UTAS consists of academics, Prof. John Dickey (director), Dr. Simon Ellingsen, Prof. Peter McCulloch, and Dr. Stas Shabala. Dr. Jim Lovell is Project Manager for the AuScope VLBI project. Dr. Jamie McCallum, Dr. Lucia Plank, and Dr. Elizaveta Rastorgueva-Foi (until mid-2015) are post-doctoral fellows who are carrying out research aimed at improving geodetic solutions in the southern hemisphere. Mr. Brett Reid is the Observatory Manager whose position is funded by the University. Ms. Imogen Jones (until mid-2015) and Dr. Warren Hankey are employed to assist in operations and media logistics in particular. In addition we have an electronics technical officer, Mr. Eric Baynes. For operation of the observatories during geodetic observations we rely heavily on support from astronomy PhD and post graduate students. Logistical and maintenance support at Katherine is provided by Mr. Martin Ephgrave and Mr. Mick Stone and at Yarragadee by Mr. Randall Carman and team at the MOBLAS5 SLR station.

School of Mathematics and Physics, University of Tasmania

Hobart 12 m and 26 m, Katherine, and Yarragadee

IVS 2015+2016 Biennial Report

3 Current Status and Activities

From late July to early November 2015, a prototype broadband receiver system from Callisto was installed on the Hobart 12 m for testing. During that time, the Hobart antenna was not able to participate in regular IVS observations, so the Hobart 26-m telescope participated instead. This is reflected in the lower than usual number of observing days for Hobart 12 m and the higher than usual number for the 26 m.

Mechanical assessments by Challenger Communications were carried out in February 2016 on all three 12-m antennas. In general, the telescopes were found to be in good condition, and Challenger made some recommendations for ongoing maintenance activities. However, at Yarragadee some damage was found in the elevation jack-screw thread. This was probably caused when sand got into the grease as the result of a tear in the boot that surrounds it. The jackscrew will be replaced in the first half of 2017.

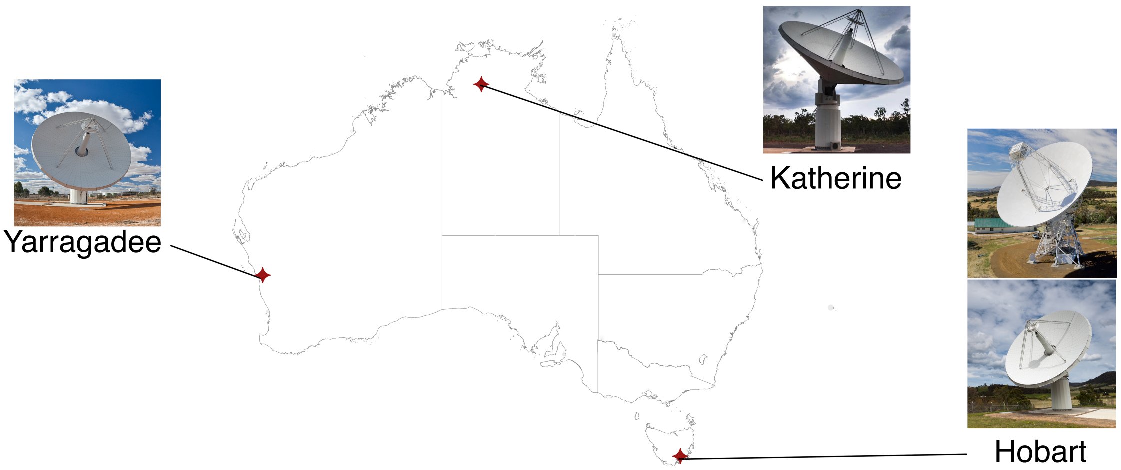

Fig. 1 The AuScope VLBI array and Hobart 26 m.

From mid-April to late May 2016, a major overhaul and maintenance was carried out on the Katherine and Yarragadee hydrogen masers by the manufacturer, Vremya-ch. Similar work was completed on the Hobart maser in October and November.

The Hobart 12 m was not used between June 3 and August 23, 2016 as it was occupied with further testing of the prototype Callisto broadband system. The Hobart 26 m was substituted for several of the experiments missed by the 12 m to compensate as much as possible. Testing with the Callisto system culminated in a successful broadband VLBI experiment with Ishioka and Kashima.

A representative from Intertronic Solutions visited the Hobart observatory in November to inspect and measure the pedestal of the 12-m antenna in preparation for the replacement of the cable wrap mechanism to occur in the first half of 2017.

In 2015, we also hosted two international meetings, the DiFX Users Meeting and the first Asia-Oceania VLBI Group (AOV) Meeting: "A Vision for Science and Technology with the AOV".

4 Geodetic VLBI Observations

In 2015 and 2016, the AuScope and Hobart 26-m antennas participated in 181 and 166 IVS sessions respectively (compared to 185 in 2014, 111 in 2013, and 72 in 2012) for a total of 509 and 414 antenna days respectively. A summary of the observations is presented in Tables 1 and 2.

Table 1 AuScope and Hobart 26-m antenna participation (number of days) in IVS sessions in 2015. The AUST15 series of observations were two 15-day CONT-like sessions as part of the AUSTRAL program.

Session	Antenna				Total
	Ho	Hb	Ke	Yg	
AOV	1	4	6	6	6
APSG	1	1	2	2	2
AUST-AST	1	8	8	8	8
AUST-GEO	1	19	17	19	19
AUST15		30	30	30	30
CRDS	5	3	6	6	6
CRF		3	3	3	3
OHIG	1	3	6	6	6
R&D	9				9
R1	15	25	43	42	45
R4	12	28	44	44	44
T2		2	3	3	3
Total	46	126	168	169	181

4.1 The AUSTRAL Program

The AUSTRAL Program commenced in July 2013. Observations are being made with the three AuScope antennas as well as the Warkworth 12 m and the Hartebeesthoek 15 m. The Hobart 26 m and the Harte-

Table 2 AuScope and Hobart 26-m antenna participation (number of days) in IVS sessions in 2016.

Session	Antenna				Total
	Ho	Hb	Ke	Yg	
AOV	2	4	5	5	6
APSG		1	2	2	2
AUST-AST	4	5	6	6	7
AUST-GEO	8	12	15	15	15
AUST-HOB	8	8			8
CRDS	6	5	5	5	6
CRF	3	2	3	3	3
OHIG		6	5	6	6
R&D	9	1			10
R1		36	39	42	49
R4		35	37	38	47
T2		6	7	7	7
Total	40	121	124	129	166

beesthoek 26 m also participate for some AUSTRAL sessions. Scheduling and correlation activities are shared between UTAS, Vienna, and Shanghai (the Curtin University software correlator was used until mid-2015).

As in previous years, the AUSTRAL observing program is focused on high priority geodetic and astrometric aims in the southern hemisphere:

1. astrometric observations to monitor and enhance the southern hemisphere reference frame in preparation for ICRF3;
2. regular observations to improve the density of the geodetic time series for the southern antennas and to measure and monitor the motion and deformation of the Australian plate;
3. four 15-day CONT-like sessions over two years to demonstrate the full capabilities of the array, characterize the level of systematic errors caused by the troposphere and source structure, and develop and try error mitigation strategies. One session was held in 2013, another in 2014, and two in 2015.
4. In 2016 we introduced eight HOB sessions that are aimed at understanding the tie between the new 12-m AuScope and "legacy" 26-m antennas at Hobart.

All AUSTRAL data are post-processed at UTAS and submitted to IVS as version 1 databases.

4.2 K-band Astrometry on the Hobart — Hartebeesthoek Baseline

The Hobart 26 m was involved in a number of single-baseline K- and X-band observations with the Hartebeesthoek 26-m telescope.

Observations are planned ahead of time with both K- and X-band schedules with X-band as a back-up in the event of poor weather at one or both sites. Observations are carried out using DBBC2 backends, utilizing the 2 Gbps capable v105E firmware. The K-band observations have largely been aimed at expanding the K-band catalog in the Southern polar cap. Only test observations in X-band have been carried out as yet.

The results from the first series of experiments have been processed and have yielded good results. Further observations are planned for 2017 and beyond.

5 Research Activities

We have now reached the critical mass to perform more research. Most of our activities are situated in the area of improved observations and operations. The easy access to a VLBI array and in particular the complete in-house capability, from scheduling to observations and all the way through to geodetic analysis, has proven very useful for our research activities, which are:

- **AUSTRAL Sessions.** The AUSTRAL program was mainly driven by the desire to improve geodetic results in terms of baseline repeatabilities. Efforts in scheduling, combined with the high data rate of 1 Gbps, have improved the results by a factor of two since the start of the program (Plank et al., 2016a). This program is evidence that research in the observing strategy pays off and that there is further room for improvement in our results.
- **South versus North.** North—South imbalance in the VLBI network has traditionally influenced our results. To mitigate these issues was one of the main justifications to build the AuScope array. In Plank et al., (2015) we could show that the regular participation of the AuScope telescopes in the IVS R1/R4 experiments had a clear impact on the results: in terms of baseline length repeatabilities, while previously the results were clearly worse for southern

baselines, one now finds repeatabilities comparable to those of northern baselines. This result and publication has helped to secure ongoing operation funds for the array.

- **Source structure simulations.** In collaboration with the Vienna group, a source structure simulator has been implemented in the Vienna VLBI Software (VieVS, Shabala et al., 2015). Performing simulations using the R1/R4 antenna network and observing schedules, we found that the systematic behavior of two component sources with low structure indices (1, 2) may have a significant impact on globally estimated source positions; while the larger additional delays due to source structure of nominally higher structure index (3, 4) are largely cancelled out in a global solution estimating source positions (Plank et al., 2016b).
- **Sibling telescopes.** The future operation of sibling and twin telescopes is another research area at UTAS. There were efforts in optimizing the scheduling of co-located telescopes (Plank et al., 2016c). A new scheduling mode was developed with the purpose of combining the AuScope 12-m telescope with the Hobart 26-m legacy antenna. This allows observations to much weaker sources (0.15 Jy), without decreasing the geodetic quality of the schedule (about 30 scans per hour per station). In 2016, four sessions (AUA009, AUA010, AUG024, and AUG026) were performed, observing 42 target weak sources that were selected by Karine Le Bail from GSFC.
- **VLBI satellite tracking.** This has been a major research focus during the last two years. Using UTAS operated telescopes in Ceduna (South Australia) and Hobart, the first VLBI time series of GNSS satellite observations was published (Plank et al., 2017). We particularly improved our knowledge about correlation and fringe fitting. In November 2016 intensive observations to the APOD satellite were done using the AuScope array. The observations are currently being correlated.
- **Dynamic Observing.** Being the most busy telescopes in the IVS, we always seek improvements in operation and automation. When operating an array, it is sad to see the telescopes resting on the weekends. This started the dynamic observing project. We have developed multiple routines that allow us to automatically schedule, download the schedule, start an experiment, and observe whenever a telescope is put as available for the dynamic observing (Lovell et al., 2016). Several DS experiments were run during weekends in 2016, also including the Hartebeesthoek 15-m telescope. We now seek more participants for a more global network. This will be further emphasized through some simulation results soon.

6 The Future

In 2017, the AuScope array will commence an upgrade to VGOS capability. This will include installation of Callisto Stirling-cycle cooled receivers with QRFH feeds, new DBBC3 systems, and FlexBuff recorders. The Hobart site will be upgraded first and the entire system tested and debugged before duplication and deployment at Katherine and Yarragadee. It will be important to stage the upgrade to maintain good global IVS array geometry during the transition from legacy to VGOS.

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