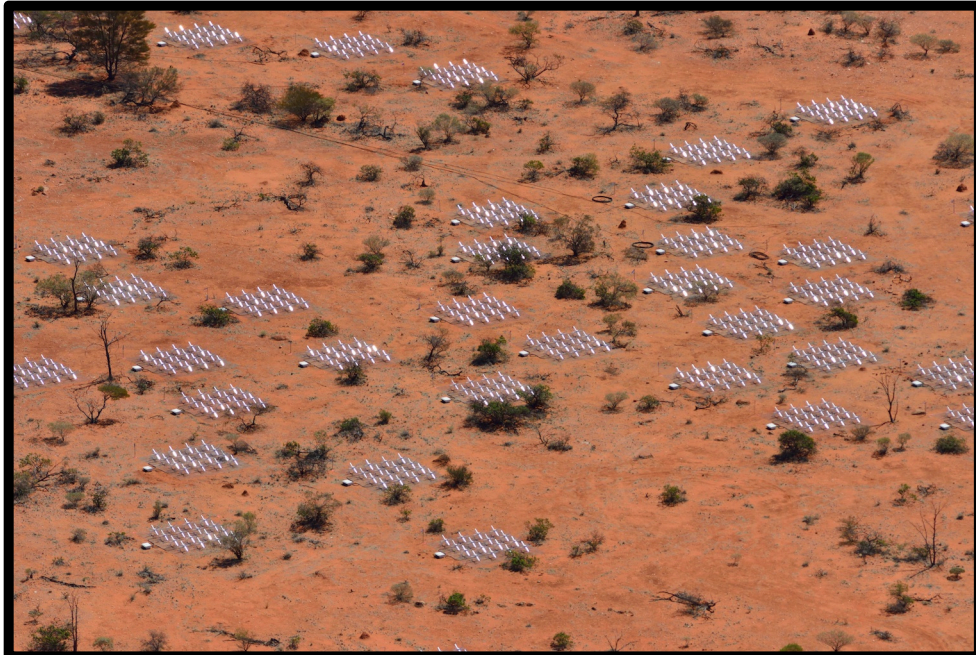


## Allocation of observing time on the Murchison Widefield Array: Second Announcement of Opportunity



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Approved for release by MWA Board: **14<sup>th</sup> March 2014**

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## Summary

This document is the second Announcement of Opportunity (AO) for observing time on the Murchison Widefield Array, a low frequency radio telescope located on a radio quiet site in Western Australia. The MWA completed its construction and commissioning phases in June 2013 and became fully operational in July 2013.

This AO (AO2) covers the allocation of observing time for the period July 2014 - June 2015. The first AO (AO1) covered the allocation of observing time for the period July 2013 – June 2014. The time allocation process for the AO1 period has been completed via two Calls for Proposals for observing semesters 2013B (July 2013 – December 2013) and 2014A (January 2014 – June 2014). Details of projects executed under AO1 are available from the MWA website (<http://mwatelescope.org>).

AO2 largely reprises AO1, with updated information on the amount of observing time available in semesters 2014B (July 2014 – December 2014) and 2015A (January 2015 – June 2015), and updated information on new observing modes available in AO2. In addition, the continued implementation of future observing modes, available during the AO2 period via Director's Discretionary Time (DDT), is flagged.

It is expected that the first Call for Proposals under AO2 will open on 17<sup>th</sup> March 2014 and close on 18<sup>th</sup> April 2014. As for previous Calls for Proposals, the proposals will be evaluated by the MWA Time Allocation Committee and an allocation will be made for semester 2014B. A second Call for Proposals will be released in September 2014, for allocation of time in semester 2015A.

The AO2 period will cover observing time allocations in both Guaranteed Time and Open Access categories. As in AO1, Shared Risk conditions will apply in AO2, due to the availability of new observing modes.

***The period covered by this AO comprises the remainder of the currently funded operations phase of the MWA. The release of any further observing time, beyond that identified in this AO, is dependent on the MWA project securing funding to support operations past June 2015.***

## Introduction and Background

The Murchison Widefield Array (MWA) is a low frequency interferometric radio telescope that operates between 80 and 300 MHz and consists of 128 aperture array “tiles” spread over an area of 3 km diameter. The MWA is located at CSIRO's Murchison Radio-astronomy Observatory (MRO), in the Murchison region of Western Australia, and is the only low frequency Square Kilometre Array (SKA) pathfinder on one of the two selected sites for the SKA. A full description of the capabilities of the MWA can be found in Tingay et al. (2013).

The MRO occupies a very sparsely populated area of Western Australia and is extraordinarily radio quiet, particularly in the FM band contained within the MWA frequency range. The instrument design and the radio-quiet location permit a number of areas of astronomical observation. A full description of the

MWA science case has been published by Bowman et al. (2013). Broadly, the four main science themes for the MWA are:

- The search for radio emission from redshifted hydrogen corresponding to the Epoch of Reionisation (EoR);
- Studies of the solar heliosphere and the Sun – Earth connection (SHI);
- Galactic and extragalactic science, including large scale continuum and polarisation surveys, pulsar science, and galactic plane surveys (GEG);
- Studies of transient and variable radio sources (Transients).

The MWA has been constructed by a consortium of thirteen institutions<sup>1</sup> in four countries (Australia, India, New Zealand and the USA) and financed by funding organisations in these countries, plus the consortium partners. One of the obligations under funding for the MWA project is that a fraction of the observing time be made available, on a competitive “Open Skies” basis, to the international astronomy community.

The purpose of this document is to describe the process by which potential users of the MWA can be allocated observing time on the instrument, including a description of any restrictions on the accessible science and modes of operation. This document draws upon the MWA project documentation describing governance of the project and MWA policies, available publically from the MWA website: <http://mwatelescope.org>.

Appendix B contains a summary timeline of important dates, as described in this AO.

## **Period covered by this Announcement of Opportunity**

This AO covers a 12 month period during which observations for scientific programs approved by the MWA Time Allocation Committee will be made.

This period is currently expected to commence from the start of July 2014 and is expected to conclude at the end of June 2015. The period will be split into two six month periods, semesters 2014B and 2015A.

Any deviation from these expectations will be communicated to potential users via the MWA website.

## **MWA Time Allocation Committee**

The MWA Time Allocation Committee (TAC) is appointed by the MWA Board and is responsible for assessing and ranking proposals for MWA observing time. The MWA TAC is described in the MWA Time Allocation Policy, available at the MWA website.

It is currently expected that full proposals for semester 2014B will be called for on the 17th of March, 2014, with a closing date of the 18<sup>th</sup> April, 2014. A second call, for semester 2015A, will be made at a date to be determined in September 2014.

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<sup>1</sup> The MWA consortium institutions are listed in Appendix A

## Shared risk operations

The operations phase of the MWA project includes continued commissioning of new observation modes. Furthermore, the MWA is a complex and non-traditional instrument (located in a very remote location) that poses new challenges in calibration and widefield imaging techniques, not least because of the vast dataset sizes produced.

As such, the MWA project operations team, and the MWA user community, is on a significant learning curve and it is likely that full exploitation of the instrument and data will take time to realise.

In recognition of this situation, as with most new instruments, the MWA will continue to operate under “Shared Risk” conditions.<sup>2</sup> Shared Risk conditions are likely to apply for the full 12 month period covered by AO2.

During Shared Risk operations there is the possibility of reduced data quality and/or data collection efficiency compared with that advertised due to unanticipated requirements, poorer than anticipated performance and/or lower efficiency. This may result in cancellation or rescheduling of some Shared Risk observations at short notice. Cancelled Shared Risk observations not executed during the period covered by this AO will not automatically be rescheduled at a later date.

Every effort will be made to provide a realistic assessment of the capabilities and performance of the MWA instrumentation. However, from time to time, some capabilities and aspects of performance may differ from those advertised.

A review of the need for a continuation of Shared Risk conditions for any subsequent AOs will be held at the conclusion of each AO period.

## Likely level of observing time available under this AO

The operations phase of the MWA proceeds according to the MWA Operations Management Plan (OMP), which details the operational requirements of the MWA during this period in terms of the size and scope of the operational team. The scope of the OMP is bounded in practical terms by the level of operations funding available, as well as constraints in terms of the data flows that can be supported into the MWA data archive housed at the Pawsey Centre (a new \$80m supercomputing facility in Perth).

These practical considerations lead to an operational model with a defined ramping up of observational duty cycle (percentage of time devoted to executing scientific observations) over the course of the operations phase. In the AO1 period, the average observational duty cycle was approximately 25%.

During the AO2 period, commencing July 2014 for a 12 month period, an average duty cycle (ratio of observing time to calendar time) of approximately 50% is expected to be supported by the MWA operational team. This corresponds to

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<sup>2</sup> The following paragraphs draw heavily from the description of “shared risks observing” for the Gemini Observatory at <http://www.gemini.edu/?q=node/11012>

2000 hours of observation in the period July – December 2014 and a further 2000 hours in the period January – June 2015, a total of 4000 hours over the period covered by this AO.

***The period covered by this AO comprises the remainder of the currently funded operations phase of the MWA. The release of any further observing time, beyond the 4000 hours identified in this AO, is dependent on the MWA project securing funding to support operations past June 2015.***

It should be noted that the duty cycle of observations is not likely to be constant throughout the AO period, depending on a number of scheduling and scientific factors.

It is also highly likely that day-time observing will be limited largely to solar observations, as night-time observations are likely to be significantly better for all other forms of observation, due to a generally more stable ionosphere. Exceptions to this are, of course, possible with suitable justification.

## Categories of time allocation

The MWA Time Allocation Policy (referred to elsewhere in this document), outlines the different categories of time allocation available to MWA users.

In response to Calls for Proposals, the MWA TAC will allocate observing time in two categories, Guaranteed Time (GT) and Open Access (OA).

1. GT will be allocated to proposals led by Individual Members (defined in the MWA Membership Policy) of the MWA or submitted by teams comprising more than 50% Individual MWA Members. GT will comprise a target 60% of available observing time on the MWA and will be allocated over the four MWA Science Programs. A proposal seeking GT time must identify which of the four MWA Science Programs the proposal corresponds to, or make fractional assignments between the four MWA science Programs (see Expression of Interest template in later section of this document). GT proposals seeking time for EoR science in whole or in part must be accompanied by an explicit endorsement from the Chair of the MWA EoR consortium. *In utilising GT, the proposers will be bound by all MWA policies.*
2. OA will be allocated to proposals led by individuals who are not Individual Members of the MWA or by teams comprising less than 50% Individual Members (as long as the proposal is not led by an MWA Individual Member or is driven by MWA Individual Members). OA will comprise a target 20% of the available observing time on the MWA and can be allocated to any area of science apart from studies of the Epoch of Reionisation. *Individuals and teams allocated time and data under OA are not bound by MWA Collaboration policies.*

Up to a further 20% of available observing time will be allocated to Director's Discretionary Time (DDT). During the AO2 period, it is expected that DDT will be preferentially used to support commissioning for observation modes that will be made available in subsequent AO periods, as well as engineering test time.

During the AO2 period, DDT may be released to TAC-approved science programs in GT or OA categories at the discretion of the Director.

Target of Opportunity observations and/or observations that require rapid rescheduling of the instrument at short notice will not be formally supported during the AO2 period, although various tests of rapid reaction Target of Opportunity observations may be conducted internal to the MWA project, using DDT.

In terms of the AO2 period, the above can be summarised in the following expectations:

**First six month period (July 2014 – December 2014: semester 2014B):**

1. A target 1200 hours of GT will be available in the period July 2014 - December 2014;
2. A target 400 hours of OA will be available in the period July 2014 – December 2014;
3. Up to 400 hours of DDT will be available in the period July 2014 - December 2014.

**Second six month period (January 2015 – June 2015: semester 2015A):**

4. A target 1200 hours of GT will be available in the period January 2015 – June 2015;
5. A target 400 hours of OA will be available in the period January 2015 – June 2015;
6. Up to 400 hours of DDT will be allocated in the period January 2015 – June 2015.

## **Instrument capabilities and available modes of observation**

The definitive description of the capabilities and expected performance of the MWA is contained in Tingay et al. (2013). For the purposes of preparing proposals, it is envisaged that the information in Tingay et al. (2013) will be largely sufficient. If teams preparing proposals require information beyond what is provided in Tingay et al. (2013), they should contact the MWA Project Scientist for advice, Dr Judd Bowman ([judd.bowman@asu.edu](mailto:judd.bowman@asu.edu)).

One aspect of the MWA performance that is not extensively covered in Tingay et al. (2013), and may be of use in preparing proposals, is the MWA uv plane coverage. Figures 1 and 2, below, provide an overview of what potential users can expect for different observation durations, bandwidths, and choices of maximum baseline (for an example declination of -30 degrees). This is not an exhaustive exploration of parameter space, but should be sufficient to inform the preparation of proposals.

Figure 7 of Tingay et al. (2013) is worthy of note, in particular the MWA tile beam shape near the high frequency end of the observing band, where the aperture array becomes sparse, causing significant grating lobes. Caution should be exercised when using the MWA above ~250 MHz for this reason, unless the target is the Sun.

As a radio telescope with a primary capability in very wide field surveys, the primary observational modes are naturally limited and widely applicable to a range of areas of science.

During the A02 period, two observational modes will be offered, Drift Scan Observations and Pointed and Tracked Observations. During A02, new data product modes will be offered for the first time, as described below.

**Drift Scan Observations:** Drift Scan Observations are observations during which the MWA primary beam is pointed at a fixed azimuth and elevation (corresponding to a fixed declination and usually corresponding to a point on the meridian). As the Earth rotates, data are produced covering a strip in right ascension at a fixed declination. The primary advantage of this observing mode is that the analog beamformer settings used to steer the primary beam are fixed, making calibration easier and more predictable. The disadvantage is that, while the confusion limit in Stokes I can be reached in this mode, it does not suit science that requires deep integrations for a given field.

**Pointed and Tracked Observations:** In contrast to Drift Scan Observations, Pointed and Tracked Observations involve tracking of a fixed right ascension and declination, involving periodic (timescale of minutes) changes to the analog beamformer settings to steer the primary beams in discrete steps. This is closer to how observations are made with a traditional radio telescope. The advantage of this mode of observation is that long and deep integrations are possible for a given field of interest (EoR field, for example). The disadvantage is that the discrete nature of the tracking introduces some potential complications into the calibration of the data.

**New data product modes for A02 period:** During the first A0 period, the data averaging applied at the output of the MWA correlator was held fixed, to implement a single data product mode (40 kHz spectral channels and 0.5 second temporal averaging). During DDT in A01, additional correlator output modes were tested and commissioned, resulting in additional available flexibility for users in A02. Briefly, the available data product modes are as follows:

- 40 kHz spectral channels and 0.5 second temporal averaging (A01 mode);
- 40 kHz spectral channels and 1.0 second temporal averaging (new mode);
- 40 kHz spectral channels and 2.0 second temporal averaging (new mode);
- 20 kHz spectral channels and 1.0 second temporal averaging (new mode);
- 20 kHz spectral channels and 2.0 second temporal averaging (new mode);
- 10 kHz spectral channels and 2.0 second temporal averaging (new mode).

It can be seen that these new data product modes will be especially useful for higher spectral resolution observations than was possible during A01. Users will be able to choose among these data product modes in MWA proposals.



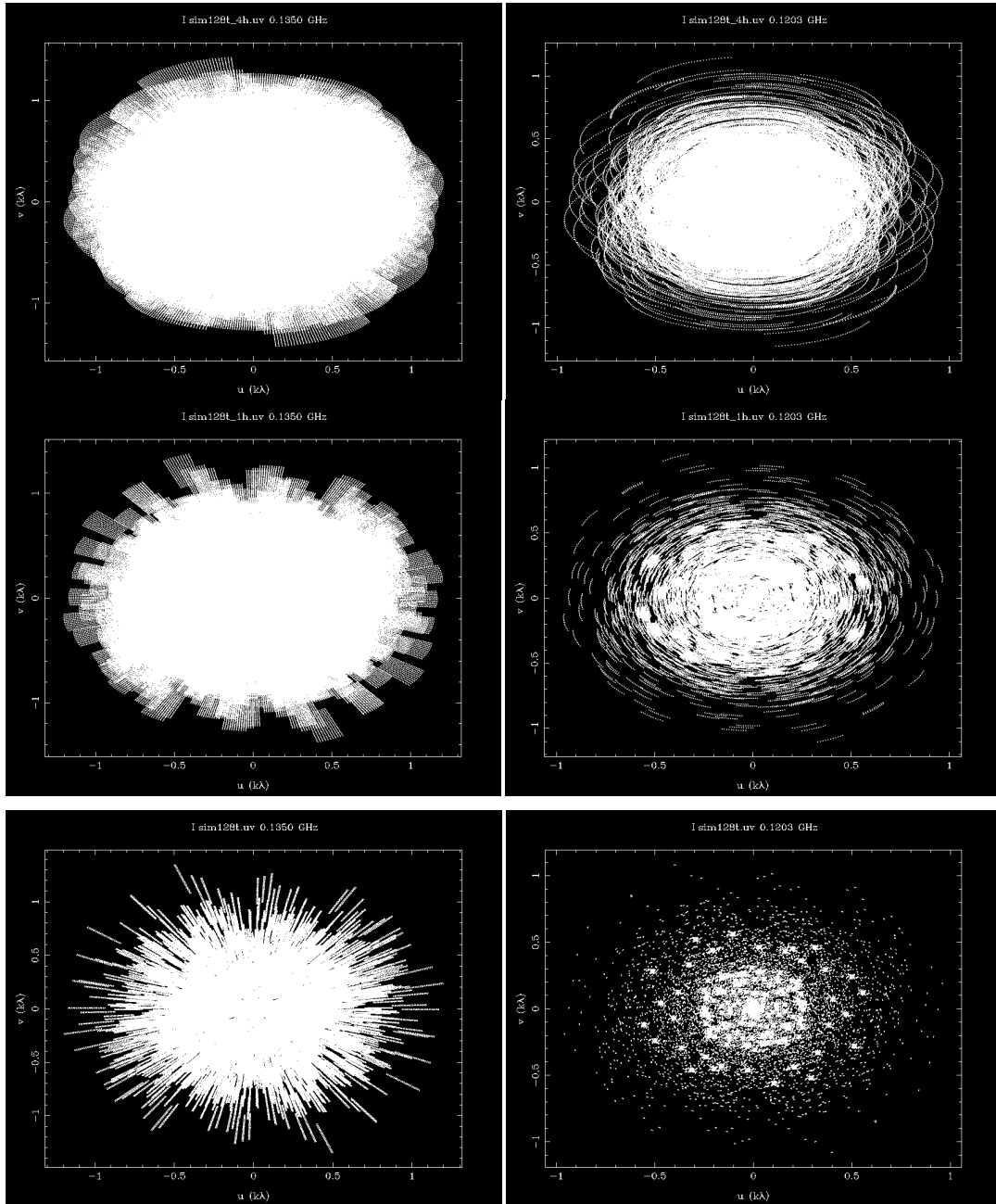


Figure 1: Example uv coverages at declination -30 degrees and observing frequency of 150 MHz for the full array. Left panels are full bandwidth (30 MHz) observations and right panels are single channel (40 kHz) observations. Top to bottom, the observation durations are 4 hours, 1 hour, and snapshot (~minute), respectively.

As noted above, Target of Opportunity observations will not be supported from the user community during the AO2 period. Also, other observational modes described in Tingay et al. (2013), such as involving use of the Voltage Capture System (VCS), will not be available for the AO2 period. These additional observational modes and capabilities will be commissioned and tested internal to the MWA project team during DDT and considered for availability for subsequent AO periods.

Specifically, a call for projects (not part of the Call for Proposals) that could be used to help test and verify the MWA VCS will be made before or during semester 2014A. These projects will be selected and executed using DDT allocations. Further information on this opportunity will be included in the call.

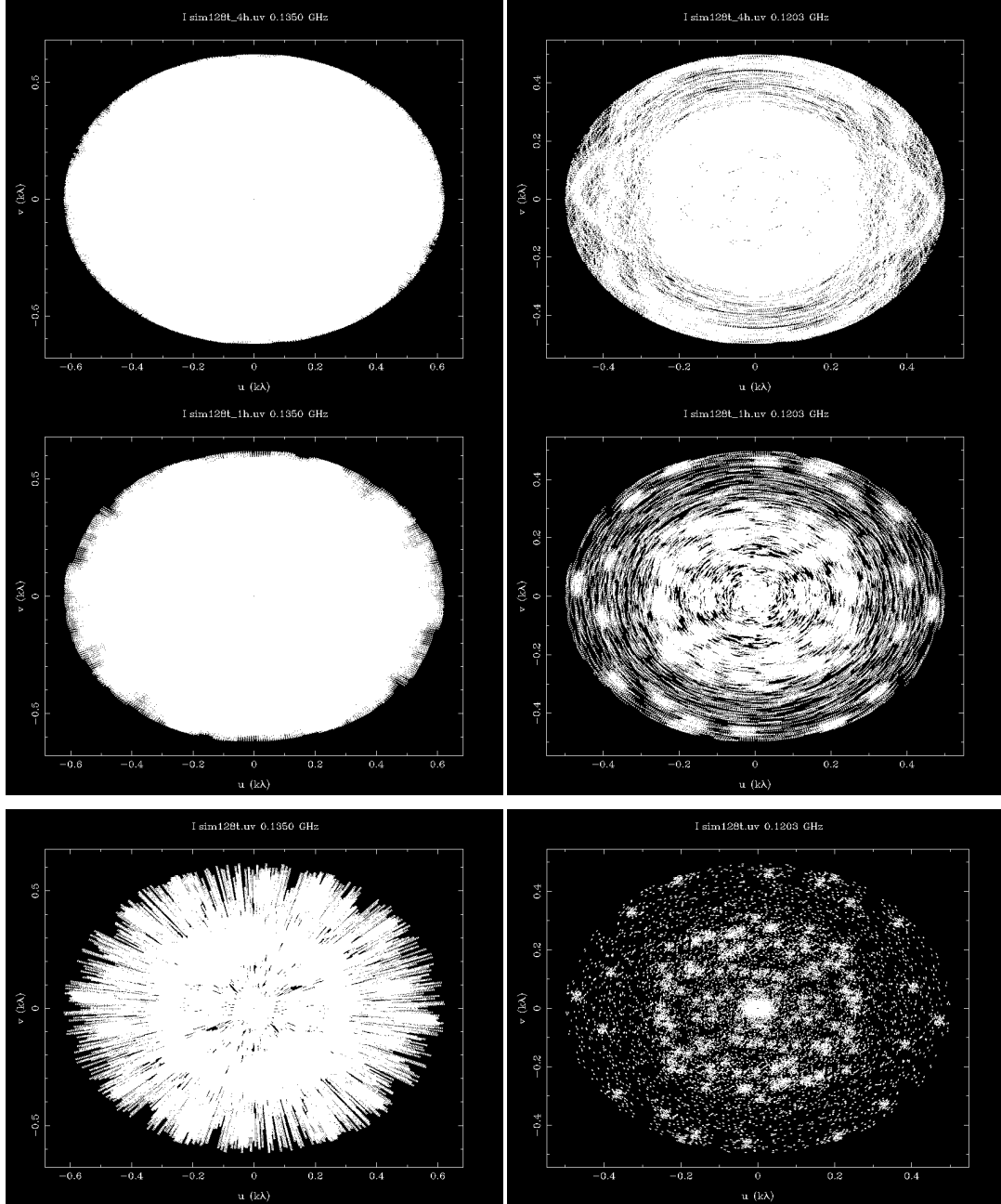


Figure 2: Example uv coverages as for Figure 1, but with maximum baseline restricted to 1 km.

### Restrictions on Epoch of Reionisation science

The use of the MWA for studies of the Epoch of Reionisation is restricted to members of the MWA EoR Collaboration, which is made up of a subset of the Individual Members of the MWA project team. Thus, observing time for EoR

science can only be proposed as part of the GT allocation, by the MWA EoR Collaboration, under the conditions stated in the MWA Time Allocation Policy, available on the MWA website.

Observations proposed for EoR science will be reviewed by the MWA TAC and judged against other proposals received in the GT category.

Further enquires regarding EoR science with the MWA can be directed to the leader of the MWA EoR Collaboration, currently Prof. Rachel Webster at The University of Melbourne ([r.webster@unimelb.edu.au](mailto:r.webster@unimelb.edu.au)).

## **Data products, data access and data processing**

The MWA will produce various levels of data product. The primary data product relevant to the AO2 period is uv data. Access to MWA data is governed by the MWA Data Access Policy, available on the MWA website.

As described by Tingay et al. (2013), the observational modes described above (observations for imaging purposes) will produce visibility data at an approximate maximum rate of 3.2 Gbps. These data are automatically transferred on a dedicated 10 Gbps network to the Pawsey HPC Centre for SKA Science in Perth, where 10 PB of storage has been allocated. These visibility data will be available to MWA users via an archive interface in the standard UVFITS format.

It should be noted, however, that if users have any requirement to retrieve large volumes of data from the MWA archive, they will be required to be responsible for organising a suitable destination for these data, as well as appropriate processing resources. MWA users requiring such large data volumes may be interested in the prospect of applying for storage and compute resources on the Pawsey Centre, via a number of merit-based allocation processes. Users interested in this possibility should familiarise themselves with the allocation processes (<http://www.ivec.org> and queries to [george.beckett@ivec.org](mailto:george.beckett@ivec.org)).

It is expected that the vast majority of users will require visibilities to pursue their science requirements. Users who wish to work with visibilities will be responsible for the data processing themselves, once data have been retrieved from the MWA archive. The MWA project team have developed data processing pipelines to transform visibility data into images, but it is not expected that these pipelines will be officially supported as tools for the general user community (due to constraints on the resources available to the MWA operational team). However, access to these pipelines will be possible, in informal collaboration with MWA project team members (see following section).

The MWA is the first of the three SKA precursors to be operational, entering the age of significant data rates, vast data sets, automated and large-scale processing, and huge archives. This archive is implemented at the Pawsey Centre, which itself is currently in its early operations phase. Therefore, it is expected that the MWA archive will be the sub-system that will evolve most strongly during the operations phase of the MWA, in response to experience gained with respect to usage patterns for the archive (number and frequency of database queries, frequencies and volumes of datasets retrieved from archive etc). The

operational form of the archive will therefore evolve strongly and will require significant communications between the MWA operational team and the MWA users during the operations phase.

## **Collaboration with members of the MWA project**

As noted above, significant software resources have been developed to image and calibrate MWA data. These have been developed to process data from the MWA 32 tile prototype (e.g. Williams et al. 2012) and, more recently, for the purposes of MWA Science Commissioning.

These software resources have proven themselves capable of producing MWA images of scientific quality, but have been developed for internal MWA project purposes. Currently, the release of the software to the general user community is under discussion within the MWA project. It is possible that the software may be made available to users, but without formal support from the MWA operational team, due to resource limitations within that team.

However, for users not familiar with the MWA or indeed with interferometry or radio astronomy, informal collaborations with MWA team members will be possible. In fact, it is strongly encouraged that teams developing proposals include at least one member deeply familiar with the MWA and MWA data processing.

Interested teams can seek further advice on collaboration with MWA team members from the MWA Director ([s.tingay@curtin.edu.au](mailto:s.tingay@curtin.edu.au)), MWA Project Scientist ([judd.bowman@asu.edu](mailto:judd.bowman@asu.edu)) or MWA Staff Scientist ([r.wayth@curtin.edu.au](mailto:r.wayth@curtin.edu.au)).

## **Acknowledgements**

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## References

- Bowman, J. et al. 2013, PASA, 30, 31  
Tingay, S.J. et al. 2012, PASA, 30, 7  
Williams, C.L. et al. 2012, ApJ, 755, 47

## Appendix A: MWA Consortium institutions

|  |             |
|--|-------------|
| Curtin University (MWA Lead and Managing Organisation):      | Australia   |
| Australian National University:                              | Australia   |
| CSIRO:   | Australia   |
| Harvard-Smithsonian Center for Astrophysics:                 | USA         |
| Massachusetts Institute of Technology, Haystack Observatory: | USA         |
| Massachusetts Institute of Technology, Kavli Institute:      | USA         |
| Raman Research Institute:                                    | India       |
| Swinburne University of Technology:                          | Australia   |
| The University of Melbourne:                                 | Australia   |
| The University of Sydney:                                    | Australia   |
| University of Tasmania:                                      | Australia   |
| The University of Western Australia:                         | Australia   |
| Victoria University of Wellington:                           | New Zealand |

## Appendix B: Summary of key dates described in this Announcement of Opportunity

|                             |  |
|-----------------------------|--|
| 1 <sup>st</sup> March 2014  | This Announcement of Opportunity released.   |
| 17 <sup>th</sup> March 2014 | Call for Proposals for semester 2014B opens. |
| 18 <sup>th</sup> April 2014 | Call for Proposals for semester 2014B ends.  |
| July 2014                   | MWA operations commence for semester 2014B   |
| September 2014              | Call for Proposals for semester 2015A opens. |
| October 2014                | Call for Proposals for semester 2015A ends.  |
| December 2014               | MWA operations conclude for semester 2014B   |
| January 2015                | MWA operations commence for semester 2015A   |
| June 2015                   | MWA operations conclude for semester 2015A   |