



MWA ASVO

2018 ICRAR/CASS RADIO SCHOOL,
Geraldton, Western Australia
October 1, 2018

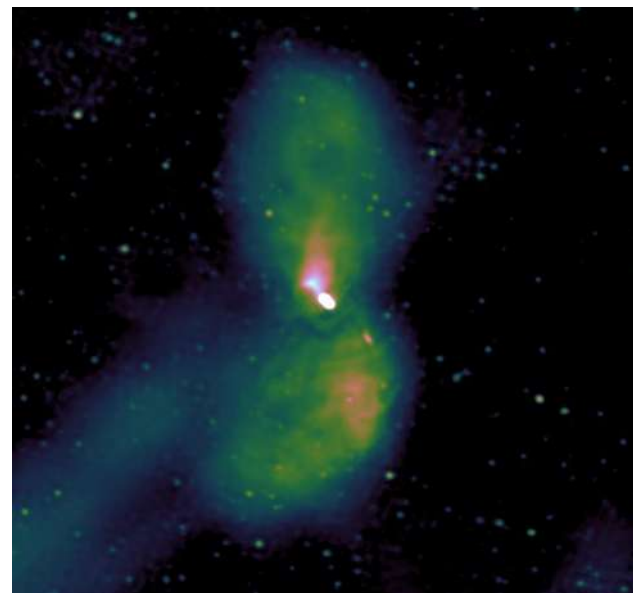
Greg Sleap
MWA Data Manager
Curtin University





About the MWA

- MWA has been operating since mid 2013
- Built by a international collaboration led by Curtin University
- 256 tiles (128 at a time) each having 16 dipoles == 2,048 dipoles
- 80-300 MHz, 30.72 MHz bandwidth



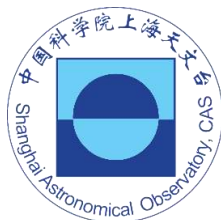
False colour image showing the nearby radio galaxy Cen A.
Credit: Randal Wayth and the MWA team.



Partner Institutions



NAGOYA UNIVERSITY

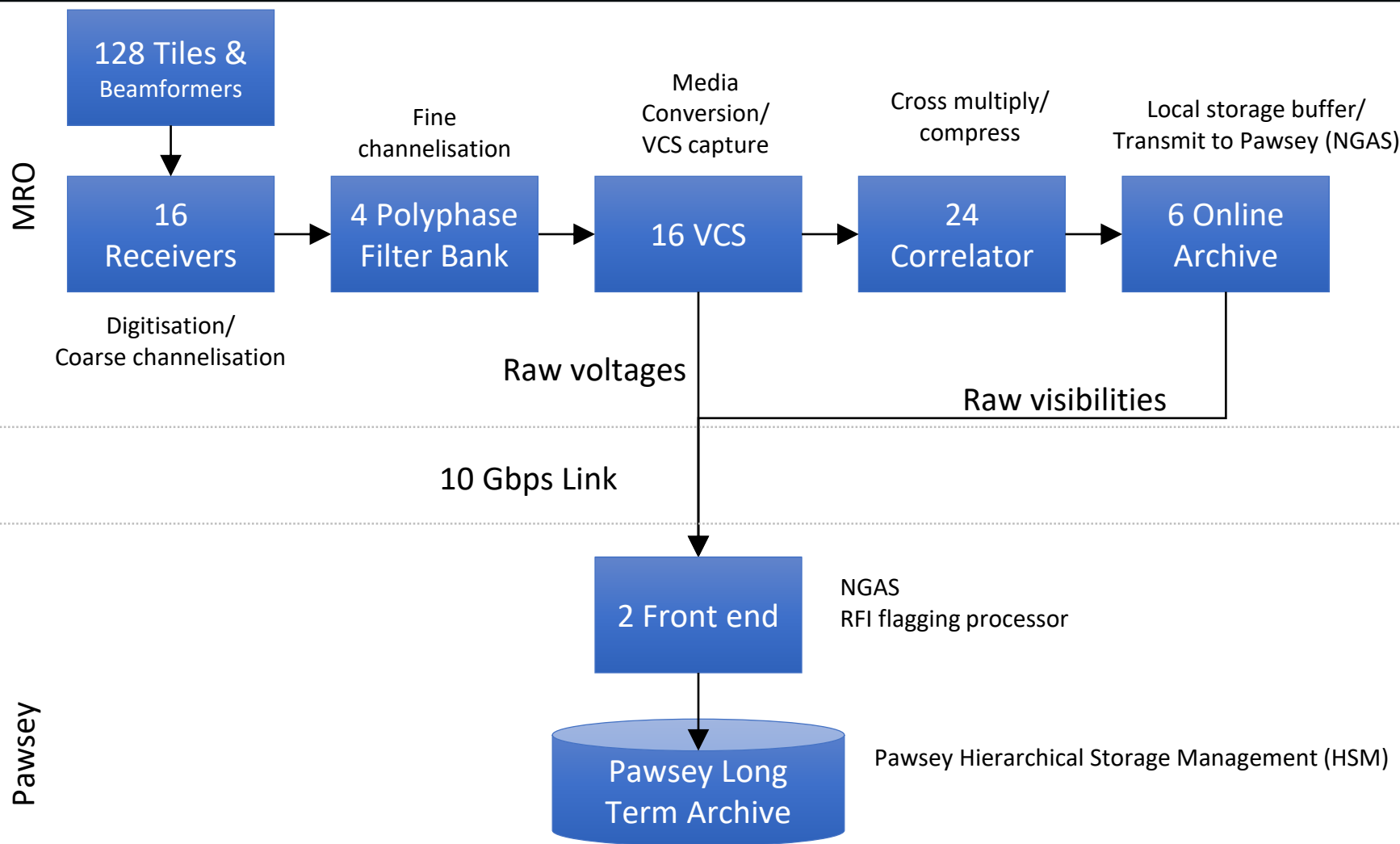


TOHOKU
UNIVERSITY





MWA Data Flow





MWA Data Flow (cont...)

- 256 tiles (128 at a time- compact/long)
- 16 dipoles per tile.
- Each tile has a beamformer. Delays allows pointing
- Sends analog signal to closest receiver via coax*





MWA Data Flow (cont...)

- 16 receivers (8 tiles each)
- Analog to digital conversion
- FPGA-based PFB (creates 256 1.28 MHz “coarse” channels and keeps the selected 24)
- Sent to Fine PFBs in MRO control room over fibre





MWA Data Flow (cont...)

- 4 Polyphase Filter Banks
 - FPGA-based fine channelisation- each of the 24 1.28 MHz is split into 128 10 kHz channels
 - Sent to VCS boxes using a custom Xilinx protocol
 - Performs F part of FX correlator
- 16 voltage capture/media conversion servers (vcs boxes)
 - Convert the Xilinx protocol into ethernet
 - Send to correlator boxes via corner turn done by network switch
 - Each server processes one-quarter of the frequency channels, from one-quarter of the tiles in the whole array (all channels for subset of tiles => one channel from all tiles)
 - Can run in voltage capture mode ~28 TB/hr



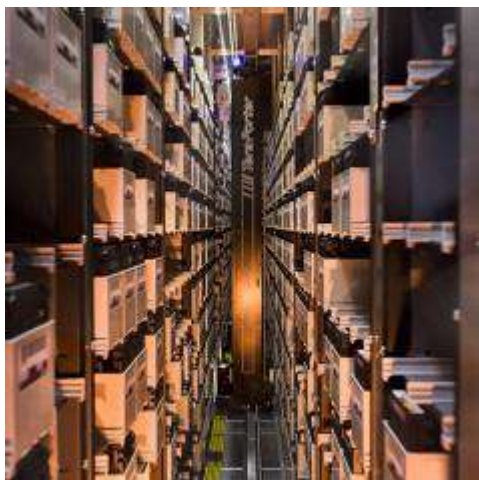
MWA Data Flow (cont...)

- 24 correlator servers (gpu boxes)
 - Each has 2 NVidia Tesla M2040 GPUs (active/backup)
 - Performs cross-multiply (X part of FX) of 1 coarse channel
 - Performs frequency and time averaging
 - Produces compressed gpubox FITS files
- 6 online archive servers (arch boxes)
 - Local NGAS instance
 - Each has 64TB buffer at MRO for 4 coarse channels (~7 days)
 - Sends to Pawsey via 10Gbps link



MWA Data Flow (cont...)

- 2 front-end servers (Pawsey)
 - NGAS stores files as they arrive.
 - Data gets written to disk cache and tape immediately
 - 1.5 PB of front end disk cache (Pawsey)
- Robotic tape library (Pawsey)
 - ~50 PB of tape storage (x2 for redundancy)





MWA Archive

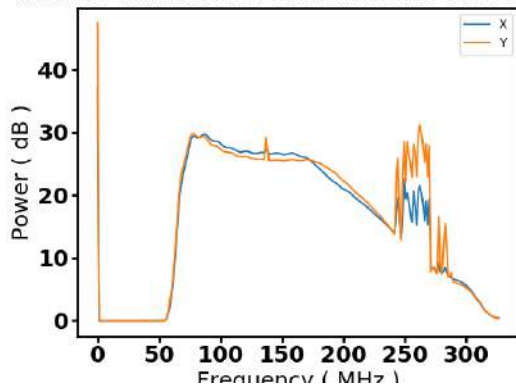
- MWA started taking science data ~mid 2013
- Volume
 - As at Aug 2018 ~28 PB*
 - (* we are in the process of purging unneeded data)
- Growth
 - Compact array mode: up to 3.2 Gb/s = 400 MB/s
 - ~3 PB / year
 - Long baseline mode: ~6.4 – 9.6 Gb/s = 800-1,200 MB/s
 - ~6-9 PB /year



MWA Data

- Raw voltages (not in scope)
- Raw visibilities (gpubox files)
- Flag files (precomputed RFI)
- Metafits & ppds files (metadata)
- “Observation” is a single pointing and data capture of the telescope with specific frequency & time averaging settings

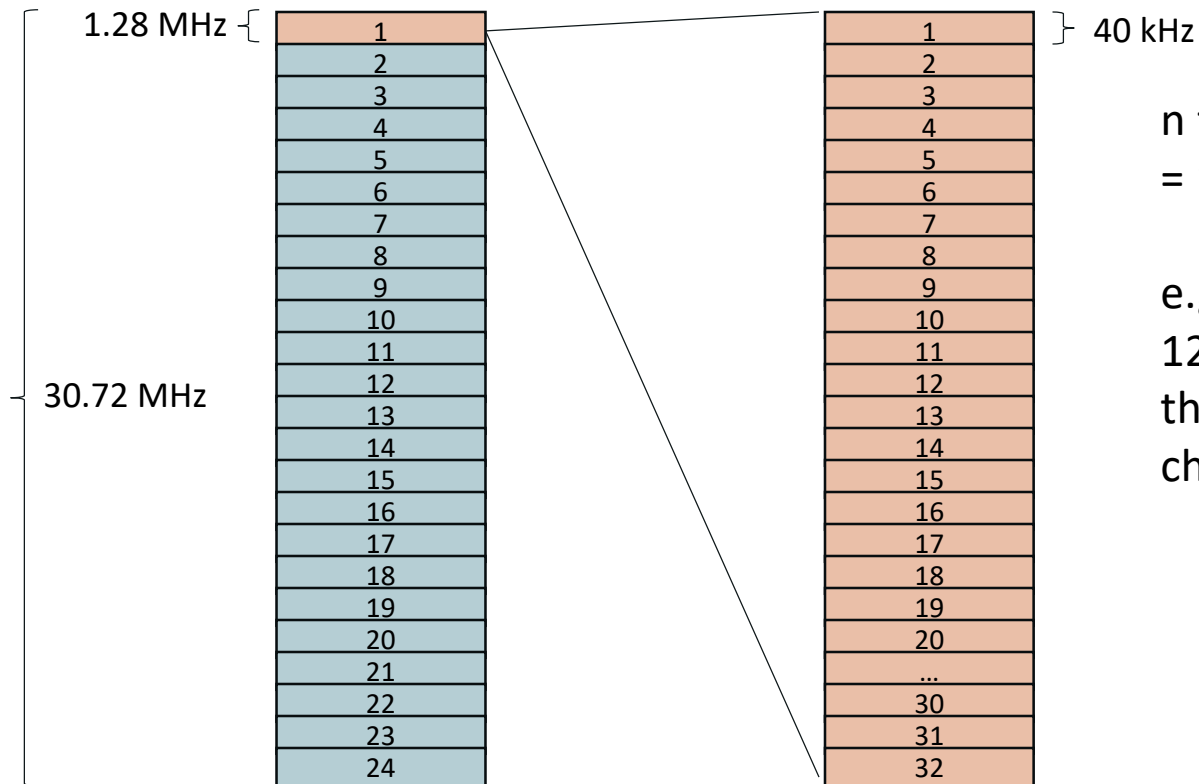
Rx: 1 Slot: 6 Polarization: X Recorded at 2018-09-28 08:23:2
Rx: 1 Slot: 6 Polarization: Y Recorded at 2018-09-28 08:23:2



A “ppd” plot. Integrated power for all channels for a tile (post PFB). No one knows what ppd stands for!



Raw Visibilities post correlator



n fine channels
= $1280 / \text{correlator_mode}$

e.g. if correlator mode is 40kHz:
 $1280 / 40 = 32$
then there are 32 40 kHz fine
channels in each coarse channel

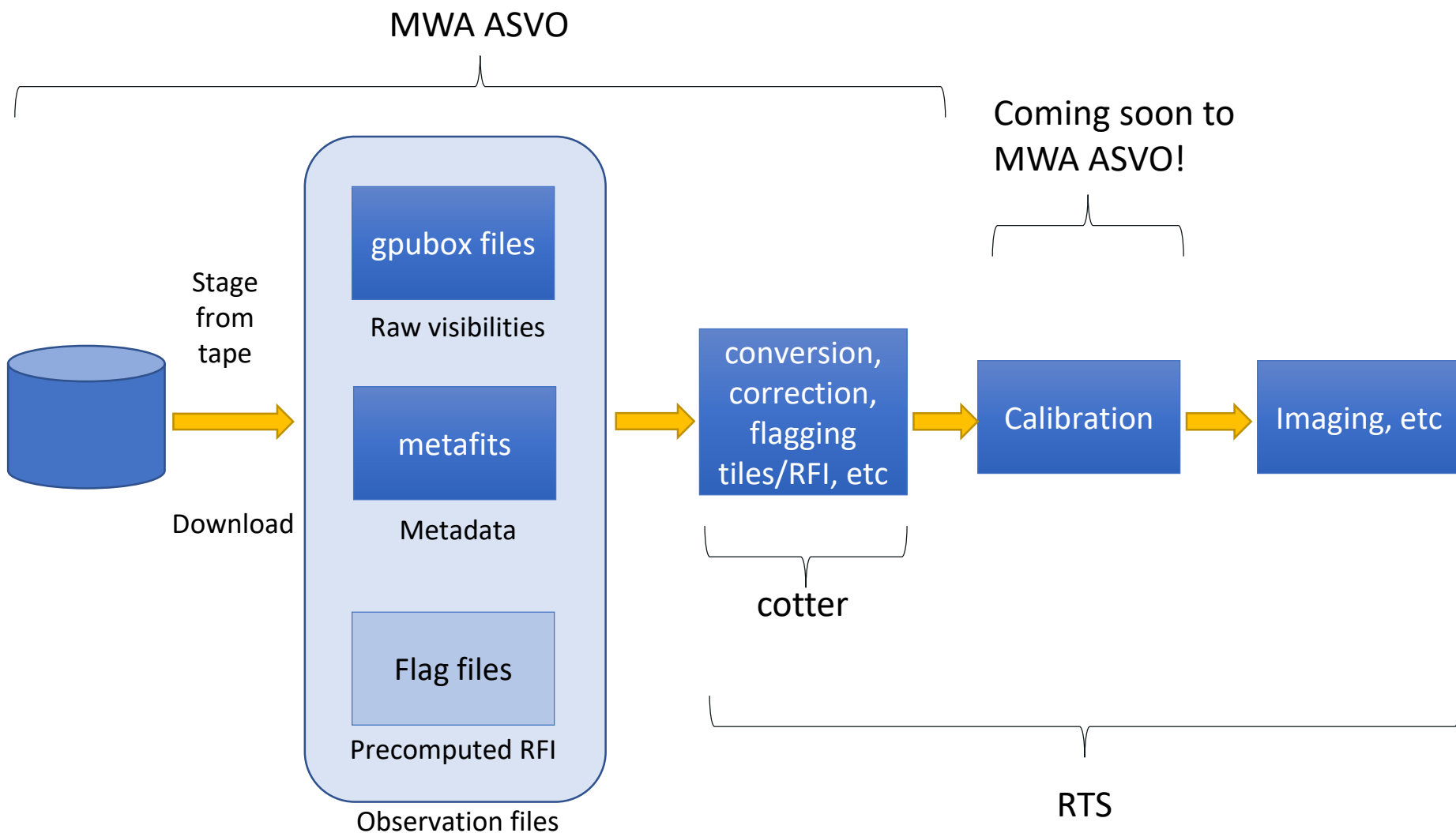
24 coarse channels

fine channels

1 coarse channel per gpubox file



General Workflow





Accessing MWA Data

- MWA All Sky Virtual Observatory (ASVO)
 - Launched late last year as a pilot
 - Website, VO service and Client/API
 - Allows access to public data (& non-public)
 - Provide uncalibrated raw visibilities
- Future
 - Produce images
 - Serve out MWA survey data





All Sky Virtual Observatory

- The All-Sky Virtual Observatory (ASVO) is enabling researchers to access data across a federated network of datasets, from all types of astronomical facilities in Australia.
- <http://www.asvo.org.au>
- TAO
- Skymapper
- AAO Data Central
- CASDA
- MWA





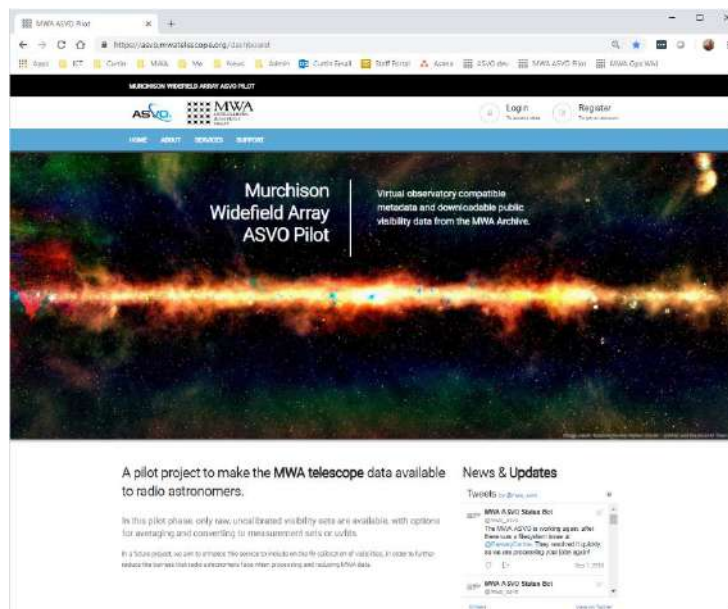
What Is the MWA ASVO?

- Download raw or converted un-calibrated visibilities from the MWA Archive
- Developed by Curtin, UWA and Pawsey with federal funding from AAL
- Website
 - Web front end
 - Cone search
- VO TAP Service
 - IVOA compliant Table Access Protocol (TAP) to discover MWA public data (courtesy CSIRO/CASDA)
 - Extract standardised “obscure” metadata for public observations using TopCat, etc
- Python 2 & 3 API (manta-ray-client on github)
 - Can perform similar functions as web front end
 - Replaces obsdownload
- Backend
 - Throttled queue system to ensure Pawsey’s systems cannot be overloaded
 - Uses André Offringa’s cotter preprocessing tool



Register!

- <https://asvo.mwatelescope.org>
- Fill in registration
- Verify your email address
- Await activation email from admin (me!)





Searching for observations

MWA ASVO Pilot - Search for Observations

https://asvo.mwatelescope.org/vo_query_form

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MURCHISON WIDEFIELD ARRAY ASVO PILOT

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Search for Observations | Data Jobs Conversion/Download

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Search for Observations

Cone Search | Search using ADQL

Cone Right Ascension (deg): 100

Cone Declination (deg): -20

Cone Radius (deg): 1

☐ Also include results where the cone is anywhere within the primary beam

Date From (UTC):

Date To (UTC):

Duration From (sec):

Duration To (sec):

Project:

Output Format:

☐ Download (votable/XML)

☒ Show on this page

Record limit: 500

Search

Show 10 entries Search:

Export Conversion | Export Visibility | Select all | Select none

Showing 1 to 10 of 45 entries Previous 1 2 3 4 5 Next

ID	Url	Name	Project ID	Description	Creator	Size (bytes)	RA (deg)	Dec (deg)	FOV (deg)	Start time (UTC)	End Time (UTC)	Duration (s)	Lower Freq (MHz)	Upper Freq (MHz)
1131210912	1131210912	FDS_DEC-19.9.235	G0006	GLEAM	tfranzen	43359437808	93.194	-19.882	20	2015-11-10 19:28:15.974	2015-11-10 19:30:08.035	112	285	315
1131219152	1131219152	FDS_DEC-19.9.235	G0006	GLEAM	tfranzen	433593643224	93.197	-19.881	20	2015-11-10 19:32:15.393	2015-11-10 19:34:07.968	112	285	315
1131219392	1131219392	FDS_DEC-19.9.235	G0006	GLEAM	tfranzen	43645223742	100.2	-19.879	20	2015-11-10 19:36:16.012	2015-11-10 19:38:07.907	112	285	315
1131219629	1131219629	FDS_DEC-19.9.235	G0006	GLEAM	tfranzen	43223270617	105.203	-19.878	20	2015-11-10	2015-11-10	112	285	315



Data Jobs

- Produces a zip file of data products which are stored for 7 days on our servers at Pawsey
- Download
 - Just stage and download raw visibilities
 - Output is gpubox files, metafits, ppds and flags
 - Equivalent to obsdownload
- Conversion
 - Uses cotter to convert and time/frequency average
 - Tile and RFI flagging
 - Corrections (e.g. passband, etc)
 - Output is CASA Measurement Set or uvfits



Conversion Job Options

MWA ASVO Pilot - Search for Cl... MWA ASVO Pilot - New Data Job

https://asvo.mwatelescope.org/job_dashboard?obs_id=1131218912

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New Data Job

Data Conversion Job

Observation ID 1131218912

Time Resolution (s) 4

Freq Resolution (kHz) 40

Edge Width (kHz) 80

Output ☒ Measurement Set ☐ UVFITS

☐ Disable RFI detection

☐ Disable collecting stats

☐ Disable geometric corrections

☐ Do not remove the flagged antennae

☒ Do not flag auto-correlations

☐ Do not correct for the digital gains

☐ Do not flag missing vis files

☒ Do not abort when not all vis files are available

☒ Flag the centre channel of each coarse channel

☐ Centre on pointing centre

☐ Apply unity pass-band

Create



Download Job Options

MWA ASVO Pilot - Search for Obs X MWA ASVO Pilot - New Data Job X

https://asvo.mwatelescope.org/job_dashboard?obs_id=1131218912#download

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New Data Job

Data Conversion Job Data Download Job

- > This type of job allows you to download raw MWA visibility data in fits format.
- > This option is only for advanced users as the data is in an MWA-specific format fits file.

Observation ID 1131218912

Download:

☒ Visibilities, PPD, Metafits and Flags

☐ PPD, Metafits and Flags

Create

Murchison Widefield Array ASVO Pilot © Copyright 2018. All Rights Reserved.

https://asvo.mwatelescope.org/job_dashboard?obs_id=1131218912#download



Monitoring Jobs

MWA ASVO Pilot - Search for Observations | MWA ASVO Pilot - Data Jobs

https://asvo.mwatelescope.org/job_results

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Data Jobs

New Data Job

Job ID	Observation ID	Details	Created (UTC)	Modified (UTC)	
57538 Completed	1151161304	Data Conversion Job Parameters Download URLs	2018-09-27T23:47:52.951Z	2018-09-28T00:51:58.770Z	Download (1.43GB) sha1: 67ae1e066ebd424ca76cc021ae5923f62de22dc95 Expires on 2018-10-02T00:51:58.776Z
57222 Completed	1151161304	Data Download Job PPD, Metafits and Flags Download URLs	2018-09-27T05:34:16.362Z	2018-09-27T05:43:27.685Z	Download (0.01GB) sha1: 2982dd1fb1a382081d5acc6dd9f1a219d5a7a5b Expires on 2018-10-04T05:43:27.685Z
57221 Completed	1151161304	Data Conversion Job Parameters Download URLs	2018-09-27T05:34:16.341Z	2018-09-27T06:34:39.002Z	Download (1.40GB) sha1: be90e37038e0edcf0b4762ce60c6e12bx1da27 Expires on 2018-10-04T06:34:39.002Z



Downloading Job Results

- All successful job results are in a single .zip
- Download using wget (browser is ok for small files)
 - `wget "URL" -O file.zip`
- All files show an SHA1 checksum
- Check it matches with:
 - `sha1sum file.zip`

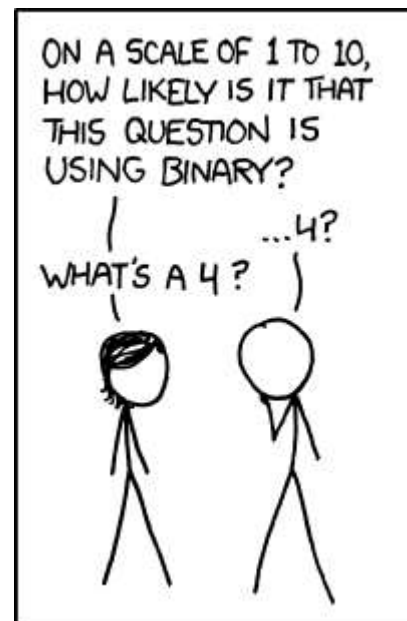


Image: xkcd



Python client & API

- Known as: manta-ray-client
- On github <https://github.com/ICRAR/manta-ray-client>
- Python 2.7 / 3.6 compatible
- Can be used “all-in-one” (submit job(s), wait for them to finish then download data)

Or

- Submit job(s), then exit
- List my jobs, then exit
- Download all my jobs (or one), then exit





Python client & API (cont...)

- Example csv file contents

```
# Do a conversion job
```

```
obs_id=1110103576, job_type=c, timeres=8, freqres=40, edgewidth=80, conversion=ms, allowmissing=true
```

```
# Do a download job
```

```
obs_id=1110103576, job_type=d, download_type=vis
```

- Example usages

```
mwa_client -c csvfile -d destdir
```

Submit jobs in the csv file, monitor them, then download the files, then exit

```
mwa_client -c csvfile -s
```

Submit jobs in the csv file, then exit

```
mwa_client -d destdir -w JOBID
```

Download the job id (assuming it is ready to download), then exit

```
mwa_client -d destdir -w all
```

Download any ready to download jobs, then exit

```
mwa_client -d destdir -w all -e error_file
```

Download any ready to download jobs, then exit, writing any errors to error_file

```
mwa_client -l
```

List all of your jobs and their status, then exit



IVOA TAP service

- TAP = Table Access Protocol
- http://vo.mwatelescope.org:8000/mwa_asvo/tap
- Supports “obscure” schema
- Basic metadata for observations:
 - Obs_id
 - RA
 - Dec
 - Duration
 - etc
- More comprehensive metadata will be added in the future
- Rich application support:
 - Aladin
 - CDS
 - Skyview
 - SPLAT
 - TOPCAT
 - Etc
- For more info see: <http://www.ivoa.net/astronomers/index.html>





Other Useful Resources

- Observation Summary Website

<http://mro.mwa128t.org/observation/obs/?obsid=obsid>

- In the future, will be merged into the MWA ASVO

MWA Observation 1115977528

[Previous Observation](#) [Next Observation](#)

Observation Settings:

Observation ID:	Project ID:	Start Time (UTC):	Stop Time (GPS):	Stop Time (UTC):	Duration (sec):	Obs Name:	Creator:	Corr. Mode:	Corr. Freq. Res.:	Corr. Int. Time:	Data Quality:	Data Comment:
1115977528	G0023 - Shadowing Kepler K2	2015-05-18 09:45:12.000	1115977824	2015-05-18 09:50:05.000	296	K2_F5_121_1waydb	HW_1FILE6	40	1.0		Good	

Schedule Metadata:

Az/El (deg):	RA/Dec (deg):	Sun Elevation:	Sun Pointing Dist.:	Jupiter Dist.:	Moon Dist.:	Sky Temp (deg K):	Calibration?:	Calibrators:	Gridpoint Name:	Gridpoint Number:
350.5 / 43.9 deg	231.3 / 19.0 deg	-3.5 deg	71.7 deg	0.1 deg	99.5 deg	233.9 deg K	No		sweet	120

Quality Metadata:

Calibration QA:	RIS Calibration QA:	None QA:	Ionosphere Magnitude:	Ionosphere PCA:	Ionosphere QA:	Window Power:	Ionosphere absolute TEC:	UVFITS Path:	RIS Calibration source:	RIS Peel source:	Source List:	EOR Field:
None	None	None	None	None	None	None	None	None	None	None	None	None

RF Streams:

Number	RA / Dec	Az / El	Hex	Attenuation (db)	Channel List	THeader	Titles
0		350.5 / 43.9		1.0	[109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132]	all_on	All Tiles

Observing Summary

Configuration	AAVS 0.5	EDA	Good Tiles	Bad Tiles	Data Files recorded	Data Files Archived	Log Entries
PHASE1	False	127	8	120			2

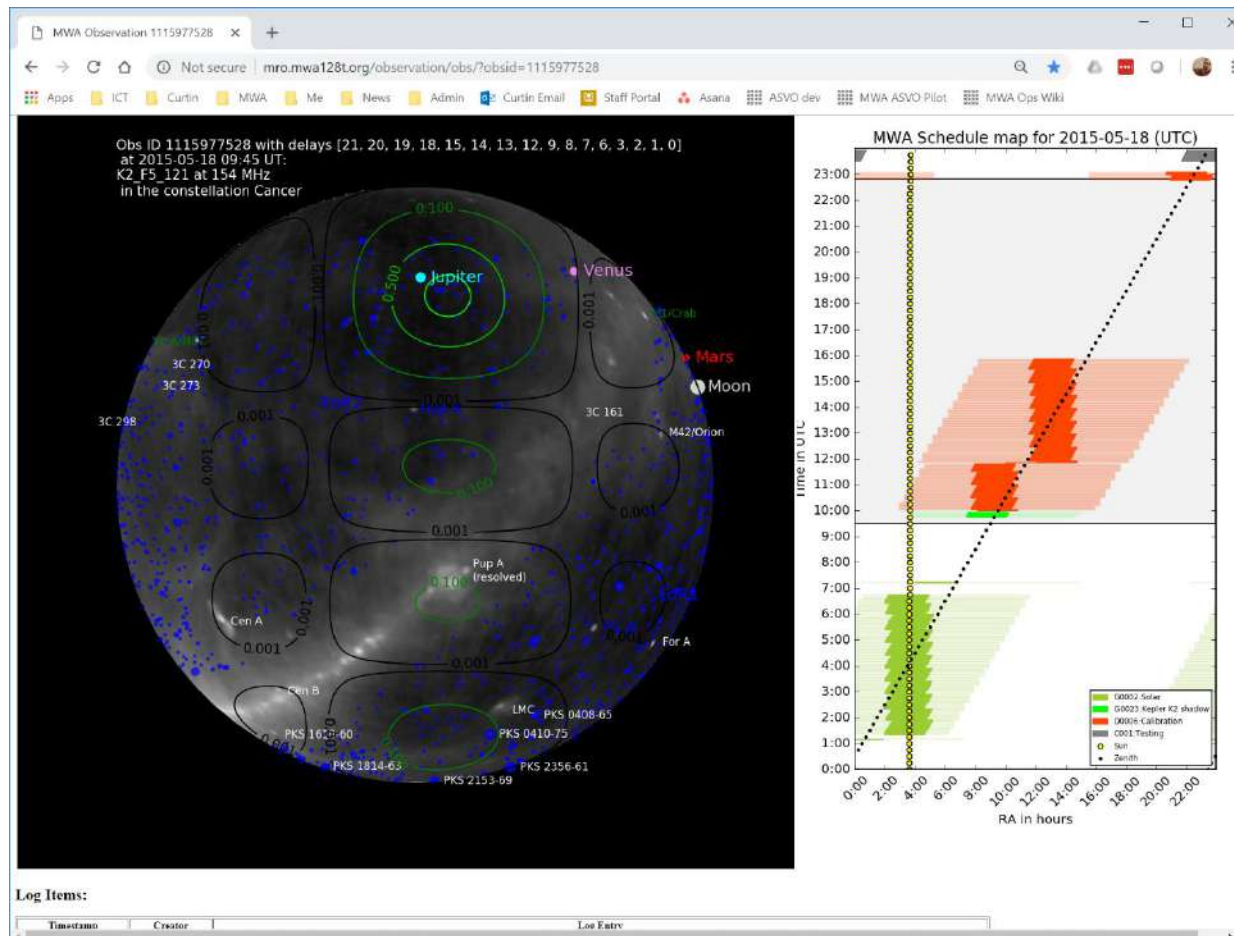
Schedule Command:

```
./mwa-local-bin/single_observation.py --starttime=2015-05-18:09:45:15 --stoptime=2015-05-18:09:50:05 --freq=121.24 --obsname=K2_F5_121_1 --intime=1 --freqres=10 --correl= --usegrid= --project=G0023 --ra=129.9 --dec=16.82
```



Observation Summary Website (cont...)

- Sky map, beam area & schedule map





Observation Summary Website (cont...)

- Status of the array at the time of the observation
- Number of bad tiles

MWA Observation 1115977528 x +

Not secure mro.mwa128t.org/observation/obs/?obsid=1115977528

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Log Items:

Timestamp	Creator	Log Entry
1115977528.0	rwayth	./usr/local/bin/single_observation.py --starttime=2015-05-18.09:45:15 --stoptime=++296s --freq=121.24 --obsname=K2_F5_121 --ltime=1 --freqres=40 --useazel --azgrid= --project=G0023 --ra=129.9 --dec=16.82
1115977528.0	locheck.py	No errors

Tile errors and flags

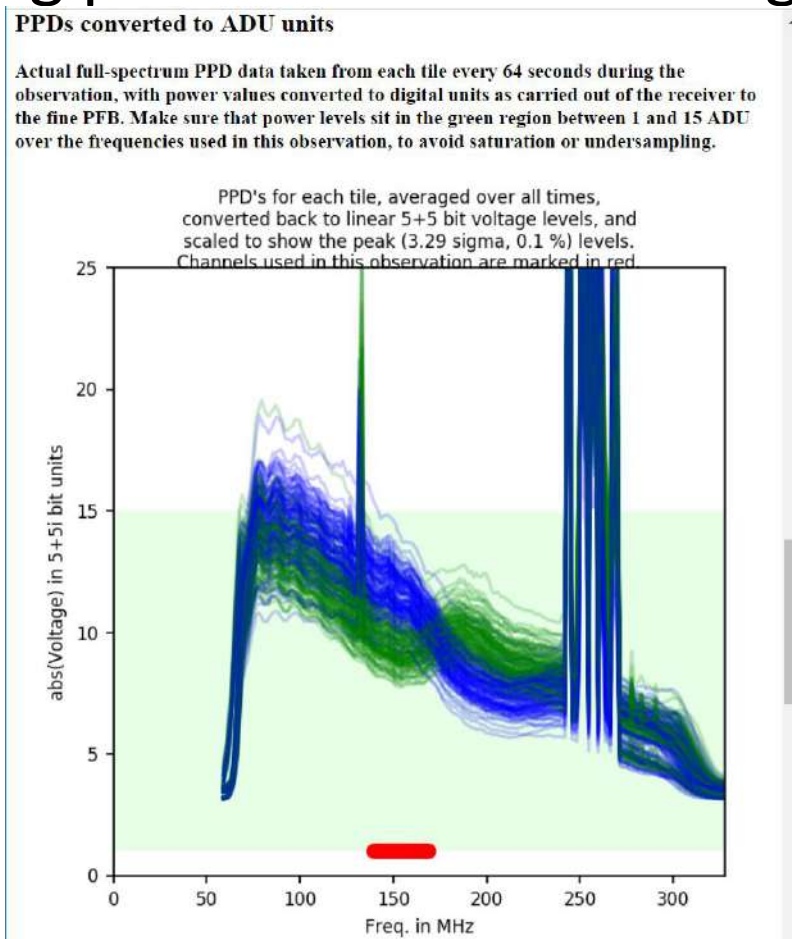
Obsid 1115977528	Rec01	Rec02	Rec03	Rec04	Rec05	Rec06	Rec07	Rec08	Rec09	Rec10	Rec11	Rec12	Rec13	Rec14	Rec15	Rec16
Slot 8	Tile018	Tile028	Tile038	Tile048	Tile058	Tile068	Tile078	Tile088	Tile098	Tile108	Tile118	Tile128	Tile138	Tile148	Tile158	Tile168
Slot 7	Tile017	Tile027	Tile037	Tile047	Tile057	Tile067	Tile077	Tile087	Tile097	Tile107	Tile117	Tile127	Tile137	Tile147	Tile157	Tile167
Slot 6	Tile016	Tile026	Tile036	Tile046	Tile056	Tile066	Tile076	Tile086	Tile096	Tile106	Tile116	Tile126	Tile136	Tile146	Tile156	Tile166
Slot 5	Tile015	Tile025	Tile035	Tile045	Tile055	Tile065	Tile075	Tile085	Tile095	Tile105	Tile115	Tile125	Tile135	Tile145	Tile155	Tile165
Slot 4	Tile014	Tile024	Tile034	Tile044	Tile054	Tile064	Tile074	Tile084	Tile094	Tile104	Tile114	Tile124	Tile134	Tile144	Tile154	Tile164
Slot 3	Tile013	Tile023	Tile033	Tile043	Tile053	Tile063	Tile073	Tile083	Tile093	Tile103	Tile113	Tile123	Tile133	Tile143	Tile153	Tile163
Slot 2	Tile012	Tile022	Tile032	Tile042	Tile052	Tile062	Tile072	Tile082	Tile092	Tile102	Tile112	Tile122	Tile132	Tile142	Tile152	Tile162
Slot 1	Tile011	Tile021	Tile031	Tile041	Tile051	Tile061	Tile071	Tile081	Tile091	Tile101	Tile111	Tile121	Tile131	Tile141	Tile151	Tile161
RecNNN	Bad receiver state (no comms, error setting attenuation or freq channels, etc.)															
TileNNN	Beamformer communication error when pointing tile.															
TileNNN	Tile flagged in the tile_flags table.															
TileNNN	2 or more disabled dipoles in the same polarisation.															
TileNNN	Good tile - no errors, not flagged.															

Tile Name	Creator	From	To	Reason for flagging
Tile103	Randall	2015-02-26 06:00 UTC	2015-05-21 12:00 UTC	dead RF



Observation Summary Website (cont...)

- PPD showing power of all tiles averaged and scaled



Thank You!

Greg Sleap

MWA Data Manager

greg.sleap@curtin.edu.au

asvo_support@mwaterlescope.org

 @mwa_asvo

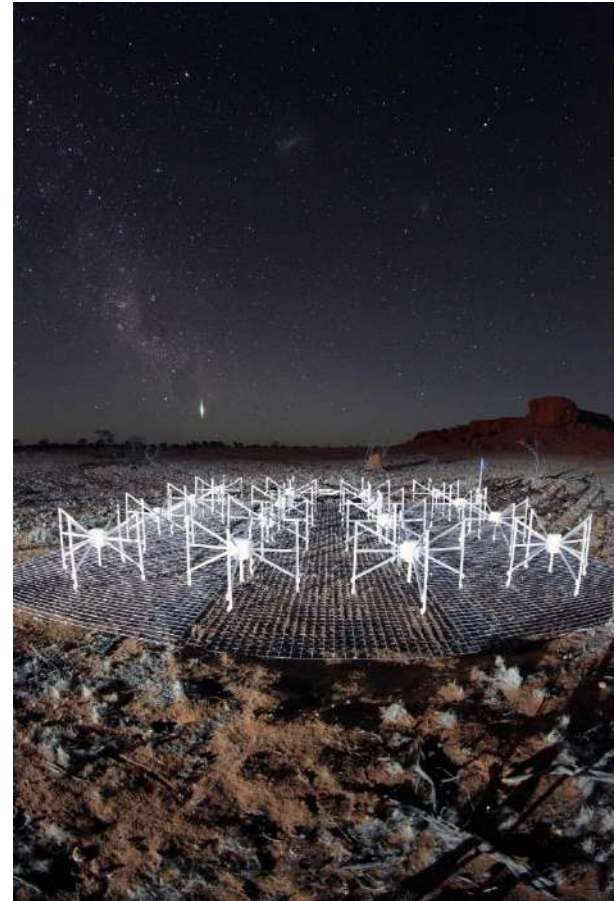


Image credit: John Goldsmith, 2012