Data processing with ASKAPsoft

The ASKAP Central Processor

Daniel Mitchell

2018 ICRAR/CASS Radio School

Before we start...

- What is the purpose of this lecture?
  - To know what ASKAPsoft is
  - To know how to use it
  - To know how ASKAP pipeline images are made
  - To prepare for the tutorials
- What is the purpose of the tutorials?
  - To gain experience with calibration and imaging
  - To gain experience with ASKAPsoft
  - To know what ASKAP pipelines do and what to look for

Overview

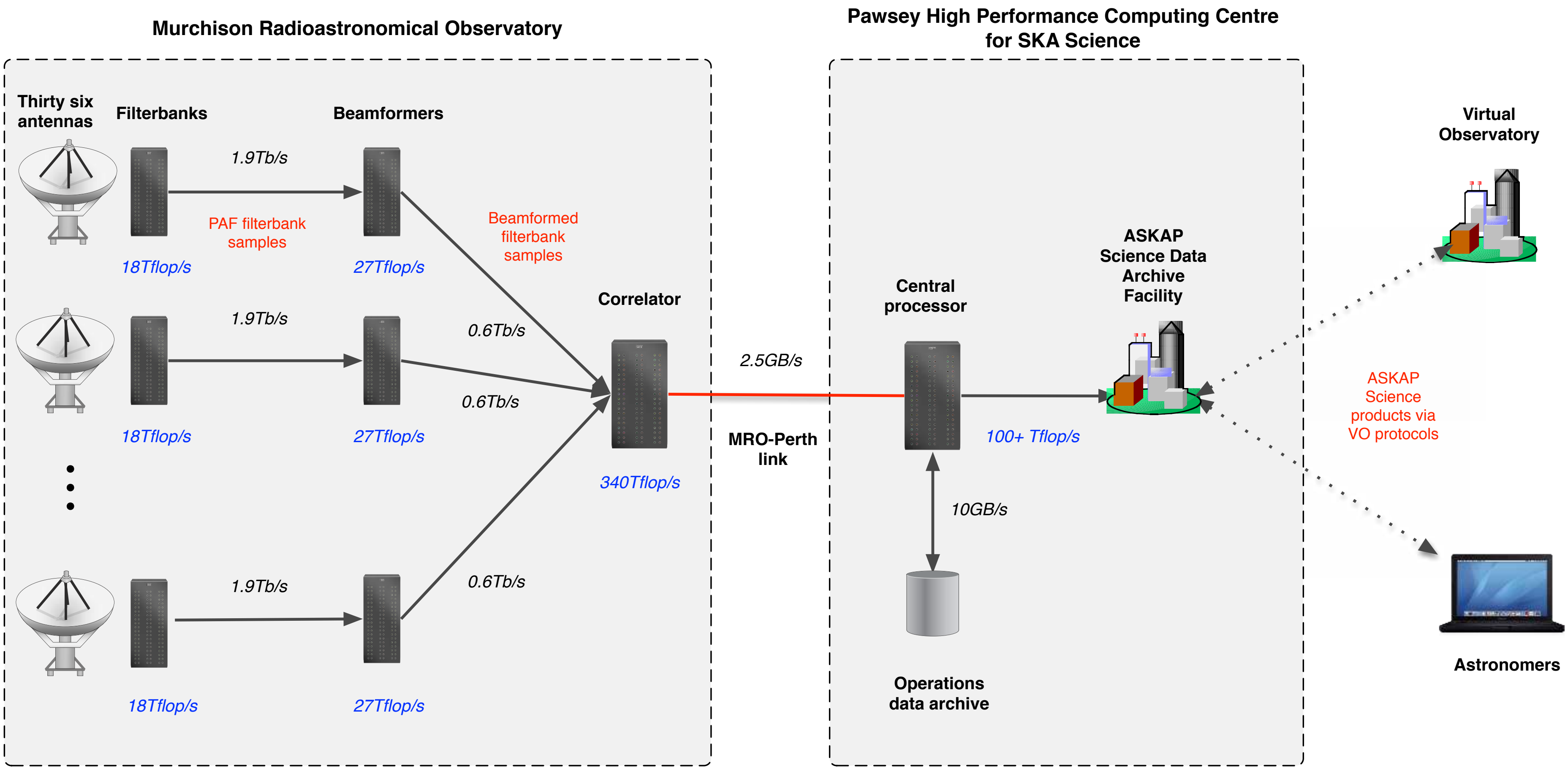
- A brief overview of ASKAP
- A brief look at the ASKAPsoft pipeline
- A closer look at ASKAPsoft
  - Some of the things ASKAPsoft does differently
  - Common ASKAPsoft tasks
- A walk through the tutorial

A brief overview of ASKAP

Key Features

- 36 x 12m antennas forming a radio synthesis array (< 6 km)
- Use of phased array feeds for wide field of view (30 square degrees)
- Operation at centimetre wavelengths @ 300 MHz bandwidth
- Situated in an isolated location, operated remotely, without a dedicated maintenance staff on-site
- Large data volumes (2.8 GB/s) which will require distributed processing
- Fully automated pipelined processing for many use cases
- Primarily survey instrument, service (queue) observing & dynamic scheduling

ASKAP Data Flow



T. Cornwell, February 22 2010

Central Processor (CP)

- CP Hardware
  - Ingest nodes (16 x node cluster)
  - 1 PB fast storage for scratch space + fast interconnect (> 10 GB/s)
  - 472 CPU nodes, 64 GB/node (Galaxy CPU nodes)
  - Head nodes and external access nodes
- CP Software (ASKAPsoft)
  - Test Framework (incl. simulators)
  - Real-time Services (manager, ingest, RFI, sky model, calibration data)
  - Calibration and Imaging Pipelines (data distribution framework, calibration, continuum, spectral line, source finder, slow transient, continuum-10”, postage stamps, zoom modes, pipeline scripts)
  - CASDA upload

A brief look at the ASKAPsoft pipeline

The Current Pipeline

1 - Fetch metadata – footprint, frequencies

2 – What tasks are required Calibration? Continuum, Spectral line?

3 – Assuming bandpass calibration is required: Fetch calibration observation of 1934-638 → Match the relevant beam → Flag the calibration data as requested / required → Generate bandpass solution

4 – Get science data → Apply calibration → Apply flags → Average to 1MHz → Image via MSMFS and continuum cube → Form sky model for self cal → Perform – self cal loops as required

5 – Mosaick all beams together

6 – Run spectral line pipeline → Apply calibration to full resolution data → Subtract best model → Image each channel parallel by frequency → Image domain continuum subtraction

7 – Detect sources → Validation → Archiving

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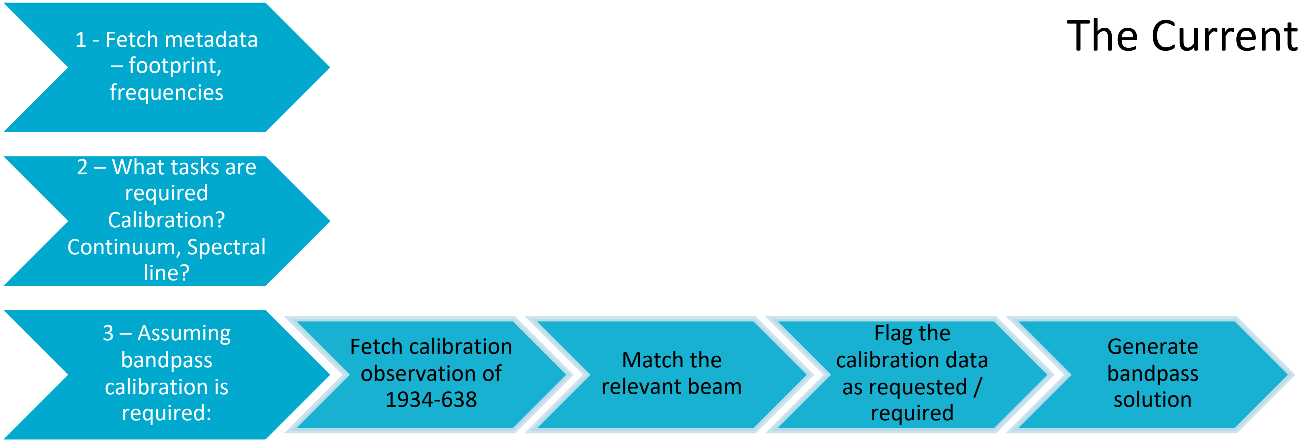

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CSIRO

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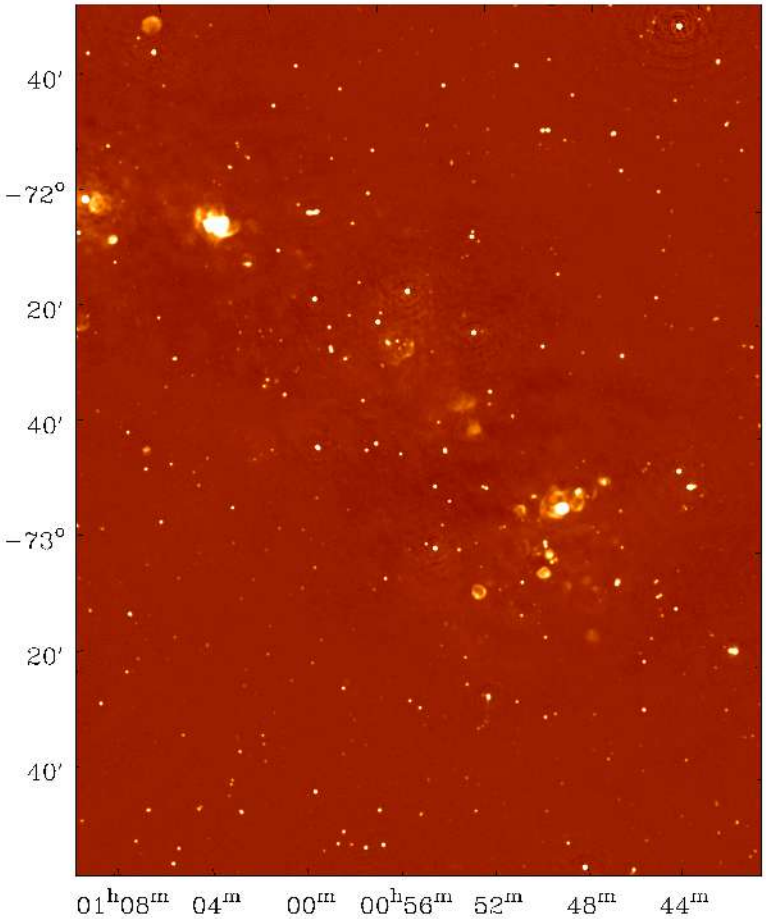
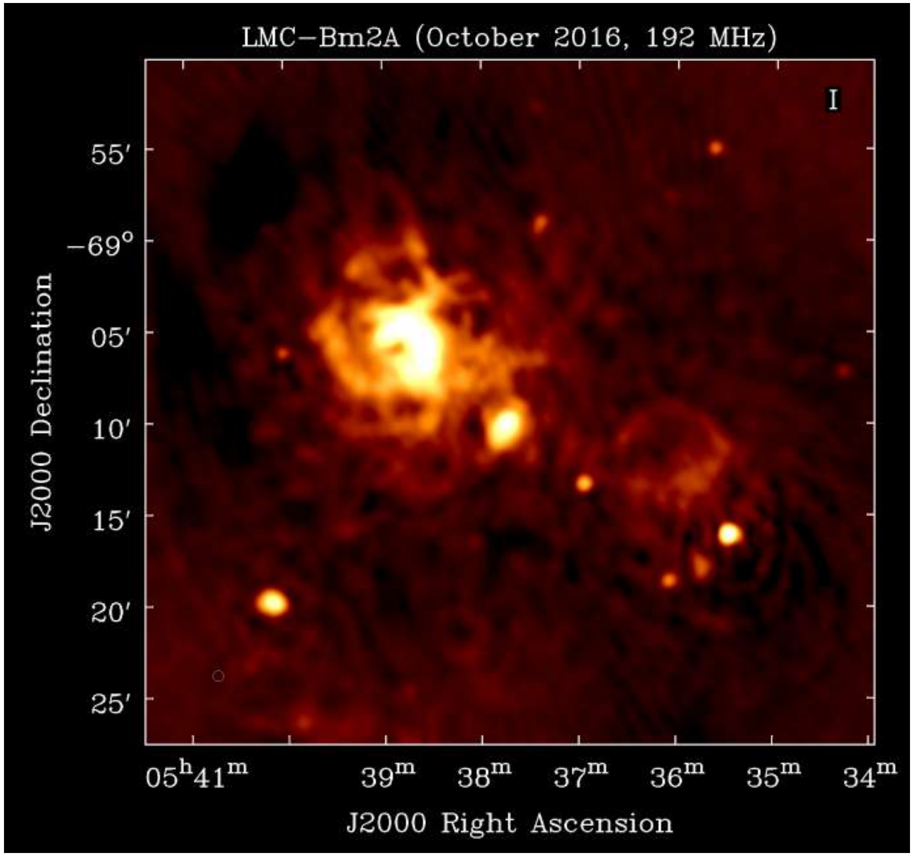
LMC and SMC





Thanks to Wasim Raja

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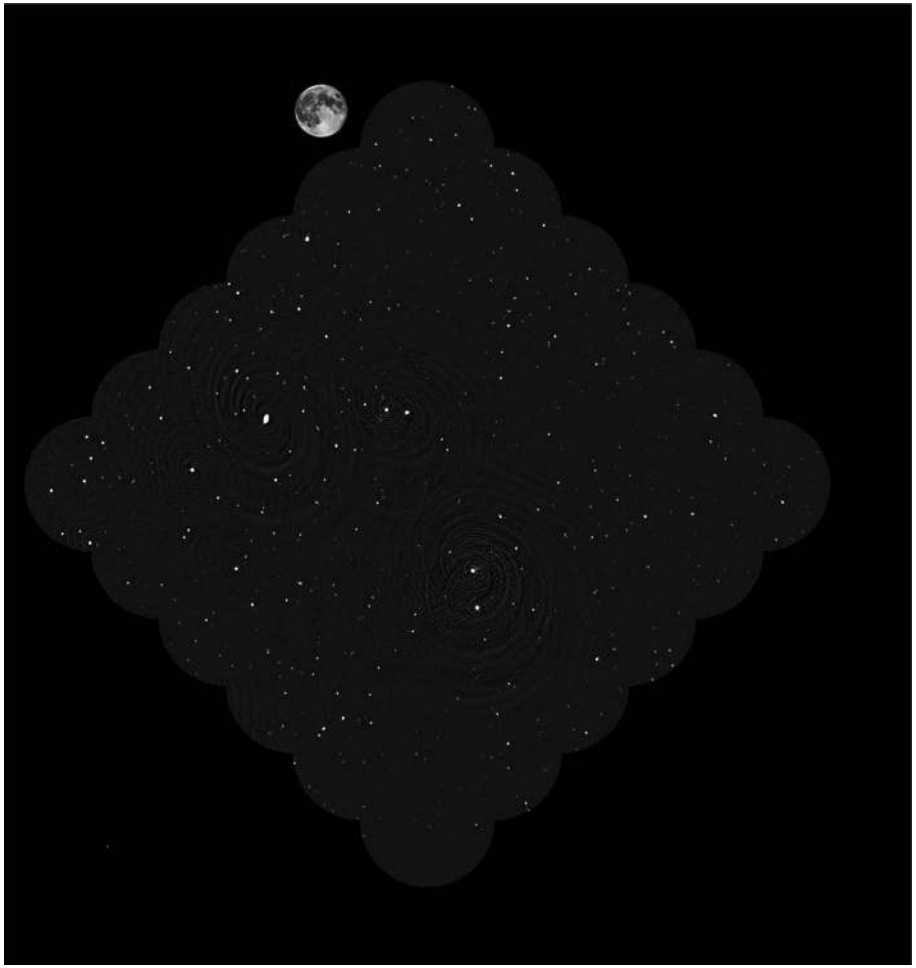
11 hr observations of the APUS field – Thanks to Wasim Raja

30+ sq. degrees
f_c = 939.5MHz
BW = 48MHz

RMS noise in image: 300µJy/Beam (Theoretically ~150-200µJy/Beam)
Dynamic range: 1.4 X 10^4

CROSS Matching: (courtesy, Martin Bell, using the VAST pipeline)
No. of sources detected: 1380 (above 7σ)
RMS Pointing error: ~7’’ (In comparison, Synthesised Beam: ~60’’X60’’)"



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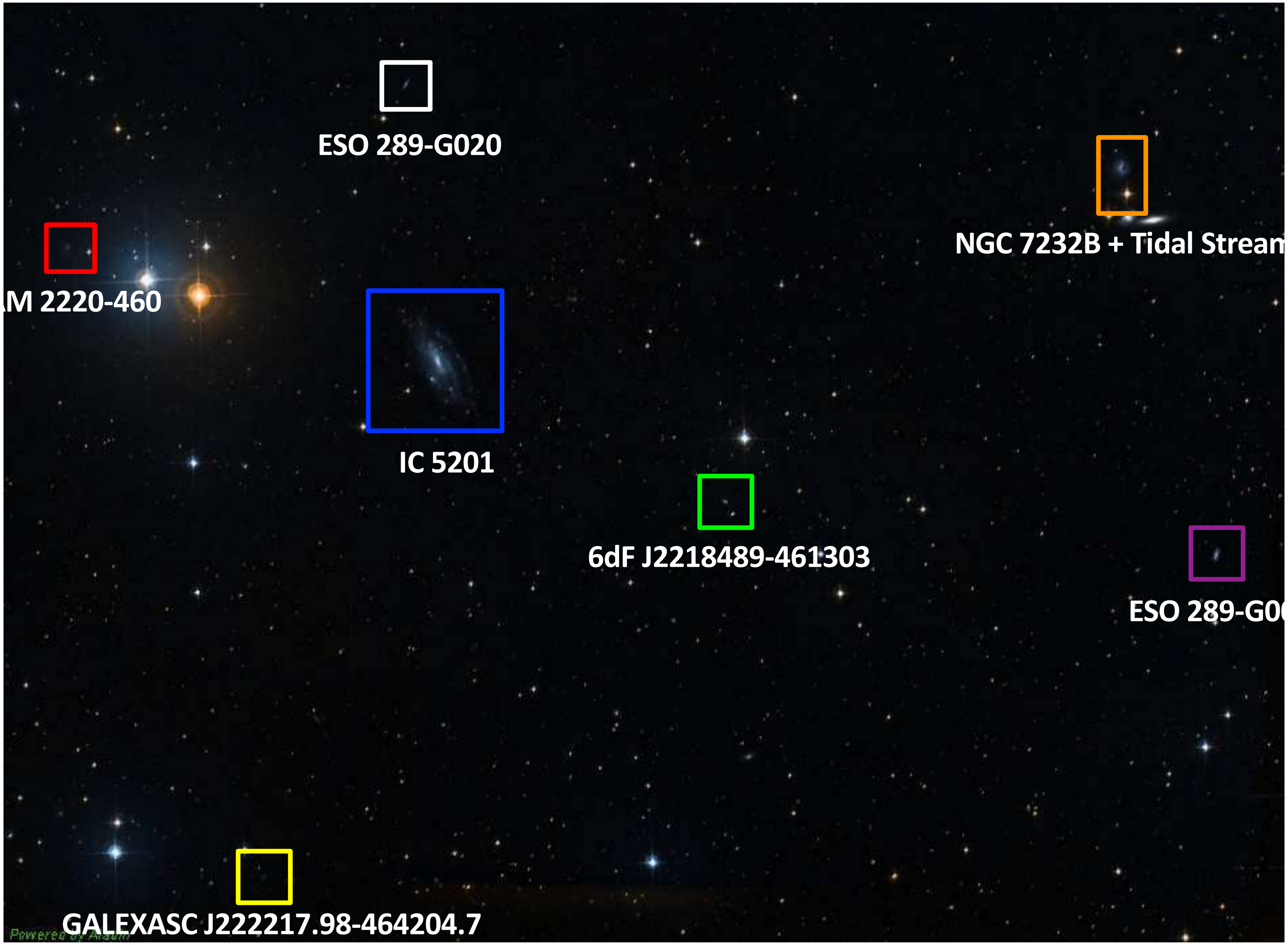
NGC 7232 Field. Thanks to Dane Kleiner and the WALLABY team



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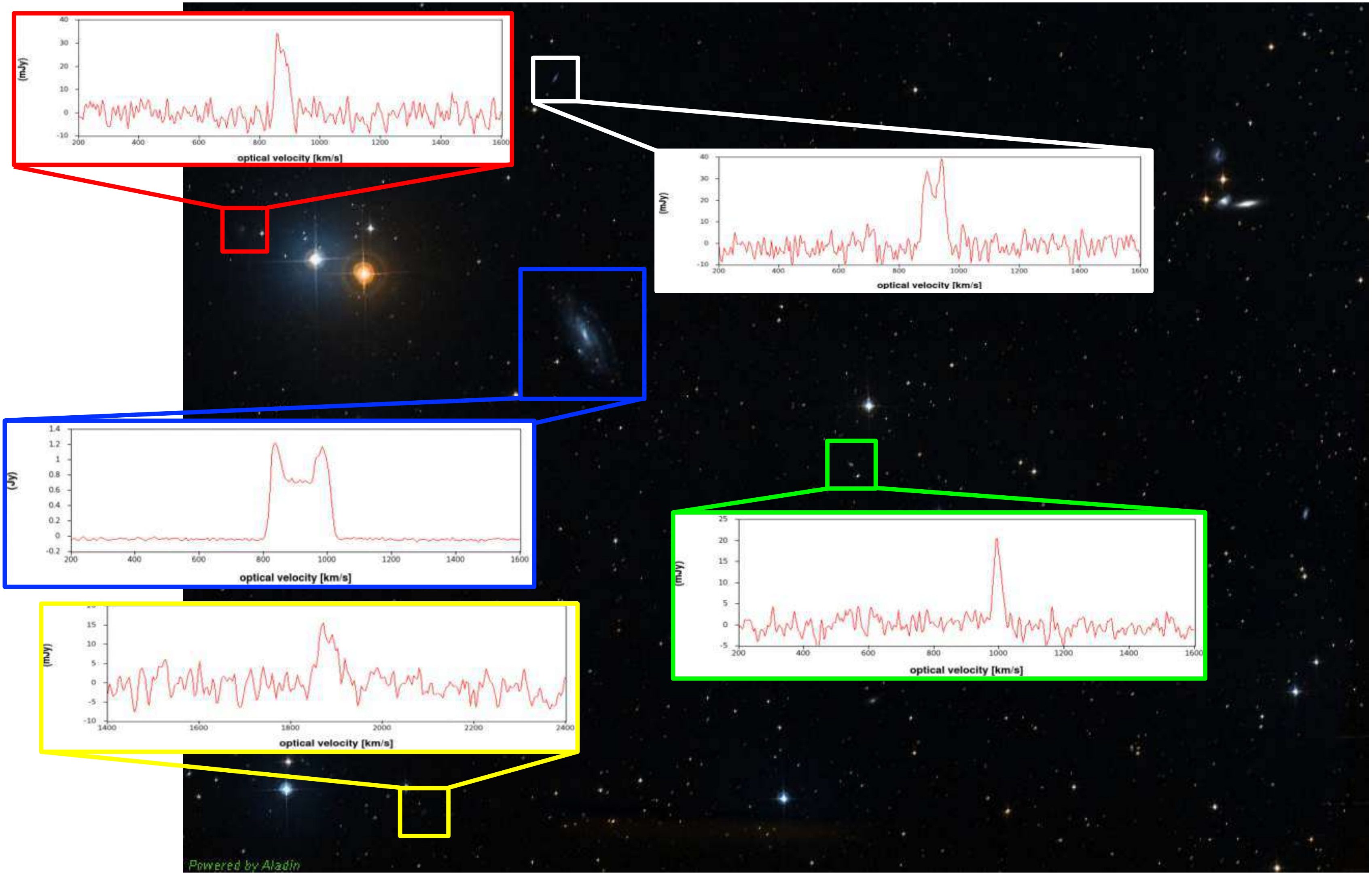

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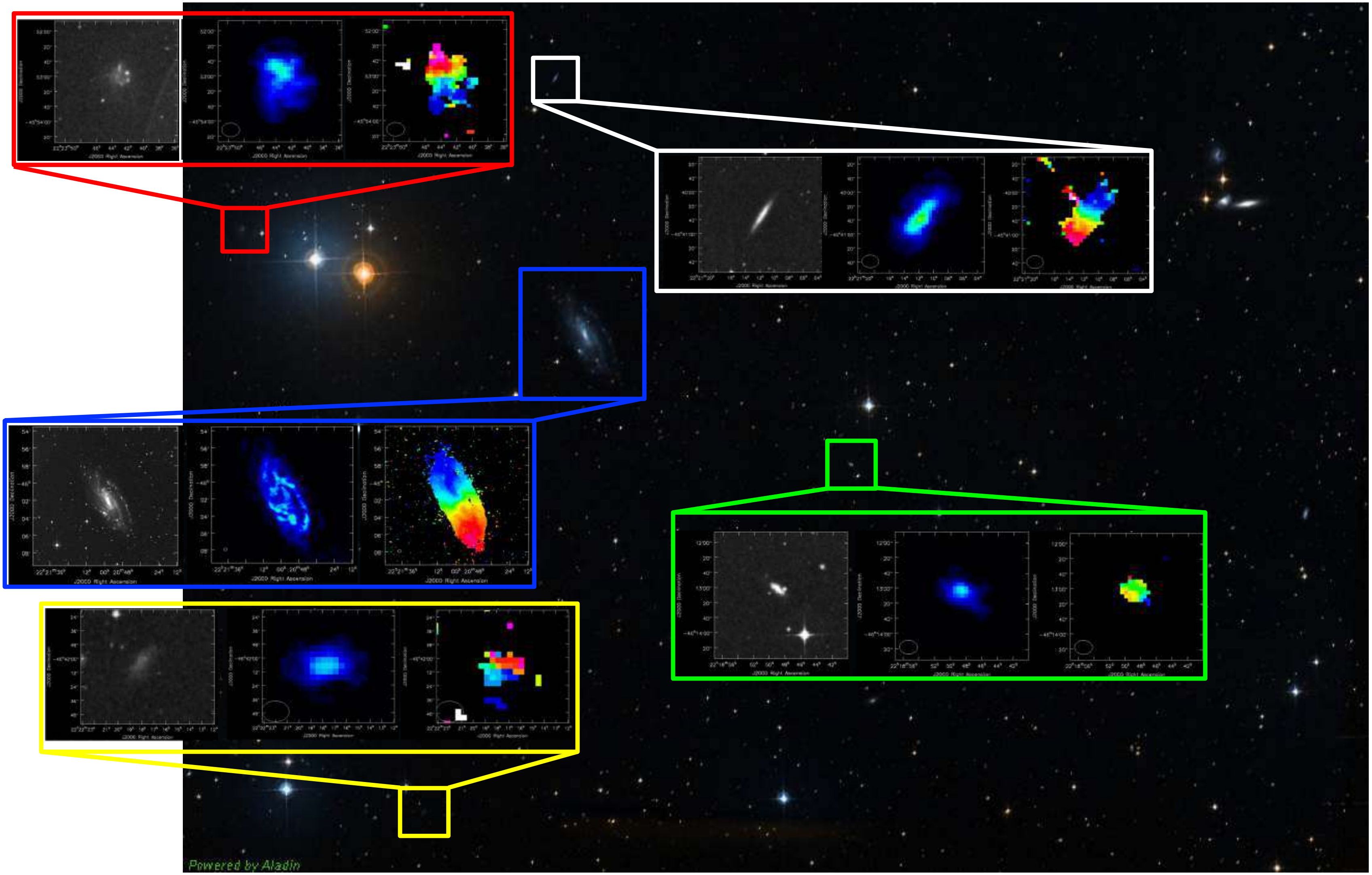

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A closer look at ASKAPsoft

ASKAPsoft

- A suite of calibration and imaging tasks built primarily for ASKAP pipelines.
- Built from the start for large-scale high-performance computing.
- Has a range of calibration tasks
- Has a range of imaging tasks and algorithms:
  - gridders: Box, SphFunc, WProject, WStack, AWProject, AProjectWStack
  - solvers: Hogbom, MultiScale, MultiScaleMFS and BasisfunctionMFS
  - preconditioners: Wiener, GaussianTaper
- Has a linear mosaicking task
- Has a source finding task
- Has tasks for vis simulation, flagging, splitting, merging, etc.

ASKAPsoft User Documentation

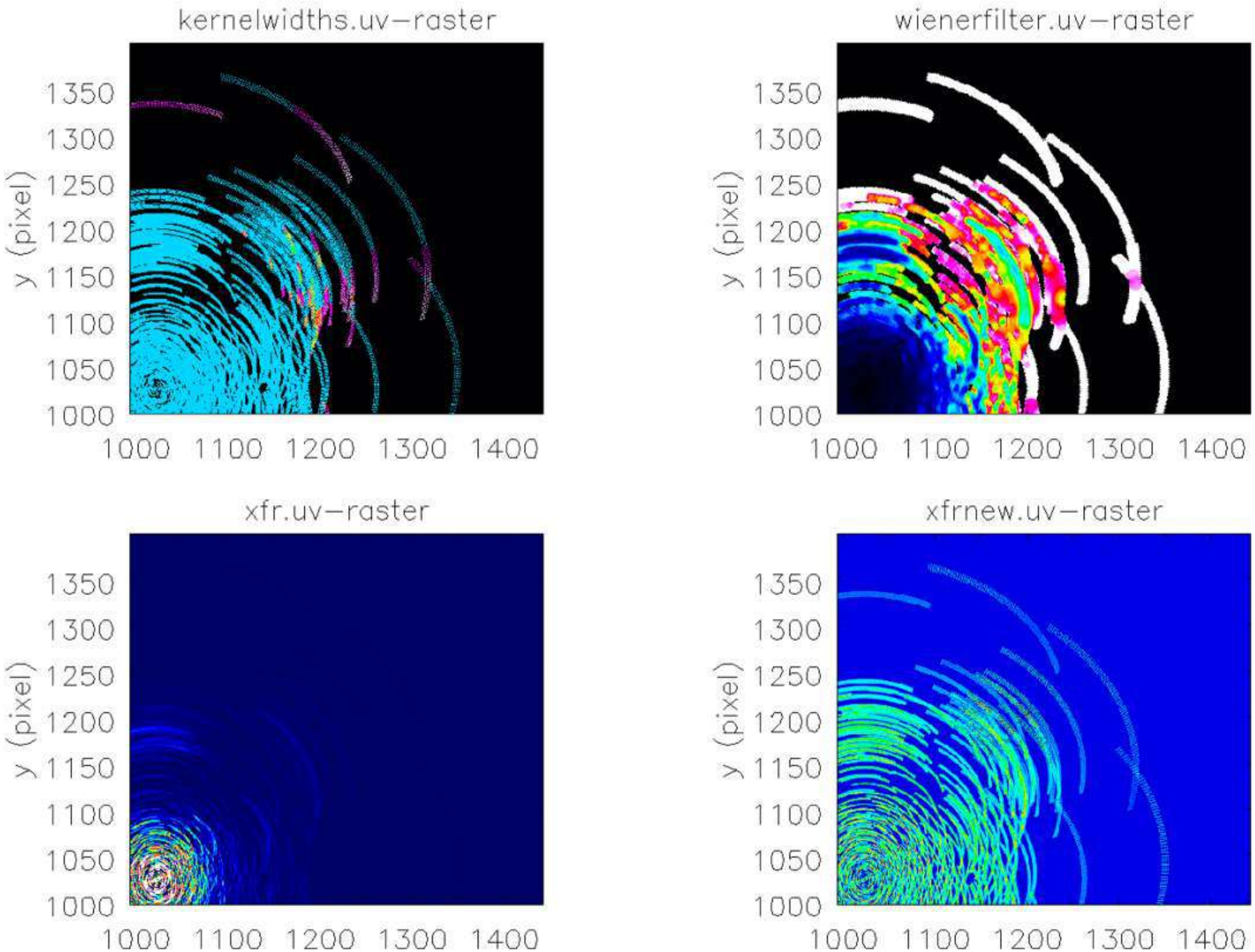
- https://www.atnf.csiro.au/computing/software/askapsoft/sdp/docs/current/
- https://www.atnf.csiro.au/computing/software/askapsoft/sdp/docs/nightly/
- Introduction
- Platform Documentation
- General Documentation
- Calibration and Imaging Documentation
- Source-Finding Documentation
- Utilities
- Services Documentation
- ASKAP Processing Pipelines
- Tutorials
- Recipes

Some of the things ASKAPsoft does differently

Preconditioning

- "Precondition" dirty images and PSFs for deconvolution
- Like standard weighting and tapering, but applied *after* gridding to uv cells rather than visibilities
  - e.g. uniform weight, robust weighting, Gaussian uv tapers
  - Uniform weighting is basically a Wiener filter
- Done to avoid multiple reads of very large visibility data sets
- Various complications when it comes to wide-field imaging
- Is it still needed for ASKAP processing?
  - Continuum visibilities: *relatively* small → use standard vis weighting?
  - Spectral line visibilities: separate weights per channel, and single-channel visibilities are *relatively* small → use standard vis weighting?

Preconditioning



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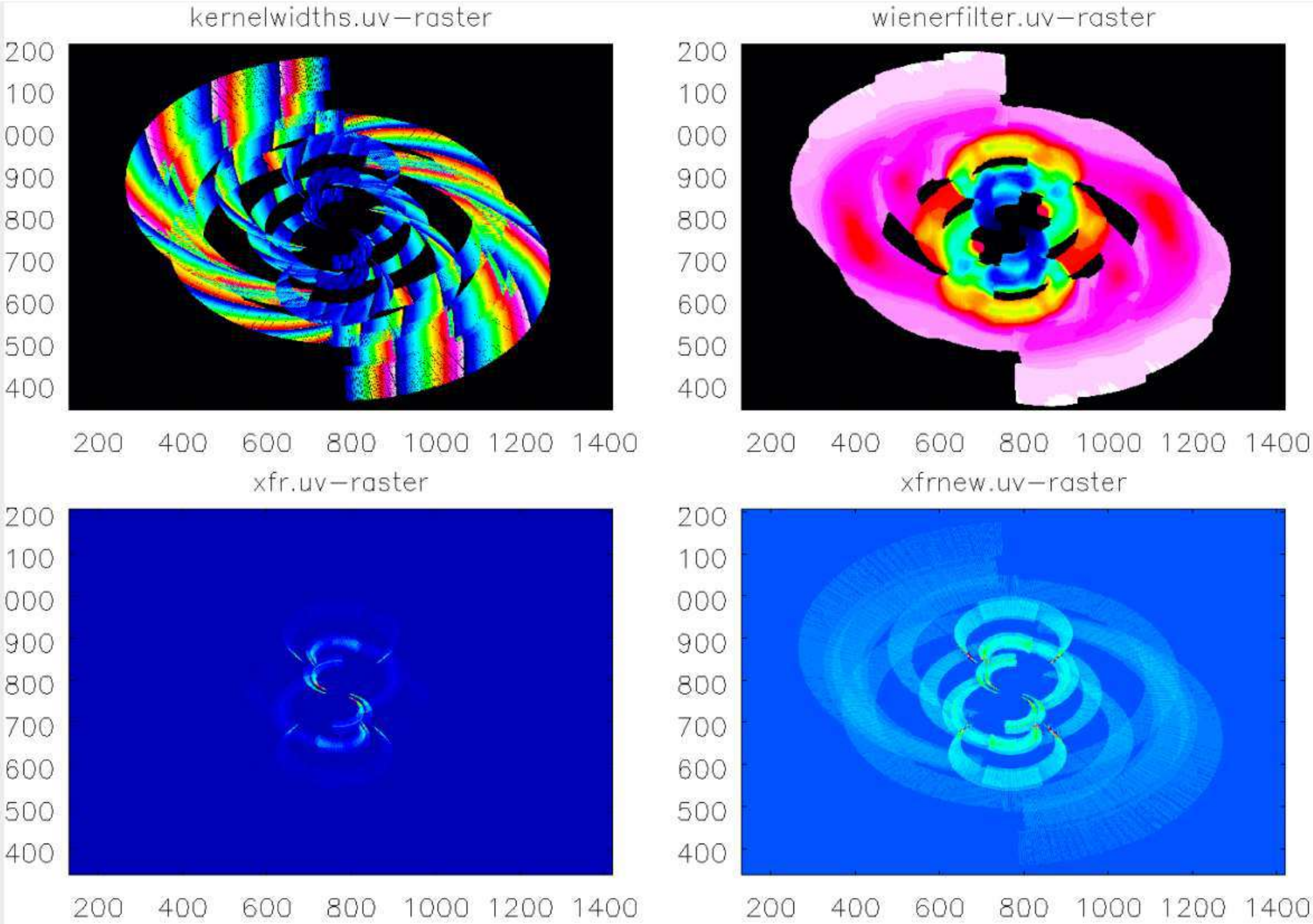

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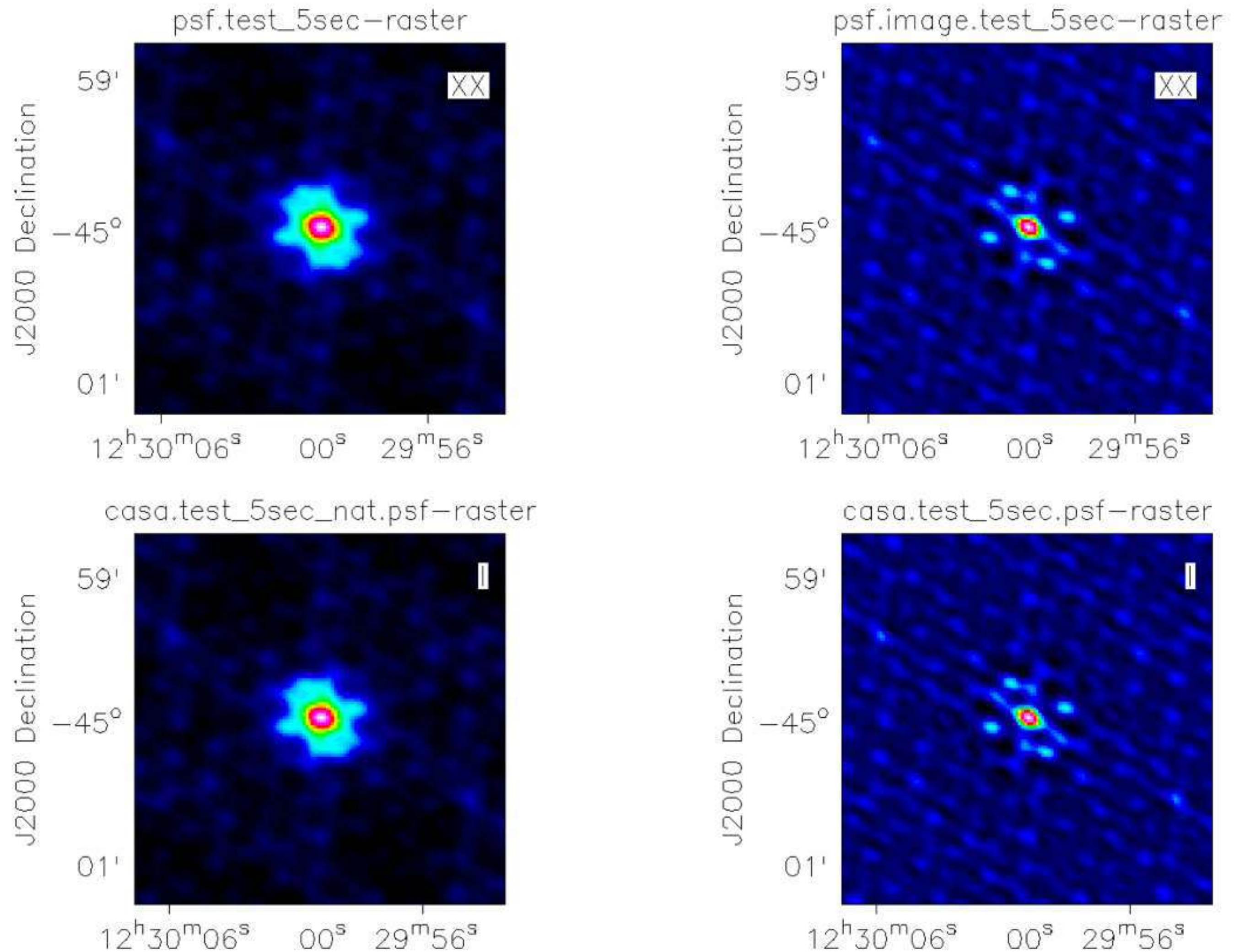

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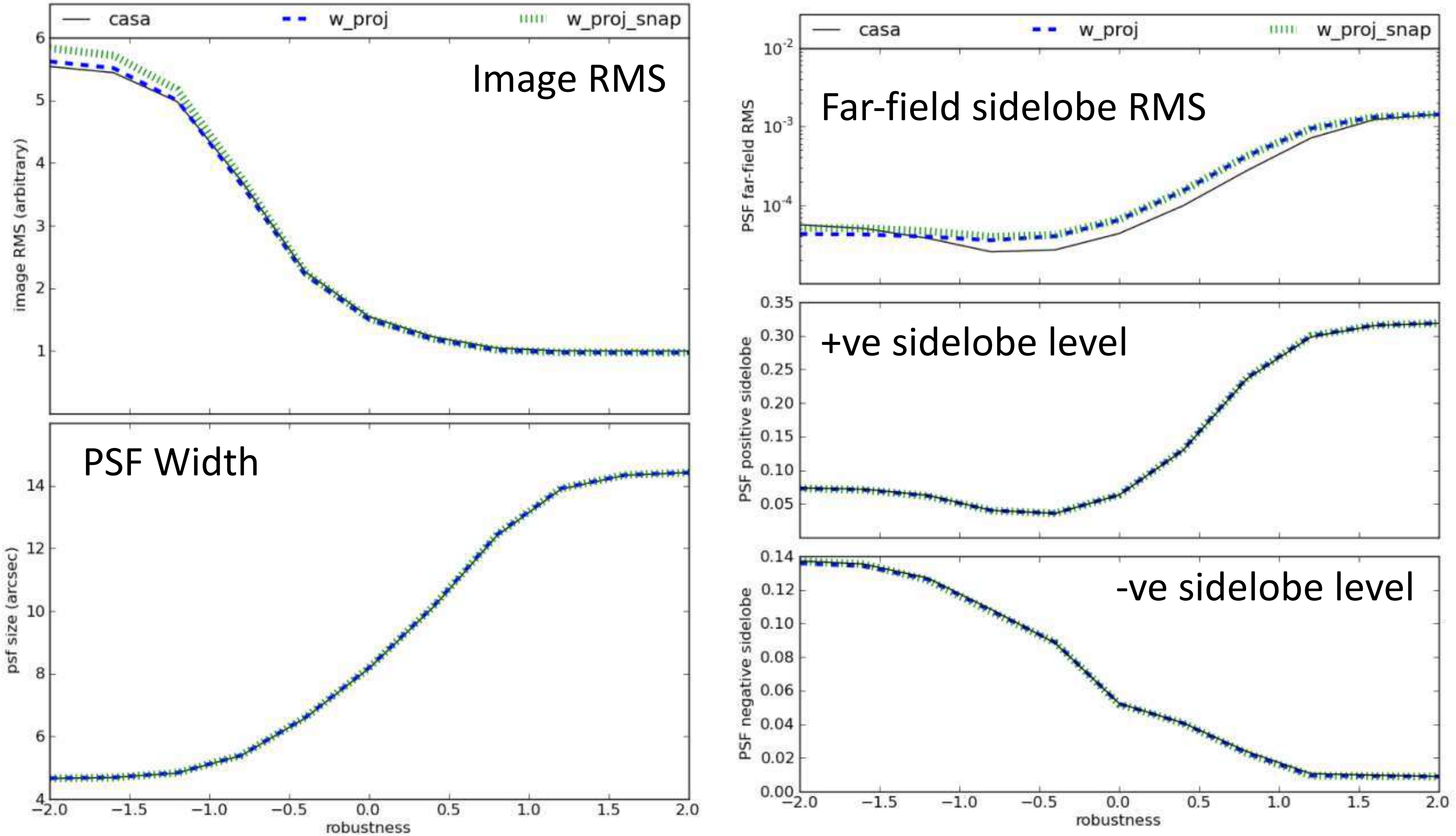


Courtesy of Josh Marvil

Multi-beam imaging

- Joint gridding
  - Original design was to grid all beams onto the same large uv plane
  - uv grid: $12{,}000^2$ pixels × 4 pol × 8 bytes (5 GB) × N_{freq} × N_{tt} × overhead
  - Kernel grids: $w_{max}\theta^2 \approx 400$ pixels across
  - With 8×8 oversampling & 3000 w-planes: ≈ 90 GB
  - Memory-bandwidth limited

- Separate gridding and joint deconvolution
  - Grid each beam separately
  - Do linear mosaic before deconvolution
  - Kernel grids: $w_{max}\theta^2 \approx 45$ pixels across (2° image width)
  - With 8×8 oversampling & 360 planes: ≈ 0.1 GB

- For early science, mostly do separate gridding and separate deconvolution

Common ASKAPsoft tasks

Cflag

- Visibility flagger. Limited in scope for HPC and eventual inclusion in *Ingest*
- Example 1

$ cflag -c config.in

```
Cflag.dataset                                = target.ms

# Enable Stokes V flagging flagger with a 5-sigma threshold
Cflag.stokesv_flagger.enable                 = true
Cflag.stokesv_flagger.threshold              = 5.0

# Enable selection based flagging with two rules
# Rule 1: Beams 0 and 1 on ant "ak01”, rule 2: Spectral Channels 0 to 16 on spectral window 0
Cflag.selection_flagger.rules                = [rule1, rule2]
Cflag.selection_flagger.rule1.antenna        = ak01
Cflag.selection_flagger.rule1.feed           = [0, 1]
Cflag.selection_flagger.rule2.spw            = 0:0~16
```

Cflag

- Visibility flagger. Limited in scope for HPC and eventual inclusion in *Ingest*
- Example 2

$ cflag -c config.in

```
Cflag.dataset                        = target.ms

# Elevation based flagging
Cflag.elevation_flagger.enable       = true
Cflag.elevation_flagger.low          = 12.0
Cflag.elevation_flagger.high         = 89.0

# Amplitude based flagging
Cflag.amplitude_flagger.enable       = true
Cflag.amplitude_flagger.high         = 10.25
Cflag.amplitude_flagger.low          = 1e-3
```

Cflag

- Visibility flagger. Limited in scope for HPC and eventual inclusion in *Ingest*
- Example 3

$ cflag -c config.in

```
Cflag.dataset                                          = target.ms

# Amplitude based flagging
Cflag.amplitude_flagger.enable                         = true

# Threshold using the median and IQR of each spectrum
Cflag.amplitude_flagger.dynamicBounds                  = true

# Threshold again after averaging spectra in time
Cflag.amplitude_flagger.integrateSpectra               = true
Cflag.amplitude_flagger.integrateSpectra.threshold     = 4.0
Cflag.amplitude_flagger.integrateTimes                 = true
```

Cbpcalibrator

- Bandpass calibration task.
- A good number of MPI ranks: 1 + nbeam x nchan / integer_factor

$ <MPI wrapper> cbpcalibrator -c config.in

```
Cbpcalibrator.dataset                        = calibration_data.ms
Cbpcalibrator.nAnt                           = 36
Cbpcalibrator.nChan                          = 16000
Cbpcalibrator.nBeam                          = 36
Cbpcalibrator.refantenna                     = 1
Cbpcalibrator.calibaccess                    = table
Cbpcalibrator.calibaccess.table              = calparameters.tab
Cbpcalibrator.calibaccess.table.maxant       = 36
Cbpcalibrator.calibaccess.table.maxchan      = 16000
Cbpcalibrator.calibaccess.table.maxbeam      = 36

Cbpcalibrator.sources.names                  = [src1]
Cbpcalibrator.sources.src1.components        = [cal]
Cbpcalibrator.sources.cal.calibrator         = 1934-638

Cbpcalibrator.ncycles                        = 25

Cbpcalibrator.gridder                        = SphFunc
```

Ccalibrator

- Calibration task.

$ <MPI wrapper> ccalibrator -c config.in

```
Ccalibrator.dataset                          = calibration_data.ms
Ccalibrator.refantenna                       = 0
calibrator.sources.names                     = [field1]
Ccalibrator.sources.field1.direction         = [12h30m00.000, -45.00.00.000, J2000]
Ccalibrator.sources.field1.components        = [src1]
Ccalibrator.sources.src1.flux.i              = 0.091
# "ra" and "dec" are actually l and m direction cosine offsets in radians relative to "direction"
Ccalibrator.sources.src1.direction.ra        = 0.00363277
Ccalibrator.sources.src1.direction.dec       = -0.00366022

Ccalibrator.ncycles                          = 25

# not building visibilities using a gridder, so specify a simple one here
Ccalibrator.gridder                          = SphFunc
```

Ccalibrator

- Calibration task.

$ <MPI wrapper> ccalibrator -c config.in

```
Ccalibrator.dataset                                   = calibration_data.ms
Ccalibrator.refantenna                                = 0
Ccalibrator.sources.names                             = [10uJy]
Ccalibrator.sources.10uJy.direction                   = [12h30m00.000, -45.00.00.000, J2000]
Ccalibrator.sources.10uJy.model                       = 10uJy.model.small

Ccalibrator.ncycles                                    = 25

# use wide-field gridder & A-projection to convolve w terms and the primary beam into the visibility model
Ccalibrator.gridder                                   = AProjectWStack
Ccalibrator.gridder.AProjectWStack.wmax               = 15000
Ccalibrator.gridder.AProjectWStack.nwplanes           = 100
Ccalibrator.gridder.AProjectWStack.oversample         = 4
Ccalibrator.gridder.AProjectWStack.diameter           = 12m
Ccalibrator.gridder.AProjectWStack.blockage           = 2m
Ccalibrator.gridder.AProjectWStack.maxfeeds           = 2
Ccalibrator.gridder.AProjectWStack.maxsupport         = 1024
Ccalibrator.gridder.AProjectWStack.frequencydependent  = false
```

Ccalapply

- Apply calibration solutions task.

ccalapply -c config.in

<or>

$ <MPI wrapper> ccalapply -c config.in

```
Ccalapply.dataset                  = science_data.ms

Ccalapply.calibaccess              = table
Ccalapply.calibaccess.table        = calparameters.tab
```

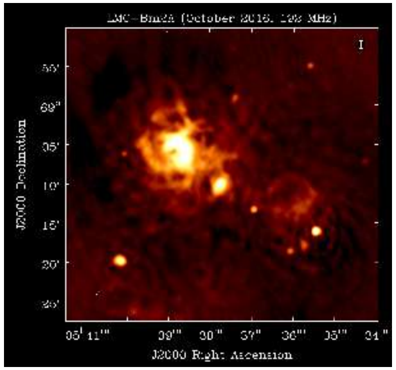
Cimager

- Continuum imaging task.
- Various parallelism options available, but *Imager* is more flexible.

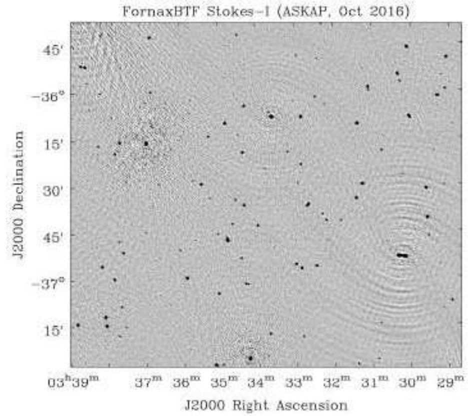
$ <MPI wrapper> cimager -c config.in

```
Cimager.dataset                              = cont_vis.ms
Cimager.Images.Names                         = [image.name] # must start with "image."
Cimager.Images.shape                         = [2048,2048]
Cimager.Images.cellsize                      = [6.0arcsec, 6.0arcsec]

Cimager.solver                               = Clean
Cimager.solver.Clean.algorithm               = BasisfunctionMFS # no Taylor terms here, so just the MS part
Cimager.solver.Clean.scales                  = [0,4,8,16]
Cimager.solver.Clean.niter                   = 1000
Cimager.solver.Clean.gain                    = 0.1
Cimager.threshold.minorcycle                 = [0.3mJy, 10%]
Cimager.threshold.majorcycle                 = 0.3mJy
Cimager.ncycles                              = 10

Cimager.restore                              = True
Cimager.restore.beam                         = fit

Cimager.preconditioner.Names                 = [Wiener]
Cimager.preconditioner.preservecf            = true
Cimager.preconditioner.Wiener.robustness     = -2
```

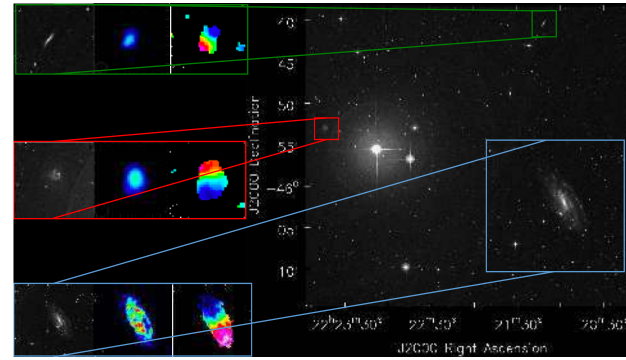
ASKAPsoft Examples



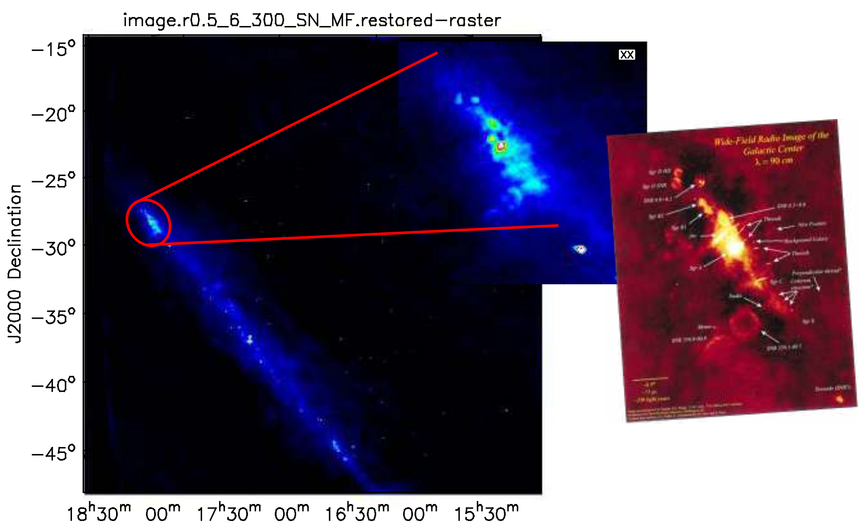
Continuum Imaging
Courtesy of Wasim Raja



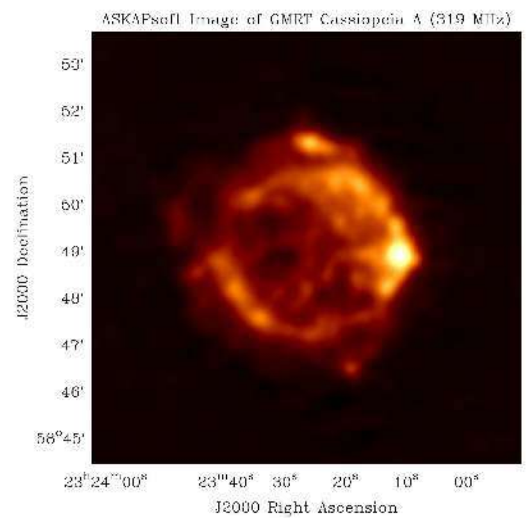
Polarised Imaging
Courtesy of Wasim Raja & Craig Anderson



Spectral Line Imaging
Courtesy of Dane Kleiner



MWA Imaging
Courtesy of Steve Ord & Daniel Mitchell



GMRT imaging
Courtesy of Wasim Raja

Linmos

- Linear Mosaicking task.
- Example 1

$ linmos -c config.in <or>

$ <MPI wrapper> linmos-mpi -c config.in

```
linmos.weighttype      = FromWeightImages
linmos.weightstate     = Inherent # expect for non-A gridders. Default “Corrected” is appropriate for A gridders.

linmos.names           = [image_feed00..35.restored]
linmos.weights         = [weights_feed00..35]

linmos.outname         = image_mosaic.restored
linmos.outweight       = weights_mosaic
```

Linmos

- Linear Mosaicking task.
- Example 2

$ linmos -c config.in <or>

$ <MPI wrapper> linmos-mpi -c config.in

```
linmos.weighttype      = FromPrimaryBeamModel

linmos.names           = [image_feed14..15.i.dirty.restored, image_feed20..21.i.dirty.restored]

linmos.outname         = image_mosaic.i.dirty.restored
linmos.outweight       = weights_mosaic.i.dirty

linmos.feeds.centre    = [12h30m00.00, -45.00.00.00]

# The following can be moved to a separate file
linmos.feeds.spacing   = 1deg
linmos.feeds.image_feed14.i.dirty.restored = [-0.5, -0.5]
linmos.feeds.image_feed15.i.dirty.restored = [-0.5,  0.5]
linmos.feeds.image_feed20.i.dirty.restored = [0.5, -0.5]
linmos.feeds.image_feed21.i.dirty.restored = [0.5,  0.5]
```

Selavy

- Source finding task.

See https://www.atnf.csiro.au/computing/software/askapsoft/sdp/docs/current/analysis/index.html

A walk through the tutorial

ASKAPsoft Imaging Tutorial

- Courtesy of (and many thanks to) Wasim Raja
- Wasim has prepared four scripts to:
  - Generate input slurm scripts, parsets and associated files
  - Launch jobs on Galaxy
- The scripts are:
  1. bandpass calibration: **do_cal_1934.sh**
  2. prepare science data: **do_pre_process_ras.sh**
  3. image/selfcal science data (continuum only): **do_selfcal_ras.sh**
  4. form linear mosaic: **do_linmos_ras.sh**
- Also:
  - a script to set up galaxy modules: **setup_modules_on_nodes.sh**
  - a file to configure various parameters: **process_ASKAPdata.config**

Tutorial — Getting Started

```
$ mkdir askap_tutorial
$ cd askap_tutorial
$ cp –r /group/askap/dmitchell/askap_tutorial/* .

$ . setup_modules_on_nodes.sh
```

setup_modules_on_nodes.sh

```
module use /group/askap/modulefiles
module unload askapsoft
module load askapsoft/0.22.1

module unload askapdata
module load askapdata

module unload askappipeline
module load askappipeline
#module load askapcli

export PMI_NO_PREINITIALIZE=1
export PMI_NO_FORK=1
export PMI_DEBUG=1

module unload askap-cray
module load askap-cray

module unload slurm
module load slurm
```

Tutorial — Getting Started

```
$ mkdir askap_tutorial
$ cd askap_tutorial
$ cp –r /group/askap/dmitchell/askap_tutorial/* .

$ . setup_modules_on_nodes.sh
$ . process_ASKAPdata.config
```

process_ASKAPdata.config

```
export TRIAL=0                                  # set to 1 to generate files but not run them

export SPLIT_CHAN=1                             # split out a subset of frequency channels
export BCHAN_SPLIT=8192
export ECHAN_SPLIT=8407 #9271

export MY_SBID_BPCAL=5181                       #  scheduling block for band-pass calibration (i.e. the id of the BP calibration
                                                # observation)
export MY_SBID_TARGET=5177                      #  scheduling block for science data (i.e. the id of the science observation)
export MY_FIELD_NAME=COSMOLOGY_T15-2            # name of the science field
export PATH_TO_SETUP_FILE=$PWD                  # change me if running from a different directory
export MY_OUTPATH=ras_data_processing_${this_user}/
mkdir -p ${MY_OUTPATH}msdata/${MY_SBID_TARGET} ${MY_OUTPATH}bpcal_solutions/${MY_SBID_BPCAL}

# Decide which beams you wish to process. Do bandpass calibration for all 36 beams, but restrict imaging and selfcal to 1 or a few
export BBEAM_BPCAL=0 # Must be 0 with the current structure of bptables
export EBEAM_BPCAL=35 # Can be less than maxBeams
export BBEAM=0 # image / selfcal beams 0 to 1
export EBEAM=1

# Some imaging parameters:
export ROBUST=-0.5
export BLOOP_SELFCAL=0
export ELOOP_SELFCAL=1
```

do_cal_1934.sh

$ ./do_cal_1934.sh

- mssplit — select a subset of channels (to limit the amount of processing)
- cflag — look for radio frequency interference and set flags
- cbpcalibrator — run the calibrator for each frequency channel

- Or just copy the solution table that I generated:

```
$ . process_ASKAPdata.config
$ mv cbpcal_1934_sb5181_bm0-bm35_refant-1_bp.tab \
  $MY_OUTPATH/bpcal_solutions/5181/
```

plot_bandpass.py

$ ssh –X username@galaxy.pawsey.org.au
- or:

$ ssh –Y username@galaxy.pawsey.org.au
- For the help menu:

$ plot_bandpass.py –h

$ optional arguments:

-t BP_TAB, --t BP_TAB Input Bandpass table (with path)

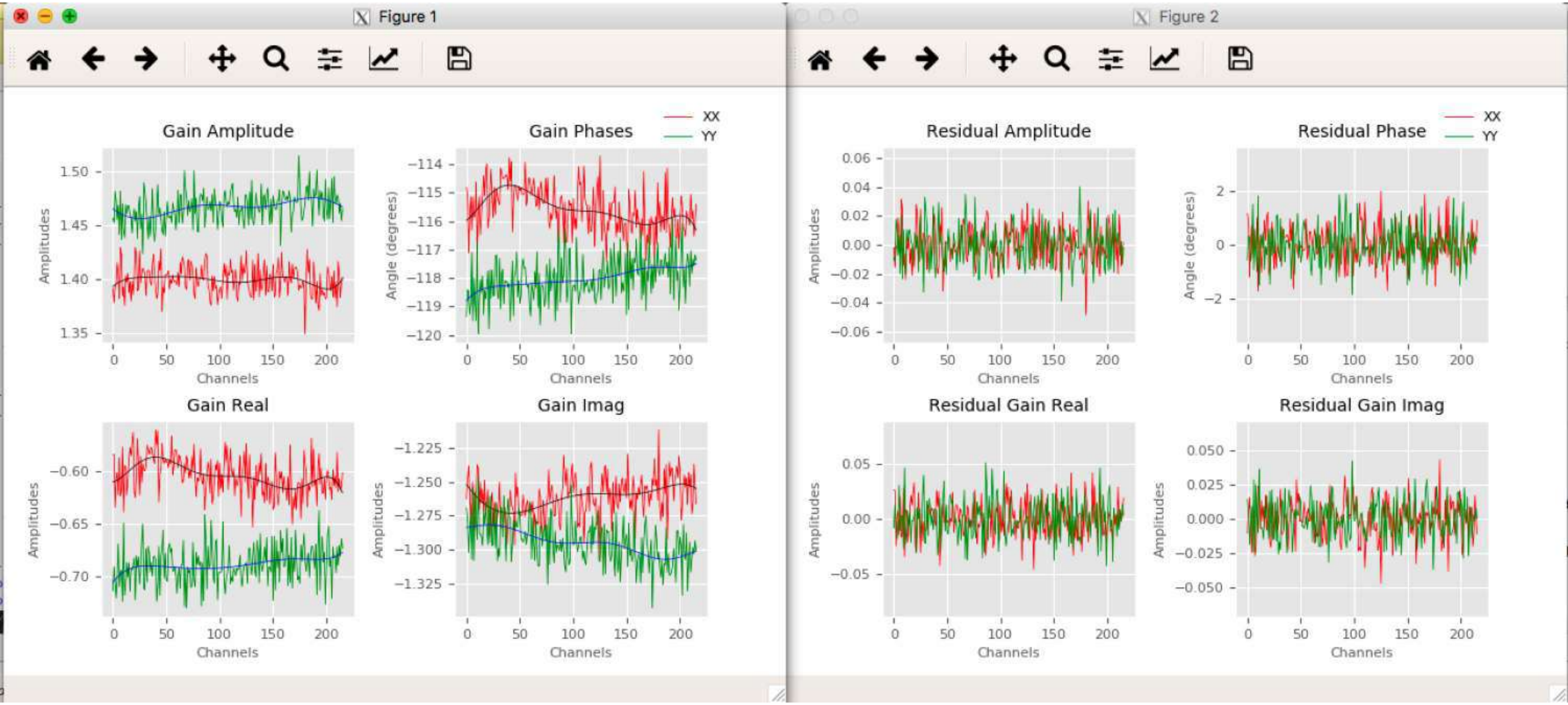
-ib BEAM_NUM, --ib BEAM_NUM The beam number you wish to process

-ia ANTE_NUM, --ia ANTE_NUM The antenna number you wish to process

$ plot_bandpass.py -t cbpcal_1934_sb5181_bm0-bm35_refant-1_bp.tab –ia 1

```
Successful readonly open of default-locked table cbpcal_1934_sb5181_bm0-bm35_refant-1_bp.tab: 3 columns, 1 rows
Plotting bandpass solutions for Input table: cbpcal_1934_sb5181_bm0-bm35_refant-1_bp.tab
For:
             Beam Num:  0
             Ante Num:  1
Smooth fits will be derived using:
           Poly Order:  2
           Harm Order:  3
   Fits will done in :  1  windows
 Residual plot bounds:  +/- 5.0 sigma
   Taper Width (npts):  15
 Niter (for F-interp):  100
    Reference Antenna:  1
```

plot_bandpass.py (-ia 0)

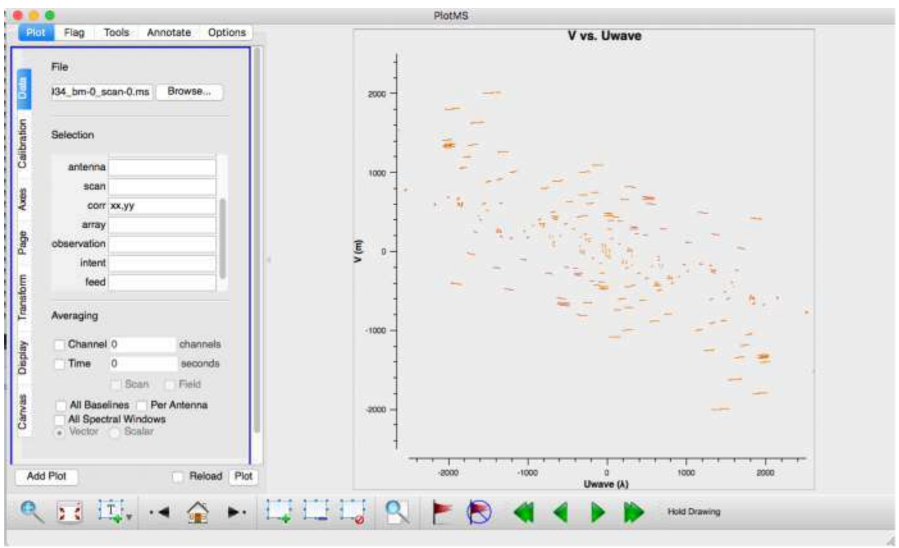


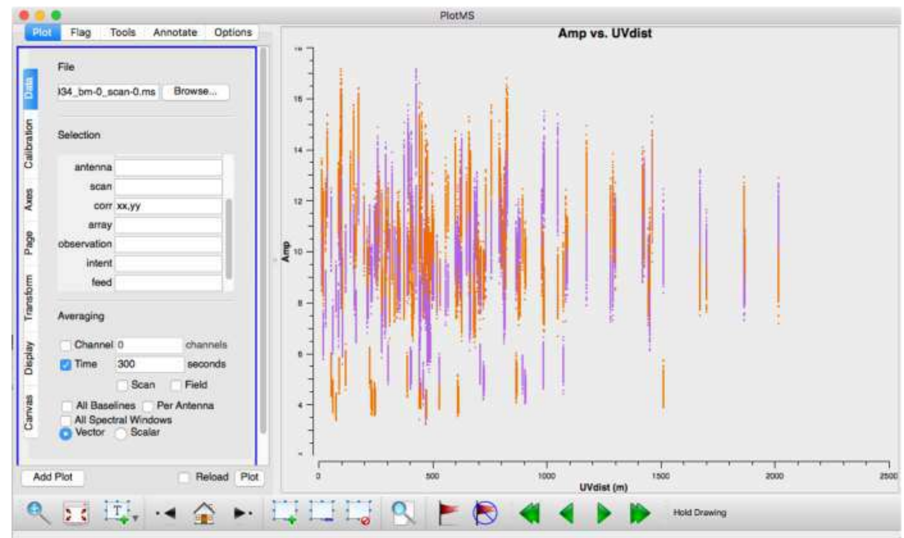
CASA tools

On local machine (replace $MY_OUTPATH with full directory path):

```
$  scp -r username@hpc-data.pawsey.org.au:$MY_OUTPATH/msdata/5181/FLAGGED_DYNAMIC/1934_bm-0_scan-0.ms .
```

```
$  casabrowser 1934_bm-0_scan-0.ms
$  casaplotms
```





do_pre_process_ras.sh

$ ./do_pre_process_ras.sh

- mssplit — select the same subset of channels from the science dataset
- ccalapply — apply calibration solutions to the science data
- cflag — look for radio frequency interference and set flags
- mssplit — average in frequency
- cflag — a final round of flagging

do_selfcal_ras.sh

$ ./do_selfcal_ras.sh

- ccalibrator — run calibration using a model of this field
- cimager — image and deconvolve the field with the new calibration solutions
- selavy — run relatively shallow source finder on the restored image
- cmodel — generate a model image from the selavy catalogue

- 1st run: set BLOOP_SELFCAL=0 & ELOOP_SELFCAL=0: imaging with no selfcal

$ squeue -u username

JOBID	USER	ACCOUNT	NAME	EXEC_HOST	ST	REASON	START_TIME	END_TIME	TIME_LEFT	NODES	PRIORITY
5055128	dmitchel	askaprt	IMG-5177-0A.I	nid00217	R	None	08:36:54	14:36:54	5:56:54	1	10001
5055129	dmitchel	askaprt	IMG-5177-1A.I	nid00299	R	None	08:36:54	14:36:54	5:56:54	1	10001

do_selfcal_ras.sh

```
$ ls -ld ${MY_OUTPATH}/image/5177/weight*
  image/5177/weights.I.COSMOLOGY_T15-2A_bm-0_iter-0
  image/5177/weights.I.COSMOLOGY_T15-2A_bm-1_iter-0
$ ls -ld ${MY_OUTPATH}/image/5177/image*restored
  image/5177/image.I.COSMOLOGY_T15-2A_bm-0_iter-0.restored
  image/5177/image.I.COSMOLOGY_T15-2A_bm-1_iter-0.restored
$ ls -ld ${MY_OUTPATH}/image/5177/image*restored.cmodel
  image/5177/image.I.COSMOLOGY_T15-2A_bm-0_iter-0.restored.cmodel
  image/5177/image.I.COSMOLOGY_T15-2A_bm-1_iter-0.restored.cmodel
$ ls -ld ${MY_OUTPATH}/image/5177/psf*
  image/5177/psf.I.COSMOLOGY_T15-2A_bm-0_iter-0
  image/5177/psf.I.COSMOLOGY_T15-2A_bm-1_iter-0
  image/5177/psf.image.I.COSMOLOGY_T15-2A_bm-0_iter-0
  image/5177/psf.image.I.COSMOLOGY_T15-2A_bm-1_iter-0
```

do_linmos_ras.sh

$ ./do_linmos_ras.sh

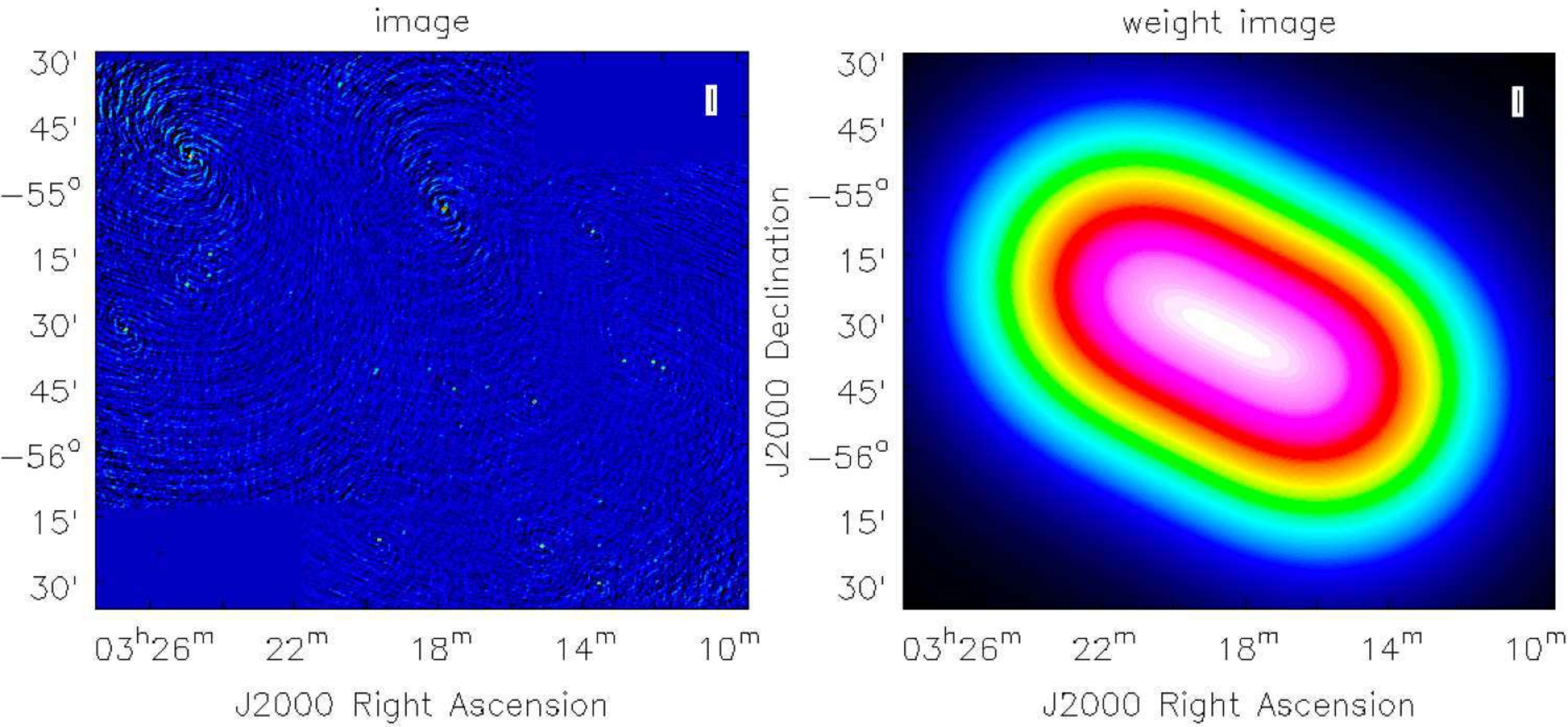
- linmos — form a linear mosaic of the final images

On local machine (replace $MY_OUTPATH with full directory path):

```
$ scp -r username@hpc-data.pawsey.org.au:$MY_OUTPATH/linmos/5177/\* .
```

```
$ casaviewer image.I.COSMOLOGY_T15-2iter-0.linmosRAS_5177
```

casaviewer image.I.COSMOLOGY_T15-2iter-0.linmosRAS_5177



One loop of self-cal

- 2nd run: set BLOOP_SELFCAL=1 & ELOOP_SELFCAL=1: imaging with a selfcal update

```
$ . process_ASKAPdata.config
$ ./do_selfcal_ras.sh
$ ./do_linmos_ras.sh

$ ls -l $MY_OUTPATH/linmos/5177/

$ scp -r username@hpc-data.pawsey.org.au:$MY_OUTPATH/linmos/5177/\*iter-1\* .

$ casaviewer image.I.COSMOLOGY_T15-2iter-1.linmosRAS_5177
```

Tutorial

- Run scripts, but also look at what they are doing

$ grep srun do_*

do_cal_1934.sh:

```
srun --export=ALL --ntasks=1 --ntasks-per-node=1 mssplit -c ${parset_split} > \${log}
srun --export=ALL --ntasks=1 --ntasks-per-node=1 cflag -c ${parset_flag} > \${log}
srun --export=ALL --ntasks=$nranks_bpcal --ntasks-per-node=20 $cbpcalibrator -c ${parset_bpcal} > \${log}
```

do_pre_process_ras.sh:

```
srun --export=ALL --ntasks=1 --ntasks-per-node=1 mssplit -c ${parset_split} > \${log}
srun --export=ALL --ntasks=19 --ntasks-per-node=19 ccalapply -c ${parset_ccalapply} > \${log}
srun --export=ALL --ntasks=1 --ntasks-per-node=1 cflag -c ${parset_flag} > \${log}
srun --export=ALL --ntasks=1 --ntasks-per-node=1 mssplit -c ${parset_average} > \${log}
srun --export=ALL --ntasks=1 --ntasks-per-node=1 cflag -c ${parset_flag2} > \${log}
```

do_selfcal_ras.sh:

```
srun --export=ALL --ntasks=$nranks_ccal --ntasks-per-node=$nppn_ccal $calib -c ${parset_ccal} > \${log}
srun --export=ALL --ntasks=$nranks_cimage --ntasks-per-node=$nppn_cimage $imager -c ${parset_cimage} > \${log}
srun --export=ALL --ntasks=$nranks_selavy --ntasks-per-node=$nppn_selavy $selavy -c ${parset_selavy} > \${log}
srun --export=ALL --ntasks=$nranks_cmodel --ntasks-per-node=$nppn_cmodel $cmodel -c ${parset_cmodel} > \${log}
```

do_linmos_ras.sh:

```
srun --export=ALL --ntasks=$nranks_linmos --ntasks-per-node=1 $linmos -c ${parset_linmos} > \${log}
```

Tutorial

```
$  ls -1 *.sbatch
IMG_COSMOLOGY_T15-2A_bm-0.I.sbatch
IMG_COSMOLOGY_T15-2A_bm-1.I.sbatch
cbpcal_1934_bm0-bm35.sbatch
linmos_COSMOLOGY_T15-2iter-0.sbatch
linmos_COSMOLOGY_T15-2iter-1.sbatch
preimag_1934_bm-0_scan-0.sbatch
preimag_1934_bm-10_scan-10.sbatch
preimag_1934_bm-11_scan-11.sbatch
preimag_1934_bm-12_scan-12.sbatch
…
prep_COSMOLOGY_T15-2A_bm-0.sbatch
prep_COSMOLOGY_T15-2A_bm-1.sbatch
```

- e.g.:

```
$  sbatch linmos_COSMOLOGY_T15-2iter-0.sbatch
```