Using the IDIA MeerKAT Pipeline

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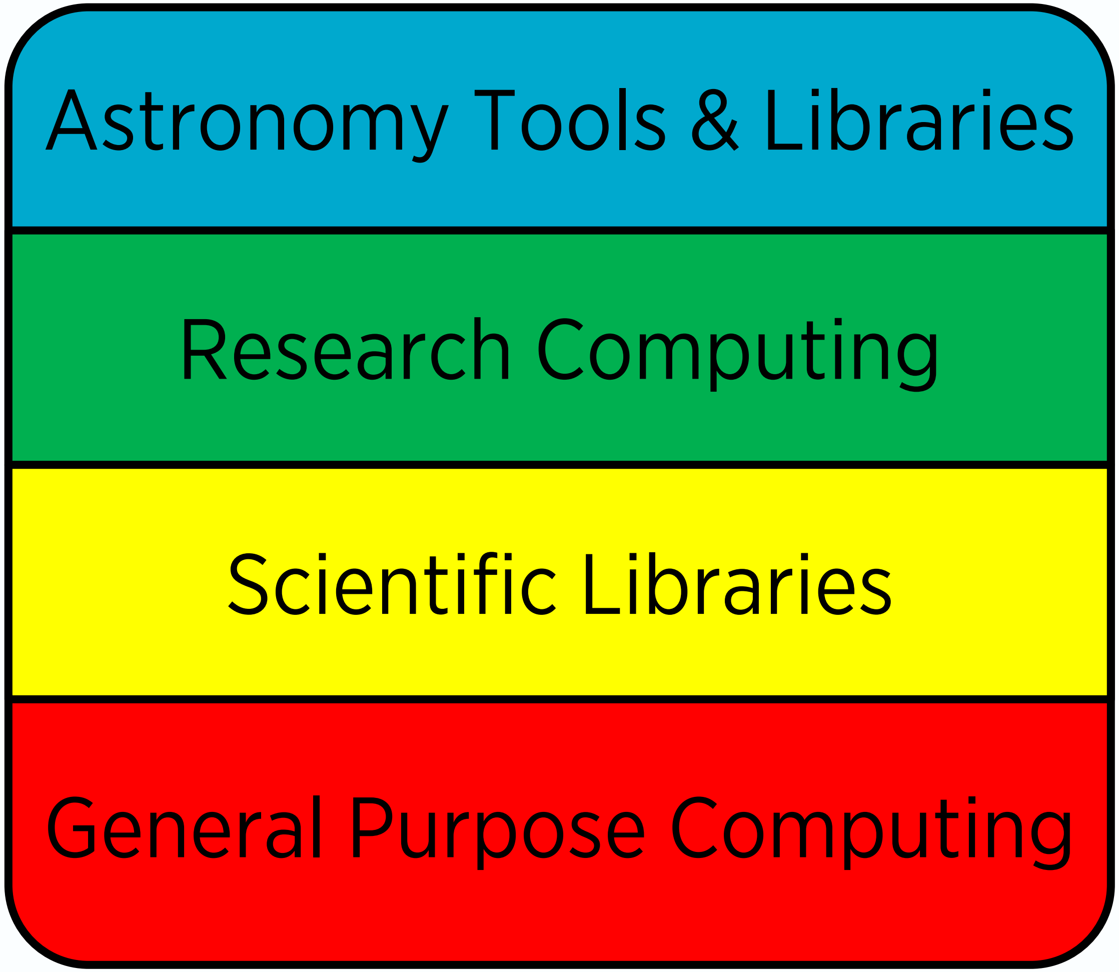
Jordan Collier | 20 Feb 2019 | MIGHTEE workshop

Our Systems: Software Stack


Astronomy Tools & Libraries

Research Computing

Scientific Libraries

General Purpose Computing

CASA

slurm
workload manager

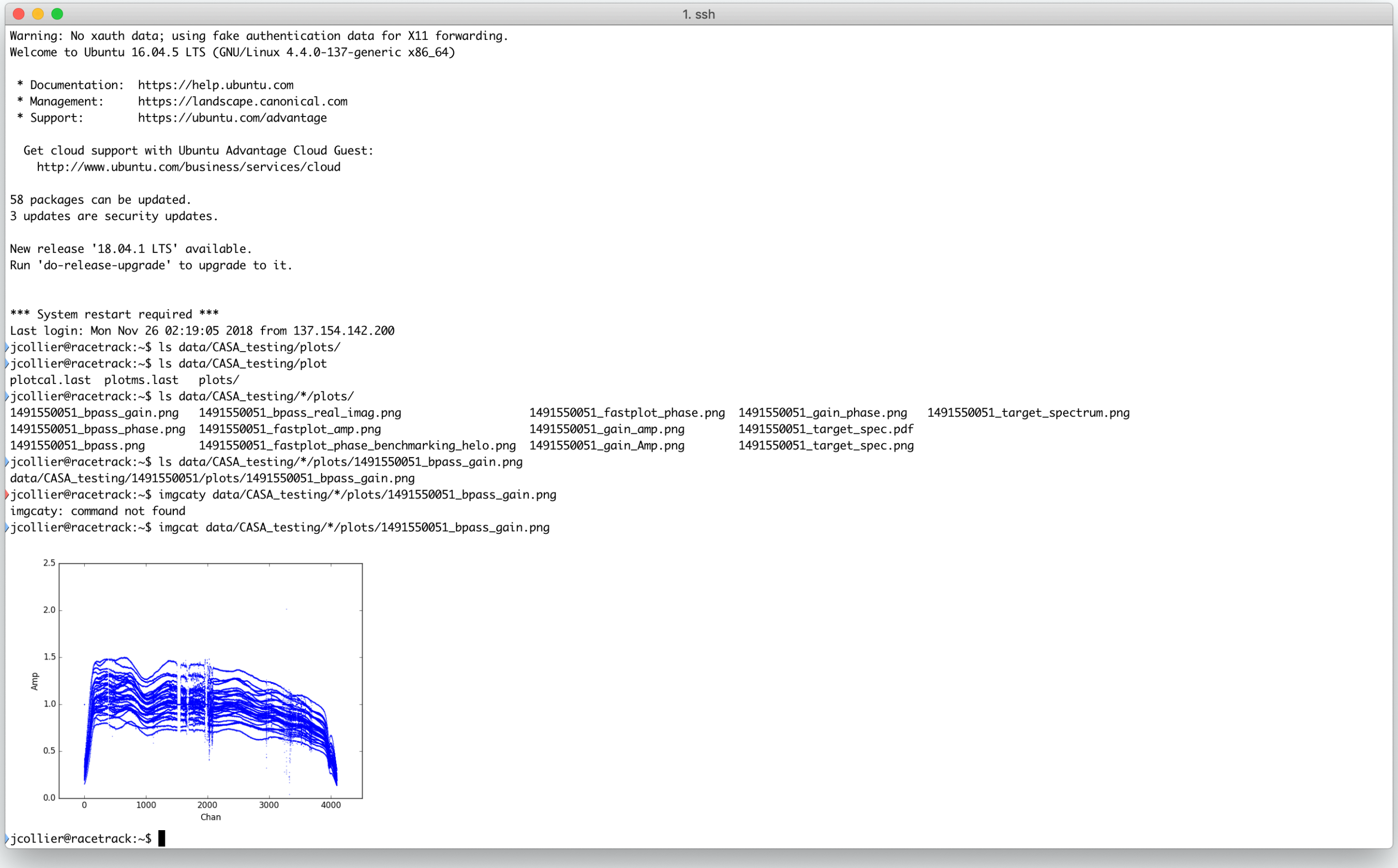
OPEN MPI

jupyterhub

Linux

openstack
CLOUD SOFTWARE

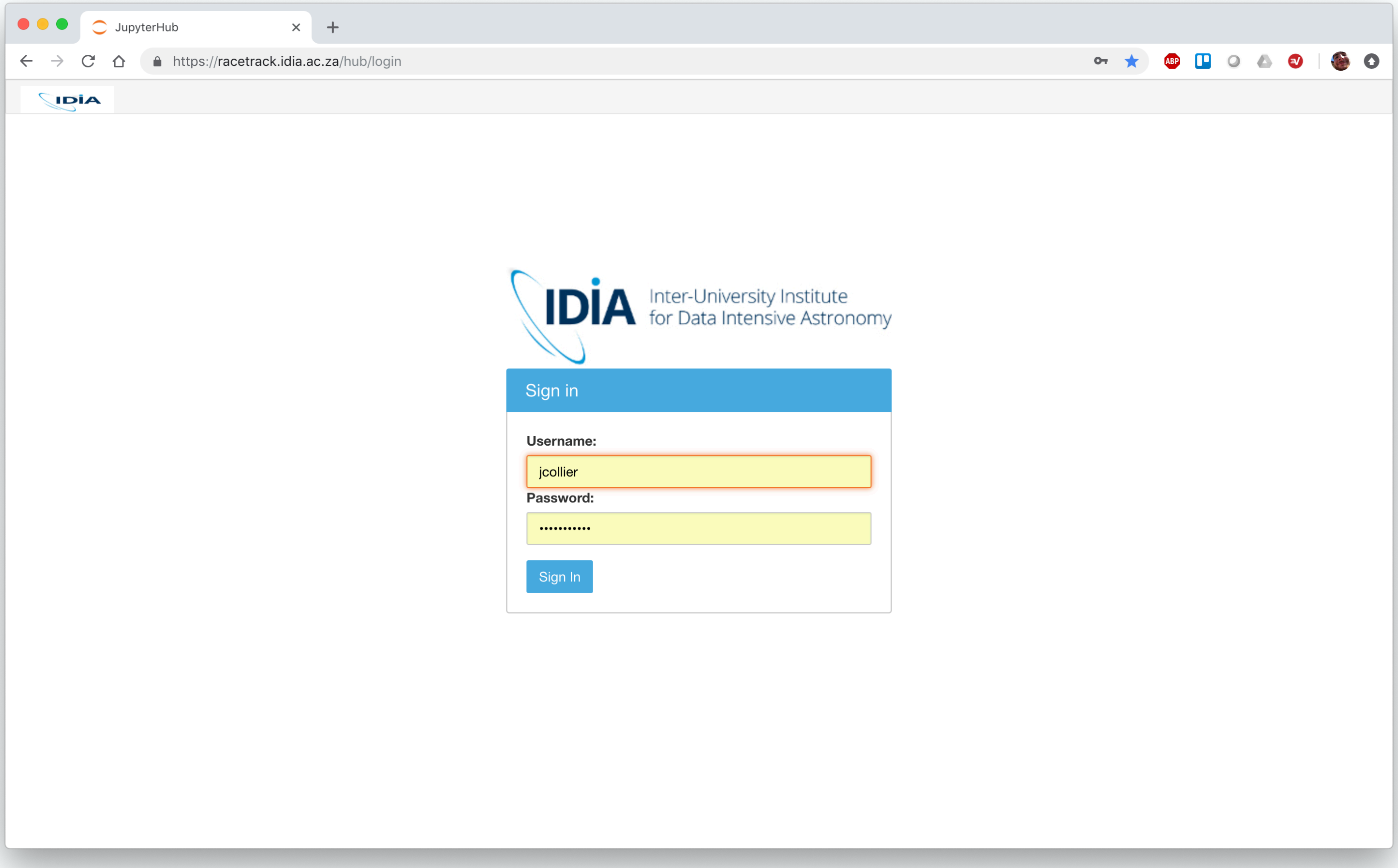
ssh access



```
Warning: No xauth data; using fake authentication data for X11 forwarding.
Welcome to Ubuntu 16.04.5 LTS (GNU/Linux 4.4.0-137-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

  Get cloud support with Ubuntu Advantage Cloud Guest:
    http://www.ubuntu.com/business/services/cloud

58 packages can be updated.
3 updates are security updates.

New release '18.04.1 LTS' available.
Run 'do-release-upgrade' to upgrade to it.


*** System restart required ***
Last login: Mon Nov 26 02:19:05 2018 from 137.154.142.200
jcollier@racetrack:~$ ls data/CASA_testing/plots/
jcollier@racetrack:~$ ls data/CASA_testing/plot
plotcal.last  plotms.last   plots/
jcollier@racetrack:~$ ls data/CASA_testing/*/plots/
1491550051_bpass_gain.png   1491550051_bpass_real_imag.png                   1491550051_fastplot_phase.png  1491550051_gain_phase.png   1491550051_target_spectrum.png
1491550051_bpass_phase.png  1491550051_fastplot_amp.png                      1491550051_gain_amp.png        1491550051_target_spec.pdf
1491550051_bpass.png        1491550051_fastplot_phase_benchmarking_helo.png  1491550051_gain_Amp.png        1491550051_target_spec.png
jcollier@racetrack:~$ ls data/CASA_testing/*/plots/1491550051_bpass_gain.png
data/CASA_testing/1491550051/plots/1491550051_bpass_gain.png
jcollier@racetrack:~$ imgcaty data/CASA_testing/*/plots/1491550051_bpass_gain.png
imgcaty: command not found
jcollier@racetrack:~$ imgcat data/CASA_testing/*/plots/1491550051_bpass_gain.png
```

```
jcollier@racetrack:~$
```

JupyterHub



JupyterHub
https://racetrack.idia.ac.za/hub/login
IDIA Inter-University Institute for Data Intensive Astronomy

Sign in

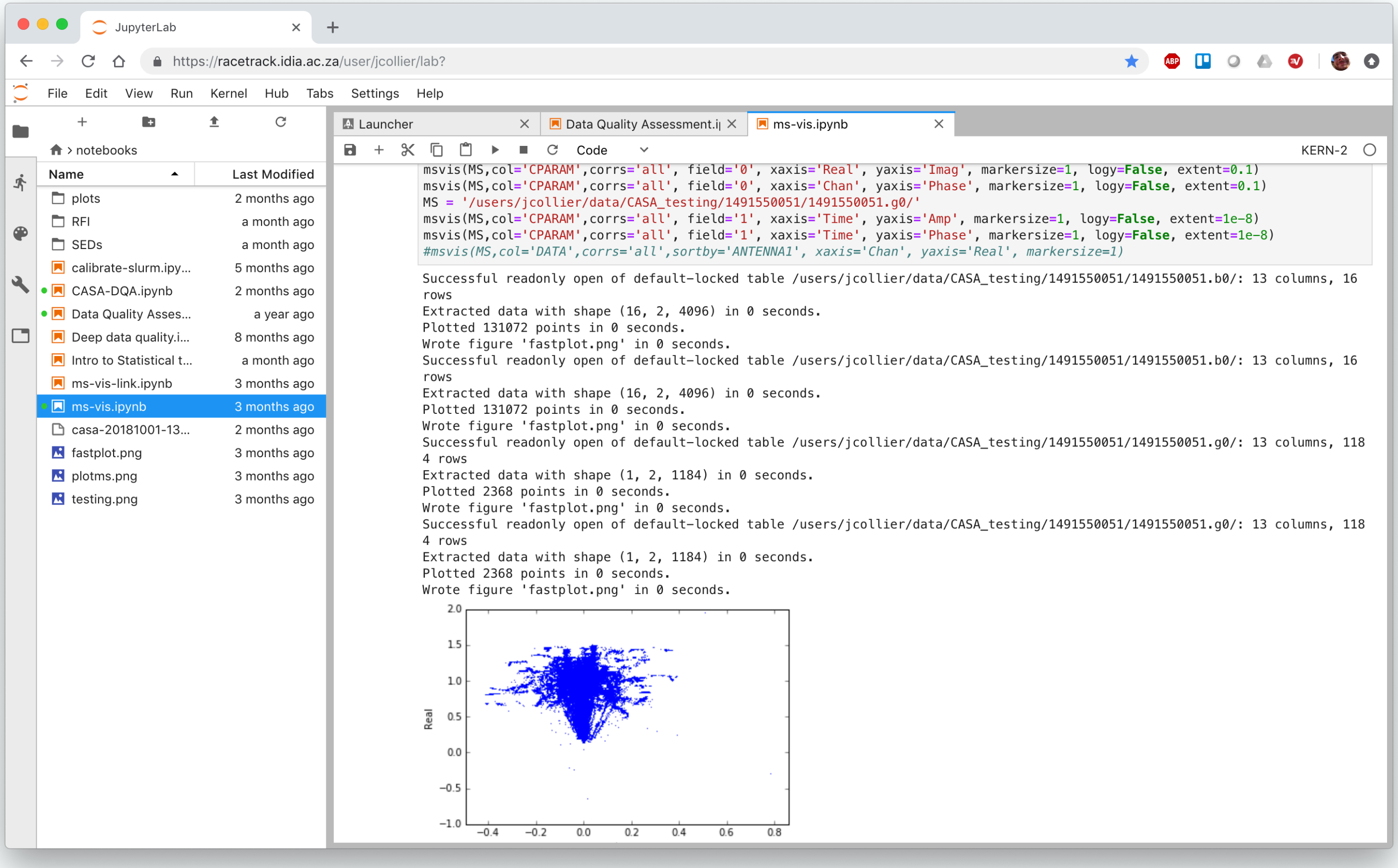
Username:

jcollier

Password:

•••••••••••

JupyterHub



Name	Last Modified
plots	2 months ago
RFI	a month ago
SEDs	a month ago
calibrate-slurm.ipy...	5 months ago
CASA-DQA.ipynb	2 months ago
Data Quality Asses...	a year ago
Deep data quality.i...	8 months ago
Intro to Statistical t...	a month ago
ms-vis-link.ipynb	3 months ago
ms-vis.ipynb	3 months ago
casa-20181001-13...	2 months ago
fastplot.png	3 months ago
plotms.png	3 months ago
testing.png	3 months ago

```
msvis(MS,col='CPARAM',corrs='all', field='0', xaxis='Real', yaxis='Imag', markersize=1, logy=False, extent=0.1)
msvis(MS,col='CPARAM',corrs='all', field='0', xaxis='Chan', yaxis='Phase', markersize=1, logy=False, extent=0.1)
MS = '/users/jcollier/data/CASA_testing/1491550051/1491550051.g0/'
msvis(MS,col='CPARAM',corrs='all', field='1', xaxis='Time', yaxis='Amp', markersize=1, logy=False, extent=1e-8)
msvis(MS,col='CPARAM',corrs='all', field='1', xaxis='Time', yaxis='Phase', markersize=1, logy=False, extent=1e-8)
#msvis(MS,col='DATA',corrs='all',sortby='ANTENNA1', xaxis='Chan', yaxis='Real', markersize=1)
```

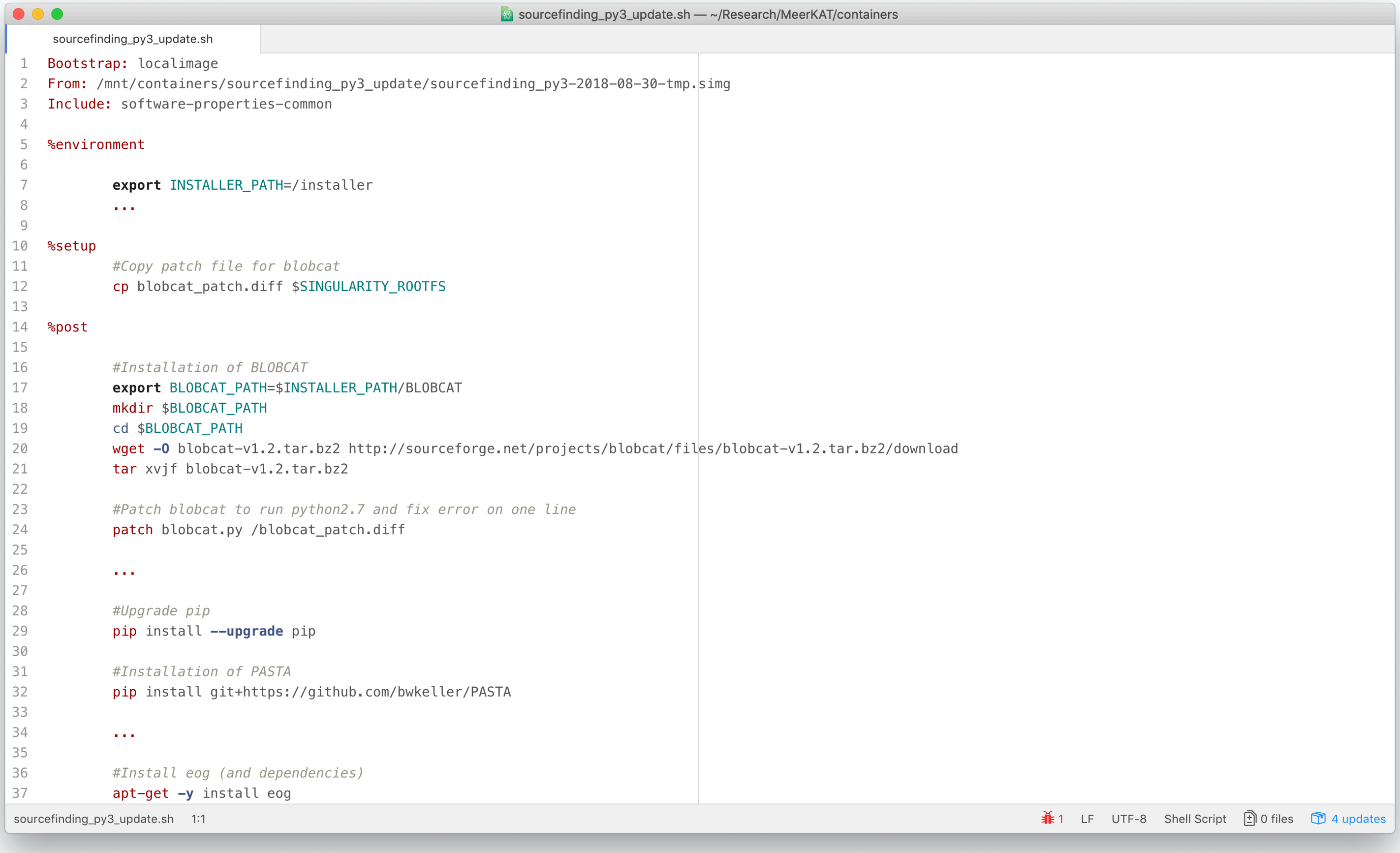
```
Successful readonly open of default-locked table /users/jcollier/data/CASA_testing/1491550051/1491550051.b0/: 13 columns, 16
rows
Extracted data with shape (16, 2, 4096) in 0 seconds.
Plotted 131072 points in 0 seconds.
Wrote figure 'fastplot.png' in 0 seconds.
Successful readonly open of default-locked table /users/jcollier/data/CASA_testing/1491550051/1491550051.b0/: 13 columns, 16
rows
Extracted data with shape (16, 2, 4096) in 0 seconds.
Plotted 131072 points in 0 seconds.
Wrote figure 'fastplot.png' in 0 seconds.
Successful readonly open of default-locked table /users/jcollier/data/CASA_testing/1491550051/1491550051.g0/: 13 columns, 118
4 rows
Extracted data with shape (1, 2, 1184) in 0 seconds.
Plotted 2368 points in 0 seconds.
Wrote figure 'fastplot.png' in 0 seconds.
Successful readonly open of default-locked table /users/jcollier/data/CASA_testing/1491550051/1491550051.g0/: 13 columns, 118
4 rows
Extracted data with shape (1, 2, 1184) in 0 seconds.
Plotted 2368 points in 0 seconds.
Wrote figure 'fastplot.png' in 0 seconds.
```

Singularity Containers

- Led by Jeremy Smith (IDIA, UWC) – slide courtesy
- Containers are a software package that contains everything required to run an application/workflow
  - files, environmental variables, libraries and dependencies
- Allows for interchangeable environments and configurations at runtime and portability between systems

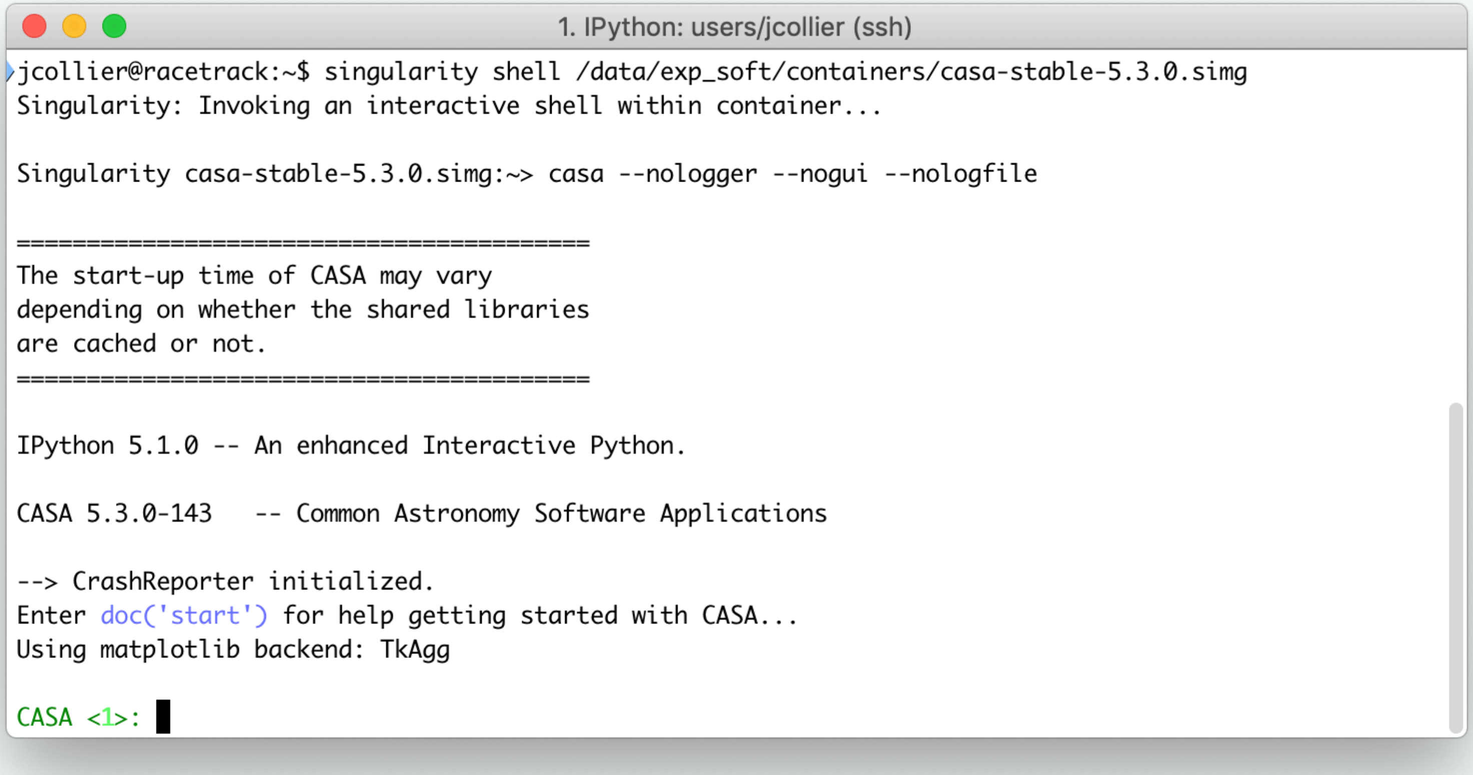
Aegean
PyBDSF
CASA
Common Astronomy Software Applications

Singularity Containers


sourcefinding_py3_update.sh — ~/Research/MeerKAT/containers
sourcefinding_py3_update.sh
sourcefinding_py3_update.sh 1:1
1 LF UTF-8 Shell Script 0 files 4 updates

```
Bootstrap: localimage
From: /mnt/containers/sourcefinding_py3_update/sourcefinding_py3-2018-08-30-tmp.simg
Include: software-properties-common

%environment

        export INSTALLER_PATH=/installer
        ...

%setup
        #Copy patch file for blobcat
        cp blobcat_patch.diff $SINGULARITY_ROOTFS

%post

        #Installation of BLOBCAT
        export BLOBCAT_PATH=$INSTALLER_PATH/BLOBCAT
        mkdir $BLOBCAT_PATH
        cd $BLOBCAT_PATH
        wget -O blobcat-v1.2.tar.bz2 http://sourceforge.net/projects/blobcat/files/blobcat-v1.2.tar.bz2/download
        tar xvjf blobcat-v1.2.tar.bz2

        #Patch blobcat to run python2.7 and fix error on one line
        patch blobcat.py /blobcat_patch.diff

        ...

        #Upgrade pip
        pip install --upgrade pip

        #Installation of PASTA
        pip install git+https://github.com/bwkeller/PASTA

        ...

        #Install eog (and dependencies)
        apt-get -y install eog
```

Singularity Containers



1. IPython: users/jcollier (ssh)

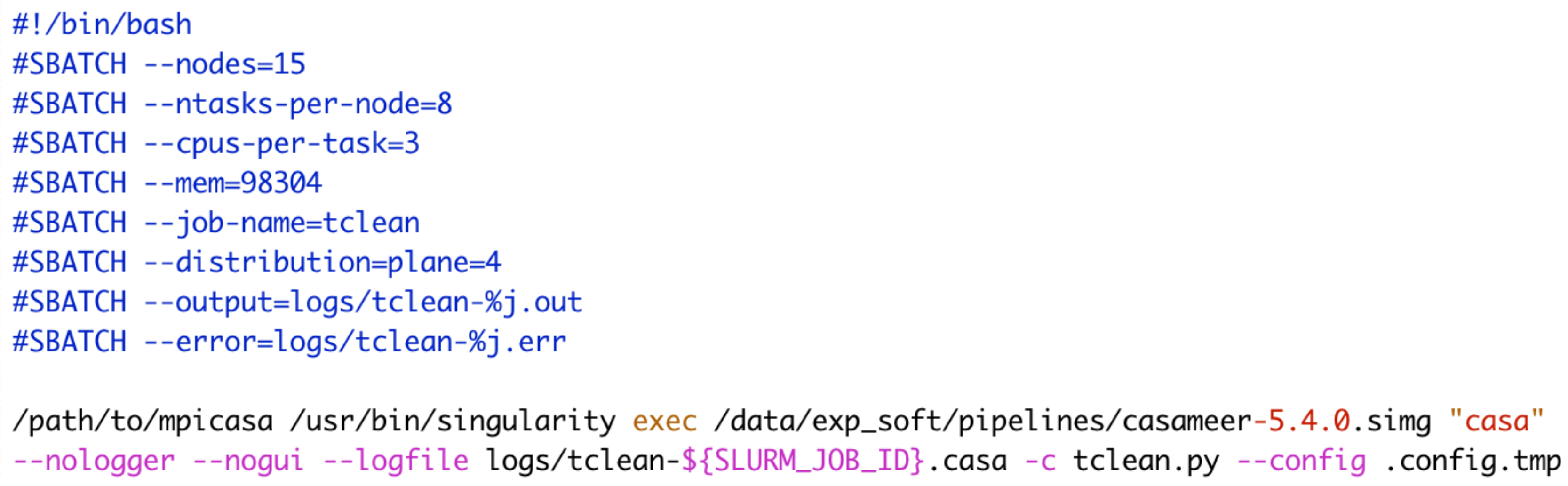
```
jcollier@racetrack:~$ singularity shell /data/exp_soft/containers/casa-stable-5.3.0.simg
Singularity: Invoking an interactive shell within container...

Singularity casa-stable-5.3.0.simg:~> casa --nologger --nogui --nologfile


=========================================
The start-up time of CASA may vary
depending on whether the shared libraries
are cached or not.
=========================================


IPython 5.1.0 -- An enhanced Interactive Python.

CASA 5.3.0-143   -- Common Astronomy Software Applications

--> CrashReporter initialized.
Enter doc('start') for help getting started with CASA...
Using matplotlib backend: TkAgg

CASA <1>: 
```

Singularity Containers

- Exec

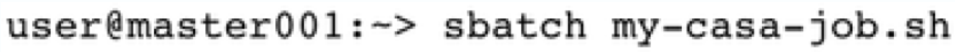
```
:~$ singularity exec /data/exp_soft/containers/sourcefinding_py3.simg python myscript.py
```

- MPICASA with SLURM using batch file (“my-casa-job.sh”)



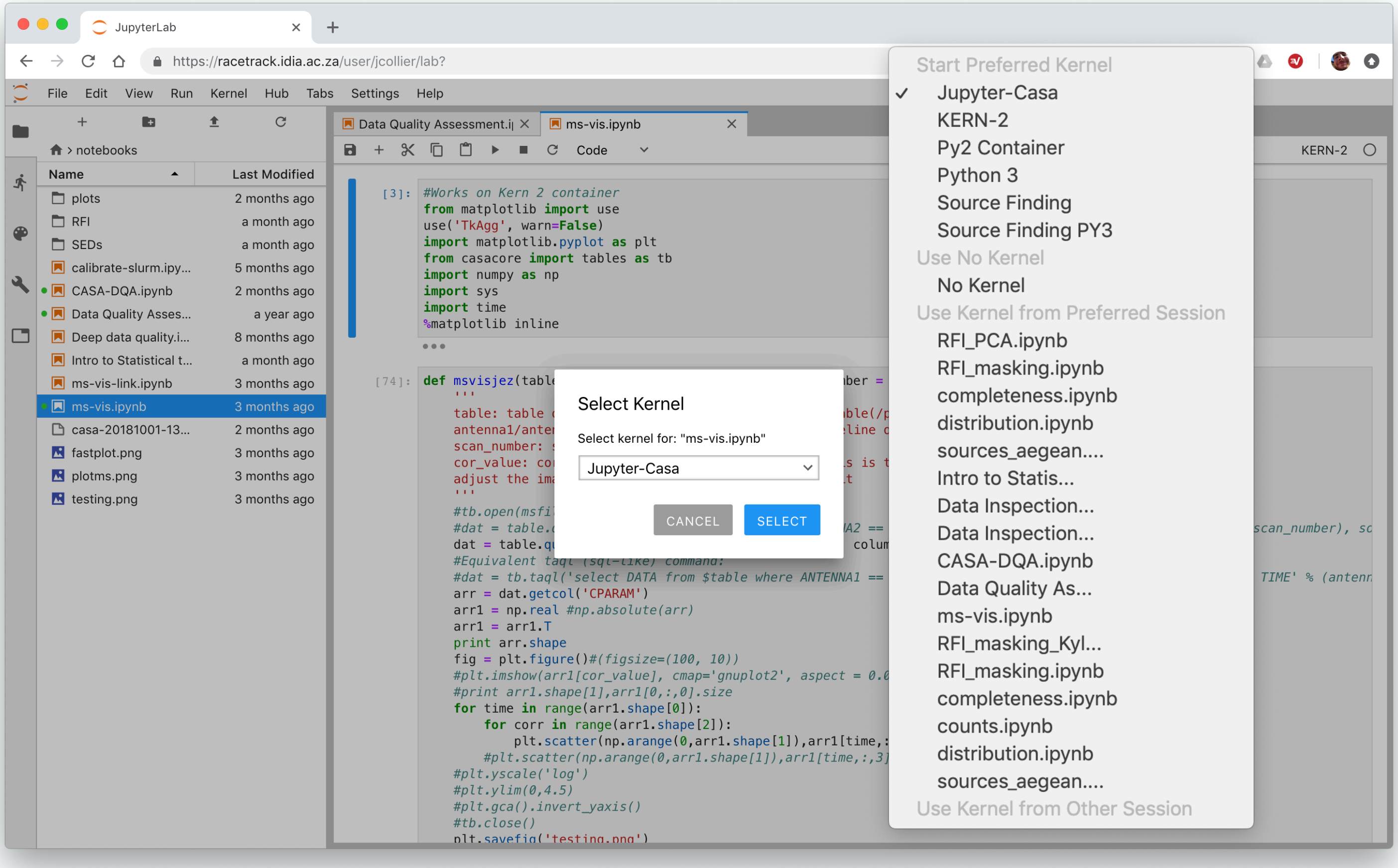
```
#!/bin/bash
#SBATCH --nodes=15
#SBATCH --ntasks-per-node=8
#SBATCH --cpus-per-task=3
#SBATCH --mem=98304
#SBATCH --job-name=tclean
#SBATCH --distribution=plane=4
#SBATCH --output=logs/tclean-%j.out
#SBATCH --error=logs/tclean-%j.err

/path/to/mpicasa /usr/bin/singularity exec /data/exp_soft/pipelines/casameer-5.4.0.simg "casa"
--nologger --nogui --logfile logs/tclean-${SLURM_JOB_ID}.casa -c tclean.py --config .config.tmp
```

- Terminal on SLURM cluster:



```
user@master001:~> sbatch my-casa-job.sh
```

JupyterHub: Singularity Containers



Name	Last Modified
plots	2 months ago
RFI	a month ago
SEDs	a month ago
calibrate-slurm.ipy...	5 months ago
CASA-DQA.ipynb	2 months ago
Data Quality Asses...	a year ago
Deep data quality.i...	8 months ago
Intro to Statistical t...	a month ago
ms-vis-link.ipynb	3 months ago
ms-vis.ipynb	3 months ago
casa-20181001-13...	2 months ago
fastplot.png	3 months ago
plotms.png	3 months ago
testing.png	3 months ago

```
[3]: #Works on Kern 2 container
     from matplotlib import use
     use('TkAgg', warn=False)
     import matplotlib.pyplot as plt
     from casacore import tables as tb
     import numpy as np
     import sys
     import time
     %matplotlib inline
```

```
[74]: def msvisjez(table                    ber =
          '''
          table: table                      ble(/p
          antenna1/anter                    eline c
          scan_number:
          cor_value: co                     s is t
          adjust the ima                    t
          '''
          #tb.open(msfi
          #dat = table.                     A2 ==                                    scan_number), sc
          dat = table.q                      colum
          #Equivalent taql (sql-like) command:
          #dat = tb.taql('select DATA from $table where ANTENNA1 ==                   TIME' % (antenn
          arr = dat.getcol('CPARAM')
          arr1 = np.real #np.absolute(arr)
          arr1 = arr1.T
          print arr.shape
          fig = plt.figure()#(figsize=(100, 10))
          #plt.imshow(arr1[cor_value], cmap='gnuplot2', aspect = 0.0
          #print arr1.shape[1],arr1[0,:,0].size
          for time in range(arr1.shape[0]):
              for corr in range(arr1.shape[2]):
                  plt.scatter(np.arange(0,arr1.shape[1]),arr1[time,:
              #plt.scatter(np.arange(0,arr1.shape[1]),arr1[time,:,3]
          #plt.yscale('log')
          #plt.ylim(0,4.5)
          #plt.gca().invert_yaxis()
          #tb.close()
          plt.savefig('testing.png')
```

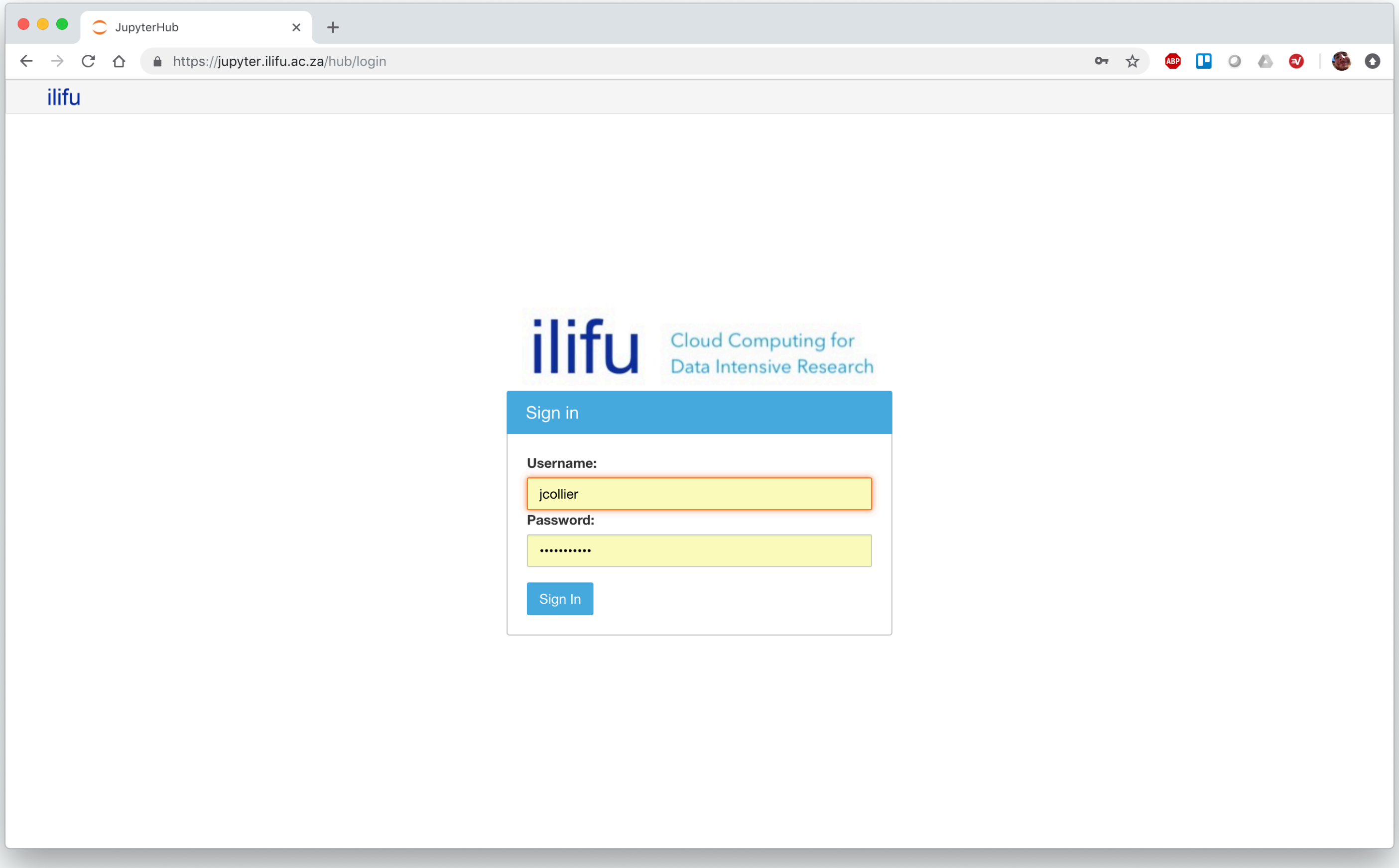
Select Kernel

Select kernel for: "ms-vis.ipynb"

Jupyter-Casa

CANCEL SELECT

JupyterHub Spawner



JupyterHub
https://jupyter.ilifu.ac.za/hub/login
ilifu
ilifu Cloud Computing for Data Intensive Research
Sign in

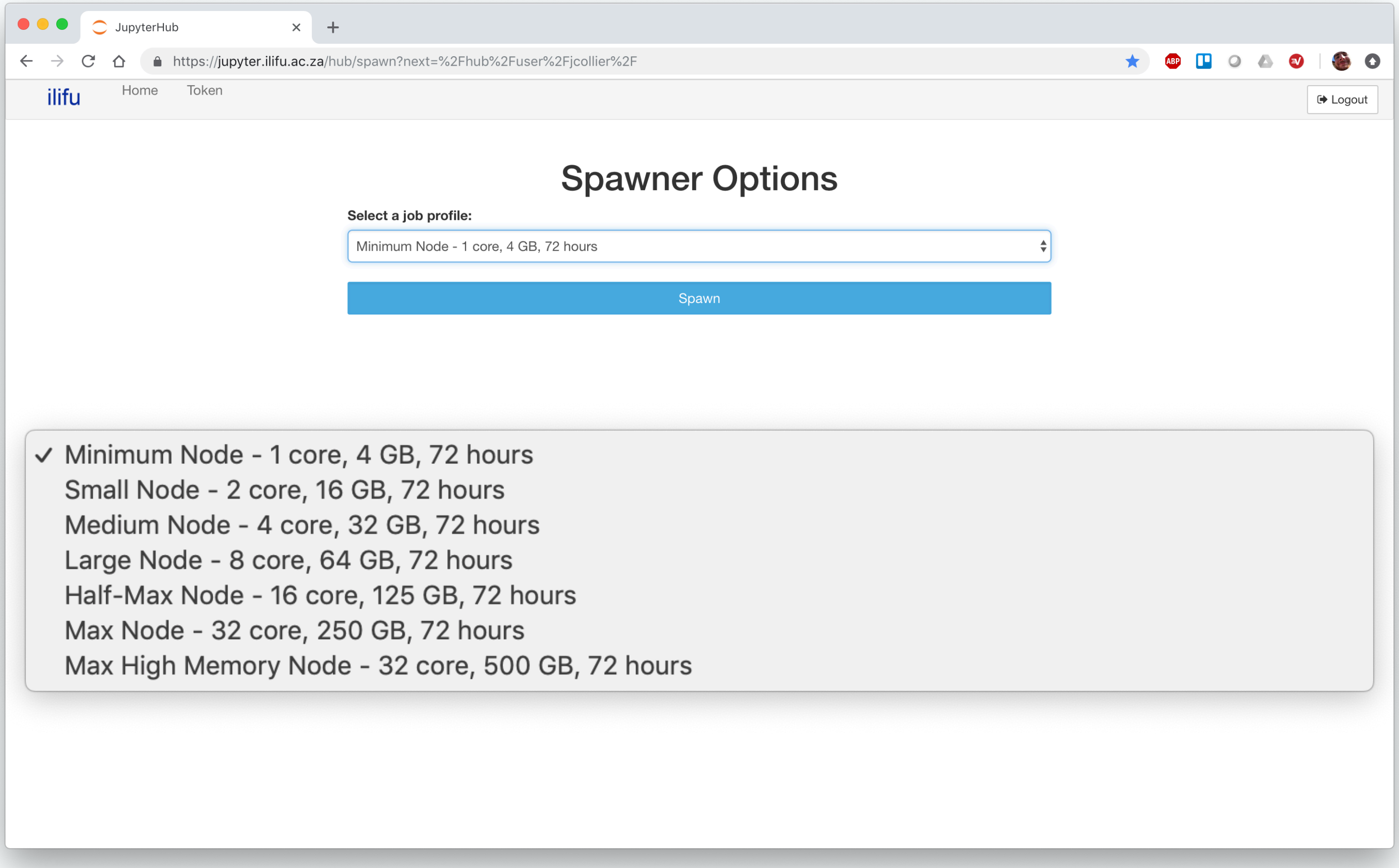
Username:

jcollier

Password:

•••••••••••

JupyterHub Spawner



JupyterHub
https://jupyter.ilifu.ac.za/hub/spawn?next=%2Fhub%2Fuser%2Fjcollier%2F
ilifu
Home
Token
Logout

Spawner Options

Select a job profile:

Minimum Node - 1 core, 4 GB, 72 hours

- ✓ Minimum Node - 1 core, 4 GB, 72 hours
- Small Node - 2 core, 16 GB, 72 hours
- Medium Node - 4 core, 32 GB, 72 hours
- Large Node - 8 core, 64 GB, 72 hours
- Half-Max Node - 16 core, 125 GB, 72 hours
- Max Node - 32 core, 250 GB, 72 hours
- Max High Memory Node - 32 core, 500 GB, 72 hours

IDIA Inter-University Institute for Data Intensive Astronomy

Using the IDIA Pipeline

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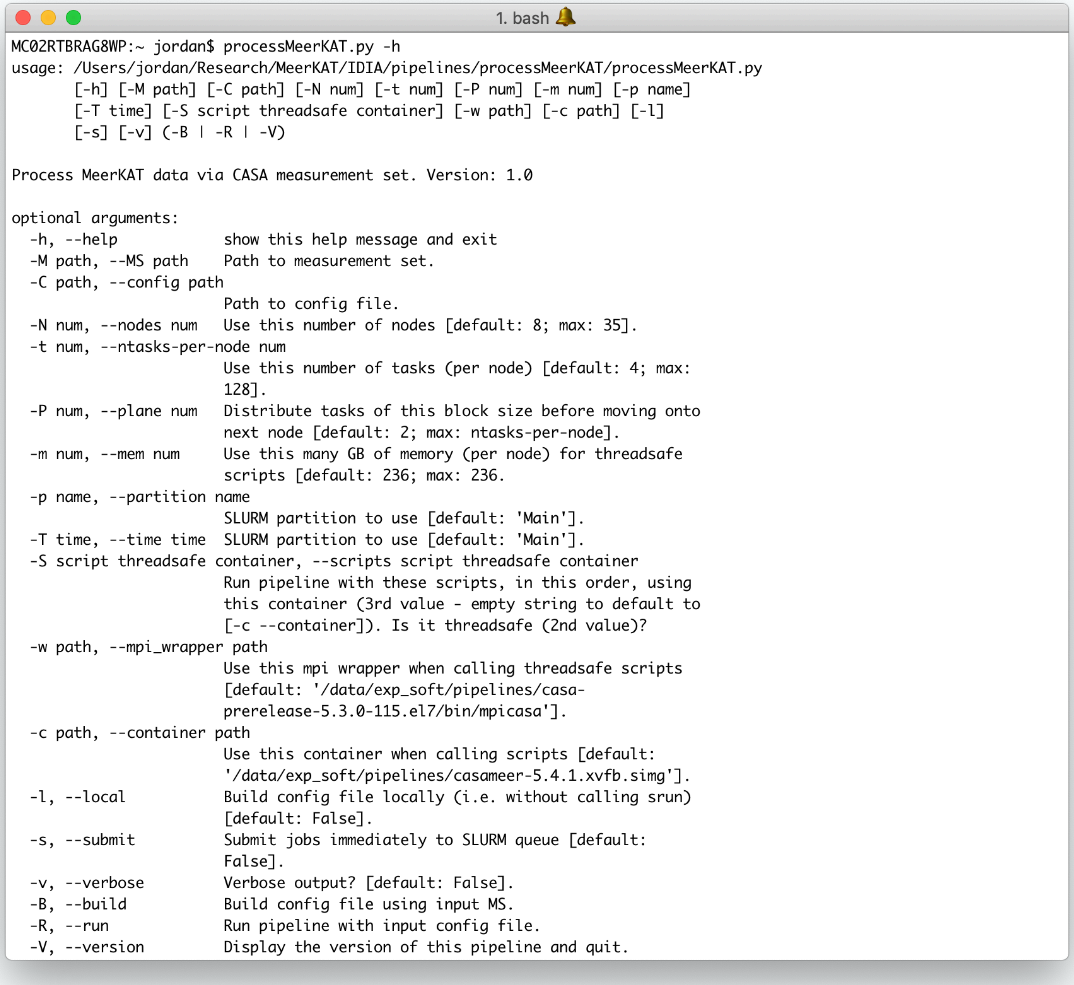
Jordan Collier | 20 Feb 2019 | MIGHTEE workshop

processMeerKAT.py

- Builds and submits pipeline job on IDIA / Ilifu SLURM cluster
- Launch pipeline
  - Input measurement set
  - Build your config file
  - OR run your config file (i.e. build job scripts)
  - Request resources
  - Optionally insert your own scripts
  - Specify containers and MPI wrappers



1. bash

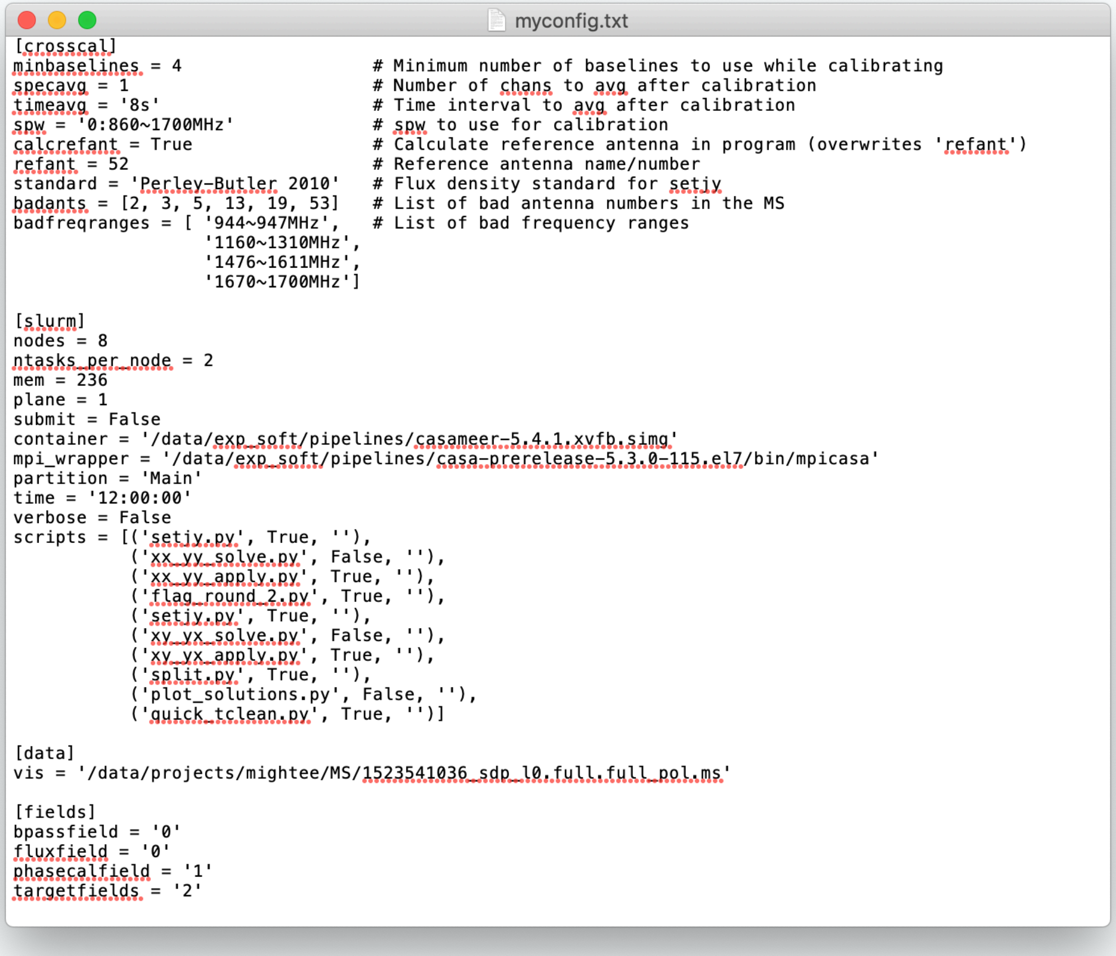
```
MC02RTBRAG8WP:~ jordan$ processMeerKAT.py -h
usage: /Users/jordan/Research/MeerKAT/IDIA/pipelines/processMeerKAT/processMeerKAT.py
       [-h] [-M path] [-C path] [-N num] [-t num] [-P num] [-m num] [-p name]
       [-T time] [-S script threadsafe container] [-w path] [-c path] [-l]
       [-s] [-v] (-B | -R | -V)

Process MeerKAT data via CASA measurement set. Version: 1.0

optional arguments:
  -h, --help            show this help message and exit
  -M path, --MS path    Path to measurement set.
  -C path, --config path
                        Path to config file.
  -N num, --nodes num   Use this number of nodes [default: 8; max: 35].
  -t num, --ntasks-per-node num
                        Use this number of tasks (per node) [default: 4; max:
                        128].
  -P num, --plane num   Distribute tasks of this block size before moving onto
                        next node [default: 2; max: ntasks-per-node].
  -m num, --mem num     Use this many GB of memory (per node) for threadsafe
                        scripts [default: 236; max: 236.
  -p name, --partition name
                        SLURM partition to use [default: 'Main'].
  -T time, --time time  SLURM partition to use [default: 'Main'].
  -S script threadsafe container, --scripts script threadsafe container
                        Run pipeline with these scripts, in this order, using
                        this container (3rd value - empty string to default to
                        [-c --container]). Is it threadsafe (2nd value)?
  -w path, --mpi_wrapper path
                        Use this mpi wrapper when calling threadsafe scripts
                        [default: '/data/exp_soft/pipelines/casa-
                        prerelease-5.3.0-115.el7/bin/mpicasa'].
  -c path, --container path
                        Use this container when calling scripts [default:
                        '/data/exp_soft/pipelines/casameer-5.4.1.xvfb.simg'].
  -l, --local           Build config file locally (i.e. without calling srun)
                        [default: False].
  -s, --submit          Submit jobs immediately to SLURM queue [default:
                        False].
  -v, --verbose         Verbose output? [default: False].
  -B, --build           Build config file using input MS.
  -R, --run             Run pipeline with input config file.
  -V, --version         Display the version of this pipeline and quit.
```

The Build Step

- `processMeerKAT.py -B -C myconfig.txt –M /data/projects/mightee/MS/1524147354_sdp_l0.full.full_pol.MS`
- Builds your config file
  - Reads MS and automatically extracts field IDs based on intent
    - Extracts total flux, bandpass, phase cal, and targets
  - Compares resources you've requested to the number of scans / sub-MSs
    - We partition by scan, so it prevents requesting too many / few threads
  - Ensures reference antenna exists

Config Files

- [crosscal]
  - Select spectral window / freqs (e.g. for HI)
  - Other parameters affecting calibration
- [slurm]
  - Resource parameters
  - List of scripts to run, and whether to call MPI
  - etc
- Path to MS stored
- Field IDs stored



```
[crosscal]
minbaselines = 4                  # Minimum number of baselines to use while calibrating
specavg = 1                       # Number of chans to avg after calibration
timeavg = '8s'                    # Time interval to avg after calibration
spw = '0:860~1700MHz'             # spw to use for calibration
calcrefant = True                 # Calculate reference antenna in program (overwrites 'refant')
refant = 52                       # Reference antenna name/number
standard = 'Perley-Butler 2010'   # Flux density standard for setjy
badants = [2, 3, 5, 13, 19, 53]   # List of bad antenna numbers in the MS
badfreqranges = [ '944~947MHz',   # List of bad frequency ranges
                  '1160~1310MHz',
                  '1476~1611MHz',
                  '1670~1700MHz']

[slurm]
nodes = 8
ntasks_per_node = 2
mem = 236
plane = 1
submit = False
container = '/data/exp_soft/pipelines/casameer-5.4.1.xvfb.simg'
mpi_wrapper = '/data/exp_soft/pipelines/casa-prerelease-5.3.0-115.el7/bin/mpicasa'
partition = 'Main'
time = '12:00:00'
verbose = False
scripts = [('setjy.py', True, ''),
           ('xx_yy_solve.py', False, ''),
           ('xx_yy_apply.py', True, ''),
           ('flag_round_2.py', True, ''),
           ('setjy.py', True, ''),
           ('xy_yx_solve.py', False, ''),
           ('xy_yx_apply.py', True, ''),
           ('split.py', True, ''),
           ('plot_solutions.py', False, ''),
           ('quick_tclean.py', True, '')]

[data]
vis = '/data/projects/mightee/MS/1523541036_sdp_l0.full.full_pol.ms'

[fields]
bpassfield = '0'
fluxfield = '0'
phasecalfield = '1'
targetfields = '2'
```

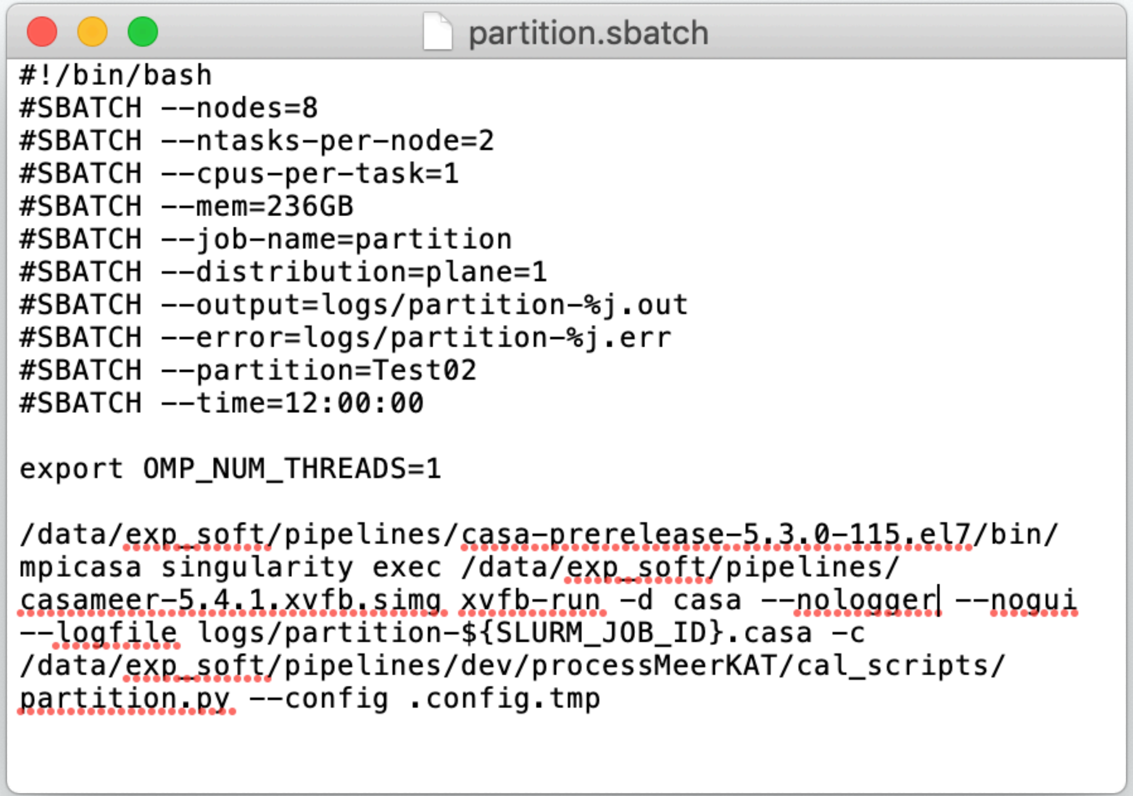
The Run Step

- `processMeerKAT.py -R -C myconfig.txt`
- Builds SLURM sbatch files
  (one for each unique python script)
  - Wrote sbatch file "validate_input.sbatch"
  - Wrote sbatch file "partition.sbatch"
  - Wrote sbatch file "calc_refant.sbatch"
  - Wrote sbatch file "flag_round_1.sbatch"
  - Wrote sbatch file "setjy.sbatch"
  - Wrote sbatch file "xx_yy_solve.sbatch"
  - Wrote sbatch file "xx_yy_apply.sbatch"
  - ...
  - Wrote sbatch file "split.sbatch"
  - Wrote sbatch file "plot_solutions.sbatch"
  - Wrote sbatch file "quick_tclean.sbatch”

- Writes master submission (bash) script

Sbatch Files

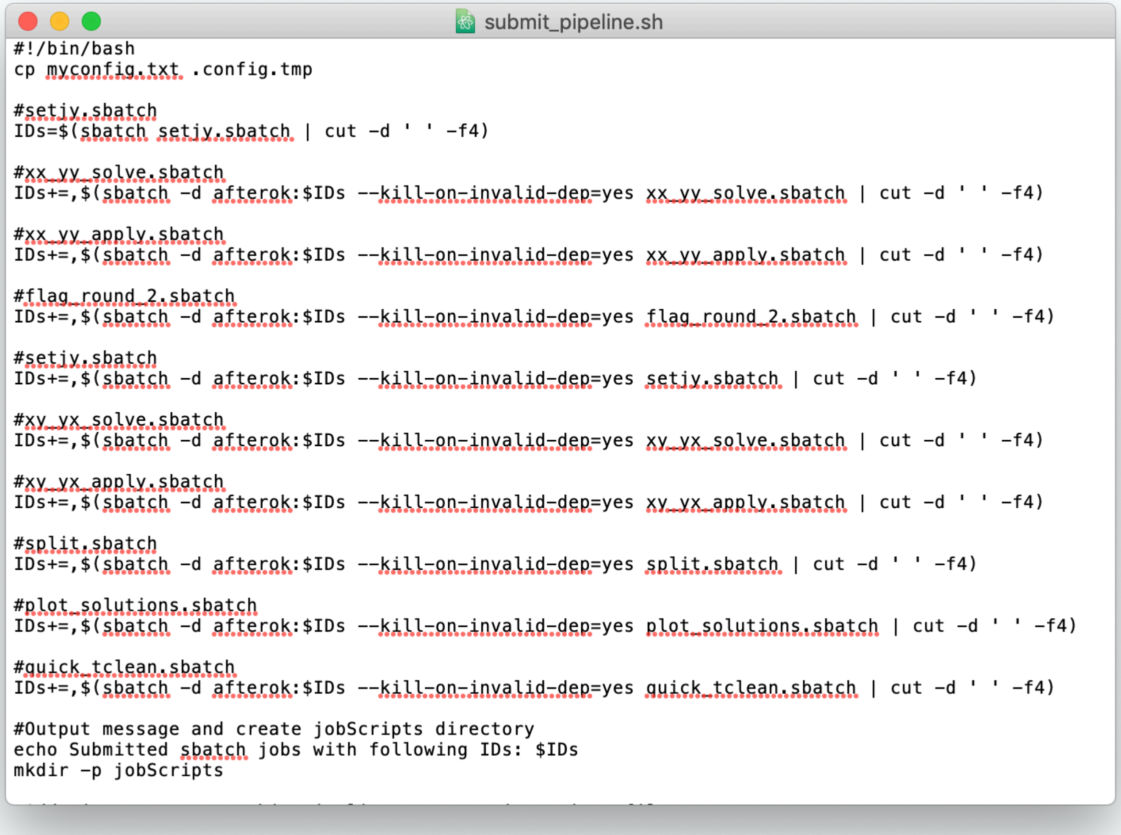
- Calls script within CASA container, within MPI wrapper
- Logs with job ID written for stdout, stderr, and CASA
- User can choose to submit these jobs one at a time
- OR use master submission script



```
#!/bin/bash
#SBATCH --nodes=8
#SBATCH --ntasks-per-node=2
#SBATCH --cpus-per-task=1
#SBATCH --mem=236GB
#SBATCH --job-name=partition
#SBATCH --distribution=plane=1
#SBATCH --output=logs/partition-%j.out
#SBATCH --error=logs/partition-%j.err
#SBATCH --partition=Test02
#SBATCH --time=12:00:00

export OMP_NUM_THREADS=1

/data/exp_soft/pipelines/casa-prerelease-5.3.0-115.el7/bin/
mpicasa singularity exec /data/exp_soft/pipelines/
casameer-5.4.1.xvfb.simg xvfb-run -d casa --nologger --nogui
--logfile logs/partition-${SLURM_JOB_ID}.casa -c
/data/exp_soft/pipelines/dev/processMeerKAT/cal_scripts/
partition.py --config .config.tmp
```

Master Submission Script

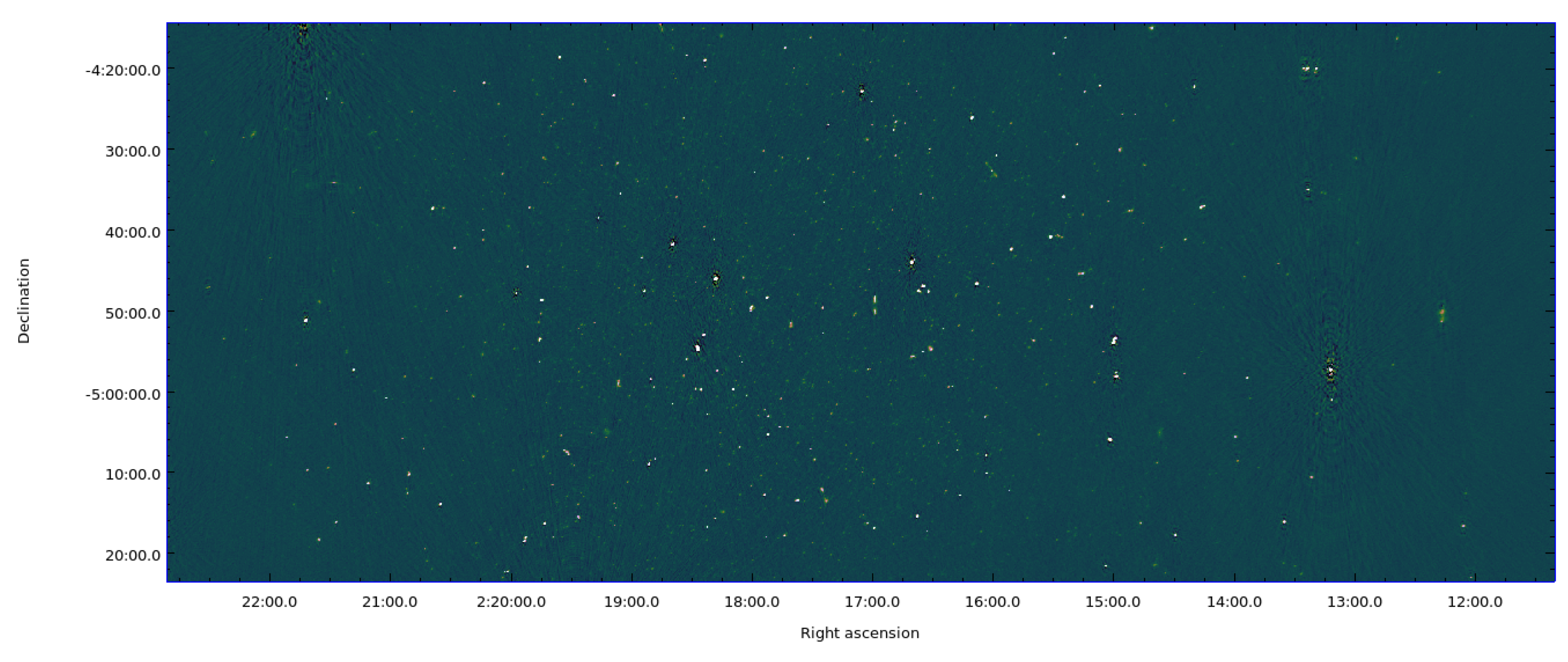
- Bash script that submits sbatch files to SLURM queue each time it's run
- Builds ancillary bash scripts that interact with pipeline run
  - Summarise progress
  - Kill all jobs
  - Find errors (after pipeline run)
  - Display runtimes (after pipeline run)



```
#!/bin/bash
cp myconfig.txt .config.tmp

#setjy.sbatch
IDs=$(sbatch setjy.sbatch | cut -d ' ' -f4)

#xx_yy_solve.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes xx_yy_solve.sbatch | cut -d ' ' -f4)

#xx_yy_apply.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes xx_yy_apply.sbatch | cut -d ' ' -f4)

#flag_round_2.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes flag_round_2.sbatch | cut -d ' ' -f4)

#setjy.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes setjy.sbatch | cut -d ' ' -f4)

#xy_yx_solve.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes xy_yx_solve.sbatch | cut -d ' ' -f4)

#xy_yx_apply.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes xy_yx_apply.sbatch | cut -d ' ' -f4)

#split.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes split.sbatch | cut -d ' ' -f4)

#plot_solutions.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes plot_solutions.sbatch | cut -d ' ' -f4)

#quick_tclean.sbatch
IDs+=,$(sbatch -d afterok:$IDs --kill-on-invalid-dep=yes quick_tclean.sbatch | cut -d ' ' -f4)

#Output message and create jobScripts directory
echo Submitted sbatch jobs with following IDs: $IDs
mkdir -p jobScripts
```

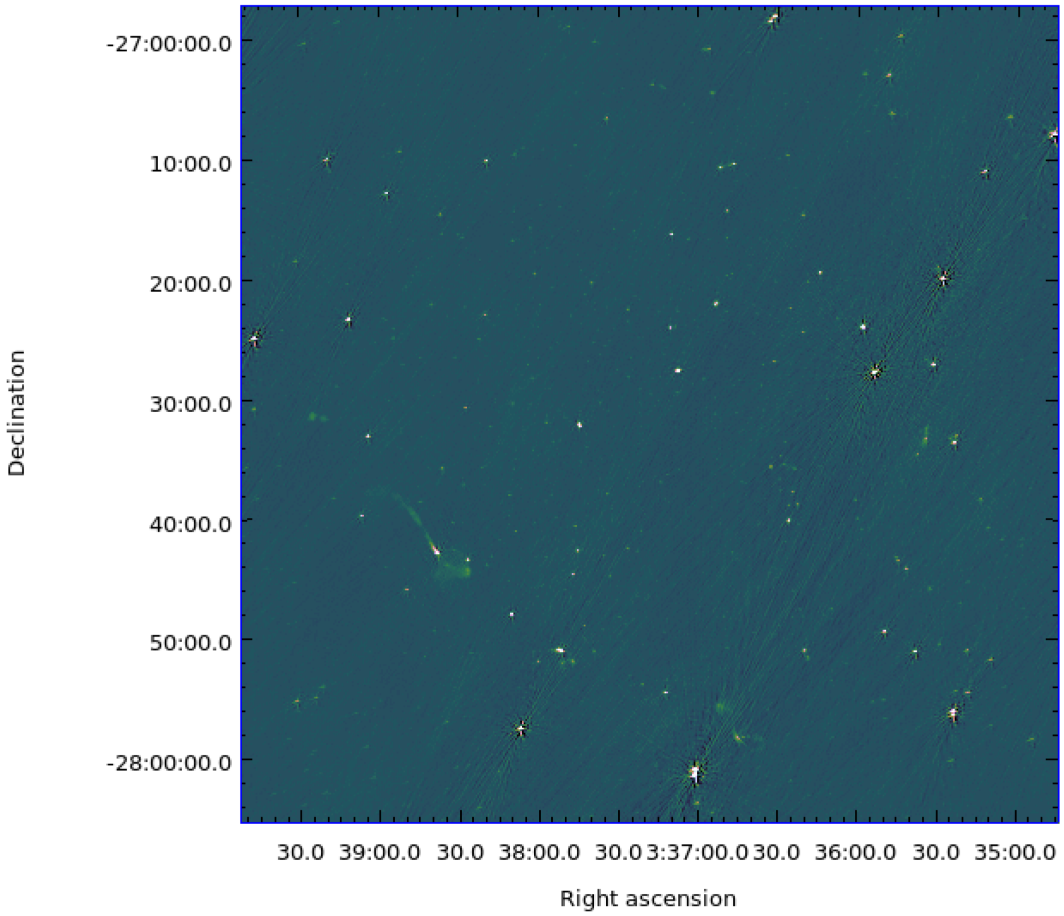
Initial QA: Quick Look Images

- Very quick and dirty imaging for QA purposes
  - No selfcal, no w-projection, no thresholding, no multi-scale, etc
  - XMM-LSS field: RMS ~10 uJy / beam



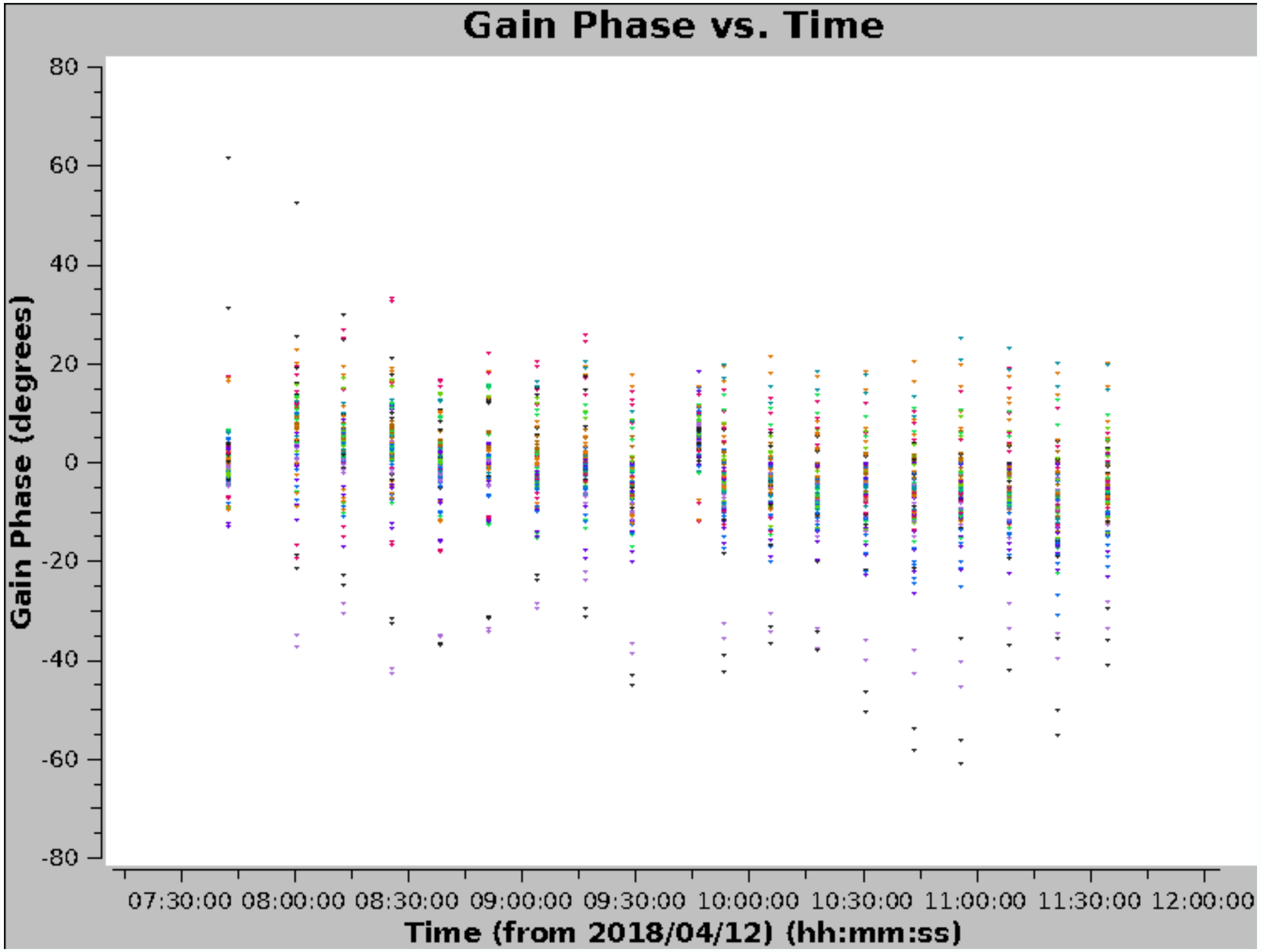
Initial QA: Quick Look Images

- CDFS field
- ~8 hours, 10 MHz spw
- RMS ~80 uJy / beam
- Scales to ~10 uJy over whole band (assuming ~100 MHz flagged out)



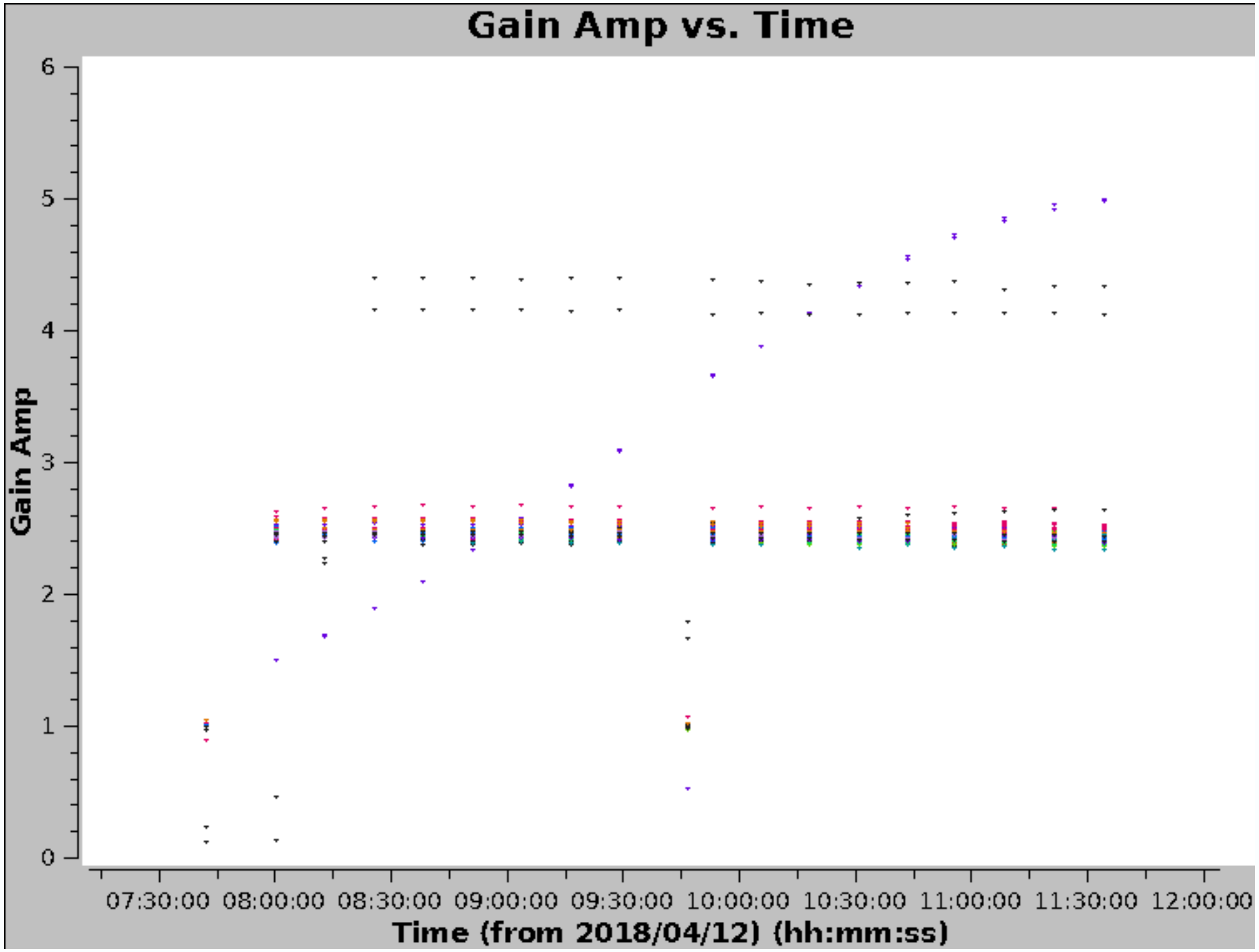
Initial QA: Calibration Solutions

- Phase cal solutions



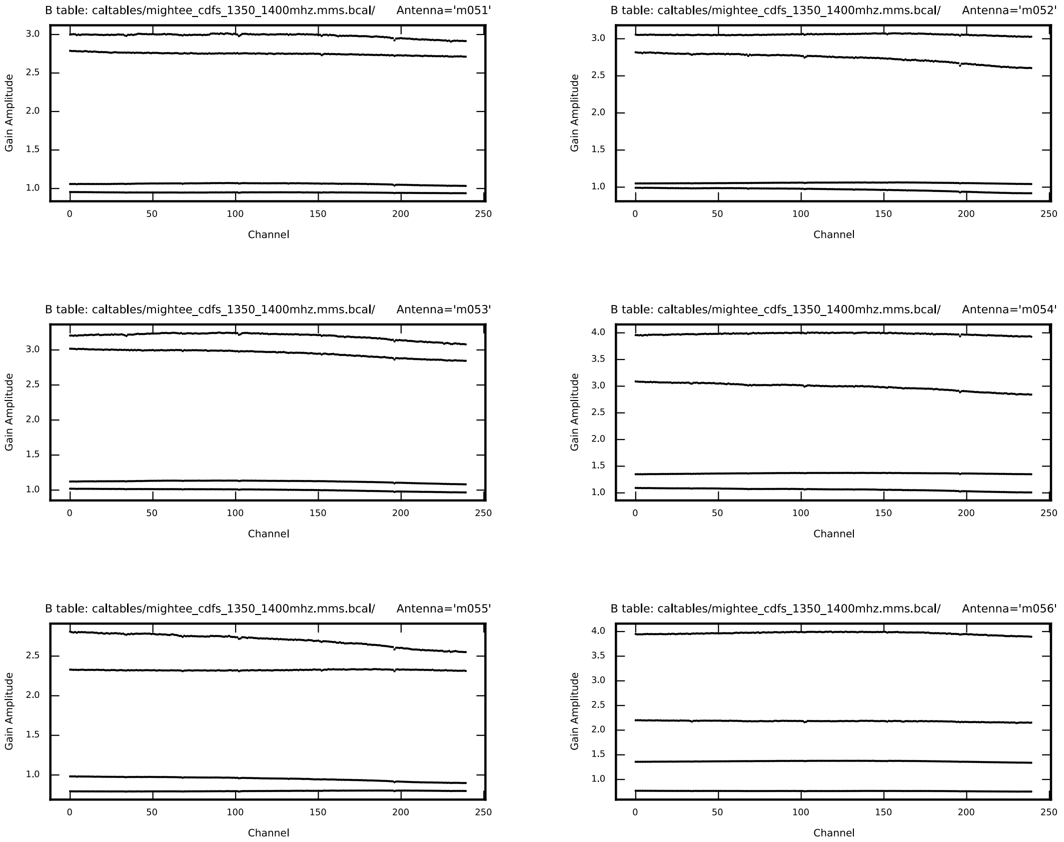
Initial QA: Calibration Solutions

- Phase cal solutions



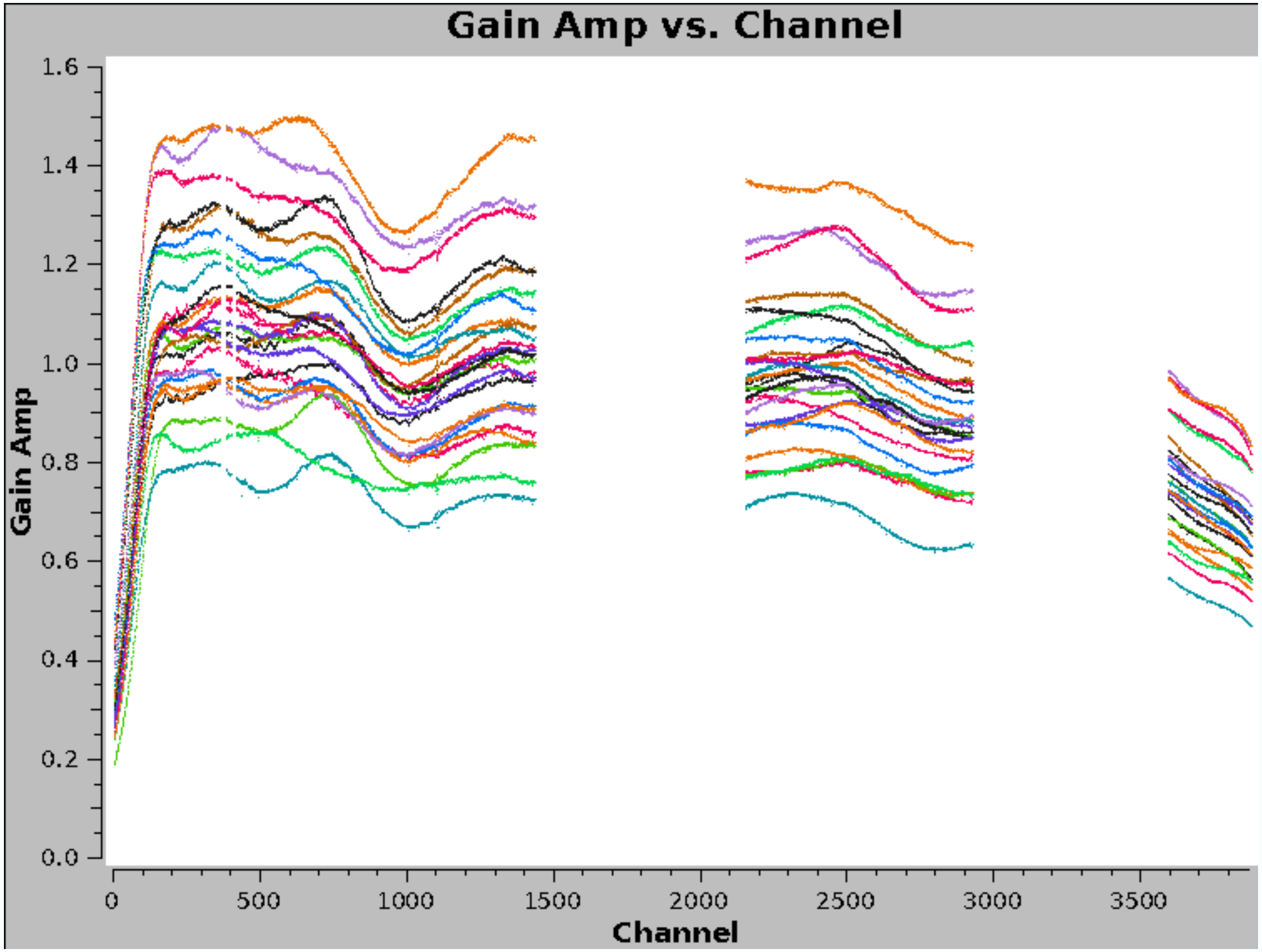
Initial QA: Calibration Solutions

- Phase cal solutions



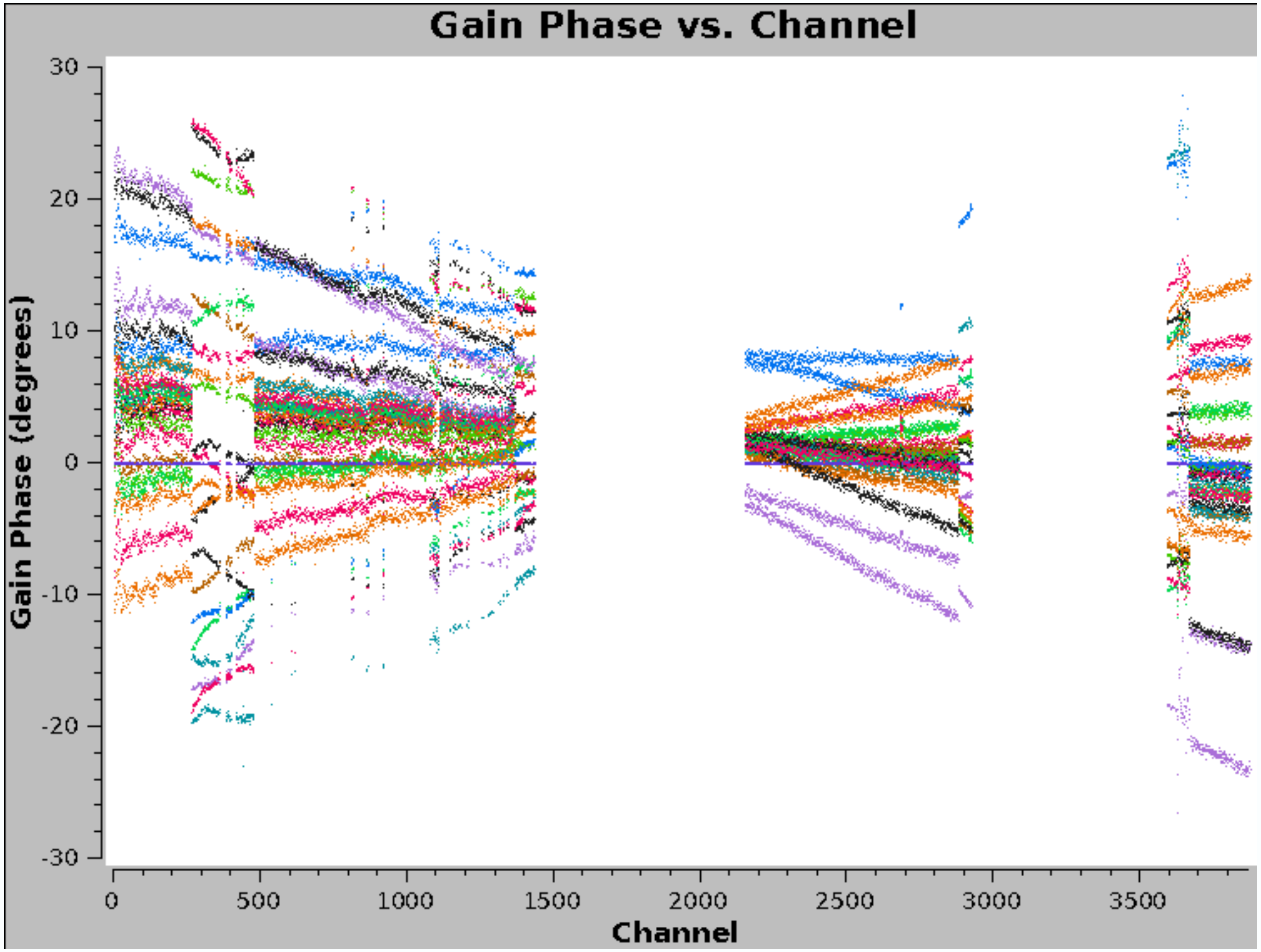
Initial QA: Calibration Solutions

- Bandpass solutions



Initial QA: Calibration Solutions

- Bandpass solutions
- And more…



A Good Framework

- Pipeline outputs calibrated MMS + MSs/MMSs split by field
- You insert your scripts at start, middle or end (e.g. WSClean)
- Each job/script is a logical step that does/doesn't use MPI, and optionally uses a different container
- HPC-friendly – dynamically uses resources & submits to queue
- Use cases we currently support
  - Full stokes calibration + Stokes I only calibration (minimal speedup)
  - Narrow band (spectral line) calibration, full-band calibration
  - Single MS (speedup for small BW), multi-MS
  - Inserting your own scripts (hard-coded or read config file)
- https://idia-pipelines.github.io/docs/processMeerKAT

Future Development

- Selfcal and AW Projection (see Krishna's talks)
- Optimisation of resources / performance
  - Currently takes ~1 day to process 64 dish 4k data (~2 TB)
  - Split data by intent during beginning, and simultaneously calibrate / flag
  - More dynamic use of threads and memory per script per intent (based on benchmarking)
    - Partitioning (IO), flagging (RAM), imaging (CPU)
  - Will see a significant speedup, necessary for arrival of 32k data
- Comprehensive data quality assessment

IDIA Inter-University Institute for Data Intensive Astronomy

Data Quality Assessment

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

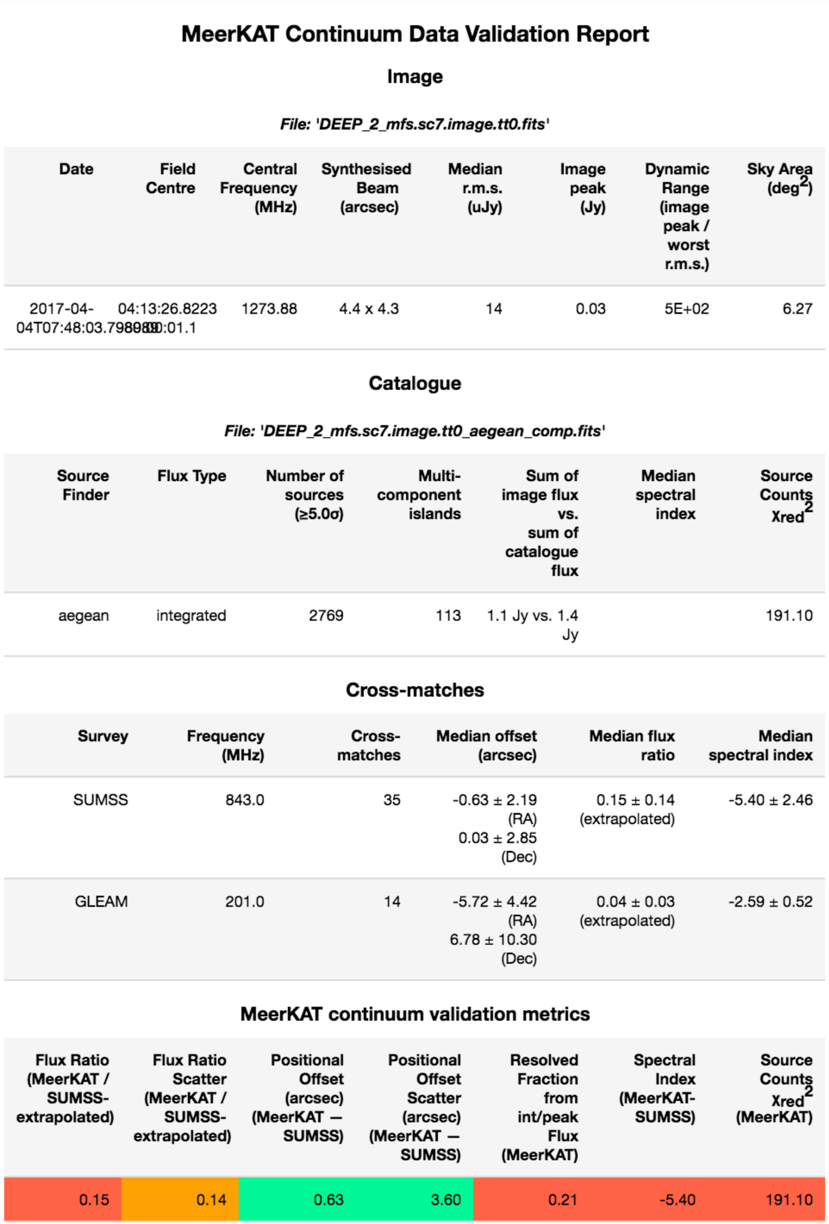
WESTERN SYDNEY UNIVERSITY

ilifu

Jordan Collier | 20 Feb 2019 | MIGHTEE workshop

Data Quality Assessment

- Already implemented: quality assessment of data products out of processing pipeline
  - i.e. scientific DQA at end of workflow
- End-to-end analysis of MeerKAT (continuum) image / catalogue
- Presents validation report
- Produces several tables summarising data and DQA metrics
- Runs in jupyter notebook on IDIA cloud with interactive plots



MeerKAT Continuum Data Validation Report

Image

File: 'DEEP_2_mfs.sc7.image.tt0.fits'

Date	Field Centre	Central Frequency (MHz)	Synthesised Beam (arcsec)	Median r.m.s. (uJy)	Image peak (Jy)	Dynamic Range (image peak / worst r.m.s.)	Sky Area (deg^2)
2017-04-04T07:48:03.798989	04:13:26.8223 [illegible]0:01.1	1273.88	4.4 x 4.3	14	0.03	5E+02	6.27

Catalogue

File: 'DEEP_2_mfs.sc7.image.tt0_aegean_comp.fits'

Source Finder	Flux Type	Number of sources (≥5.0σ)	Multi-component islands	Sum of image flux vs. sum of catalogue flux	Median spectral index	Source Counts Xred^2
aegean	integrated	2769	113	1.1 Jy vs. 1.4 Jy		191.10

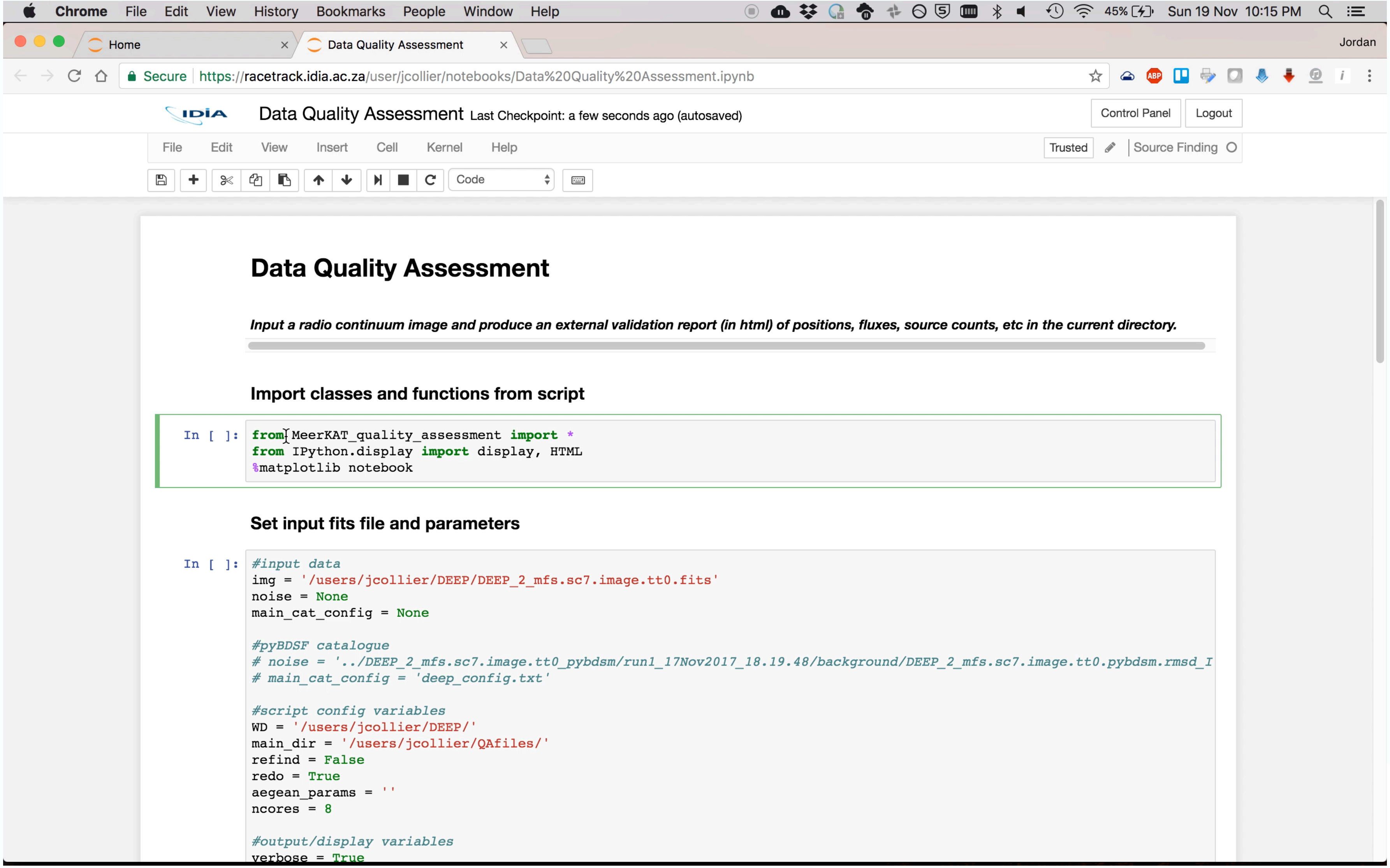
Cross-matches

Survey	Frequency (MHz)	Cross-matches	Median offset (arcsec)	Median flux ratio	Median spectral index
SUMSS	843.0	35	-0.63 ± 2.19 (RA) 0.03 ± 2.85 (Dec)	0.15 ± 0.14 (extrapolated)	-5.40 ± 2.46
GLEAM	201.0	14	-5.72 ± 4.42 (RA) 6.78 ± 10.30 (Dec)	0.04 ± 0.03 (extrapolated)	-2.59 ± 0.52

MeerKAT continuum validation metrics

Flux Ratio (MeerKAT / SUMSS-extrapolated)	Flux Ratio Scatter (MeerKAT / SUMSS-extrapolated)	Positional Offset (arcsec) (MeerKAT — SUMSS)	Positional Offset Scatter (arcsec) (MeerKAT — SUMSS)	Resolved Fraction from int/peak Flux (MeerKAT)	Spectral Index (MeerKAT-SUMSS)	Source Counts Xred^2 (MeerKAT)
🟥 0.15	🟧 0.14	🟩 0.63	🟩 3.60	🟥 0.21	🟥 -5.40	🟥 191.10

Data Quality Assessment


Chrome File Edit View History Bookmarks People Window Help
45%
Sun 19 Nov 10:15 PM
Home
Data Quality Assessment
Jordan
Secure | https://racetrack.idia.ac.za/user/jcollier/notebooks/Data%20Quality%20Assessment.ipynb
IDIA
Data Quality Assessment Last Checkpoint: a few seconds ago (autosaved)
Control Panel
Logout
File Edit View Insert Cell Kernel Help
Trusted
Source Finding
Code

Data Quality Assessment

Input a radio continuum image and produce an external validation report (in html) of positions, fluxes, source counts, etc in the current directory.

Import classes and functions from script

```
In [ ]: from MeerKAT_quality_assessment import *
        from IPython.display import display, HTML
        %matplotlib notebook
```

Set input fits file and parameters

```
In [ ]: #input data
        img = '/users/jcollier/DEEP/DEEP_2_mfs.sc7.image.tt0.fits'
        noise = None
        main_cat_config = None

        #pyBDSF catalogue
        # noise = '../DEEP_2_mfs.sc7.image.tt0_pybdsm/run1_17Nov2017_18.19.48/background/DEEP_2_mfs.sc7.image.tt0.pybdsm.rmsd_I
        # main_cat_config = 'deep_config.txt'

        #script config variables
        WD = '/users/jcollier/DEEP/'
        main_dir = '/users/jcollier/QAfiles/'
        refind = False
        redo = True
        aegean_params = ''
        ncores = 8

        #output/display variables
        verbose = True
```

Data Quality Assessment

- Have started looking at DQA of early pipeline data products
- In close collaboration with MeerKAT SDP.
  - Framework to measure quality of pipelines.
  - Standard set of metrics between all pipelines
    - Defer processing to most efficient pipelines?
  - Mapping science requirements from LSPs to technical requirements for pipelines

Data Quality Assessment

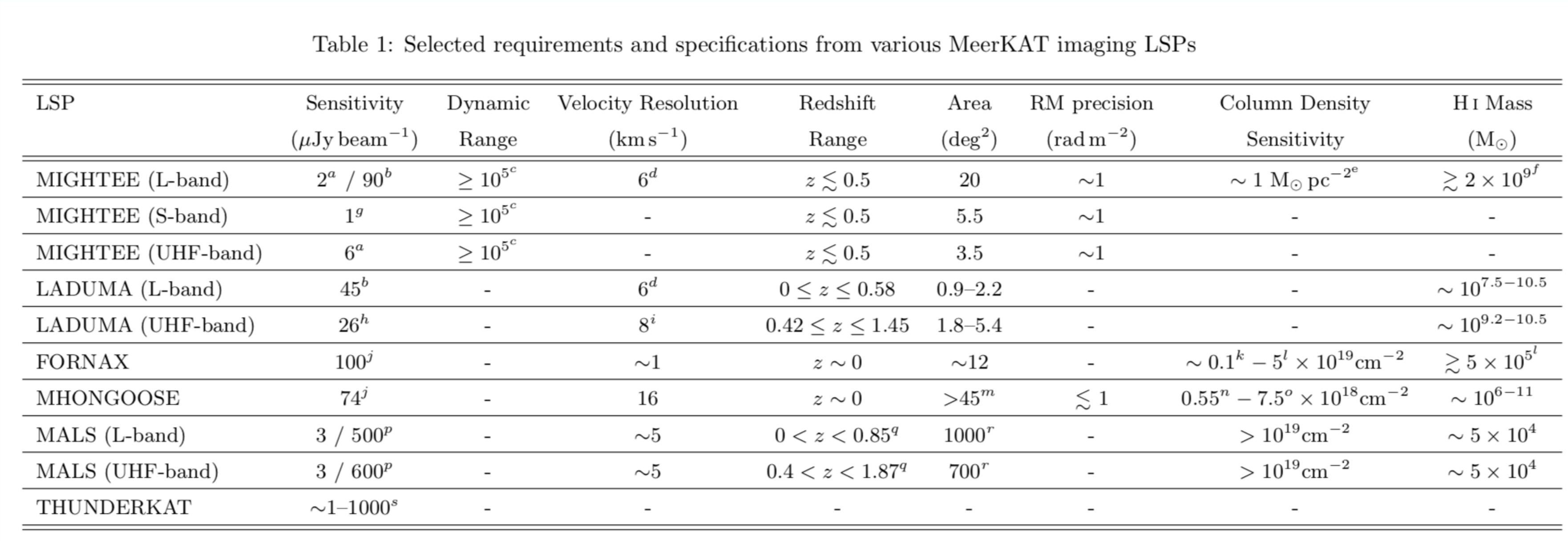


Table 1: Selected requirements and specifications from various MeerKAT imaging LSPs

LSP	Sensitivity	Dynamic	Velocity Resolution	Redshift	Area	RM precision	Column Density	H I Mass
	(μJy beam^{-1})	Range	(km s^{-1})	Range	(deg^2)	(rad m^{-2})	Sensitivity	(M$_\odot$)
MIGHTEE (L-band)	2^a / 90^b	$\geq 10^{5^c}$	6^d	$z \lesssim 0.5$	20	$\sim$1	~ 1 M$_\odot$ pc$^{-2^e}$	$\gtrsim 2 \times 10^{9^f}$
MIGHTEE (S-band)	1^g	$\geq 10^{5^c}$	-	$z \lesssim 0.5$	5.5	$\sim$1	-	-
MIGHTEE (UHF-band)	6^a	$\geq 10^{5^c}$	-	$z \lesssim 0.5$	3.5	$\sim$1	-	-
LADUMA (L-band)	45^b	-	6^d	$0 \leq z \leq 0.58$	0.9–2.2	-	-	$\sim 10^{7.5-10.5}$
LADUMA (UHF-band)	26^h	-	8^i	$0.42 \leq z \leq 1.45$	1.8–5.4	-	-	$\sim 10^{9.2-10.5}$
FORNAX	100^j	-	$\sim$1	$z \sim 0$	$\sim$12	-	$\sim 0.1^k - 5^l \times 10^{19}$cm^{-2}	$\gtrsim 5 \times 10^{5^l}$
MHONGOOSE	74^j	-	16	$z \sim 0$	$>45^m$	$\lesssim 1$	$0.55^n - 7.5^o \times 10^{18}$cm^{-2}	$\sim 10^{6-11}$
MALS (L-band)	3 / 500^p	-	$\sim$5	$0 < z < 0.85^q$	1000^r	-	$> 10^{19}$cm^{-2}	$\sim 5 \times 10^4$
MALS (UHF-band)	3 / 600^p	-	$\sim$5	$0.4 < z < 1.87^q$	700^r	-	$> 10^{19}$cm^{-2}	$\sim 5 \times 10^4$
THUNDERKAT	$\sim$1–1000^s	-	-	-	-	-	-	-

Data Quality Assessment

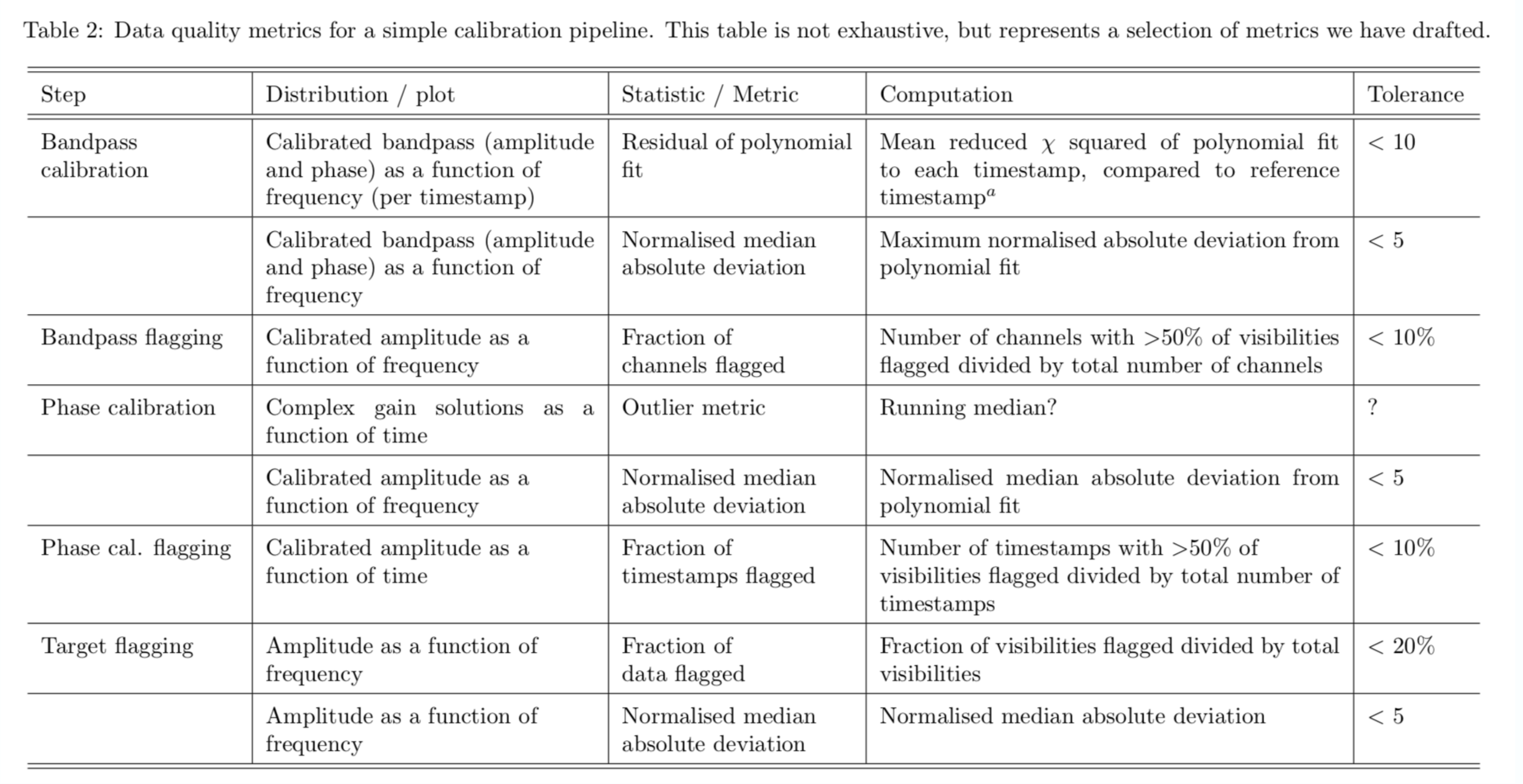
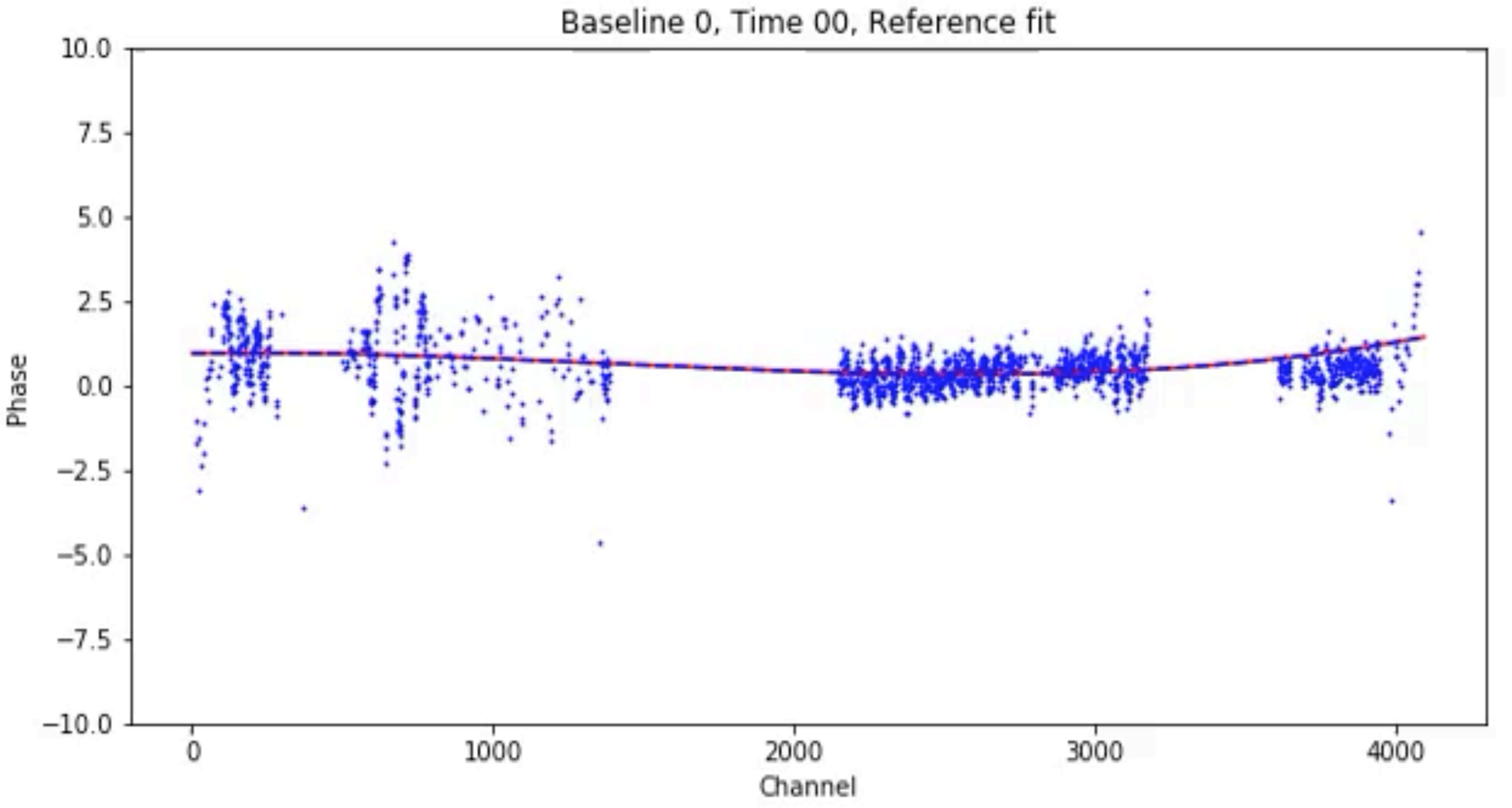


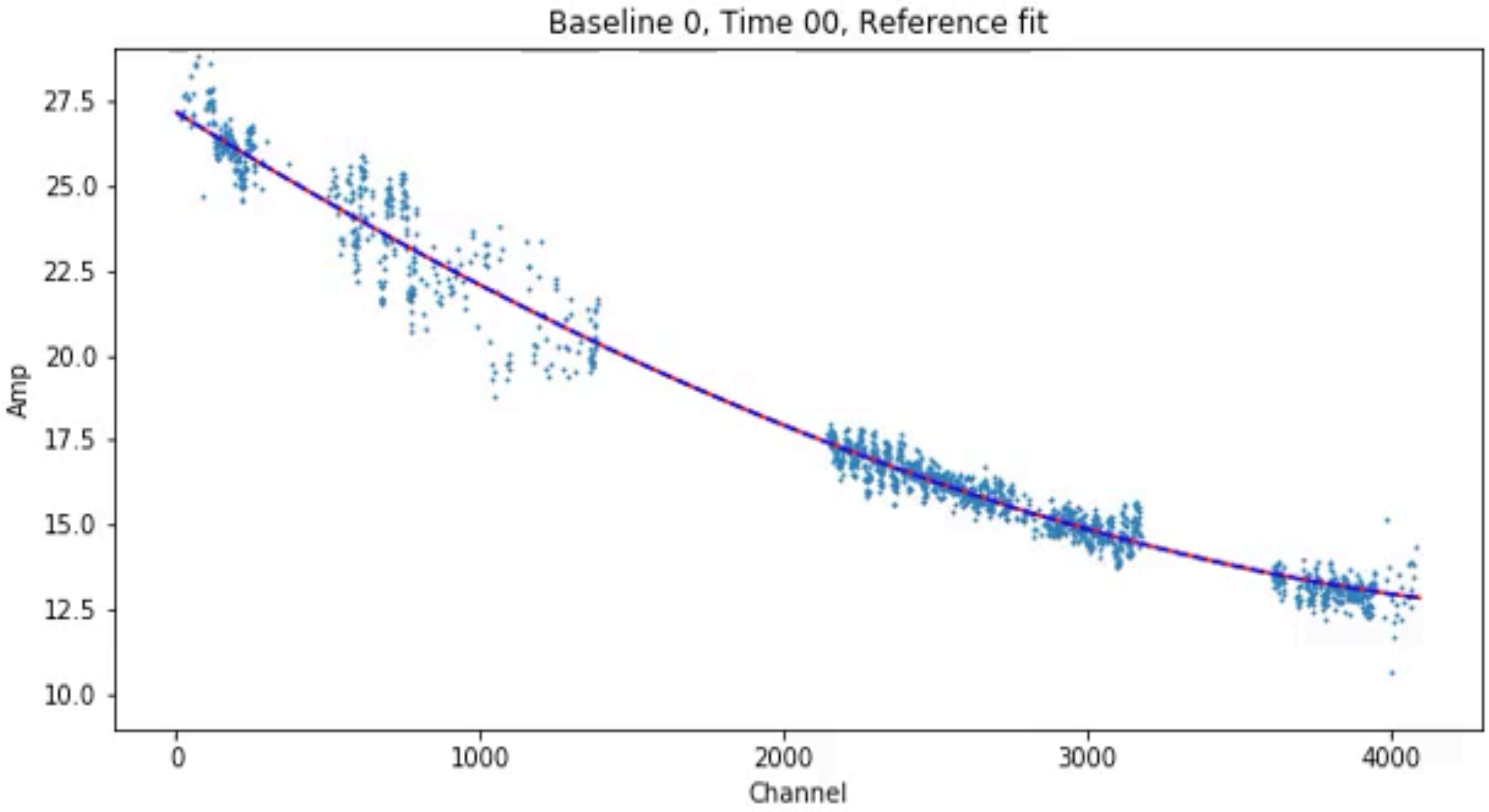
Table 2: Data quality metrics for a simple calibration pipeline. This table is not exhaustive, but represents a selection of metrics we have drafted.

Step	Distribution / plot	Statistic / Metric	Computation	Tolerance
Bandpass calibration	Calibrated bandpass (amplitude and phase) as a function of frequency (per timestamp)	Residual of polynomial fit	Mean reduced χ squared of polynomial fit to each timestamp, compared to reference timestamp[a]	< 10
	Calibrated bandpass (amplitude and phase) as a function of frequency	Normalised median absolute deviation	Maximum normalised absolute deviation from polynomial fit	< 5
Bandpass flagging	Calibrated amplitude as a function of frequency	Fraction of channels flagged	Number of channels with >50% of visibilities flagged divided by total number of channels	$< 10\%$
Phase calibration	Complex gain solutions as a function of time	Outlier metric	Running median?	?
	Calibrated amplitude as a function of frequency	Normalised median absolute deviation	Normalised median absolute deviation from polynomial fit	< 5
Phase cal. flagging	Calibrated amplitude as a function of time	Fraction of timestamps flagged	Number of timestamps with >50% of visibilities flagged divided by total number of timestamps	$< 10\%$
Target flagging	Amplitude as a function of frequency	Fraction of data flagged	Fraction of visibilities flagged divided by total visibilities	$< 20\%$
	Amplitude as a function of frequency	Normalised median absolute deviation	Normalised median absolute deviation	< 5

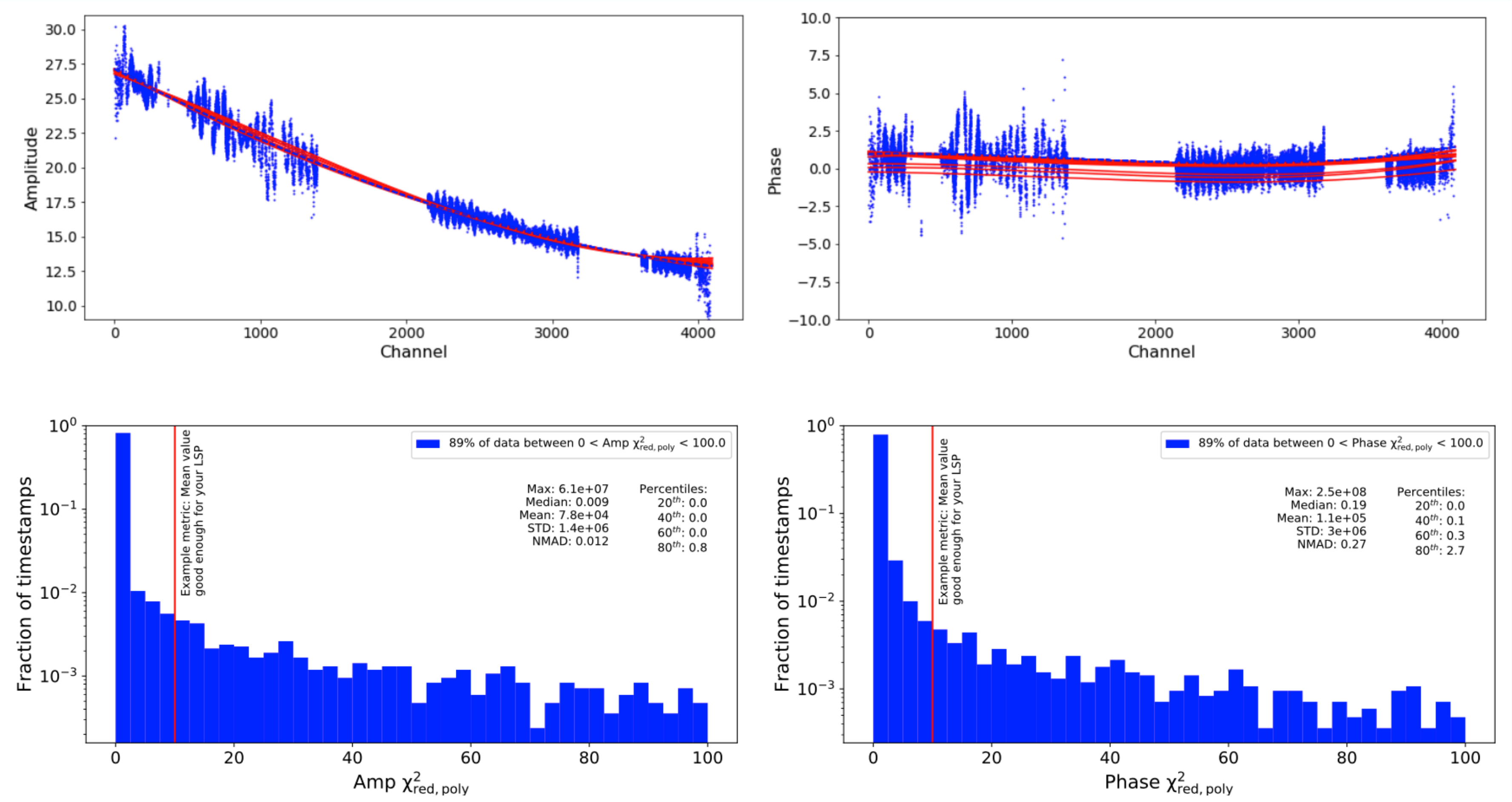
Data Quality Assessment



Data Quality Assessment



Data Quality Assessment



Data Quality Assessment

- DQA being discussed amongst SKA pathfinders in general, within SPARCS DQA WG
  - http://spacs.pbworks.com/w/page/126067640/dataquality
- Drafted list of metrics between us
  - https://docs.google.com/spreadsheets/d/1l8x0doPW6LhoWZMLeB5W4tcwzdgw18FWdh5DxnK6_vs/edit#gid=0

Summary

- The IDIA “processMeerKAT” pipeline is an efficient, user-friendly pipeline, that is widely tested and documented
- It runs on the Ilifu cluster, making dynamic use of resources, and containers, and presents a good framework for pipelines
- Many use cases are supported, incl. inserting your own scripts
- Even the quick look images are good
- Coming soon: selfcal, AW projection, optimisation/speedup

THANK YOU

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