

Introduction to CASA

Rubinur Khatun
NCRA

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What is CASA?

- Common Astronomical Software Applications (CASA)
- Python based offline data reduction package for Jansky Very Large Array (J-VLA), Atacama Large Millimeter/submillimeter Array (ALMA)
- Developed by National Radio Astronomical Observatory (NRAO, US) (lead), European Southern Observatory (ESO), National Astronomical Observatory of Japan (NAOJ), CSIRO-Australia Telescope National Facility (CSIRO-ATNF), Netherlands Institute for Radio Astronomy (ASTRON)
- Import/export data, inspect, edit, calibrate, image, view, analyze

Why CASA?

- Easy to write script (python) and tasks
- It has many tasks and a LOT of tool methods
- CASA has some of the most sophisticated algorithms implemented (multi-scale clean, Taylor term expansion for wide bandwidths, W-term projection, OTF mosaicing, etc.)
- It has a active Algorithm Research Group.

Obtaining and Installing

- Latest version: CASA Release 5.6.0
https://casa.nrao.edu/casa_obtaining.shtml
- Open terminal
- `cd <path of the directory>`
- `ls` to find downloaded casa file
- `tar xzvf casa-release-##version##.tar.gz`
- `gedit ~/.bashrc`
- `export PATH=$PATH:<path to the directory>/casa-release-##version##/bin`
- `source ~/.bashrc`
- Type “casa” to run casa

CASA startup

\$ casa

```
Messages (/home/ruby/casa-20190825-091630.log)
ruby@ruby-laptop:~$ casa

=====
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 5.1.0-74 -- Common Astronomy Software Applications

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

CASA <1>: 
```

Time	Priority	Origin	Message
2019-08-25 09:17:34	INFO	::casa	
2019-08-25 09:17:34	INFO	::casa	CASA Version 5.1.0-74

CASA Interactive Interface

- IPython Features:
 - shell access (ls, pwd, rm, vi)
 - Tab auto-completion
 - command history
- session logging
 - ipython.log – ipython command history
 - casapyTIME.log – casa logger messages
- numbered input/output
- history/searching

Tasklist

- To see list of tasks organized by type: `tasklist`

```

n: home/ruby
CASA <1>: tasklist
----- tasklist()
Available tasks, organized by category (experimental tasks in parenthesis ()
  deprecated tasks in curly brackets {}).

Import/export      Information      Editing      Manipulation
-----
exportasdm        imhead          fixplanets   concat
exportfits        inreframe       fixvis       conjugatevis
exportuvfits      instat          flagcmd      cvel
importasdm        imval           flagdata     fixvis
importatca        listcal         flagmanager  hanningsmooth
importfits        listfits        msview       inhead
importfitsidi     listhistory     plotms       mstransform
importmiriad      listobs         oldhanningsmooth
importuvfits      listpartition   oldsplit
importvla         listvis         partition
(importevla)      plotms          plotms
(importgmrt)      plotuv          split
                  vishead        testconcat
                  visstat        uvcontsub
                  visstat2       virtualconcat
                  visstatold     vishead
                  (asdmsummary) (cvel2)
                  (listsdm)      (statwt)
                  (makemask)     (uvcontsub3)

Calibration       Modeling        Imaging        Analysis
-----
accum             predictcomp     clean         incollapse
applycal         setjy           deconvolve   incontsub
bandpass        uvcontsub      feather       indev
blcal           uvmodelfit     ft           infit
calstat         uvsub          imcontsub    inhead
clearcal        (uvcontsub3)  (boxit)     inhistory
delmod          (uvcontsub3)  (csvclean)  immath
fixplanets      (uvcontsub3)  (tclean)    immoments
fluxscale      (uvcontsub3)  (tclean2)   impbcor
ft              (uvcontsub3)  {widebandpbcor}
gaincal         (uvcontsub3)  {mosaic}    inpv
gencal         (uvcontsub3)  {widefield} inrebin
initweights    (uvcontsub3)  (uvcontsub3) inreframe
listcal        (uvcontsub3)  (uvcontsub3) inregrid
plotants       (uvcontsub3)  (uvcontsub3) insmooth
plotbandpass   (uvcontsub3)  (uvcontsub3) instat
plotcal        (uvcontsub3)  (uvcontsub3) insubimage
polcal         (uvcontsub3)  (uvcontsub3) intrans
predictcomp    (uvcontsub3)  (uvcontsub3) inval
rerefant       (uvcontsub3)  (uvcontsub3) listvis
setjy          (uvcontsub3)  (uvcontsub3) rffit
smoothcal     (uvcontsub3)  (uvcontsub3) slsearch
uvmodelfit    (uvcontsub3)  (uvcontsub3) specflux
uvsub         (uvcontsub3)  (uvcontsub3) specsmooth
wvrgcal       (uvcontsub3)  (uvcontsub3) splattotable
              (uvcontsub3)  (uvcontsub3) (specfit)
              (uvcontsub3)  (uvcontsub3) (spxfit)

Visualization    Simulation      Single dish    Utility
-----
clearplot       simanalyze     importasap   browsetable
inview          simobserve     sdbaseline   caltabconvert
msview         (sinalma)    sdcal        clearplot
plotants       (sinalma)    sdfit        clearstat
plotbandpass   (sinalma)    sdfixscan    concat
plotcal        (sinalma)    sdimaging    conjugatevis
plotms         (sinalma)    sdsMOOTH     find
plotprofilemap (sinalma)    (sdgaincal) help par.parameter
  
```

Right task

To see list of tasks with short help:

taskhelp

```
Terminal File Edit View Search Terminal Help
CASA ~3> taskhelp
~3> taskhelp()
Available tasks:
accum          : Accumulate incremental calibration solutions into a calibration table
applycal      : Apply calibrations solutions(s) to data
asdmsummary   : Summarized description of an ASDM dataset.
autoclean     : CLEAN an image with automatically-chosen clean regions.
bandpass      : Calculates a bandpass calibration solution
blcal        : Calculate a baseline-based calibration solution (gain or bandpass)
boxit        : Box regions in image above given threshold value.
browseable    : Browse a table (MS, calibration table, image)
calstat       : Displays statistical information on a calibration table
caltabconvert : Convert old-style caltables into new-style caltables.
clean        : Invert and deconvolve images with selected algorithm
clearcal     : Re-initializes the calibration for a visibility data set
clearplot    : Clear the matplotlib plotter and all layers
clearstat    : Clear all autolock locks
concat       : Concatenate several visibility data sets.
conjugatevis  : Change the sign of the phases in all visibility columns.
csvclean     : This task does an invert of the visibilities and deconvolve in the image plane.
cvel        : regrid an MS to a new spectral window / channel structure or frame
cvel2       : Regrid an MS or MMS to a new spectral window, channel structure or frame
deconvolve   : Image based deconvolver
delmod       : Deletes model representations in the MS
exportasdm   : Convert a CASA visibility file (MS) into an ALMA or EVLA Science Data Model
exportfits   : Convert a CASA image to a FITS file
exportuvfits : Convert a CASA visibility data set to a UVFITS file:
feather      : Combine two images using their Fourier transforms
find         : Find string in tasks, task names, parameter names:
fixplanets   : Changes FIELD and SOURCE table entries based on user-provided direction or POINTING table, optionally fixes the UVW coordinates
fixvis      : Recalculates (u, v, w) and/or changes Phase Center
flagcmd      : Flagging task based on batches of flag-commands
flagdata     : All-purpose flagging task based on data-selections and flagging modes/algorithms.
flagmanager  : Enable list, save, restore, delete and rename flag version files.
fluxscale    : Bootstrap the flux density scale from standard calibrators
ft          : Insert a source model a visibility set:
gaincal      : Determine temporal gains from calibrator observations
gencal       : Specify Calibration Values of Various Types
hanningsmooth : Hanning smooth frequency channel data to remove Gibbs ringing
imcollapse   : Collapse image along one axis, aggregating pixel values along that axis.
incontsub    : Estimates and subtracts continuum emission from an image cube
indev        : Create an image that can represent the statistical deviations of the input image.
infit        : Fit one or more elliptical Gaussian components on an image region(s)
inhead       : List, get and put image header parameters
inhistory    : Retrieve and modify image history
inmath       : Perform math operations on images
inmoments    : Compute moments from an image
inpbcor      : Construct a primary beam corrected image from an image and a primary beam pattern.
inportasap   : Convert ASAP Scantable data into a CASA visibility file (MS)
inportasdm   : Convert an ALMA Science Data Model observation into a CASA visibility file (MS)
inportatca   : Import ATCA RPFITS file(s) to a measurement set
inportevla   : Convert an Science Data Model observation into a CASA Measurement Set
inportfits   : Convert an image FITS file into a CASA image
inportfitsidi : Convert a FITS-IDI file to a CASA visibility data set
inportgmrt   : Convert a UVFITS file to a CASA visibility data set
inportmiriad : Convert a Miriad visibility file into a CASA MeasurementSet
inportnro    : Convert NOSTAR data into a CASA visibility file (MS)
inportuvfits : Convert a UVFITS file to a CASA visibility data set
inportvla    : Import VLA archive file(s) to a measurement set
inpv        : Construct a position-velocity image by choosing two points in the direction plane.
inrebin     : Rebin an image by the specified integer factors
inreframe   : Change the frame in which the image reports its spectral values
inregrid    : regrid an image onto a template image
insmooth    : Smooth an image or portion of an image
instat      : Displays statistical information from an image or image region
insubimage  : Create a (sub)image from a region of the image
```


Task description

- Help taskname
e.g: help listobs

```
home/ruby
help on instance of listobs_cli_ in module listobs_cli:

listobs = class listobs_cli_
  Methods defined here:

  __call__(self, vis=None, selectdata=None, spw=None, field=None, antenna=None, uvrange=None, timerange=None, correlation=None, listunfl=None, cachesize=None, overwrite=None)
    List the summary of a data set in the logger or in a file

  Detailed Description:

  List the summary information of a data set in the logger or in a file, based on a data selection. Only rows can be selected and printed. No in-row selection is possible (channel or correlation).

  Lists the following properties of a measurement set:
  scan list, field list, spectral window list with correlators, antenna locations, ms table information.

Arguments:
vis:      Name of input visibility file (MS)
Default Value:

selectdata:  Data selection parameters
Default Value: True

spw:      Selection based on spectral-window/frequency/channel.
Default Value:

field:     Selection based on field names or field index numbers. Default is all.
Default Value:

antenna:   Selection based on antenna/baselines. Default is all.
Default Value:

uvrange:   Selection based on uv range. Default: entire range. Default units: meters.
Default Value:

timerange: Selection based on time range. Default is entire range.
Default Value:

correlation: Selection based on correlation. Default is all.
Default Value:

scan:      Selection based on scan numbers. Default is all.
Default Value:

intent:    Selection based on observation intent. Default is all.
Default Value:

feed:      Selection based on multi-feed numbers: Not yet implemented
Default Value:

array:     Selection based on (sub)array numbers. Default is all.
Default Value:

observation: Selection based on observation ID. Default is all.
Default Value:

verbose:   Controls level of information detail reported. True reports more than False.
Default Value: True

listfile:  Name of disk file to write output. Default is none (output is written to logger only).
Default Value:

listunfl:  List unflagged row counts? If true, it can have significant negative performance impact.
```

```
me/ruby
Default Value: False

Returns: void

Example :

List the summary information of a data set in the logger or in a file, based on a data selection. Only rows can be selected and printed. No in-row selection is possible (channel or correlation). Refer to the task listvis to list visibilities.

Lists the following properties of a measurement set:
scan list, field list, spectral window list with correlators, antenna locations, ms table information.

Keyword arguments:
vis -- Name of input visibility file
      default: none, example: vis='ngc5921.ms'

selectdata -- Select a subset of data for flagging
      default: False
      options: True,False
      The summary listing will only apply to the specified selection.

antenna -- Select data based on baseline
      default: '' (all); example: antenna='5&6' baseline 5-6
      antenna='5&6;7&8' #baseline 5-6 and 7-8
      antenna='5' # all cross-correlation baselines between antenna 5 and all other available antennas
      antenna='5,6' # all baselines with antennas 5 and 6
      antenna='1&&1' # only the auto-correlation baselines for antenna 1
      antenna='1&&*' # cross and auto-correlation baselines between antenna 1 and all other available antennas
      antenna='1-7&&&' # only the auto-correlation baselines for antennas in range 1-7

spw -- Select data based on spectral window and channels
      default: '' (all); example: spw='1'
      spw='<2' #spectral windows less than 2
      spw='>1' #spectral windows greater than 1

correlation -- Correlation types
      default: '' (all);
      example: correlation='RR LL'

field -- Select data based on field id(s) or name(s)
      default: '' (all); example: field='1'
      field='0~2' # field ids inclusive from 0 to 2
      field='3C*' # all field names starting with 3C

uvrange -- Select data within uvrange (default units meters)
      default: '' (all); example:
      uvrange='0-1000klambda'; uvrange from 0-1000 kilo-langda
      uvranges='>4klanda'; uvranges greater than 4 kilo-lambda
      uvrange='0-1000km'; uvrange in kilometers

timerange -- Select data based on time range:
      default = '' (all); example,
      timerange = 'YYYY/MM/DD/hh:mm:ss~YYYY/MM/DD/hh:mm:ss'
      Note: YYYY/MM/DD can be dropped as needed:
      timerange='09:14:00~09:54:00' # this time range
      timerange='09:44:00' # data within one integration of time
      timerange='>10:24:00' # data after this time
      timerange='09:44:00+00:13:00' #data 13 minutes after time

scan -- Select data based on scan number
      default: '' (all); example: scan='>3'

intent -- Select data based on observation intent
      default: '' (all); example: intent='*CAL*,*BAND*'

feed -- Selection based on the feed - NOT IMPLEMENTED YET

array -- Selection based on the antenna array
```

Importing data in to CASA

- Importing GMRT data into CASA: Flexible Image Transport System (FITS), UVFITS (understood by AIPS, MIRIAD)

- input – UVFITS data file

output – Measurement Set (MS) which is understood by CASA

- MS:

Contains the visibilities in the MAIN table in table.* files

also contains sub-tables

e.g. FIELD, SOURCE, ANTENNA, WEATHER etc.

sub-tables are sub-directories

Structure of a MS

- Three data columns
 - ◆ Observed data
 - ◆ Correted data
 - ◆ Model data

What does my data file have?

Listobs

- Which sources, how many scans
- Observing frequency, time and duration
- Frequency and time resolution
- Array coordinates

```
Messages (/home/ruby/casa-20190825-091630.log)
File Edit View
Search Message:
Message
#####
#### Begin Task: listobs #####
listobs(vis="ngc7469.ms",selectdata=True,spw="",field="",antenna="",
uvrange="",timerange="",correlation="",scan="",intent="",
feed="",array="",observation="",verbose=True,listfile="",
listunfl=False,cachesize=50,overwrite=False)
-----
MeasurementSet Name: /media/ruby/d57cd194-d5b2-46a2-8974-cda6317d7ca8/Archive_data/ngc7469.ms MS Version 2
-----
Observer: unavailable Project: AA281
Observation: VLA
Computing scan and subscan properties...
Data records: 296946 Total elapsed time = 4930 seconds
Observed from 20-Feb-2003/20:59:10.0 to 20-Feb-2003/22:21:20.0 (TAI)

ObservationID = 0 ArrayID = 0
Date Timerange (TAI) Scan FldId FieldName nRows SpwIds Average Interval(s) ScanIntent
20-Feb-2003/20:59:10.0 - 21:19:30.0 1 0 0137+331 85644 [0,1] [10, 10]
21:22:50.0 - 21:25:20.0 2 1 2250+143 10530 [0,1] [10, 10]
21:25:30.0 - 21:37:00.0 3 2 NGC7469 48438 [0,1] [10, 10]
21:37:10.0 - 21:39:30.0 4 1 2250+143 9828 [0,1] [10, 10]
21:39:40.0 - 21:51:10.0 5 2 NGC7469 48438 [0,1] [10, 10]
21:51:20.0 - 21:53:50.0 6 1 2250+143 10530 [0,1] [10, 10]
21:55:00.0 - 21:57:30.0 7 3 0029+349 10530 [0,1] [10, 10]
21:59:40.0 - 22:11:30.0 8 4 MRK0348 49842 [0,1] [10, 10]
22:12:30.0 - 22:15:00.0 9 3 0029+349 10530 [0,1] [10, 10]
22:18:20.0 - 22:21:20.0 10 5 0119+321 12636 [0,1] [10, 10]
(nRows = Total number of rows per scan)

Fields: 6
ID Code Name RA Decl Epoch SrcId nRows
0 B 0137+331 01:37:41.299400 +33.09.35.13200 J2000 0 85644
1 7 2250+143 23:03:15.600000 +08.52.25.00000 J2000 1 10530
2 NGC7469 00:29:14.242400 +34.56.32.24600 J2000 2 96876
3 B 0029+349 00:29:14.242400 +34.56.32.24600 J2000 3 21060
4 MRK0348 00:48:47.132000 +31.57.24.83000 J2000 4 49842
5 C 0119+321 01:19:35.000400 +32.10.50.05400 J2000 5 12636

Spectral Windows: (2 unique spectral windows and 1 unique polarization setups)
SpwID Name #Chans Frame Ch0(MHz) ChanMid(kHz) TotBW(kHz) CtrFreq(MHz) Corrs
0 1*50 MHz channels @ 4.89 GHz (TOPO) 1 TOPO 4885.100 50000.000 50000.0 4885.1000 RR RL LR LL
1 1*50 MHz channels @ 4.84 GHz (TOPO) 1 TOPO 4835.100 50000.000 50000.0 4835.1000 RR RL LR LL

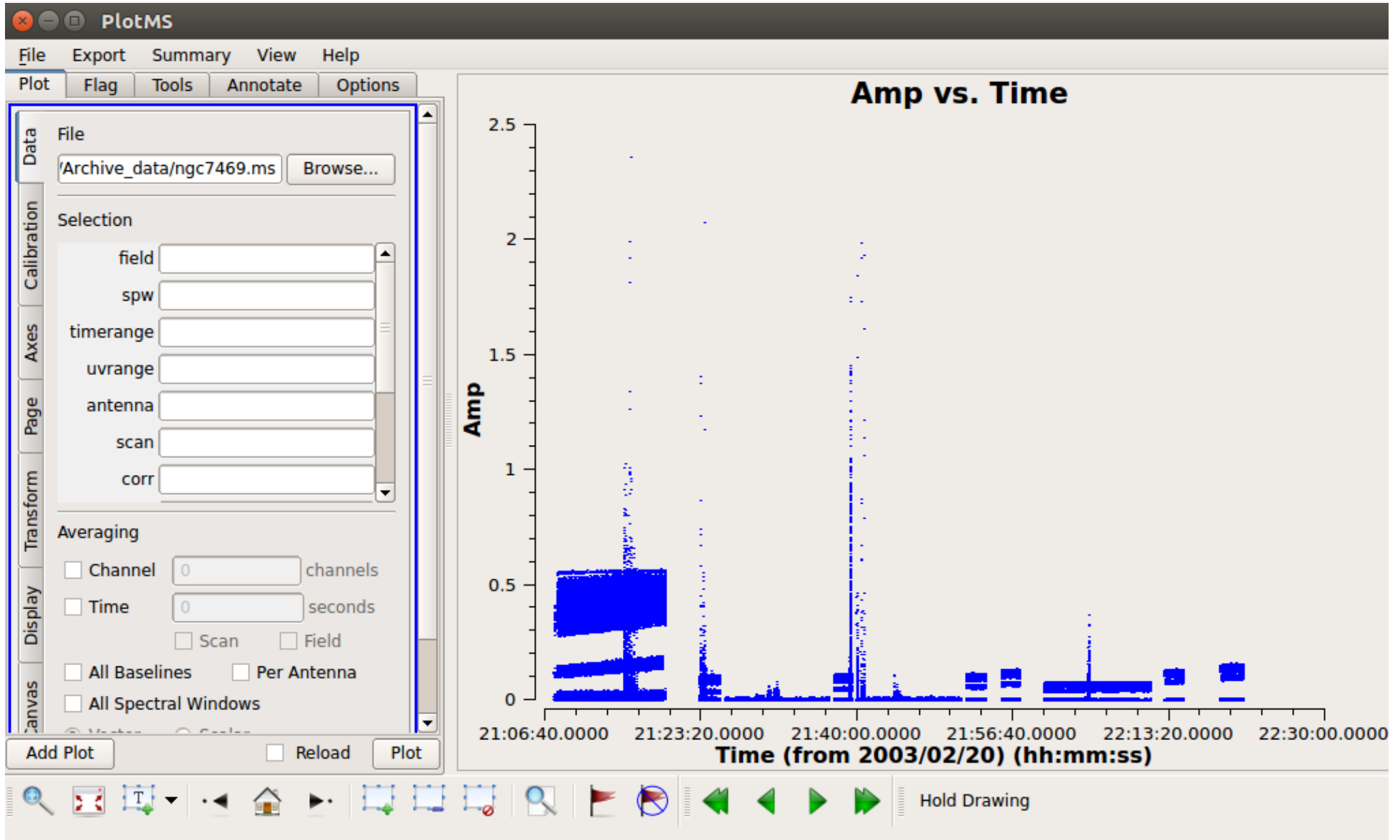
Sources: 6
ID Name SpwID RestFreq(MHz) SysVel(km/s)
0 0137+331 any 0 100
1 2250+143 any 0 100
2 NGC7469 any 0 100
3 0029+349 any 0 100
4 MRK0348 any 0 100
5 0119+321 any 0 100

Antennas: 27:
ID Name Station Diam. Long. Lat. Offset from array center (m) ITRF Geocentric coordinates (m)
East North Elevation x y z
0 VA01 VLA: N5 25.0 m -107.37.06.7 +33.54.08.0 -17.0041 194.1095 -0.1501 -1601168.763569 -5041869.092569 3555036.897007
1 VA02 VLA: E4 25.0 m -107.37.00.8 +33.53.59.7 133.6579 -62.2621 1.1044 -1601068.763445 -5042051.971898 3554824.807792
2 VA03 VLA: E2 25.0 m -107.37.04.4 +33.54.01.1 40.6623 -18.9186 0.9618 -1601150.045266 -5042000.672097 3554860.703840
3 VA04 VLA: W6 25.0 m -107.37.15.6 +33.53.56.4 -244.9777 -185.2291 1.6999 -1601447.174295 -5041992.568915 3554739.675464
4 VA05 VLA: N6 25.0 m -107.37.06.9 +33.54.10.3 -23.2149 285.4003 -0.4802 -1601162.564123 -5041829.052145 3555095.883223
5 VA06 VLA: W8 25.0 m -107.37.21.6 +33.53.53.0 -401.2440 -270.6420 2.2251 -1601614.043217 -5042001.708862 3554652.472841
6 VA07 VLA: E5 25.0 m -107.36.58.4 +33.53.58.8 195.8412 -91.2764 1.1966 -1601014.416532 -5042086.288084 3554800.776893
7 VA08 VLA: N3 25.0 m -107.37.08.9 +33.54.00.1 -74.4901 -50.2094 1.1516 -1601265.126766 -5041982.601780 3554834.838073
8 VA09 VLA: N2 25.0 m -107.37.06.2 +33.54.03.5 -4.7686 54.7020 0.6026 -1601180.826588 -5041947.501096 3554921.609014
9 VA10 VLA: W1 25.0 m -107.37.05.9 +33.54.00.5 3.4959 -39.7668 0.9975 -1601188.997009 -5042000.533768 3554843.419574
```

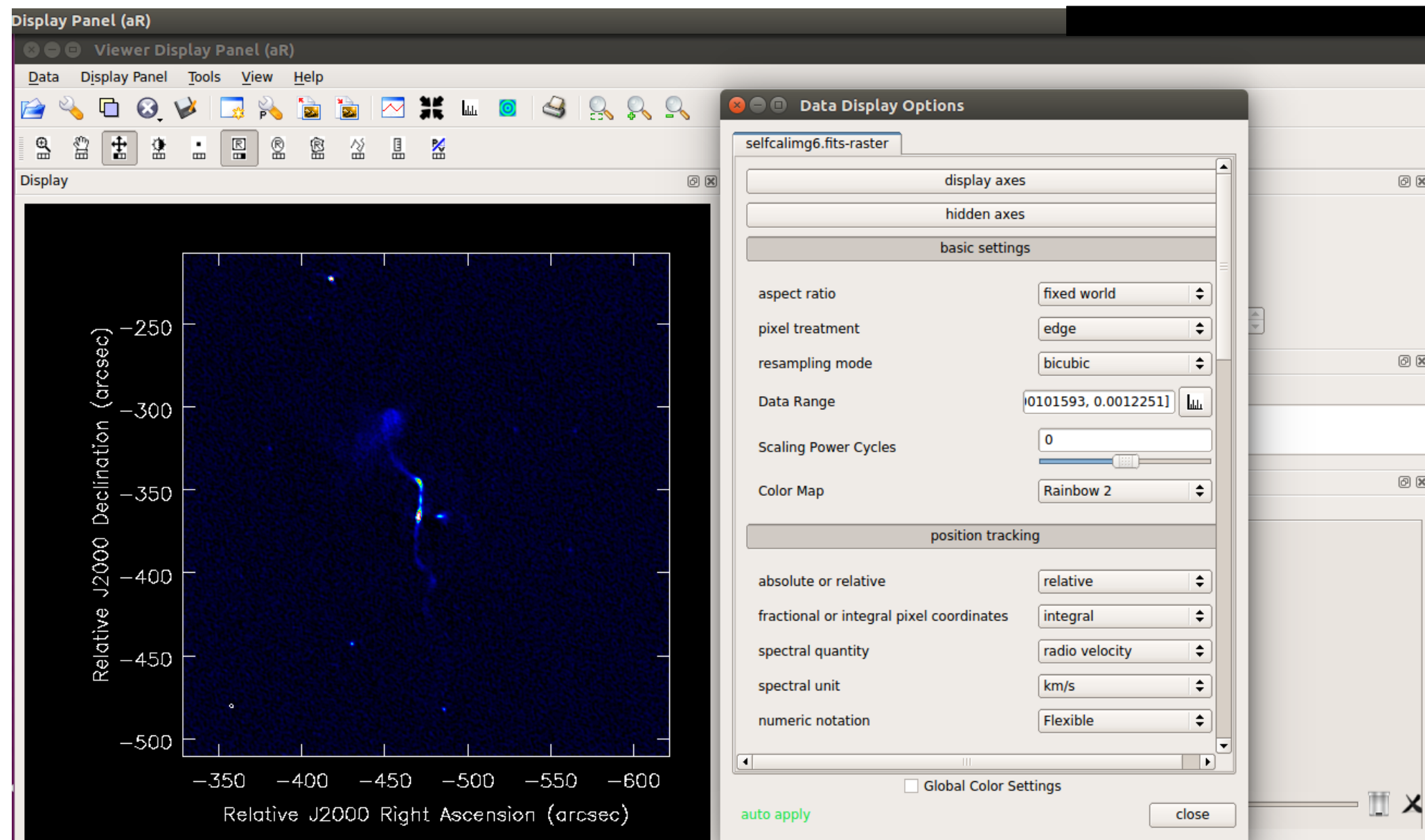
Examining/exploring the data: Visualization Tools

- Data needs to be displayed to understand it!
- Visualization tools can be used.
- Examples:
 - Visibilities: `plotms`
 - Images: `viewer`
 - Calibration tables: `plotcal`
- **large datasets can be a challenge!**

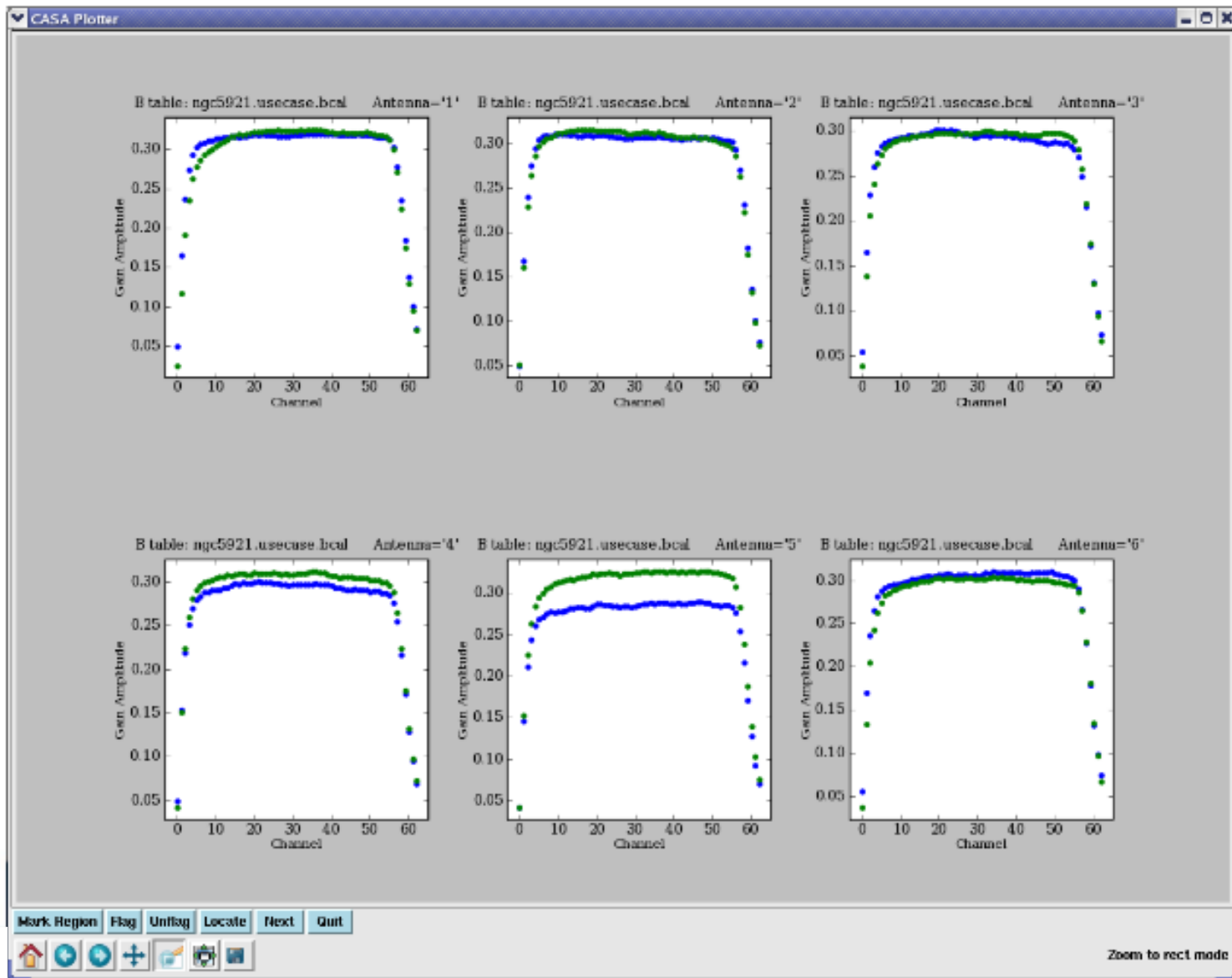
Plotms



Viewer



Plotcal



Data selection syntax

- Range: X~Y
- Time: YYYY/MM/DD/HH:MM:SS
- Time range: Time1~Time2
- Antenna: 1~3 = 1,2,3
11,12,15
- Baseline: ANT1 (OPERATOR) ANT2
 - & - only cross-correlations
 - && - both auto and cross corr.
 - &&& - only auto corr.

GMRT tutorials: Continuum data reduction in CASA

Radio Astronomy School 2019

RAS Tutorials

GMRT tutorials: Continuum data reduction in CASA

Version 1.0 August 2019

Useful links

- [CASA task help](#)
- [CASA tutorial](#)
- [Using CASA](#)

Disclaimer: These tutorials provide guidelines to help users become familiar with GMRT data reduction in CASA. Only a general case is shown here. GMRT being a versatile instrument may require other specialised strategies that are not described here.

Contents

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- Delay and bandpass calibration
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- Flagging on calibrated data
- Averaging data in frequency
- Imaging
- Self-calibration

<http://www.ncra.tifr.res.in/~ruta/ras2019/CASA-tutorial-test.html>

Contribution from Divya, Ruta