CASA

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some slides from J. Ott

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

CASA

- CASA is the offline data reduction package for ALMA and the EVLA (data from other telescopes usually work, too, but not primary goal of CASA).
- Import/export data, edit, calibrate, image, analyze.
- Also supports single dish (based on ATNF's ASAP).
- CASA has many tasks and a LOT of tools.

CASA

- Easy to write scripts and tasks.
- Lots of documentation, reduction tutorials, helpdesk.
- CASA has some of the most sophisticated algorithms implemented (multi-scale clean, Taylor term expansion for wide bands, W-term projection, OTF mosaicing, etc.)
- It has an active Algorithm Research Group.

CASA

- Web site: http://casa.nrao.edu/
- Available for both Linux and Mac OS.
- Two versions of CASA, *Release* and *Stable* can be downloaded.
  - The *Stable* version has more functionality but has not been as rigorously tested as the *Release*.
  - The available documentation is only for the *Release*, so *Stable* may behave somewhat differently than what is currently documented.
  - Make sure to subscribe to the CASA mailing list for announcements of new releases, workshops, etc… (casa-announce), or for critical bugs and code updates (casa-users) at: http://casa.nrao.edu/ → Getting Help → Mailing lists

CASA

- Documentation is available at http://casa.nrao.edu/ → 'Using CASA'
- Training material is available at http://casaguides.nrao.edu
- For help, use the NRAO help desk at: http://help.nrao.edu

Outline

- CASA startup
- CASA basic python interface
- Tasks and tools
- The Measurement Set
- Data selection syntax
- Visualization tools
- Make your own task!

CASA Startup

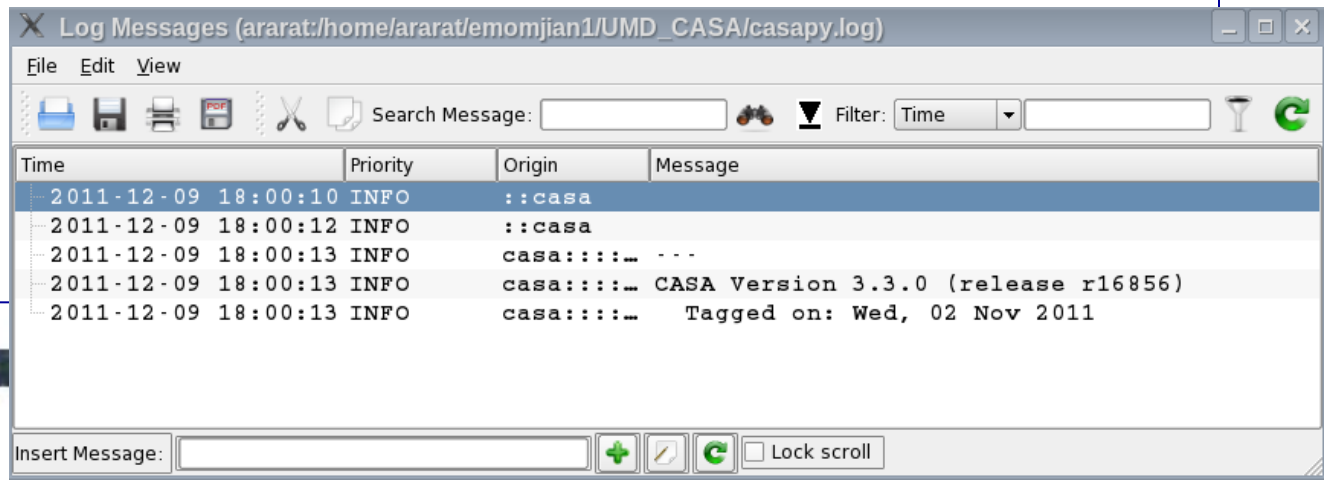
```
> casapy

CASA Version 3.3.0 (r16856)
  Compiled on: Thu 2011/11/03 18:24:40 UTC

--------------------------------------------------------------------------------
   For help use the following commands:
   tasklist              - Task list organized by category
   taskhelp              - One line summary of available tasks
   help taskname         - Full help for task
   toolhelp              - One line summary of available tools
   help par.parametername - Full help for parameter name
   Single Dish sd* tasks are available after asap_init() is run

--------------------------------------------------------------------------------
Activating auto-logging. Current session state plus future input saved.
Filename       : ipython.log
Mode           : backup
Output logging : False
Raw input log  : False
Timestamping   : False
State          : active

–   CASA <2>:
```



CASA Interface

- Uses IPython for its command line interface:
  - Filesystem navigation, shell access
  - Autoparenthesis
  - Namespace completion (<TAB>)
  - Session logging
    - ipython.log – ipython command history
    - casapy.log – casa messages
  - Numbered input/output with command history, full searching

Python Pointers

- to run a .py script:

  execfile('<scriptname>')

  example: execfile('ngc5921_demo.py')

- indentation matters!
  - be careful when doing cut-and-paste to Python
  - cut a few (4-6) lines at a time
- Python counts from 0 to n-1!
- variables are global when using *task interface*
- Task names are objects (not variables)

Tasks and tools in CASA

- Tasks - high-level functionality, well difined purpose
  - function call or parameter handling interface
  - these are what you should use in tutorial
- Tools - complete functionality
  - tool.method calls, used by tasks
  - sometimes shown in tutorial scripts

- Shell commands can be run with a leading exclamation mark !du –hs

CASA

- All CASA tasks can be listed by *tasklist*.
- The tasks are grouped as:
  - Import/export
  - Information
  - Editing
  - Manipulation
  - Calibration
  - Modeling
  - Imaging
  - Analysis
  - Visualization
  - Simulation
  - Single dish
  - Utility
- AIPS – CASA dictionary is available at https://safe.nrao.edu/wiki/bin/view/Software/CASA-AIPSDictionary
- (Historic) MIRIAD-CASA and CLIC-CASA dictionaries are available in the CASA cookbook.

Tasks

To list the tasks: *tasklist*

```
--------> tasklist()
Available tasks, organized by category (experimental tasks in parens ()
  deprecated tasks in curly brackets {}).
  Single Dish sd* tasks are available after asap_init() is run.


Import/export
-------------
exportfits
exportuvfits
importaipscaltable
importasdm
importfits
importfitsidi
importuvfits
importvla
(exportasdm)
(importevla)
(importgmrt)
{importoldasdm}

Information
-----------
imhead
imstat
imval
listcal
listhistory
listobs
listvis
plotms
plotuv
plotxy
vishead
visstat
(listsdm)

Editing
-------
fixplanets
fixvis
flagautocorr
flagcmd
flagdata
flagmanager
msview
plotms
plotxy
(flagdata2)
(testautoflag)

Manipulation
------------
concat
conjugatevis
cvel
fixvis
hanningsmooth
imhead
msmoments
plotms
plotxy
split
testconcat
uvcontsub
vishead
{uvcontsub2}

Calibration
-----------
accum
applycal
bandpass
blcal
calstat
clearcal
fixplanets
fluxscale
ft
gaincal
gencal
listcal
plotants
plotcal
polcal
setjy
smoothcal
uvmodelfit
uvsub

Modeling
--------
setjy
uvcontsub
uvmodelfit
uvsub
{uvcontsub2}

Imaging
-------
clean
deconvolve
feather
ft
imcontsub
(boxit)
(csvclean)
{mosaic}
{widefield}

Analysis
--------
imcollapse
imcontsub
imfit
imhead
immath
immoments
impbcor
imregrid
imsmooth
imstat
imtrans
imval
listvis
slsearch
splattotable
(specfit)

Visualization
-------------
clearplot
imview
msview
plotants
plotcal
plotms
plotuv
plotxy
viewer

Simulation
----------
sim_analyze
sim_observe
simdata

Single dish
-----------
asap_init
sdaverage
sdbaseline
sdcal
sdcoadd
sdfit
sdflag
sdflagmanager
sdimaging
sdimprocess
sdlist
sdmath
sdplot
sdsave
sdscale
sdsmooth
sdstat
sdtpimaging

Utility
-------
browsetable
clearplot
clearstat
concat
conjugatevis
find
help par.parameter
help taskname
imview
msview
plotms
rmtables
startup
taskhelp
tasklist
testconcat
toolhelp

User defined tasks
------------------
```

Tasks

To see list of tasks with short help:
taskhelp

```
CASA <4>: taskhelp
--------> taskhelp()
Available tasks:

accum               : Accumulate incremental calibration solutions into a calibration table
applycal            : Apply calibrations solutions(s) to data
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.
browsetable         : Browse a table (MS, calibration table, image)
calstat             : Displays statistical information on a calibration table
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
deconvolve          : Image based deconvolver
exportasdm          : Convert a CASA visibility file (MS) into an ALMA 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 given direction or POINTING table, optionally fixes the UVW coordinates
fixvis              : Recalculates (u, v, w) and/or changes Phase Center
flagautocorr        : Flag autocorrelations
flagcmd             : Flagging task based on flagging commands
flagdata            :  All purpose flagging task based on selections
flagdata2           :  All purpose flagging task based on selections. It allows the combination of several modes.
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 into the MODEL_DATA column of a visibility set:
```

Task Interface

- parameters are set as global Python variables

  (set) <param> = <value>

  (e.g. , vis = 'ngc5921.demo.ms')
- using inp, default, saveinputs, tget, tput
- execute

  <taskname> or go

Task Interface

Call a task by

>inp <*taskname*>

if default values are desired, first type

>default <*taskname*>, followed by inp

```
CASA <9>: inp
--------> inp()
#  gaincal :: Determine temporal gains from calibrator observations
vis                 =         ''            #  Name of input visibility file
caltable            =         ''            #  Name of output gain calibration table
field               =         ''            #  Select field using field id(s) or field name(s)
spw                 =         ''            #  Select spectral window/channels
intent              =         ''            #  Select observing intent
selectdata          =      False            #  Other data selection parameters
solint              =      'inf'            #  Solution interval: egs. 'inf', '60s' (see help)
combine             =         ''            #  Data axes which to combine for solve (scan, spw, and/or field)
preavg              =       -1.0            #  Pre-averaging interval (sec) (rarely needed)
refant              =         ''            #  Reference antenna name(s)
minblperant         =          4            #  Minimum baselines _per antenna_ required for solve
minsnr              =        3.0            #  Reject solutions below this SNR
solnorm             =      False            #  Normalize average solution amplitudes to 1.0 (G, T only)
gaintype            =        'G'            #  Type of gain solution (G,T,GSPLINE,K,KCROSS)
smodel              =         []            #  Point source Stokes parameters for source model.
calmode             =       'ap'            #  Type of solution: ('ap', 'p', 'a')
append              =      False            #  Append solutions to the (existing) table
gaintable           =       ['']            #  Gain calibration table(s) to apply on the fly
gainfield           =       ['']            #  Select a subset of calibrators from gaintable(s)
interp              =       ['']            #  Temporal interpolation for each gaintable (=linear)
spwmap              =         []            #  Spectral windows combinations to form for gaintables(s)
gaincurve           =      False            #  Apply internal VLA antenna gain curve correction
opacity             =         []            #  Opacity correction to apply (nepers), per spw
parang              =      False            #  Apply parallactic angle correction on the fly
async               =      False            #  If true the taskname must be started using gaincal(...)
```

Task Interface

Some parameters are expandable, e.g., selectdata

```
CASA <11>: selectdata =true

CASA <12>: inp
----------> inp()
#  gaincal :: Determine temporal gains from calibrator observations
vis                 =         ''            #  Name of input visibility file
caltable            =         ''            #  Name of output gain calibration table
field               =         ''            #  Select field using field id(s) or field name(s)
spw                 =         ''            #  Select spectral window/channels
intent              =         ''            #  Select observing intent
selectdata          =       True            #  Other data selection parameters
     timerange      =         ''            #  Select data based on time range
     uvrange        =         ''            #  Select data within uvrange (default units meters)
     antenna        =         ''            #  Select data based on antenna/baseline
     scan           =         ''            #  Scan number range
     observation    =         ''            #  Select by observation ID(s)
     msselect       =         ''            #  Optional complex data selection (ignore for now)

solint              =      'inf'            #  Solution interval: egs. 'inf', '60s' (see help)
combine             =         ''            #  Data axes which to combine for solve (scan, spw, and/or field)
preavg              =      -1.0             #  Pre-averaging interval (sec) (rarely needed)
refant              =         ''            #  Reference antenna name(s)
minblperant         =          4            #  Minimum baselines _per antenna_ required for solve
minsnr              =        3.0            #  Reject solutions below this SNR
solnorm             =      False            #  Normalize average solution amplitudes to 1.0 (G, T only)
gaintype            =        'G'            #  Type of gain solution (G,T,GSPLINE,K,KCROSS)
smodel              =         []            #  Point source Stokes parameters for source model.
calmode             =       'ap'            #  Type of solution: ('ap', 'p', 'a')
append              =      False            #  Append solutions to the (existing) table
gaintable           =       ['']            #  Gain calibration table(s) to apply on the fly
gainfield           =       ['']            #  Select a subset of calibrators from gaintable(s)
interp              =       ['']            #  Temporal interpolation for each gaintable (=linear)
spwmap              =         []            #  Spectral windows combinations to form for gaintables(s)
gaincurve           =      False            #  Apply internal VLA antenna gain curve correction
opacity             =         []            #  Opacity correction to apply (nepers), per spw
parang              =      False            #  Apply parallactic angle correction on the fly
asyncc              =      False            #  If true the taskname must be started using gaincal(...)
```

Task Execution

- Two ways to invoke:
  - call from Python as functions with arguments

    taskname(arg1=val1, arg2=val2, ...), like

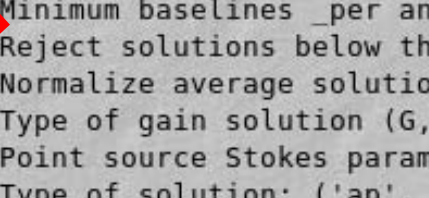
    clean(vis='input.ms',
    imagename='galaxy',selectvis=T, robust=0.5,
    imsize=[200,200])

    unspecified parameters will be defaulted
  - use standard tasking interface
  - see Chapter 1.3 in Cookbook

Parameter Checking

```
CASA <19>: inp
---------> inp()
#  gaincal :: Determine temporal gains from calibrator observations
vis                 =         ''            #  Name of input visibility file
caltable            =         ''            #  Name of output gain calibration table
field               =         ''            #  Select field using field id(s) or field name(s)
spw                 =         ''            #  Select spectral window/channels
intent              =         ''            #  Select observing intent
selectdata          =      False            #  Other data selection parameters
solint              =      'inf'            #  Solu                    'inf', '60s' (see help)
combine             =         ''            #  Data                    ine for solve (scan, spw, and/or field)
preavg              =       -1.0            #  Pre-                    (sec) (rarely needed)
refant              =         ''            #  Refe                    s)
minblperant         =          4            #  Minimum baselines _per antenna_ required for solve
minsnr              =        3.0            #  Reject solutions below this SNR
solnorm             =      False            #  Normalize average solution amplitudes to 1.0 (G, T only)
gaintype            =        'G'            #  Type of gain solution (G,T,GSPLINE,K,KCROSS)
smodel              =         []            #  Point source Stokes parameters for source model.
calmode             =  'noidea'             #  Type of solution: ('ap', 'p', 'a')
append              =      False            #  Append solutions to the (existing) table
gaintable           =       ['']            #  Gain calibration table(s) to apply on the fly
gainfield           =       ['']            #  Select a subset of calibrators from gaintable(s)
interp              =       ['']            #  Temporal interpolation for each gaintable (=linear)
spwmap              =         []            #  Spectral windows combinations to form for gaintables(s)
gaincurve           =      False            #  Apply internal VLA antenna gain curve correction
opacity             =         []            #  Opacity correction to apply (nepers), per spw
parang              =      False            #  Apply parallactic angle correction on the fly
async               =      False            #  If true the taskname must be started using gaincal(...)
```

erroneous values in red



Help on Tasks

In-line help for all tasks (help <taskname>)

>help gaincal

```
Help on gaincal task:

Determine temporal gains from calibrator observations

      The complex gains for each antenna/spwid are determined from the
      data column (raw data) divided by the model column.  The gains can
      be obtained for a specified solution interval, spw combination and
      field combination.  The GSPLINE spline (smooth) option is still under
      development.

      Previous calibrations (egs, bandpass, opacity, parallactic angle) can
      be applied on the fly.  At present with dual-polarized data, both
      polarizations must be unflagged for any solution to be obtained.

      Keyword arguments:
      vis -- Name of input visibility file
              default: none; example: vis='ngc5921.ms'
      caltable -- Name of output gain calibration table
              default: none; example: caltable='ngc5921.gcal'

      --- Data Selection (see help par.selectdata for more detailed information)

      field -- Select field using field id(s) or field name(s).
                 ['go listobs' to obtain the list id's or names]
              default: ''=all fields
              If field string is a non-negative integer, it is assumed a
                field index,  otherwise, it is assumed a field name
              field='0~2'; field ids 0,1,2
              field='0,4,5~7'; field ids 0,4,5,6,7
              field='3C286,3C295'; field named 3C286 and 3C295
              field = '3,4C*'; field id 3, all names starting with 4C
          DON'T FORGET TO INCLUDE THE FLUX DENSITY CALIBRATOR IF YOU HAVE ONE
```

Tools in CASA

- What if there's no task?

→use CASA tools (tasks are built upon tools)

- tools are functions/methods
  - call from casapy as <tool>.<method>()
  - default tool objects are pre-constructed
    - e.g. imager (im) , calibrater (cb), ms (ms) , etc. (see toolhelp)

CASA Tool List

To list the default tools:

>toolhelp

~1000 tools available

```
Available tools:

at : Juan Pardo ATM library
cb : Calibration utilities
cp : Cal solution plotting utilities
cs : Coordinate system utilities
fg : Flagging/Flag management utilities
ia : Image analysis utilities
im : Imaging utilities
me : Measures utilities
ms : MeasurementSet (MS) utilties
mp : MS plotting (data (amp/phase) versus other quantities)
pm : PlotMS utilities
rg : Region manipulation utilities
tb : Table utilities (selection, extraction, etc)
tp : Table plotting utilities
qa : Quanta utilities
sl : Spectral line import and search
sm : Simulation utilities
vp : Voltage pattern/primary beam utilties
---
pl : pylab functions (e.g., pl.title, etc)
sd : (after running asap_init()) Single dish utilities
```

Tools are described in the CASA Toolkit Reference:

http://casa.nrao.edu/docs/CasaRef/CasaRef.html

The Measurement Set

- The MS is a directory on disk, it consists of a MAIN table and sub-tables.
  - The MAIN table contains the visibility data. It consists of the `table.*` files.
  - The sub-tables (e.g. FIELD, SOURCE, ANTENNA, etc.) contain auxiliary and secondary information.
  - The sub-tables are sub-directories.
- To copy: must use cp -rf to get contents
- Best to remove MS with rmtables('filename')

Example MS

```
CASA <31>: ls day2_TDEM0003_20s_full/
ANTENNA/            STATE/           table.f18_TSM1  table.f25_TSM1
DATA_DESCRIPTION/   table.dat        table.f19       table.f3
FEED/               table.f1         table.f2        table.f4
FIELD/              table.f10        table.f20       table.f5
FLAG_CMD/           table.f11        table.f21       table.f6
HISTORY/            table.f12        table.f21_TSM0  table.f7
OBSERVATION/        table.f13        table.f22       table.f8
POINTING/           table.f14        table.f22_TSM1  table.f9
POLARIZATION/       table.f15        table.f23       table.info
PROCESSOR/          table.f16        table.f23_TSM1  table.lock
SORTED_TABLE/       table.f17        table.f24       WEATHER/
SOURCE/             table.f17_TSM1   table.f24_TSM1
SPECTRAL_WINDOW/    table.f18        table.f25
```

```
CASA <32>: ls day2_TDEM0003_20s_full/ANTENNA/
table.dat  table.f0  table.info  table.lock
```

Data Selection Syntax

- See Chapter 2.5 of Cookbook
  - field - string with source name or field ID
    - can use '*' as wildcard, first checks for name, then ID
    - example: field = '1331+305' ; field = '3C*' ; field = '0,1,4~5'
  - spw - string with spectral window ID plus channels
    - use ':' as separator of spw from optional channelization
    - use '^' as separator of channels from step
    - example: spw = '0~2' ; spw = '1:10~30' ; spw = '2~5:5~54^5'

Selection Syntax

- see Chapter 2.5 of Cookbook
  - antenna - string with antenna name or ID
    - first check for name, then pad name, then ID
    - example: antenna = '1~5,11' ; antenna = 'ea*', '!ea01'
    - For a baseline, use: antenna ='ea01&ea10'
  - timerange - string with date/time range
    - specify 'T0~T1', missing parts of T1 default to T0.
    - example: timerange = '2007/10/16/01:00:00~06:30:00'
    - If year, month, day are not specified → defaults to 1st day in the data set.

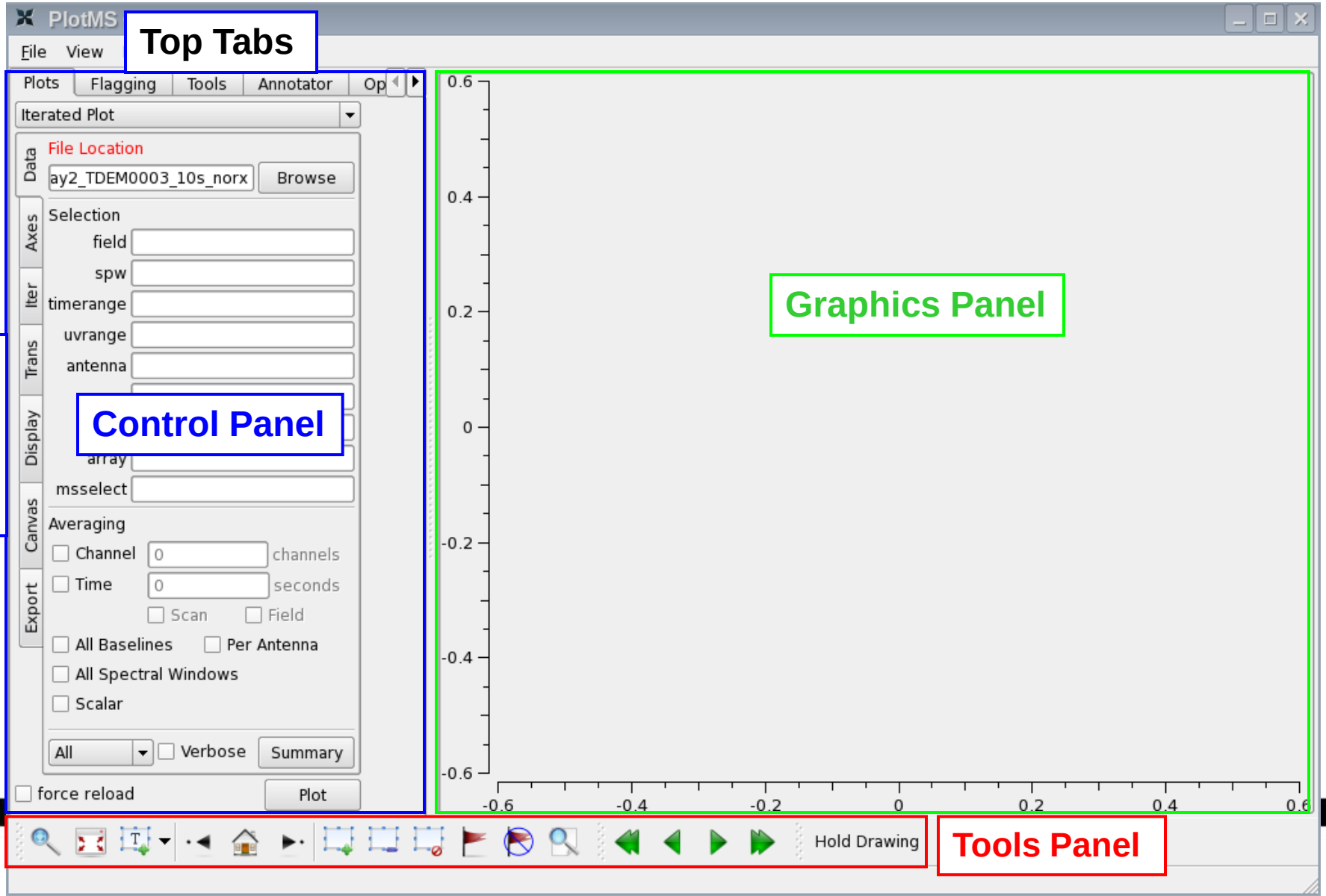
Calibration

- Data structure: 3 columns (scratch columns):
- DATA column: raw data
- MODEL column: source model, e.g. extended flux calibrators, selfcal model
- CORRECTED_DATA: calibrated data
- Columns are created when needed, this may take some time (it triples the size of your data set)
- Calibration is with calibration tables, e.g. bandpass, gain, pol, antenna offset, etc.

Visualization Tools

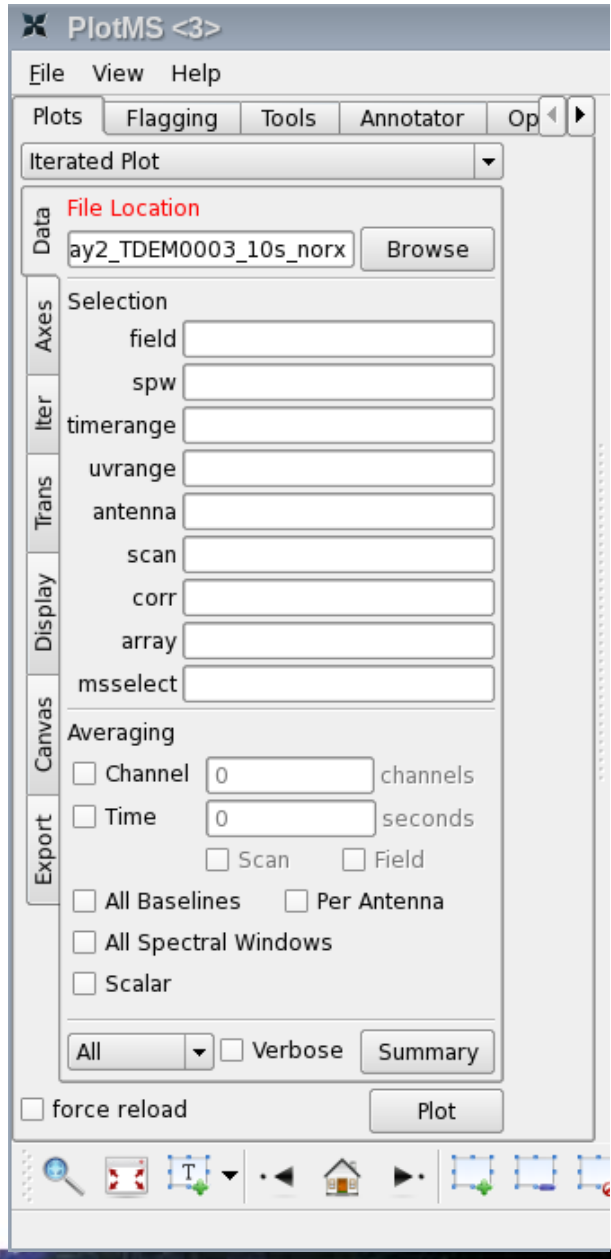
- Visibilities: plotms, msview
- Images: viewer, imview
- Calibration tables: plotcal (or plotms)
- Any table values: browsetable
- Single dish: sdplot
- Plot anything: use python's matplotlib

Data Review: *plotms* (unix command line *casaplotms*)



Data Review: *plotms*

Control Panel: Data



Data Review: *plotms*

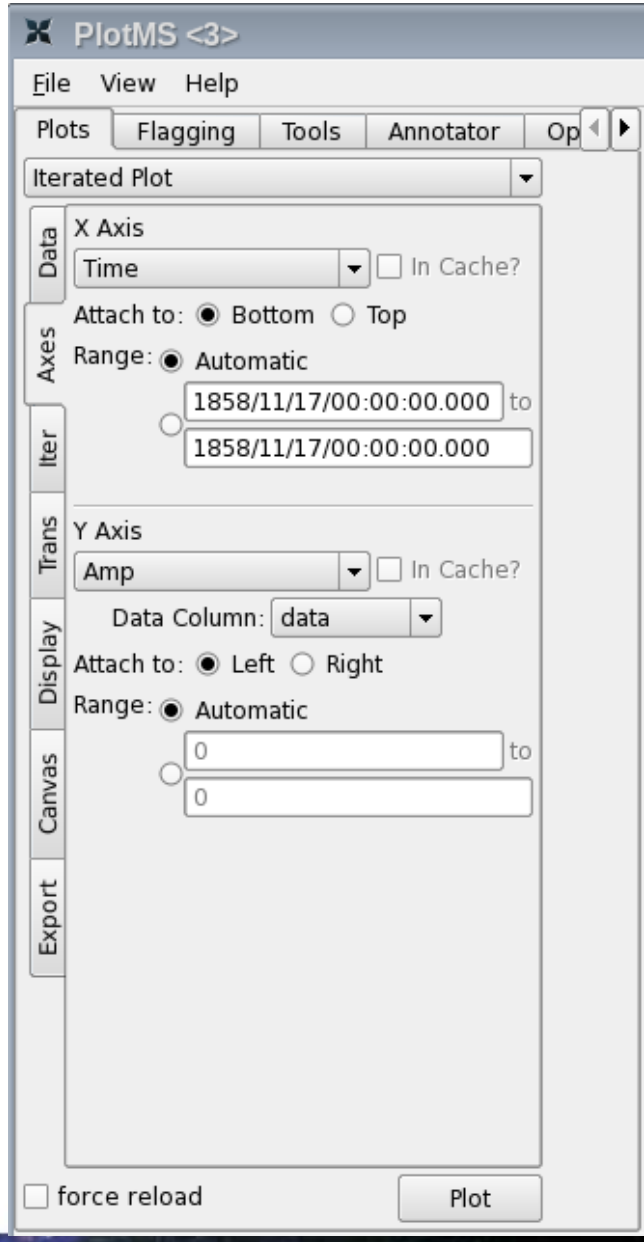
Axes

MS Ids and other meta info:

'scan' (number)
'field' (index)
'time',
'interval'='timeint'='timeinterval'='time_interval'
'spw' (index)
'chan'='channel' (index)
'freq'='frequency' (GHz)
'vel'='velocity' (km/s)
'corr'='correlation' (index)
'ant1'='antenna1' (index)
'ant2'='antenna2' (index)
'baseline' (a baseline index)
'row' (absoute row Id from the MS)

Visibility values, flags:

'amp'='amplitude'
'phase' (deg)
'real'
'imag'='imaginary'
'wt'='weight'
'flag'
'flagrow'



Data Review: *plotms*

Axes

Observational geometry:

'uvdist' (meters)

'uvwave'='uvdistl'='uvdist_l' (wavelengths, per channel)

'u' (meters)

'v' (meters)

'w' (meters)

'azimuth' (at array reference; degrees)

'elevation' (at array reference; degrees)

'hourang'='hourangle' (at array reference; hours)

'parang'='parangle'='parallacticangle' (at array reference; degrees)

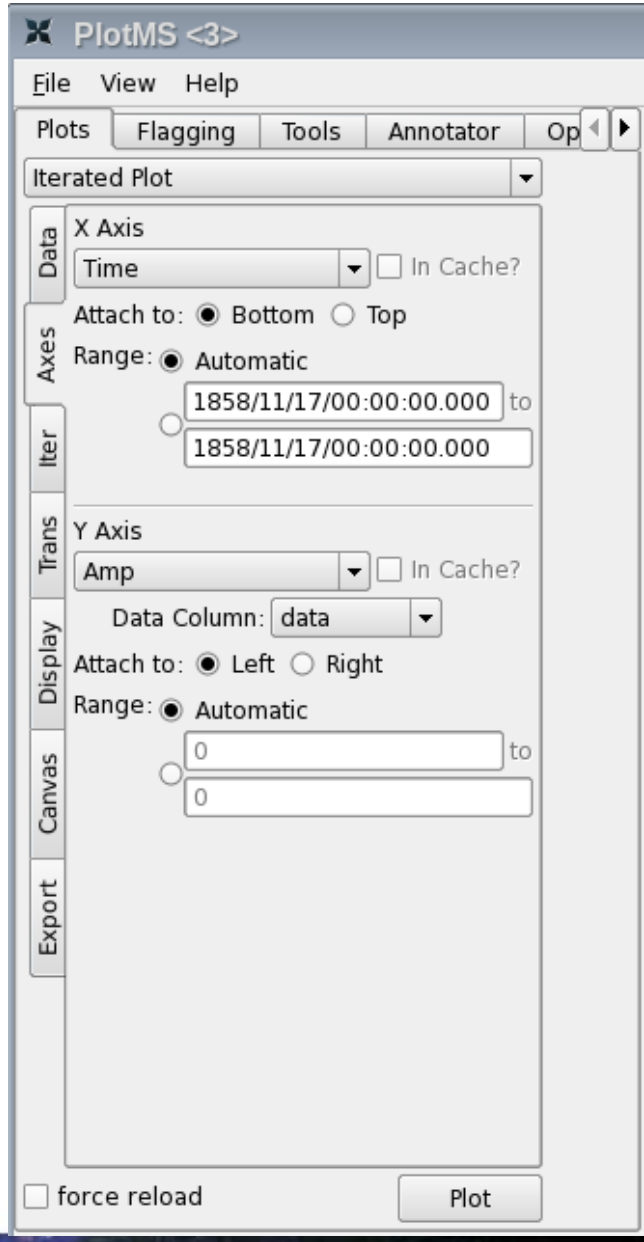
Antenna-based (only works vs. data Ids):

'ant'='antenna'

'ant-azimuth'

'ant-elevation'

'ant-parang'='ant-parangle'

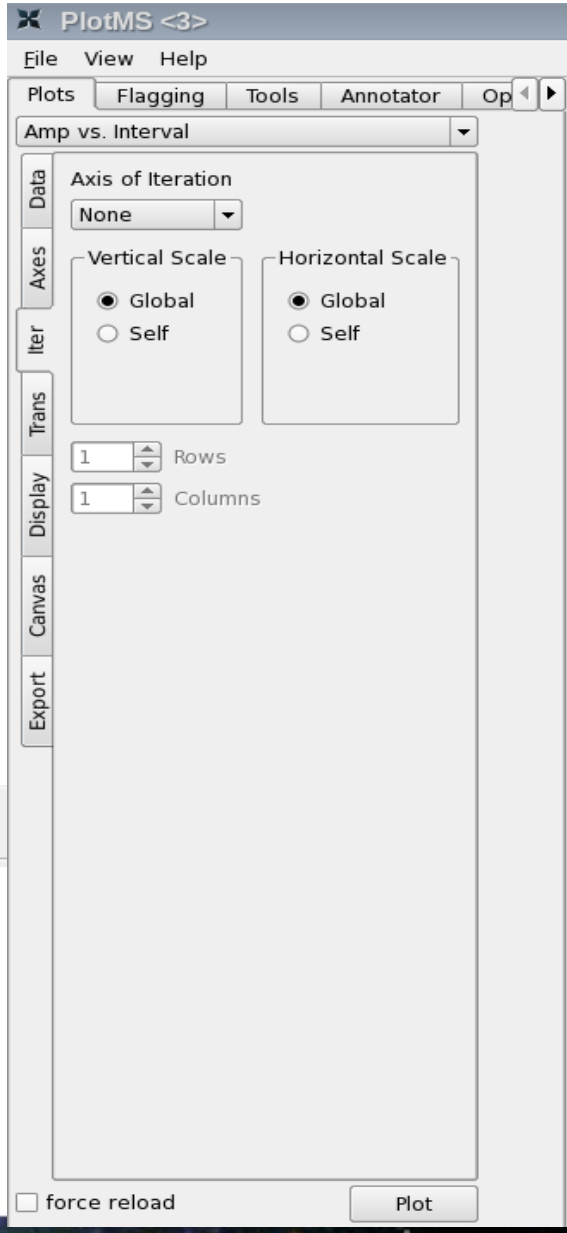


Data Review: *plotms*

Iteration

- Scan
- Field
- Spw
- Baseline
- antenna

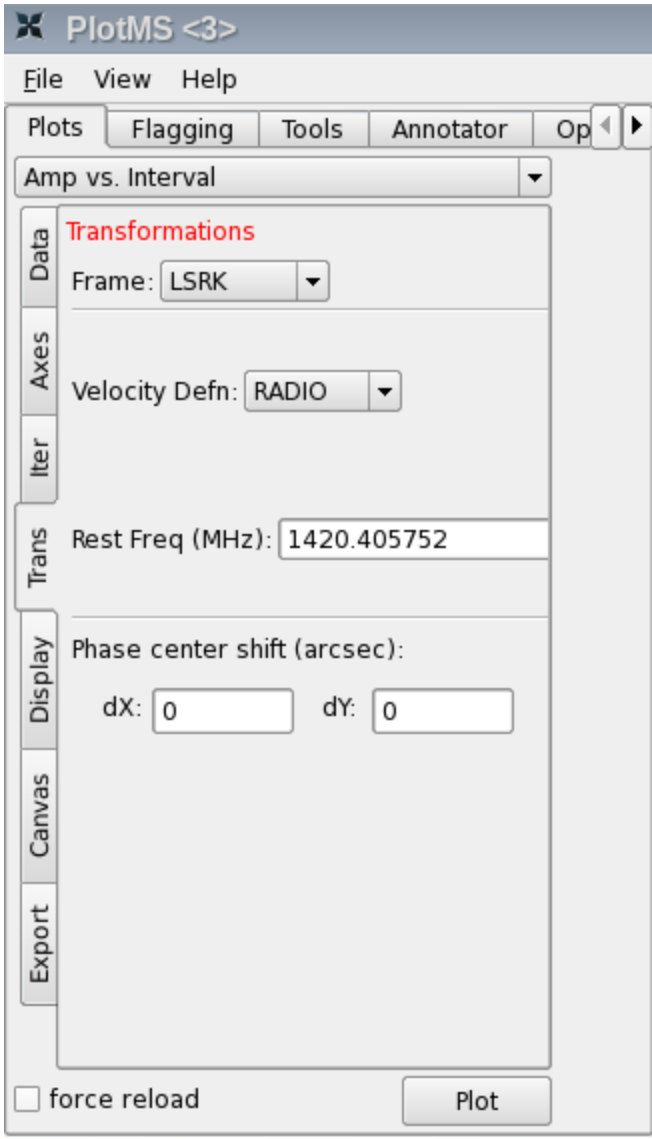
Tool panel



Data Review: *plotms*

Transformations

Frame: TOPO, GEO, BARY, LSRK, LSRD, etc..

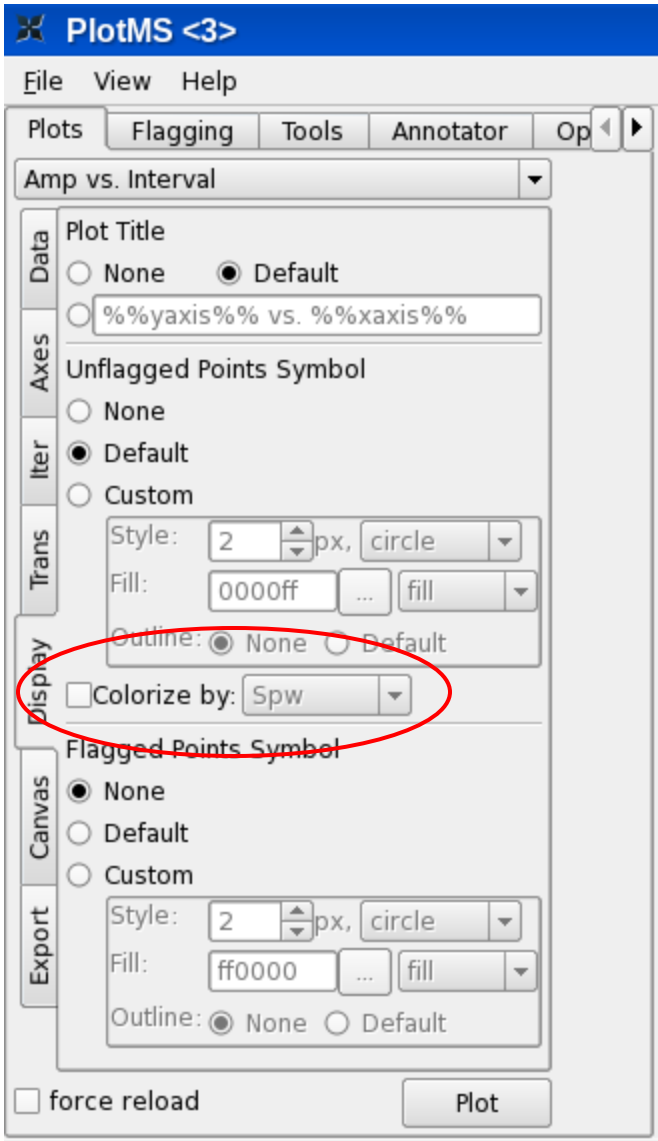


Data Review: *plotms*

Display

Colorize by:

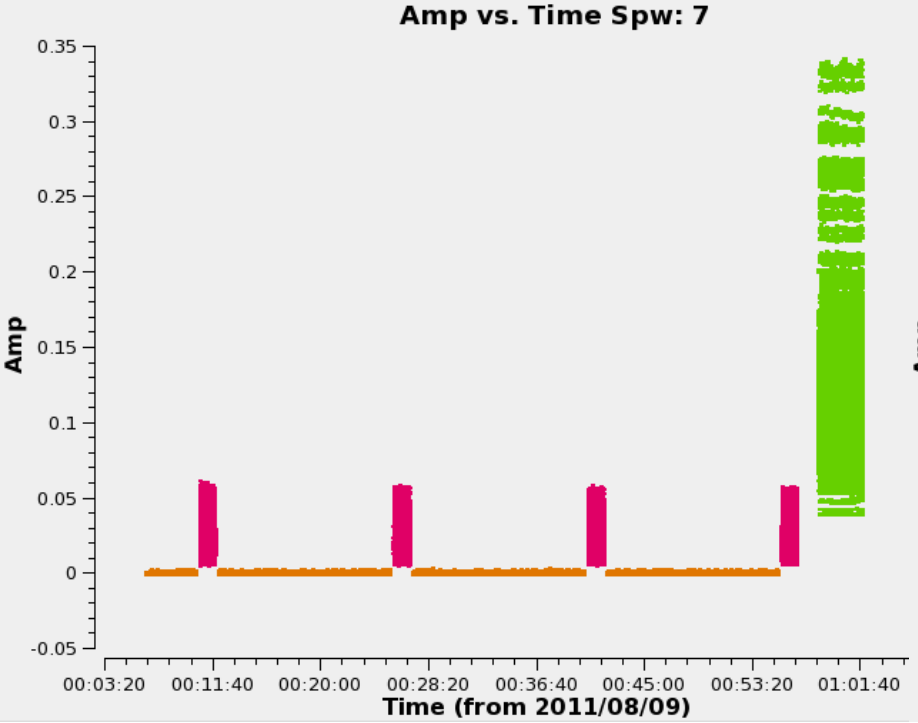
- Scan
- Field
- Spw
- Antenna1
- Antenna2
- Baseline
- Channel
- Correlation

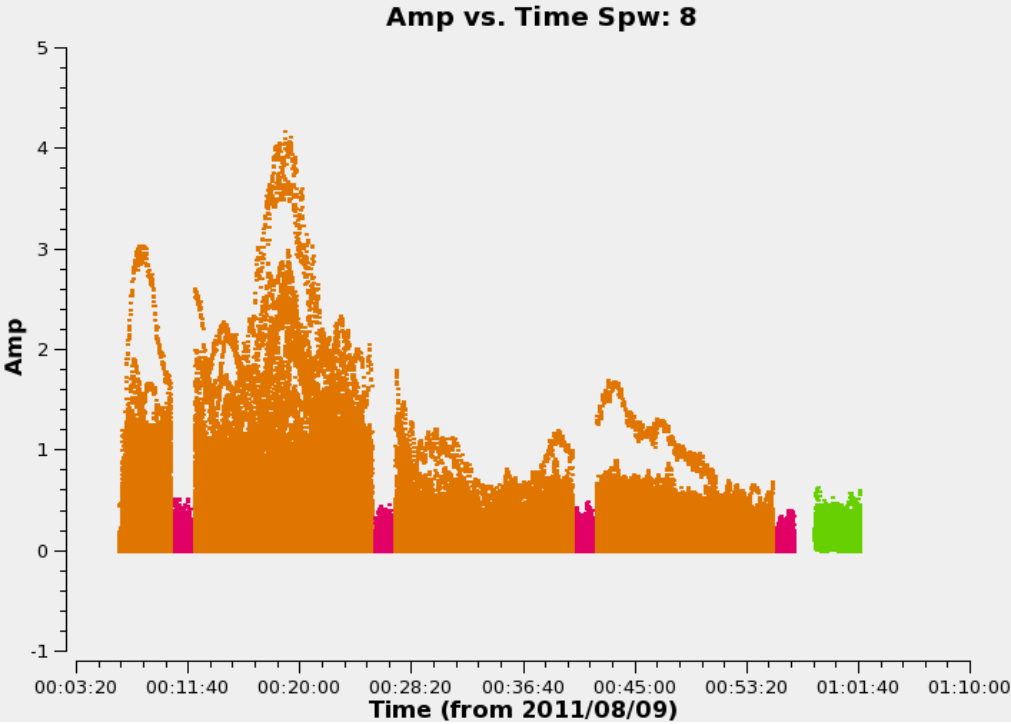


Data Review: *plotms*

Example: x-axis: time, y-axis: amp

iter: spw (with all channels averaged)

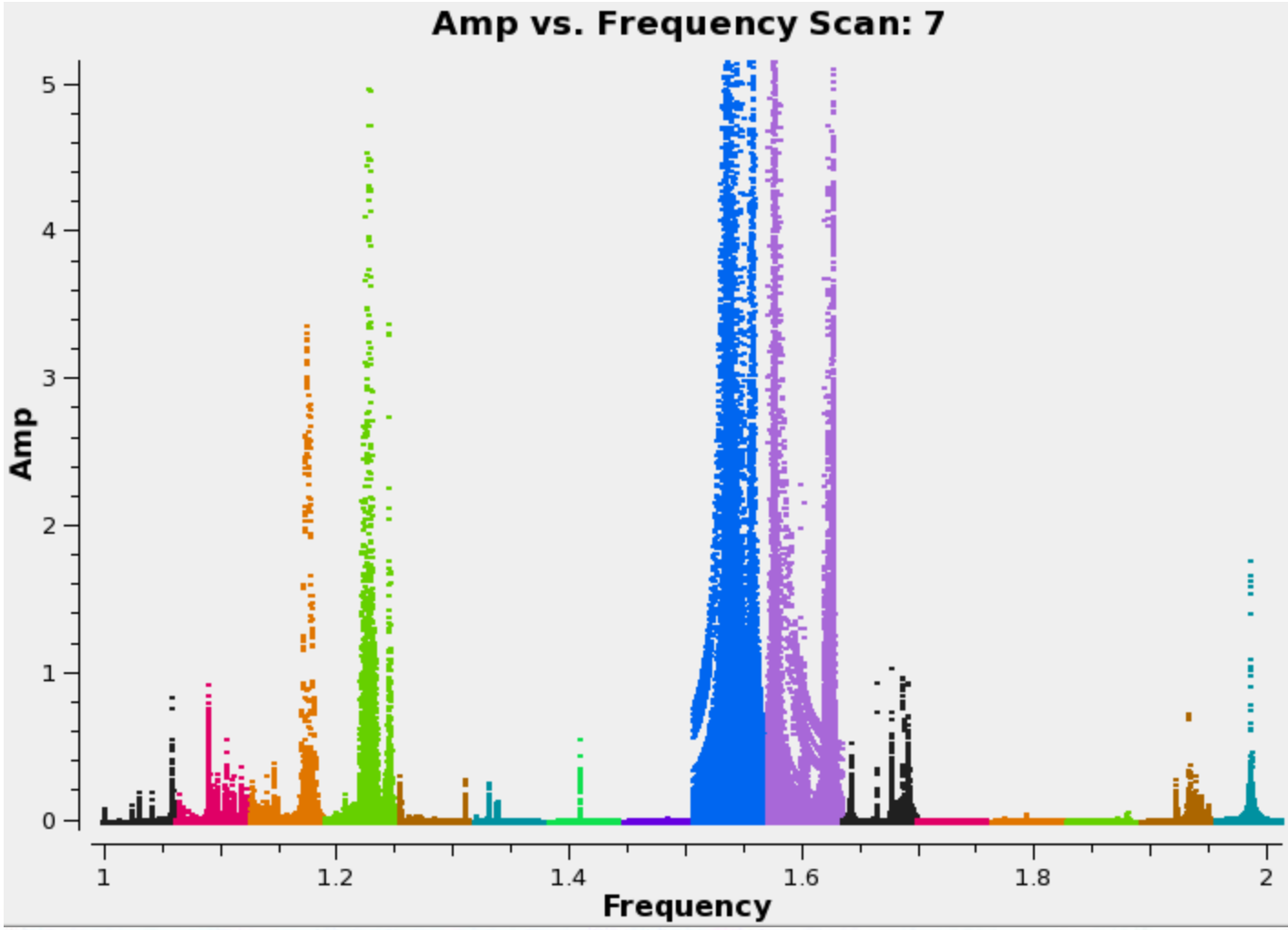




Data Review: *plotms*

Example: x-axis: frequency, y-axis: amp

iteration: scan



Data review: *msview*

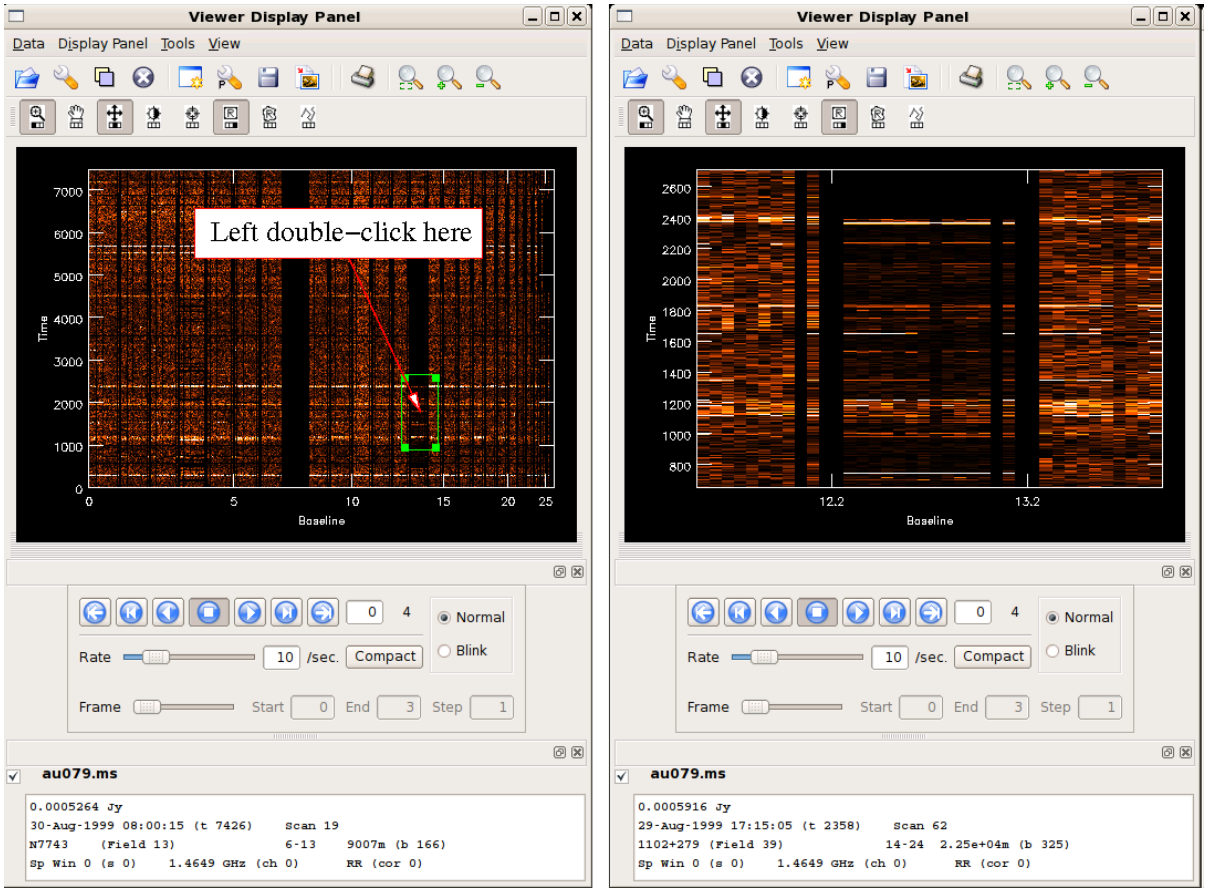


Image Viewer: *viewer*

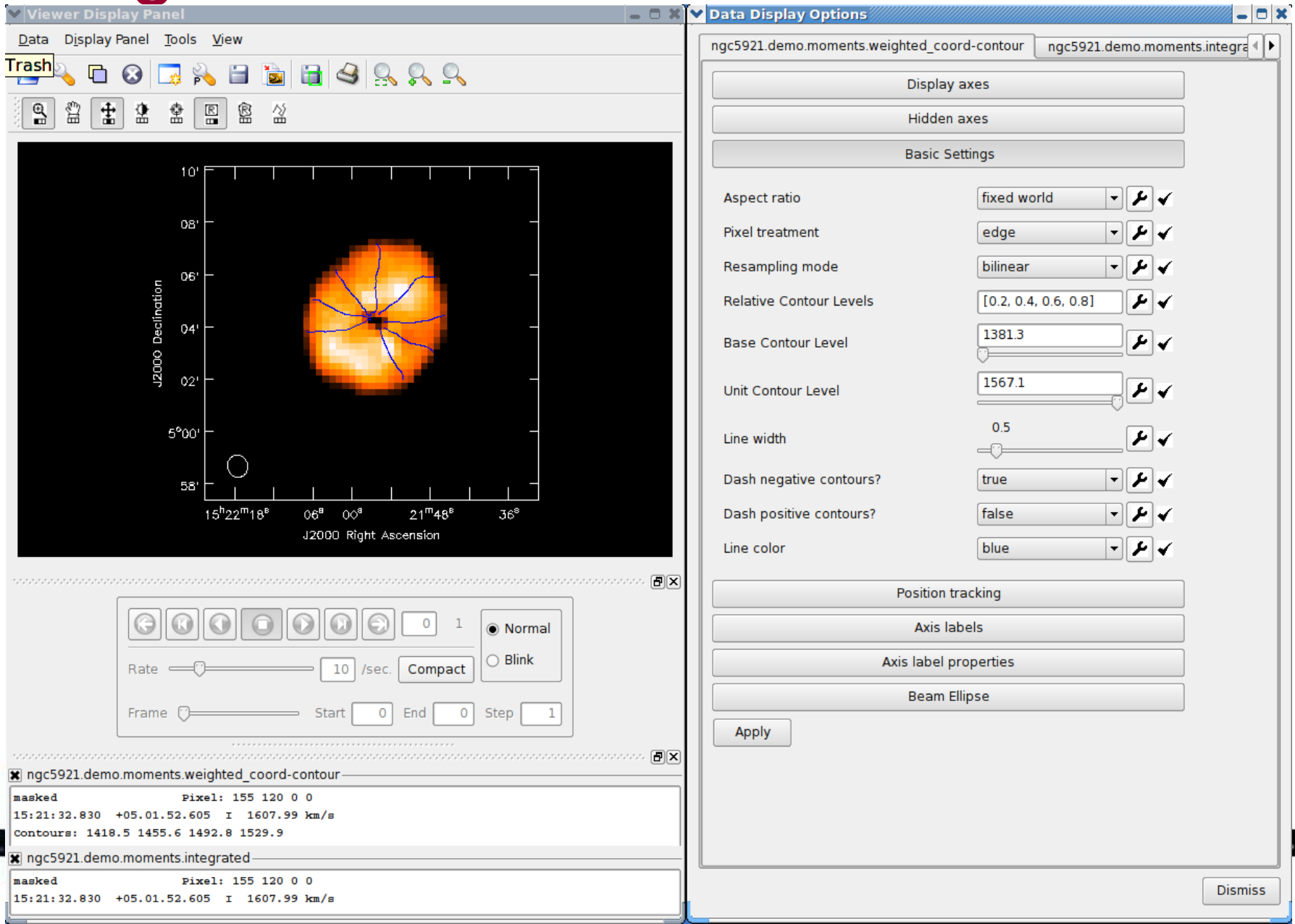
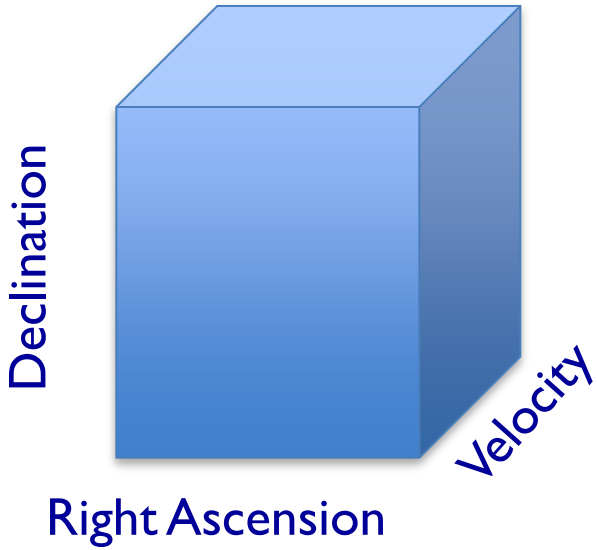
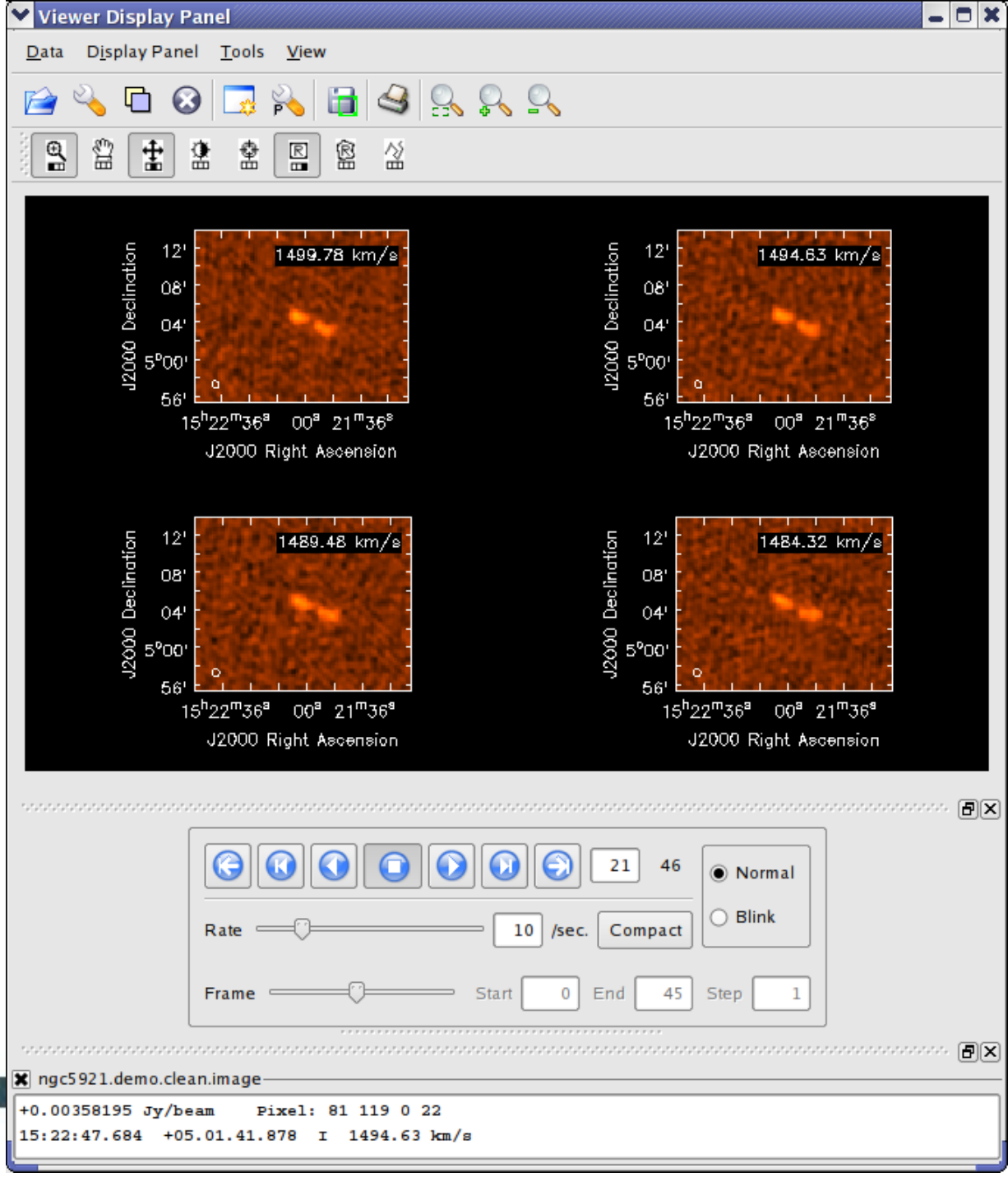
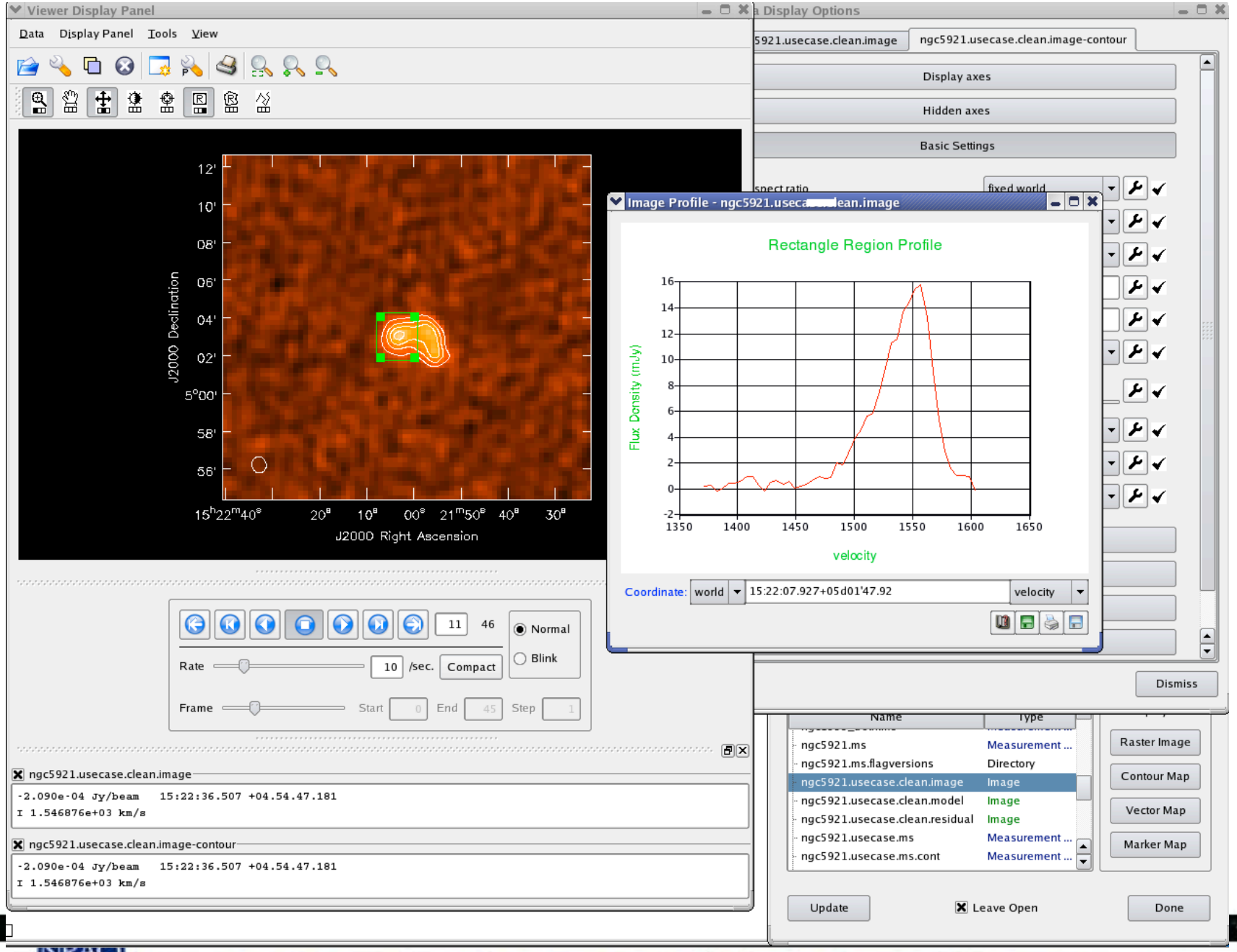


Image Viewer

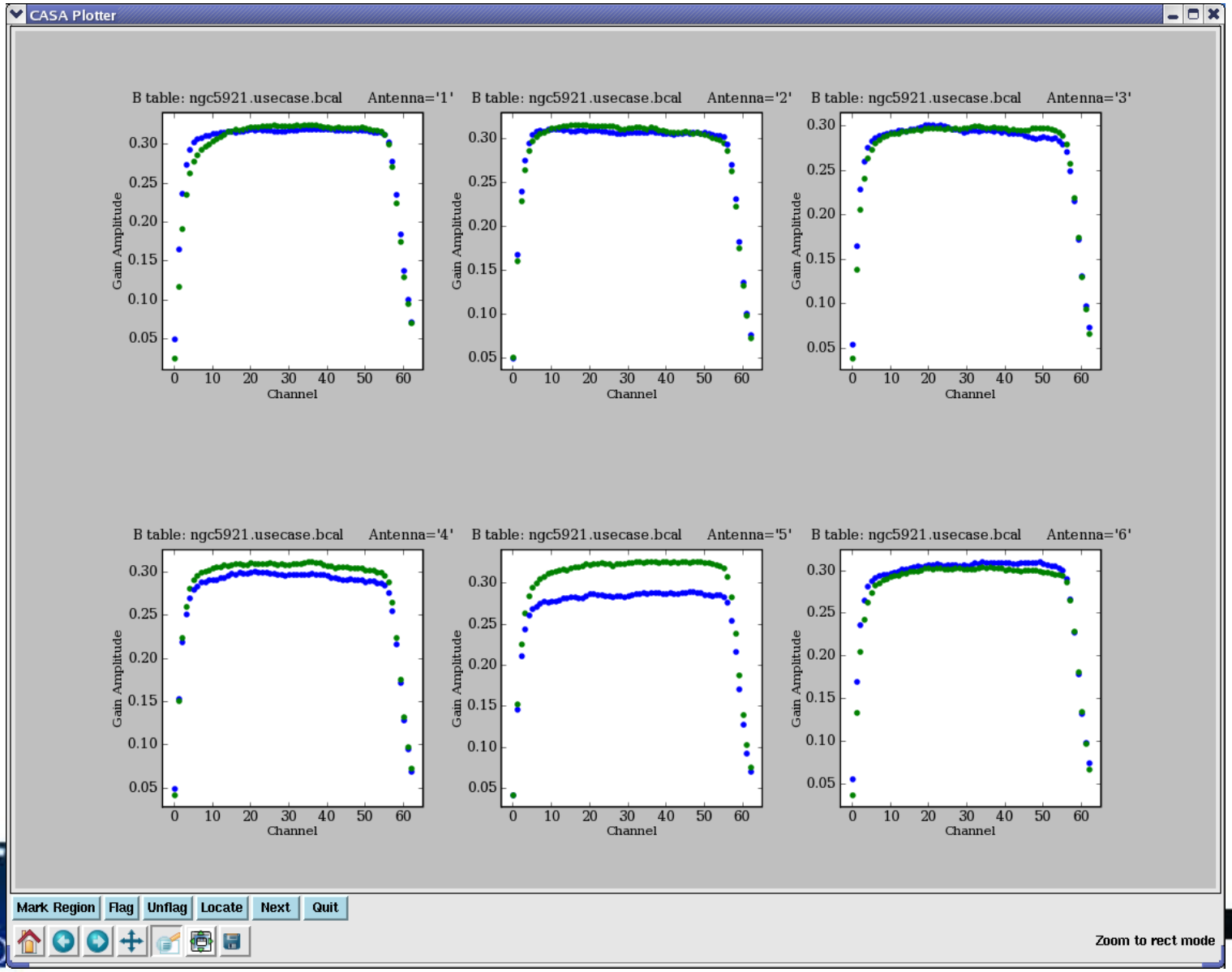
- Displaying cubes
- Movies
- Channel maps



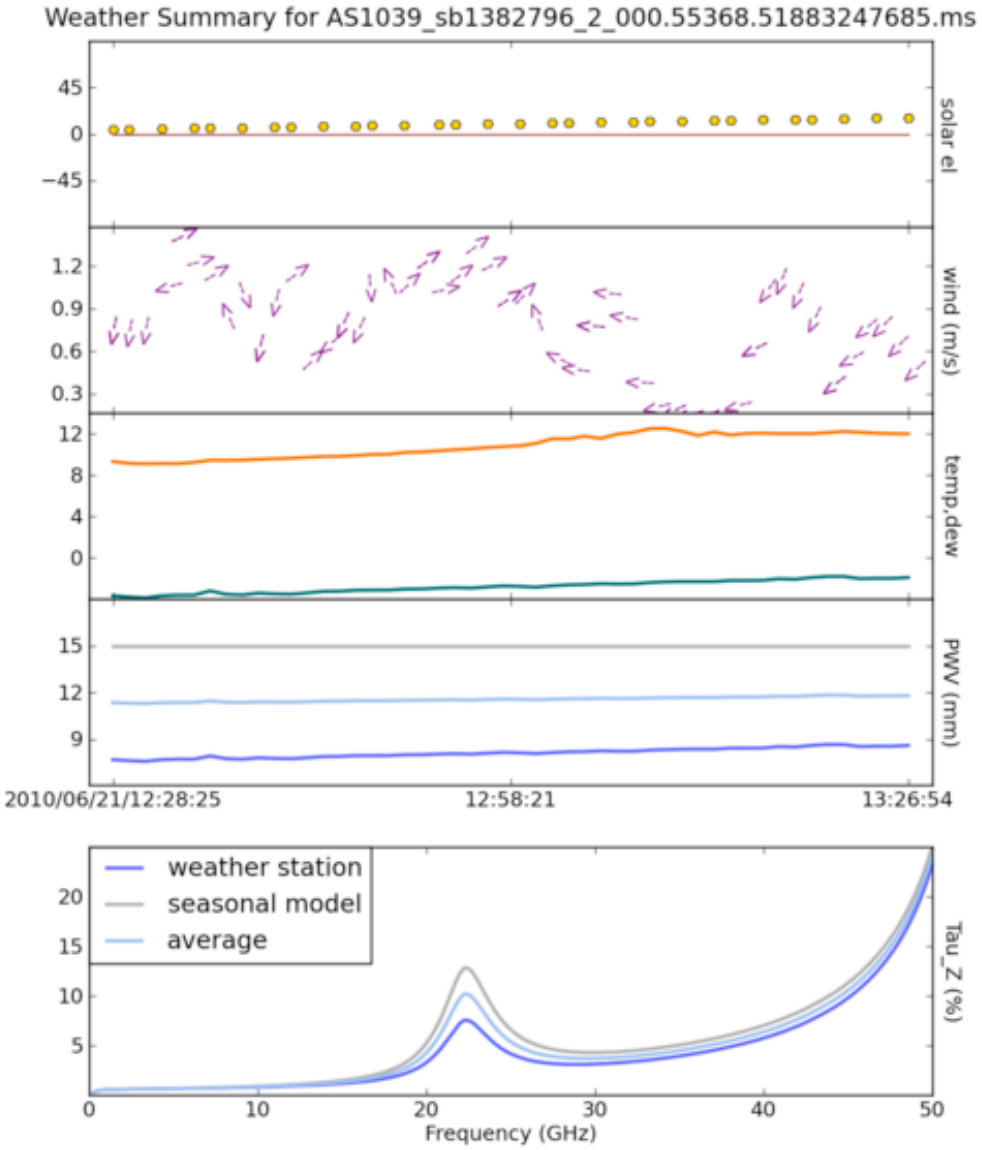



Viewer Display Panel
Data
Display Panel
Tools
View
J2000 Declination
J2000 Right Ascension
Image Profile - ngc5921.usecase.clean.image
Rectangle Region Profile
Flux Density (mJy)
velocity
Coordinate:
world
15:22:07.927+05d01'47.92
velocity
Display Options
ngc5921.usecase.clean.image
ngc5921.usecase.clean.image-contour
Display axes
Hidden axes
Basic Settings
fixed world
Normal
Blink
Rate
10
/sec.
Compact
Frame
Start
End
Step
ngc5921.usecase.clean.image
-2.090e-04 Jy/beam 15:22:36.507 +04.54.47.181
I 1.546876e+03 km/s
ngc5921.usecase.clean.image-contour
-2.090e-04 Jy/beam 15:22:36.507 +04.54.47.181
I 1.546876e+03 km/s
Name
Type
ngc5921.ms
Measurement ...
ngc5921.ms.flagversions
Directory
ngc5921.usecase.clean.image
Image
ngc5921.usecase.clean.model
Image
ngc5921.usecase.clean.residual
Image
ngc5921.usecase.ms
Measurement ...
ngc5921.usecase.ms.cont
Measurement ...
Raster Image
Contour Map
Vector Map
Marker Map
Dismiss
Update
Leave Open
Done

Review calibration tables: *plotcal*



Anything - matplotlib



Flagging (or unflagging) Data
A few important notes

1. Data in CASA are either flagged or not flagged.
   - Every MS has a flag column.
   - Every bit of data has its own flag (set either to true or false).
   - Applying flags means setting the flag column entries of the selected bits of data to true.
2. Most flagging tasks have the option of creating a flag backup.
3. A flag backup is a MS that contains the state of the flags before running a flagging task.
4. Using *flagmanager*, backed-up flags can be restored.

Buildmytasks

- Using Python, you can write your own scripts!
- Such scripts can be converted to tasks.
- If you wish, you can share them with the community (e.g., through NRAO).
- Contributed scripts are currently available at:

  http://casaguides.nrao.edu/ → Data Reduction Guides → EVLA Guides → Contributed Scripts

Let's Use CASA!