EUROPEAN ARC
ALMA Regional Centre || Italian

The CASA Software

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CASA
Common Astronomy Software Applications

Contents

- Introduction to CASA
  - What is CASA?
  - Casa Interface
  - Data in CASA
  - Data Selection
  - Processing Philosophy → NGC 3256 (ALMA!!!)
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- CASA Useful links/Documentation

CASA is...

CASA = Common Astronomy Software Applications

- CASA is a set of C++ application libraries for the data reduction and analysis of radio astronomical data
- applications run through the IPython interface to Python
- developed for ALMA and EVLA projects
- …but also for data from other radio, millimeter, and sub-mm telescopes

CASA design and implementation

Overall architecture:

- A data structure

  Tables: Images, Caltables, and the Measurement Set

- A set of data import/export facilities

  the so-called fillers: ASDM → MS, FITS → MS, UVFITS → MS, PdBI → MS, etc.

- A set of low-level tools for data access, display, and editing ,

  tools to load/write data into/from casacore datatypes, matplotlib for basic x/y plotting

  Qt-based table browser

CASA design and implementation

- A set of high-level tools for science analysis
  built around the Measurement Equation (Hamaker 1996)
- A programmable command line interface with scripting
  Python (augmented by IPython) gives a MATLAB-like interactive language
- Documentation
  inline documentation using doxygen + an extensive cookbook (500 pages) + user reference manual

How does CASA look ?

Installation - CASA comes as a tgz-file for Linux or a dmg-file for Mac OS-X

See "Obtaining CASA" link on http://casa.nrao.edu/
Download latest version at
http://casa.nrao.edu/casa_obtaining.shtml

Linux:
Unpack tgz file in a location of your choice.
cd into the created casapy directory.
export PATH=$PWD:$PATH

Mac OS-X:
Open the CASA disk image file
Double-click the CASA application to run it for the first time.

Task and Tools

- Task: high (user) level functionality
  - call from Python as functions
  - standard tasking interface
    - parameter manipulation using inp, default, saveinputs, tget
  - arguments are parameters
  - documentation: Cookbook
- Toolkit: full functionality represented
  - tools are functions and underlying tasks
  - documentation: Reference Manual

The CASA user interface

Starting up CASA… preliminary operations (only for ARC cluster!)

ssh scheduler –l username –X

Username = almauserN
Password = almaNpasswd

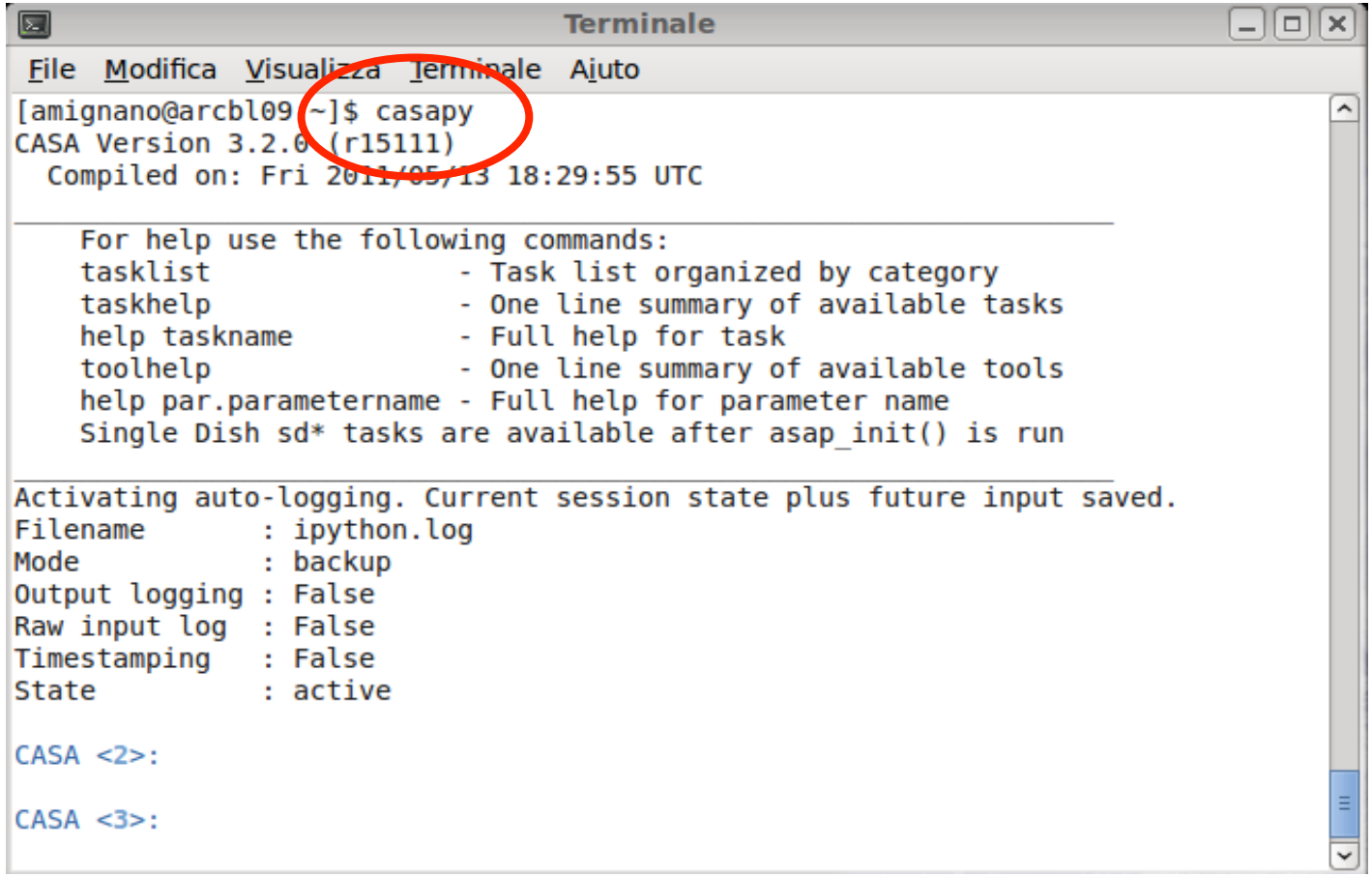
N = 1→10 i.e.
>ssh scheduler –l almauser3 –X
>Enter passwd: alma3passwd

cd FIRSTLOOK_DATA/ NGC3256_SV/ ANTENNAE_SV/

casapy-setup (tab is your friend!!)

The CASA user interface

Starting up CASA…



The CASA user interface

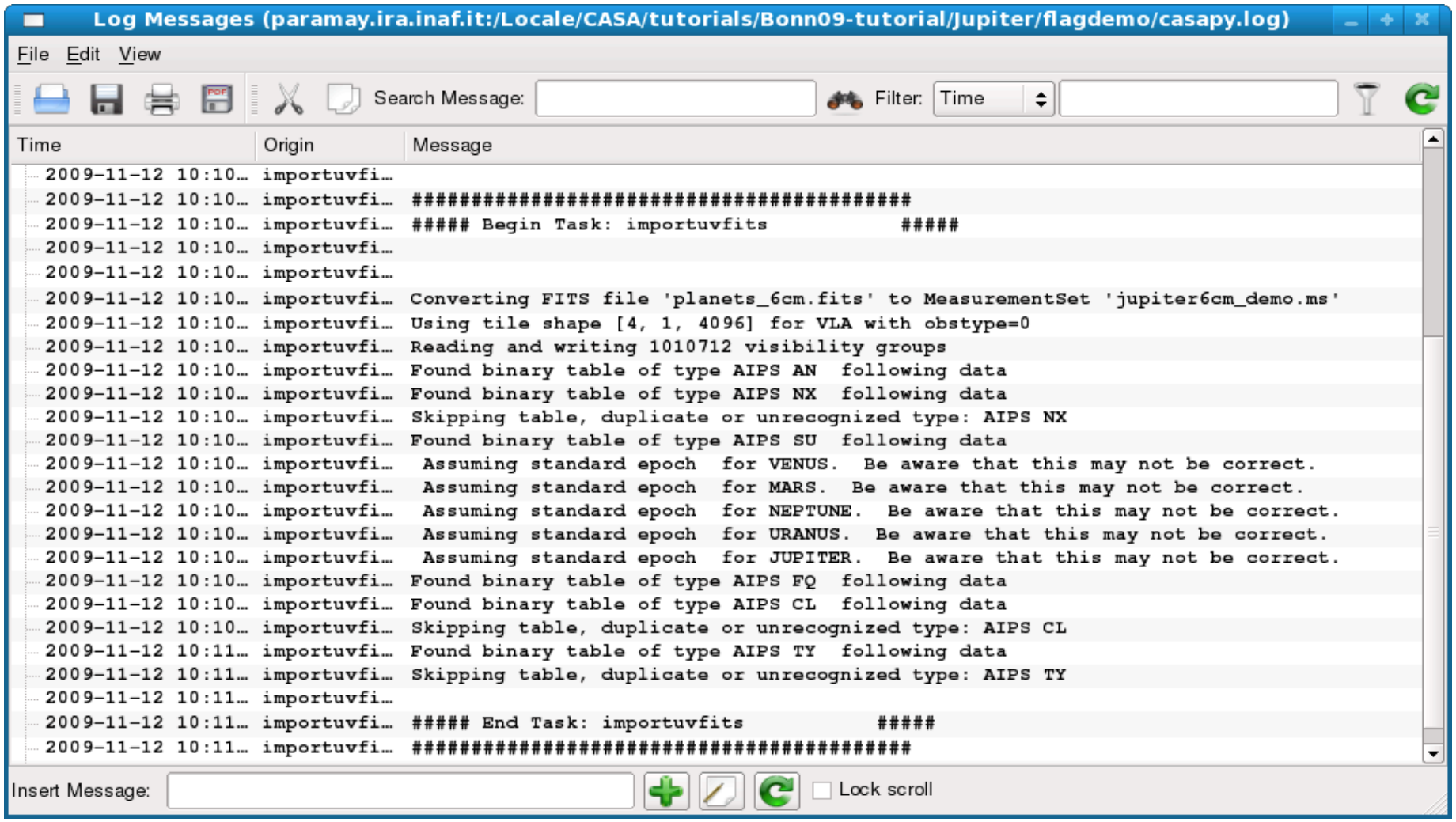
```
CASA <3>: tasklist
-------> tasklist()
Available tasks, organized by category (experimental tasks in parens ()
  deprecated tasks in curly brackets {}).
  Single Dish sd* tasks are available after asap_init() is run.


Import/export       Information         Editing             Manipulation
------------------  ------------------  ------------------  ------------------
exportfits          imhead              fixvis              concat
exportuvfits        imstat              flagautocorr        conjugatevis
importaipscaltable  imval               flagcmd             cvel
importasdm          listcal             flagdata            hanningsmooth
importevla          listhistory         flagmanager         imhead
importfits          listobs             msview              msmoments
importfitsidi       listvis             plotms              plotms
importuvfits        plotms              plotxy              plotxy
importvla           plotxy              (flagdata2)         split
(exportasdm)        vishead                                 testconcat
(importevla2)       visstat                                 vishead
(importgmrt)                                                (uvcontsub2)
{importoldasdm}

Calibration         Modeling            Imaging             Analysis
------------------  ------------------  ------------------  ------------------
accum               setjy               clean               imcollapse
applycal            uvcontsub           deconvolve          imcontsub
bandpass            uvmodelfit          feather             imfit
blcal               uvsub               ft                  imhead
calstat             (uvcontsub2)        imcontsub           immath
clearcal                                (autoclean)         immoments
fixvis                                  (boxit)             imregrid
fluxscale                               (csvclean)          imsmooth
fringecal                               {mosaic}            imstat
ft                                      {widefield}         imtrans
gaincal                                                     imval
gencal                                                      listvis
listcal                                                     slsearch
plotants                                                    splattotable
plotcal                                                     (specfit)
polcal
setjy
smoothcal
uvmodelfit
uvsub
```

The Logger

The CASA user interface

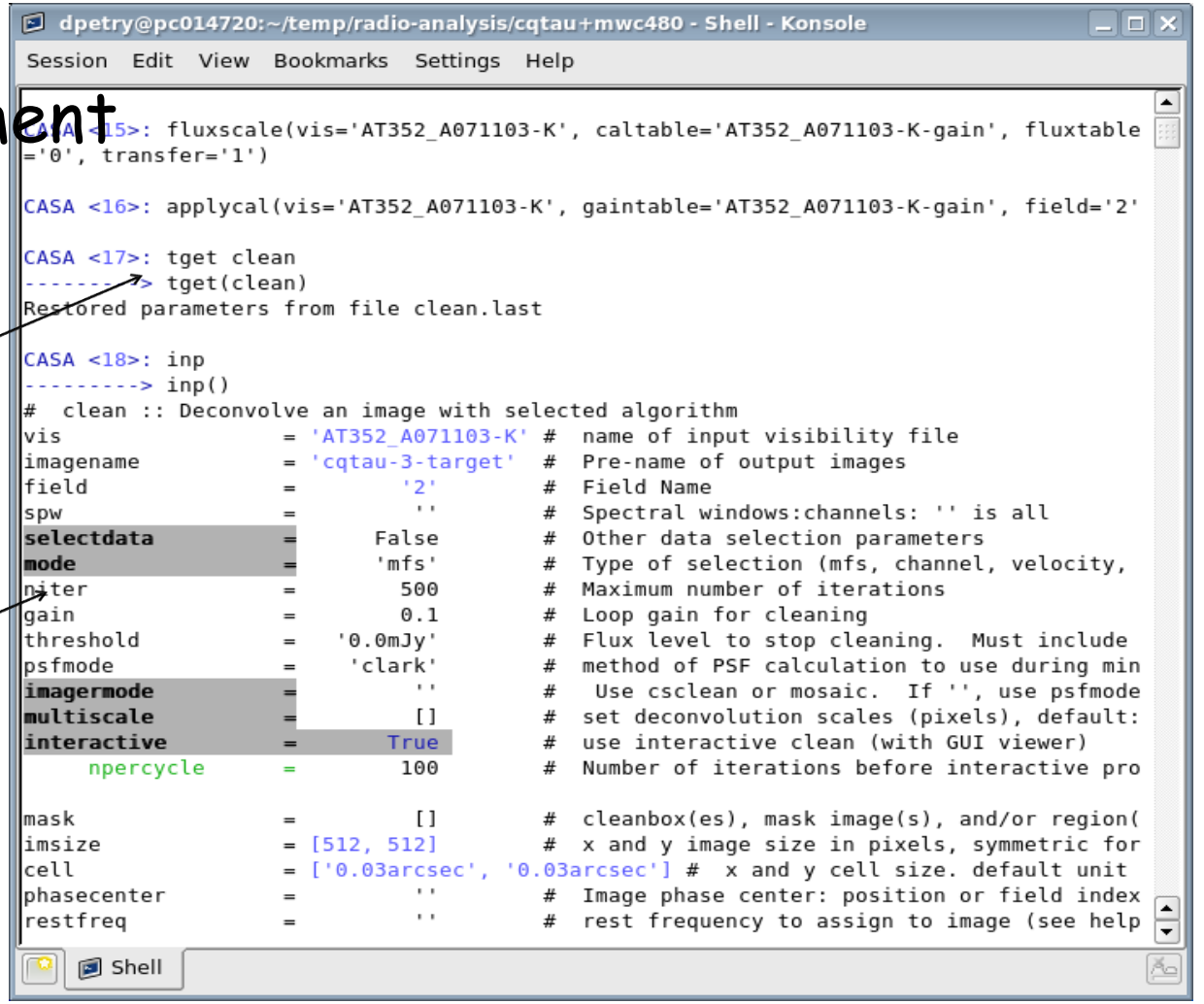


The CASA user interface

enter commands in a MATLAB-like environment

recall previous settings

list present settings for current task (includes parameter verification)



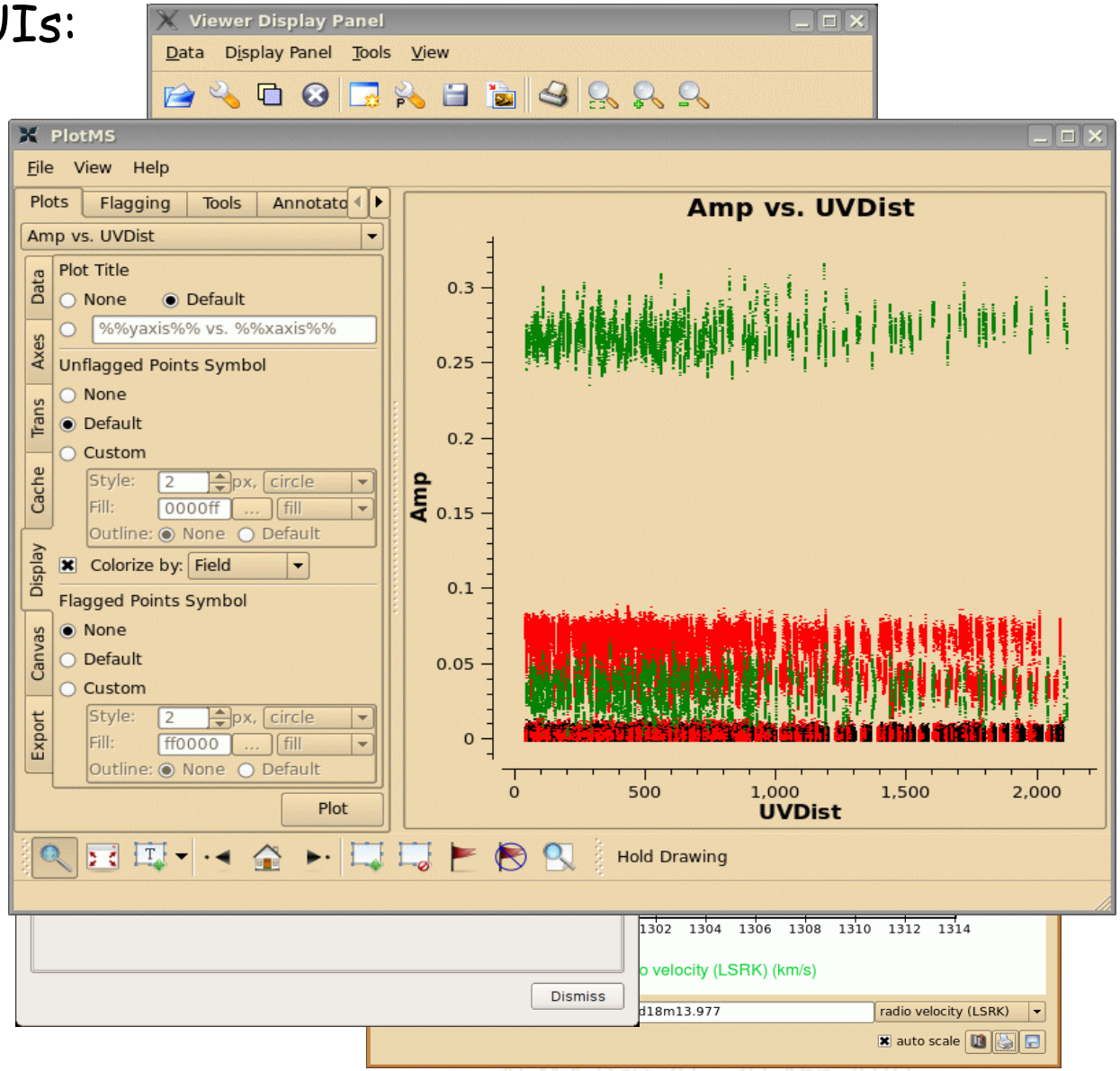
The CASA user interface

Where needed, tools have GUIs:

Plotxy, plotcal, browstable, viewer, plotms

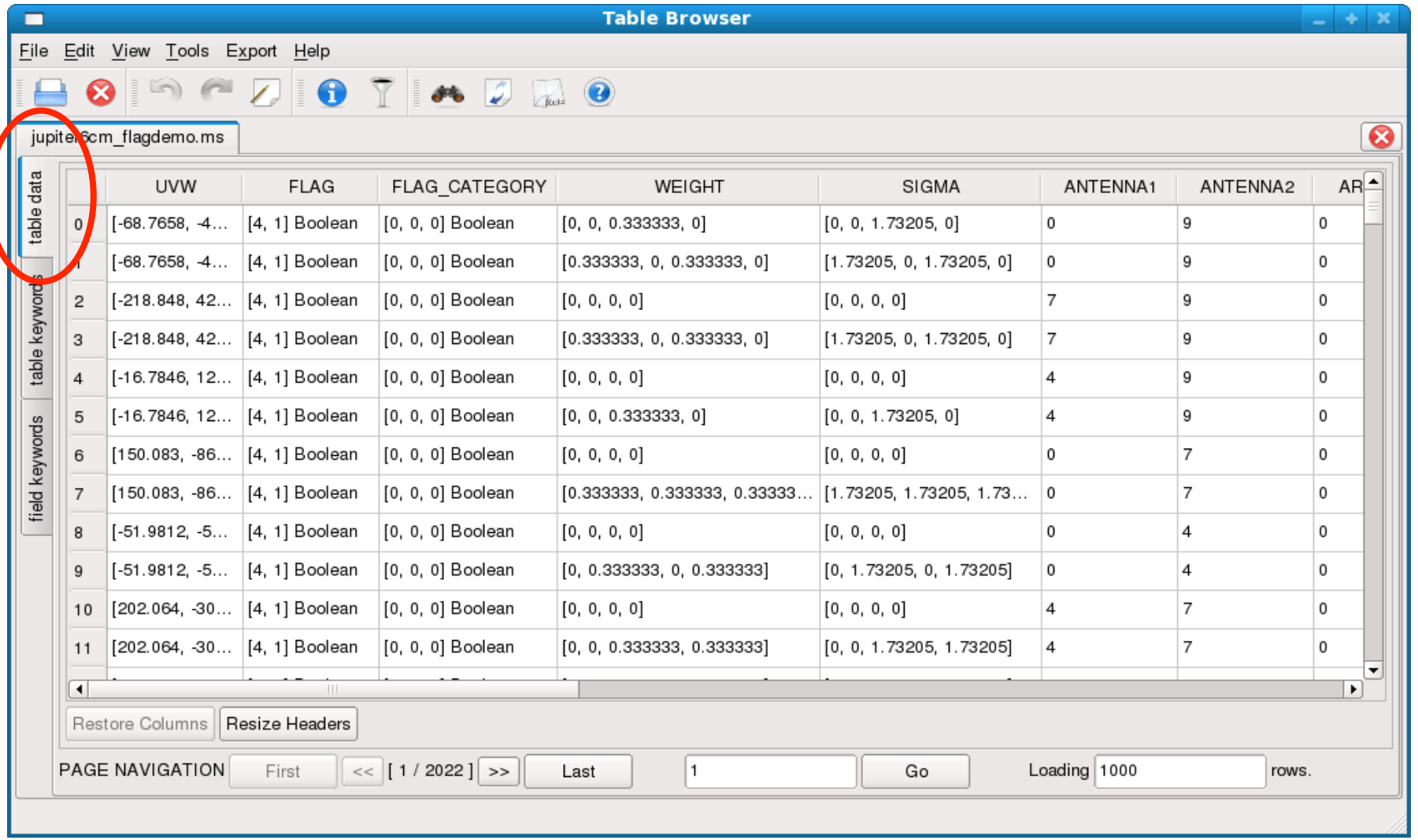
The ***viewer is a powerful multi-function tool*** for data selection
and visualization.

Plotms is going to replace plotxy, but still in beta (advanced) version.



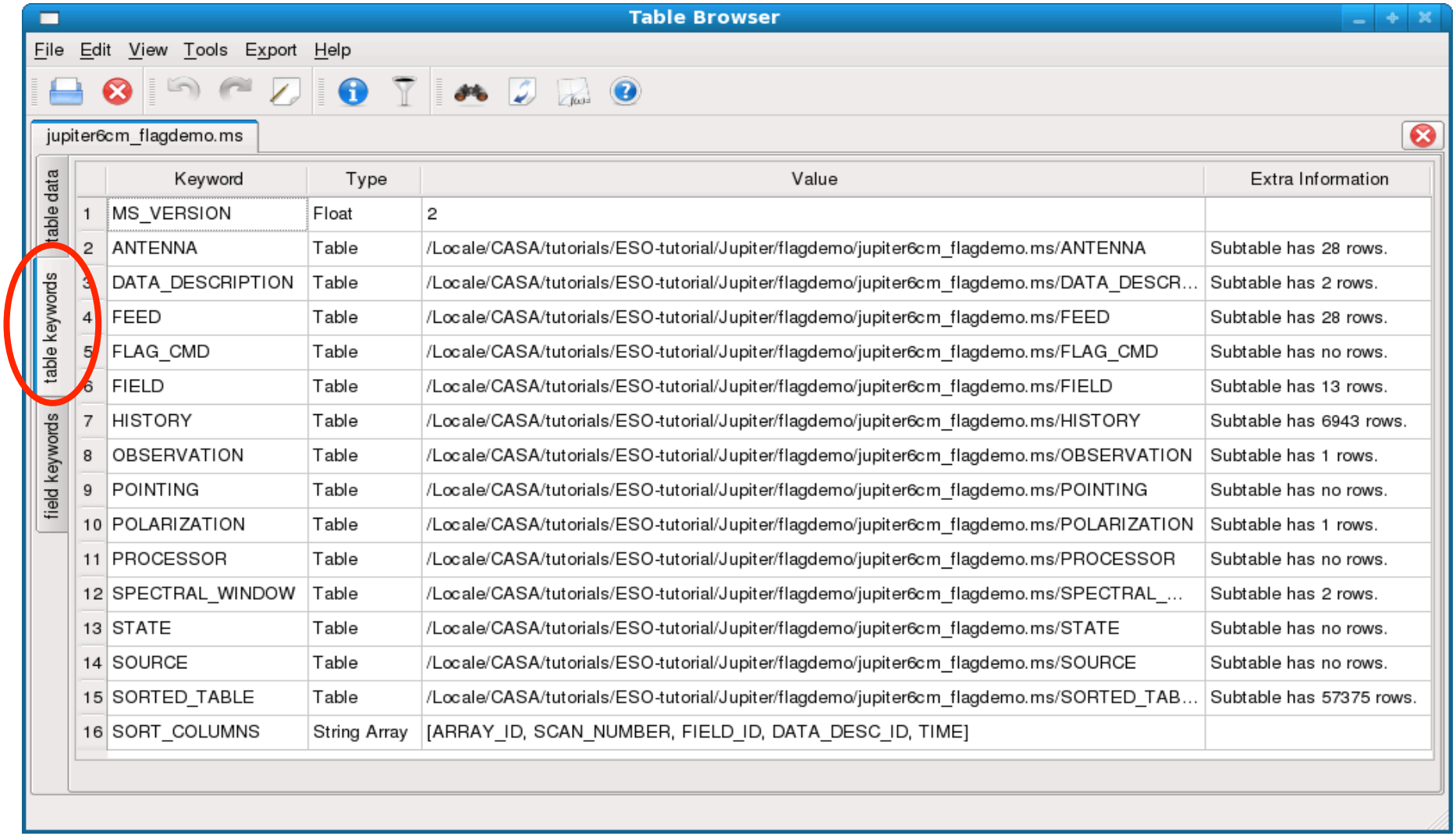
The CASA user interface

browsetable: *allows you to display any CASA table, e.g. Measurement*



	UVW	FLAG	FLAG_CATEGORY	WEIGHT	SIGMA	ANTENNA1	ANTENNA2	AR
0	[-68.7658, -4...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0.333333, 0]	[0, 0, 1.73205, 0]	0	9	0
1	[-68.7658, -4...	[4, 1] Boolean	[0, 0, 0] Boolean	[0.333333, 0, 0.333333, 0]	[1.73205, 0, 1.73205, 0]	0	9	0
2	[-218.848, 42...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0, 0]	[0, 0, 0, 0]	7	9	0
3	[-218.848, 42...	[4, 1] Boolean	[0, 0, 0] Boolean	[0.333333, 0, 0.333333, 0]	[1.73205, 0, 1.73205, 0]	7	9	0
4	[-16.7846, 12...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0, 0]	[0, 0, 0, 0]	4	9	0
5	[-16.7846, 12...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0.333333, 0]	[0, 0, 1.73205, 0]	4	9	0
6	[150.083, -86...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0, 0]	[0, 0, 0, 0]	0	7	0
7	[150.083, -86...	[4, 1] Boolean	[0, 0, 0] Boolean	[0.333333, 0.333333, 0.33333...	[1.73205, 1.73205, 1.73...	0	7	0
8	[-51.9812, -5...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0, 0]	[0, 0, 0, 0]	0	4	0
9	[-51.9812, -5...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0.333333, 0, 0.333333]	[0, 1.73205, 0, 1.73205]	0	4	0
10	[202.064, -30...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0, 0]	[0, 0, 0, 0]	4	7	0
11	[202.064, -30...	[4, 1] Boolean	[0, 0, 0] Boolean	[0, 0, 0.333333, 0.333333]	[0, 0, 1.73205, 1.73205]	4	7	0

The CASA user interface



	Keyword	Type	Value	Extra Information
1	MS_VERSION	Float	2	
2	ANTENNA	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/ANTENNA	Subtable has 28 rows.
3	DATA_DESCRIPTION	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/DATA_DESCR...	Subtable has 2 rows.
4	FEED	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/FEED	Subtable has 28 rows.
5	FLAG_CMD	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/FLAG_CMD	Subtable has no rows.
6	FIELD	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/FIELD	Subtable has 13 rows.
7	HISTORY	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/HISTORY	Subtable has 6943 rows.
8	OBSERVATION	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/OBSERVATION	Subtable has 1 rows.
9	POINTING	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/POINTING	Subtable has no rows.
10	POLARIZATION	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/POLARIZATION	Subtable has 1 rows.
11	PROCESSOR	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/PROCESSOR	Subtable has no rows.
12	SPECTRAL_WINDOW	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/SPECTRAL_...	Subtable has 2 rows.
13	STATE	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/STATE	Subtable has no rows.
14	SOURCE	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/SOURCE	Subtable has no rows.
15	SORTED_TABLE	Table	/Locale/CASA/tutorials/ESO-tutorial/Jupiter/flagdemo/jupiter6cm_flagdemo.ms/SORTED_TAB...	Subtable has 57375 rows.
16	SORT_COLUMNS	String Array	[ARRAY_ID, SCAN_NUMBER, FIELD_ID, DATA_DESC_ID, TIME]	

Data in CASA

- Data in CASA are stored in tables
  - also tables for images and calibration tables
- Visibility data are stored in Measurement Set (MS) table
- the MS is a directory on the disk
  - MAIN table containing the visibility data
  - sub-tables *(=sub-directories)* containing auxiliary information
    - e.g. FIELD, SPECTRAL WIN., ANTENNA, etc.

Data in CASA

Terminal

File Edit View Terminal Tabs Help

```
paramay:/Locale/CASA/tutorials/Bonn09-tutorial/Jupiter/flagdemo> ls jupiter6cm_demo.ms
ANTENNA           OBSERVATION   SPECTRAL_WINDOW  table.f2_TSM1  table.f6       table.info
DATA_DESCRIPTION  POINTING      STATE            table.f3       table.f6_TSM0  table.lock
FEED              POLARIZATION  table.dat        table.f3_TSM1  table.f7
FIELD             PROCESSOR     table.f0         table.f4       table.f7_TSM1
FLAG_CMD          SORTED_TABLE  table.f1         table.f5       table.f8
HISTORY           SOURCE        table.f2         table.f5_TSM1  table.f8_TSM1
paramay:/Locale/CASA/tutorials/Bonn09-tutorial/Jupiter/flagdemo>
```

Terminal

File Edit View Terminal Tabs Help

```
paramay:/Locale/CASA/tutorials/Bonn09-tutorial/Jupiter/flagdemo> ls jupit
er6cm_demo.ms/FIELD
table.dat  table.f0  table.f0i  table.info  table.lock
paramay:/Locale/CASA/tutorials/Bonn09-tutorial/Jupiter/flagdemo>
```

Data in CASA

The Measurement Set …

- developed by Cornwell, Kemball, & Wieringa between 1996 and 2000
- designed to store both interferometry (multi-dish) and single-dish data
- supports (in principle) any setup of radio telescopes
- supports description and processing of the data via the Measurement Equation

Data in CASA

What's in the Measurement Set?

MAIN	Model, e.g.:	Corrected data	Flags
Original visibility data	*FT of image made from MS* *FT of supplied model image* *FT of calibrator flux density*	*Copy of visibilities with calibration tables applied* (Used in imaging but not calibration)	(Edits are stored here first; backup tables can be made and used to modify)

There are scratch columns

The Measurement Equation
(Hamaker, Bregman & Sault 1996)

- decompose into individual calibration components,

$$\vec{V}_{ij}^{obs} = \vec{\vec{B}}_{ij}\vec{\vec{G}}_{ij}\vec{\vec{D}}_{ij}\vec{\vec{P}}_{ij}\vec{\vec{T}}_{ij}\vec{\vec{F}}_{ij}\vec{V}_{ij}^{ideal}$$

where:

B = Bandpass, G = gain, D = D-Term (pol. leackage),
T = Tropospheric effects, F = Faraday rotation

- linearise and solve by χ^2 minimization

Data Selection

- Standard MS selection syntax
  - e.g for task gaincal

```
CASA <24>: inp gaincal
---------> inp(gaincal)
#  gaincal :: Determine temporal gains from calibrator observations
vis                 = 'jupiter6cm.demo.ms/' #  Name of input visibility file
caltable            = 'jupiter.gcal'    #  Name of output gain calibration table
field               = '0137+331,1331+305' #  Select field using field id(s) or field name(s)
spw                 =       '0,1'       #  Select spectral window/channels
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
     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)
```

  - Field, spw common standard selection
  - Expandable selectdata with other selection criteria
  - Check you parameter by the “inp”

Data Selection

- field – string with source name or field ID
  - can use "*" as wildcard, first checks for name, then ID
  - e.g.:

    field="1331+305";
    field="3C286, 3C84";
    field="0"

- spw – string with spectral window ID + channels
  - use ":" as separator of spw from channelization
  - use "~" as separator for ranges ("start~stop")
  - e.g.:

    spw="0~2" , spectral windows 0,1,2
    spw="1:10~30", spectral window 1, channel 10-30 inclusive
    spw="0~2:5~54^5" , spw 0,1,2 channels 5-54 in step of 5

Data Selection

- antenna – string with antenna name or ID
  - first check for name, then ID (VLA name 1-27, ID 0-26)
  - example:

    antenna="1~5,11"; → from antenna 1 to 5 and antenna 11
    antenna="VA06"; → all baseline with VA06 antenna
    antenna="VA06&&" → autocorrelation
    antenna="!VA06" → all baselines, exept the ones with VA06

- Timerange – string with date/time range
  - specify "T0~T1", "T0+dT", ">T0"
  - example:

    timerange="22:40:00~03:30:00"
    timerange="23:41:00+01:00:00"
    timerange=">23:41:00"

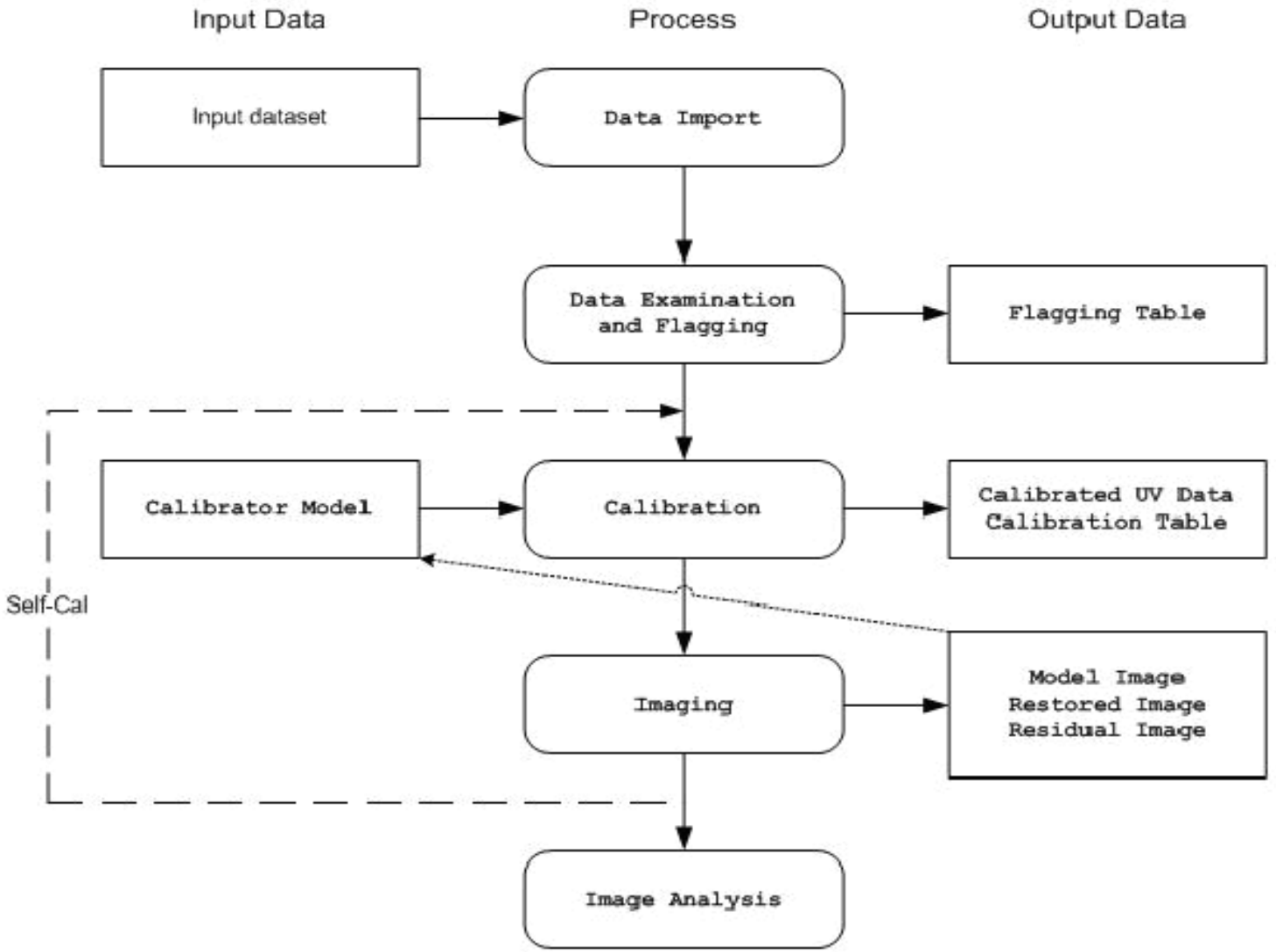
Processing Philosphy

Import

Examine

Calibrate

Image



Processing Philosophy

Import Data

- task importuvfits
  - UVFITS data (e.g. from AIPS)
- task importvla
  - VLA "export" format (e.g. from archive)
- task importasdm
  - ALMA data format (also EVLA eventually)

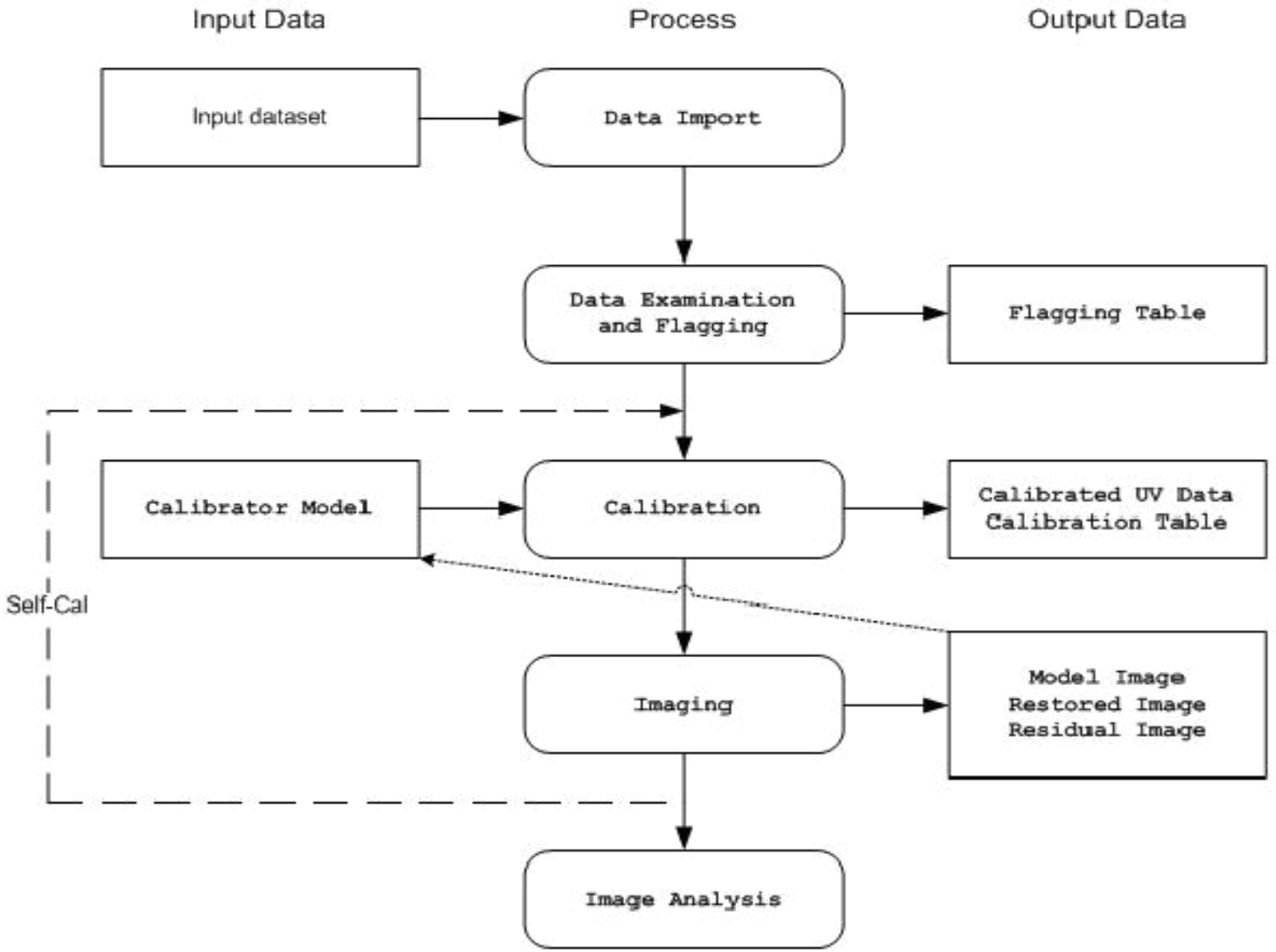
Processing Philosphy

Import

Examine

Calibrate

Image

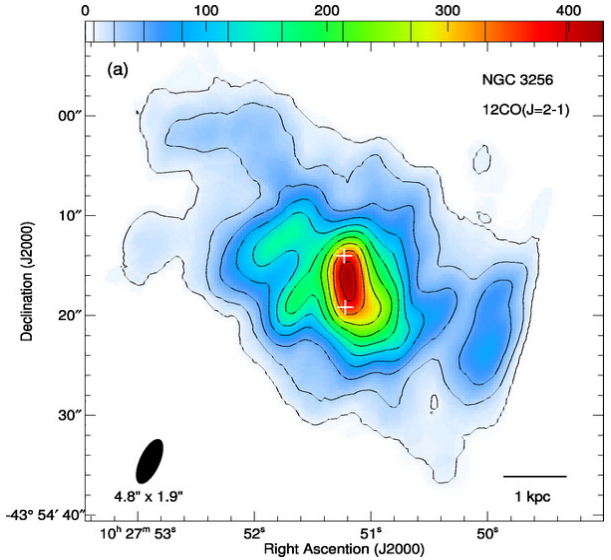


The Case of NGC3256

ALMA Science Verification Data (April, 16-17 2011)

- CO (1-0) Band 3
- spectral resolution 15.625 MHz (40 kms-1)
- Angular resolution 6.5" (8 antennas)

HST image of NGC3256 (credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and A. Evans



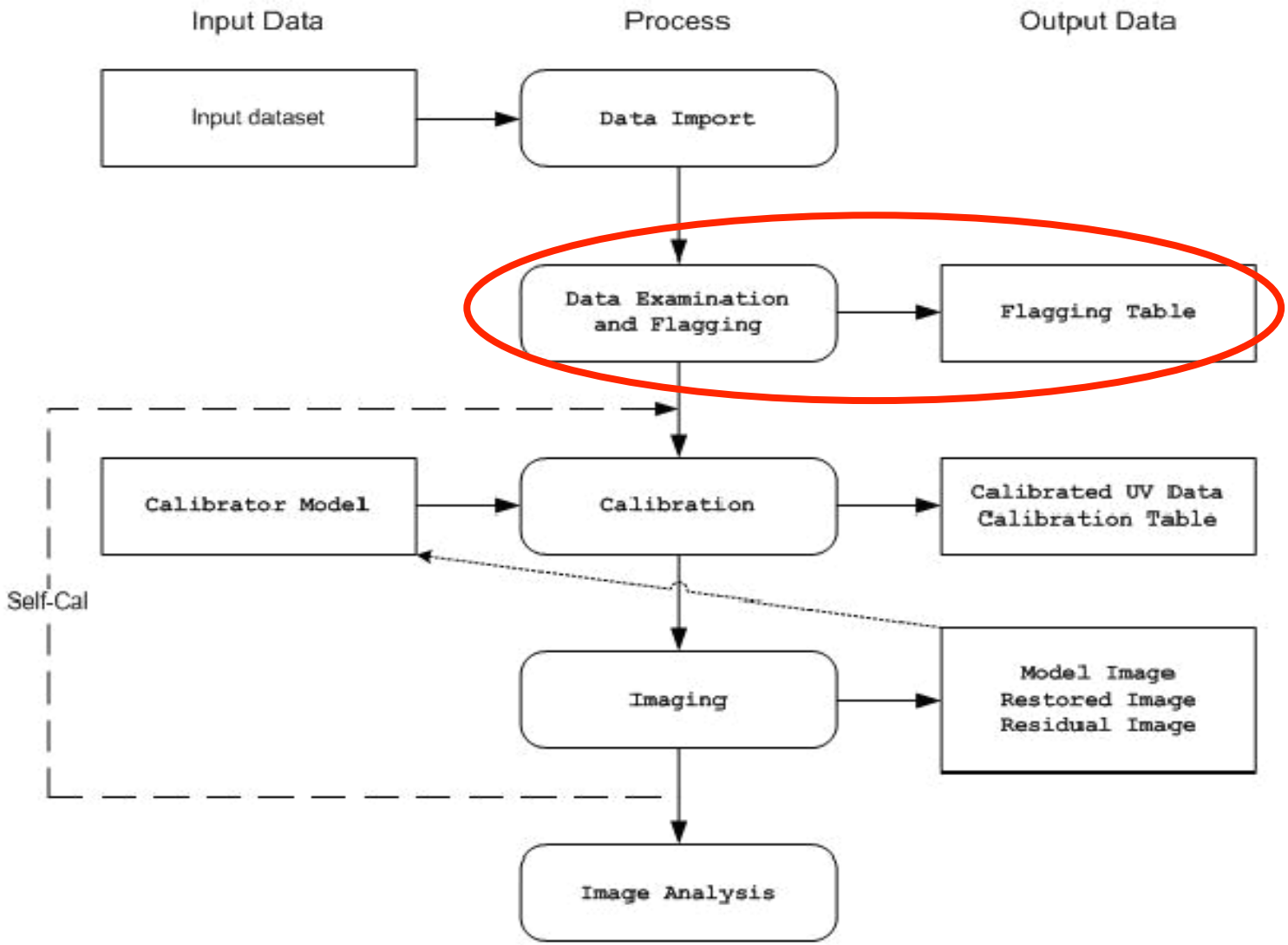
SMA map of CO (2–1) emission in the center of NGC 3256 (Sakamoto, Ho & Peck, 2006)

Import

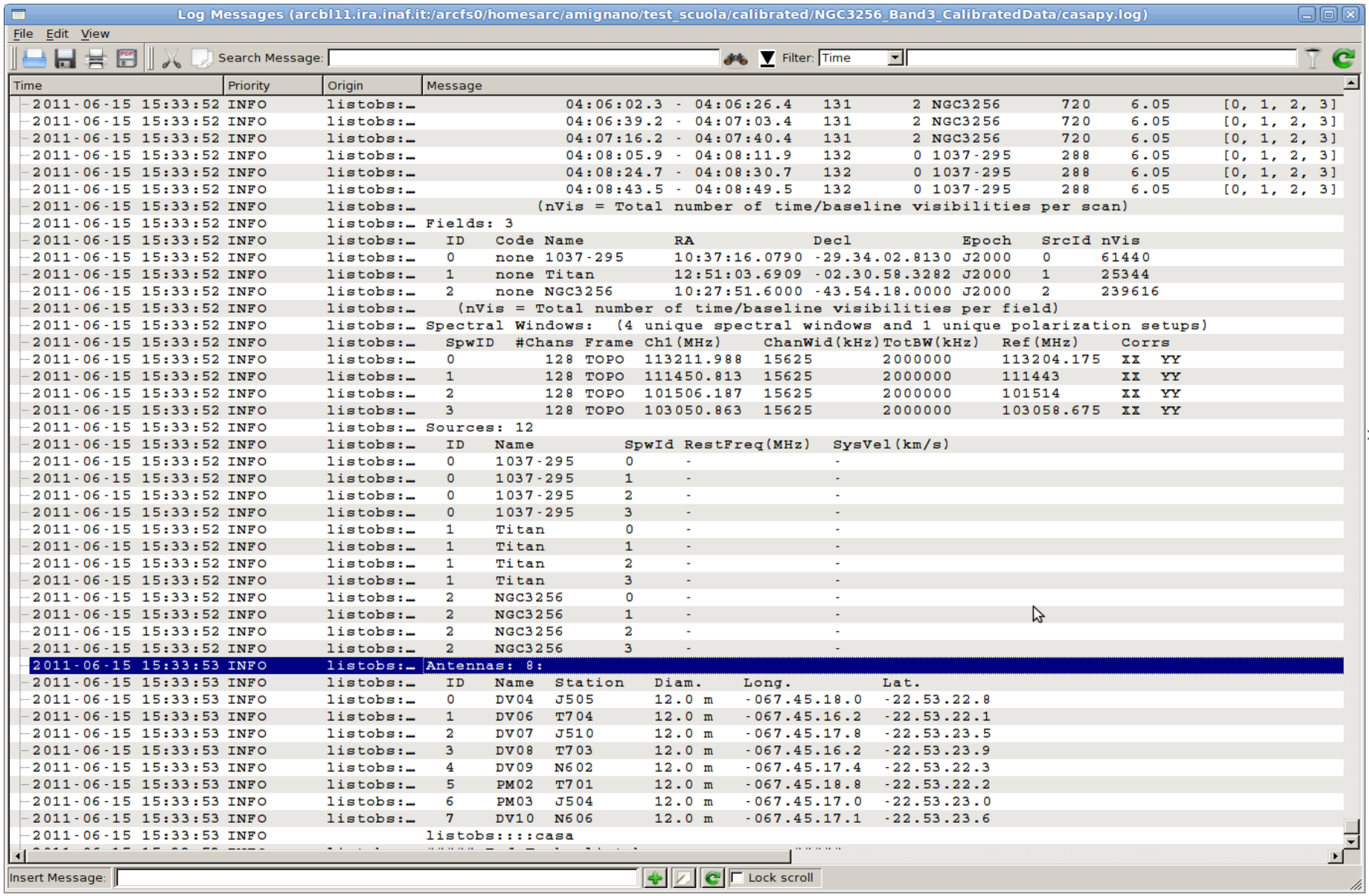
Examine

Calibrate

Image



Data Examination and Flagging



Data Examination and Flagging

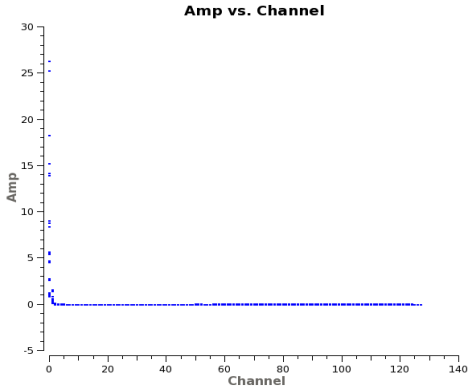
Data Examination (2)

- plotms

```
plotms(vis='ngc3256_line.ms', xaxis='channel', yaxis='amp',
       averagedata=T, avgbaseline=T,
       avgtime='1e8', avgscan=T)
```

```
plotms(vis='ngc3256_line.ms', xaxis='time', yaxis='amp',
       averagedata=T, avgchannel='128', coloraxis='field',
       iteraxis='spw')
```

```
plotms(vis='ngc3256_line.ms', xaxis='uvdist', yaxis='amp', field='1',
       averagedata=T, avgchannel='128', avgtime='1e8',
       coloraxis='scan`)
```



Data Examination and Flagging

Data Editing

- flagdata

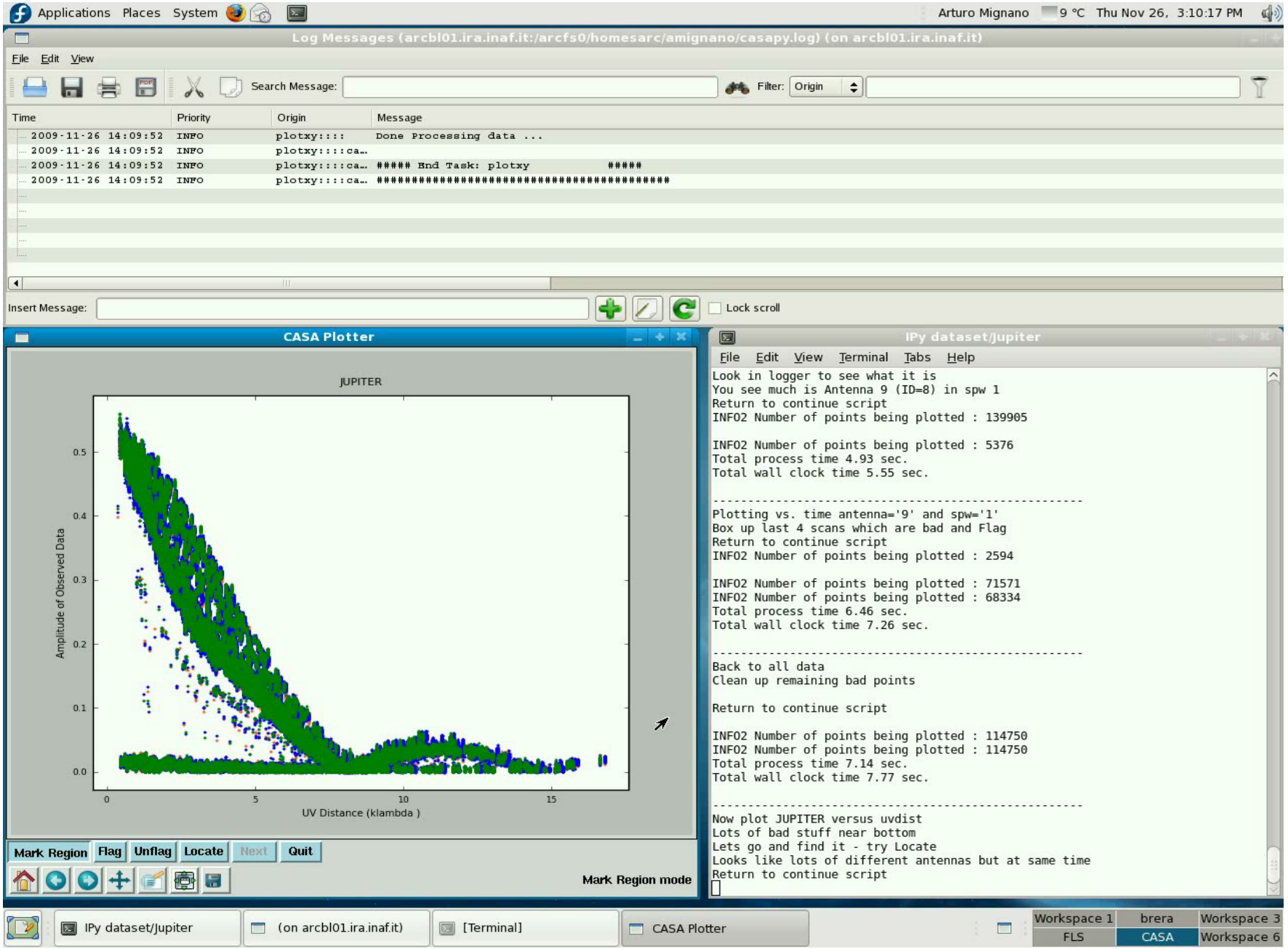
```
flagdata(vis=name+'.ms', mode = 'shadow')

flagdata(vis='ngc3256_line.ms', flagbackup=T, spw=['*:0~16','*:125~127'])

flagdata(vis = 'ngc3256_line.ms', flagbackup = T, timerange='>2011/04/16/12:00:00', field='Titan')
```

- flagmanager

```
flagmanager(vis = name+'.ms', mode = 'save', versionname = 'Apriori')
```

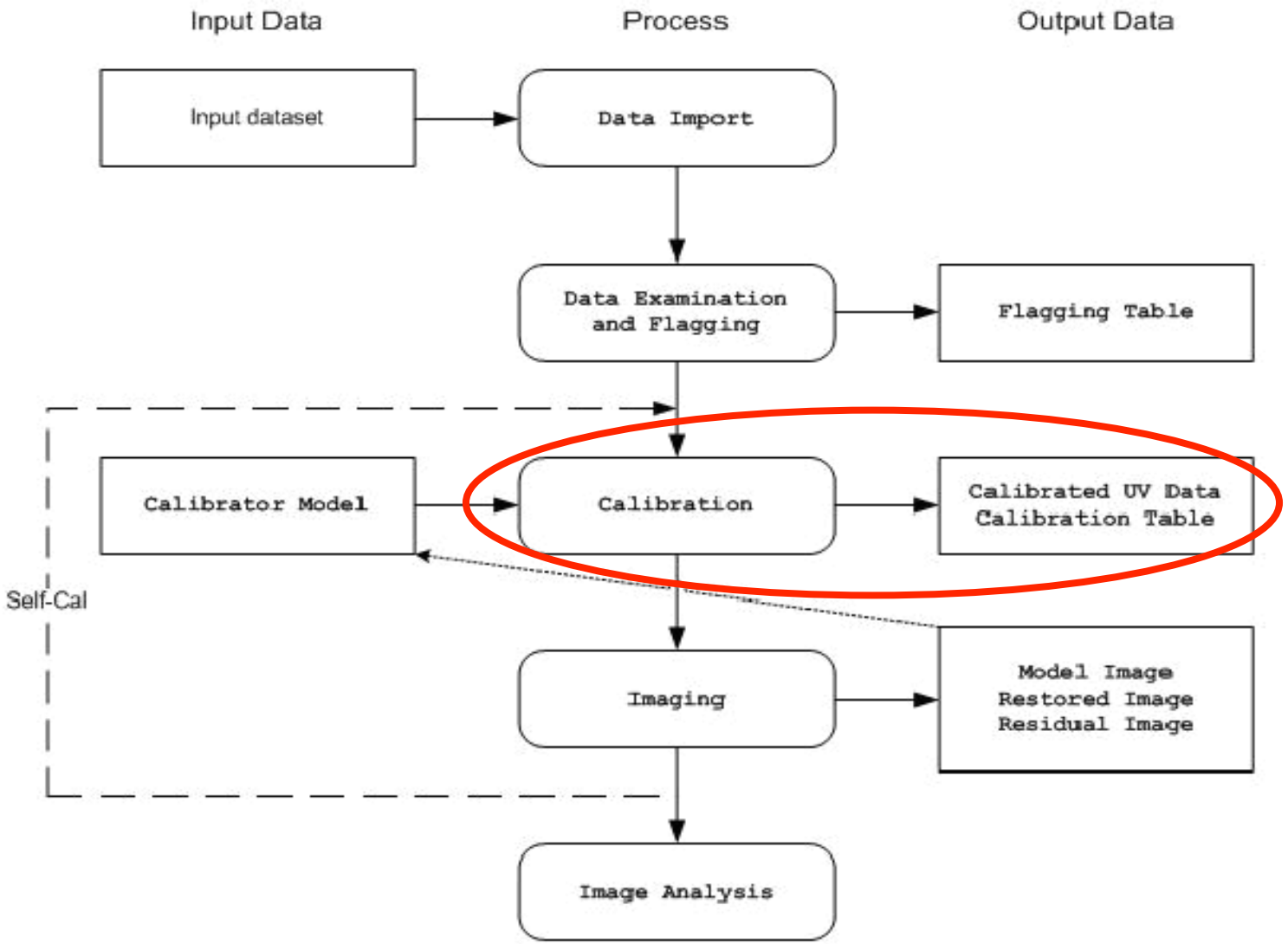

Applications Places System
Arturo Mignano 9 °C Thu Nov 26, 3:10:17 PM
Log Messages (arcbl01.ira.inaf.it:/arcfs0/homesarc/amignano/casapy.log) (on arcbl01.ira.inaf.it)
File Edit View
Search Message:
Filter: Origin
Time Priority Origin Message
2009-11-26 14:09:52 INFO plotxy:::: Done Processing data ...
2009-11-26 14:09:52 INFO plotxy::::ca…
2009-11-26 14:09:52 INFO plotxy::::ca… ##### End Task: plotxy #####
2009-11-26 14:09:52 INFO plotxy::::ca… ##########
Insert Message:
Lock scroll
CASA Plotter
JUPITER
Amplitude of Observed Data
UV Distance (klambda)
Mark Region
Flag
Unflag
Locate
Next
Quit
Mark Region mode
IPy dataset/Jupiter
File Edit View Terminal Tabs Help
Look in logger to see what it is
You see much is Antenna 9 (ID=8) in spw 1
Return to continue script
INFO2 Number of points being plotted : 139905
INFO2 Number of points being plotted : 5376
Total process time 4.93 sec.
Total wall clock time 5.55 sec.
Plotting vs. time antenna='9' and spw='1'
Box up last 4 scans which are bad and Flag
Return to continue script
INFO2 Number of points being plotted : 2594
INFO2 Number of points being plotted : 71571
INFO2 Number of points being plotted : 68334
Total process time 6.46 sec.
Total wall clock time 7.26 sec.
Back to all data
Clean up remaining bad points
Return to continue script
INFO2 Number of points being plotted : 114750
INFO2 Number of points being plotted : 114750
Total process time 7.14 sec.
Total wall clock time 7.77 sec.
Now plot JUPITER versus uvdist
Lots of bad stuff near bottom
Lets go and find it - try Locate
Looks like lots of different antennas but at same time
Return to continue script
IPy dataset/Jupiter
(on arcbl01.ira.inaf.it)
[Terminal]
CASA Plotter
Workspace 1
brera
Workspace 3
FLS
CASA
Workspace 6

Import

Examine

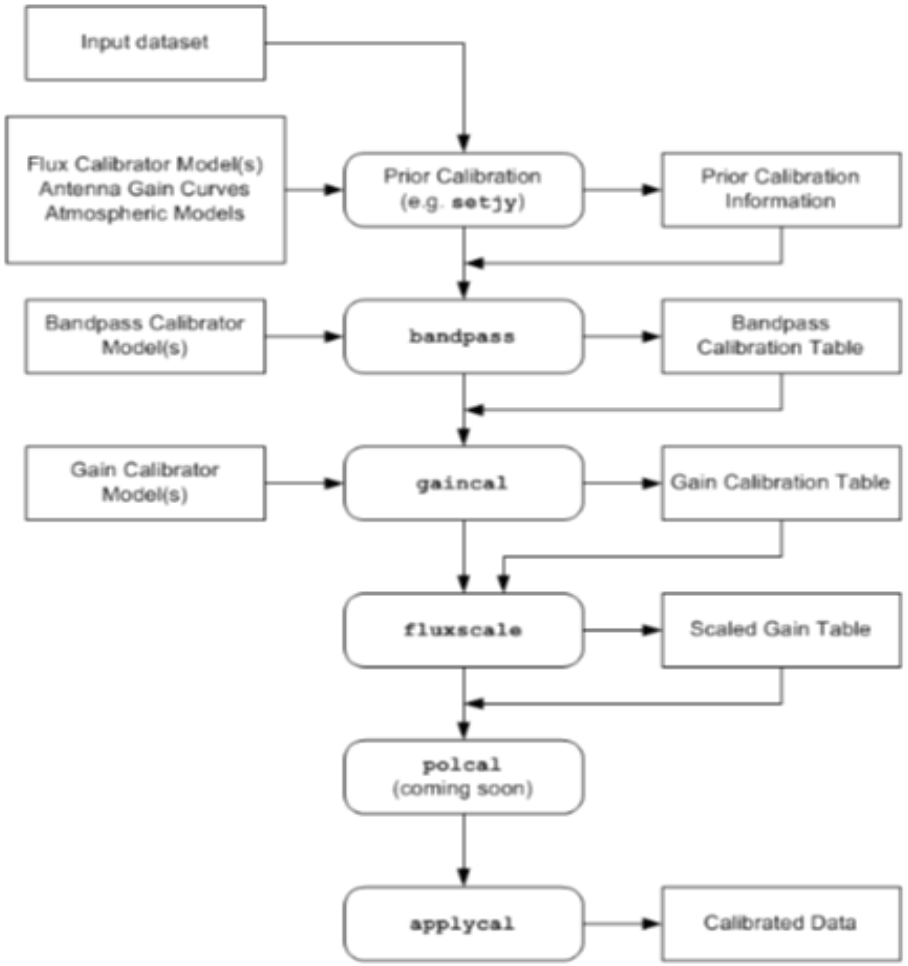
Calibrate

Image



Calibration in CASA

- prior calibration: setjy
- solvers: gaincal, bandpass, blcal, fringecal
- manipulation: plotcal, accum, smoothcal
- application: applycal, split
- other: uvcontsub, uvmodelfit

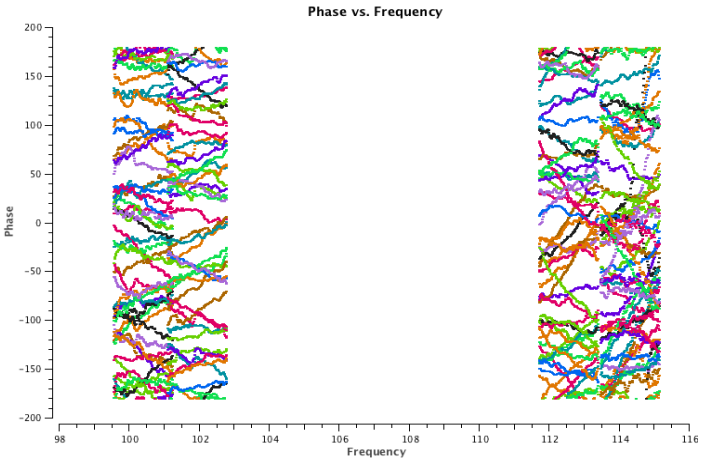


The Case of NGC3256

Data Calibration

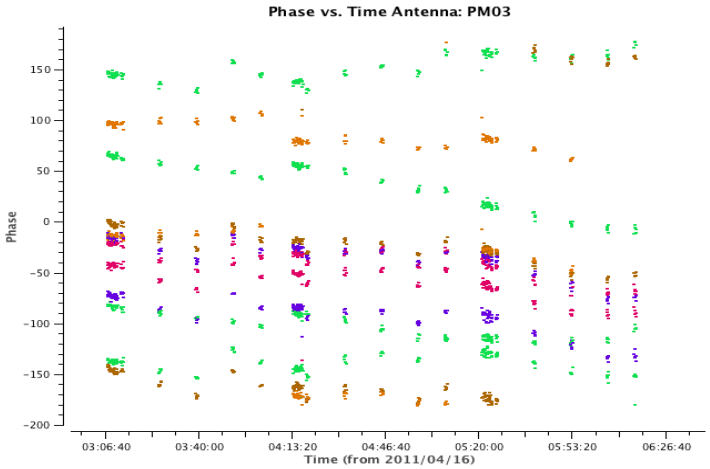
- bandpass (A,p vs freq)

bandpass(vis = 'ngc3256_line.ms', caltable = 'cal-ngc3256.B1', gaintable = 'cal-ngc3256.G1', timerange='<2011/04/16/15:00:00', field = '1037*', minblperant=3, minsnr=2, solint='inf', combine='scan', bandtype='B', fillgaps=1, refant = 'DV04', solnorm = T)



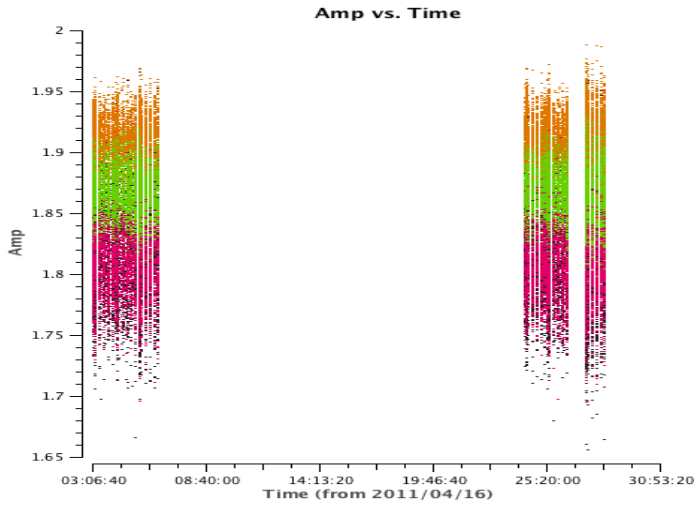
- gaincal (A,p vs time)

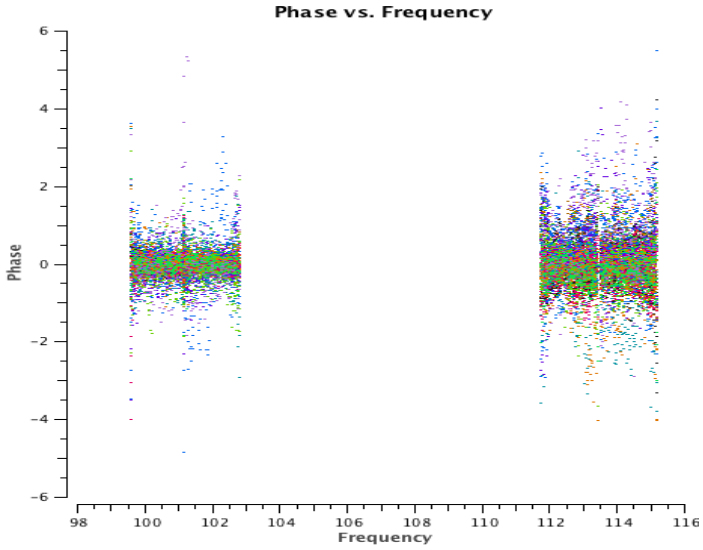
gaincal(vis = 'ngc3256_line.ms', caltable = 'cal-ngc3256.G2', spw = '*:16~112', field = '1037*,Titan', minsnr=1.0, solint= 'inf', selectdata=T, solnorm=False, refant = 'DV04', gaintable = 'cal-ngc3256.B1', calmode = 'ap')



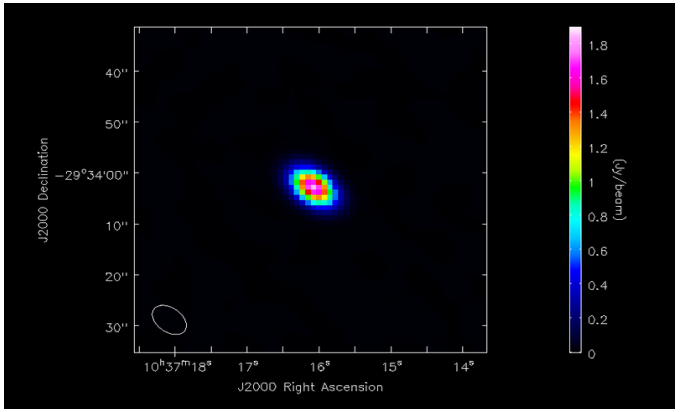
The Case of NGC3256

Data Calibration





- plotcal, setjy, fluxscale, applycal, split
- image the calibrator, why not?

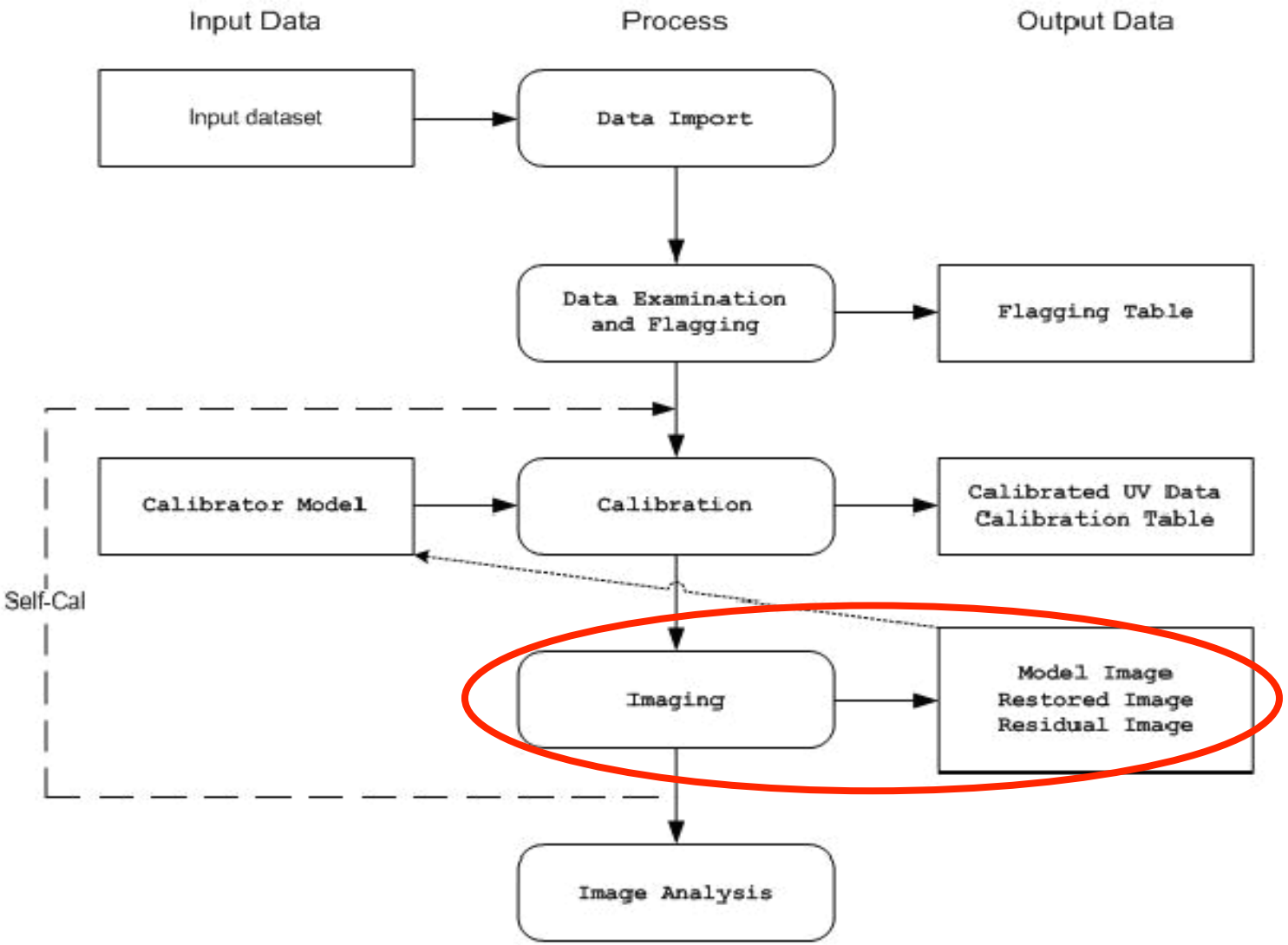


Import

Examine

Calibrate

Image



Imaging in CASA

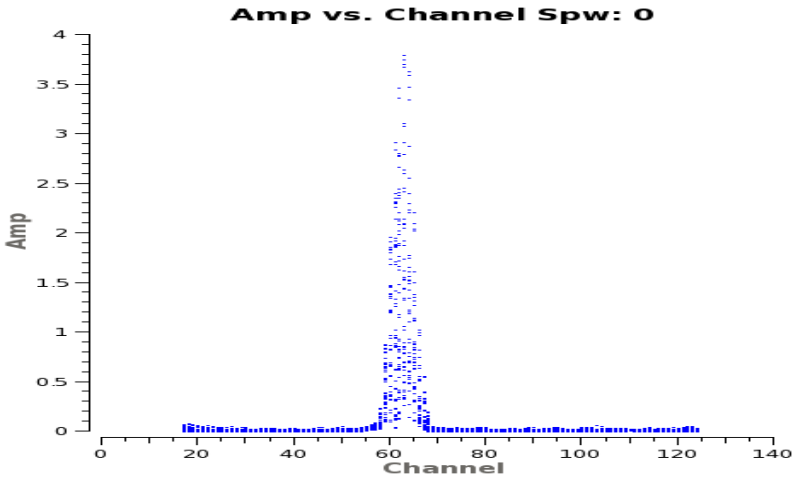
- task clean (variety of algorithms)
  - single-field cleaning
  - uses mosaic uv-gridder (uv-plane mosaicing on single image)
  - widefield imaging (apply W-Projection or faceting corrections)
- task feather: combine single-dish and uvMS

The Case of NGC3256

Imaging

- uvcontsub

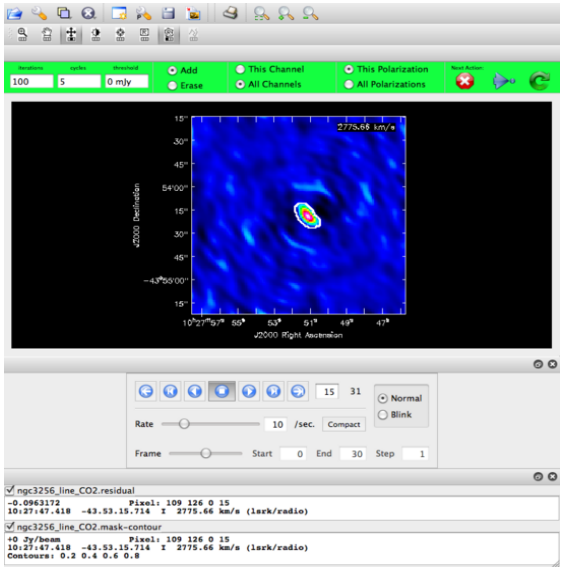
```
uvcontsub(vis = 'ngc3256_line_target_sc.ms',
          fitspw='0:20~53;71~120,1:70~120,2:20~120,
          3:20~120', fitorder = 1, fitmode = 'subtract')
```

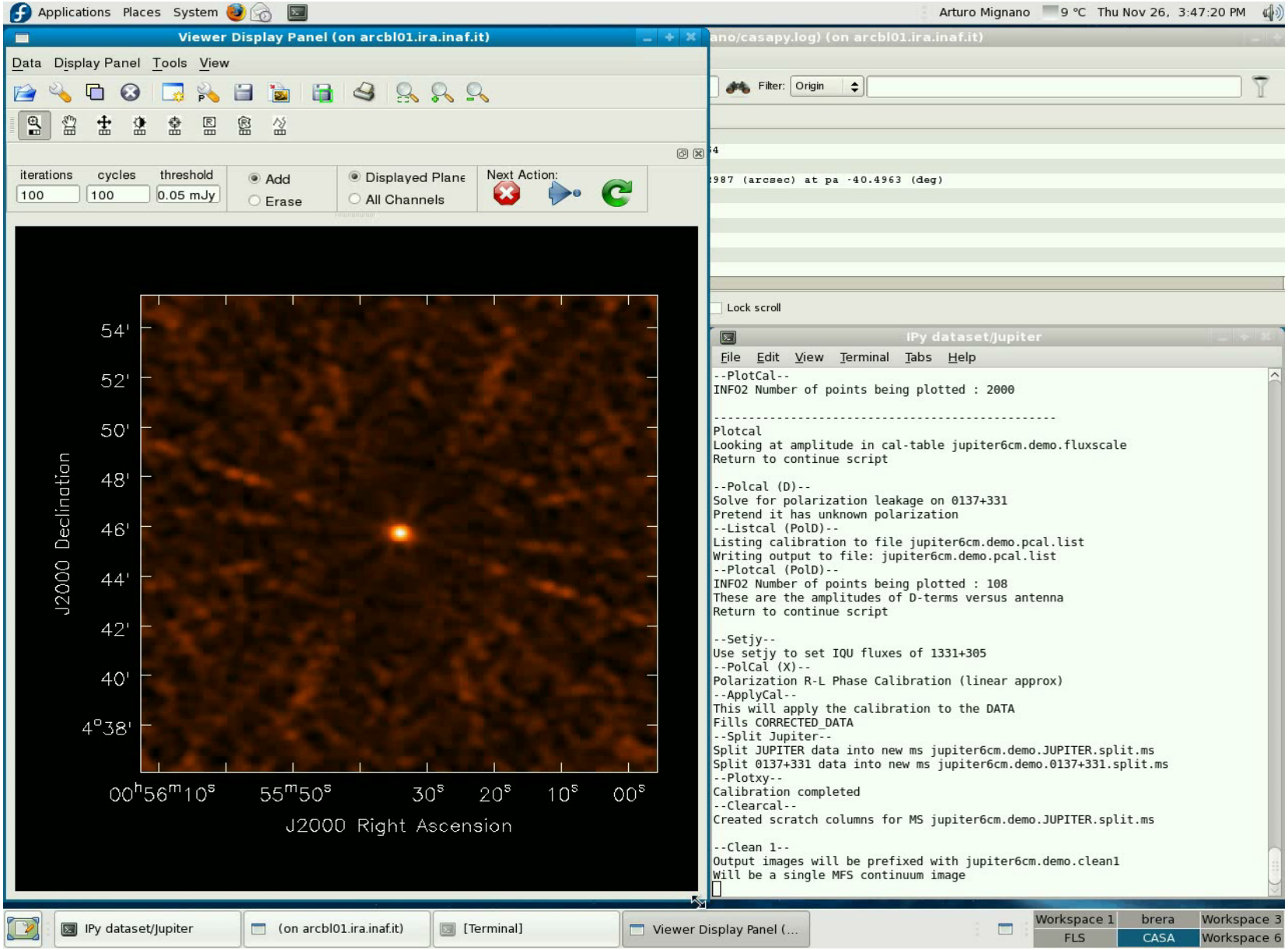


Amplitude vs. channel for spw 0/1. CN/CO lines.

- clean

```
clean(vis='ngc3256_line_target_sc.ms', imagename=
      'result-ngc3256_line_CO', spw='0:38~87', mode='channel',
    start='', nchan=50, width='', psfmode='hogbom',
restfreq='115.27 GHz', mask=[53,50,87,83],
            niter=500, interactive=T, imsize=128, cell='1arcsec',
            weighting='briggs', robust=0.0, threshold='5mJy')
```




Applications Places System
Arturo Mignano 9 °C Thu Nov 26, 3:47:20 PM
Viewer Display Panel (on arcbl01.ira.inaf.it)
Data Display Panel Tools View
iterations cycles threshold
100 100 0.05 mJy
Add Erase
Displayed Plane All Channels
Next Action:
54' 52' 50' 48' 46' 44' 42' 40' 4°38'
J2000 Declination
00h56m10s 55m50s 30s 20s 10s 00s
J2000 Right Ascension
Filter: Origin
Lock scroll
IPy dataset/Jupiter
File Edit View Terminal Tabs Help
--PlotCal--
INFO2 Number of points being plotted : 2000
Plotcal
Looking at amplitude in cal-table jupiter6cm.demo.fluxscale
Return to continue script
--Polcal (D)--
Solve for polarization leakage on 0137+331
Pretend it has unknown polarization
--Listcal (PolD)--
Listing calibration to file jupiter6cm.demo.pcal.list
Writing output to file: jupiter6cm.demo.pcal.list
--Plotcal (PolD)--
INFO2 Number of points being plotted : 108
These are the amplitudes of D-terms versus antenna
Return to continue script
--Setjy--
Use setjy to set IQU fluxes of 1331+305
--PolCal (X)--
Polarization R-L Phase Calibration (linear approx)
--ApplyCal--
This will apply the calibration to the DATA
Fills CORRECTED_DATA
--Split Jupiter--
Split JUPITER data into new ms jupiter6cm.demo.JUPITER.split.ms
Split 0137+331 data into new ms jupiter6cm.demo.0137+331.split.ms
--Plotxy--
Calibration completed
--Clearcal--
Created scratch columns for MS jupiter6cm.demo.JUPITER.split.ms
--Clean 1--
Output images will be prefixed with jupiter6cm.demo.clean1
Will be a single MFS continuum image
IPy dataset/Jupiter
(on arcbl01.ira.inaf.it)
[Terminal]
Viewer Display Panel (...
Workspace 1 brera Workspace 3
FLS CASA Workspace 6

The Case of NGC3256

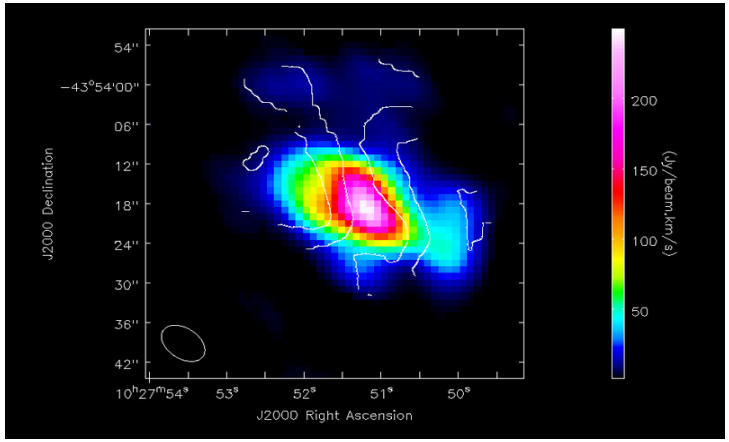
Analysis

- immoments
  0-moment = line intensity
  1-moment = line mean

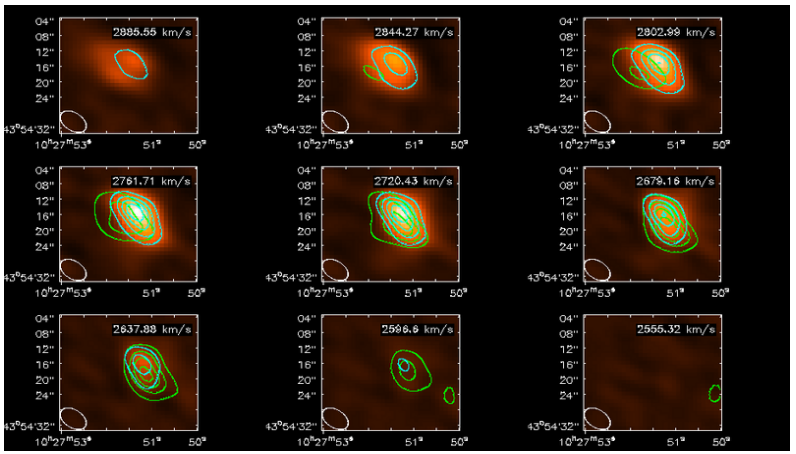
```
immoments(imagename='result-ngc3256_line_CO.image',
                    moments=[0], chans='15~34', box='38,38,90,90',
                  outfile='result-ngc3256_CO1-0.mom0')
```

- imstat, imhead …

```
calstat = imstat (imagename='result-ngc3256_cont.image',
                  region='', box='10,10,90,35')
rms=(calstat['rms'][0])
```



The CO(1-0) "moment 0" total intensity maps of NGC3256, with contours of the velocity field overlaid .



The 'hot metal' colours represent the higher frequency CN lin the green contours are the CO line, and the cyan contours ar the lower frequency CN line.

CASA on the Web

- http://casa.nrao.edu -- CASA Home Page
- Main resource for end users
  - http://my.nrao.edu -- NRAO Services (incl. registration/download of CASA)
- Help Desk/Installation Front; manned by scientists (ALMA, ARC, NAUG, etc) to handle front-line users support.

Casa Documentation

- CASA Analysis cookbook: http://casa.nrao.edu/Doc/Cookbook/casa_cookbook.pdf
- CASA User Reference Manual: http://casa.nrao.edu/docs/casaref/CasaRef.html
- Python: http://python.org/doc (e.g., see Tutorial for novices)
- IPython: http://ipython.scipy.org/moin/Documentation
- matplotlib: http://matplotlib.sourceforge.net/