

ALMA simulations: simdata

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ALMA Regional Centre



ALMA simulations with simdata

simdata is a CASA *task* used to produce mock ALMA data from an input sky model (theoretical model or previous observation)

The main work is done by the *smtool*: the simdata task (a Python script) is a user-friendly interface to this tool with additional work done on plotting and analysis

simdata is the 'official' ALMA simulator, supported by the ALMA project, and under active development

ALMA Sensitivity Calculator

ESO - Observing Tools and Services

http://www.eso.org/sci/facilities/alma/observing/tools/etc/

RSS

alma primer



European Southern Observatory



Observing with ALMA

ESO — Reaching New Heights in Astronomy



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28 Oct 2009

ALMA

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ALMA Sensitivity Calculator

This tool will calculate the necessary integration times for a given sensitivity, or vice versa, for your ALMA observing project. Input and output parameters are explained below. You can also get additional information on the valid range for each parameter by hovering your mouse pointer over each field in the calculator applet.

To run the calculator you need the Java Plug-in installed. If you do not see the calculator then it is likely that you do not have it installed. Instructions for installing the plugin will vary depending on your browser and operating system. A plugin compatible with the Java Development Kit version 1.6 (or Java6) is recommended (version 1.5 should work at the moment). Please contact your IT department for installation help if necessary.

Common Parameters

Sensitivity Type	<input type="text" value="Point Source detection"/>
RA	<input type="text" value="00:00:00.000"/>
Dec	<input type="text" value="00:00:00.000"/>
Effective Bandwidth	<input type="text" value="16.0"/> GHz
Frequency (GHz)	<input type="text" value="345.0"/>
Observatory site	<input type="text" value="Chajnantor"/>
Water Vapour Column Density	<input type="text" value="ETC Chooses"/>

Parameters

Common Parameters

Sensitivity Type:
Choose between a point-like or extended source.

RA/Dec:
Coordinates of the observation target.

Effective Bandwidth: The

The ALMA Sensitivity Calculator is also part of the OT !

The screenshot shows a window titled "Sensitivity Calculator" with two main sections: "Common Parameters" and "Individual Parameters".

Common Parameters:

- Dec: -12:34:56.700
- Polarization: Dual
- Observing Frequency: 350.0 GHz
- Bandwidth per Polarization: 8.0 GHz
- Water Vapour Column Density: Calculator Chooses
- tau/Tatm: tau=0.228, Tatm=59.335 K
- Tsys: 207.026 K

Individual Parameters:

	12m Array	7m Array	Total Power Array
Number of Antennas	50	12	4
Resolution	0.05 arcsec	5.889203 arcsec	14.723008 arcsec
Sensitivity(rms)	.01 mJy	1 mJy	1 mJy
	0.01101 K	0.00032 K	0.00003 K
Integration Time	7.46255 h	7.17734 min	42.47564 min

Integration Time Unit Option: Automatic

Buttons: Calculate Integration Time, Calculate Sensitivity, Close

ALMA Observation Support Tool

- to be hosted by the UK ARC node (Manchester) and/or ESO
- written by Ian Heywood (Oxford)

The screenshot shows a web browser window titled "ALMA observation support tool - Mozilla Firefox" with the address bar set to "http://localhost/". The page content is titled "ALMA Observation Support Tool" and contains a form with several sections:

- Array:** Instrument dropdown menu set to "ALMA".
- Sky:** Upload FITS image (Browse... button), Declination text input (-40d00m00.0s), Peak Pixel Value text input (1.0) with a unit dropdown (mJy).
- Observation Parameters:** Observing Band (central frequency) dropdown (3 (100 GHz)), Bandwidth text input (2) with a unit dropdown (GHz), Desired Resolution (arcseconds) text input (0.1), Start Hour Angle text input (0.0), Duration (seconds) text input (3600), Number of Polarizations dropdown (1).
- Corruption:** Atmospheric Conditions dropdown (Good).
- Imaging:** Imaging weights dropdown (Natural), CLEAN components dropdown (0 (Return dirty image)).
- Other:** Your email address text input (you@yourdomain.com) and a Submit button.

Green callout boxes provide additional instructions:

- Leave blank to use central point source model
- Ensure correct formatting
- For image rescaling, leave blank for no rescaling
- Use broad for continuum, narrow for single channel
- OST will choose config if instrument is set to 'ALMA'
- Deviation of start of observation from transit
- Determines level of phase noise

The browser's status bar at the bottom shows "Done" and the taskbar includes the application icon "ALMA observation sup..." and system icons.

ALMA OST example output

Applications Places System Thu 21 Jan, 11:06 PM

ALMA OST - Job ID: 20100121230311 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://localhost/output/20100121230311.html

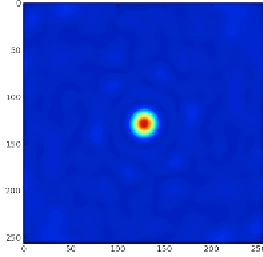
Google

ALMA Observation Support Tool - Result

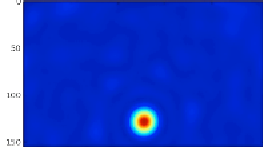
Job ID: 20100121230311 / Submitted by: you@yourdomain.com

Array config	alma
Sky	Central point source model
Central frequency	100 GHz
Bandwidth	2 GHz
Duration	3600 seconds

Your simulated image



Dirty beam (PSF)



http://localhost/output/20100121230311.image.png

ALMA OST - Job ID: 20...

Uses of simdata

simdata is or will be used by the ALMA project to:

- simulate various sources of data corruption
- produce lots of (mock) ALMA data to test subsystems like archive and pipeline
- produce mock data for end-to-end testing

future observers can use simdata to test their science case:

- can I do this with ALMA ?
- can I already do this during Early Science ? Should I ?
- how to optimize my science goal ?

on-line guide to simdata


Simulating Observations in CASA - CASA Guides

http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA

Astro-ph ADS ESO ESO-ERP ARC TWiki ARC Internal TWiki ALMASW casa/osx_distro GAMA Herschel-ATLAS SERVS IDL help iCosmos CSV

Simulating Observations in CASA ... +

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Simulating Observations in CASA

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- 2 Steps to simulation
- 3 Tutorials, Recipes, and Example images
- 4 Technical and Planning

Introduction

Simulation capability in CASA follows the usual two-layered structure: there is a beginner-level python task interface called `simdata`, which calls methods in the `sm` C++ tool. The task interface turns a model of the sky (2 to 4 dimensions including frequency and Stokes) into the visibilities that would be measured with ALMA, (E)VLA, CARMA, SMA, ATCA, PdB, etc. The task also can produce a cleaned image of the model visibilities, compare that image with your input convolved with the synthesized beam, and calculate a fidelity image. `simdata` can add thermal noise (from receiver, atmosphere, and ground) to the visibilities.

The `sm` tool has methods that can be used to add phase delay variations, gain fluctuations and drift, cross-polarization, and (coming soon) bandpass and pointing errors to your simulated data. `sm` also has more flexibility in adding thermal noise than `simdata`, for example for new observatories that are unknown to `simdata`.

New for 3.0.2: Two task interfaces will be present, the old `simdata` and a new `simdata2`. We recommend using `simdata2` -- `simdata` is being retained because it has had more extensive testing, and `simdata2` is very new, but in the future `simdata` will be removed.

CASA simulation uses the [aatm](#) atmospheric model, a thin wrapper of Juan Pardo's [ATM](#) library, to accurately calculate all atmospheric corruption terms (noise, phase delay) accurately as a function of frequency and site characteristics.

Done

on-line guide to simdata

Simulating Observations in CASA – CASA Guides

http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA

Astro-ph ADS ESO ESO-ERP ARC TWiki ARC Internal TWiki ALMASW casa/osx_distro GAMA Herschel-ATLAS SERVS IDL help iCosmos CSV

Simulating Observations in CASA ...

Steps to simulation


If you have **CASA 3.0.2** and **simdata2**, you should use **simdata2**. It's better and better supported.

simdata

pdf presentation explaining the same things as below: [File:Tutorial.dec2009.pdf](#)

1. Install CASA

simdata inputs look like this (v3.0.2; click to enlarge):



the links below describe the various sections of inputs


2. [Input Model](#) - Preparing a patch of sky for **simdata** to pseudoobserve.
3. [Antenna List](#) - how to specify the positions and diameters of your antennas or stations.
4. [Specifying Observation](#) - how to set up what/when/how you want to observe, and the output image details
5. [Corrupting Observation](#) - (Optional) For added realism, corrupt your visibilities with thermal and phase noise.
6. [Deconvolve Image](#) (Optional) Go back from the calculated visibilities to a synthesis image

simdata2

Only works in **CASA 3.0.2** [Obtaining CASA](#)

1. Install CASA

simdata2 inputs look like this (v3.0.2; click to enlarge):



The subtasks are modular i.e. as long as you follow a few conventions about filenames, you can run each bit independently and optionally. For example, you can modify the sky model, then predict ACA visibilities, then run again and predict ATCA 12m visibilities and image and analyze both measurement sets together. You can run once to predict, run interactive clean yourself, and as long as you called your image \$project.image, run `simdata2` just to calculate a difference image and analyze the results.

2. [Modify Model](#) - relabel (scale) the spectral and spatial coordinates and brightness of the sky model image.
3. [Set Pointings](#) - calculate a mosaic of pointings and save in a text file. You could also make the text file yourself.
4. [Predict](#) - Calculate visibilities for a specified array on a specified day
5. [Corrupt](#) - Corrupt the measurement set with thermal noise, phase noise, cross-polarization, etc.
6. [Image](#) A subset of `clean` to re-image the visibilities
7. [Analyze](#) Calculate and display the difference between output and input, and fidelity image.

Done

on-line guide to simdata

Simulating Observations in CASA - CASA Guides

http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA

Astro-ph ADS ESO ESO-ERP ARC TWiki ARC Internal TWiki ALMASW casa/osx_distro GAMA Herschel-ATLAS SERVS IDL help iCosmos CSV

Simulating Observations in CASA ...

Tutorials, Recipes, and Example images

Simulated ALMA Observation of M51 at $z = 0.1$ and $z = 0.3$: fully annotated tutorial
This uses a BIMA-SONG cube of a nearby galaxy and scales it to greater distance.

[simdata page](#) [simdata2 page](#)

NOTE: increasing the exposure time to run faster

Protoplanetary Disk: sky model and lightly annotated script
This uses a theoretical model of dust continuum from Sebastian Wolf, scaled to the distance of a nearby star.

[simdata page](#) [simdata2 page](#)

Nearby edge-on spiral galaxy: sky model, script, and discussion
This uses a Galactic CO cube from the Galactic Ring Survey and places it at 10Mpc, similar to what NGC891 would look like if it were observable from the southern hemisphere.

[\[simdata script\]](#) [simdata2 page](#)

[Other example input images](#)

[Other example output simulations](#) (scripts to reproduce these are coming)

Technical and Planning

I always welcome input on developing the CASA simulator, and these links are meetings, technical documents, and planning discussions. Much of it won't make sense to a new user of CASA::simdata, but may be of interest to those wanting to delve deeper:

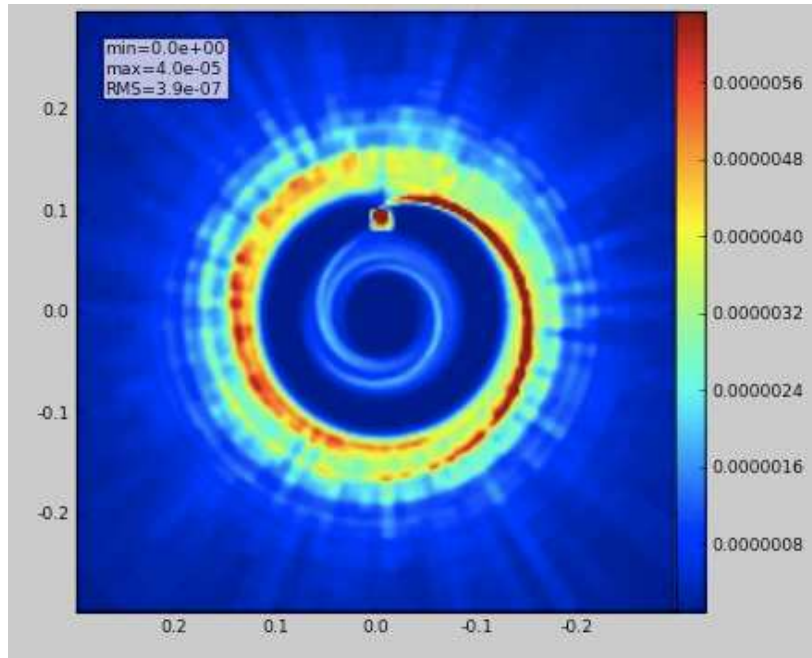
- [Simulation Library](#) This will become a library of use cases and examples illustrating different science and observation setups. It is in early stages as of Jan 2010, and we're actively seeking volunteers to turn their simulation projects into use cases.
- [Jan 2010 workshop](#) Including slides and discussion of how simdata and Simulator work "under the hood" and plans for development

simulation database

The screenshot shows a web browser window with the following elements:

- Browser Title Bar:** ALMA simulation library [licensed for non-commercial use only] / FrontPage
- Address Bar:** http://almasimulations.pbworks.com/w/page/15289425/FrontPage
- Navigation Bar:** Astro-ph ADS ESO ESO-ERP ARC TWiki ARC Internal TWiki ALMASW casa/osx_distro GAMA Herschel-ATLAS SERVS IDL help iCosmos CSV
- Page Header:** ALMA simulation library (left), Get your own free workspace (right), log in help (right)
- Navigation:** Wiki Pages & Files
- Search:** Search this workspace
- Page Content:**
 - VIEW EDIT** tabs
 - FrontPage** title
 - last edited by Mark Lacy 9 mos ago
 - ALMA simulation library** section header
 - Text: "This Wiki contains a list of ALMA simulation projects which we hope to include into the ALMA Archive, for testing purposes and as examples to users. Each of the projects is based around one or more scientific simulation datasets, produced by theorists, which serve as input science models to the ALMA simulator *simdata()*, which produces mock ALMA datasets that can be put into the ALMA archive along with the associated project datafiles generated by the Observe Tool."
 - Text: "The following is needed for each of the projects:"
 - List:
 - science simulations
 - a description of the dataset, and the choice of observing mode(s) and parameters
 - a project datafile produced by the Observe Tools, tagged as a simulation project
 - Text: "Links to files at your home institution would be preferred, as disk space is limited on this (free) wiki !"
 - Text: "Some of the projects have links to proposed projects in the [DRSP](#) , but this is not required."
 - Text: "Please use free formatting for your project when editing this wiki: this whole page will be reformatted at some point, once we know what information should be there."
- Right Sidebar:**
 - Message: "To join this workspace, [create an account](#)."
 - Text: "Already have an account? [Log in!](#)"
 - Navigator** section with a list:
 - FrontPage
 - Logins
 - Meeting
 - Press Release
 - Press Room
 - Project
 - Buttons: Pages Files options
 - SideBar** section with text:
 - "This is your Sidebar, which you can edit like any other page in your workspace."
 - "This Sidebar appears everywhere on your workspace. Add to it whatever you like -- a navigation section, a link to your favorite web sites, or anything else."

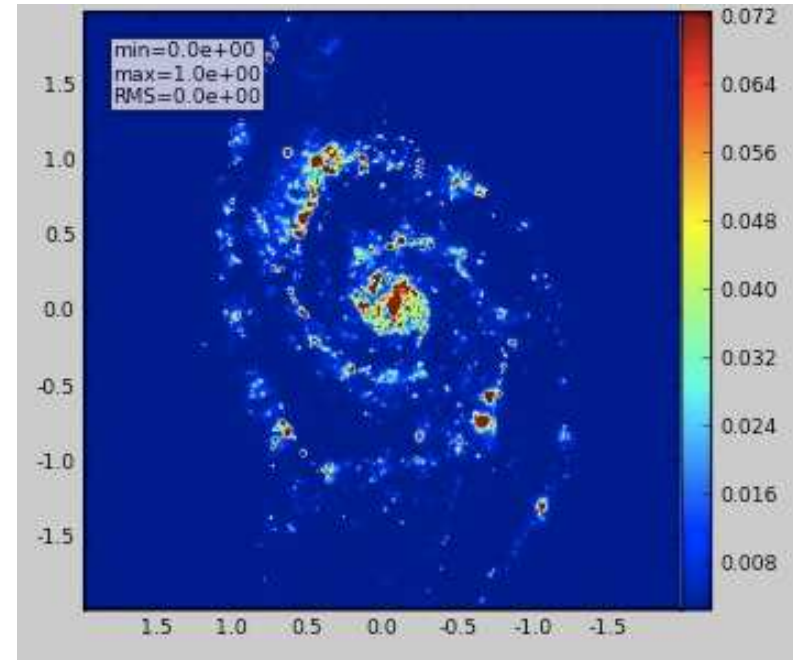
Using simdata to make decisions for Early Science: two example science cases



A proto-planetary disk

A simulation by Sebastian Wolf
(Wolf and D'Angelo 2005)

-> a Jupiter-mass planet around a 0.5 solar mass star

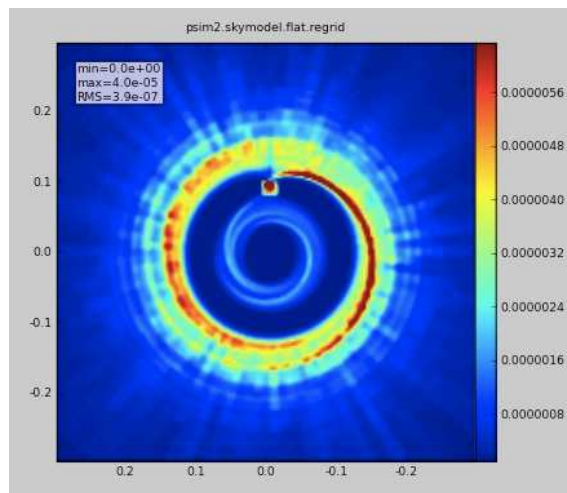


A nearby galaxy

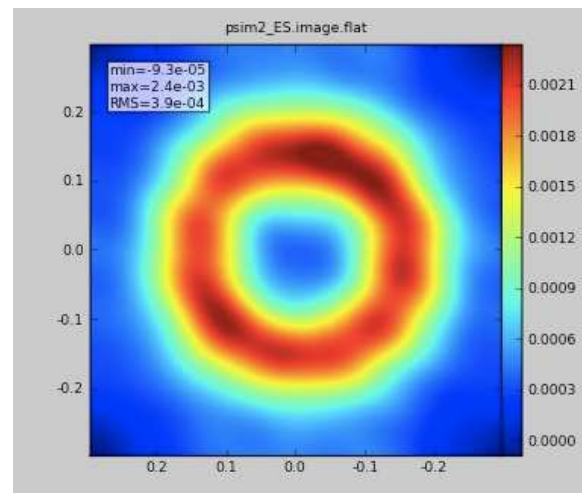
An H-alpha image of M51
provided by D. Thilker(NRAO)

-> should be a reasonable representation of the atomic
FIR lines and other tracers of massive star formation

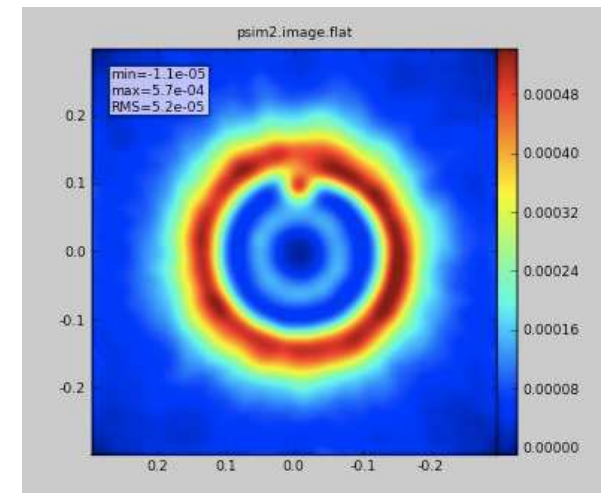
Proto-planetary disk (ALMA band 9)



Skymodel

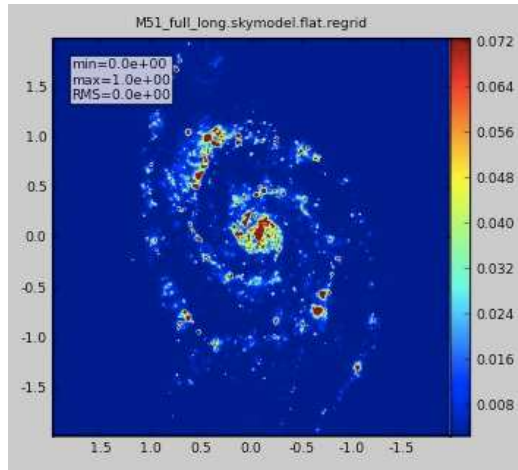


Early Science
(30 mins)

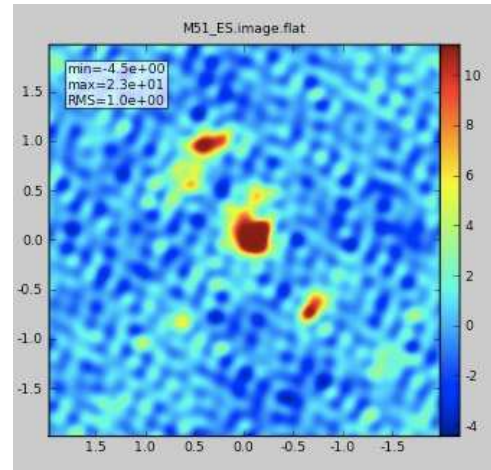


Full Array
(10 mins)

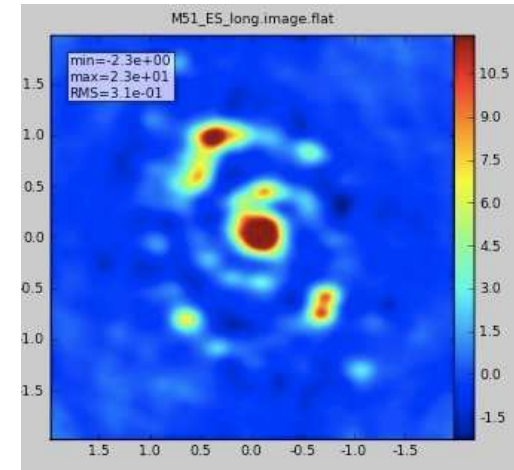
Nearby galaxy (ALMA band 9)



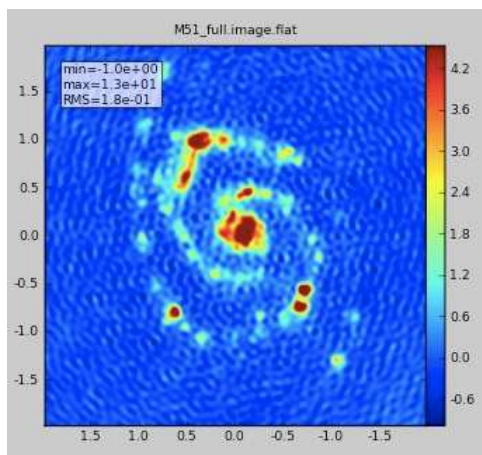
Skymodel



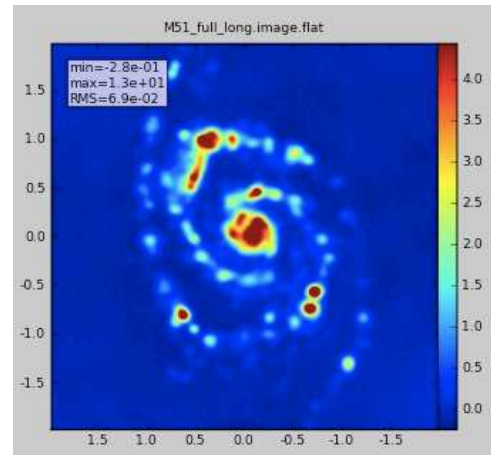
ES (30 min)



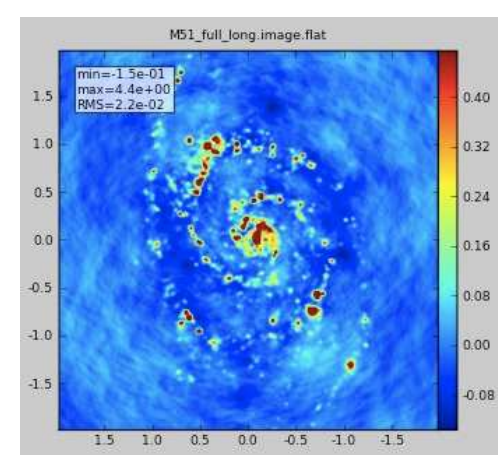
ES (4h)



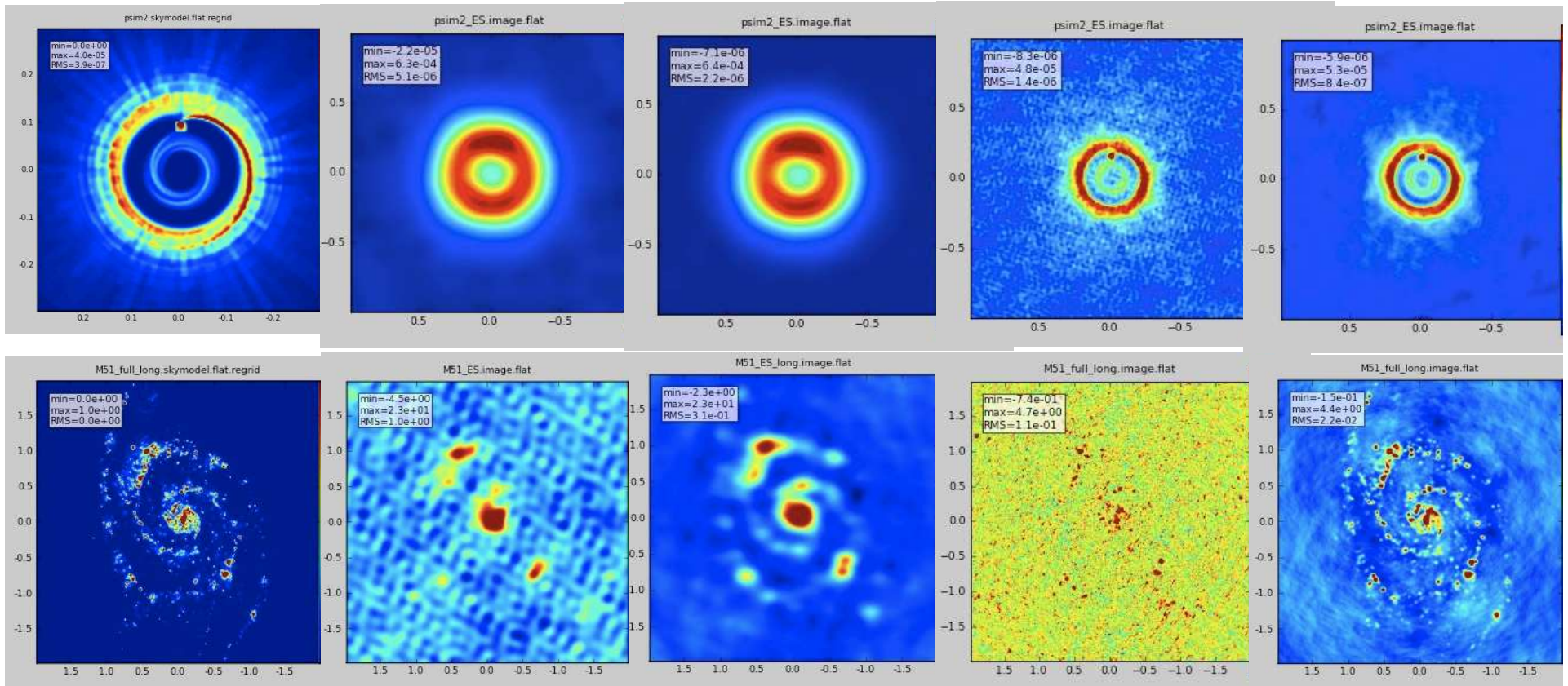
Full 2 km array (30 min)



Full 2 km array (4h)



Full 6 km array (4h)



Input skymodel

Earl Science 10m

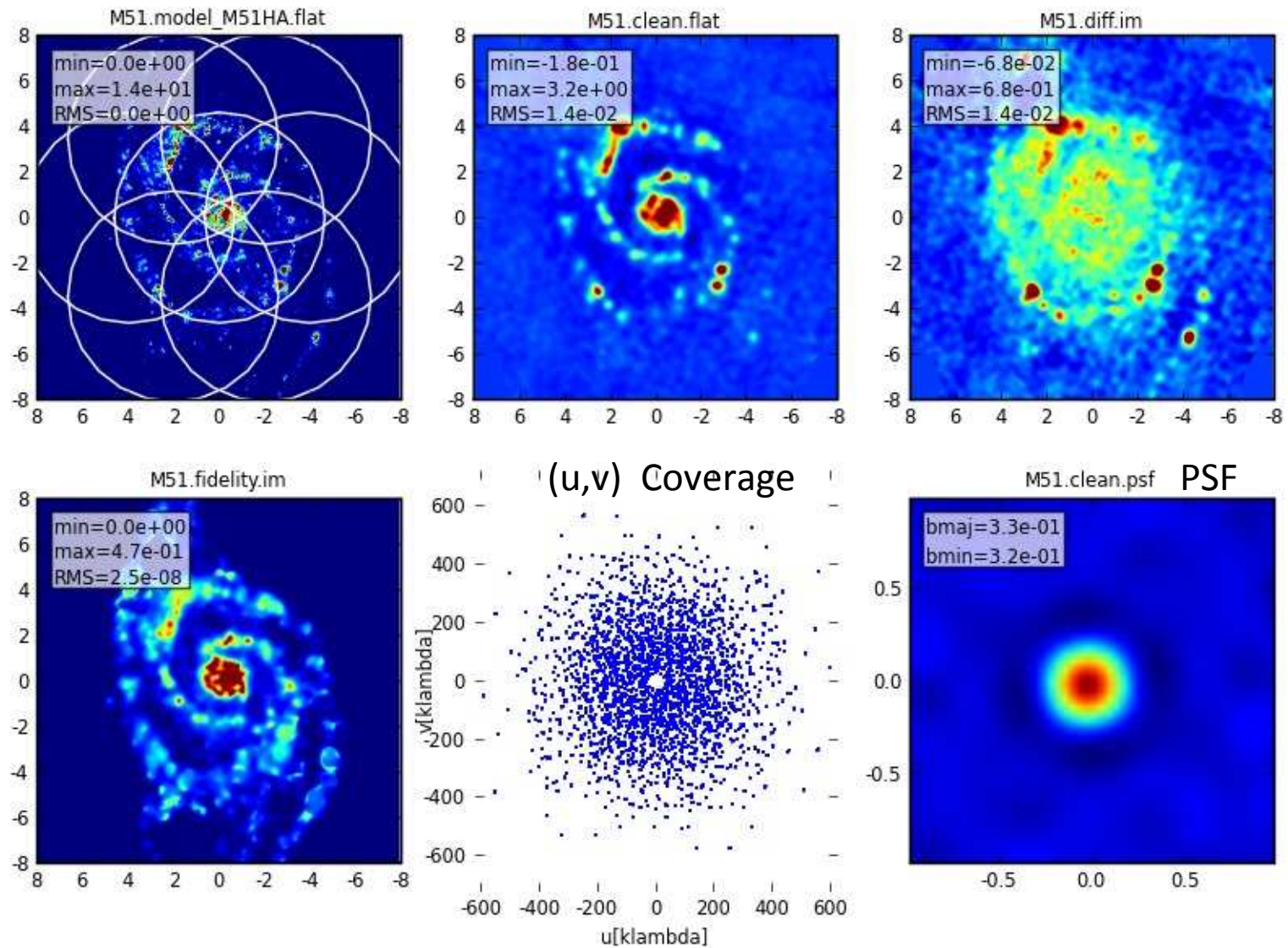
Early Science 4h

Full 10m

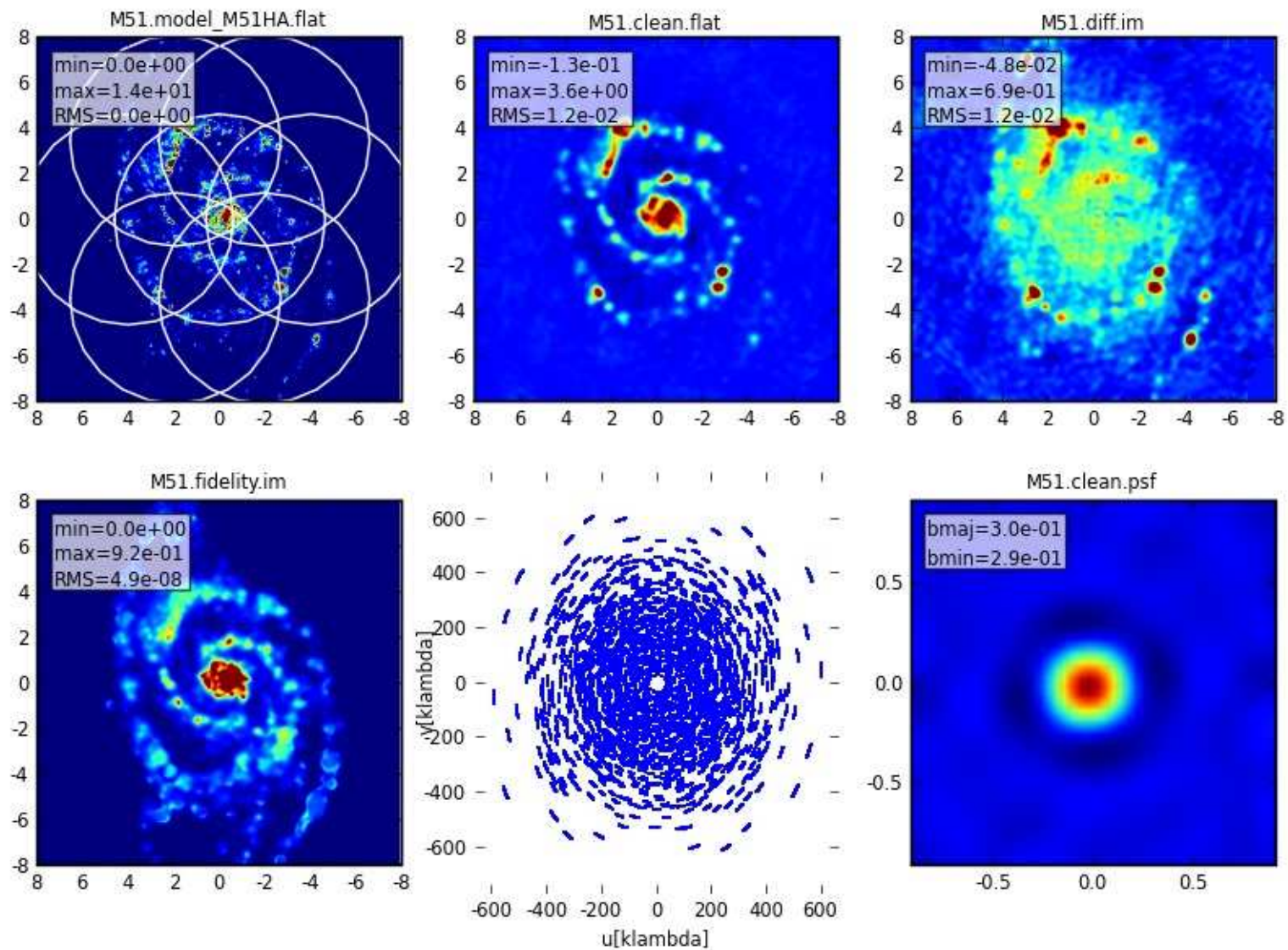
Full 1h

(all simulations are for single pointings)

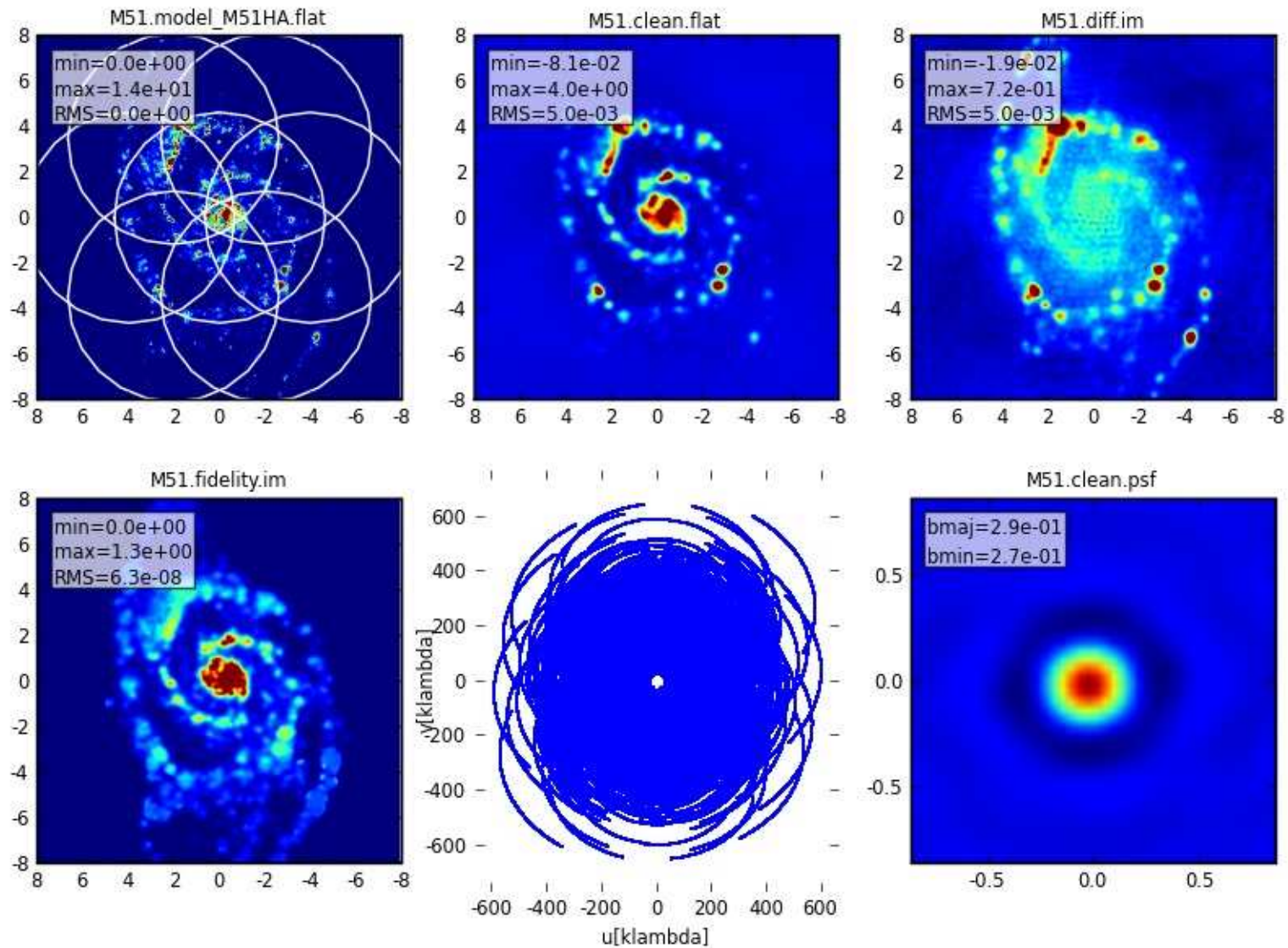
ALMA (u,v) coverage t=2 min



ALMA (u,v) Coverage t=30 min



ALMA (u,v) Coverage t=5 hr



Default simdata parameters

```
CASA <5>: inp
-----> inp()
# simdata :: mosaic simulation task;
project          = 'sim'          # root for output file names
modifymodel     = False          # modify model image
  skymodel       = '$project.skymodel' # model image to observe or modify

setpointings   = True          #
  integration    = '10s'         # integration (sampling) time
  direction      = ''            # "J2000 19h00m00 -40d00m00" or "" to center on model
  mapsize        = ['1arcmin', '1arcmin'] # angular size of map or "" to cover model
  maptype        = 'hexagonal'   # hexagonal, square, etc
  pointingspacing = '1arcmin'    # spacing in between pointings or "" for 0.5 PB

predict        = True          # calculate visibilities using ptgfile
  complist       = ''            # optional componentlist to observe with skymodel
  compwidth      = '2GHz'        # optional bandwidth if simulating from components only
  antennalist    = 'alma,out10,cfg' # antenna position file or "" for no interferometric MS
  refdate        = '2012/05/21/22:05:00' # time/date of observation *see help
  totaltime      = '7200s'       # total time of observation
  caldirection   = ''            # pt source calibrator [experimental]
  calflux        = '1Jy'         #
  sdantlist      = ''            # single dish antenna position file or "" for no total power MS
  sdant          = 0             # single dish antenna index in file

thermalnoise  = ''            # add thermal noise: [tsys-atmltsys-manual""]
leakage          = 0.0           # cross polarization
image         = False          # (re)image $project.ms to $project.image
analyze       = False          # (only first 6 selected outputs will be displayed)
graphics        = 'screen'      # display graphics at each stage to [screen|file|both|none]
verbose         = False          #
overwrite       = False          # overwrite files starting with $project
async           = False          # If true the taskname must be started using simdata(...)
```

```
CASA <6>: □
```



changing model parameters

modifymodel=True

```
CASA <10>: inp
-----> inp()
# simdata :: mosaic simulation task:
project          = 'sim'          # root for output file names
modifymodel    = True          # modify model image
  skymodel       = '$project,skymodel' # model image to observe or modify
  inbright       = ''             # set peak surface brightness e.g. "1.2Jy/pixel" or ""
  indirection    = ''             # "J2000 19h00m00 -40d00m00" or ""
  incell         = ''             # cell/pixel size e.g. "0.1arcsec" or ""
  incenter       = ''             # frequency of center channel e.g. "89GHz" or ""
  inwidth        = ''             # channel width e.g. "10MHz" or ""

setpointings  = True           #
  integration    = '10s'         # integration (sampling) time
  direction      = ''            # "J2000 19h00m00 -40d00m00" or "" to center on model
  mapsize        = ['1arcmin', '1arcmin'] # angular size of map or "" to cover model
  maptype        = 'hexagonal'   # hexagonal, square, etc
  pointingspacing = '1arcmin'    # spacing in between pointings or "" for 0.5 PB

predict       = True           # calculate visibilities using ptgfile
  complist       = ''            # optional componentlist to observe with skymodel
  compwidth      = '2GHz'        # optional bandwidth if simulating from components only
  antennalist    = 'alma,out10,cfg' # antenna position file or "" for no interferometric MS
  refdate        = '2012/05/21/22:05:00' # time/date of observation *see help
  totaltime      = '7200s'       # total time of observation
  caldirection   = ''            # pt source calibrator [experimental]
  calflux        = '1Jy'         #
  sdantlist      = ''            # single dish antenna position file or "" for no total power MS
  sdant          = 0             # single dish antenna index in file
```

changing other parameters

thermalnoise='tsys-atm'

image=True

analyze=True

```
thermalnoise = 'tsys-atm' # add thermal noise: [tsys-atm|tsys-manual|""]  
  user_pwv    = 1.0       # Precipitable Water Vapor in mm  
  t_ground   = 269.0     # ambient temperature  
  
leakage      = 0.0       # cross polarization  
image       = True      # (re)image $project.ms to $project.image  
  vis       = '$project.ms' # Measurement Set(s) to image  
  modelimage = ''        # prior image to use in clean e.g. existing single dish image  
  imsize    = 0         # output image size in pixels (x,y) or 0 to match model  
  cell      = ''        # cell size with units or "" to equal model  
  niter     = 500       # maximum number of iterations (0 for dirty image)  
  threshold = '0.1mJy' # flux level (+units) to stop cleaning  
  weighting = 'natural' # weighting to apply to visibilities  
  mask      = []        # clean mask -- see help clean  
  outertaper = []      # uv-taper on outer baselines in uv-plane  
  stokes    = 'I'      # Stokes params to image  
  
analyze     = True      # (only first 6 selected outputs will be displayed)  
  showarray = False    # like plotants  
  showuv    = True     # display uv coverage  
  showpsf  = True     # display synthesized (dirty) beam  
  showmodel = True     # display sky model at original resolution  
  showconvolved = False # display sky model convolved with output beam  
  showclean = True     # display the synthesized image  
  showresidual = False  # display the clean residual image  
  showdifference = True # display difference image  
  showfidelity = True   # display fidelity
```

Antenna configurations

Antenna configurations are simple text files, listing all antennas that are part of the array of choice.

Several examples come with CASA, and can be found in the CASA repository directory in the subdirectory data/alma/simmos

As an example, using antenna configuration file 'alma.out20.cfg', type (in CASA):

```
>repodir=os.getenv("CASAPATH").split(' ')[0]  
>antennalist=repodir+"/data/alma/simmos/alma.out20.cfg"
```

NOTE: none of the ALMA antenna configurations are official yet !!

Example antenna configuration for full operations (included with CASA 3.1)

```
alma.out20.cfg
# observatory=ALMA
# coordsys=UTM
# datum=SAM56
# zone=19
# hemisphere=S
#UTM-X      UTM_Y      Z      Diam (m)  Pad #
627801.31   7453100.27  5029.4  12.0      3
627762.59   7453069.82  5029.9  12.0      23
627808.00   7453045.89  5028.3  12.0      43
628103.00   7453218.00  5022.2  12.0      102
627454.00   7453191.00  5023.4  12.0      103
627980.00   7452724.00  5029.8  12.0      104
627856.00   7453486.00  5026.6  12.0      105
627499.00   7452791.00  5023.5  12.0      106
628250.00   7453047.00  5015.9  12.0      107
627422.00   7453453.00  5029.0  12.0      108
627837.00   7452578.00  5032.9  12.0      109
628059.00   7453493.00  5022.3  12.0      110
627320.00   7452981.00  5025.1  12.0      111
628242.00   7452816.00  5015.9  12.0      112
627593.00   7453611.00  5031.0  12.0      113
627615.00   7452488.00  5028.0  12.0      114
628287.00   7453384.00  5016.4  12.0      115
627237.00   7453285.00  5026.9  12.0      116
628261.00   7452578.00  5019.8  12.0      117
627878.00   7453858.00  5029.4  12.0      118
627369.00   7452511.00  5019.2  12.0      119
628488.00   7453134.00  5007.2  12.0      120
627265.00   7453482.00  5026.1  12.0      121
628003.00   7452241.00  5018.9  12.0      122
628166.00   7453836.00  5022.7  12.0      123
627021.00   7452792.00  5011.4  12.0      124
628593.00   7452742.00  5012.6  12.0      125
627364.00   7453932.00  5025.9  12.0      126
627640.00   7452147.00  5028.4  12.0      127
628567.00   7453703.00  5010.7  12.0      128
626779.00   7453196.00  5013.0  12.0      129
628571.00   7452164.00  5030.1  12.0      130
627725.00   7454268.00  5029.5  12.0      131
627047.00   7452073.00  5015.2  12.0      132
628948.00   7453327.00  4984.2  12.0      133
626603.00   7453811.00  5011.8  12.0      134
```

Example antenna configuration for Early Science (included with CASA 3.1)

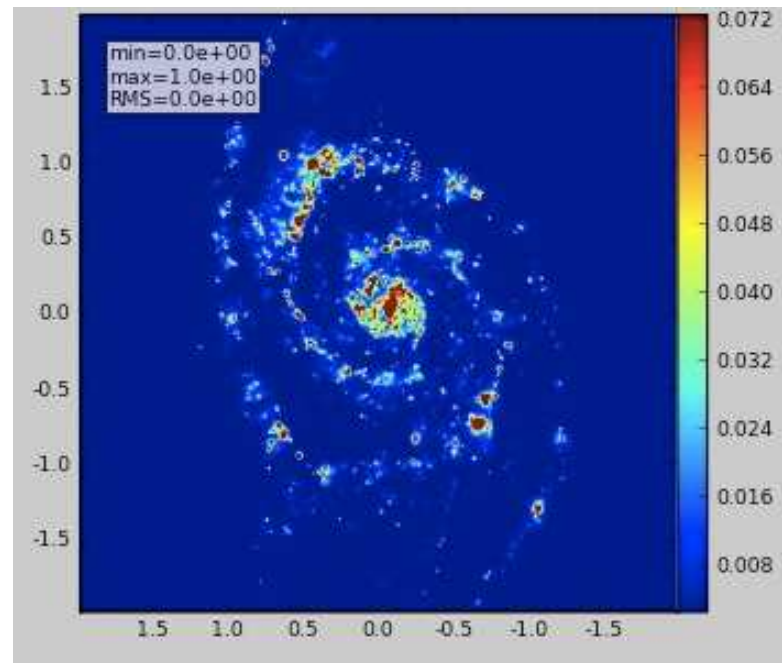
```
alma.early.250m.cfg
# observatory=ALMA
# coordsys=LOC (local tangent plane)
# x y z diam pad
27.93 -2.60 28.8 12.0 A004
54.29 -0.50 28.8 12.0 A006
49.46 20.31 28.8 12.0 A007
24.03 57.34 28.8 12.0 A009
-10.10 29.31 28.8 12.0 A021
-25.52 54.02 28.8 12.0 A023
17.77 -25.06 28.8 12.0 A036
-3.61 -40.67 28.8 12.0 A046
-47.01 -107.01 28.8 12.0 A062
60.01 -106.38 28.8 12.0 A064
117.80 22.30 28.8 12.0 A067
-106.40 71.10 28.8 12.0 A068
-126.60 -66.90 28.8 12.0 A069
141.00 -42.60 28.8 12.0 A070
-84.20 139.40 28.8 12.0 A071
47.77 161.05 28.8 12.0 A137
```


Another example antenna configuration for Early Science (not included with CASA 3.1)

```
alma.early.large.cfg
# observatory=ALMA
# coordsys=LOC (local tangent plane)
# x y z diam pad#
13.07 67.69 29.8 12.0 A10
-62.21 27.04 29.9 12.0 A31
-47.01 -107.01 28.9 12.0 A62
60.01 -106.38 28.1 12.0 A64
-104.1 -179.6 26.8 12.0 A76
90.2 -218.8 33.5 12.0 A79
64.77 240.05 29 12.0 A80
-166.23 215.05 29.9 12.0 A83
65.77 415.05 26.6 12.0 A93
-368.23 382.05 29 12.0 A96
268.77 422.05 22.3 12.0 A98
-197.23 540.05 31 12.0 A101
496.77 313.05 16.4 12.0 A103
87.77 787.05 29.4 12.0 A106
-525.23 411.05 26.1 12.0 A109
-550.23 297.05 27.1 12.0 A136
```

Time for a demo ...

starring...



as a less nearby galaxy ...