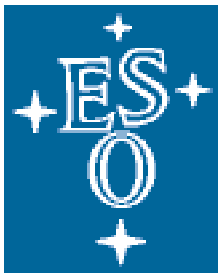
ALMA simulations: simdata

Eelco van Kampen, ESO



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

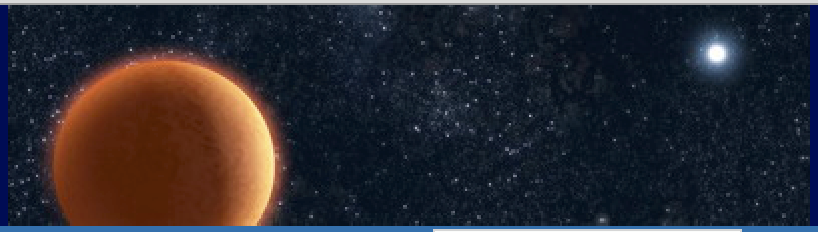
simdata is the 'official' ALMA simulator, supported by the ALMA project, and under active development

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

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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	Point Source detection
RA	00:00:00.000
Dec	00:00:00.000
Effective Bandwidth	16.0 GHz
Frequency (GHz)	345.0
Observatory site	Chajnantor
Water Vapour Column Density	ETC Chooses

Parameters

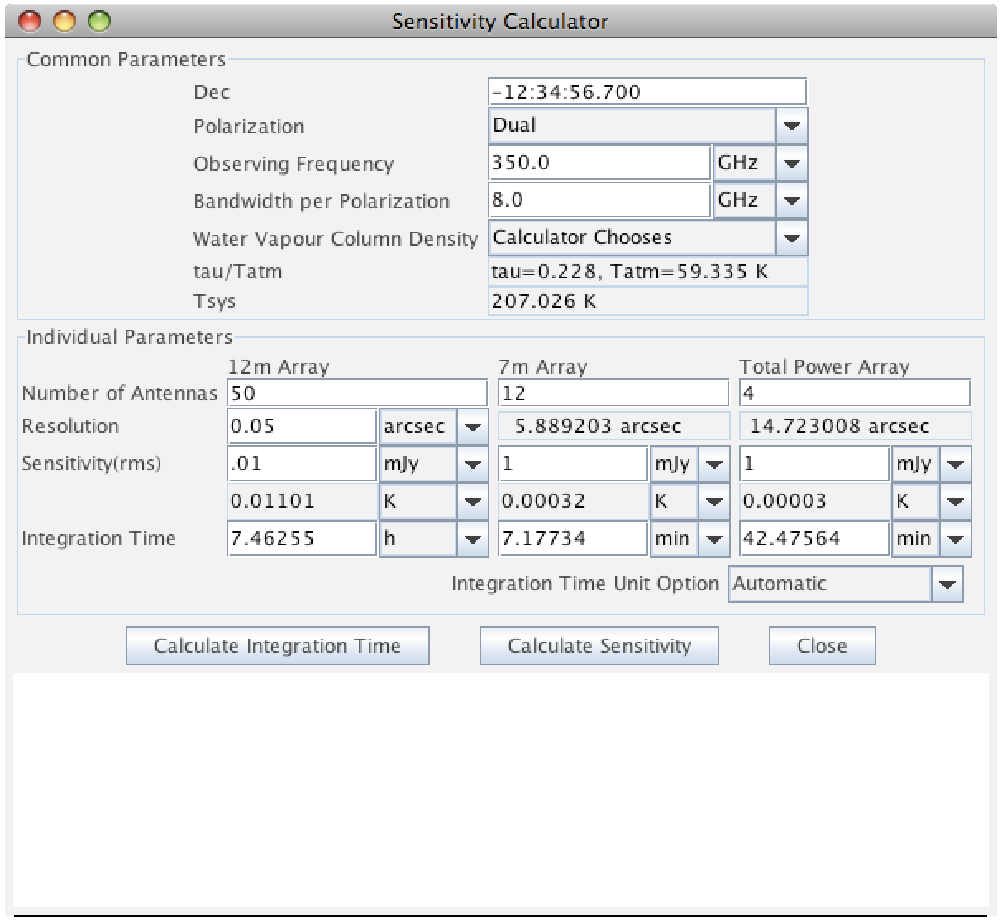
Common Parameters

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

RA/Dec: Coordinates of the observation target.

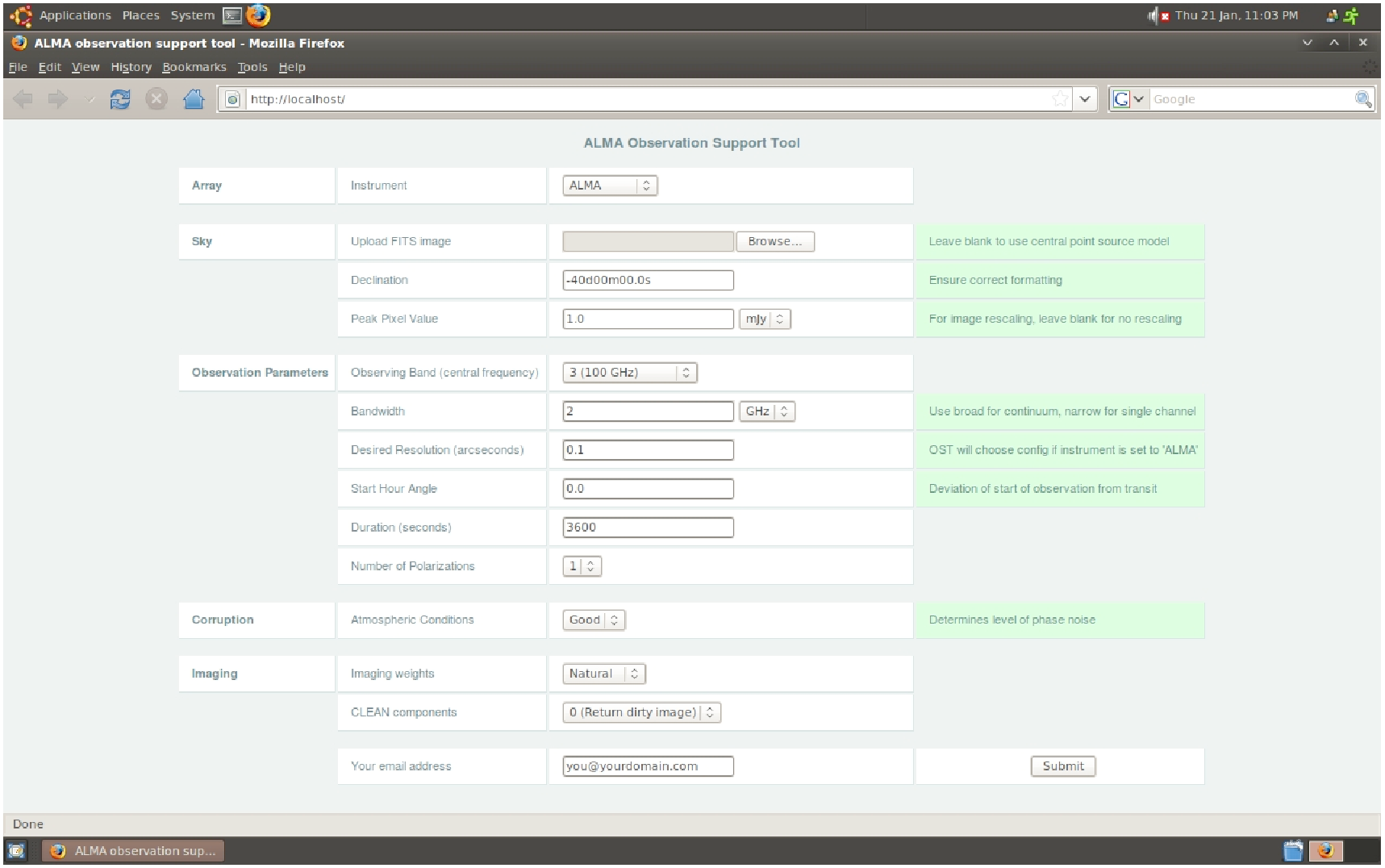
Effective Bandwidth: The

The ALMA Sensitivity Calculator is also part of the OT !

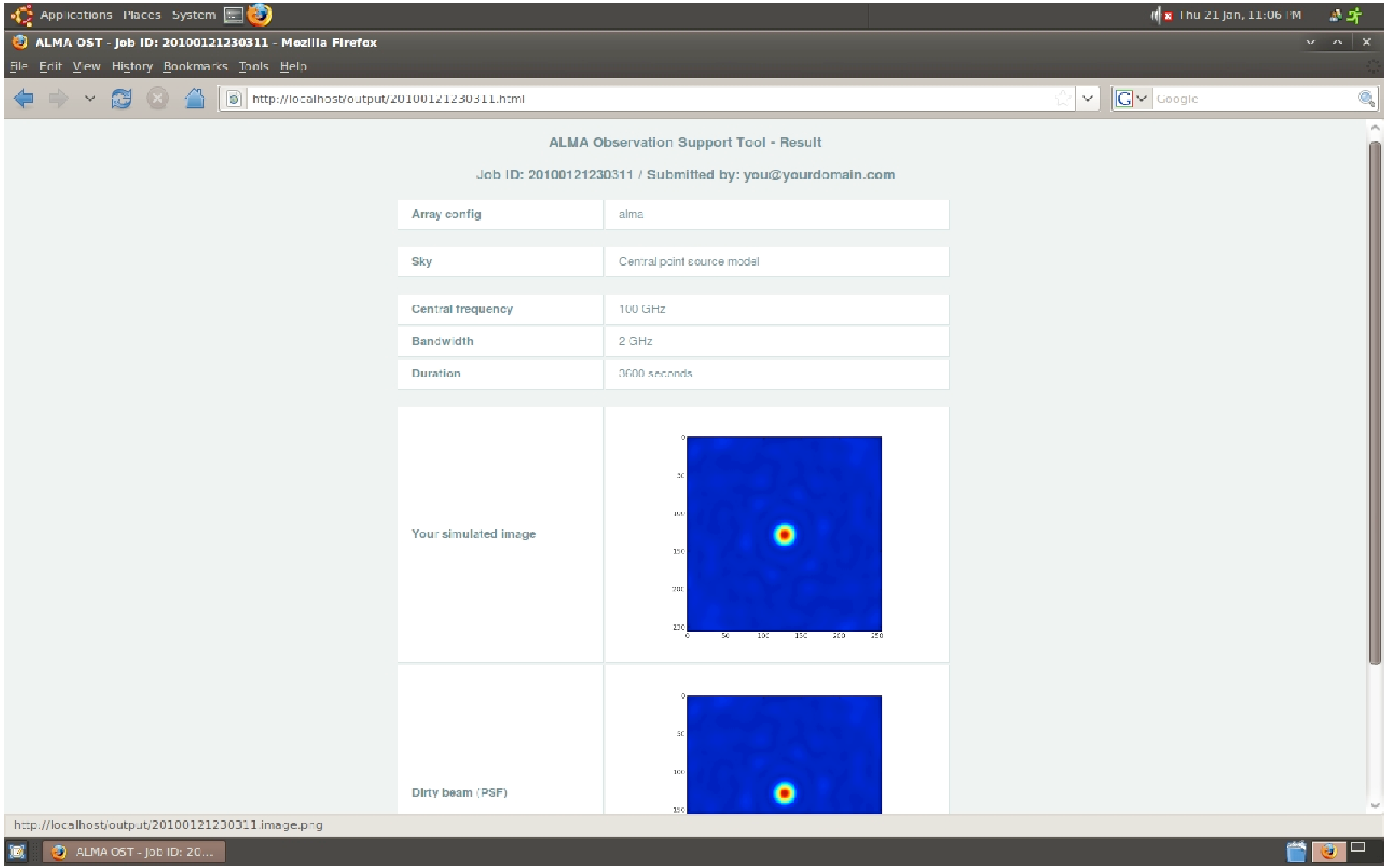


ALMA Observation Support Tool

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



ALMA OST example output

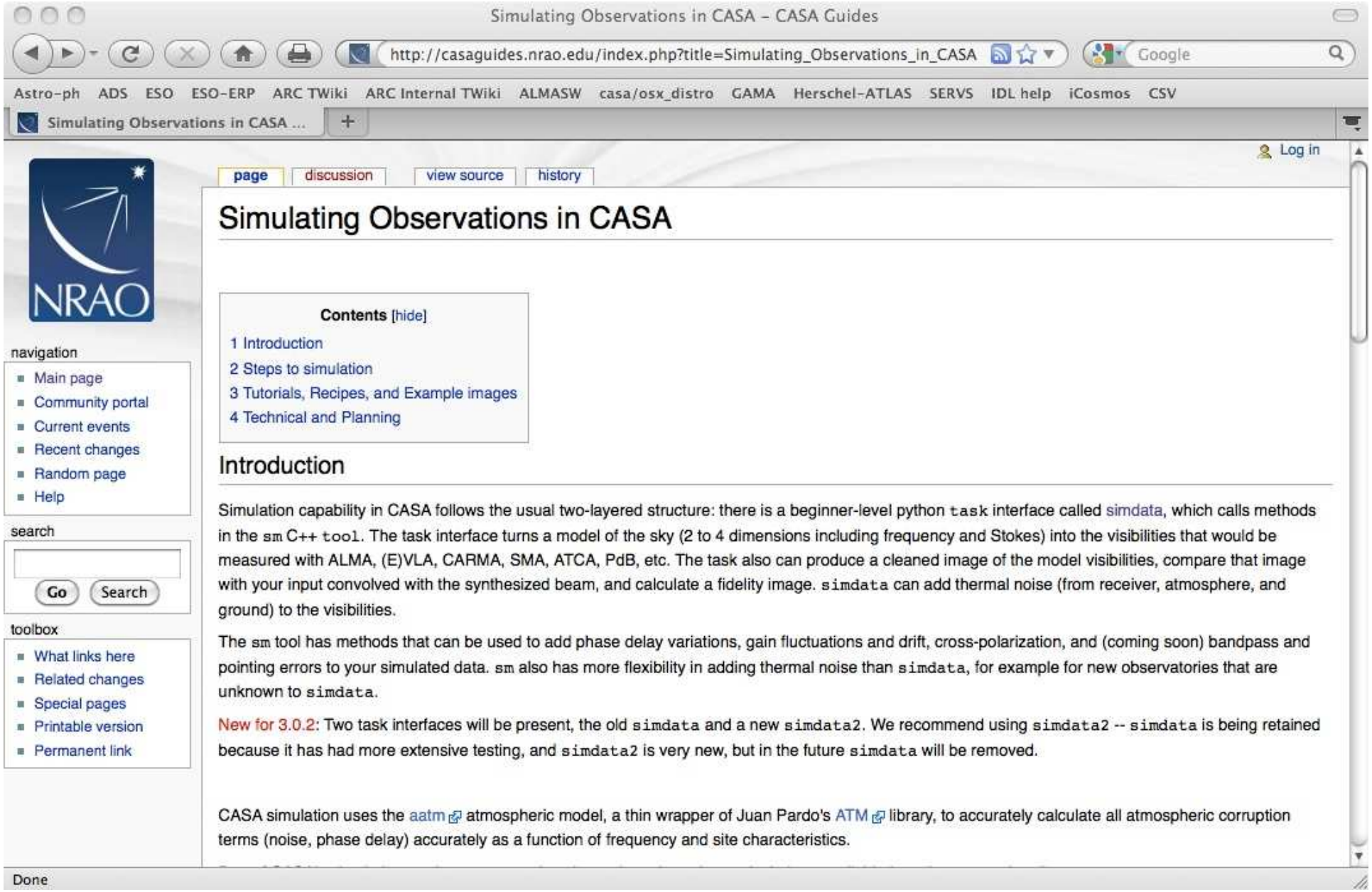


Uses of simdata

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



on-line guide to simdata

Simulating Observations in CASA – CASA Guides

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

Google

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 ...

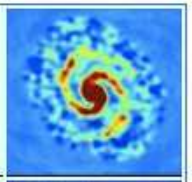
Tutorials, Recipes, and Example images

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**

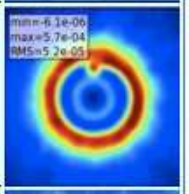
NOTE: increasing the exposure time to run faster



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.

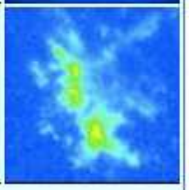
simdata page **simdata2 page**



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)

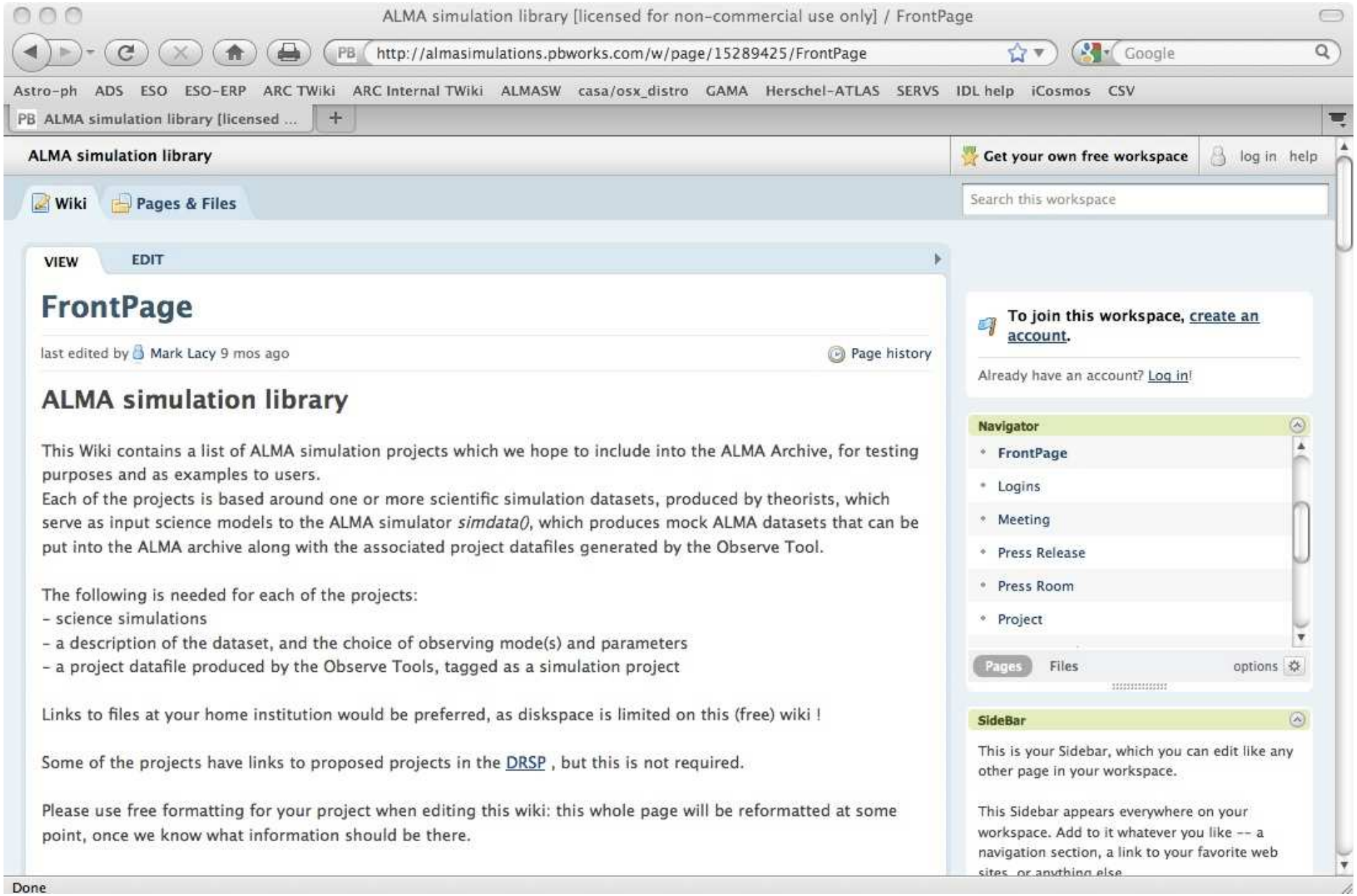
Technical and Planning

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:

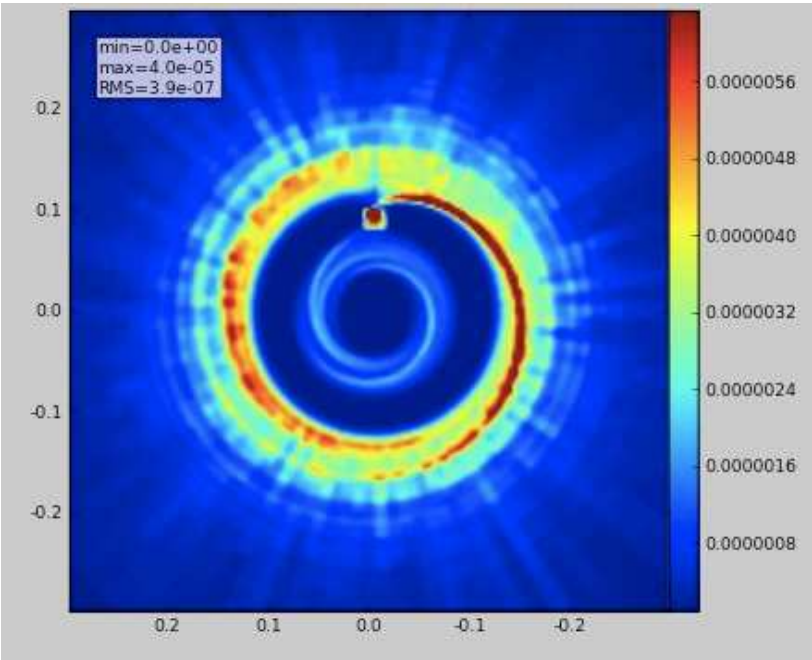
- Simulation Library This will become a library of use cases and examples illustrating different science and observation setups. It is in early stages as of Jan 2010, and we're actively seeking volunteers to turn their simulation projects into use cases.
- Jan 2010 workshop Including slides and discussion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

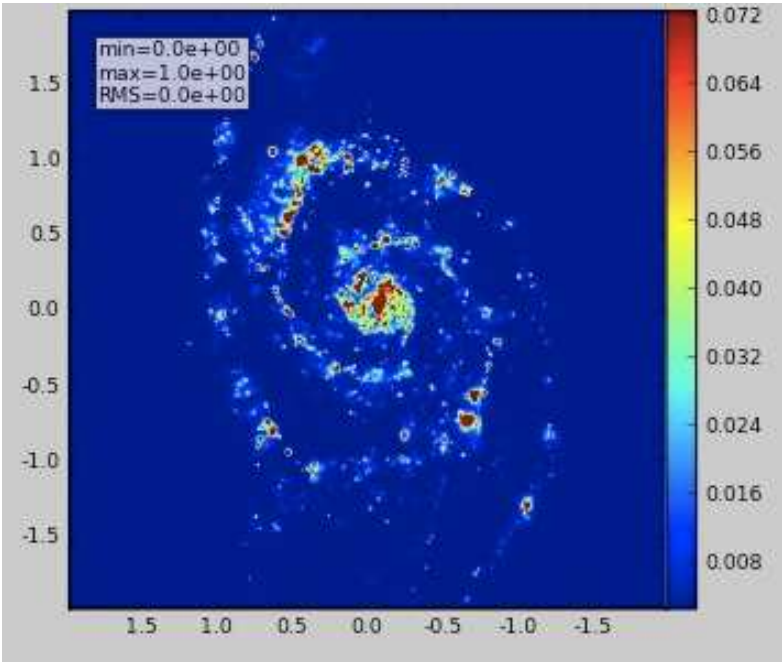
Done

simulation database



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)

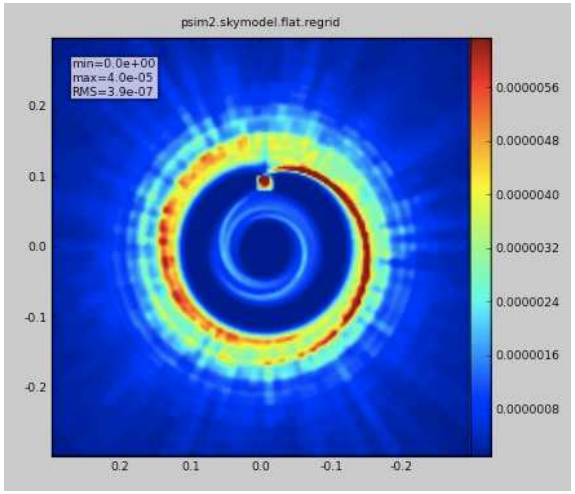
-> a Jupiter-mass planet around a 0.5 solar mass star

A nearby galaxy

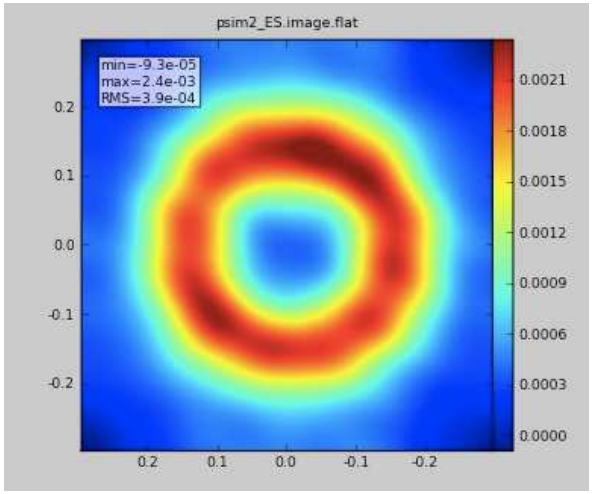
An H-alpha image of M51 provided by D. Thilker(NRAO)

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

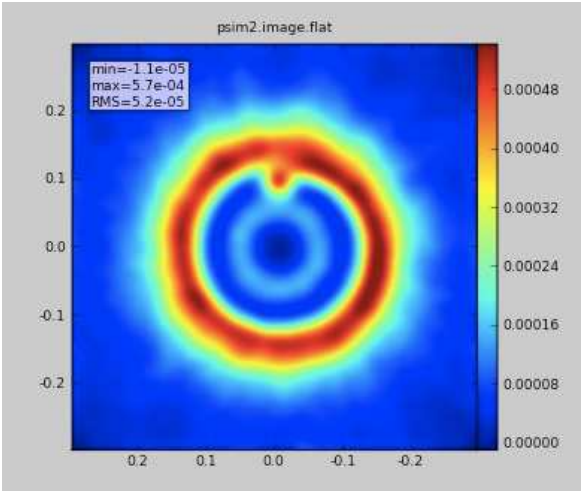
Proto-planetary disk (ALMA band 9)



Skymodel

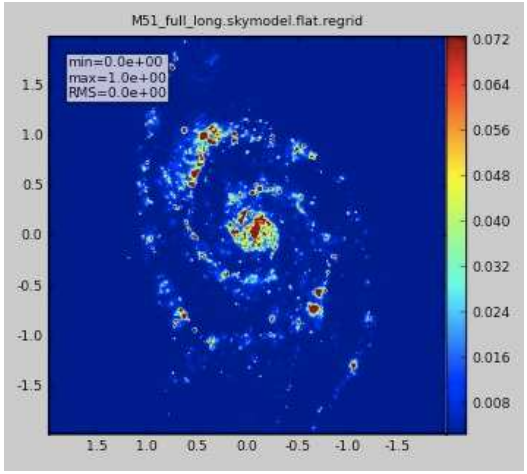


Early Science
(30 mins)

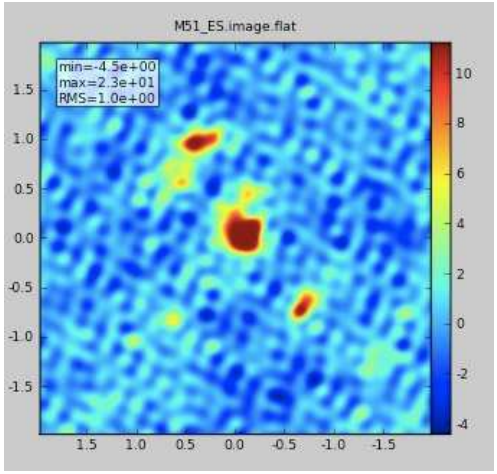


Full Array
(10 mins)

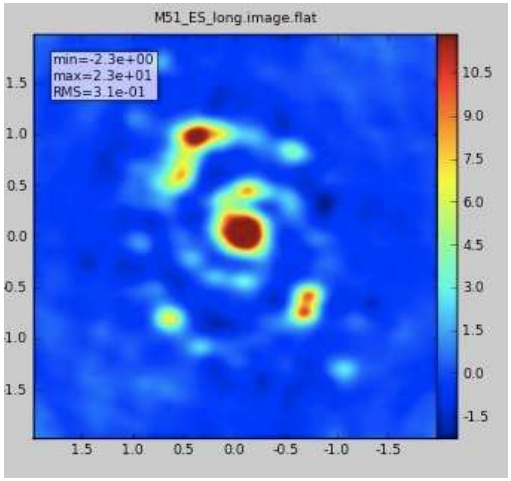
Nearby galaxy (ALMA band 9)



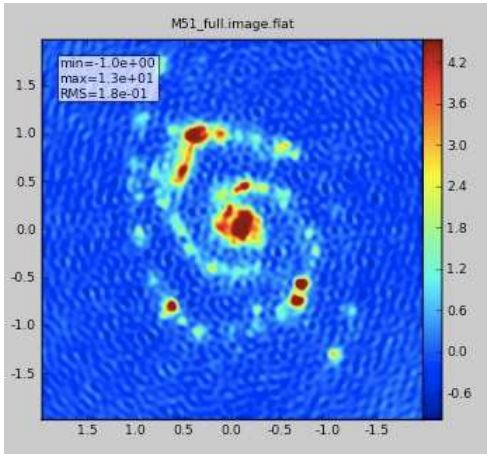
Skymodel



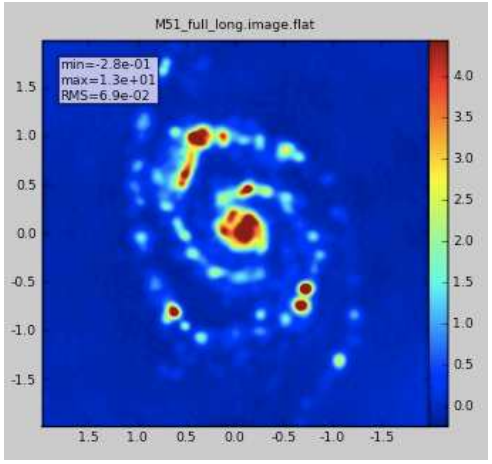
ES (30 min)



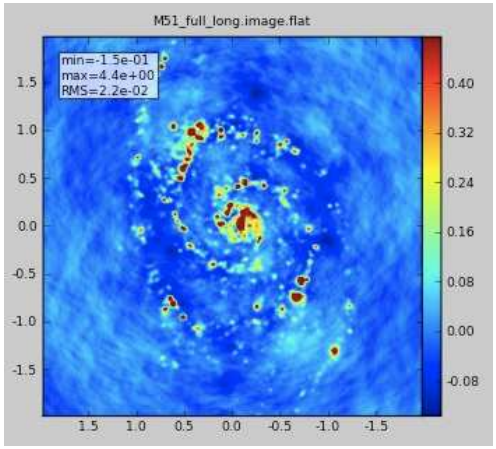
ES (4h)



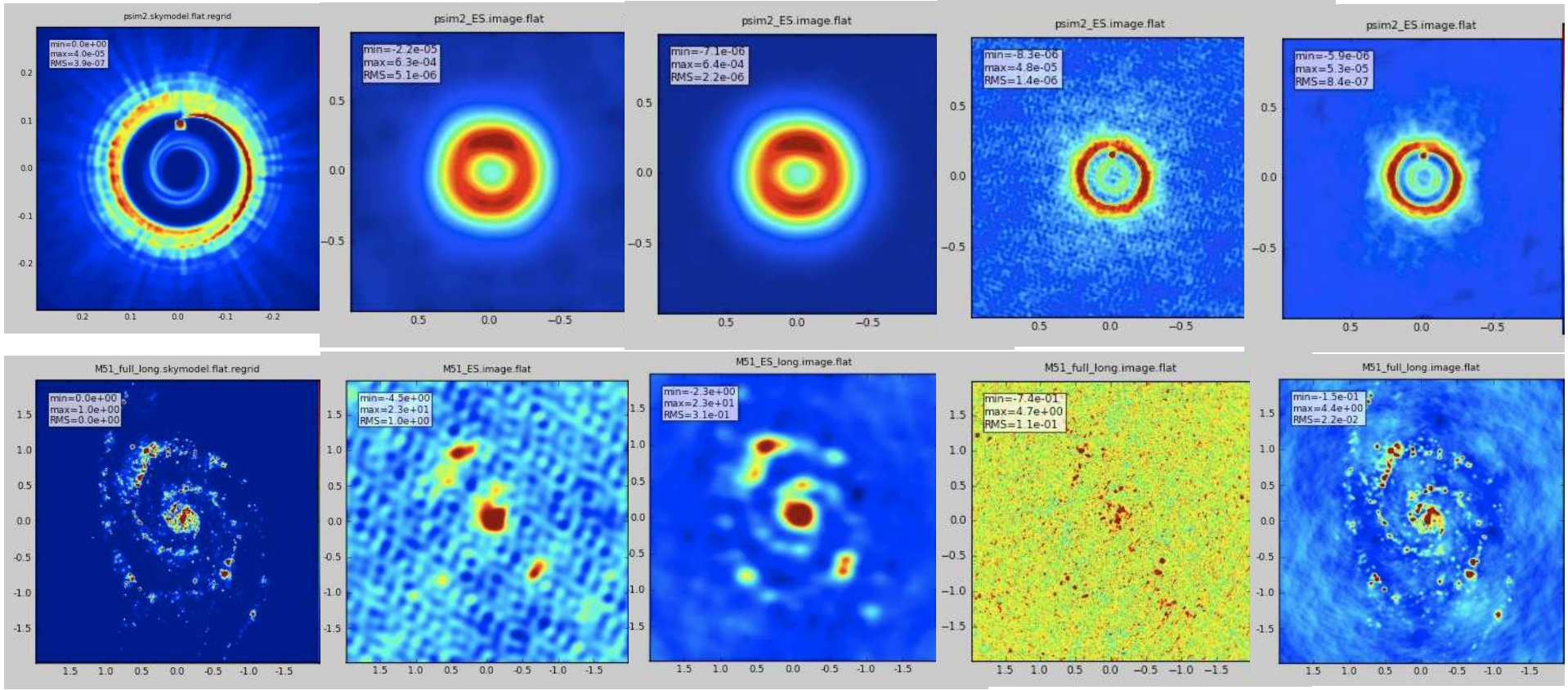
Full 2 km array (30 min)



Full 2 km array (4h)



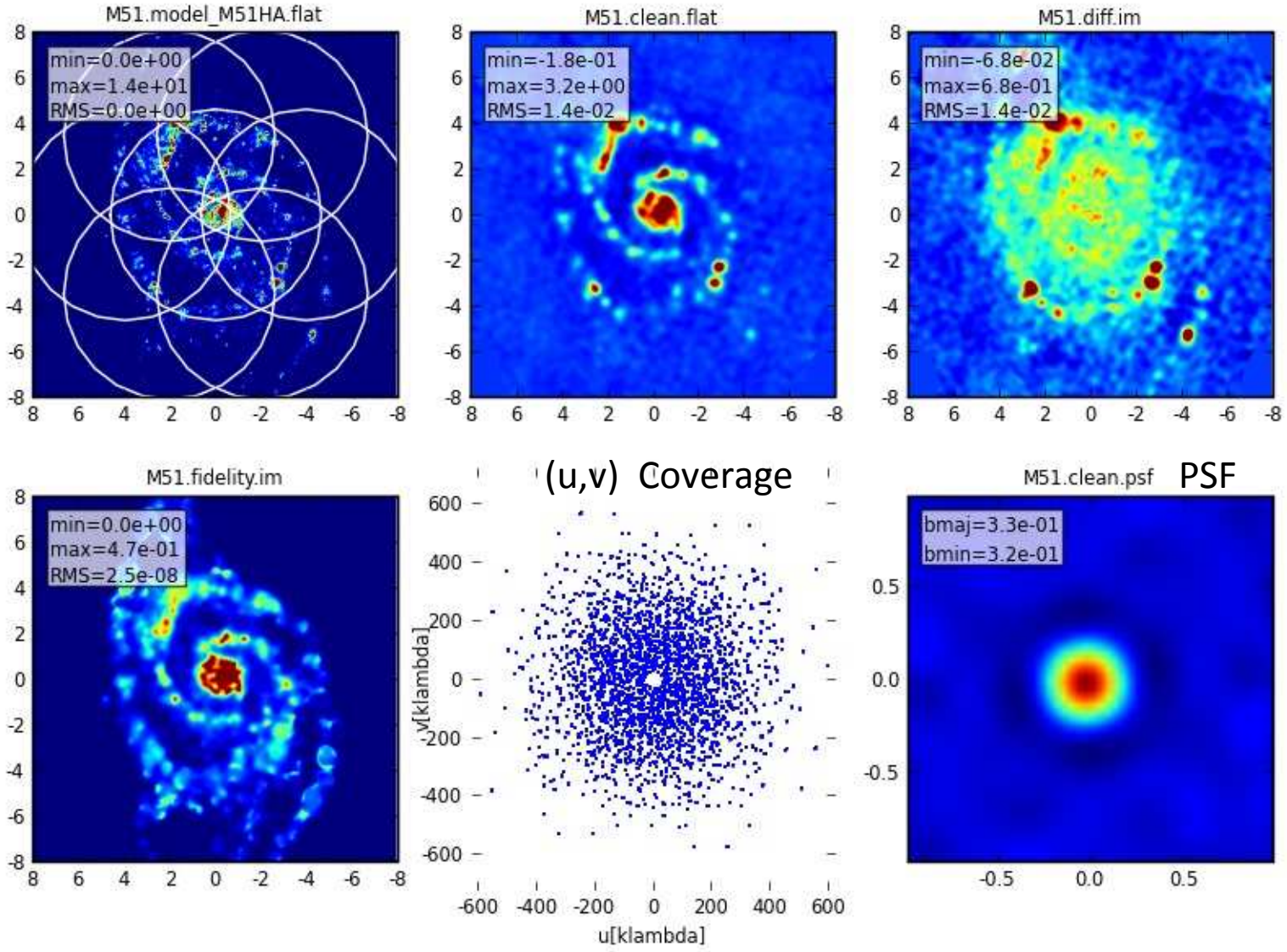
Full 6 km array (4h)



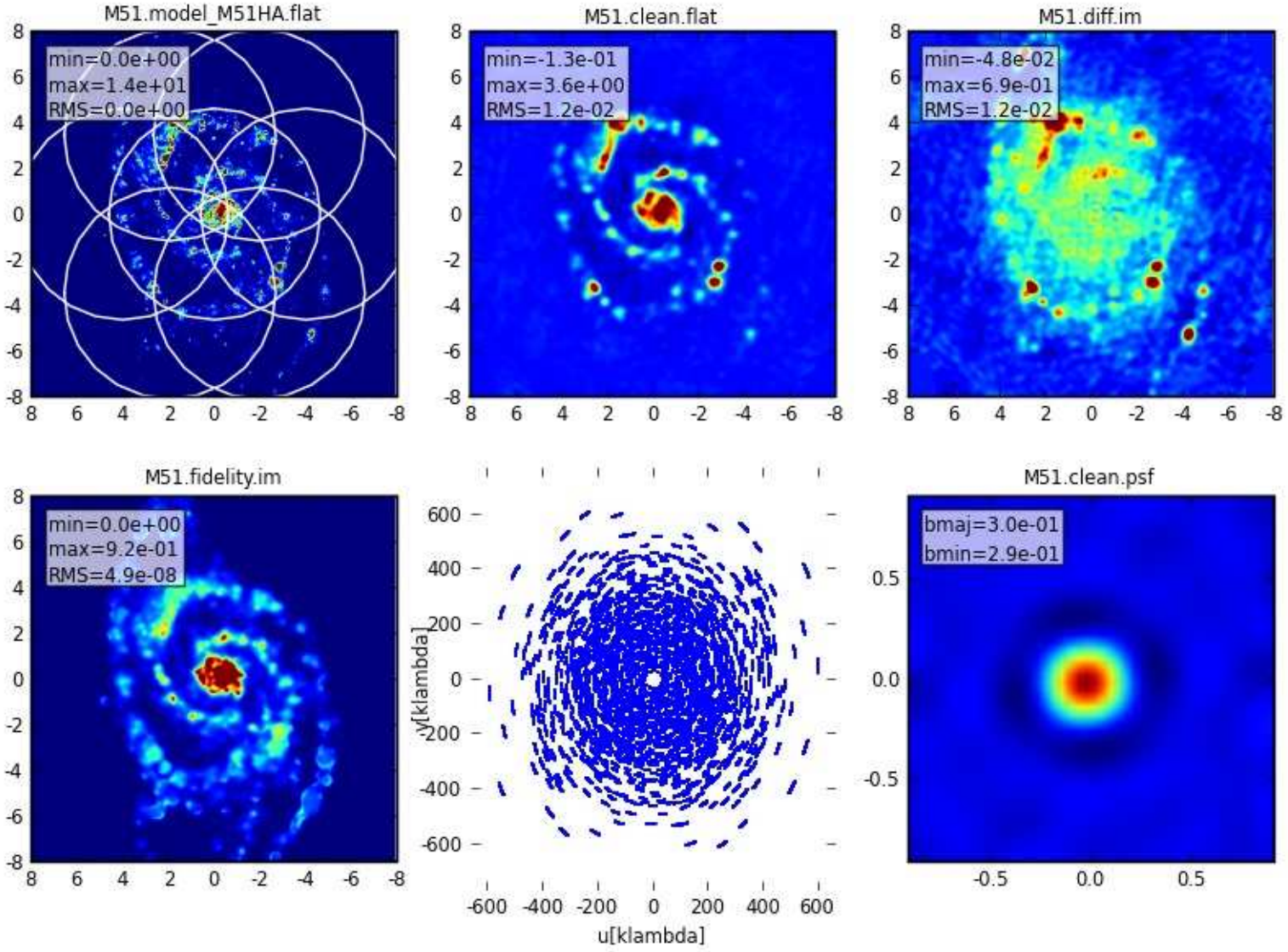
Input skymodel Earl Science 10m Early Science 4h Full 10m Full 1h

(all simulations are for single pointings)

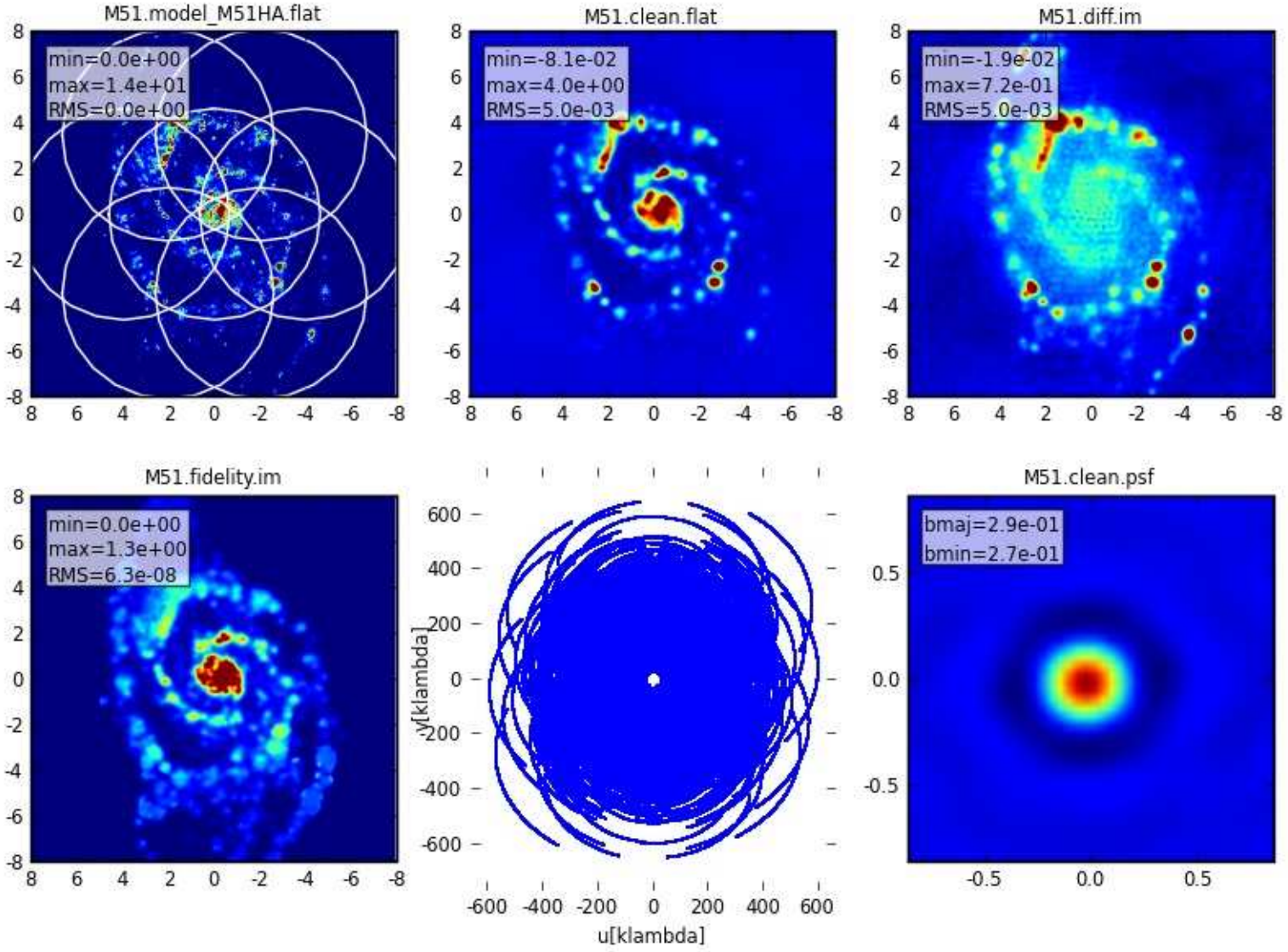
ALMA (u,v) coverage t=2 min



ALMA (u,v) Coverage t=30 min



ALMA (u,v) Coverage t=5 hr



Default simdata parameters

xterm

```
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 visibilites 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-atm|tsys-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

xterm

```
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 visibilites 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
626693.00  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
```

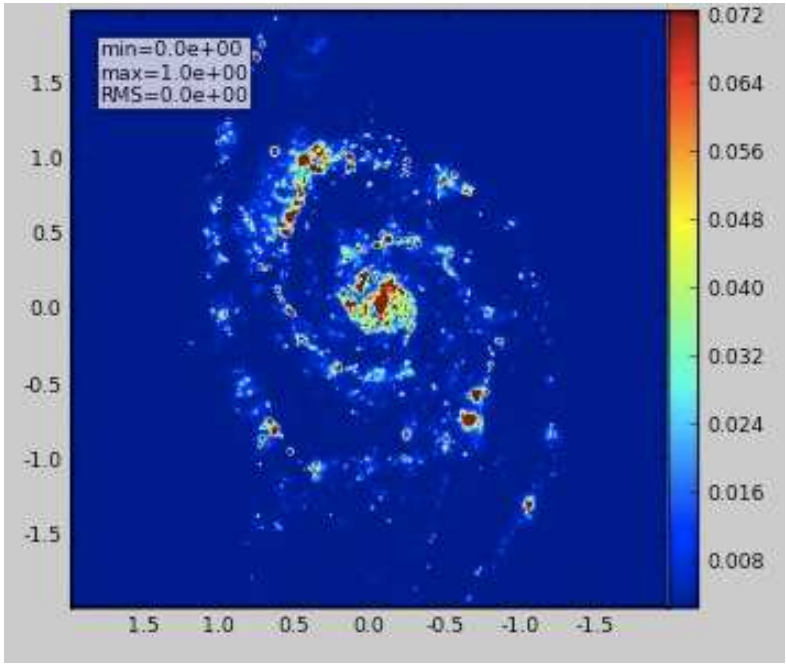
Another example antenna configuration for Early Science (not included with CASA 3.1)

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 …