

ALMA simulators for Cycle 2

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EUROPEAN ARC
ALMA Regional Centre



The use of simulators

Proposers can use simulations to test their science case:

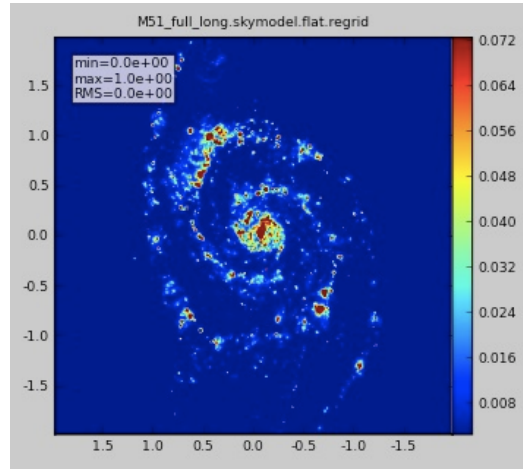
- can I do this with ALMA ? Do I need the ACA, or TP ?
- can I do this during Cycle 2 ? Should I ?
- how to optimize my science goal ?

PIs can use simulations to interpret their observed data

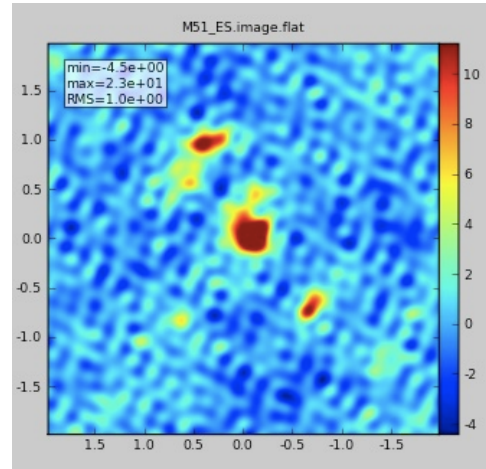
The simulation tools are also used by **the ALMA project** itself

Nearby galaxy (ALMA band 9)

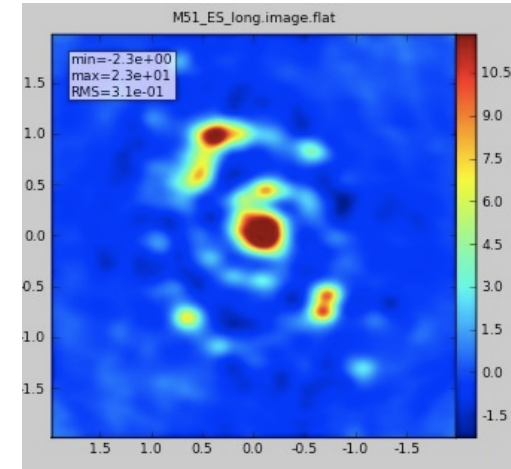
An H-alpha image of M51 provided by D. Thilker (NRAO)



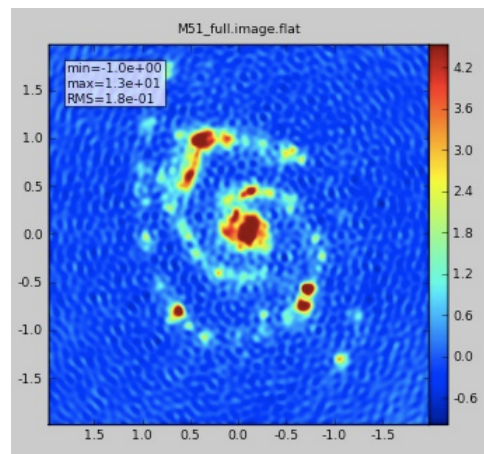
Skymodel



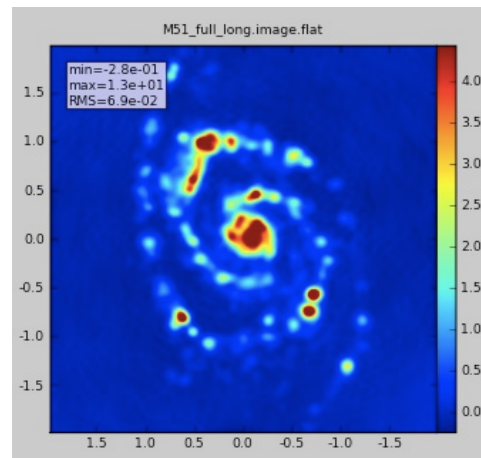
ES (30 min)



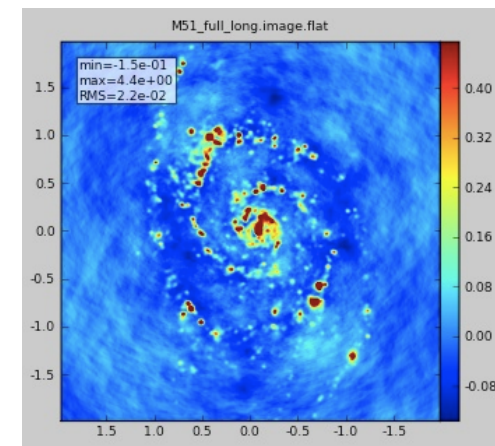
ES (4h)



Full 2 km array (30 min)



Full 2 km array (4h)



Full 6 km array (4h)

Cycle 2 ALMA simulators

Novice users: OST (hosted at the UK ARC: <http://almaost.jb.man.ac.uk>)

Expert users: simobserve/simanalyze/simalma (part of CASA)

Simobserve/simanalyze/simalma are CASA **tasks** 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 three tasks (Python scripts) act as a user-friendly interface to this tool with additional work done on plotting and analysis

The OST (Observation Support Tool) is a webtool that also uses the sm **tool** under the hood, but is much simplified (hence faster) and restricted, with a website acting as a simple GUI to set parameters and run the simulation



The OST (Observation Support Tool)

almost.jb.man.ac.uk

ALMA observation support tool

almost.jb.man.ac.uk

SAO/NASA ADS ... Astrophysics ESO ESO-ERP S2CLS SERVS

ALMA EUROPEAN ARC ALMA Regional Centre || UK

ALMA Observation Support Tool

Version 2.0 (ALMA Cycle 2)

Array Instrument: ALMA [Current Status](#) [Help](#) [ALMA Helpdesk](#) [OST Latest News](#)

Sky Setup

Source model: OST Library: Central point source Choose a library source model or supply your own

Upload a FITS file: Browse... No file selected. You may upload your own model here (max 10MB)

Declination: -35d00m00.0s Ensure correct formatting of this string (-4-00d00m00.0s)

Image peak / point flux in: mjy 0.0 Set to 0.0 for no rescaling of source model

Observation Setup

Central frequency in GHz: 90 The value entered must be within an ALMA band

Bandwidth in MHz: 32 Use broad for continuum, narrow for single channel

Use recommended continuum setup? No Yes If Bandwidth = 7.5GHz use the ALMA recommended spectral window spacing for continuum simulations.

Required resolution in arcseconds: 1.0 OST will choose config if instrument is set to ALMA

Pointing strategy: Mosaic Selecting single will apply primary beams attenuation

Start hour angle: 0.0 Deviation of start of observation from transit

Phase Cycle in seconds: 0.0 The length of time between cutting to a phase calibrator. Currently limited to either 0s or between 300s and 900s.

On Phase Calibrator in seconds: 0.0 The length of time spent observing phase calibrator (including seeing time). Currently limited to either 0s or between 30s and 120s.

On-source time in hours: 1 Per pointing for Mosaic.

Number of visits: 1 How many times the observation is repeated

Number of polarizations: 2 This affects the noise in the final map

Corruption

Atmospheric conditions: PWV = 0.472 mm (1st Octfile) Determines level of noise due to water vapour

Imaging

Imaging weights: Natural This allows a resolution / sensitivity trade-off

Perform deconvolution?: No (Return dirty image) Apply the CLEAN algorithm to deconvolve the image

Output image format: FITS CASA format images are returned as a tar file

Your email address is: essential

on-line 'casaguides' to *simobserve*

The screenshot shows a web browser window with the title "Simulating Observations in CASA 4.1 - CASA Guides". The address bar shows the URL "casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA_4.1". The browser has several tabs open, including "Simulation Guide for ...", "CASA", and "Simulating Observati...". The page content includes the NRAO CASA logo, a search bar, and a table of contents for the guide. The main text of the introduction is also visible.

page discussion view source history

Simulating Observations in CASA 4.1

- This guide is applicable to CASA version 4.1. For older versions of CASA please see [Simulating Observations in CASA 4.0](#).

Contents [hide]

- 1 Introduction
- 2 ALMA Simulations and Proposals
- 3 Tutorials
 - 3.1 Example Input Images
- 4 Advanced CASA Simulation
 - 4.1 Under the Hood: The sm Tool
 - 4.2 Ephemeris and Geodesy
- 5 Warning: CLEAN Bias
- 6 User Feedback

Introduction

There are two main tasks for simulating observations in CASA: [simobserve](#) and [simanalyze](#). Starting with a model of sky brightness, [simobserve](#) generates the visibilities that would be measured with a telescope such as ALMA, the VLA, CARMA, SMA, ATCA, or PdB. The [simobserve](#) task can add thermal noise to the visibilities. The [simobserve](#) task uses the [aatm](#) atmospheric model (based on Juan Pardo's [ATM](#) library) to simulate real observing conditions and introduce atmospheric "corruption", i.e. noise and phase delay.

Next, the task [simanalyze](#) will produce a cleaned image based on the generated visibilities. It can compare the simulated image with your input (convolved with the output clean beam) and then calculate a "fidelity image" that indicates how well the simulated output matches the convolved input image.

Note for proposers

Values from simobserve or the OST should not be used to calculate exposure times for ALMA Science Goals. Only values from the ALMA sensitivity calculator should be used for this purpose, as it is the ALMA sensitivity calculator that will be used in the technical assessment of ALMA proposals.

Representative Cycle 2 antenna configurations are included in CASA 4.2 and the OST (and can be downloaded from the Science Portal), but the actual configuration could differ somewhat when the observation is scheduled.

General comments

There are two types of input models:

- a theoretical model (a science simulation)
- a previous observation, in the same waveband or a related one

In the first case the input image is noise free, in the second case it is not. Therefore the noise estimated by *simobserve* or the OST comes on top of the original noise, and could result in overestimation.

Both *simobserve* and the OST are based on the sm tools in CASA, but do not include the same noise terms, and have different default clean parameters.

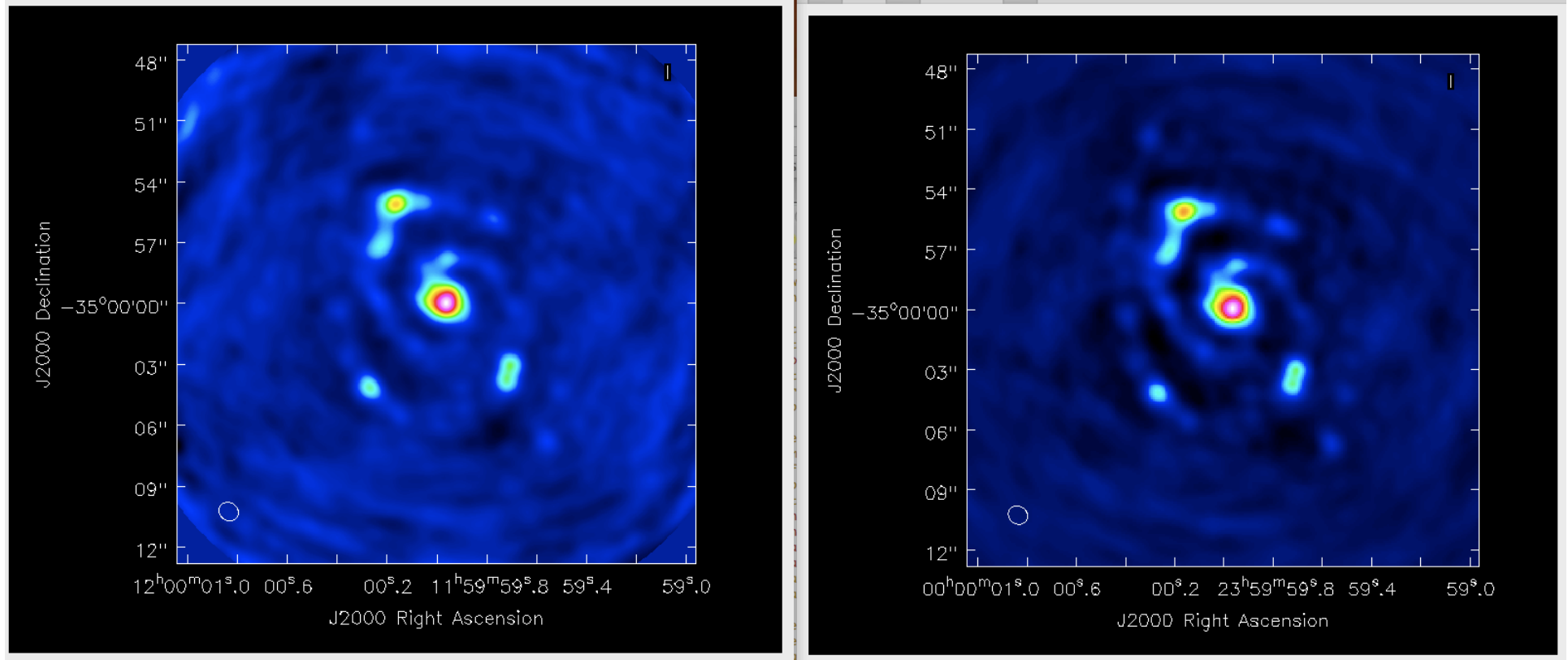
Warning: CLEAN Bias

As is the case for real images, cleaning images produced by *simobserve* can lead to a spurious decrease in object fluxes and noise on the image (an effect known as "clean bias"). This is particularly true for observations with poor coverage of the uv-plane, i.e. using telescopes with small numbers of antennas, such as the ALMA Early Science configurations, and/or in short "snapshot" observations. Users should always clean images with care, using a small number of iterations and/or a conservative (3-5sigma) threshold and boxing bright sources.

simobserve versus OST: images

simobserve

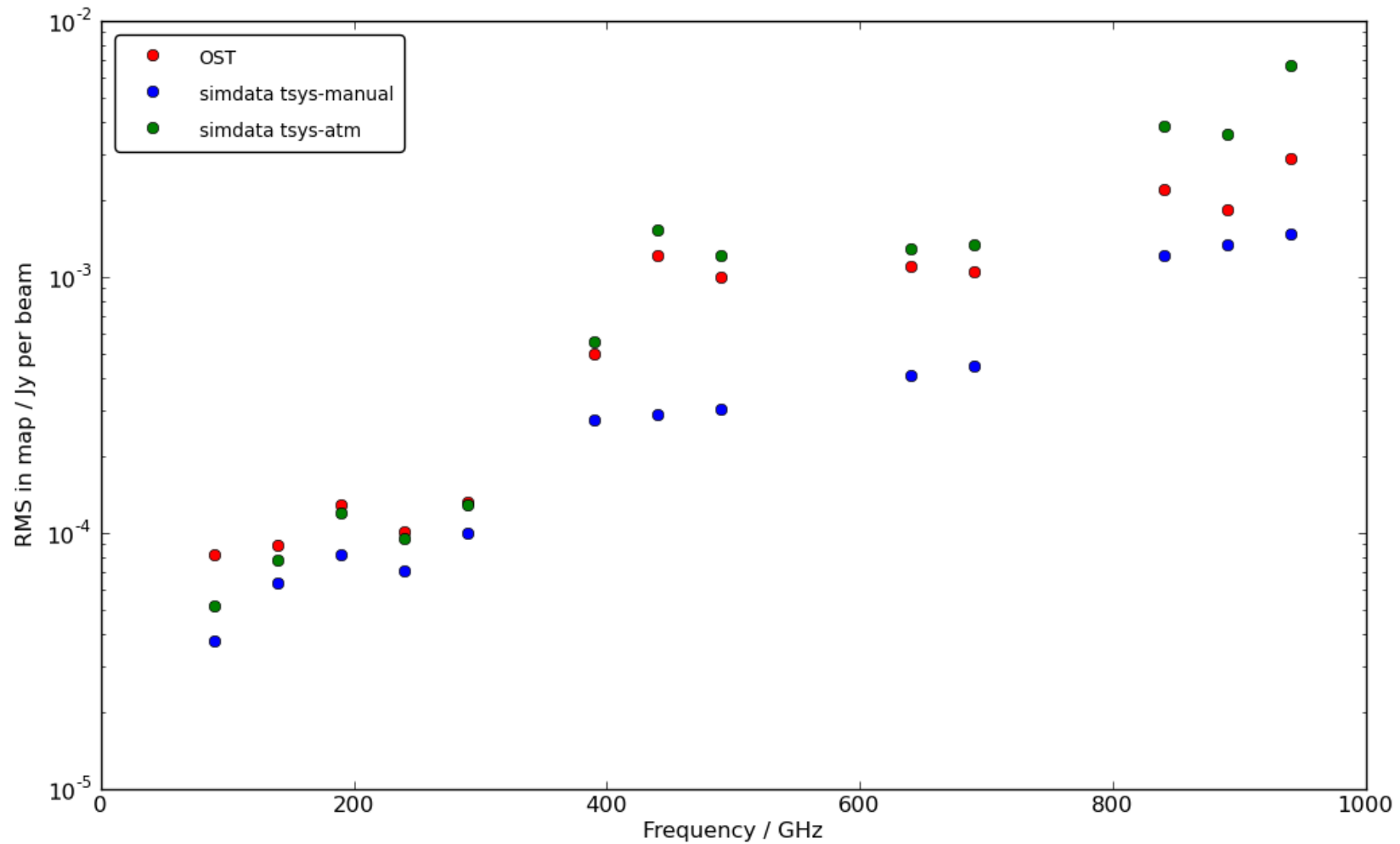
OST



M51@ $z=0.5$, Early Science configuration, band 6

simobserve versus OST: noise levels

rms noise comparison for all ALMA bands (using pure noise maps)



ALMA+ACA+TP

Deconvolving the predicted visibilities back into an image

Many ways of doing this, including:

1) use the total power image as a model when deconvolving the ACA image, and then use the result as a model when deconvolving the 12m interferometric image (this tends to give low weight to the large spatial scales)

2) use multiscale clean, in the clean task (again using the lower resolution image as a model when deconvolving the higher resolution one)

3) create each image independently, and then use the CASA feather task to combine them entirely in the image plane

Note: use different dates for ALMA, ACA and TP simulated visibilities, as generic antenna names are used by *simobserve* ... (dataset concatenation !).

New *simalma* task in CASA to help you do this in one go ... but see next slide !

CASA 4.1 or 4.2 ?

From the CASA download page:

The screenshot shows a web browser window titled 'CASA' with the URL 'casa.nrao.edu/casa_obtaining.shtml'. The page content includes a navigation bar with various project logos, a main heading 'CASA', and a sub-heading 'Linux'. Under 'Linux', there are three bullet points: 'Latest Release Linux 64bit:' with a download link and instructions; 'Stable Linux 64bit (CASA 4.2-Oct; 24 Oct 2013, r26945)' with a download link and instructions, and a green note 'Please use this version for ALMA Cycle 2 simulations'; and 'Older Releases for Linux:' with an 'Archive' link. Below this is a 'Mac OS' section with three bullet points: 'Mac OS 10.7 & 10.8 (Lion - 64bit):' with a download link and instructions; 'Mac OS 10.6 (Snow Leopard - 64bit):' with a download link and instructions; and 'Stable Mac OS 10.7 & 10.8 (CASA 4.2-Aug2; 10 Sep 2013, r26465)' with a download link and instructions, and a red note 'do NOT use for ALMA Cycle 2 simulations - please stay tuned until a version r26945 or higher will be available. For now, use the Linux 4.2 "stable" version r26945) for ALMA Cycle 2 simulations.' At the bottom, there are links for 'Older Releases for Mac OS:' pointing to '10.5', '10.6', and '10.7'. On the left side of the browser window, there are three annotations: 'CASA 4.1 →', 'CASA 4.2 →', and 'CASA 4.2 →' in red text.

CASA 4.1 →

CASA 4.2 →

CASA 4.1 →

CASA 4.2 →

The latest CASA release is 4.1.0 (r24668, May 28, 2013)

Linux

- Latest Release Linux 64bit: [Download](#) [Instructions](#)
- **Stable Linux 64bit (CASA 4.2-Oct; 24 Oct 2013, r26945)**
Please use this version for ALMA Cycle 2 simulations [Download](#) [Instructions](#)
- Older Releases for Linux: [Archive](#)

Mac OS

- Mac OS 10.7 & 10.8 (Lion - 64bit): [Download](#) [Instructions](#)
- Mac OS 10.6 (Snow Leopard - 64bit): [Download](#) [Instructions](#)
- **Stable Mac OS 10.7 & 10.8 (CASA 4.2-Aug2; 10 Sep 2013, r26465)**
do NOT use for ALMA Cycle 2 simulations - please stay tuned until a version r26945 or higher will be available. For now, use the Linux 4.2 "stable" version r26945) for ALMA Cycle 2 simulations. [Download](#)
- Older Releases for Mac OS: [10.5](#) [10.6](#) [10.7](#)

Default *simobserve* parameters

```
CASA <3>: inp
-----> inp()
# simobserve :: mosaic simulation task
project          = 'sim'          # root prefix for output file names
skymodel         = ''            # model image to observe
complist        = ''            # componentlist to observe
setpointings    = True
  integration     = '10s'        # integration (sampling) time
  direction       = ''          # "J2000 19h00m00 -40d00m00" or "" to center on model
  mapsize         = ['', '']    # angular size of map or "" to cover model
  maptype         = 'ALMA'      # hexagonal, square (raster), ALMA, etc
  pointingspacing = ''         # spacing in between pointings or "0,25PB" or "" for Nyquist

obsmode         = 'int'         # observation mode to simulate [int(interferometer)|sd(singledish)|""(none)]
  antennalist     = 'alma.out10.cfg' # interferometer antenna position file
  refdate         = '2014/05/21'  # date of observation - not critical unless concatting simulations
  hourangle       = 'transit'     # hour angle of observation center e.g. -3:00:00, or "transit"
  totaltime       = '7200s'      # total time of observation or number of repetitions
  caldirection    = ''          # pt source calibrator [experimental]
  calflux         = '1Jy'

thermalnoise    = ''           # add thermal noise: [tsys-atm|tsys-manual|""]
leakage         = 0.0          # cross polarization (interferometer only)
graphics        = 'both'      # display graphics at each stage to [screen|file|both|none]
verbose         = False
overwrite       = True        # overwrite files starting with $project
async           = False       # If true the taskname must be started using simobserve(...)
```

Setting *simobserve* parameters

skymodel=<filename>

thermalnoise='tsys-atm'

```
# simobserve :: mosaic simulation task:
project          = 'sim'          # root prefix for output file names
skymodel         = 'beautiful model' # model image to observe
  inbright       = ''            # scale surface brightness of brightest pixel e.g. "1.2Jy/pixel"
  indirection    = ''            # set new direction e.g. "J2000 19h00m00 -40d00m00"
  incell         = ''            # set new cell/pixel size e.g. "0.1arcsec"
  incenter       = ''            # set new frequency of center channel e.g. "89GHz" (required even for 2D model)
  inwidth        = ''            # set new channel width e.g. "10MHz" (required even for 2D model)

complist         = ''            # componentlist to observe
setpointings    = True          #
  integration     = '10s'        # integration (sampling) time
  direction       = ''            # "J2000 19h00m00 -40d00m00" or "" to center on model
  mapsize         = ['', '']     # angular size of map or "" to cover model
  maptype         = 'ALMA'       # hexagonal, square, etc
  pointingspacing = ''           # spacing in between pointings or "0.25PB" or "" for 0.5 PB

obsmode         = 'int'         # observation mode to simulate [int(interferometer)|sd(singledish)|""(none)]
  antennalist     = 'alma,out10.cfg' # interferometer antenna position file
  refdate         = '2012/05/21'   # date of observation - not critical unless concatting simulations
  hourangle       = 'transit'      # hour angle of observation center e.g. -3:00:00, or "transit"
  totaltime       = '7200s'        # total time of observation or number of repetitions
  caldirection    = ''            # pt source calibrator [experimental]
  calflux         = '1Jy'          #

thermalnoise    = 'tsys-atm'     # add thermal noise: [tsys-atm|tsys-manual|""]
  user_pvw        = 1.0           # Precipitable Water Vapor in mm
  t_ground        = 269.0         # ambient temperature
  seed            = 11111         # random number seed

leakage         = 0.0            # cross polarization (interferometer only)
graphics        = 'both'         # display graphics at each stage to [screen|file|both|none]
verbose         = False          #
overwrite       = True           # overwrite files starting with $project
async           = False          # If true the taskname must be started using simobserve(...)
```

Default *simanalyze* parameters

```
# simanalyze :: image and analyze simulated datasets
project      = 'sim'          # root prefix for output file names
image       = True           # (re)image $project.*.ms to $project.image
  vis       = 'default'     # 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
  imdirection = ''         # set output image direction, (otherwise center on the 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      = []           # Cleanbox(es), mask image(s), region(s), or a level
  outertaper = []         # uv-taper on outer baselines in uv-plane
  stokes    = 'I'         # Stokes params to image

analyze     = False        # (only first 6 selected outputs will be displayed)
graphics   = 'both'       # display graphics at each stage to [screen|file|both|none]
verbose    = False
overwrite  = True         # overwrite files starting with $project
async     = False        # If true the taskname must be started using simanalyze(...)
```

Setting *simanalyze* parameters

analyze=True

```
# simanalyze :: image and analyze simulated datasets
project      = 'sim'          # root prefix for output file names
image       = True          # (re)image $project.*,ms to $project.image
  vis        = 'default'     # 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
  imdirection = ''          # set output image direction, (otherwise center on the 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       = []           # Cleanbox(es), mask image(s), region(s), or a level
  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)
  showuv     = True         # display uv coverage
  showpsf    = True         # display synthesized (dirty) beam (ignored in single dish simulation)
  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 (ignored in single dish simulation)
  showdifference = True    # display difference image
  showfidelity = True      # display fidelity

graphics    = 'both'       # display graphics at each stage to [screen|file|both|none]
verbose     = False
overwrite   = True         # overwrite files starting with $project
async      = False        # If true the taskname must be started using simanalyze(...)
```


Antenna configurations

Antenna configurations are simple text files, listing all antennas that are part of the array of choice. Many come with CASA, and can be found in the CASA repository directory in the subdirectory `data/alma/simmos`

For example, to select ALMA full science configuration #20, use (in `simobserve`)

```
> antennalist='alma.out20.cfg'
```

One can also choose a configuration corresponding to a certain resolution, eg:

```
> antennalist = "alma;0.05arcsec"
```

NOTE: the 'full operations' antenna configurations are meant to be representative. The Cycle 2 antenna configuration files are all included in CASA 4.2, but need to be requested separately for CASA 4.1 (can be downloaded from the Science Portal !).

Example antenna configuration for full operations (included with CASA)

```
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
```

All antenna configurations included in CASA 4.1

all files in CASA's subdirectory /data/alma/simmos :

```
WSRT.cfg  
aca.i.cfg  
aca.ns.cfg  
aca.tp.cfg  
aca_cycle1.cfg  
alma.cycle0.compact.cfg  
alma.cycle0.extended.cfg  
alma.out01.cfg  
alma.out02.cfg  
alma.out03.cfg  
alma.out04.cfg  
alma.out05.cfg  
alma.out06.cfg  
alma.out07.cfg  
alma.out08.cfg  
alma.out09.cfg  
alma.out10.cfg  
alma.out11.cfg  
alma.out12.cfg  
alma.out13.cfg  
alma.out14.cfg  
alma.out15.cfg  
alma.out16.cfg  
alma.out17.cfg  
alma.out18.cfg  
alma.out19.cfg  
alma.out20.cfg  
alma.out21.cfg  
alma.out22.cfg  
alma.out23.cfg  
alma.out24.cfg  
alma.out25.cfg  
alma.out26.cfg  
alma.out27.cfg  
alma.out28.cfg  
alma_cycle1_1.cfg  
alma_cycle1_2.cfg  
alma_cycle1_3.cfg  
alma_cycle1_4.cfg  
alma_cycle1_5.cfg  
alma_cycle1_6.cfg  
carma.a.cfg  
carma.b.cfg  
carma.c.cfg  
carma.d.cfg  
carma.e.cfg  
meerkat.cfg  
pdbi-a.cfg  
pdbi-b.cfg  
pdbi-c.cfg  
pdbi-d.cfg  
sma.compact.cfg  
sma.compact.n.cfg  
sma.extended.cfg  
sma.subcompact.cfg  
sma.vextended.cfg  
vla.a.cfg  
vla.b.cfg  
vla.bna.cfg  
vla.c.cfg  
vla.cnb.cfg  
vla.d.cfg  
vla.dnc.cfg
```

Output filenames

Output produced: (not all will always exist, depending on input parameters)
To support different runs with different arrays, the names have the
configuration name from `antennalist` appended.

`project.[cfg].skymodel` = 4d input sky model image (optionally) scaled
`project.[cfg].skymodel.flat.regrid.conv` = input sky `regridded` to match the
output image, and convolved with the output synthesized beam
`project.[cfg].skymodel.png` = diagnostic figure of sky model with `pointings`

`project.[cfg].ptg.txt` = list of mosaic `pointings`
`project.[cfg].quick.psf` = `psf` calculated from `uv` coverage
`project.[cfg].ms` = noise-free measurement set
`project.[cfg].noisy.ms` = corrupted measurement set
`project.[cfg].observe.png` = diagnostic figure of `uv` coverage and
visibilities

`project.[cfg].image` = synthesized image
`project.[cfg].flux.pbcoverage` = `primary` beam correction for mosaic image
`project.[cfg].residual` = residual image after cleaning
`project.[cfg].clean.last` = parameter file of what parameters were used in
the clean task
`project.[cfg].psf` = synthesized beam calculated from weighted `uv`
distribution
`project.[cfg].image.png` = diagnostic figure of clean image and residual

`project.[cfg].fidelity` = fidelity image
`project.[cfg].analysis.png` = diagnostic figure of difference and fidelity

`project.[cfg].simdata.last` = saved input parameters for `simdata` task

Running simobserve interactively

1: start up CASA: `casapy`

2: `default("simobserve")`

3: `inp()`

4: manually set the various parameters

5: `go()` or `simobserve()`

repeat 4+5

This works the same way for *simanalyze* (or any other CASA task)

Running simobserve using a script

1: open yoursript.py in your favorite editor

2: start up CASA: `casapy`

3: `execfile("yoursript.py")`

edit yoursript.py and repeat 3

Things you (could) need

Tutorial material, to be found at <ftp://ftp.eso.org/pub/general/simdata/> :

- input models (skymodels): FITS files (or use your own !)
 - scripts / parameter settings: python files
 - Cycle 2 antenna configuration files (only for CASA 4.1 - they are included in CASA 4.2)
- Downloading 'ALL.tar' or 'ALL.zip' gets you all of these in one go.

OST: <http://almaost.jb.man.ac.uk/>

CASA (includes *simobserve*, *simanalyze*, *simalma*): <http://casa.nrao.edu/>

Simulation CASAguides starting point:

http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA_4.1

Simulating datacubes (advanced users):

[http://casaguides.nrao.edu/index.php?title=N891_simdata_\(CASA_3.4\)](http://casaguides.nrao.edu/index.php?title=N891_simdata_(CASA_3.4))

Useful tools:

- FITS viewer/editor: for example Fv (<http://heasarc.nasa.gov/lheasoft/ftools/fv/>)
- CosmoCalc: <http://www.astro.ucla.edu/~wright/CosmoCalc.html>

Things we need

Feedback on the simulators !

- bug reports (especially *almasim*)
- suggestions for improvement (always possible)
- interesting input models (for a casaguide)

Send feedback to evkampen@eso.org