ALMA simulators tutorial

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The two ALMA simulators

Expert users: the CASA simulator: simobserve / simanalyze / simalma

CASA ***tasks*** are 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 tasks (Python scripts) are a user-friendly interface to this tool with additional work done on plotting and analysis

Novice users: the web-based OST (webtool hosted by the UK ARC)

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

simobserve / simanalyze / simalma
What's new in CASA 4.3 ?

- tasknames have **not** been changed. Yay !
- improvements to *simalma*, which is now no longer earmarked as 'experimental'

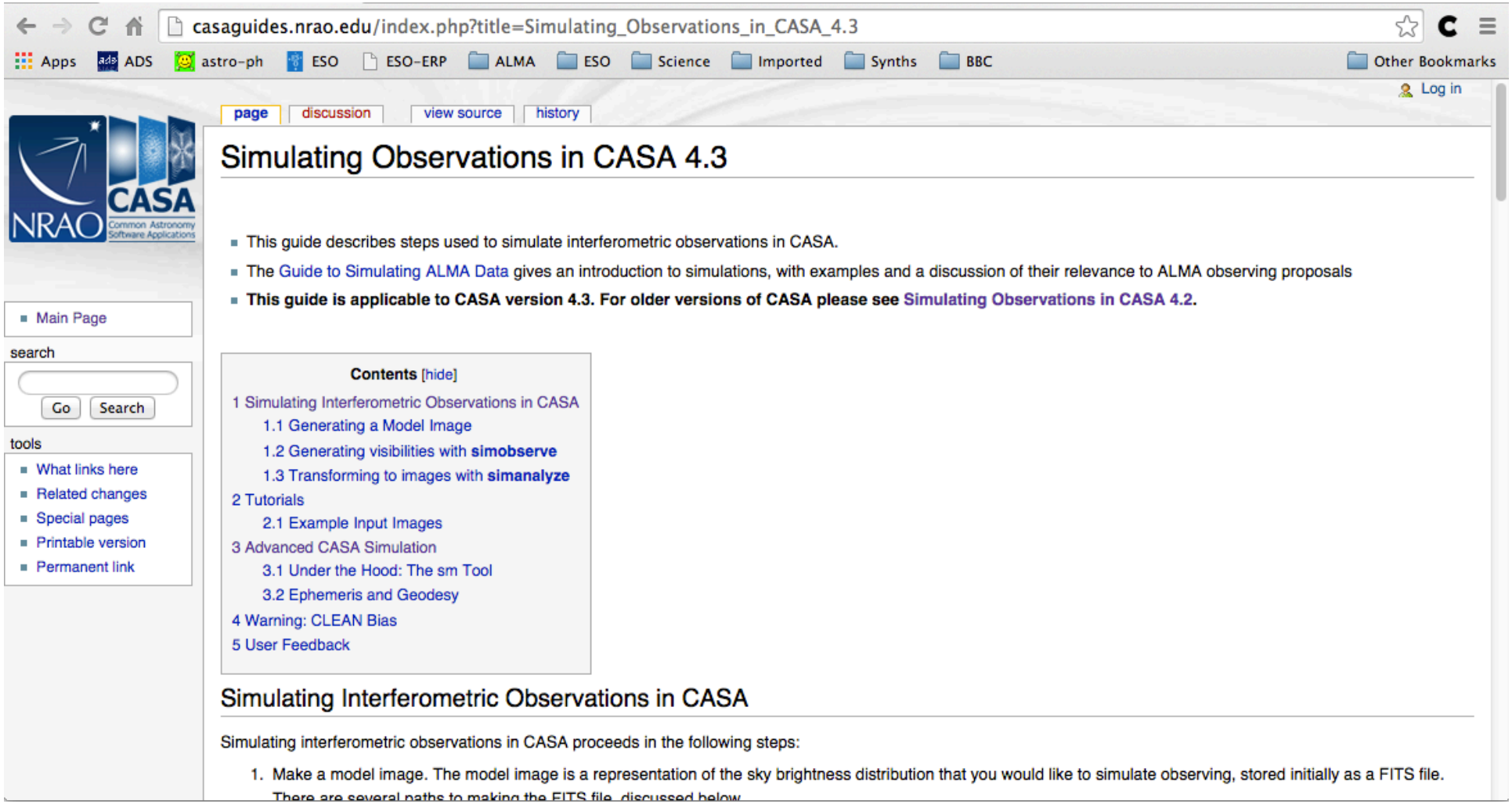
Note that *simalma* :

- only works for ALMA configurations
- runs in 'dry mode' (drymode=True) by default

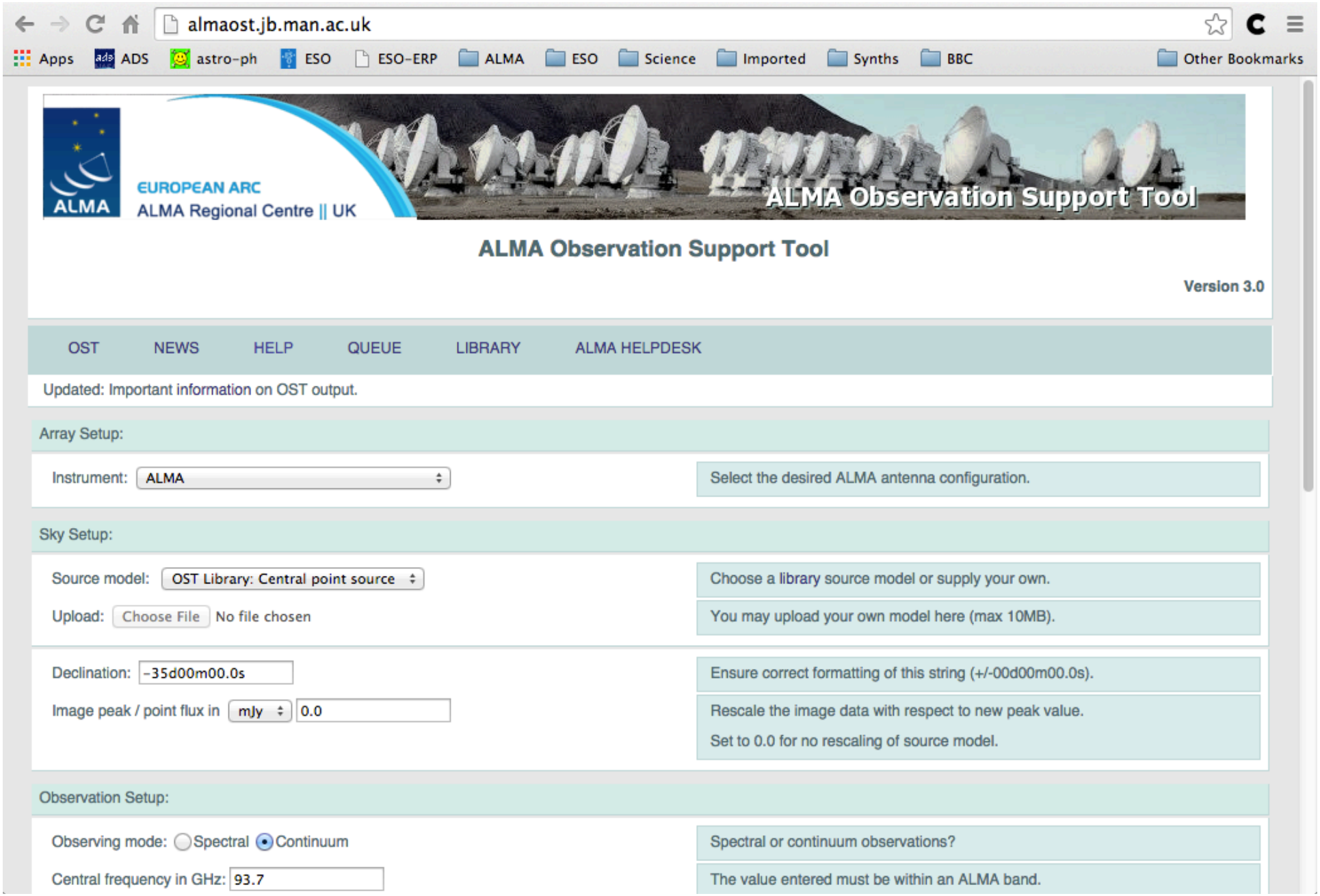
For details, type 'help simalma' in CASA, or check out the casaguides on simulations at http://casaguides.nrao.edu

on-line guide to simulation using CASA

Goto **casaguides.nrao.edu** and click on ‘Simulating Observations’ to get to:

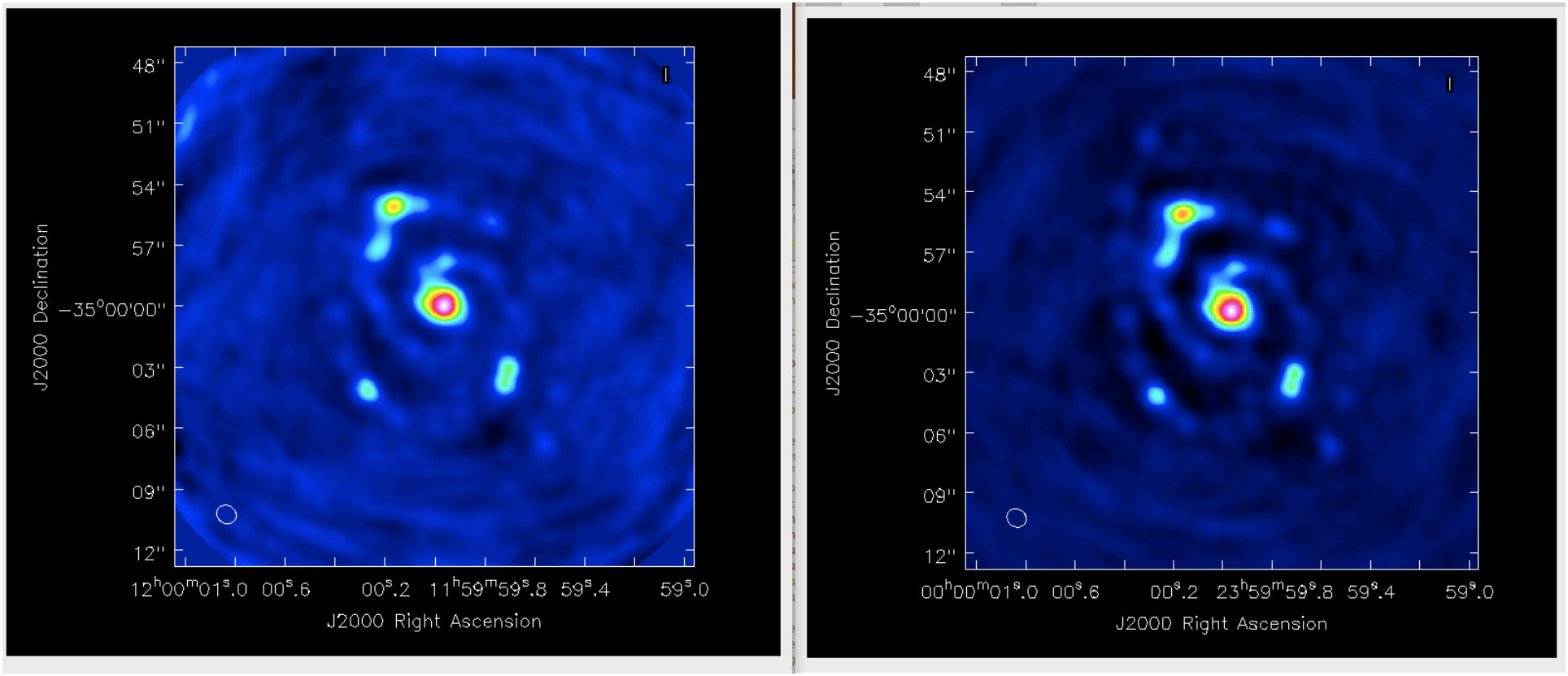


The OST (Observation Support Tool)



simobserve versus OST: images

simobserve OST



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

Note for proposers

In general, because the ALMA Sensitivity Calculator (ASC) will be used for the technical assessment of ALMA proposals, only values from the ASC should be used to estimate exposure times in ALMA proposals.

Representative Cycle 3 antenna configurations are included in CASA 4.3 and the OST, 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.

Default *simobserve* parameters

In CASA, type:

default('simobserve')

inp

```
#  simobserve :: visibility 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 ALMA default INT=lambda/D/sqrt(3),
                                        #   SD=lambda/D/3

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", "5h", "-4.5" (a number without units
                                        #   will be interpreted as hours), 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_pwv       =       0.5        #  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
```

Default *simanalyze* parameters

In CASA, type:

default('simanalyze')

inp

```
#  simanalyze :: image and analyze measurement sets created with simobserve
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     =         ''        #  lower resolution prior image to use in clean e.g. existing total power 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 e.g. "10arcsec" or "" to equal model
     interactive    =      False        #  interactive clean?  (make sure to set niter>0 also)
     niter          =          0        #  maximum number of iterations (0 for dirty image)
     threshold      =   '0.1mJy'        #  flux level (+units) to stop cleaning
     weighting      =  'natural'        #  weighting to apply to visibilities.  briggs will use robust=0.5
     mask           =         []        #  Cleanbox(es), mask image(s), region(s), or a level
     outertaper     =         []        #  uv-taper on outer baselines in uv-plane
     pbcor          =       True        #  correct the output of synthesis images for primary beam response?
     stokes         =        'I'        #  Stokes params to image
     featherimage   =         ''        #  image (e.g. total power) to feather with new 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
dryrun              =      False        #  only print information [experimental; only for interfermetric data]
logfile             =         ''
```

Default *simalma* parameters

In CASA, type:

default('simalma')

inp

```
#  simalma :: Simulation task for ALMA
project             =      'sim'        #  root prefix for output file names
dryrun              =       True        #  dryrun=True will only produce the informative report, not run simobserve/analyze
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

antennalist         = ['alma.cycle1.1.cfg', 'aca.cycle1.cfg'] #  antenna position files of ALMA 12m and 7m arrays
hourangle           =  'transit'        #  hour angle of observation center e.g. -3:00:00, or "transit"
totaltime           = ['20min', '1h']   #  total time of observation; vector corresponding to antennalist
tpnant              =          0        #  Number of total power antennas to use (0-4)
pwv                 =        0.5        #  Precipitable Water Vapor in mm. 0 for noise-free simulation
image               =       True        #  image simulated data
     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          =          0        #  maximum number of iterations (0 for dirty image)
     threshold      =    '0.1mJy'       #  flux level (+units) to stop cleaning

graphics            =     'both'        #  display graphics at each stage to [screen|file|both|none]
verbose             =      False
overwrite           =      False        #  overwrite files starting with $project
```

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: none of the 'full operations' antenna configurations are official yet !!

The representative (!) Cycle 3 antenna configuration files are all included in CASA 4.3, as well as those for Cycles 0, 1 and 2 (can be useful).

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
626693.00  7453811.00  5011.8  12.0       134
```

All antenna configurations included in CASA 4.3

WSRT.cfg
aca.all.cfg
aca.cycle1.cfg
aca.cycle2.i.cfg
aca.cycle2.ns.cfg
aca.cycle3.cfg
aca.i.cfg
aca.ns.cfg
aca.tp.cfg
aca_cycle1.cfg
alma.all.cfg
alma.cycle0.compact.cfg
alma.cycle0.extended.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
alma.cycle2.1.cfg
alma.cycle2.2.cfg
alma.cycle2.3.cfg
alma.cycle2.4.cfg
alma.cycle2.5.cfg
alma.cycle2.6.cfg
alma.cycle2.7.cfg
alma.cycle3.1.cfg
alma.cycle3.2.cfg
alma.cycle3.3.cfg
alma.cycle3.4.cfg
alma.cycle3.5.cfg
alma.cycle3.6.cfg
alma.cycle3.7.cfg
alma.cycle3.8.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

simobserve 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 clean 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].simobserve.last = saved input parameters for simobserve 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* and *simalma*

Running *simobserve* etc. using a script

1: open yourscript.py in your favorite editor

2: start up CASA: casapy

3: execfile(“yourscript.py”)

edit yourscript.py and repeat 3

Things you (could) need

OST: http://almaost.jb.man.ac.uk/
OST paper: http://lanl.arxiv.org/abs/1106.3516

CASA (includes *simobserve*, *simanalyze, simalma*): http://casa.nrao.edu/
Cycle 3 antenna configuration files are on the Science Portal – but included in CASA 4.3 !

CASA guides:
http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA_4.3
http://casaguides.nrao.edu/index.php?title=First_Look_at_Imaging

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

- suggestions for improvement (always possible)

- interesting input models (for the simulation database)

Send feedback to evkampen@eso.org