Using CASA to Simulate Interferometer Observations

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Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Simulating Interferometer Data

- Take a model image and simulate how it would look if observed by ALMA or the EVLA.
  - Other arrays (e.g., SMA, CARMA, etc.) also included

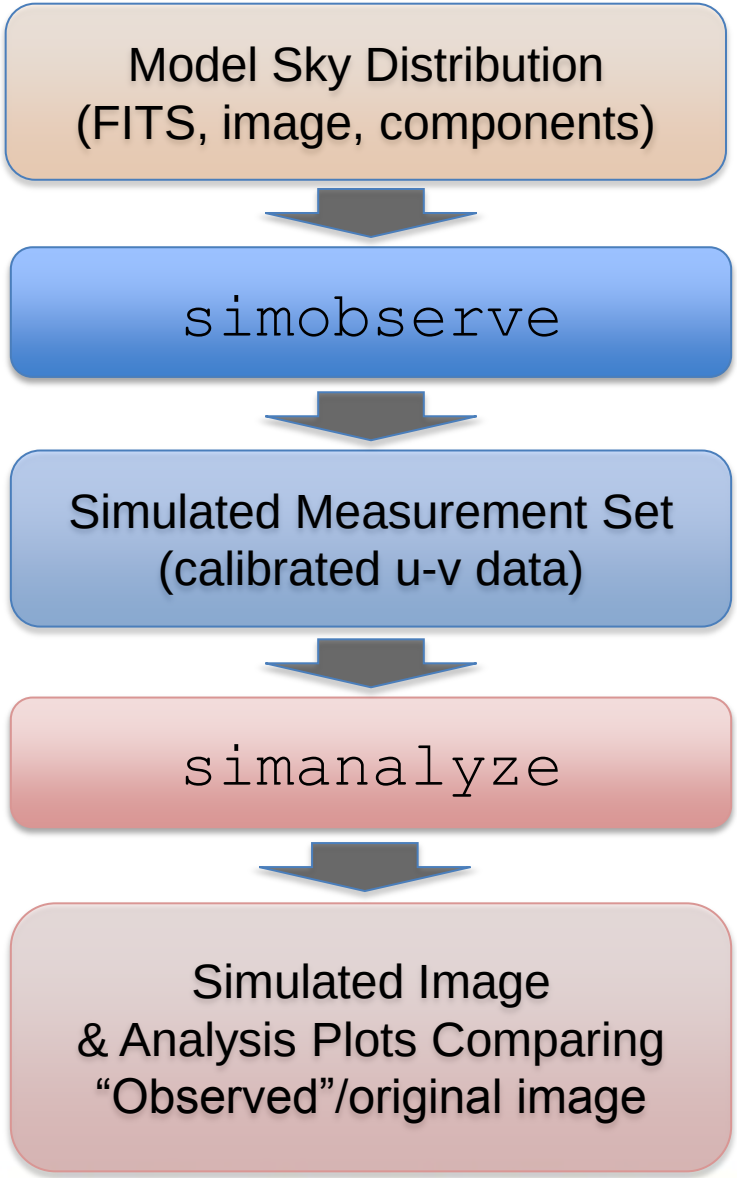
- Explore the effects of:
  - Number of antennas
  - Antenna configuration
  - Length of observation
  - Thermal noise
  - Phase noise

- Functionality included in CASA via tasks `simobserve` and `simanalyze` (nee `simdata`).

- CASAguides includes several walkthroughs: http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA

Basic Simulation Workflow

In CASA…



Simulation Tasks

- `simobserve` simulates interferometric (and single dish)observations of a source.
- `simanalyze` images and analyzes these simulations.

Visualization	Simulation	Single dish	Utility
clearplot	simanalyze	asap_init	browsetable
imview	simdata	sdbaseline	caltabconvert
msview	simobserve	sdcal	clearplot
plotants		sdcoadd	clearstat
plotcal		sdfit	concat
plotms		sdflag	conjugatevis
plotuv		sdflagmanager	find
plotxy		sdgrid	help par.parameter
viewer		sdimaging	help taskname
(plotweather)		sdimprocess	imview
		sdlist	msview
		sdmath	plotms
		sdplot	rmtables
		sdreduce	startup
		sdsave	taskhelp
		sdscale	tasklist
		sdsmooth	testconcat
		sdstat	toolhelp
		sdtpimaging	

"`tasklist`" output

simobserve

- simulates interferometer observations of a source.

```
#  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, 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        = 'Sopapilla'        #  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(...)
```

"`inp simobserve`" output

CASA Refresher

- In `casapy` type

  `default simobserve`

  `inp simobserve`

```
#  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, 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        = 'Sopapilla'        #  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(...)
```

CASA Refresher

- `inp` shows parameter names

```
#  simobserve :: mosa  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, 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    =  lma.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        =  opapilla        #  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(...)
```

Expandable parameter
(currently NOT expanded)

Expandable parameter
(currently expanded)

CASA Refresher

- `inp` shows current value (change, e.g., by `project = "myproj"`)

```
#  simobserve :: casaic 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, 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         = 'Sopapilla'        #  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(...)
```

Invalid Value

CASA Refresher

- `inp` shows brief description

```
#  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, 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        = 'Sopapilla'          #  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(...)
```

CASA Refresher

- Change values by

```
project = "myproj"
inp
```

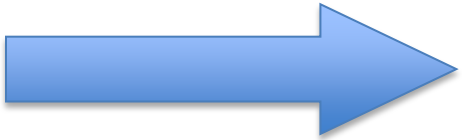
```
#  simobserve :: mosaic simulation task:
project             =   'myproj'        #  root prefix for output file names
                        ''
complist            =          ''       #  componentlist to observe
setpointings        =        True
     integration    =       '10s'       #  integration (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        =          ''       #  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(...)
```

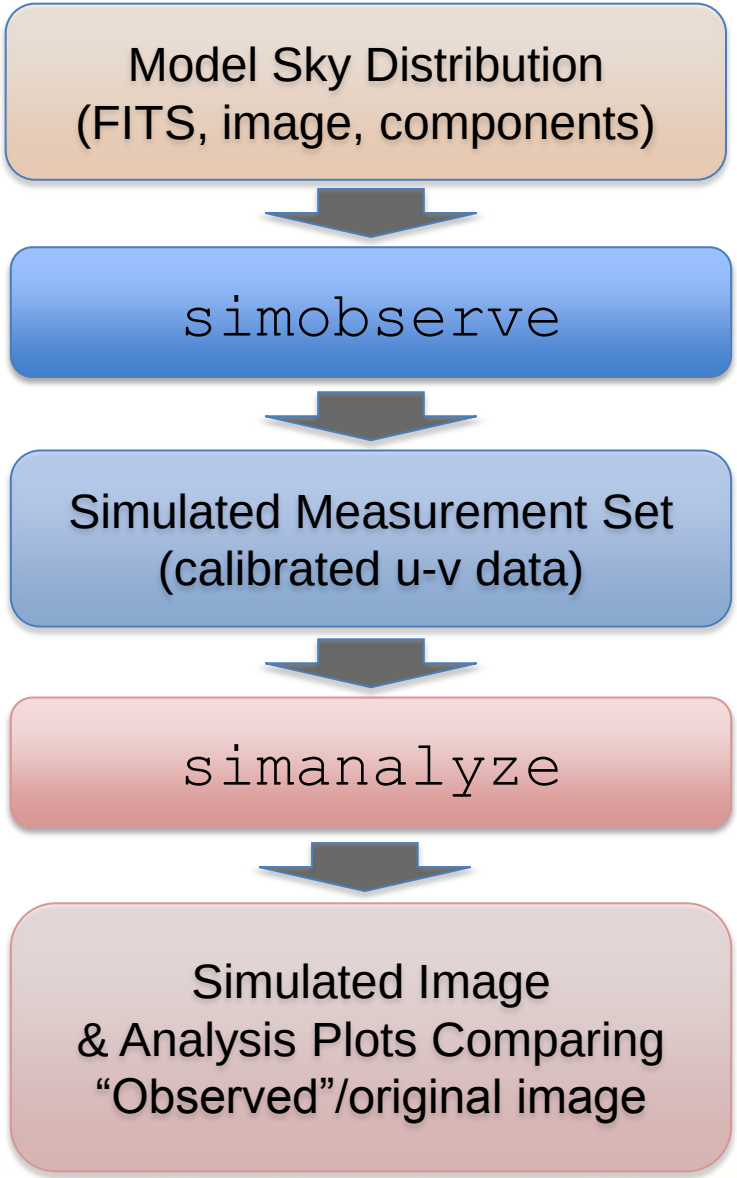
CASA Refresher

- When all parameters are set, execute with "`go simobserve`"
- If you get stuck:
  - Type "`tasklist`" to see all tasks
  - Type "`help taskname`" to get help on taskname
  - Type "`default taskname`" to set the default inputs
  - Type "`inp`" to review the inputs of the current task
  - Ask!

Basic Simulation Workflow

In CASA…





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What Defines a Simulation?

Model Sky Distribution
(Required)

What does the sky really look like in your field?

Telescope
(Required)

Number of Antennas, Configuration, Diameter

Observation
(Required)

Integration time, scan length, pointing centers

Corruption
(Optional)

Thermal noise, phase noise, polarization leakage

NRAO

simobserve

- Model sky distribution as FITS file or “component list”

```
#  simobserve :: mosaic simulation task:
project              =         'sim'  #  root prefix for output file names
skymodel             =          ''    #  model image to observe
complist             =          ''    #  component list 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         =  'Sopapilla'   #  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(...)
```

Model Sky Distribution
(Required)

What does the sky really look like in your field?

simobserve

- Telescope via configuration file.

```
#  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, 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  ...al 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 rotations
     caldirection   =         ''         #  pt source calibrator [experimental]
     calflux        =      '1Jy'

thermalnoise        = 'Sopapilla'        #  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(...)
```

Telescope
(Required)

Number of Antennas,
Configuration, Diameters

simobserve

- Observations defined via `setpointings` and `obsmode`

```
#  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, 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        = 'Sopapilla'        #  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
```

Observation
(Required)

Integration time, scan length, pointing centers

simobserve

- Corruption with `thermalnoise` & toolkit

```
#  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, 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        = 'Sopapilla'        #  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
```

Corruption
(Optional)

Thermal noise, phase noise, polarization leakage

simobserve

- Model sky distribution as FITS file or “component list”

```
#  simobserve :: mosaic simulation task:
project              =         'sim'  #  root prefix for output file names
skymodel             =          ''    #  model image to observe
complist             =          ''    #  component list 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         =  'Sopapilla'   #  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(...)
```

Model Sky Distribution
(Required)

What does the sky really look like in your field?

Input Sky Model

- Model sky distribution as FITS file. `simobserve` needs:
  - Coordinates
  - Brightness units
  - Pixel scale (angular and spectral)
  - Polarization*
- These may be specified in your FITS header or supplied/over-written by `simobserve`.

```
skymodel        = '30dor.fits'
    inbright    =          ''
    indirection =          ''
    incell      =          ''
    incenter    =          ''
    inwidth     =          ''

complist        =          ''      #  componentlist to observe
```

```
#  model image to observe
#  scale surface brightness of brightest pixel e.g. "1.2Jy/pixel"
#  set new direction e.g. "J2000 19h00m00 -40d00m00"
#  set new cell/pixel size e.g. "0.1arcsec"
#  set new frequency of center channel e.g. "89GHz" (required even for 2D model)
#  set new channel width e.g. "10MHz" (required even for 2D model)
```

Input Sky Model

- Alternatively, supply a Gaussian “component list.” Example at:

http://casaguides.nrao.edu/index.php?title=Simulation_Guide_Component_Lists_(CASA_3.3)

```
skymodel        = '30dor.fits'    #  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
```

Simulation Guide Component Lists (CASA 3.3)

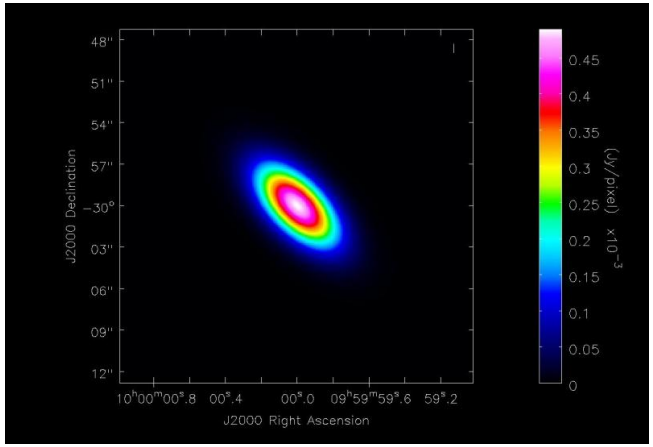
Simulating Observations in CASA

This guide is applicable to CASA version 3.3.

To create a script of the Python code on this page see Extracting scripts from these tutorials.

Contents [hide]

Explanation of the guide



Simple Example

- Simulate observing 1mm dust continuum in a 30-Doradus (LMC)-like region at the distance of M31/M33 (800 kpc).

- We have a near-IR image of 30 Doradus, will need to:

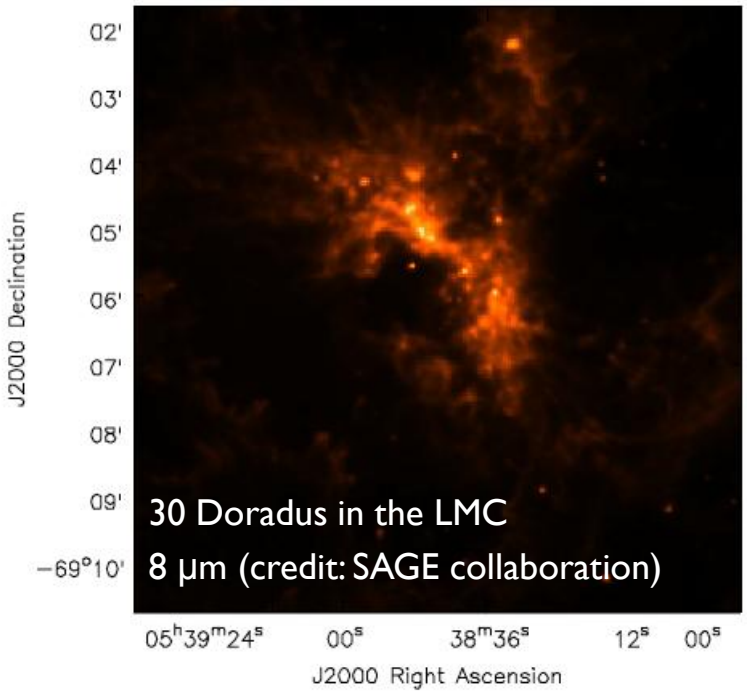
  - Scale the brightness and observing frequency

  - Adjust the pixel scale
    (move it from 50-800 kpc)

  - Set a new position

  - Define the observations
    INTEGRATION TIME, TELESCOPE, ETC.

Our Model



NRAO

Simple Example

```
skymodel        = '30dor.fits'
    inbright    =         ''
    indirection =         ''
    incell      =         ''
    incenter    =         ''
    inwidth     =         ''

complist        =         ''
```

```
#  model image to observe
#  scale surface brightness of brightest pixel e.g. "1.2Jy/pixel"
#  set new direction e.g. "J2000 19h00m00 -40d00m00"
#  set new cell/pixel size e.g. "0.1arcsec"
#  set new frequency of center channel e.g. "89GHz" (required even for 2D model)
#  set new channel width e.g. "10MHz" (required even for 2D model)

#  componentlist to observe
```

- inbright = “0.6mJy/pixel”
  REQUIRES SPECTRAL MODEL/OTHER KNOWLEDGE TO ESTIMATE (SCIENCE!)
- Indirection = “J2000 10h00m00s -40d00m00s”
- `incell`=“0.15arcsec”
  NATIVE CELL SIZE = 2.3”, MOVING FROM 50 KPC□800 KPC SCALE BY 50/800
- `incenter`=“230GHz”, `inwidth`=“2GHz”
  NEED TO SUPPLY OBSERVING FREQUENCY & BANDWIDTH (HERE 1MM DUST CONTINUUM)

Simple Example

```
skymodel        = '30dor.fits'      #  model image to observe
inbright        = '0.6mJy/pixel'    #  scale surface brightness of brightest pixel e.g. "1.2Jy/pixel"
indirection     = 'J2000 10h00m00s -40d00m00s' #  set new direction e.g. "J2000 19h00m00 -40d00m00"
incell          = '0.15arcsec'      #  set new cell/pixel size e.g. "0.1arcsec"
incenter        =   '230GHz'        #  set new frequency of center channel e.g. "89GHz" (required even for 2D model)
inwidth         =     '2GHz'        #  set new channel width e.g. "10MHz" (required even for 2D model)
```

- inbright = “0.6mJy/pixel”
  REQUIRES SPECTRAL MODEL/OTHER KNOWLEDGE TO ESTIMATE (SCIENCE!)
- Indirection = “J2000 10h00m00s -40d00m00s”
- `incell`=“0.15arcsec”
  NATIVE CELL SIZE = 2.3”, MOVING FROM 50 KPC□800 KPC SCALE BY 50/800
- `incenter`=“230GHz”, `inwidth`=“2GHz”
  NEED TO SUPPLY OBSERVING FREQUENCY & BANDWIDTH (HERE 1MM DUST CONTINUUM)

simobserve

- Telescope via configuration file.

```
#  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, 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        = 'Sopapilla'        #  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(...)
```

Telescope
(Required)

Number of Antennas, Configuration, Diameter

Configuration Files

- Define telescope array for `simobserve`.

Config Files in CASA Already

ALMA, EVLA, CARMA, SMA, etc.

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

Example Config File: ALMA Cycle 1 ACA

```
# observatory=ACA
# coordsys=LOC (local tangent plane)
# ACA-9-02
# x y z diam pad#
-47.99531371    -564.8585951    -2.318302577   7.  J501
-55.96985522    -568.8204563    -2.321721131   7.  J502
-48.84480314    -574.4357151    -2.325168129   7.  J503
# -35.89239576  -569.6206755    -2.318648465   7.  J504
-65.31846157    -560.7014943    -2.320087842   7.  J505
-63.03702802    -574.7165969    -2.320317857   7.  J506
-36.9451361     -560.0096901    -2.312799631   7.  J507
-49.2177138     -555.3091122    -2.31446963    7.  J508
# -58.07695154  -555.2943694    -2.318542758   7.  J509
# -58.44032563  -583.1862979    -2.322046322   7.  J510
-50.54653873    -587.383557     -2.319365815   7.  J511
-40.68629067    -577.980051     -2.318432548   7.  J512
```

x *y* *z* diameter name

Configuration Files

- Pick an intermediate-extent full-ALMA configuration

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

simobserve

- Observations defined via `setpointings` and `obsmode`

```
#  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, 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        = 'Sopapilla'        #  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
```

Observation
(Required)

Integration time, scan length, pointing centers

setpointings

- `setpointings` dictates field, integration time, mosaic

```
setpointings        =       True
     integration    =     '600s'       #  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
```

- `integration` sets data averaging (and field visit) time
  HERE AVERAGING 600S (10M) ENSURES A QUICK INITIAL EXECUTION

- `direction` sets field or map center

- `mapsize`, `maptype`, `pointingspacing` define a mosaic
  BY DEFAULT IT WILL COVER THE MODEL, HERE THAT MEANS A 9-POINT MOSAIC

obsmode

- `obsmode` sets total time, date, observing sequence

```
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'
```

- `totaltime` sets total observation direction
  HERE 7200S IS A TYPICAL ALMA OBSERVATION DURATION

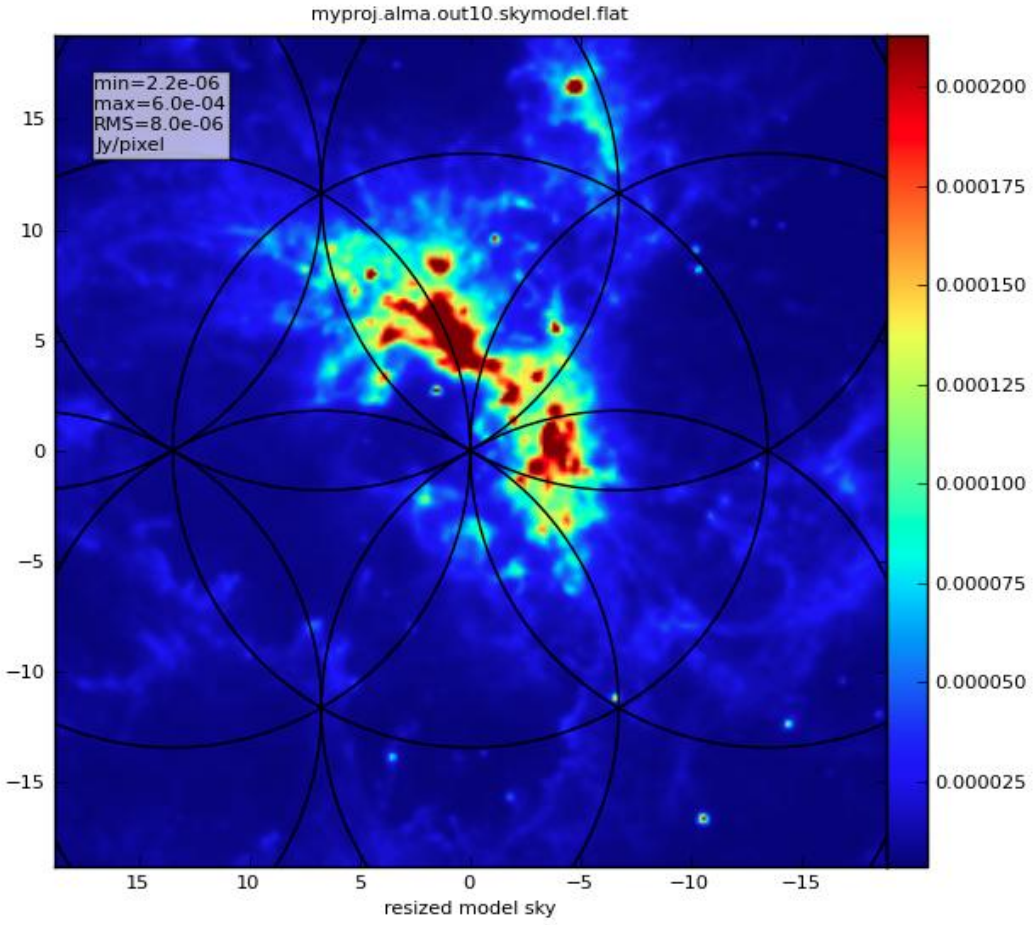
- Optionally specify the date, LST, and a calibrator sequence.

`go simobserve`

SIMOBSERVE CREATES A MEASUREMENT SET (MS) IN
`projectname/projectname.ms`

skymodel image

- `simobserve` outputs diagnostic plots to project directory
  TEXT FILES SHOW THE LOCATION OF POINTING CENTERS (OR `LISTOBS`)



simobserve

- Corruption with `thermalnoise` & toolkit

```
#  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, 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        = 'Sopapilla'        #  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
```

Corruption
(Optional)

Thermal noise, phase noise, polarization leakage

Multiple sets of observations

- One can simulate multiple sets of observations with multiple calls to simobserve
  - Simulate combining data from compact and extended arrays
  - Simulate combining data from interferometers and single dish telescopes
- The CLEAN task can take multiple measurement sets to combine interferometric observations
- The FEATHER task can combine single dish and interferometric observations

thermalnoise

- Set observing conditions to add random noise to image

- See CASAguides and toolkit for other ways to corrupt data.
  E.G., PHASE NOISE

- We will make a noisy and a not-noisy version to compare.

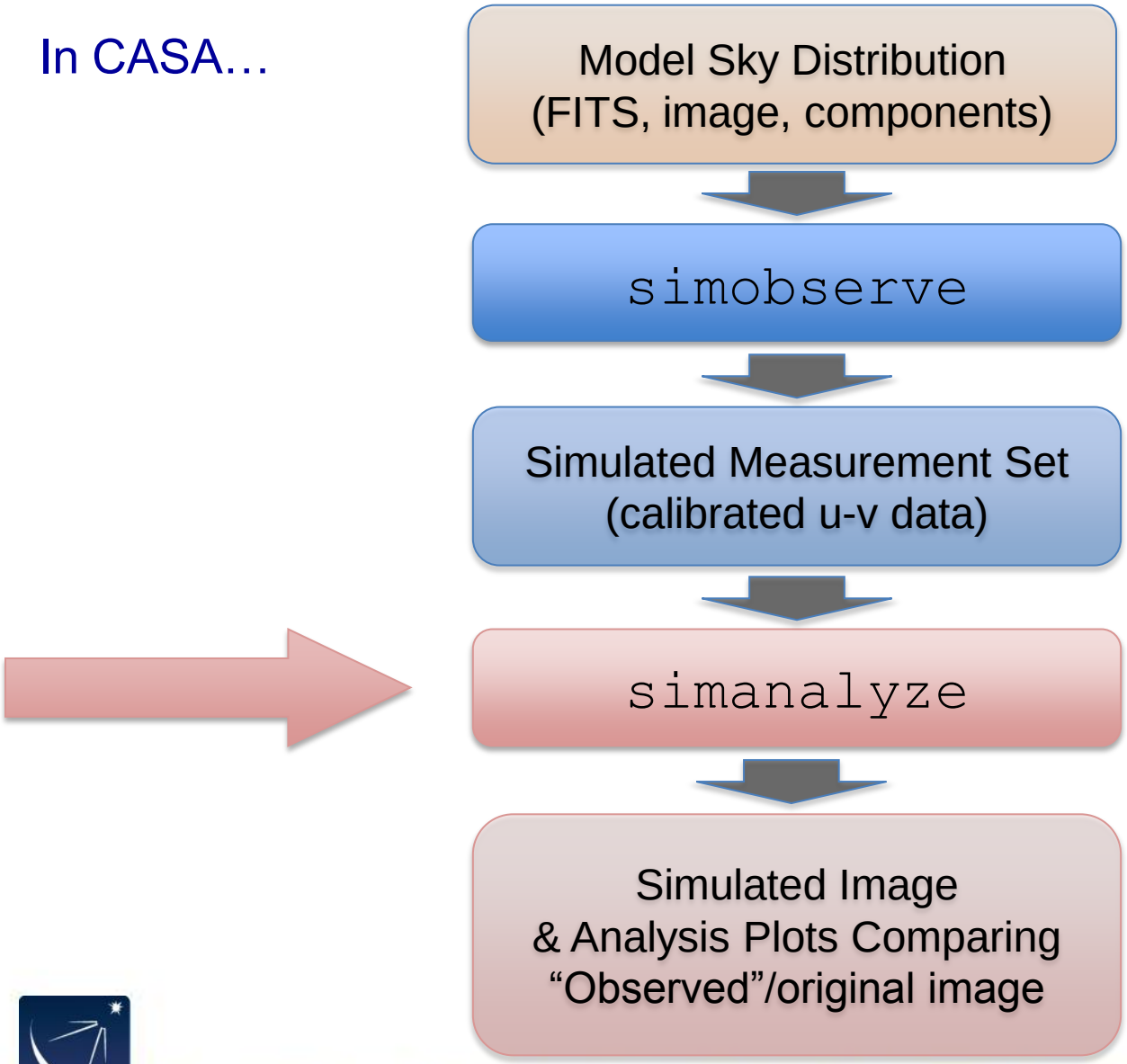
  - MAKE SURE TO SHOW THIS,
    OR NOT SAY IT

`go simobserve`

SIMOBSERVE CREATES A MEASUREMENT SET (MS) IN
`projectname/projectname.ms`

Basic Simulation Workflow

In CASA…



simanalyze

- Image and analyze `simobserve` output

```
CASA <8>: inp simanalyze
--------> inp(simanalyze)
#  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(...)
```

image

- Grid, invert, and CLEAN the simulated data set.

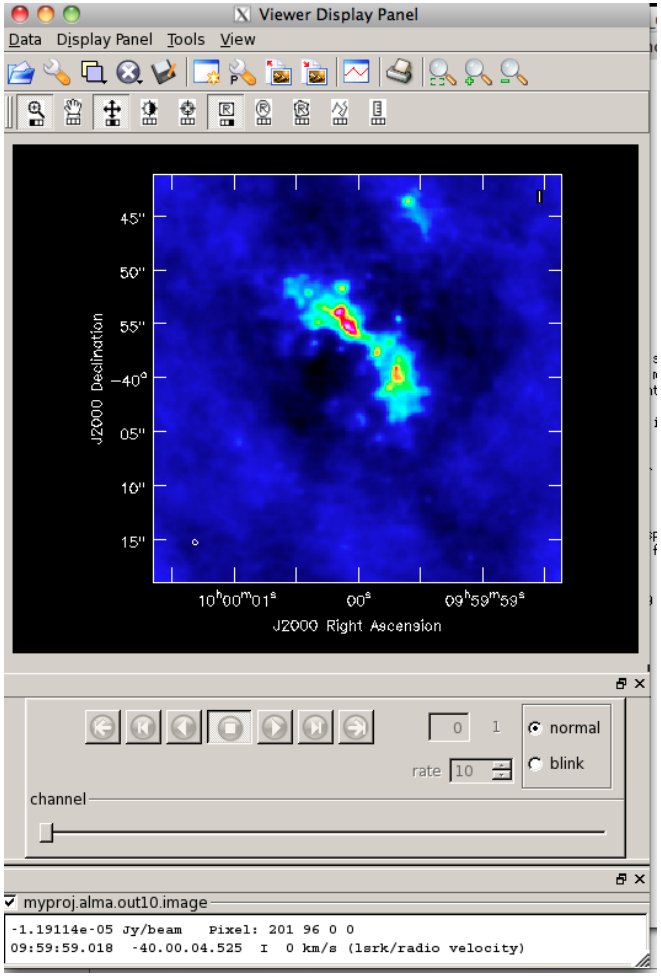
```
image          =       True   #  (re)image $project.*.ms to $project.image
     vis       =  'default'   #  Measurement Set(s) to image
     modelimage =         ''  #  prior image to use in clean e.g. existing single dish image
     imsize    =          0   #  output image size in pixels (x,y) or 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
```

- Similar but reduced options compared to CLEAN.
  DEFAULTS ARE “SMART”, INFORMED BY THE MODEL.

- You can also image the simulated observations with CLEAN.
  THEY ARE A NORMAL CASA MEASUREMENT SET FOR ALL PURPOSES

image

- Output files can be examined with the CASA viewer.
  IN CASA 3.4 THESE LIVE IN `projectname/projectname.image`



analyze

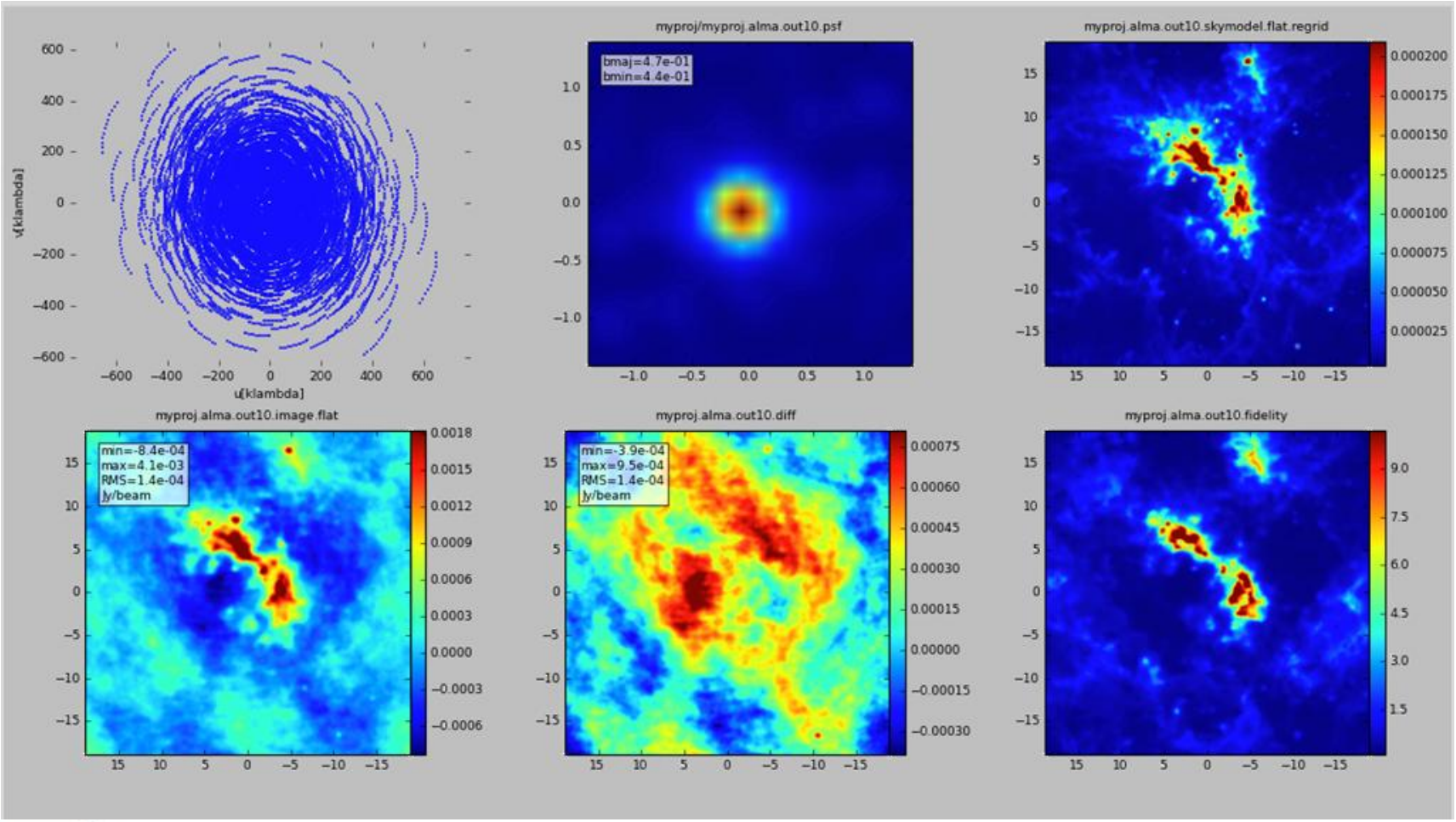
- Create diagnostic plots based on `simobserve` and image

```
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
```

- Pick up to 6 of these.

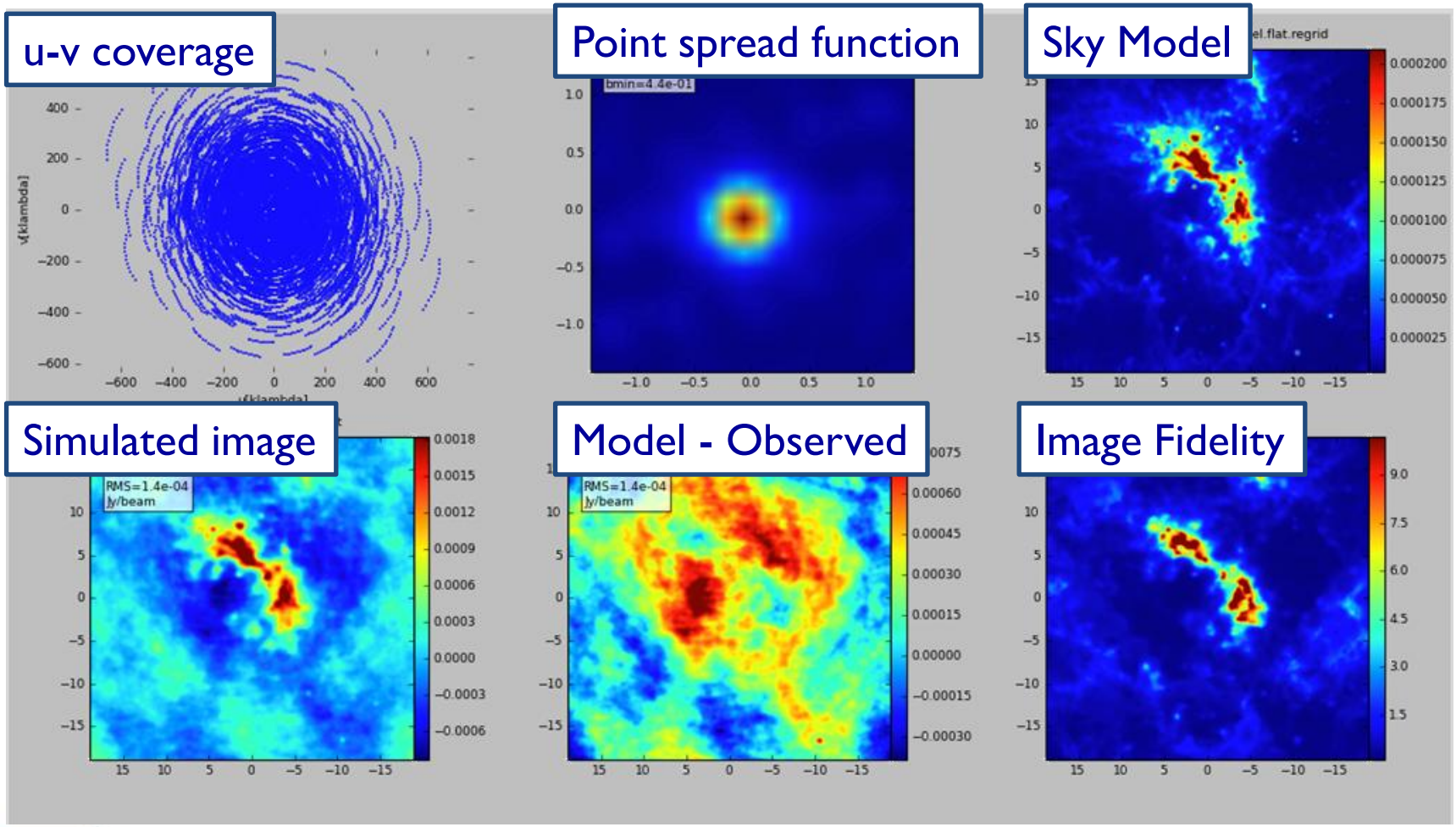
analyze

- Create diagnostic plots based on `simobserve` and image



analyze

- Create diagnostic plots based on `simobserve` and image



Try It Yourself!

- Simulate one of the suite of model images at http://casaguides.nrao.edu/index.php?title=Sim_Inputs