ALMA simulation for proposals

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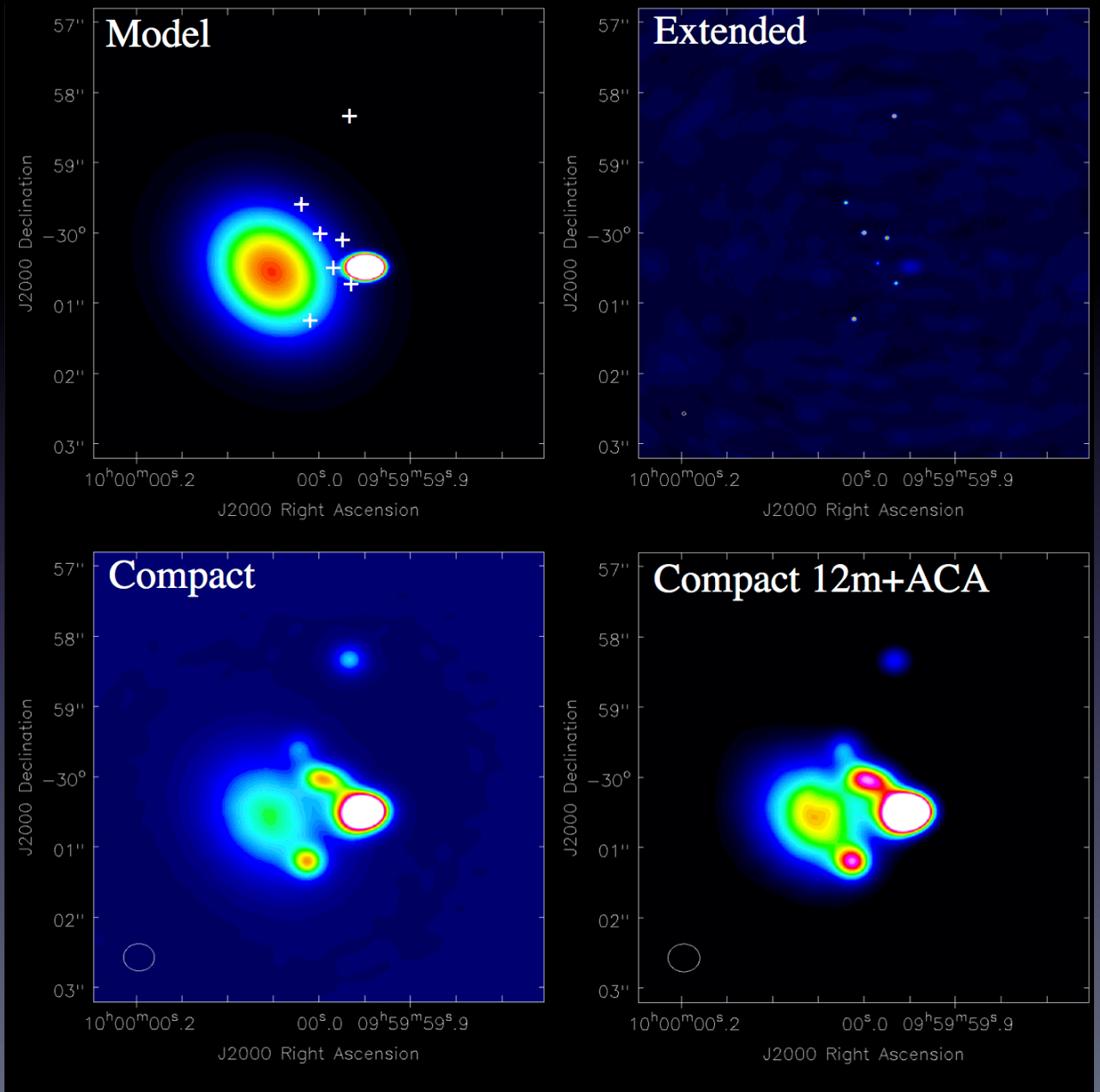
Why?

- Mock observations of ALMA
- Not necessary, however:
- Show whether your science can be done by ALMA
- Verify what you need for your science goals: e.g., which configurations

- Comparison of different array configurations



http://casaguide.nrao.edu

Basics of Interferometry

- Interferometer data : uv visibility

  - Power corresponding to the correlation of the waves received at two antennas

  - FT relation with sky intensity

  - (u, v) coordinates

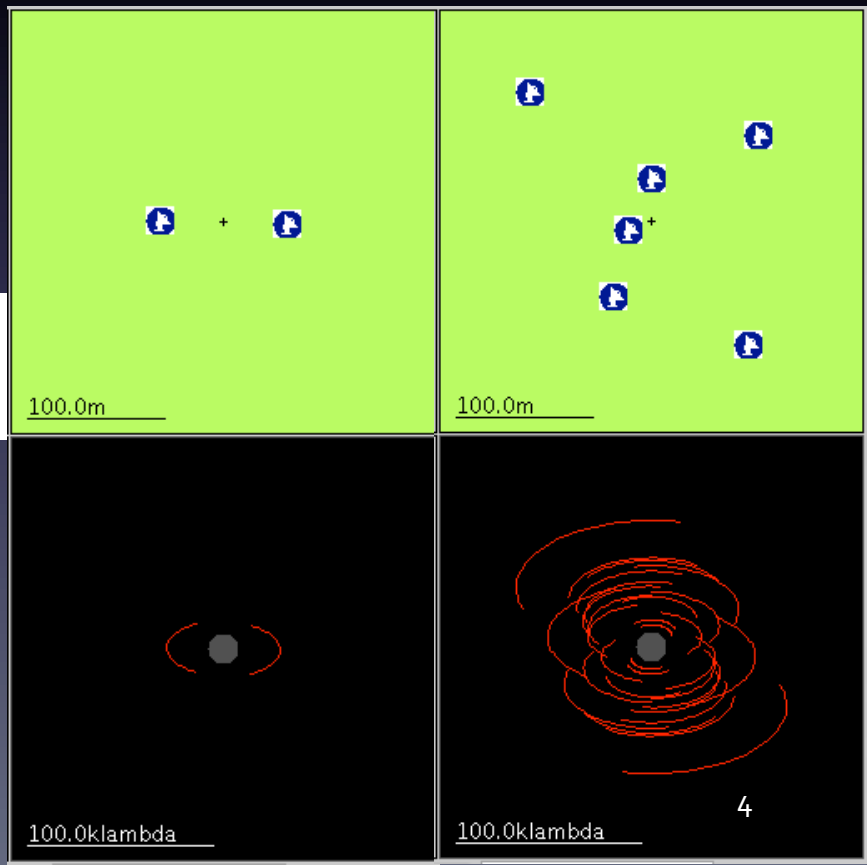
$$V(u,v) \rightleftarrows A_N(l,m)I(l,m).$$

$$S(u,v)V(u,v) \rightleftarrows FT^{-1}[S(u,v)] * FT^{-1}[V(u,v)]$$
$$B_D(l,m) * [A_N(l,m)I(l,m)].$$

- Keywords

  uv coverage, uv distance,

  synthesized beam, primary beam…



$$V(u,v) \rightleftarrows A_N(l,m)I(l,m).$$

$$\begin{aligned} S(u,v)V(u,v) &\rightleftarrows FT^{-1}[S(u,v)] * FT^{-1}[V(u,v)] \\ &\quad B_D(l,m) * [A_N(l,m)I(l,m)]. \end{aligned}$$

- Simulating interferometric data (visibilities)
  1. sky intensity distribution: I(l,m)
  2. primary beam correction: A_N(l,m) I(l,m)
  3. FT
  4. Sampling in V(u,v) → S(u,v) V(u,v)
- Interferometric data reduction
  1. data: S(u,v) V(u,v)
  2. IFT
  3. de-convolution of B_D(l,m) to find A_N(l,m) I(l,m)

Two approaches

- CASA simulation tools
- Observation support tool (OST)

  EU ARC, University of Manchester

  Web-based

  http://almaost.jb.man.ac.uk

CASA 123

- Common Astronomy Software Applications

  http://casa.nrao.edu
- Install CASA - version 4.3.1
- > casapy

  : tasklist

  : taskhelp

  : inp(<task>)

  : project = 'sim' (example of putting in a parameter value)

  .....

  : go (or a task name)

CASA simulation tools

- CASA version 4.3
  http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA_4.3
- Simobserve
  generate visibilities
- Simanalyze
  produce a cleaned image
- (Simalma)
  particular cases with total power antennas

Caveats

- RMS noise should not be used for proposals
- 20% underestimates for both surface brightness and total flux in single dish maps

What you need

- Possible starting points: e.g.,

  images taken at a different wavelength

  numerical simulation results

  knowledge on object size and total flux

Simobserve

```
CASA <32>: inp
---------> inp()
#  simobserve :: visibility simulation task
project             =      'sim'        #  root prefix for output file names
skymodel            = '30dor.fits'      #  model image to observe
     inbright       = '0.06mJy/pixel'   #  scale surface brightness of brightest pixel
                                        #   e.g. "1.2Jy/pixel"
     indirection    = 'J2000 10h00m00 -40d00m00' #  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)

complist            =         ''        #  componentlist to observe
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 (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.cycle3.1.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'
```

- Generate visibilities
- 30 Dor

```
thermalnoise        = 'tsys-atm'        #  add thermal
     user_pwv       =       0.5         #  Precipitable
     t_ground       =     269.0         #  ambient temp
     seed           =     11111         #  random numbe

leakage             =       0.0         #  cross polari
graphics            =    'both'         #  display grap
                                        #   [screen|fil

verbose             =     False
overwrite           =      True         #  overwrite fi

CASA <29>:
```

- Outputs:

  sim.alma.cycle3.1.ms/

  sim.alma.cycle3.1.noisy.ms/

  sim.alma.cycle3.1.observe.png

  sim.alma.cycle3.1.ptg.txt

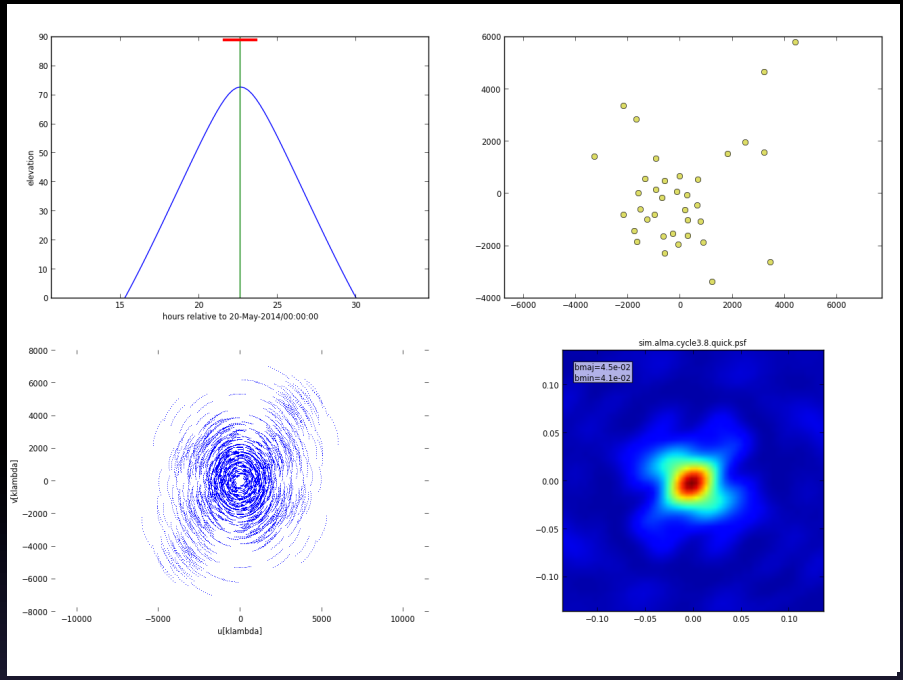
  sim.alma.cycle3.1.quick.psf/

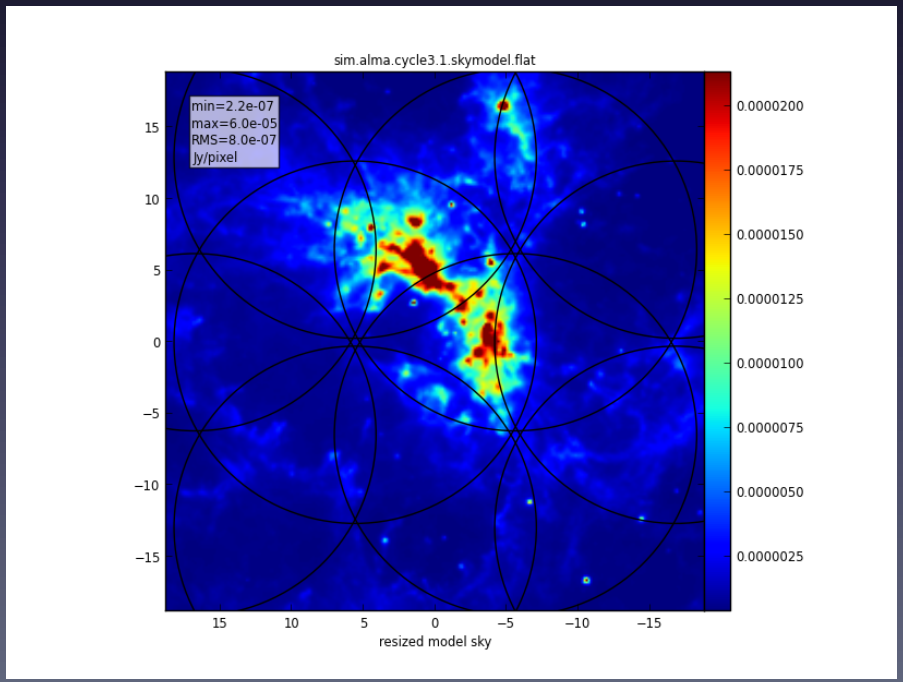
  sim.alma.cycle3.1.simobserve.last

  sim.alma.cycle3.1.skymodel/

  sim.alma.cycle3.1.skymodel.flat/

  sim.alma.cycle3.1.skymodel.png



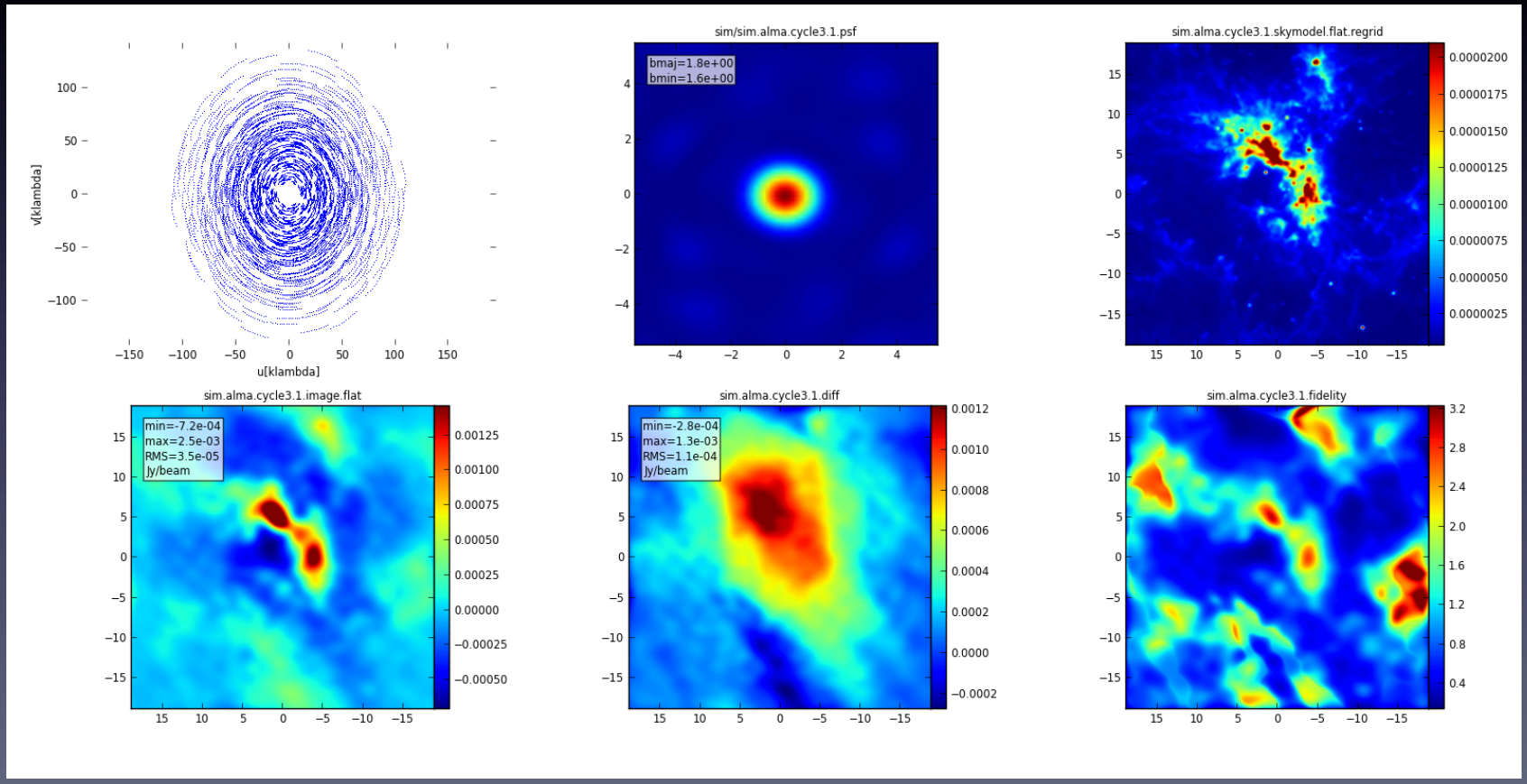


Simanalyze

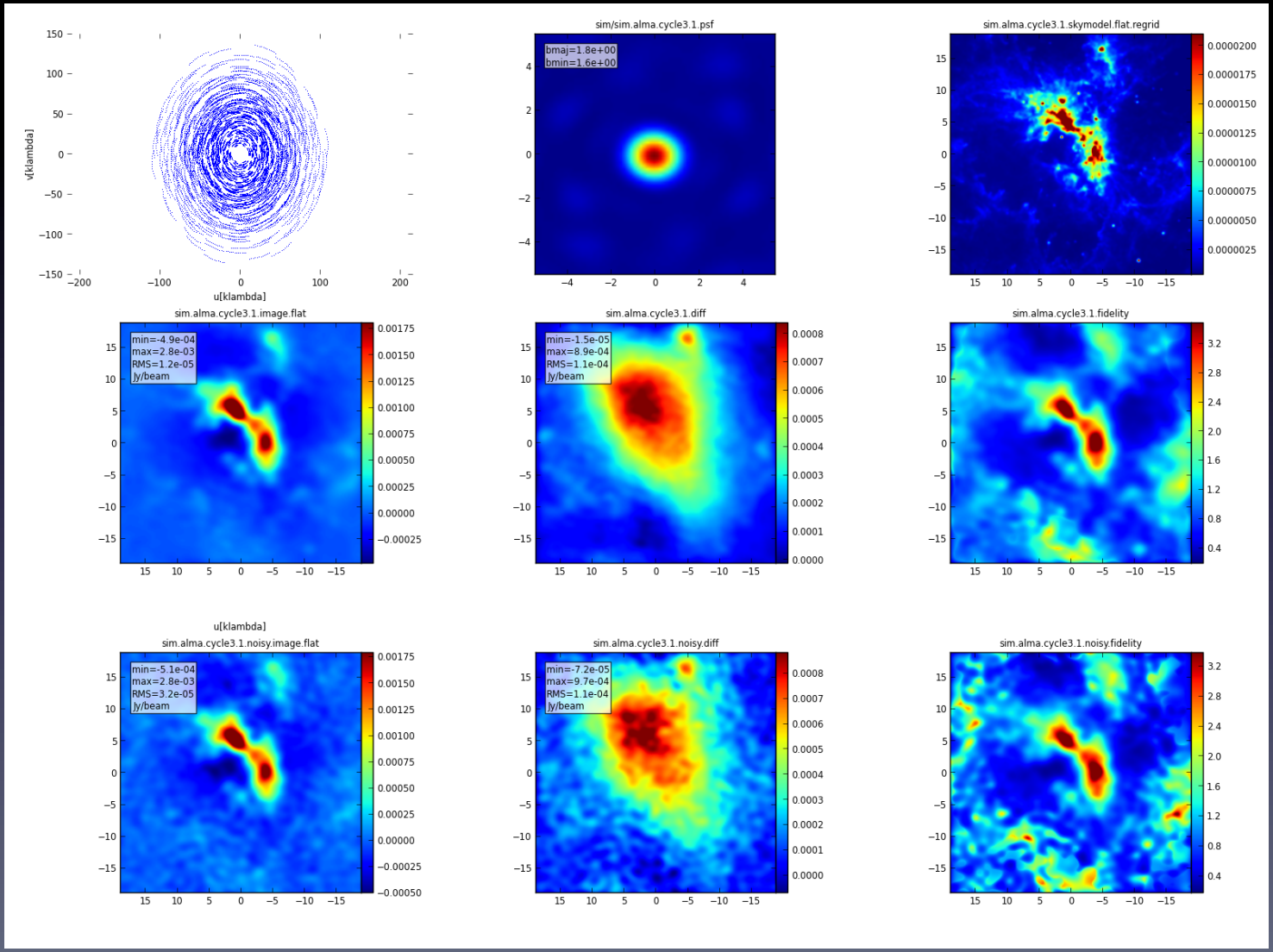
```
CASA <46>: inp
---------> inp()
#  simanalyze :: image and analyze measurement sets created with simobserve
project             =       'sim'        #  root prefix for output file names
image               =        True        #  (re)image $project.*.ms to $project.image
     vis            = 'sim.alma.cycle3.1.ms' #  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           = '0.15arcsec'       #  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             =        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 clean
                                         #   beam
     showclean      =        True        #  display the synthesized image
     showresidual   =       False        #  display the clean residual image (ignored in
                                         #   single dish simulation)
     showdifference =        True        #  display differen
                                         #   and input model
                                         #   output clean be
     showfidelity   =        True        #  display fidelity

graphics            =      'both'        #  display graphics
                                         #   [screen|file|bo
verbose             =       False
overwrite           =        True        #  overwrite files
dryrun              =       False        #  only print infor
                                         #   interfermetric
logfile             =          ''

CASA <47>:
```

- Generate (cleaned) image

- Outputs: uv coverage, dirty beam, model,
  (clean) image, difference, fidelity
- viewer



- Comparison of cases with and without noise



OST

- Web-based
- Results can be delayed depending on job load
- http://almaost.jb.man.ac.uk

ALMA Observation Support Tool

Version 3.0

OST | NEWS | HELP | QUEUE | LIBRARY | ALMA HELPDESK

Updated: Important information on the new OST version.

Array Setup:

Instrument: ALMA — Select the desired ALMA antenna configuration.

Sky Setup:

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

Upload: Choose File No file chosen — You may upload your own model here (max 10MB).

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

Image peak / point flux in mJy 0.0 — Rescale the image data with respect to new peak value. Set to 0.0 for no rescaling of source model.

Observation Setup:

Observing mode: ○ Spectral ◉ Continuum — Spectral or continuum observations?

Central frequency in GHz: 93.7 — The value entered must be within an ALMA band.

Bandwidth in MHz: 32 — Select the total bandwidth for continuum observations. Enter 7.5 GHz to select ALMA recommend full continuum setup.

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

Required resolution in arcseconds: 1.0 — OST will choose array config based on this value if *instrument* is set to ALMA.

Pointing strategy: Mosaic — Selecting single will apply primary beam attenuation.

On-source time in hours: 3 — Per pointing for mosaics.

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

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

Include cycling to phase calibrator?: ○ Yes ◉ No — This affects the *uv*-coverage of your simulation.

Atmospheric Corruption:

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

Imaging Product:

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

Submission:

Your email address is essential! — Submit

30 Dor

EUROPEAN ARC
ALMA Regional Centre || UK

ALMA Observation Support Tool

Job ID: 20150402023018ygikV / Submitted by: wkwon@kasi.re.kr

Messages

- The brightness unit of your uploaded sky model was not recognised and has been adjusted to Jy/pixel.

You should carefully check that your sky model remains sensible, and consider tuning the rescaling value to compensate for any discrepancies.

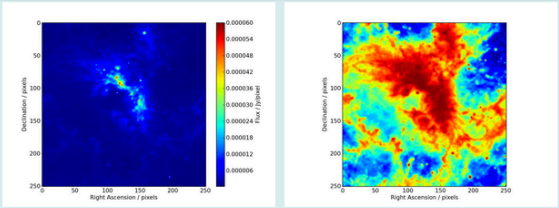
- The peak pixel of your model image has been rescaled to 0.06 mJy
- The maximum image dimension that can be processed is 2048 pixels, thus a portion of the model may be outside of your simulated map.

Consider relaxing the resolution demands or simulating a smaller patch of sky.

- Your simulated observation requires more than 30 pointing directions. To prevent clutter these have not been plotted on the images below.

Overview

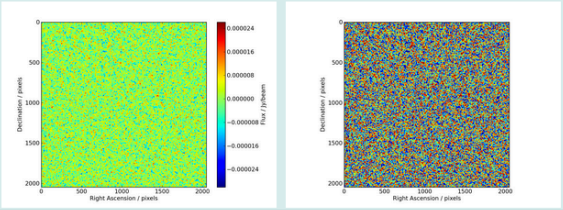
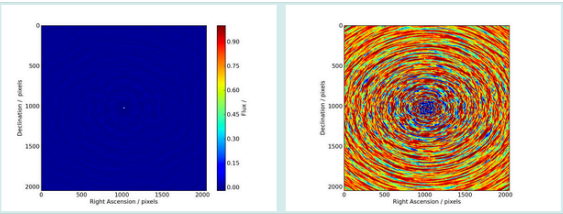
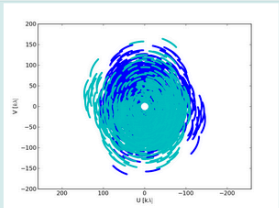
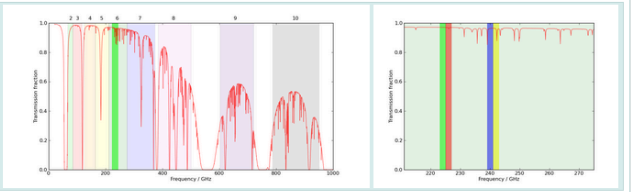
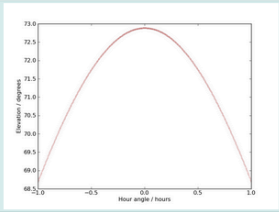
Click thumbnails to view full-size images. Left: linear colour scale, right: with histogram equalization.

Array configuration:	ALMA out02
Source model:	30dor.fits
Input image:	
Maximum elevation:	72.88 degrees
Central frequency:	230 GHz (ALMA Band 6)
Total Bandwidth:	7.5 GHz
Track length:	2 hours × 1.0 visits
Hexagonal mosaic pointings :	1817 required to cover requested sky area with uniform sensitivity
System temperature:	Tsys = 83.1356846157 K
PWV :	0.475 mm
Theoretical RMS noise:	6.25586380064e-06 Jy (in naturally-weighted map)
Restoring beam (resolution):	Major axis = 1.68 arcsec, minor axis = 1.528 arcsec, PA = 92.712 deg

For use with CASA simdata

Input sky model:	Download processed model in FITS format
Download CASA simobserve/analyze file:	20150402023018ygikV.simdata.last
Download pointing file:	20150402023018ygikV.ptg.txt

Data products

Your simulated image: Download FITS file	
Dirty Beam (Point Spread Function):	
Coverage in the *uv*-plane:	
Atmospheric transmission for all bands (left) and the selected band (right)	
Elevation vs time:	

NGC 1333

EUROPEAN ARC
ALMA Regional Centre || UK

ALMA Observation Support Tool

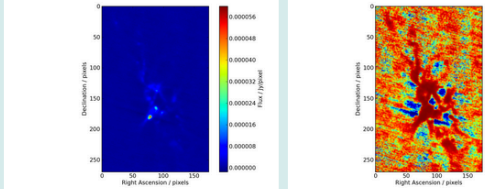
Job ID: 20150402103725KcYKi / Submitted by: wkwon@kasi.re.kr

Messages

- The peak pixel of your model image has been rescaled to 0.06 mJy

Overview

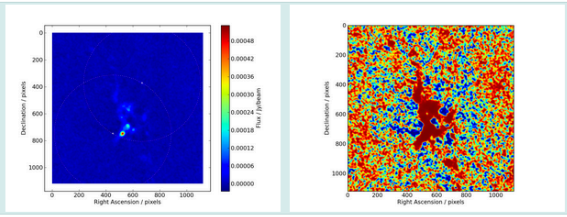
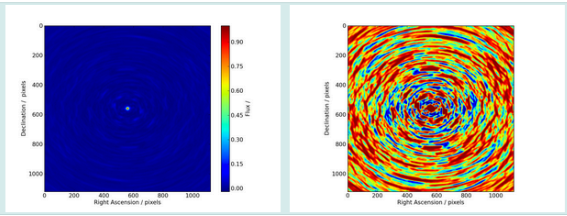
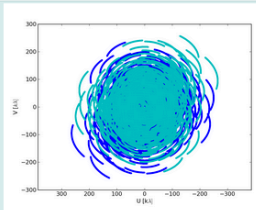
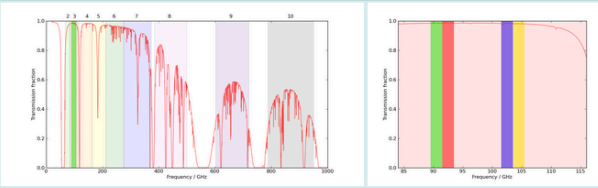
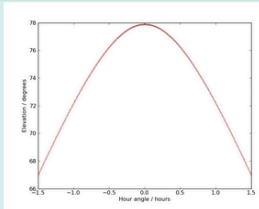
Click thumbnails to view full-size images. Left: linear colour scale, right: with histogram equalization.

Array configuration:	ALMA out10
Source model:	NGC 1333 at 8 kpc
Input image:	
Maximum elevation:	77.88 degrees
Central frequency:	93.7 GHz (ALMA Band 3)
Total Bandwidth:	7.5 GHz
Track length:	3 hours × 1.0 visits
Hexagonal mosaic pointings :	2 required to cover requested sky area with uniform sensitivity
System temperature:	Tsys = 67.8855666394 K
PWV :	0.475 mm
Theoretical RMS noise:	3.9840730481e-06 Jy (in naturally-weighted map)
Restoring beam (resolution):	Major axis = 1.199 arcsec, minor axis = 1.108 arcsec, PA = 62.99 deg

For use with CASA simdata

Input sky model:	Download processed model in FITS format
Download CASA simobserve/analyze file:	20150402103725KcYKi.simdata.last
Download pointing file:	20150402103725KcYKi.ptg.txt

Data products

Your simulated image: Download FITS file	
Dirty Beam (Point Spread Function):	
Coverage in the *uv*-plane:	
Atmospheric transmission for all bands (left) and the selected band (right)	
Elevation vs time:	

Summary

- ALMA simulator
- CASA simulation tasks/tools

  http://casa.nrao.edu

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

  simobserve

  simanalyze

  (simalma)
- Observation Support Tool

  http://almaost.jb.man.ac.uk