ALMA simulations

Rosita Paladino

& the Italian ARC

EUROPEAN ARC
ALMA Regional Centre || Italian

Two software tools available to help users simulate images resulting from an ALMA observations:

Simulations with CASA tasks
sim_observe & sim_analyze (CASA 3.3)
simobserve & simanalyze (CASA 3.4)
Tasks to produce ALMA data from an input sky model (theoretical model or previous observations)

Observation Support Tool
The OST is a webtool hosted by the UK ARC with a website acting as a simple GUI to set parameters and run the simulations

✔ Steps to simulations

model how the sky appears to the telescope.
Ideally the image should be noise-free and have infinite resolution
In practice: **the input noise must be less than the expected output noise and resolution at least as sharp as the output resolution**

using sim_observe

modify the model scale the spectral and spatial coordinates and the brightness

set pointings for mosaic observations

predict: calculate visibilities for a specified array

corrupt: add thermal noise

using sim_analyze

image the visibility data with clean

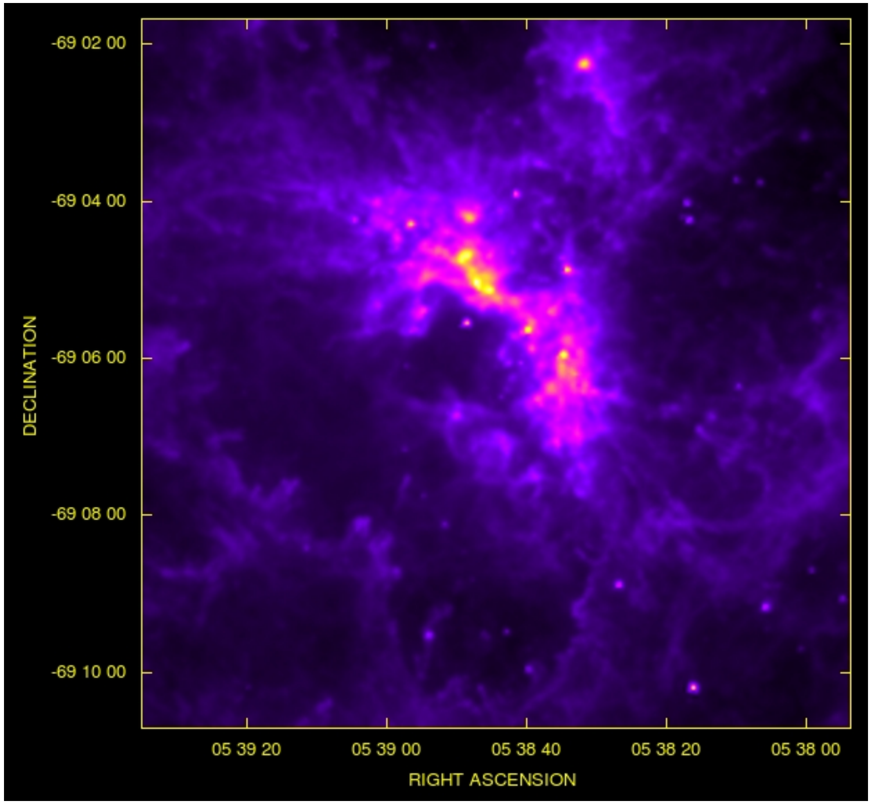
analyze calculate and display the difference between output and input, and the fidelity image

$$\frac{I(x)}{I(x)-T(x)}$$

I(x) observed image
T(x) true intensity given

A very simple simulation

http://casaguides.nrao.edu/index.php?title=Simulation_Guide_for_New_Users_%28CASA_3.3%29



HII region in the Large Magellanic Cloud
D ~ 52 kpc

How it would look like if moved to the distance of M33 ~ 750 kpc?

30Dor Spitzer IRAC 8 μm image from SAGE

input of sim_observe

```
CASA <2>: inp sim_observe
--------> inp(sim_observe)
#  sim_observe :: 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

observe             =       True        #  calculate visibilites using ptgfile
     antennalist    = 'alma.out10.cfg'  #  antenna position file or "" for no interferometric MS
     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'
     sdantlist      =         ''        #  single dish antenna position file or "" for no total power MS
     sdant          =          0        #  single dish antenna index in file

thermalnoise        =         ''        #  add thermal noise: [tsys-atm|tsys-manual|""]
leakage             =        0.0        #  cross polarization
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 sim_observe(...)
```

model

pointing details

observing details

corrupt

model

CASA <5>: project='cycle1_tut'

CASA <6>: skymodel='30dor.fits'

sym_observe will create a directory named **cycle1_tut** where all outputs will be written

```
---------> inp()
#  sim_observe :: mosaic simulation task:
project             = 'cycle1_tut'      #  root prefix for output file names
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)
```

CASA <7>: incenter='230GHz '

CASA <8>: inwidth='2GHz'

CASA<9>: inbright='0.06mJy/pixel'

CASA<10>: incell='0.15arcsec'

CASA<11>: indirection='J2000 10h00m00 -40d00m00'

We tell sim_observe that the model is actually a 230 GHz continuum map taken with a 2GHz band.

The surface brightness in this case is chosen such that the extended emission will be detected in few hours, usually one should calculate the expected brightness, using reliable tracers.

The incell tell sim_observe to rescale the pixels. The original cellsize is 2.2 arcsec, scaling it for the distance:

$$2.2\frac{d_{old}}{d_{new}}=0.15$$

pointing details

```
CASA <12>: setpointings=True

CASA <13>: integration='600s'

CASA<14>: direction=' '

CASA<15>: mapsize=[' ',' ']

CASA<16>: maptype='ALMA'

CASA<17>: pointingspacing=' '
```

The 8μm image is ~ 10' on a side, the rescaled model, covering ~40 arcsec, it will fit in a small mosaic of ~6 pointings.

The integration time is the averaging time for each data point. The default value is '10s', which is appropriate to simulate real observations. sim_observe run much faster using a larger value. So you could use a large value to set the input and check if they work, and then reduce the value to run a realistic simulation.

The default values for direction and mapsize tell sim_observe to center the observations on the model coordinates (indirection), and to cover the entire model with a mosaic.
The default mosaic pattern 'ALMA' uses the same hexagonal algorithm as the OT.
The default spacing sets the pointings half a primary beam apart, corresponding to Nyquist sample.

observing details

```
CASA <18>: observe=True

CASA <19>: totaltime='7200s'

CASA<20>: antennalist=' '
```

Here we set the observational details.
Most of the parameters can be left unchanged since are not relevant for this simulation.

Two important ones are:
the total observing time spent on source we set it to 2 hours,
and antennalist wich defines the configuration of the array.

CASA has stored ALMA and ACA configuration files (as well as EVLA,WSRT, PdBI, CARMA, SMA) in the directory **mycasadir/data/alma/simmos/*cfg,** you can use them in this way:

```
CASA<20>: repodir=os.getenv("CASAPATH").split(' ')[0]

CASA<21>: antennalist=repodir +"/data/alma/simmos/alma.cycle0.compact.cfg"
```

sim_observe can also determine the array configuration to use, if you provide the desired resolution:

```
CASA<21>: antennalist='ALMA;0.5arcsec'
```

Or you can have your "own" configuration in the working directory:

```
CASA<21>: antennalist='miALMA.cfg'
```

The 6 different configurations available during Cycle 1 are already included in CASA 3.4, if using older versions can be downloaded from :

http://almascience.eso.org/documents-and-tools

corrupt

CASA <22>: thermalnoise=''

This parameter allows to add thermal noise from the atmosphere and from the ALMA receivers according to ALMA specifications for each band.

For interferometric simulations one can select thermalnoise = 'tsys-manual' or 'tsys-atm' for single-dish simulation, only tsys-manual is available.

tsys-atm uses a ATM model to construct an atmospheric profile for the ALMA site

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

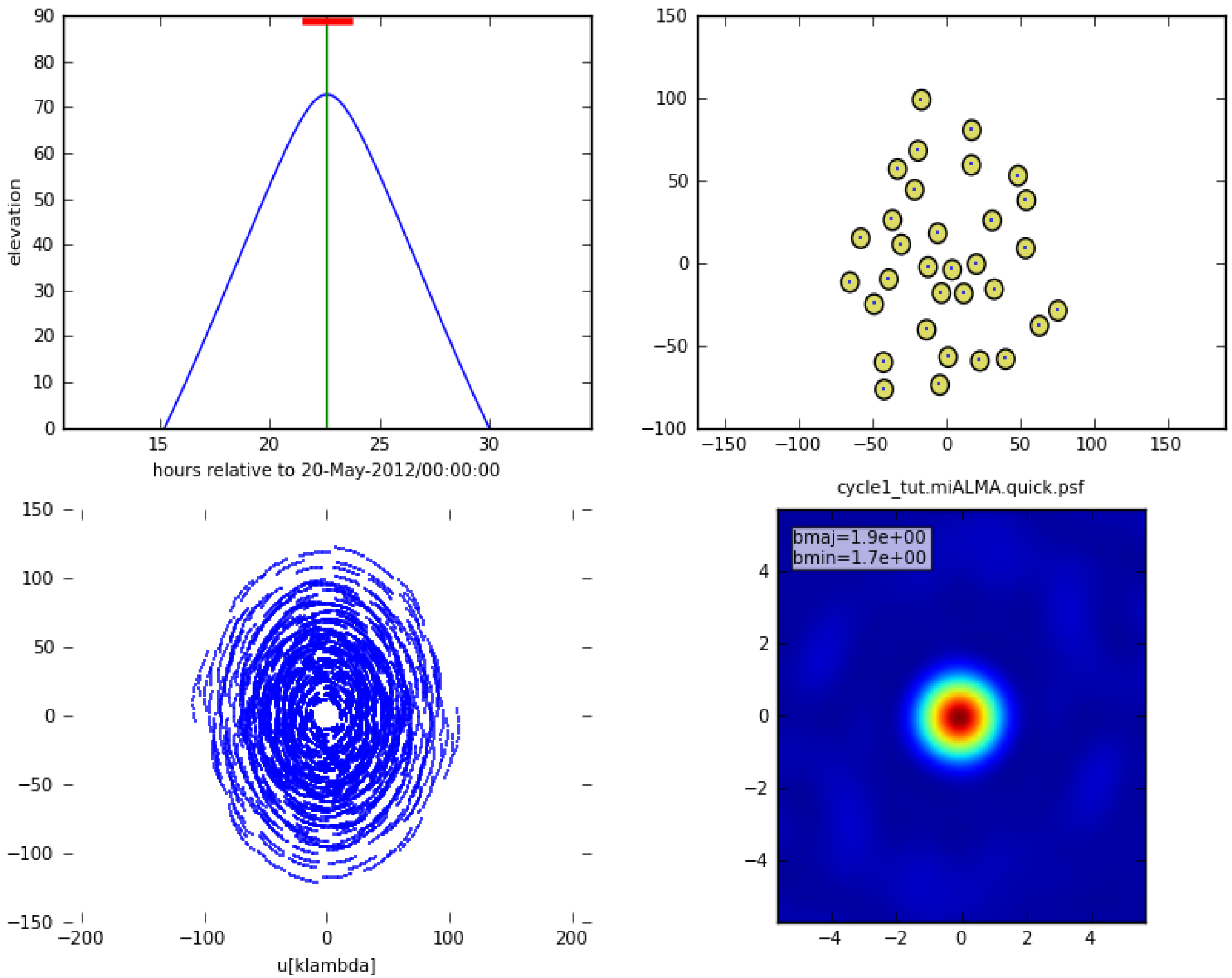
tsys-manual requires the user to specify **t_sky** the physical temperature in the atmosphere and **tau0** the zenit opacity in the center of the simulated band

```
thermalnoise        = 'tsys-manual'     #  add thermal noise: [tsys-atm|tsys-manual|""]
     t_ground       =      269.0        #  ambient temperature
     t_sky          =      263.0        #  atmospheric temperature
     tau0           =        0.1        #  zenith opacity
     seed           =      11111        #  random number seed
```

Adding noise can be slow

for this very simple simulation we don't include any thermal noise

output of sim_observe



Output written to the dir 'project'
in our case **cycle1_tut**

1. Simulated measurement set
project.[conf].ms

2. CASA Image of the PSF
project.[conf].quick.psf

3. CASA image of the rescaled skymodel
project.[conf].skymodel

4. Flattened CASA image of the skymodel
project.[conf].skymodel.flat

5. ASCII text listing mosaic pointings
project.[conf].ptg.txt

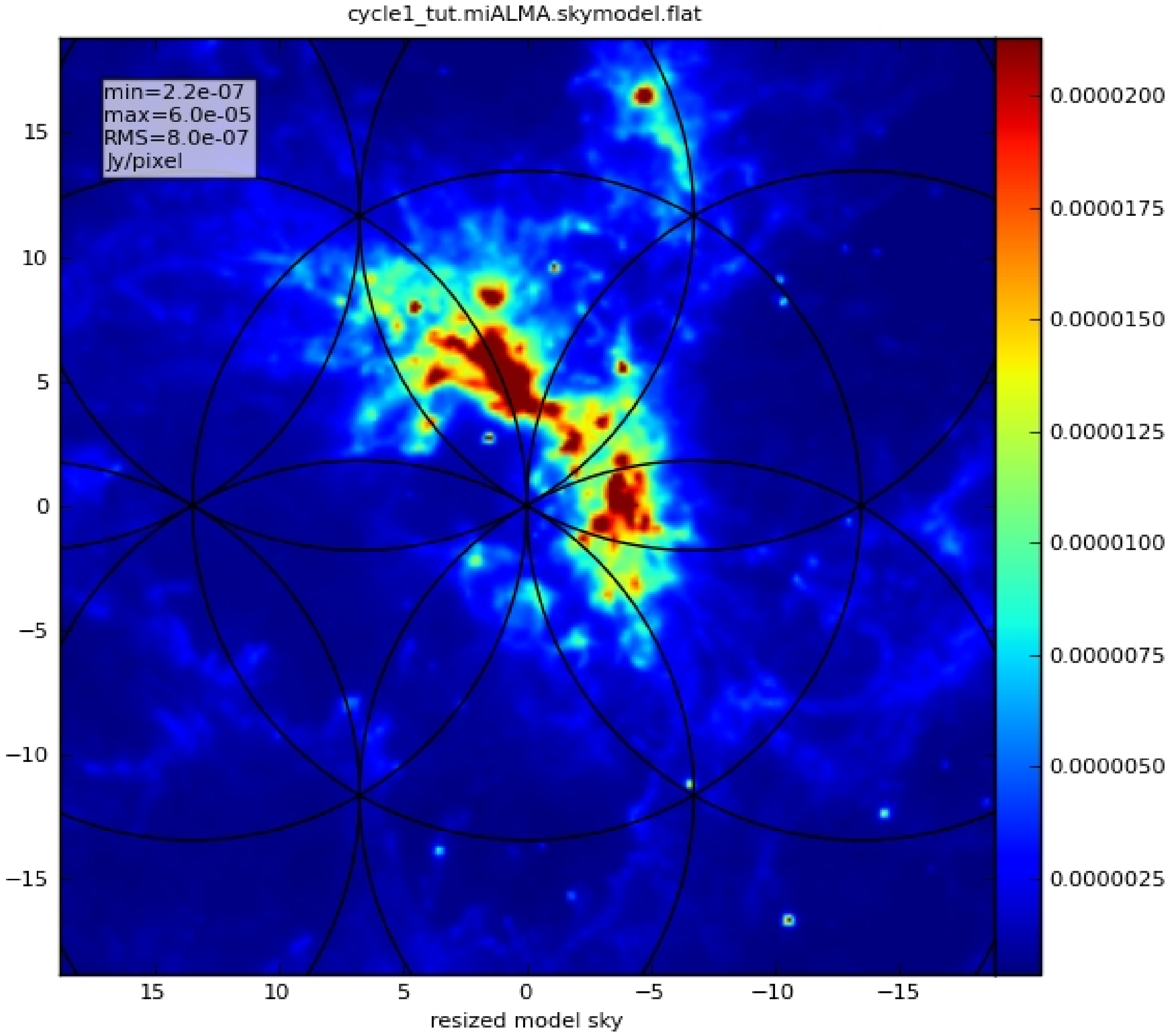
6. ← This PNG summary image
project.[conf].observe.png

7. PNG image of the skymodel overlaid with mosaic pointings →
project.[conf].skymodel.png

EUROPEAN ARC
ALMA Regional Centre || Italian

output of sim_observe

Image of the skymodel overlaid with mosaic pointings



input of sim_analyze

```
--------> inp()
#  sim_analyze :: image and analyze simulated datasets
project             = 'cycle1_tut'      #  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         = [252, 252]        #  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 sim_analyze(...)
```

clean parameters

outputs

EUROPEAN ARC
ALMA Regional Centre || Italian

output of sim_analyze

```
CASA <18>: analyze=True

CASA <19>: showuv=True

CASA<20>: showpsf=True

CASA<21>: showmodel=True

CASA<22>: showconvolved=True

CASA<23>: showclean=True

CASA<24>: showresidual=False

CASA<25>: showdifference=True

CASA<26>: showfidelity=False

CASA<27>: graphics='both'
```

Output written to the dir 'project' in our case **cycle1_tut,**
if graphics = 'file' or 'both'

if graphics = 'screen'
only the picked 6 plots will be displayed in the plotter

1. The uv coverage

2. The synthesyzed beam PSF
project.[conf].psf

3. The original skymodel
project.[conf].skymodel.flat.regrid

4. The skymodel convolved with the synthesized beam
project.[conf].skymodel.flat.regrid.conv

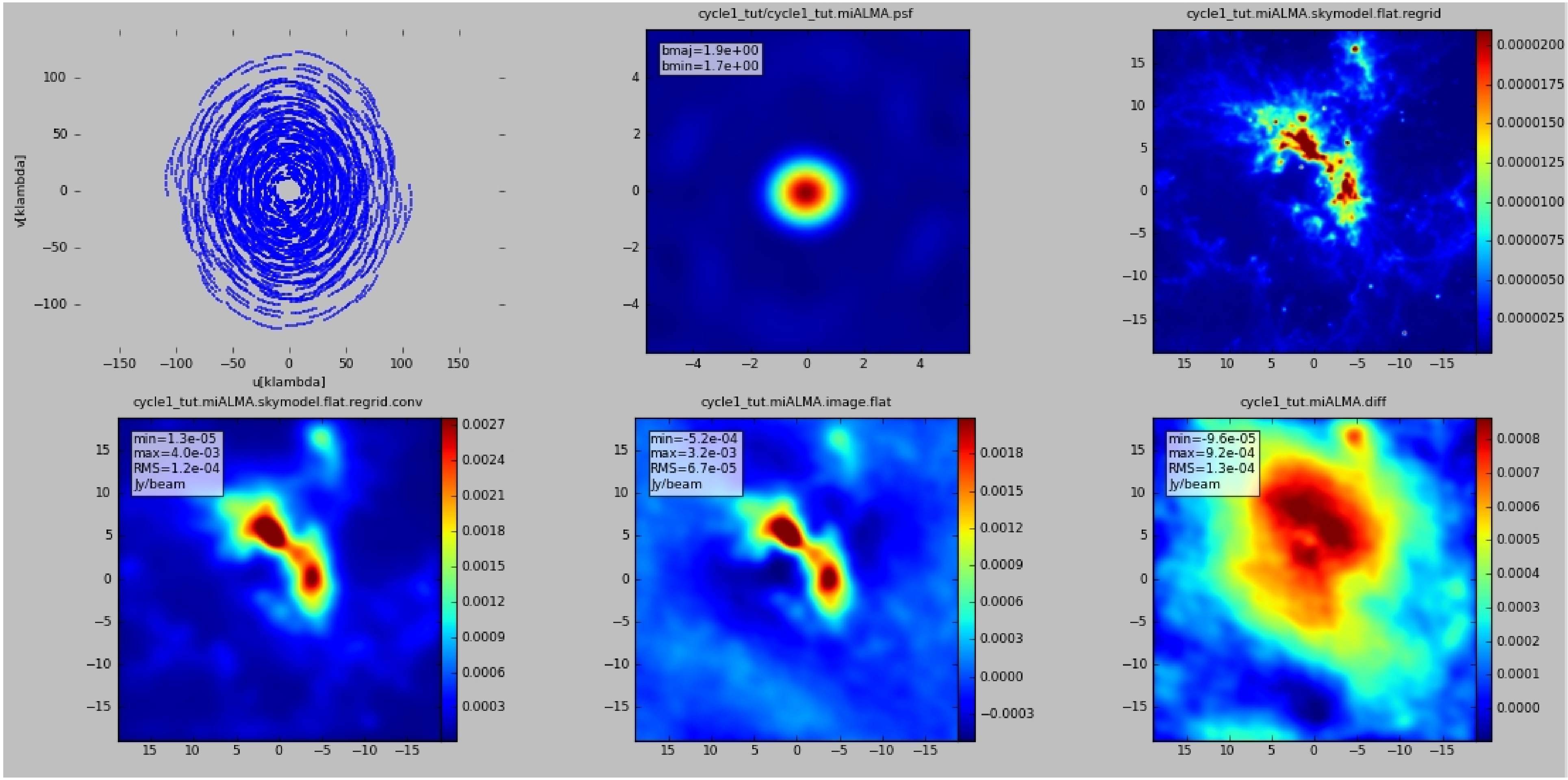
5. The cleaned image
project.[conf].image.flat

6. The difference between the cleaned image and the convolved model
project.[conf].diff

Not shown but saved:
the residual image project.[conf].residual
the fidelity image project.[conf].fidelity

EUROPEAN ARC
ALMA Regional Centre || Italian

output of sim_analyze displayed on the screen

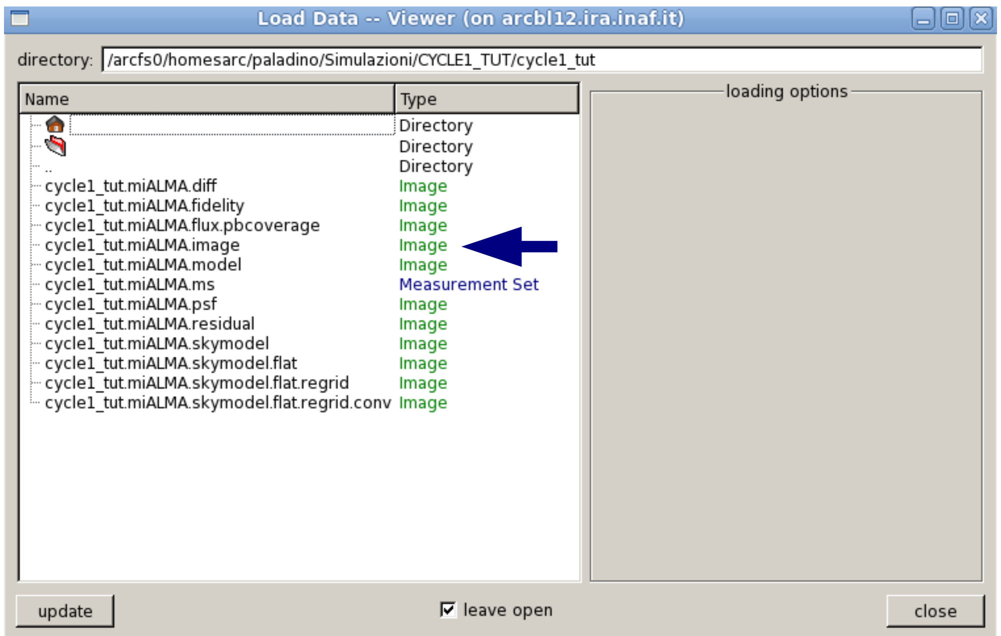


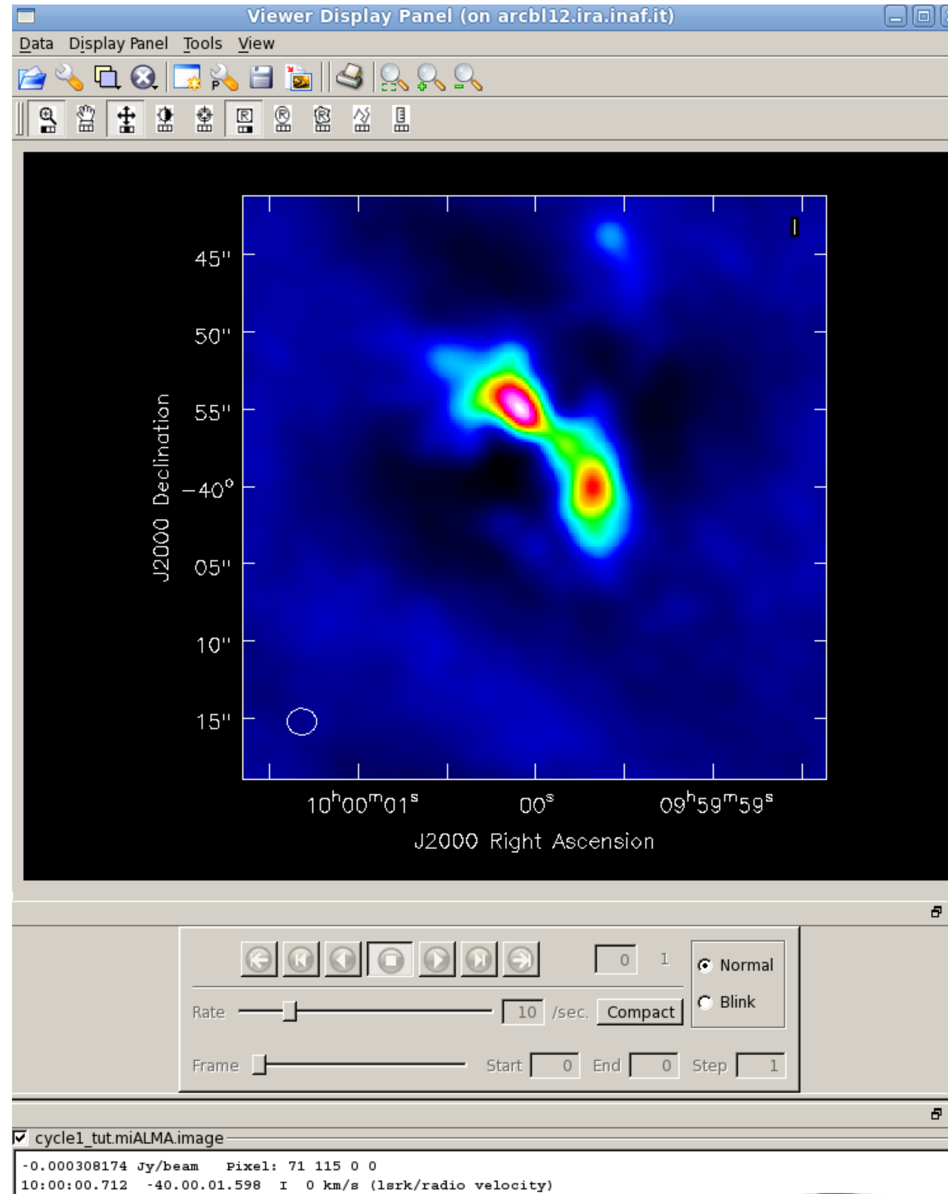
EUROPEAN ARC
ALMA Regional Centre || Italian

Each image output can be visualized using the CASA viewer

CASA <18>: **viewer**

--------------> viewer()

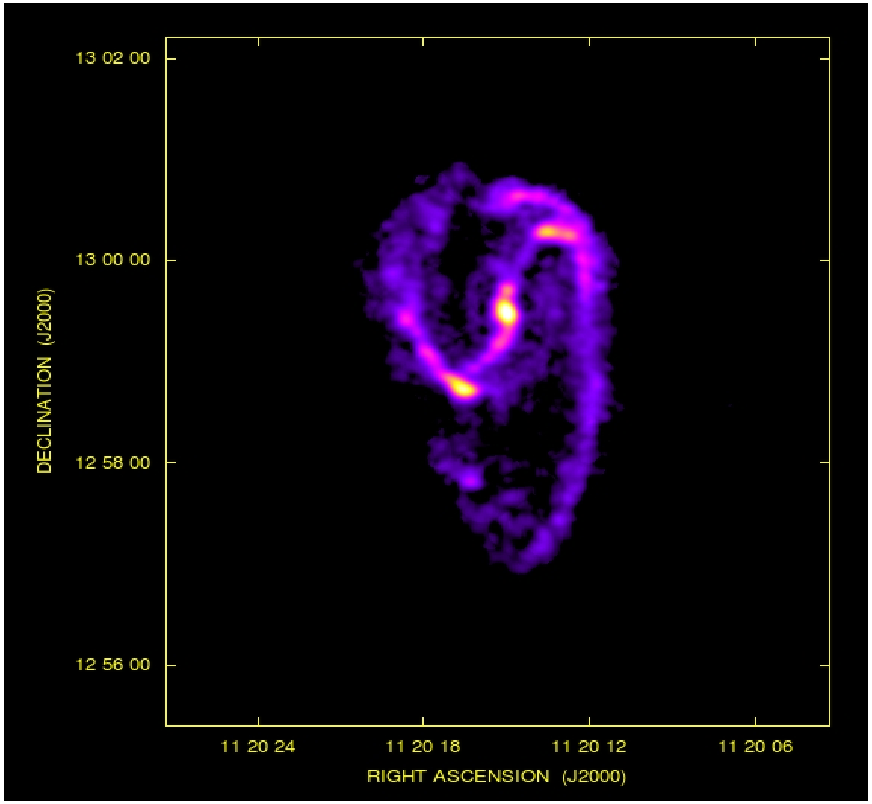




EUROPEAN ARC
ALMA Regional Centre || Italian

A more complex simulation

Following:
http://casaguides.nrao.edu/index.php?title=M51_at_z_%3D_0.1_and_z_%3D_0.3_%28CASA_3.3%29



NGC3627
at distance of 15 Mpc

How it would appear at redshift z=0.1?

BIMA SONG CO(1-0) observations (Helfer 2003)

EUROPEAN ARC
ALMA Regional Centre || Italian

sim_observe input

prepare the model

Cosmology calculations

z_old_cmb = 0.003587 (NED)
z_old_lsrk = 0.002425 (NED)
z_new = 0.1
da_old=15.081
da_new=375.9
dl_old=15.2
dl_new=454.8

Read from BIMA image:

beam properties: bmaj & bmin
pixel size: oldCell
flux peak: peak
frequency:oldFreq
number of channels: nchan
channel width: oldDnu

Scale the image to an appropriate model:
fluxScale=(dl_old/dl_new)**2*(1.0+z_new) / (1.0 + z_old_cmb)
inbright="%fJy/pixel" % (peak*fluxScale)

Scale pixel size:
newCell= oldCell * da_old / da_new
incell = "%farcesec" % (newCell)

Adjust the frequency axis:
newFreq = oldFreq * (1.0+z_old_lsrk) / (1.0+z_new)
newDnu = abs ((1.0+z_old_lsrk) / (1.0+z_new) * oldDnu)
inwidth = "%fHz" % newDnu
incenter="%fHz" % (newFreq + 0.5*nchan*newDnu)

sim_observe input

Map size and mosaicing

imSize = 400.0 *(da_old / da_new)
mapsize = “%farcsec” % imSize
primaryBeam = 17.0 * (300e9 / newFreq)
pointingspacing=”%farcsec” % (primaryBeam / 2.0)
(for z=0.1 simulation we don't need mosaic (mapsize~16arcsec),
it is needed for lower redshift simulations)

move to southern hemisphere
indirection= J2000 11:20:15.07 -12.59.21

Array configuration

we simulate **8 hr** observations using the different Cycle1 configurations

antennalist='cycle1_config/alma_cycle1_*.cfg'

totaltime=28800s
integration=100s

(a more appropriate integration time for a realistic simulation would be 10s)

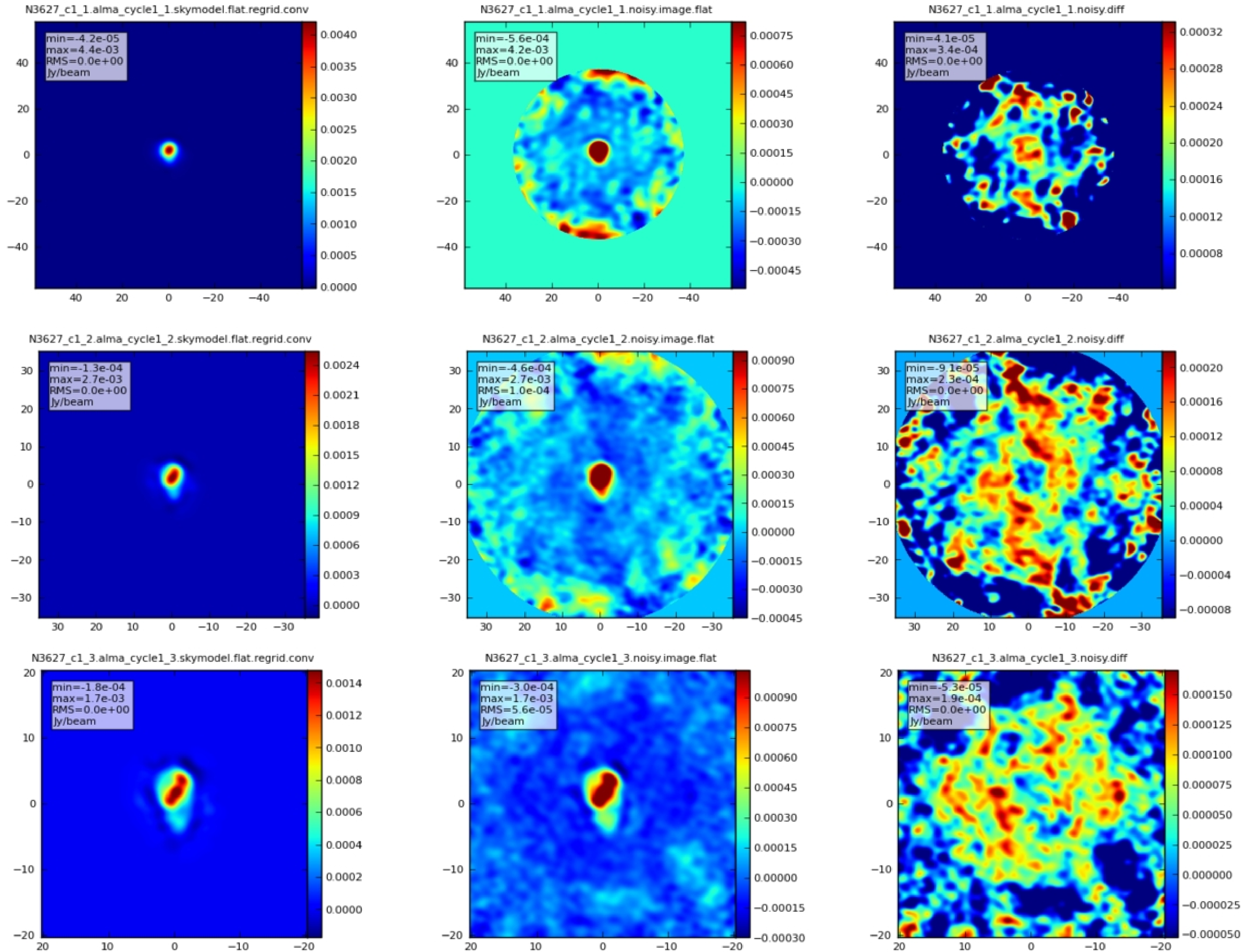
Simulations of NGC3627 at z=0.1

Gaussian beam convolved input model | **simulated and cleaned image** | **difference (conv model - iamge)**

C32-1 4.7''x 3.7''

C32-2 3.0''x 2.3''

C32-3 2.0''x 1.6''



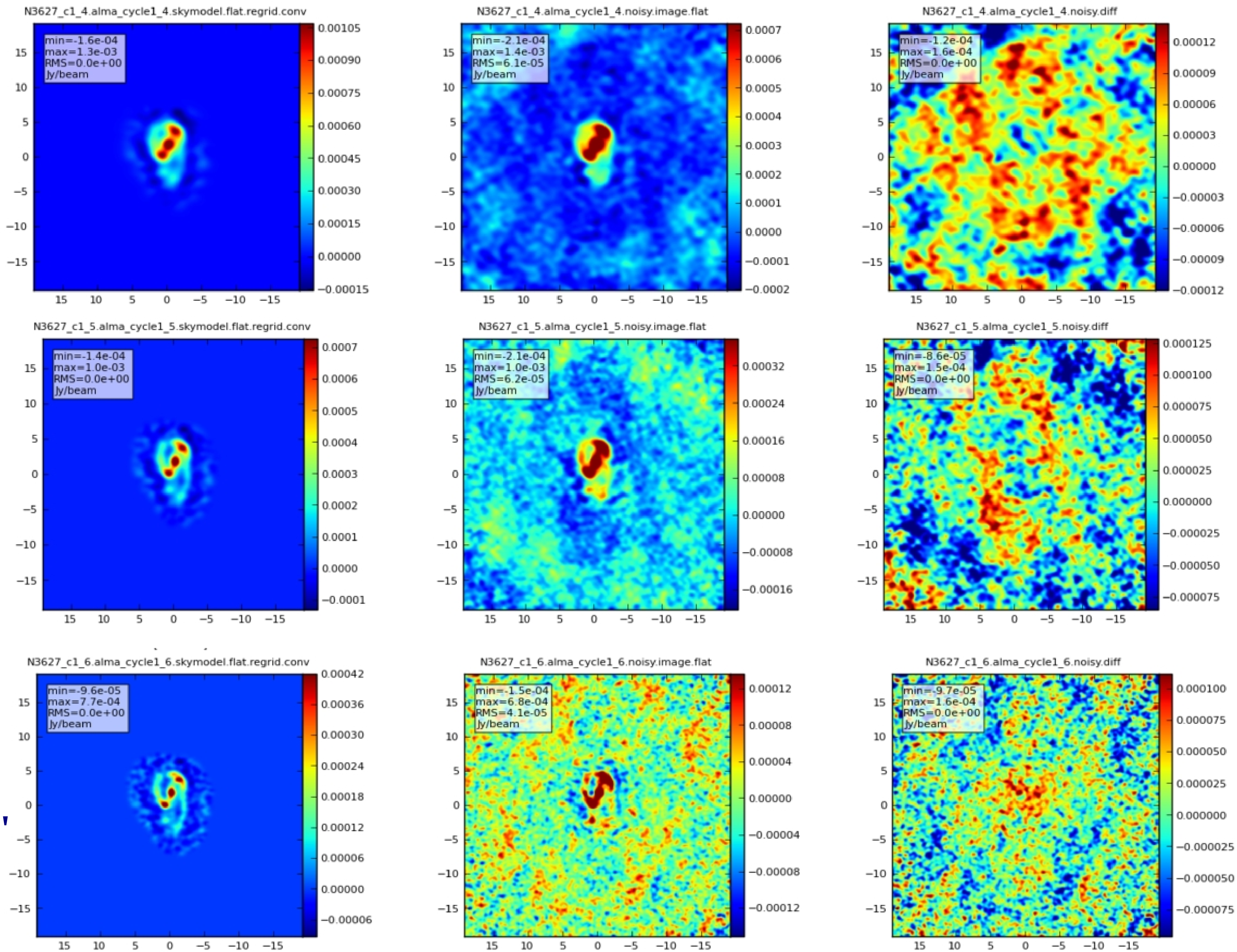
Simulations of NGC3627 at z=0.1

Gaussian beam convolved input model | **simulated and cleaned image** | **difference (conv model - image)**

C32-4
1.6''x 1.2''

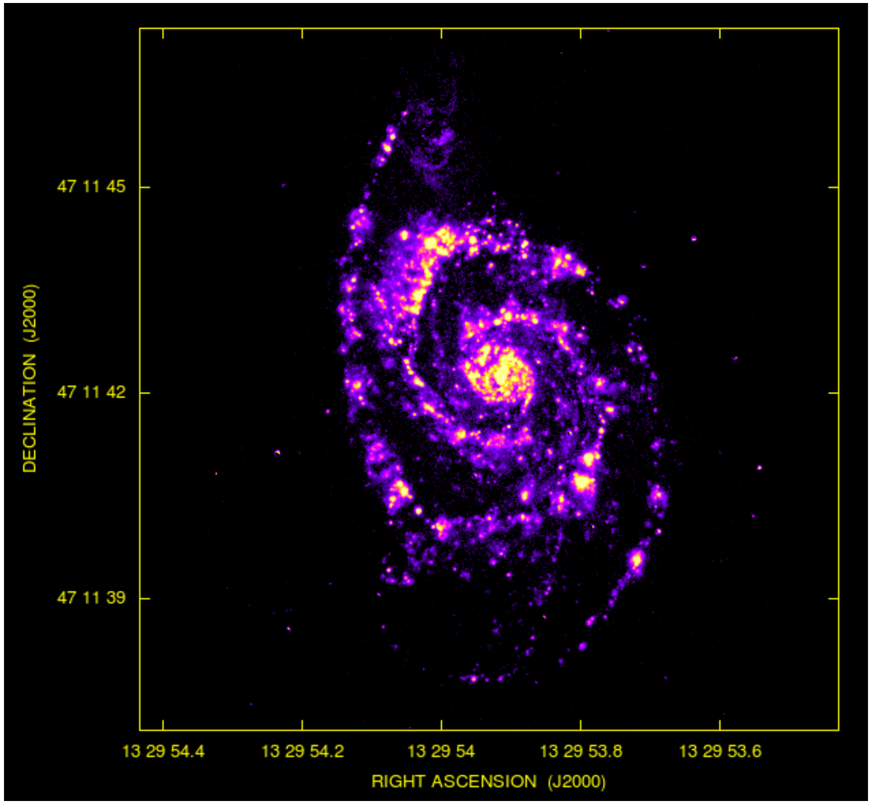
C32-5
1.1''x 0.92''

C32-6
0.73''x 0.62''



ACA + main array simulations

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



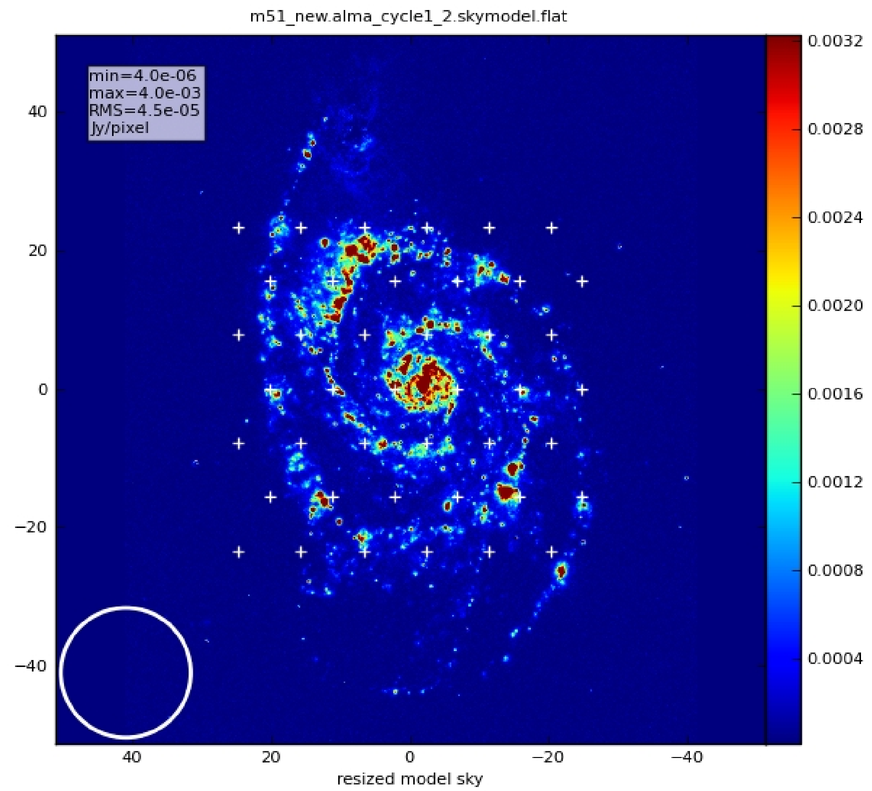
Placing M51 in the southern hemisphere at
distance of ~ 90 Mpc
and observing it at 330 GHz with ALMA configuration C32-2 available in cycle 1

Model: Hα image of M51

Simulation of 12 m main array observations

Map size and mosaicing

setpointing = True
mapsize='1arcmin'
maptype='hex'
pointingspacing='9arcsec'
obsmode='int'
antennalist='alma.cycle1_2.cfg'
totaltime='3600s'



hexagonal mosaic overplotted on the sky model

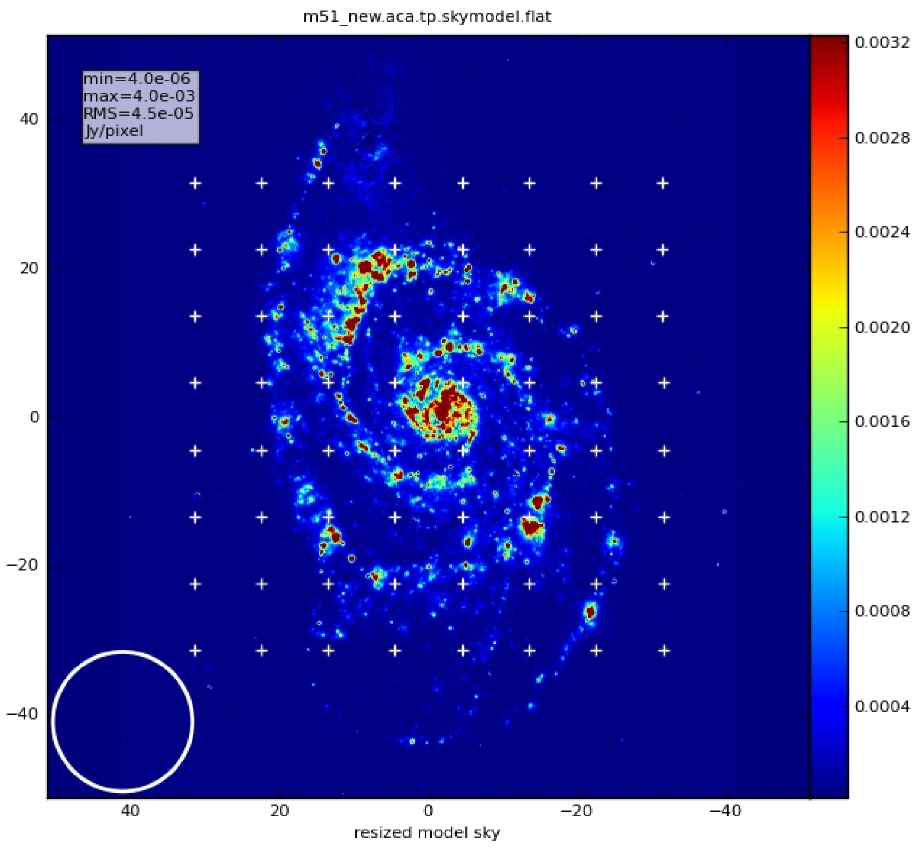
Simulation of 12m total power raster map

Map size and mosaicing

setpointing = True
mapsize='1.3arcmin'
maptype='square'
obsmode='sd'
sdantlist='aca.tp.cfg'
sdant=0
refdate='2012/12/01'
totaltime='2h'

sim_observe cannot simulate an actual raster map but a square mosaic and short itegration will be a good approximation

It is generally recommended to observe a larger area by ½ primary beam in tp mode to combine with 12 m array

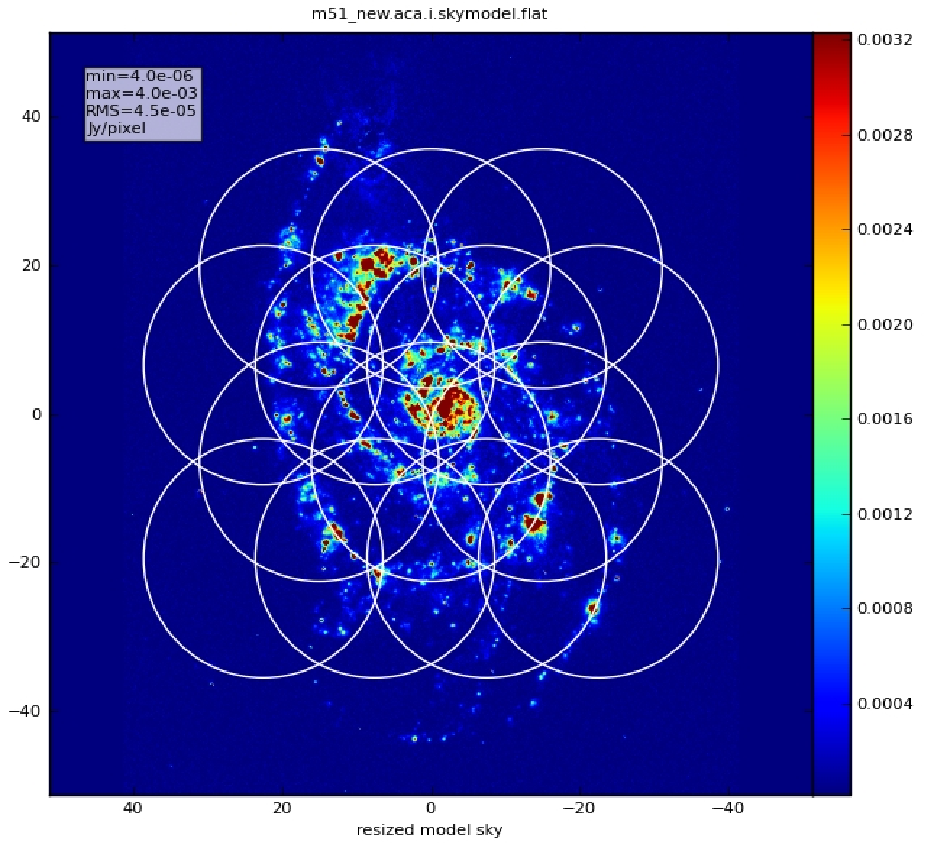


rectangular mosaic overplotted on the sky model

Simulation of ACA 7m observations

Map size and mosaicing

setpointing = True
mapsize='1arcmin'
maptype='hex'
pointingspacing='15arcsec'
obsmode='int'
sdantlist=''
refdate='2012/12/02'
totaltime='3'



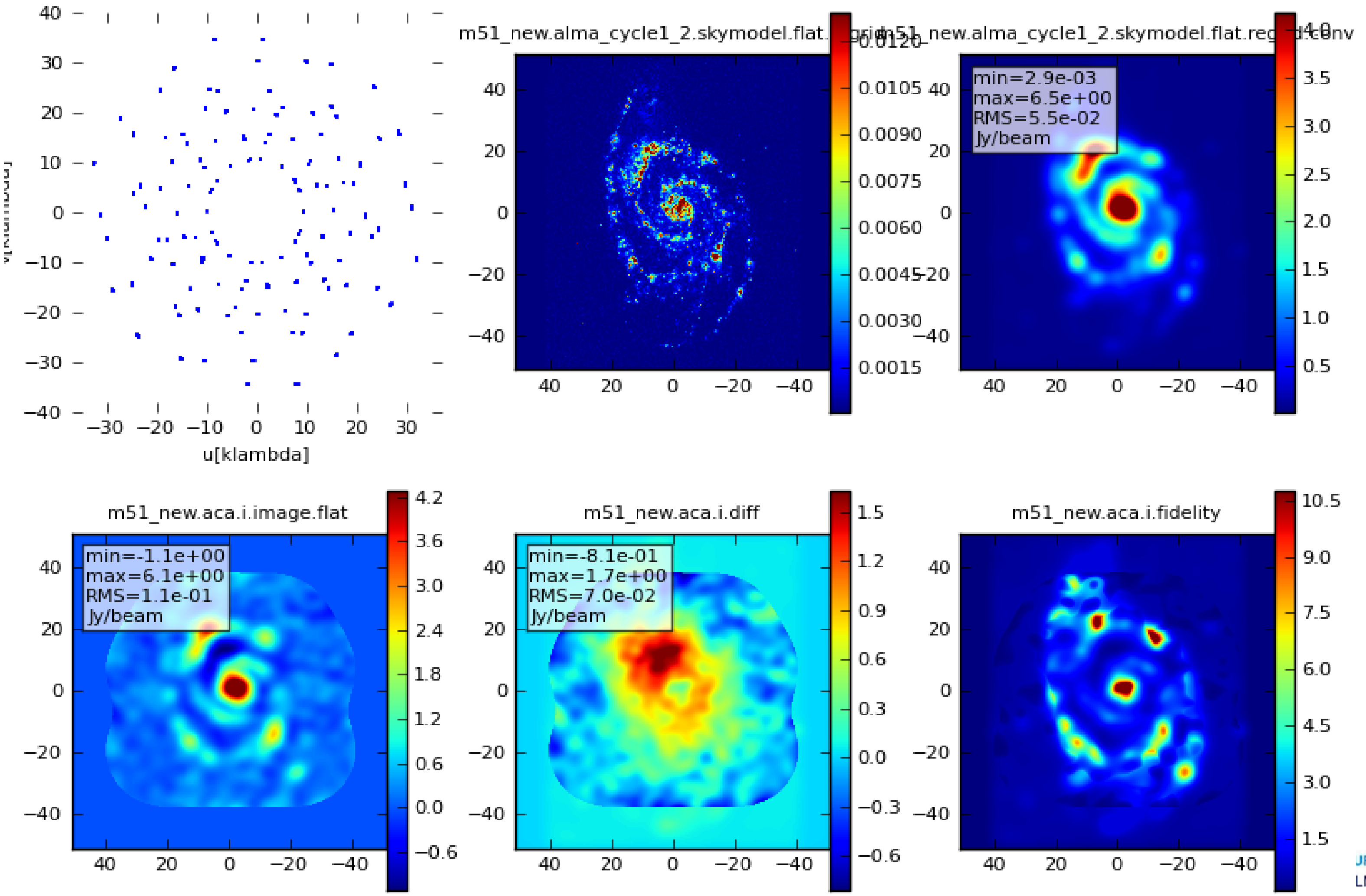
hexagonal mosaic overplotted on the sky model

ACA + 12m main array simulations

One possible technique for the combination:

First image ACA + total power using total power as a model

```
default("sim_analyze")
project            =  "m51c"
vis                =  '$project.aca.i.ms,$project.aca.tp.sd.ms'
imsize             =  [512,512]
cell               =  '0.2arcsec'
analyze            =  True
showpsf            =  False
showresidual       =  False
showconvolved      =  True
go()
```

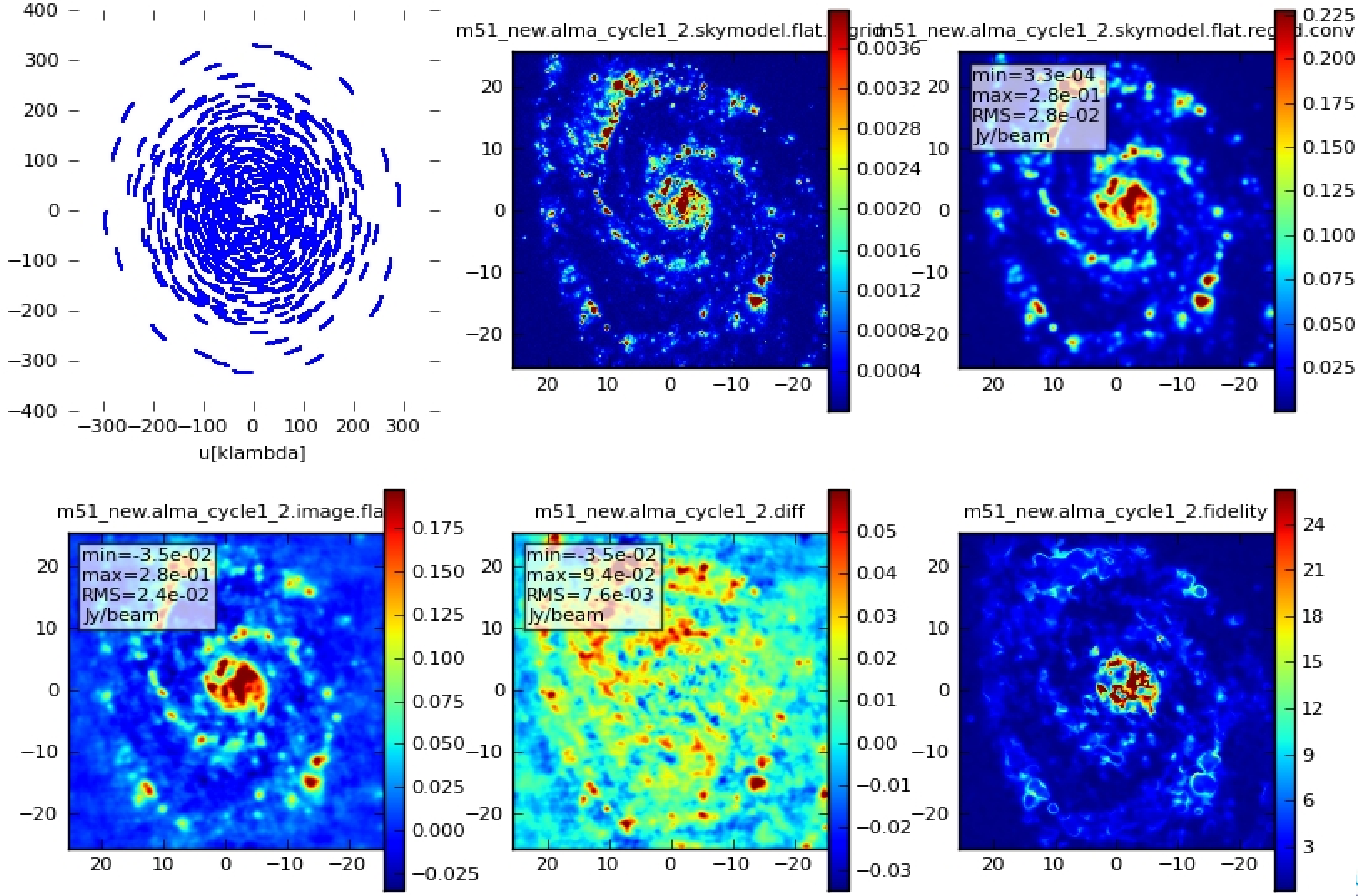


EUROPEAN ARC
ALMA Regional Centre || Italian

ACA + 12m main array simulations

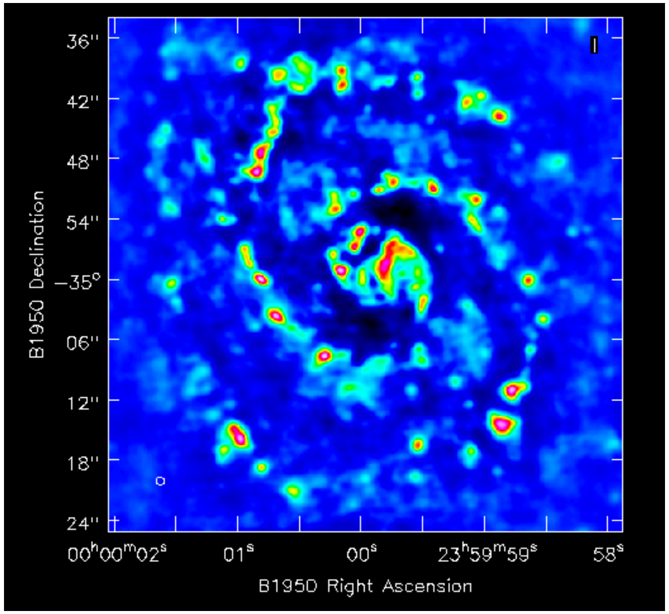
Add the 12 m interferometric data

```
default("sim_analyze")
project            =  "m51c"
vis                =  '$project.ALMA_0.5arcsec.ms'
imsize             =  [512,512]
cell               =  '0.1arcsec'
modelimage         =  "$project.aca.i.image"
analyze            =  True
showpsf            =  False
showresidual       =  False
showconvolved      =  True
go()
```

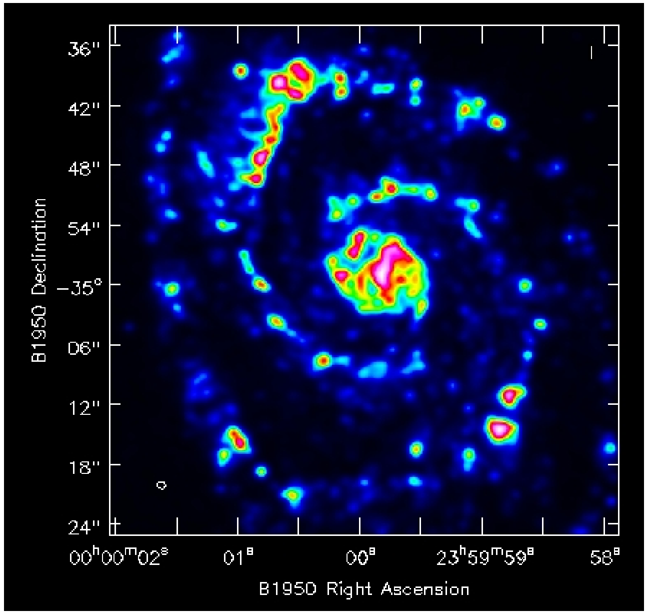


ACA + 12m main array simulations

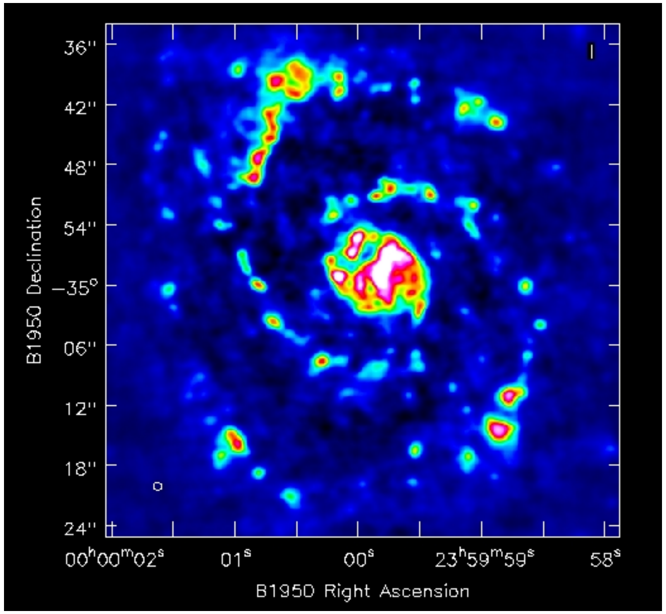
Cleaned Image
C32-2 without ACA



gaussian beam
convolved model



Cleaned image
C32+ACA

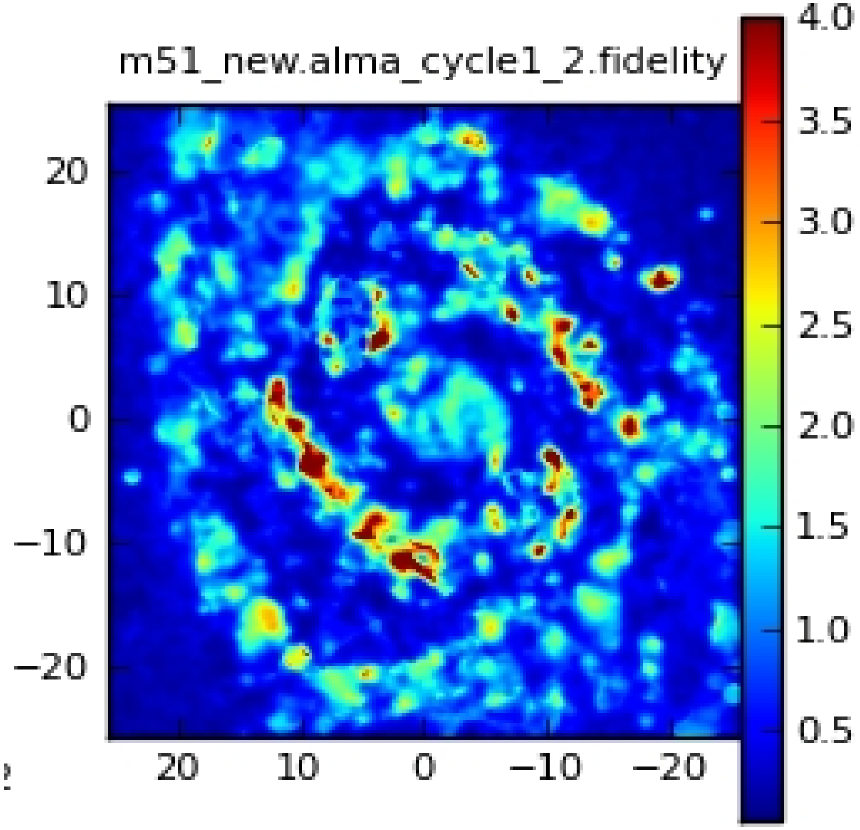


The addition of ACA observations with 12 m Array observations
Provides better imaging of complex sources with structures over a wide range of angular scales. The TP array measures signals on angular scales not measured by the 12 m array, while the 7 m array provides measurements on spatial scales intermediate between the two.

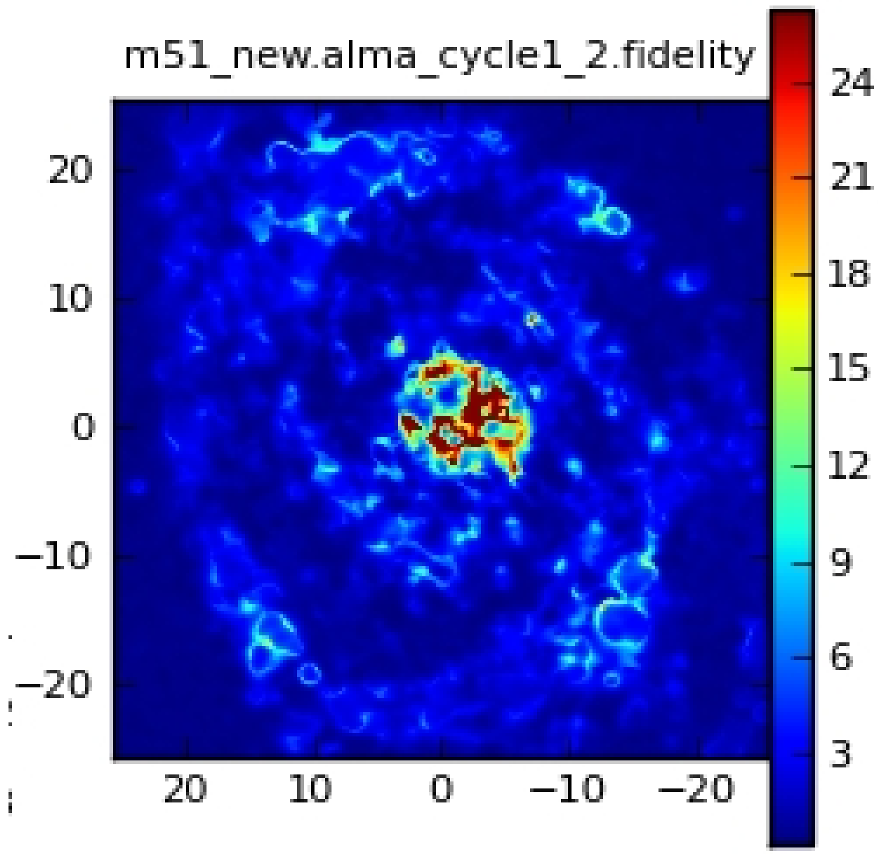
EUROPEAN ARC
ALMA Regional Centre || Italian

ACA + 12m main array simulations

Fidelity image
C32-2 without ACA



Fidelity image
C32+ACA



ACA + 12m main array simulations

Other possible technique for the combination can be:

using the msclean clean (again using the lower resolution image as a model when deconvolving the higher resolution one)

or

creating each image independently, and then using the CASA task "feather" to combine them entirely in the image plane

or

combining the uv data in a single mesaurement set

The ALMA project does NOT make any recommendation yet about the optimal technique. Detailed recommendation will be updated on the CASA guide website.

ALMA Observation Support Tool

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

Version 1.2 (ALMA Cycle 1)	Important Message		
Array	Instrument	ALMA	Queue 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	Scegli file Nessun file selezionato	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	Set to 0.0 for no rescaling of source model

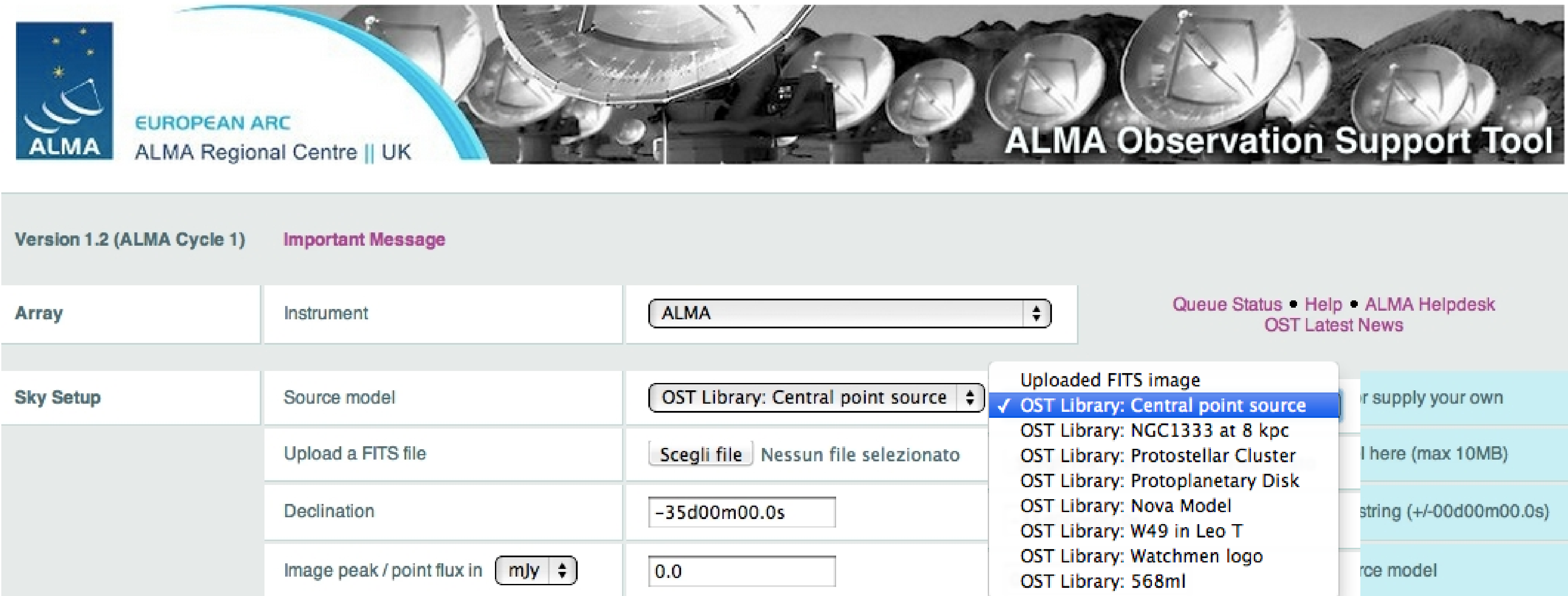
EUROPEAN ARC
ALMA Regional Centre || Italian

ALMA Observation Support Tool

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

ALMA Observation Support Tool

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



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
	Required resolution in arcseconds	1.0	OST will choose config if instrument is set to ALMA
	Pointing strategy	Mosaic	Selecting single will apply primary beam 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 30s and 600s)
	On Phase Calibrator in seconds	0.0	The length of time spent observing phase calibrator (currently limited to either 0s **or** between 30s and 600s)
	On-source time in hours	3	Per pointing for Mosaics.
	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 Octile)	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!	Submit

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
	Required resolution in arcseconds	1.0	OST will choose config if instrument is set to ALMA
	Pointing strategy	Mosaic	Selecting single will apply primary beam 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 30s and 600s)
	On Phase Calibrator in seconds	0.0	The length of time spent observing phase calibrator (currently limited to either 0s **or** between 30s and 600s)
	On-source time in hours	3	Per pointing for Mosaics.
	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 Octile)	se due to water vapour
Imaging	Imaging weights	Natural	/ 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!	Submit

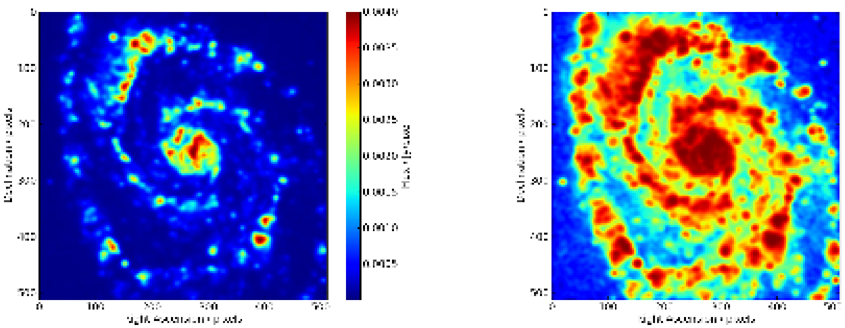
- ✓ PWV = 0.472 mm (1st Octile)
- PWV = 0.658 mm (2nd Octile)
- PWV = 0.913 mm (3rd Octile)
- PWV = 1.262 mm (4th Octile)
- PWV = 1.796 mm (5th Octile)
- PWV = 2.748 mm (6th Octile)
- PWV = 5.186 mm (7th Octile)

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
	Required resolution in arcseconds	1.0	OST will choose config if instrument is set to ALMA
	Pointing strategy	Mosaic	Selecting single will apply primary beam 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 30s and 600s)
	On Phase Calibrator in seconds	0.0	The length of time spent observing phase calibrator (currently limited to either 0s **or** between 30s and 600s)
	On-source time in hours	3	Per pointing for Mosaics.
	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 Octile)	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!	Submit

Your email address is essential!

You will be notified via email when the simulation is complete.

Result overview

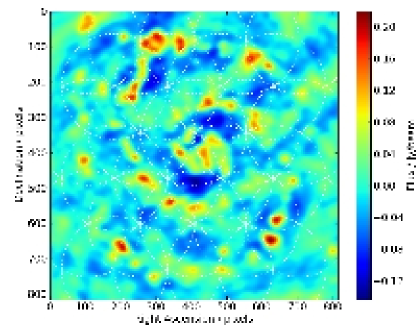
Overview	
Click thumbnails to view full-size images. Left: linear colour scale, right: with histogram equalization.	
Array configuration	ALMA Cycle 1 C32-2 (288 m baseline)
Source model	prova_modello.fits
	
Maximum elevation	55.0 degrees
Central frequency	330 GHz = Band 7
Bandwidth	0.005 GHz
Track length	4 hours × 1.0 visits
Hexagonal mosaic pointings	27 required to cover requested sky area with uniform sensitivity
System temperature	Tsys = 145.125414615 K
PWV	0.475 mm
Theoretical RMS noise	0.000505694876414 Jy (in naturally-weighted map)
Restoring beam (resolution)	Major axis = 0.97 arcsec, minor axis = 0.735 arcsec, PA = 92.308 deg

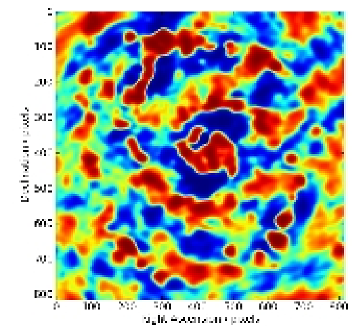
Data products

Data products

Image
with and without
histogram equilization

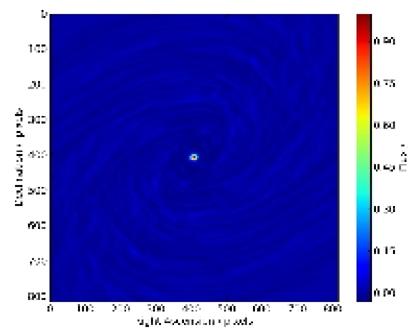
Your simulated image
Download FITS file

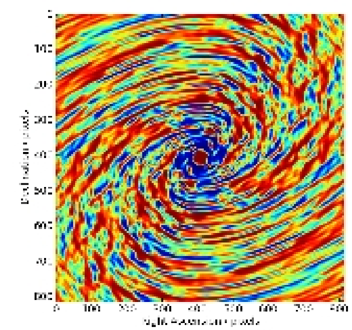




Dirty Beam
(Point Spread Function)

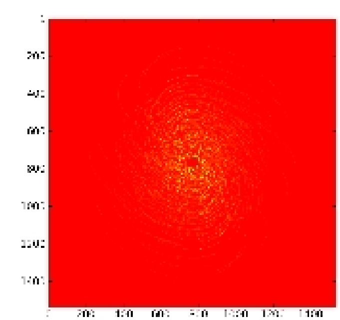
synthesyzed beam
PSF

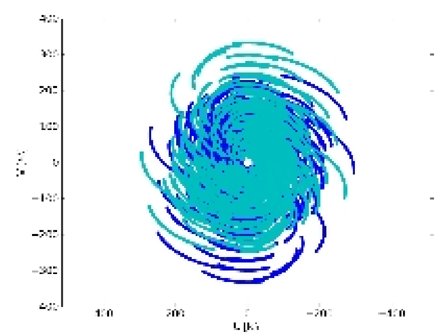




uv-plane coverage

Coverage in the uv-plane

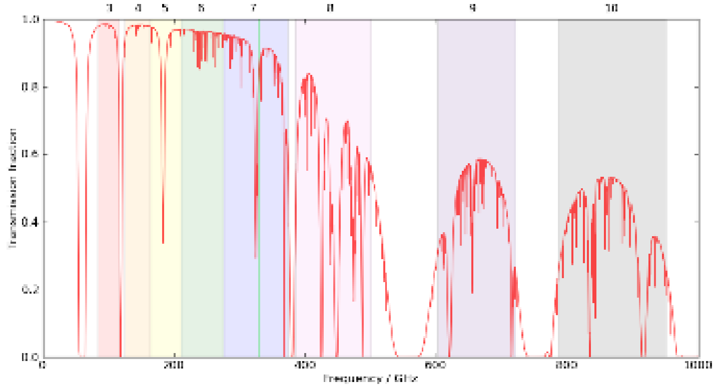


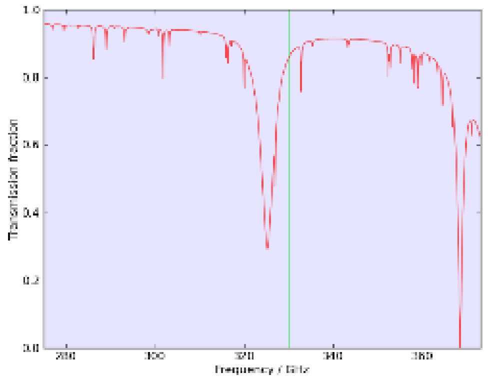


Data products

Atmospheric transmission for all bands (left) and the selected band (right)

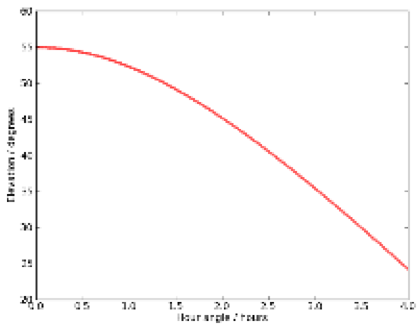
Atmospheric transmission for all bands (left) and the selected band (right)





Elevation vs time

Source elevation vs time



In summary

Simulations can provide informative results on the feasibility of proposed observations.

- They can provide information on the fraction of the flux that is resolved out by a given configuration.
- The fidelity images produced, if relevant, can be specified in the technical justification
- If a high dynamic range is required in order to achieve the science goals, simulations can establish whether the observations is feasible.

BUT

Significant differences exist sometimes between the noise predicted by the ALMA sensitivity calculator and the measured RMS in the simulated images. Simulations should only be used to **qualitatively** assess the sensitivity.

Proposed observing times and expected sensitivity should be based on the sensitivity calculator.

Grazie