Simulating ALMA observations

Rice University - March 30, 2017

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Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array

Why and how simulating ALMA obs

- To understand what's the best observational strategy (e.g. ALMA array configuration, Band, required sensitivity…); to demonstrate project feasibility in the proposal

- Two possible ways:
  - ALMA Observation Support Tool
    http://almaost.jb.man.ac.uk/
  - Simobserve/Simanalyze tasks in the CASA software

- A "sky model" (FITS) is needed, e.g. from numerical simulations or extrapolation from real images at other wavelengths

ALMA Observation Support Tool (online)

ALMA Observation Support Tool

Version 5.0

OST NEWS HELP QUEUE LIBRARY ALMA HELPDESK

!!! OST User Notice: Version 5.0 released - 21/03/2017 !!! (more info). **OST Team**

Array Setup:

Instrument: ALMA — Select the desired ALMA antenna configuration.

Sky Setup:

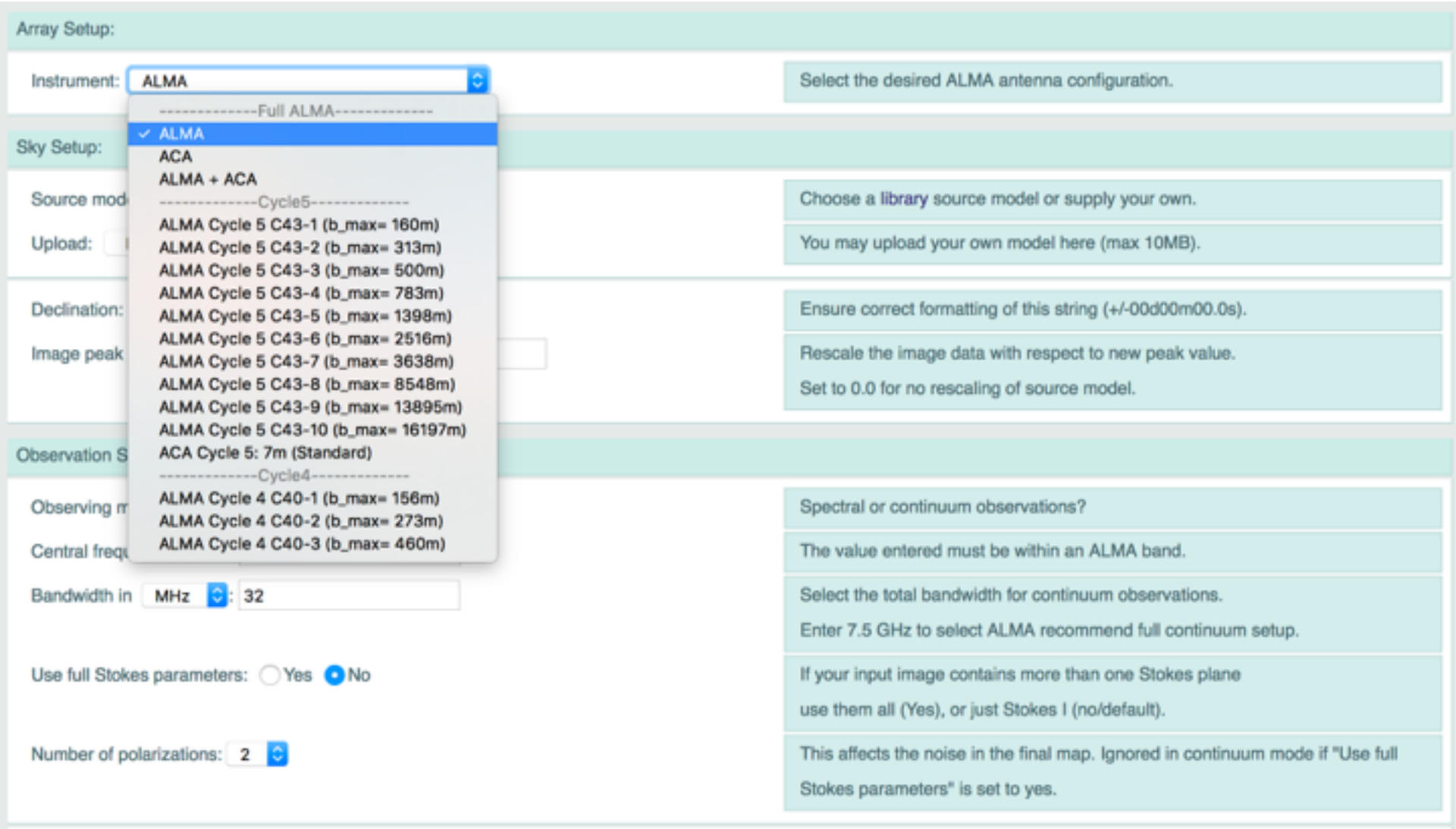
Source model: OST Library: Central point source — Choose a library source model or supply your own.

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

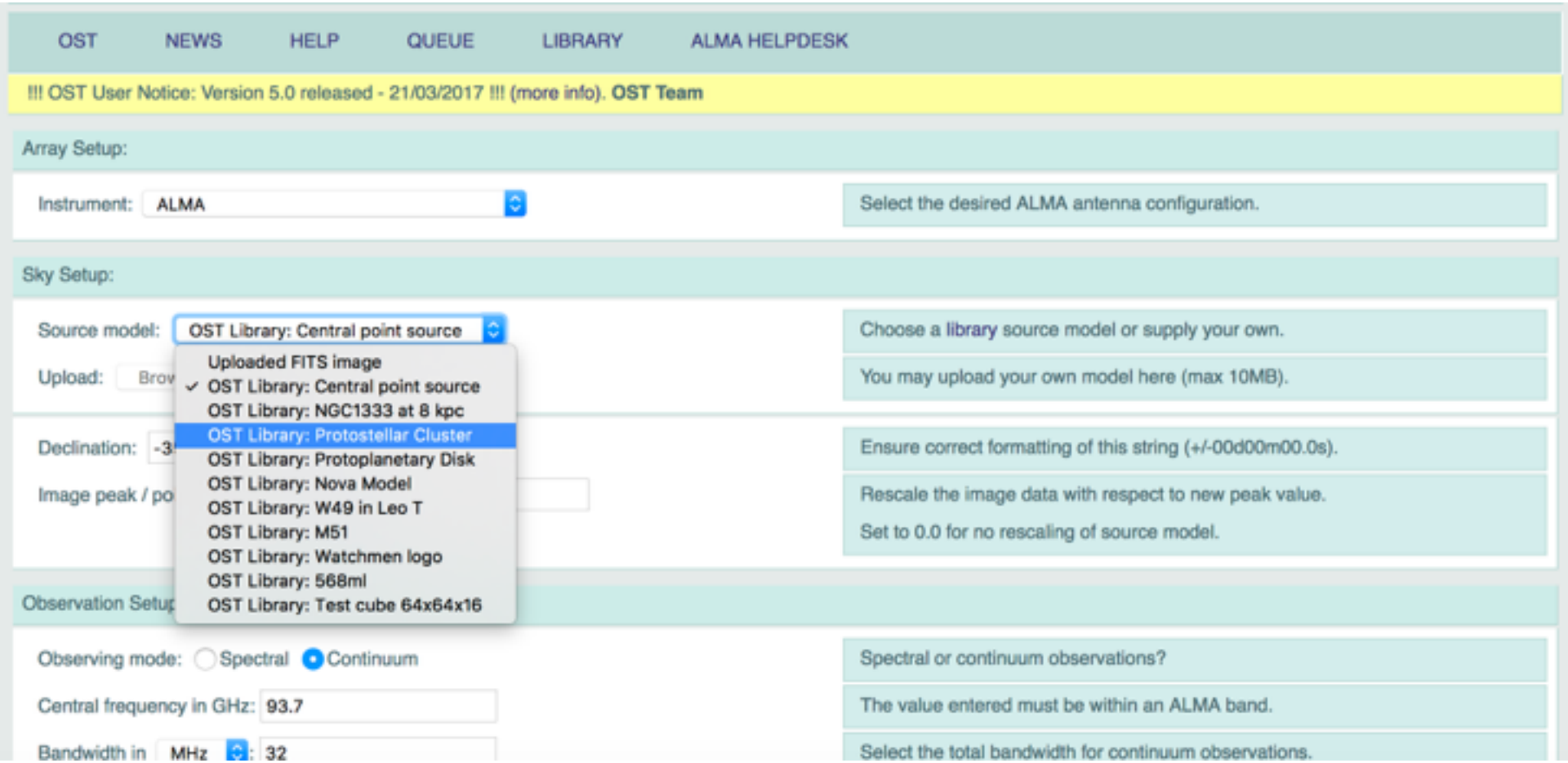
Declination: -35d00m00.0s — Ensure correct formatting of this string (+/-00d00m00.0s).

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.

ALMA Observation Support Tool (online)



ALMA Observation Support Tool (online)

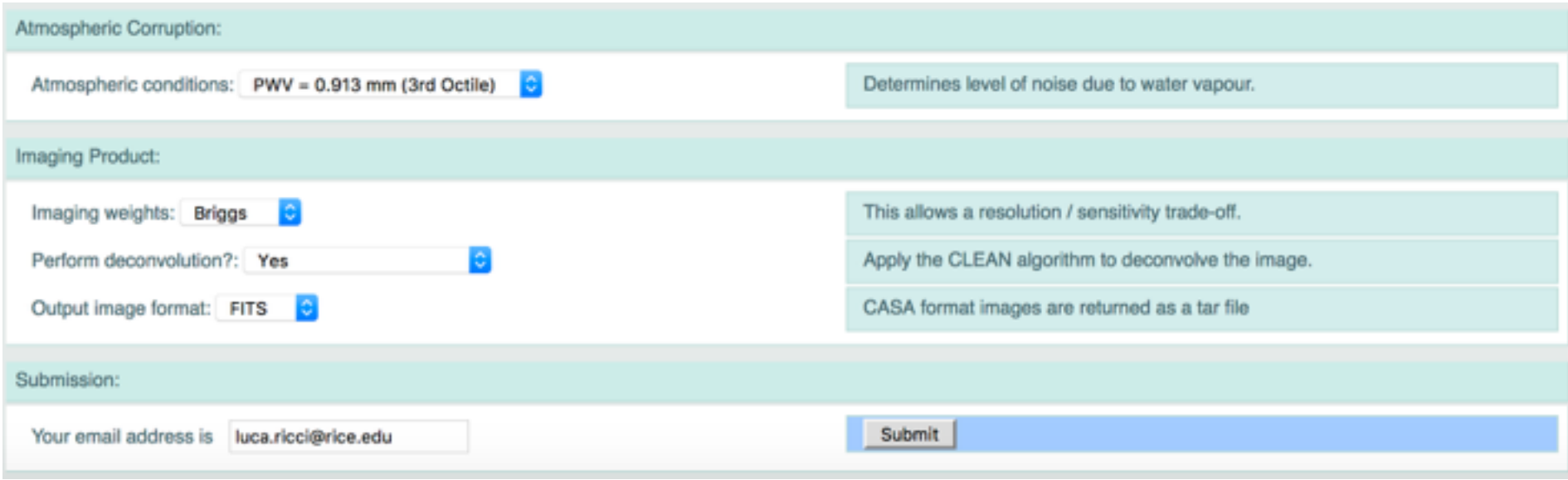


ALMA Observation Support Tool (online)

Observation Setup:

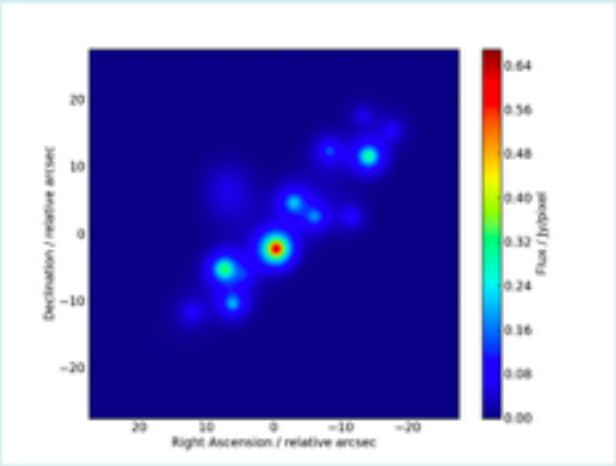
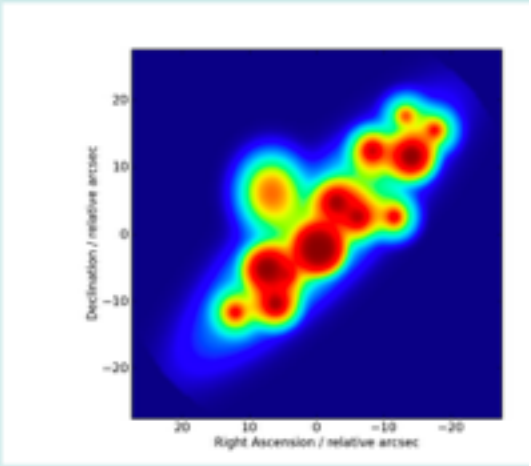
Observing mode: ○ Spectral ● Continuum	Spectral or continuum observations?
Central frequency in GHz: 345.0	The value entered must be within an ALMA band.
Bandwidth in GHz: 7.5 OK	Select the total bandwidth for continuum observations. Enter 7.5 GHz to select ALMA recommend full continuum setup.
Use recommended continuum setup? : ○ No ● Yes	Position spectral windows at the ALMA recommended positions for 7.5GHz bandwidth continuum observations.
Use full Stokes parameters: ○ Yes ● No	If your input image contains more than one Stokes plane use them all (Yes), or just Stokes I (no/default).
Number of polarizations: 2	This affects the noise in the final map. Ignored in continuum mode if "Use full Stokes parameters" is set to yes.
Required resolution in arcseconds: 1.0	OST will choose array config based on this value if *instrument* is set to ALMA.
Pointing strategy: Single	Selecting single will apply primary beam attenuation.
On-source time in hours : 6	Per pointing for Pointing Strategy = 'mosaic'. Total time over all pointings Pointing Strategy = 'single' and 'User pointing' See here for more information.
Start hour angle: -3.0	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.

ALMA Observation Support Tool (online)



- Email is sent upon submission and completion of the simulation

Output 1/3

Array configuration:	ALMA Cycle 5 C43-1 (160 m baseline)
Source model:	Modelled protostellar cluster
Input image:	 
Maximum elevation:	77.88 degrees
Central frequency:	345.0 GHz (ALMA Band 7)
Total Bandwidth:	7.5 GHz
Track length:	6 hours x 1.0 visits
System temperature:	Tsys = 149.766073787 K
PWV :	0.942 mm
Theoretical RMS noise:	8.11986448544e-06 Jy (in naturally-weighted map)
Restoring beam (resolution):	Major axis = 1.016 arcsec, minor axis = 0.845 arcsec, PA = 90.926 deg

Output 2/3

For use with CASA simdata

Input sky model:	Download processed model in FITS format (and with primary beam attenuation)
Download CASA simobserve/analyze file:	20170328214203Hpxsd.simdata.last
Download pointing file:	20170328214203Hpxsd.ptg.txt

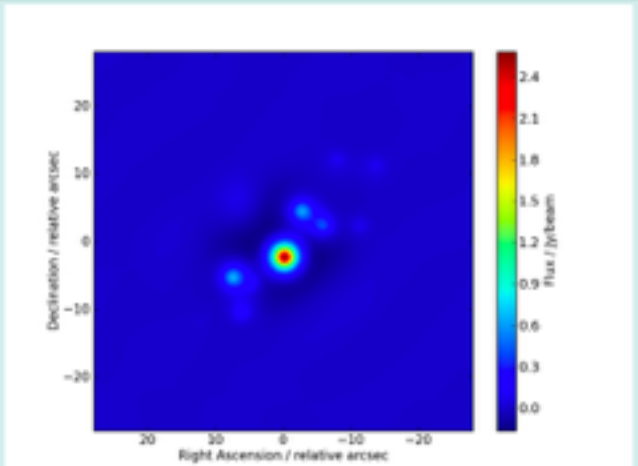
Data products

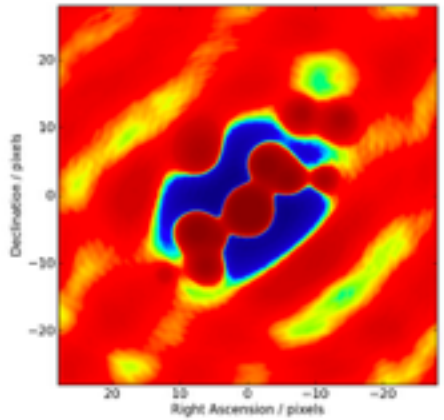
Your simulated image:

Download FITS file

and

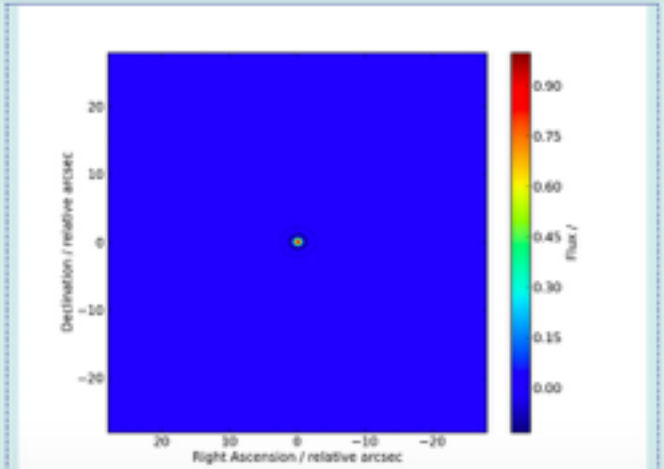
with primary beam correction

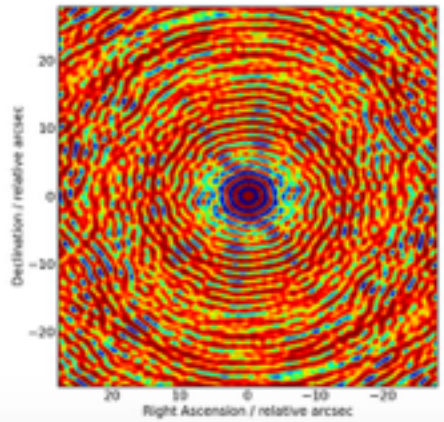




Dirty Beam

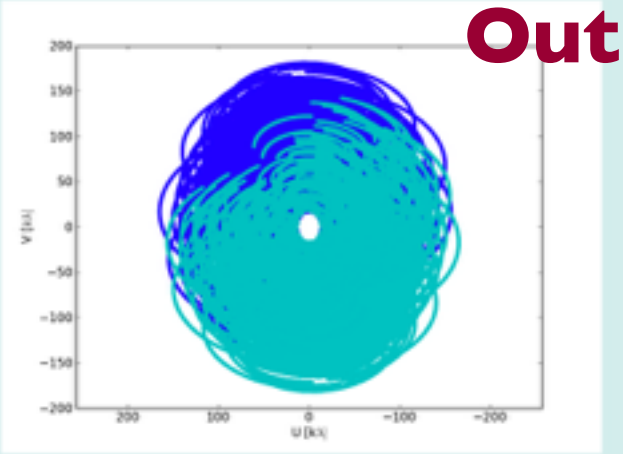
(Point Spread Function):





Output 3/3

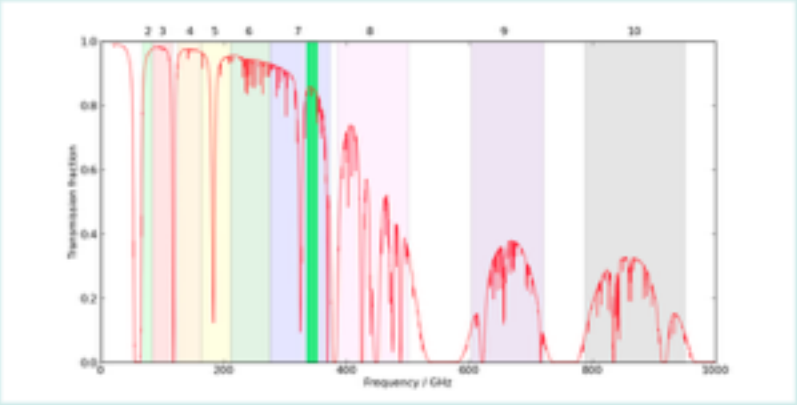
Coverage in the *uv*-plane:

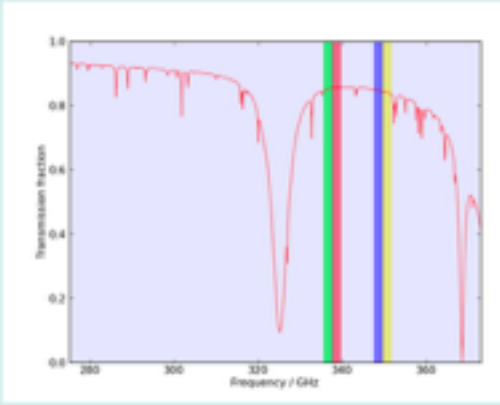


Atmospheric transmission for

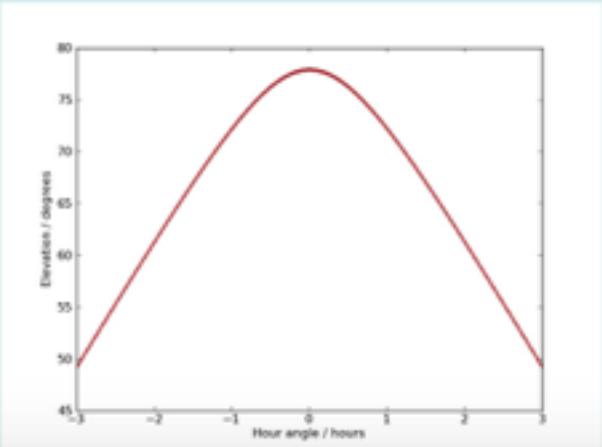
all bands (left) and

the selected band (right)





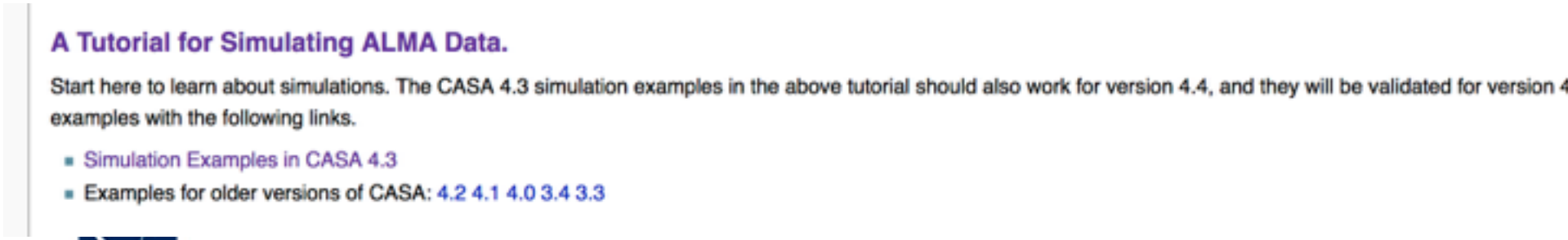
Elevation vs time:



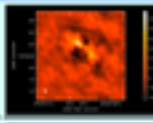
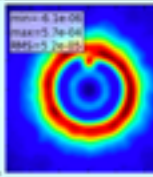
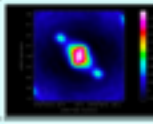
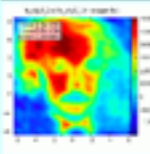
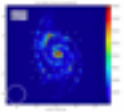
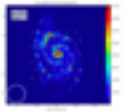
Simobserve/Simanalyze in CASA

- More flexible that the Online tool
- Two steps, starting from an input image:
  - Simobserve Fourier transforms the input image -> .ms file
  - Simanalyze generates the dirty image and dirty beam (PSF) and also deconvolves ("cleans") it -> final image

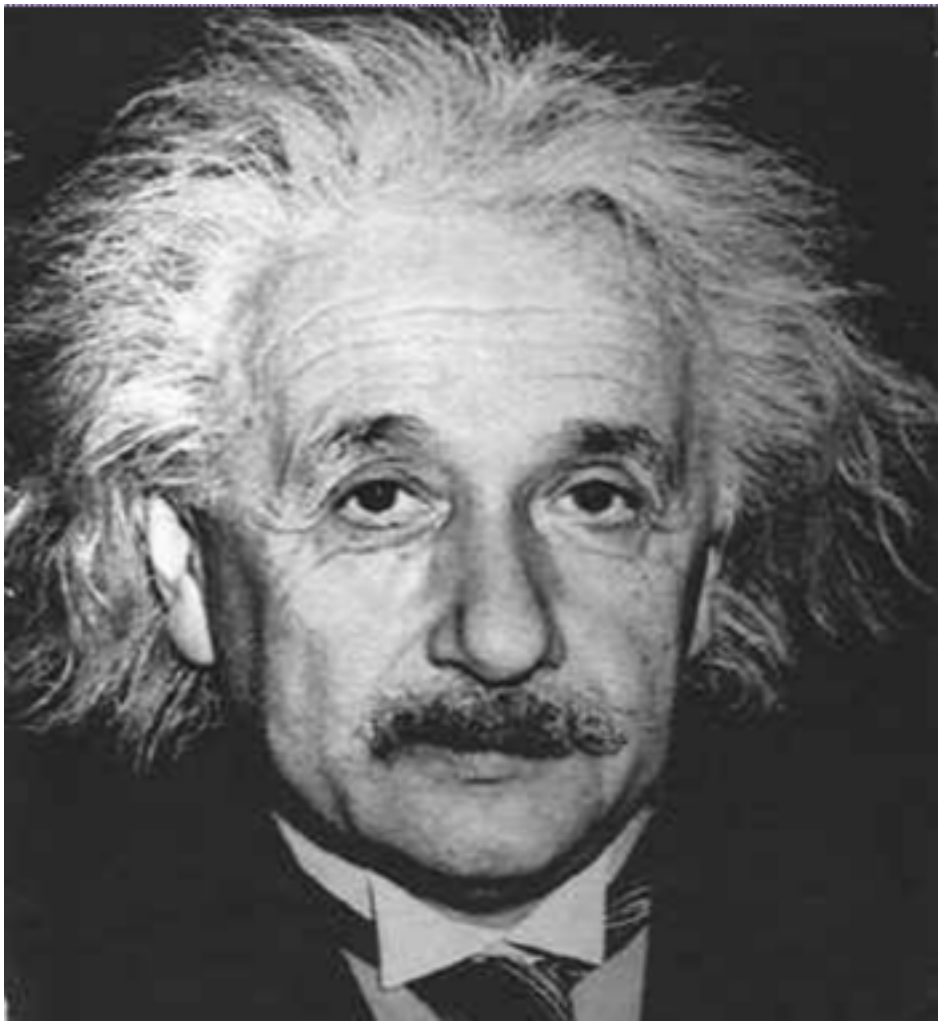
Helpful tutorials here:
https://casaguides.nrao.edu/index.php?title=ALMAguides



Simobserve/Simanalyze in CASA

Simulation Guide for New Users (CASA 4.3) A fully annotated tutorial that uses a Spitzer SAGE 8 micron continuum image of 30 Doradus and scales it to greater distance. A good place for new users to start.	
Protoplanetary Disk Simulation (CASA 4.3) A sky model with a lightly annotated script that simulates a protoplanetary disk. Uses a theoretical model of dust continuum from Sebastian Wolff, scaled to the distance of a nearby star. This is another fairly generic simulation - if you're short on time, you probably don't need to go through this one and the New Users guide, but it can be useful to go through multiple examples.	
Simulation Guide Component Lists (CASA 4.3) Tutorial for simulating data based on multiple sources (using both a FITS image and a component list). If you are interested in simulating from a list of simple sources (point, Gaussian, disk), rather than or in addition to a sky model image, then read the considerations here.	
Einstein-Face (CASA 4.3) A sky model and lightly annotated script that simulates the face of Einstein as seen by ALMA. This simulation is particularly useful for those who wish to better understand spatial filtering by an interferometer, but doesn't demonstrate new capabilities of the simulation tasks beyond those described above.	
ACA Simulation (CASA 4.3) A tutorial for simulating ALMA observations that use multiple configurations or use the 12-meter array in combination with the ALMA Compact Array. This tutorial demonstrates combining data from each ALMA component "by hand". This guide is of particular interest to those wishing to explore using the 12-m array in combination with the ACA, and those interested in combining data from multiple 12-m array configurations.	
Simalma (CASA 4.3) This tutorial demonstrates how to use **simalma**, a task that simplifies simulations that include the main 12-m array plus the ACA. Like the previous guide, this one is of particular interest to those wishing to explore multi-component ALMA observations.	

Observing Einstein with ALMA

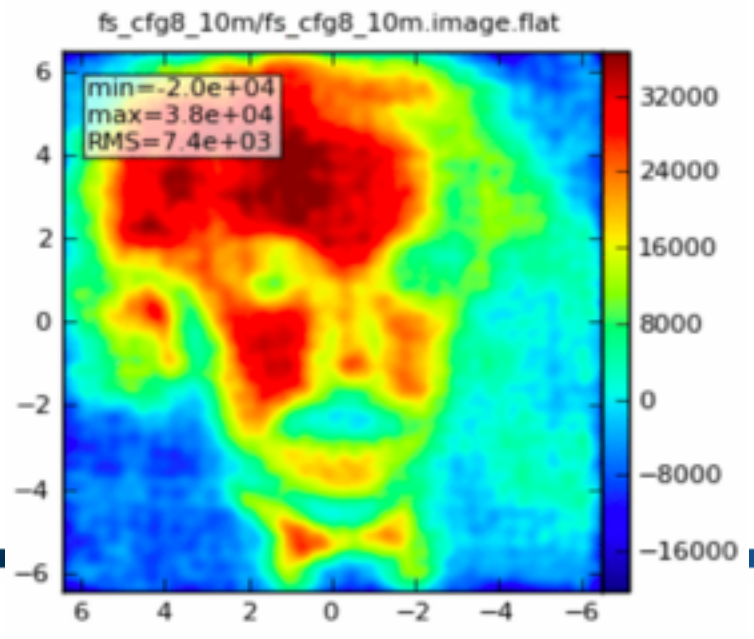


Input model FITS
(converted from jpg)

Observing Einstein with ALMA

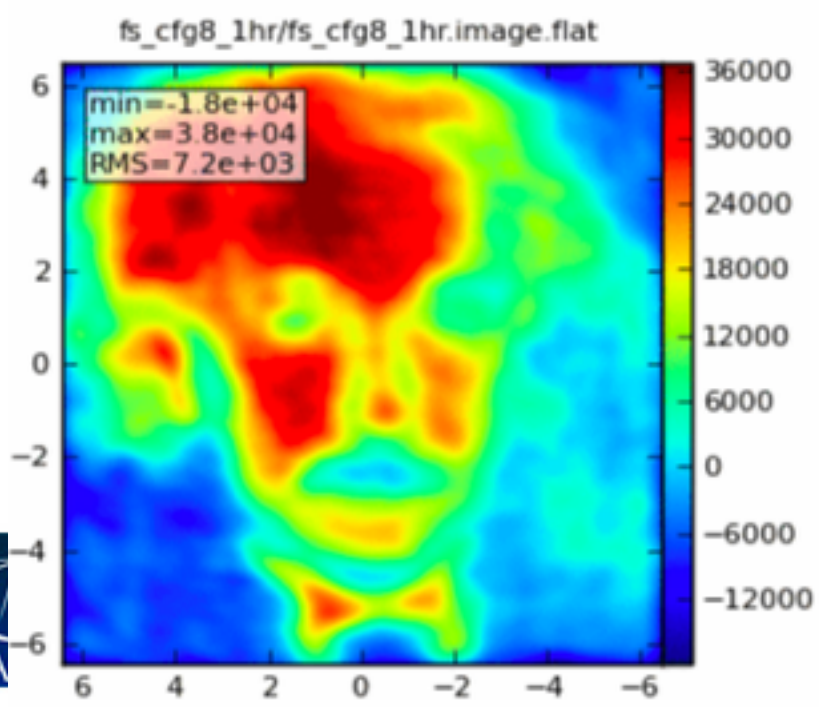
```
# simobserve is used to simulate the observation
default('simobserve')
# Full science, configuration 08, 10 minutes
project = 'fs_cfg8_10m'
skymodel = 'Einstein.fits'
indirection = 'J2000 03h30m00 -28d00m00'
incell = '0.043arcsec'
incenter = '245GHz'
inwidth = '2GHz'
setpointings = T
integration = '300s'
mapsize = ['1arcmin','1arcmin']
maptype = 'hexagonal'
pointingspacing = '1arcmin'
graphics = 'both'
obsmode = 'int'
antennalist =  "alma.out08.cfg"
totaltime = '600s'
thermalnoise = ""
simobserve()
```

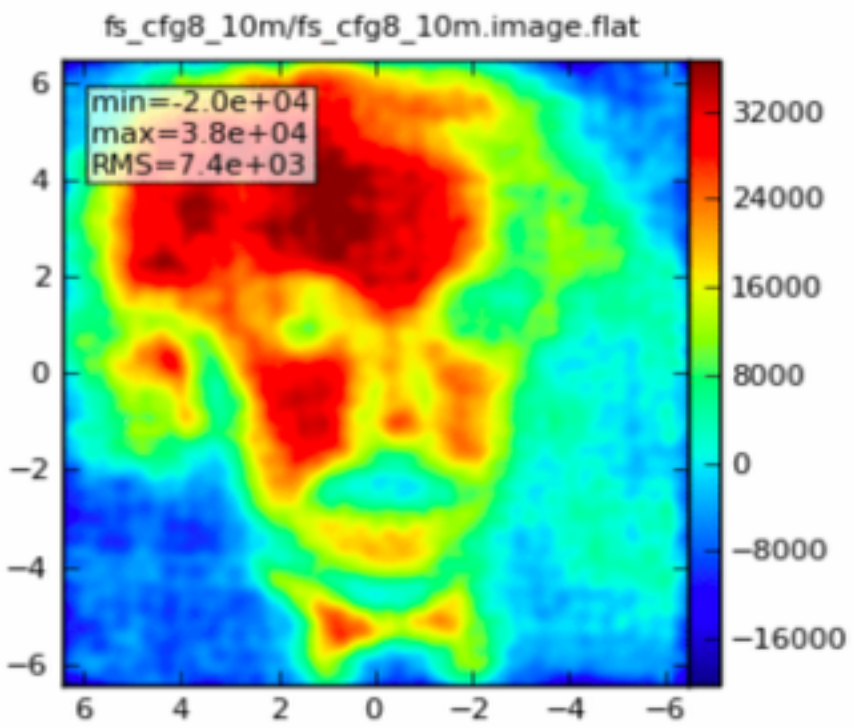
```
# simanalyze is used to take the simulation output, and provide helpful plots
default('simanalyze')
project = 'fs_cfg8_10m'
image = T
vis = project+'.alma.out08.ms'
imsize = [300,300]
cell = '0.043arcsec'
niter = 2000
weighting = 'natural'
analyze = F
overwrite = T
simanalyze()
```



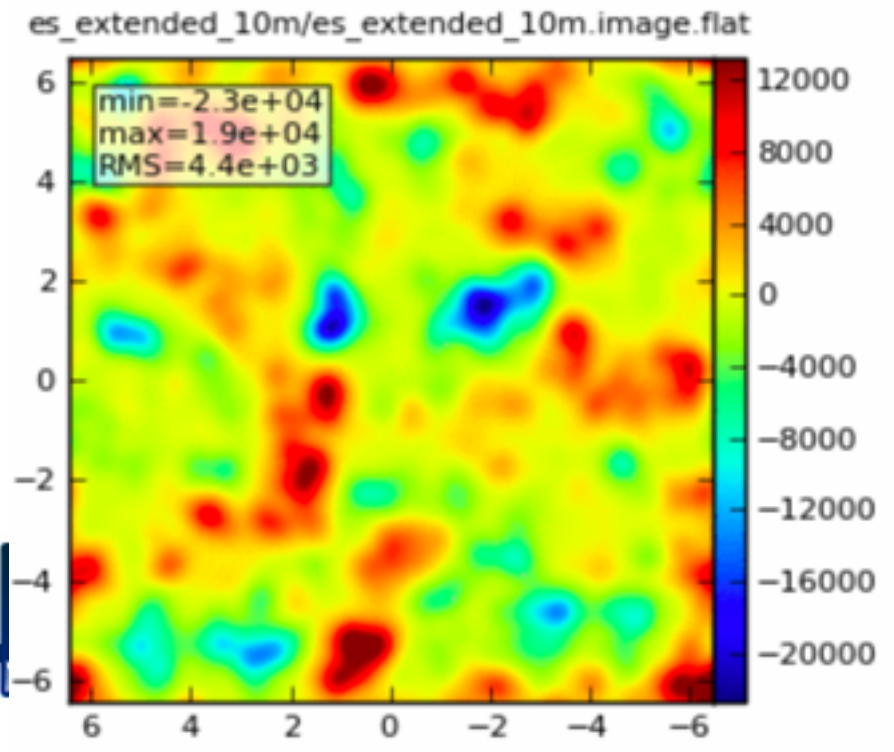
clean beam ~ 0.62 x 0.56”

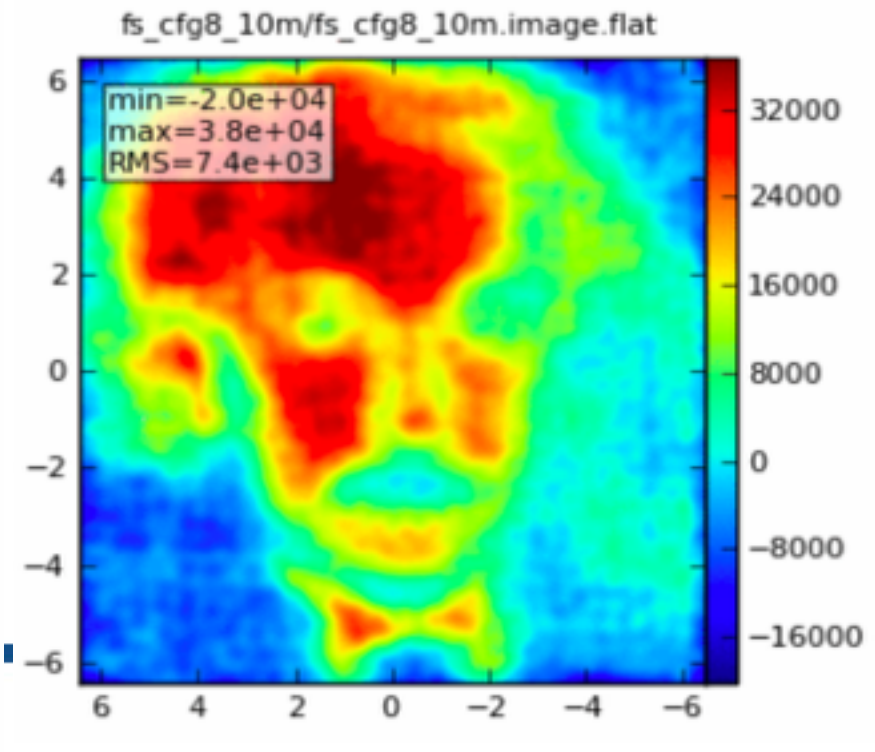
```
tget(simobserve)
# Full science, configuration 08, 1 hour
project = 'fs_cfg8_1hr'
totaltime = '3600s'
simobserve()
tget(simanalyze)
project = 'fs_cfg8_1hr'
vis = project+'.alma.out08.ms'
simanalyze()
```





```
tget(simobserve)
project = 'es_extended_10m'
antennalist = "alma.cycle0.extended.cfg"
totaltime = '600s'
simobserve()
tget(simanalyze)
project = 'es_extended_10m'
vis = project+'.alma.cycle0.extended.ms'
simanalyze()
```





```
tget(simobserve)
antennalist = "alma.out16.cfg"
project = 'fs_cfg16_1hr'
totaltime = '3600s'
simobserve()
tget(simanalyze)
project = 'fs_cfg16_1hr'
vis = project+'.alma.out16.ms'
simanalyze()
```

clean beam ~ 0.17 x 0.15”