Simulating ALMA Observations

How to get started and what to expect

Simulating ALMA data

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Andrew McNichols

NRAO (CASA Simulations, next-generation CASA)

casa-feedback@nrao.edu

amcnicho@nrao.edu

Credit:
Remy Indebetouw (NRAO)

Why simulate ALMA observations?

"Running a simulation can help convince the TAC that your proposed observations are feasible"

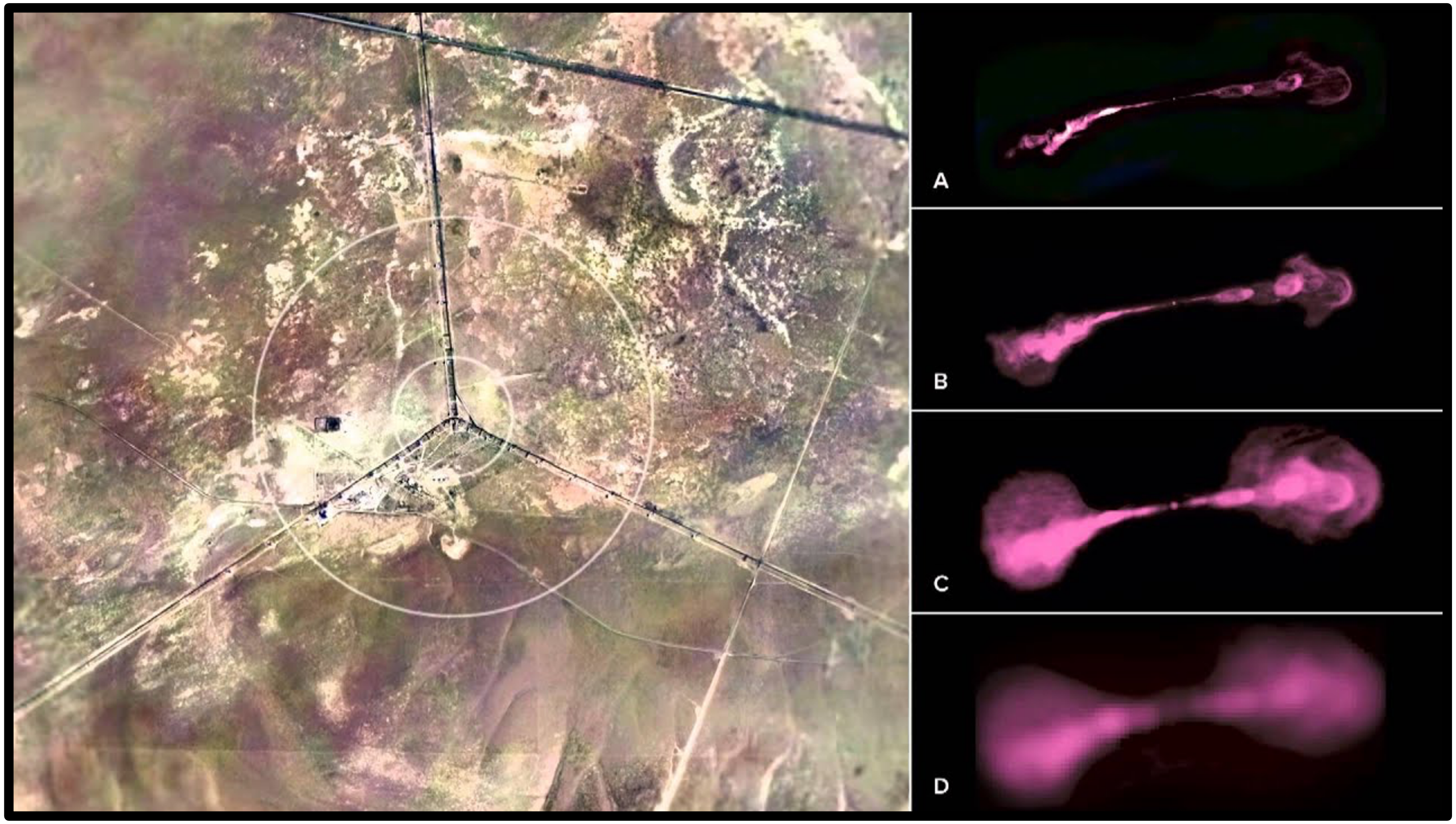
Why simulate ALMA observations?

yourself

"Running a simulation can help convince ~~the TAC~~ that your proposed observations are feasible"

Why simulate ALMA observations?

Proposed resolution / array configuration



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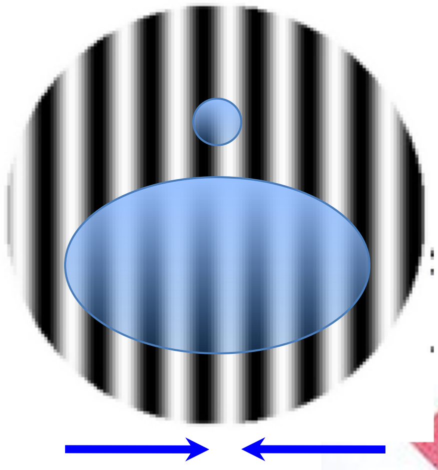
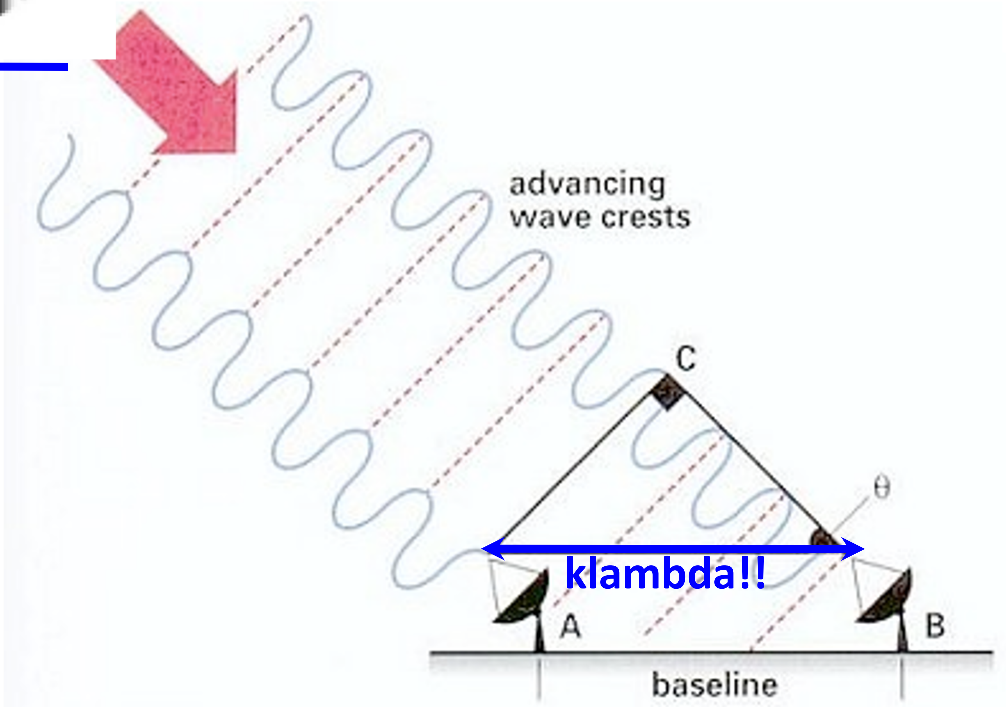


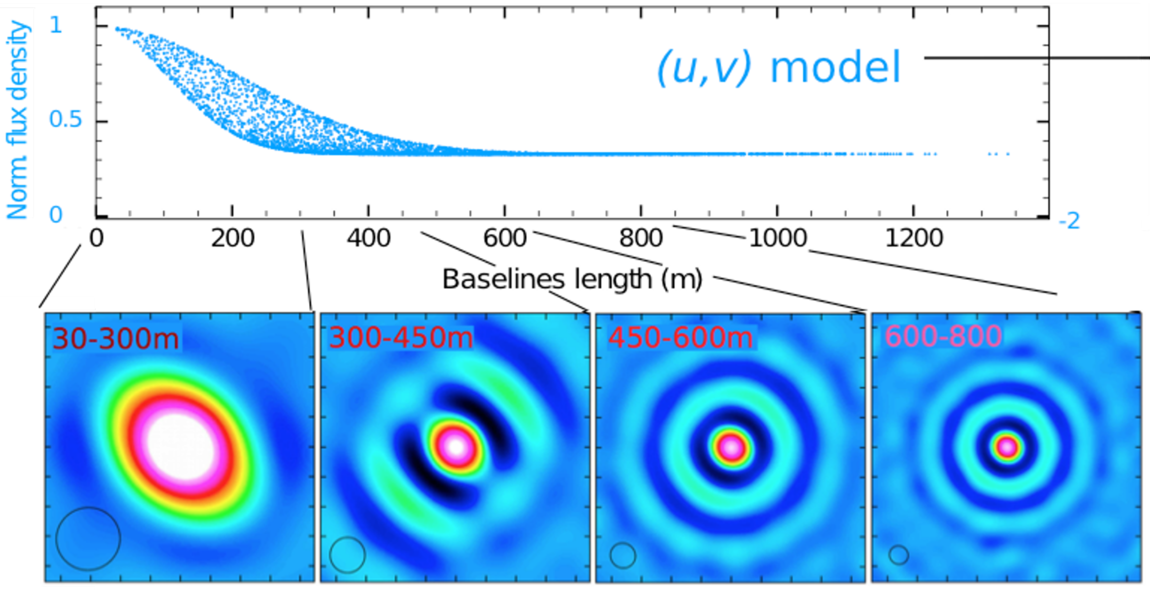
Extended emission
 Resolved out on long baselines



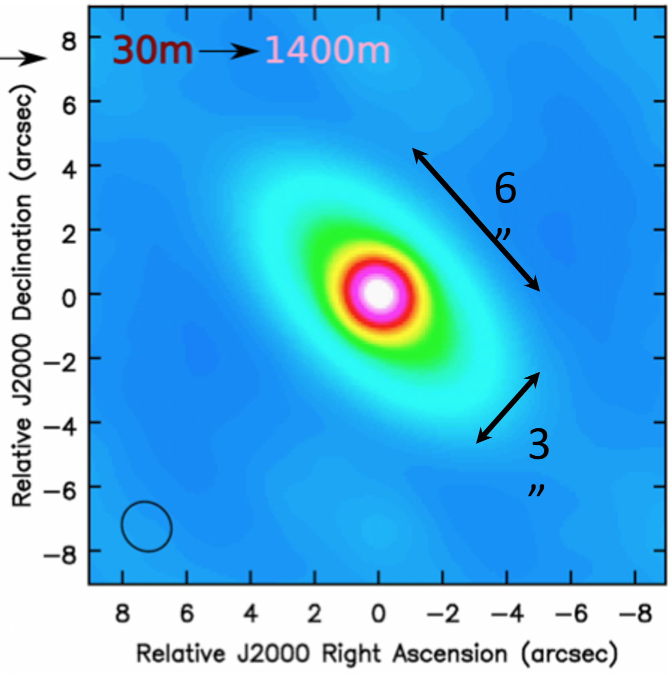
Why simulate ALMA observations?

Proposed resolution / array configuration

35 GHz



Point-source + Gaussian



Emonts et al 2018, ASPC, 517, 587

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Emonts et al 2018, ASPC, 517, 587

35 GHz

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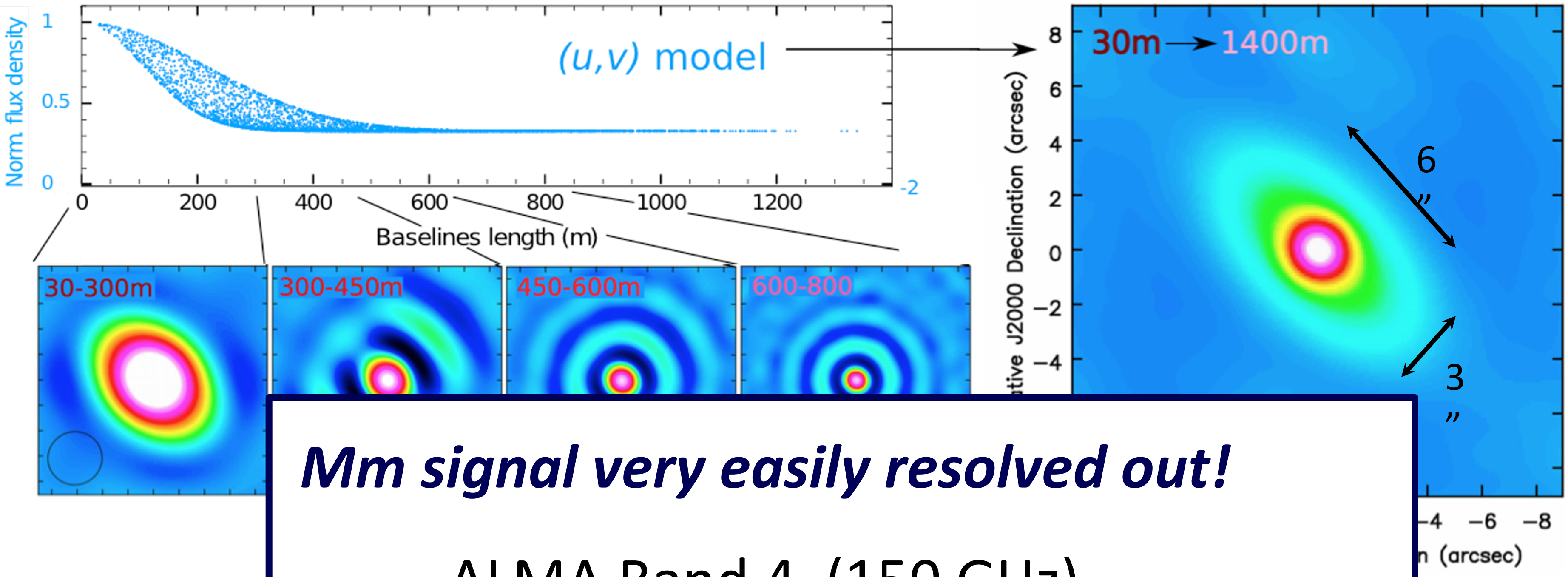


Mm signal very easily resolved out!

ALMA Band 4 (150 GHz)

 1km baseline: < 0.5 arcsec

CO(4-3) at z=2: < 4 kpc

How to simulate ALMA observations?

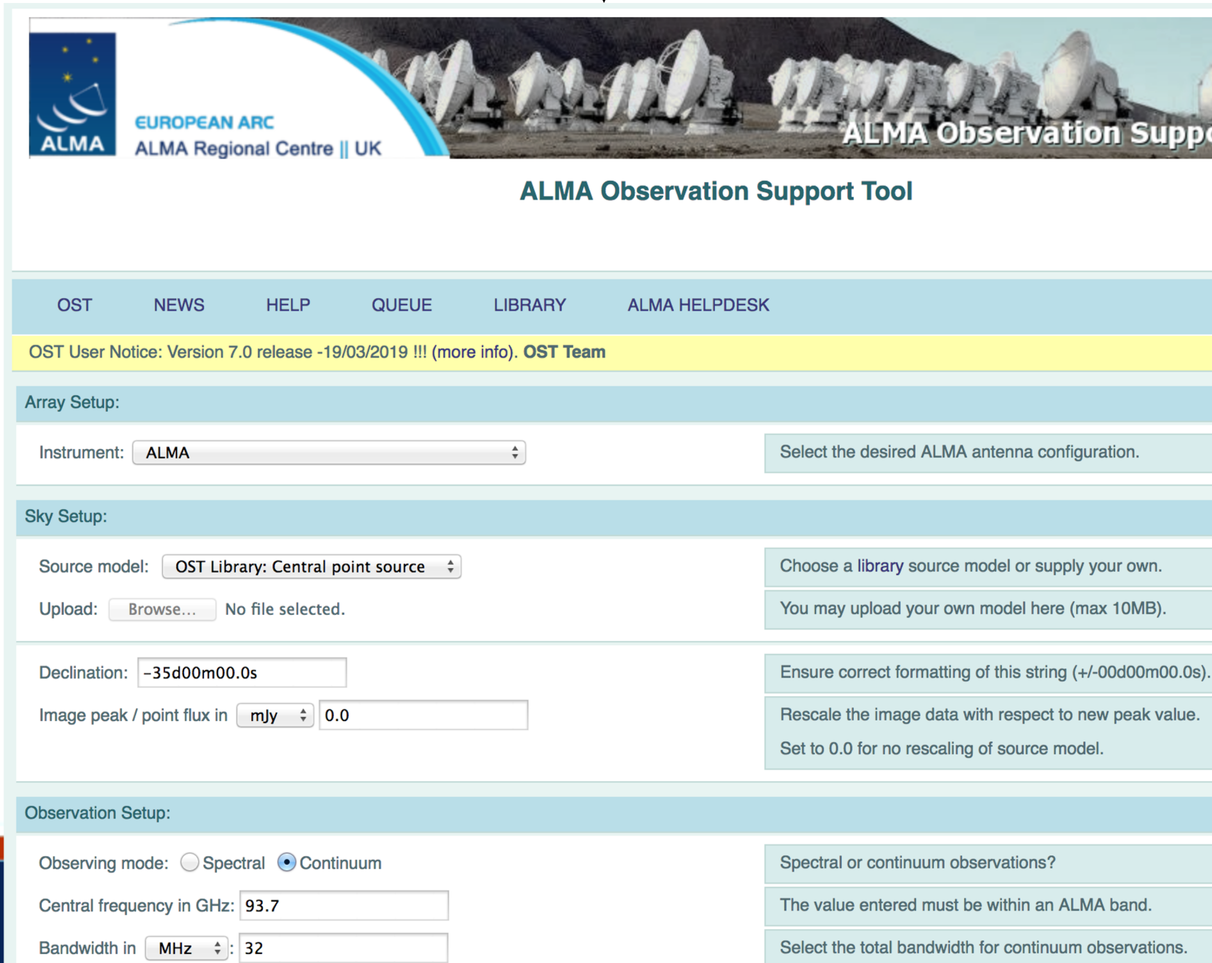
CASA

Common Astronomy Software Applications

https://casa.nrao.edu

Option 1: CASA

Option 2: ALMA Observations Support Tool



ALMA Observation Support Tool

OST NEWS HELP QUEUE LIBRARY ALMA HELPDESK

OST User Notice: Version 7.0 release -19/03/2019 !!! (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.

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.

CASA

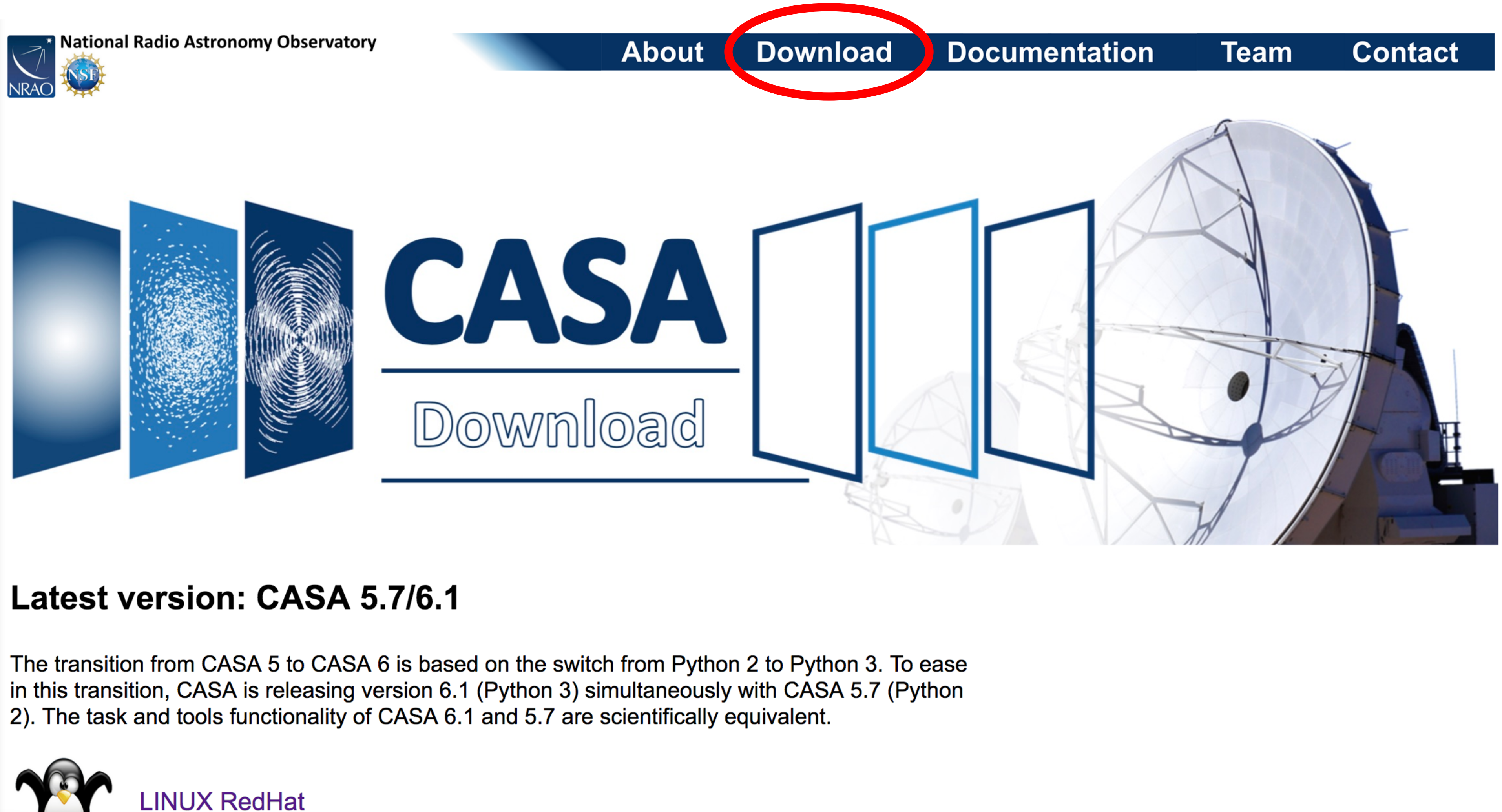
Latest release: CASA 6.1

Official ALMA version: ***CASA 5.6.1***
(CASA 6.1.1 with ALMA-pipeline pending)

CASA

Download CASA versions

https://casa.nrao.edu



Latest version: CASA 5.7/6.1

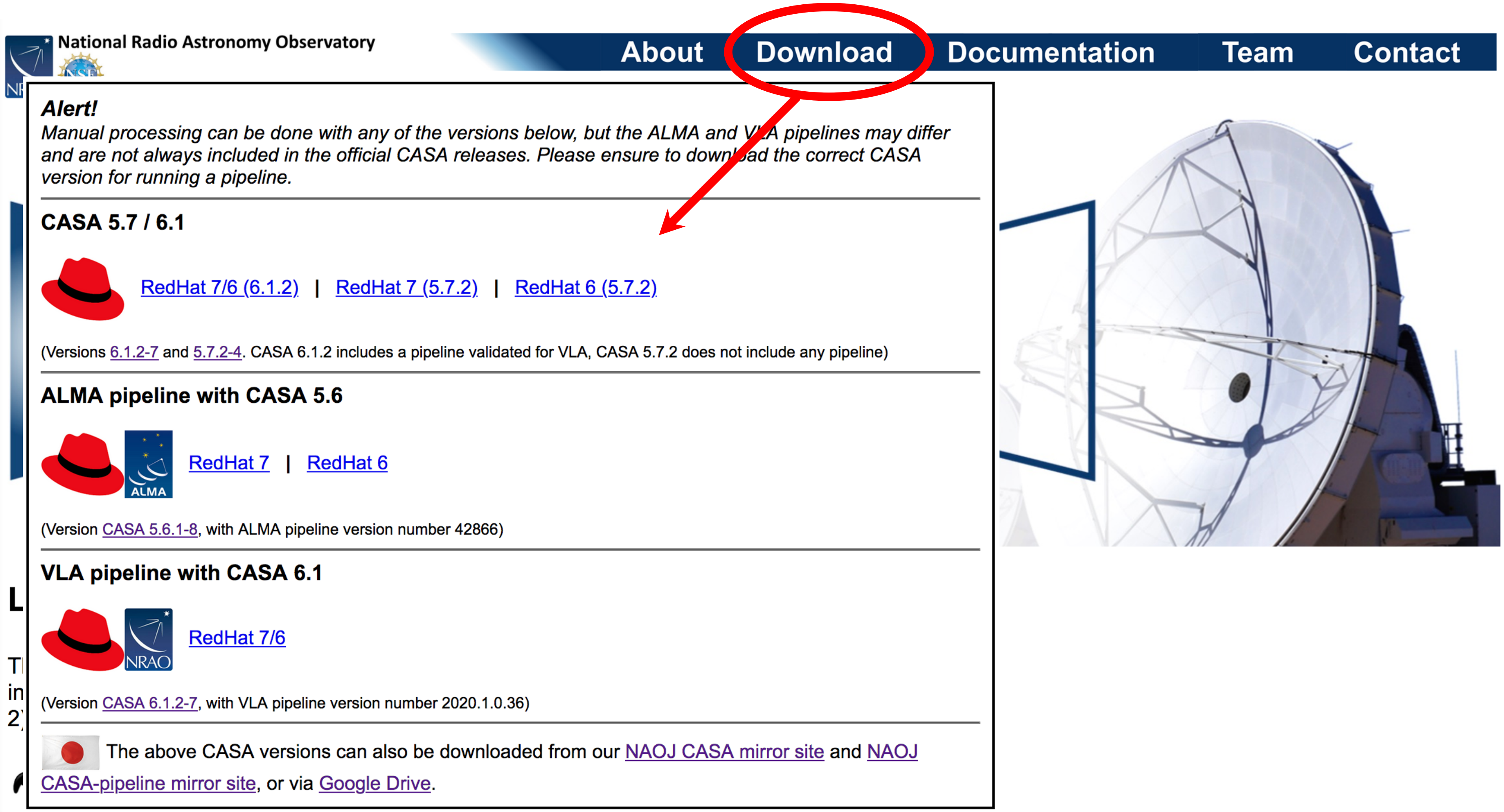
The transition from CASA 5 to CASA 6 is based on the switch from Python 2 to Python 3. To ease in this transition, CASA is releasing version 6.1 (Python 3) simultaneously with CASA 5.7 (Python 2). The task and tools functionality of CASA 6.1 and 5.7 are scientifically equivalent.

LINUX RedHat

CASA

Download CASA versions

https://casa.nrao.edu



Alert!
Manual processing can be done with any of the versions below, but the ALMA and VLA pipelines may differ and are not always included in the official CASA releases. Please ensure to download the correct CASA version for running a pipeline.

CASA 5.7 / 6.1

RedHat 7/6 (6.1.2) | RedHat 7 (5.7.2) | RedHat 6 (5.7.2)

(Versions 6.1.2-7 and 5.7.2-4. CASA 6.1.2 includes a pipeline validated for VLA, CASA 5.7.2 does not include any pipeline)

ALMA pipeline with CASA 5.6

RedHat 7 | RedHat 6

(Version CASA 5.6.1-8, with ALMA pipeline version number 42866)

VLA pipeline with CASA 6.1

RedHat 7/6

(Version CASA 6.1.2-7, with VLA pipeline version number 2020.1.0.36)

The above CASA versions can also be downloaded from our NAOJ CASA mirror site and NAOJ CASA-pipeline mirror site, or via Google Drive.

CASA

Latest release: CASA 6.1

- Monolithic tar-file (pipelines/manual)

  Plug-and-play (like always)

- Modular pip-wheels (manual)

  Integration Python (Jupyter Notebooks)

  CASA 6.1: tools & tasks (CASA 6.2: GUIs)

CASA

Latest release: CASA 6.1

ALMA Cycle 8: CASA 6.1.1

(release pending)

- simulator ⍰ tclean
  (CASA 5.6 and earlier ⍰ old clean)

- simulator ⍰ Cycle-8 array-
  configuration files

Do **<u>not</u>** use CASA 5.3 for simulations!
(bug tool ‘cl.addcomponents / ia.modify’)

CASA
Common Astronomy
Software Applications

How to simulate ALMA observations?

1. CASA simulation tasks:

- simobserve: *create MS*
- simanalyze: *image MS*

$$\left.\begin{array}{l}\text{simobserve}\\\text{simanalyze}\end{array}\right]\text{— simalma}$$

└→ *(or tclean)*

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2. Simulator tools:

sm tool / simutil

CASA
Common Astronomy Software Applications

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$\Big]$ simalma

Common Astronomy Software Applications

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6.1.1: ALMA Cycle 0 – 8 + ACA

VLA, ngVLA, ATCA, PdbI, WSRT, CARMA, MeerKAT, SMA, VLBA

(Config files: ALMA Cycle 8 = Cycle 7)

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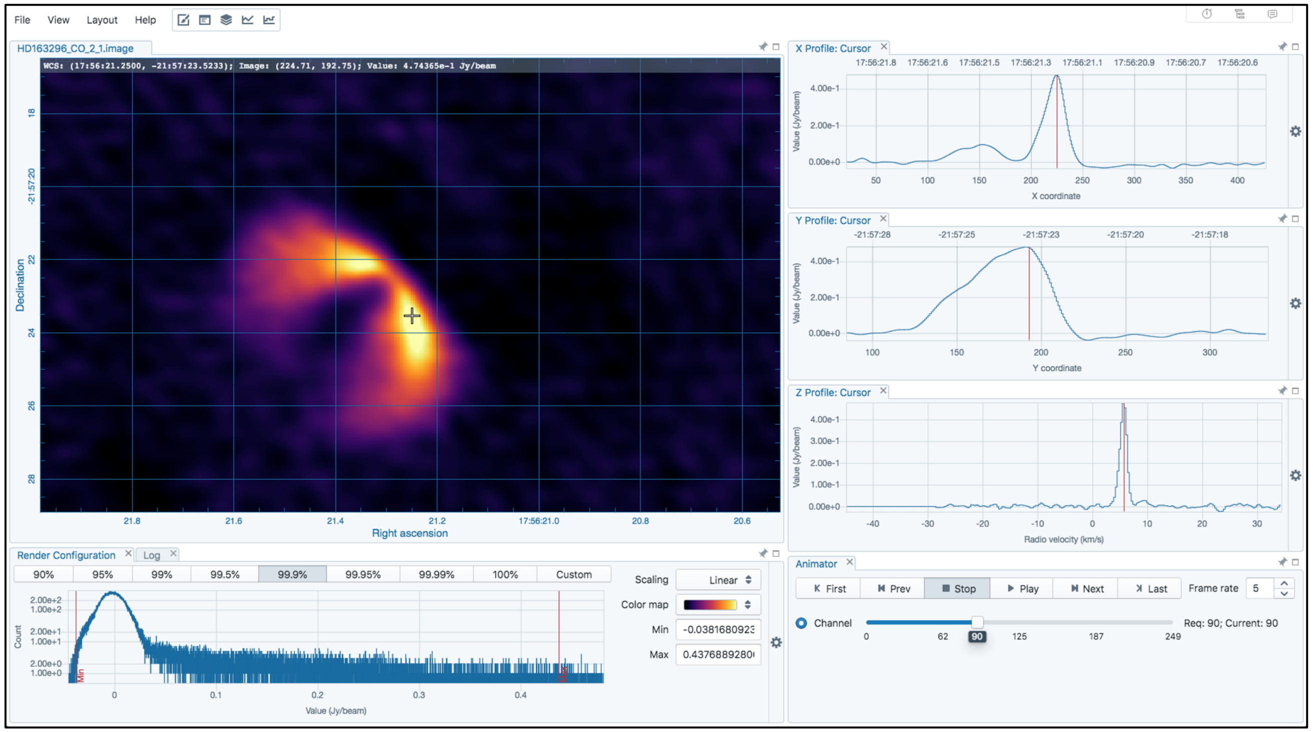
4. Visualization images:

CASA Viewer / CARTA

Common Astronomy Software Applications

How to simulate ALMA observations?

Cube Analysis and Rendering Tool for Astronomy



CARTA version 1.4

Not all features of Viewer, but rapid progress!

Replace CASA Viewer in near future

https://cartavis.github.io/

Consortium: ASIAA, IDIA, NRAO, Univ. Alberta

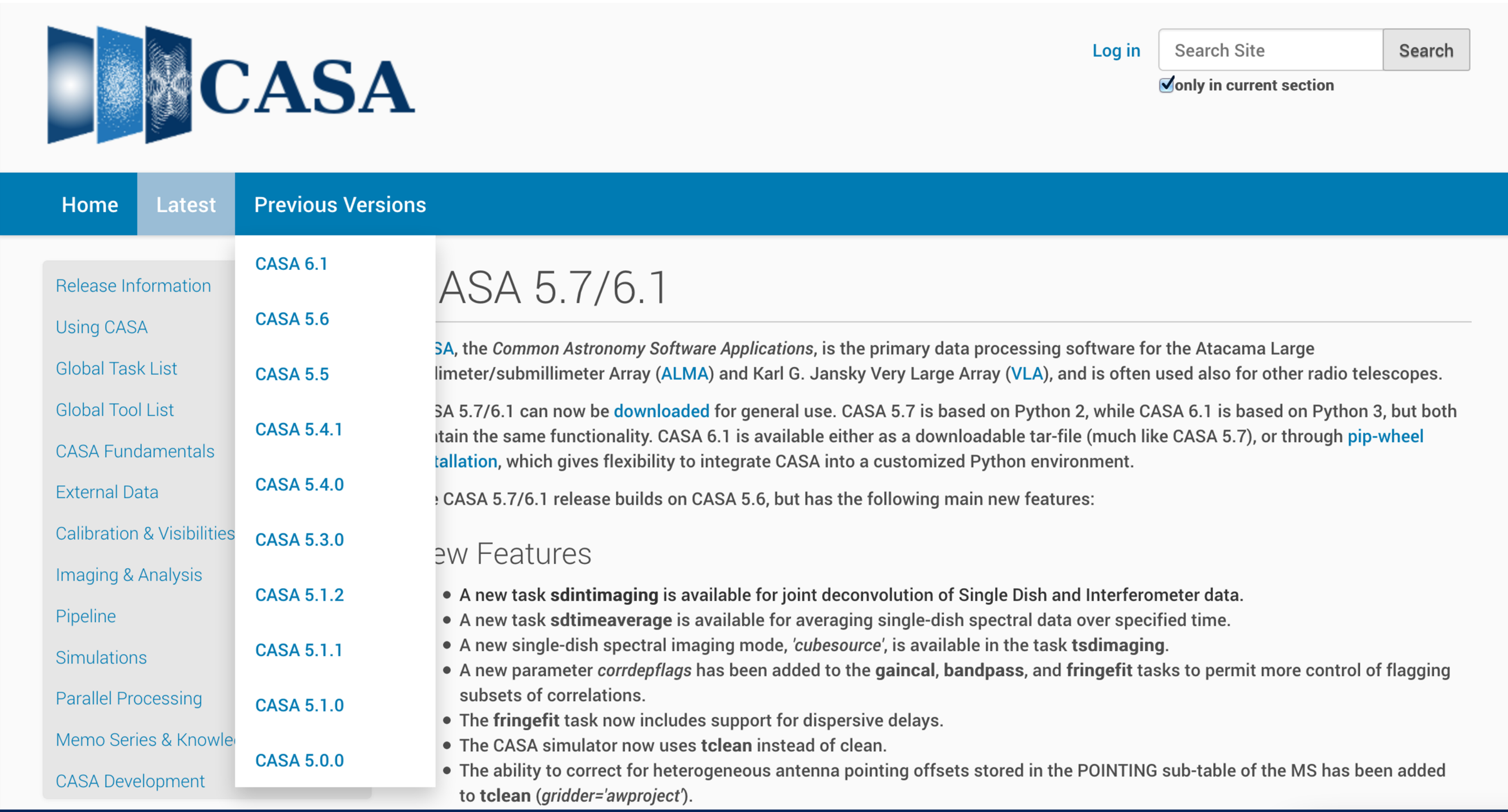
4. Visualization images:

CASA Viewer / CARTA

More information on ALMA simulations

1. CASA Docs: Official CASA documentation

https://casa.nrao.edu/casadocs/



ASA 5.7/6.1

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SA 5.7/6.1 can now be downloaded for general use. CASA 5.7 is based on Python 2, while CASA 6.1 is based on Python 3, but both itain the same functionality. CASA 6.1 is available either as a downloadable tar-file (much like CASA 5.7), or through pip-wheel tallation, which gives flexibility to integrate CASA into a customized Python environment.

CASA 5.7/6.1 release builds on CASA 5.6, but has the following main new features:

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- A new task **sdintimaging** is available for joint deconvolution of Single Dish and Interferometer data.
- A new task **sdtimeaverage** is available for averaging single-dish spectral data over specified time.
- A new single-dish spectral imaging mode, *'cubesource'*, is available in the task **tsdimaging**.
- A new parameter *corrdepflags* has been added to the **gaincal**, **bandpass**, and **fringefit** tasks to permit more control of flagging subsets of correlations.
- The **fringefit** task now includes support for dispersive delays.
- The CASA simulator now uses **tclean** instead of clean.
- The ability to correct for heterogeneous antenna pointing offsets stored in the POINTING sub-table of the MS has been added to **tclean** (*gridder='awproject'*).

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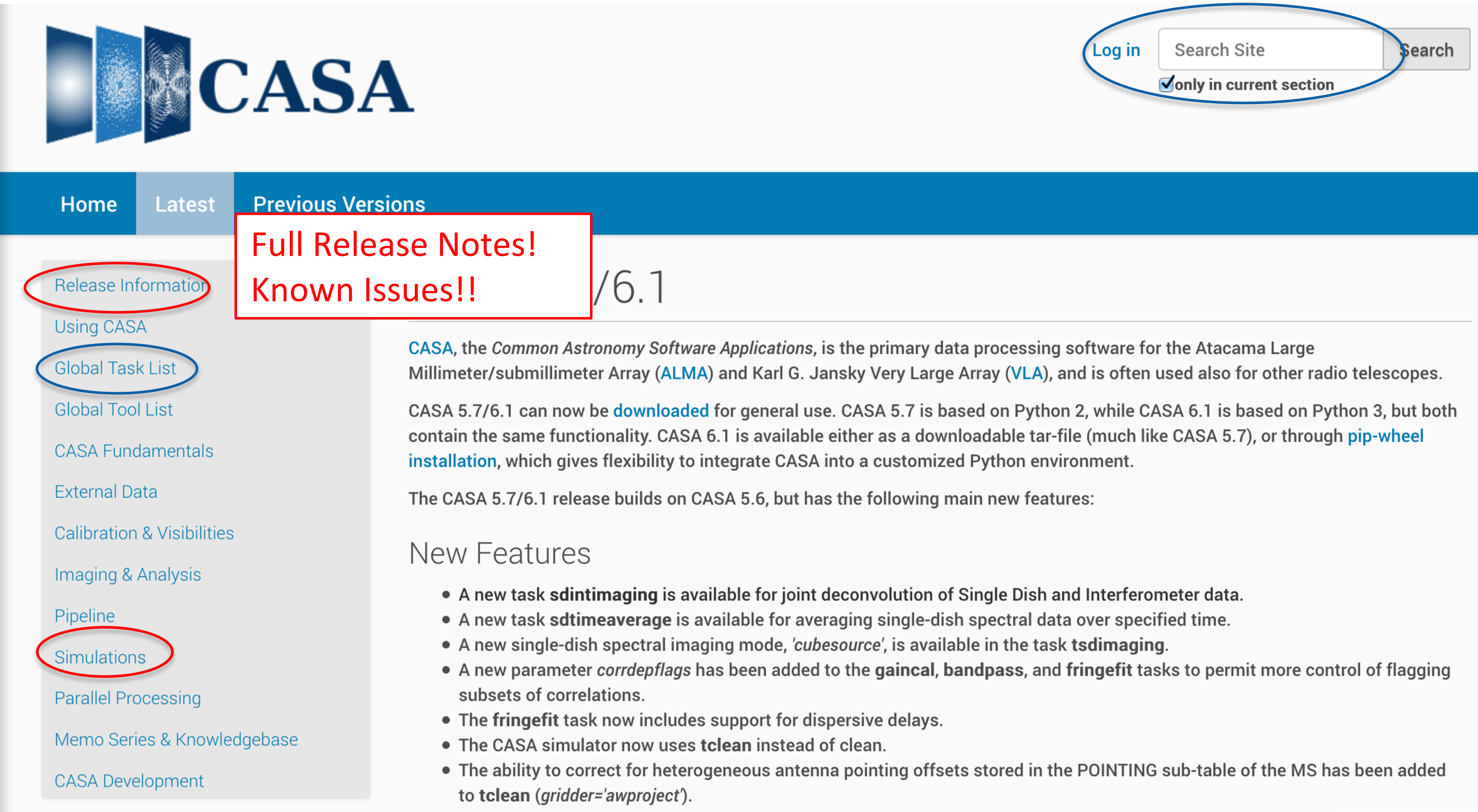

/6.1

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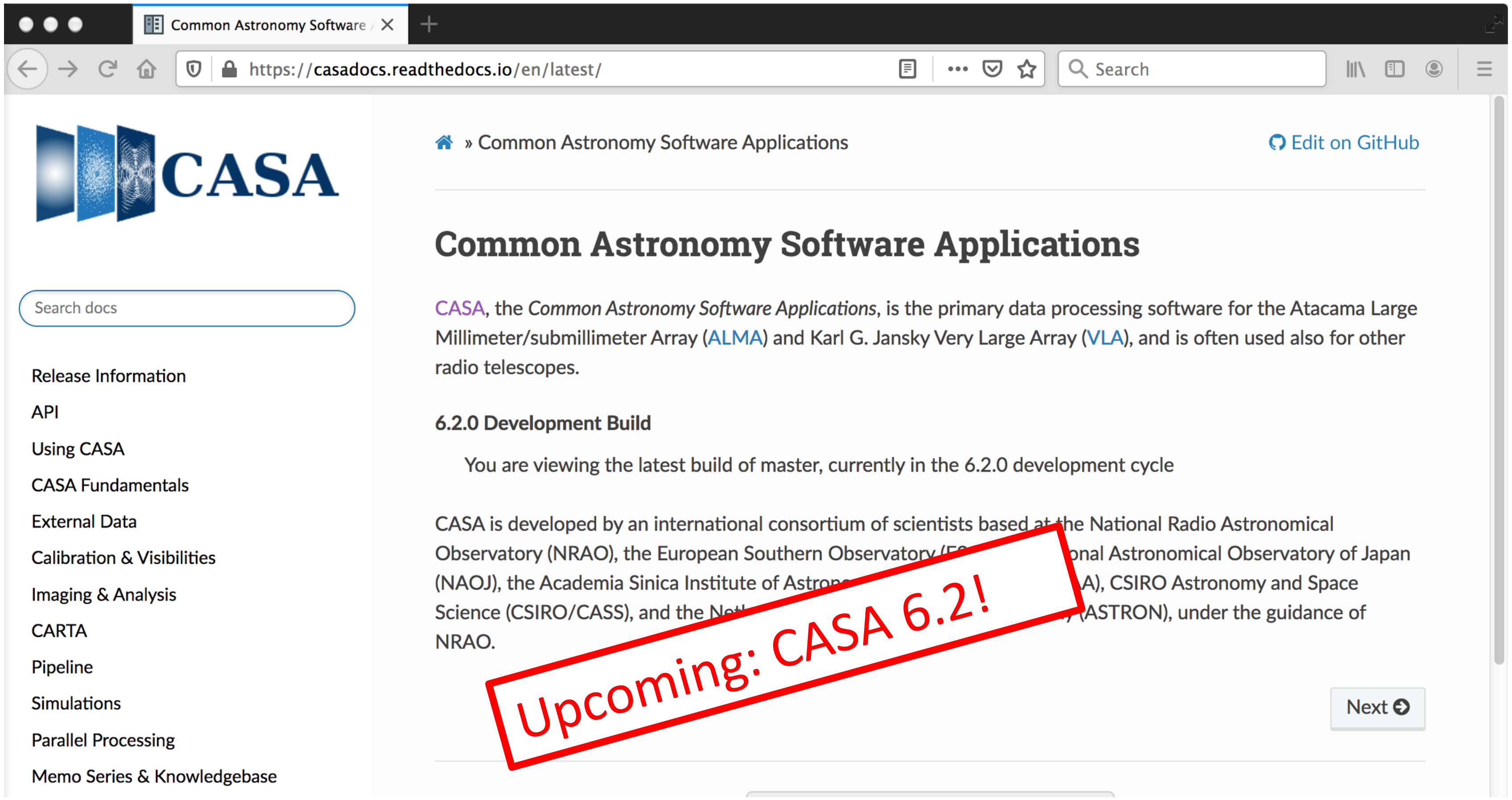
Common Astronomy Software
https://casadocs.readthedocs.io/en/latest/
Search
CASA
Search docs
Edit on GitHub
Next

» Common Astronomy Software Applications

Release Information
API
Using CASA
CASA Fundamentals
External Data
Calibration & Visibilities
Imaging & Analysis
CARTA
Pipeline
Simulations
Parallel Processing
Memo Series & Knowledgebase

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6.2.0 Development Build

You are viewing the latest build of master, currently in the 6.2.0 development cycle

CASA is developed by an international consortium of scientists based at the National Radio Astronomical Observatory (NRAO), the European Southern Observatory (ES onal Astronomical Observatory of Japan (NAOJ), the Academia Sinica Institute of Astron A), CSIRO Astronomy and Space Science (CSIRO/CASS), and the Neth (ASTRON), under the guidance of NRAO.

Upcoming: CASA 6.2!

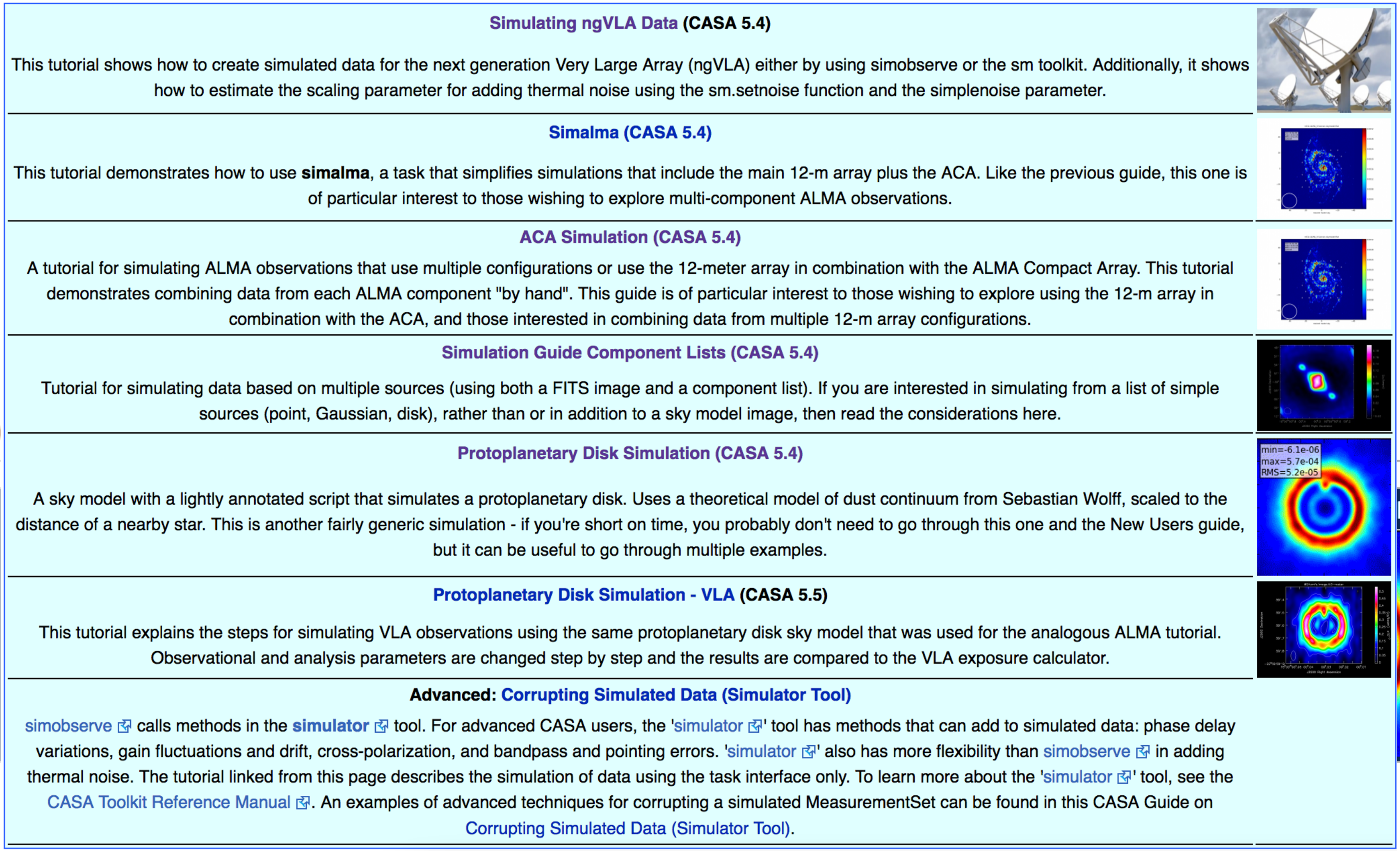
More information on ALMA simulations

1. CASA Docs: Official CASA documentation
https://casa.nrao.edu/casadocs/

2. CASA Guides: Telescope-specific CASA strategies
https://casaguides.nrao.edu/

CASA Tutorials

More information on ALMA simulations



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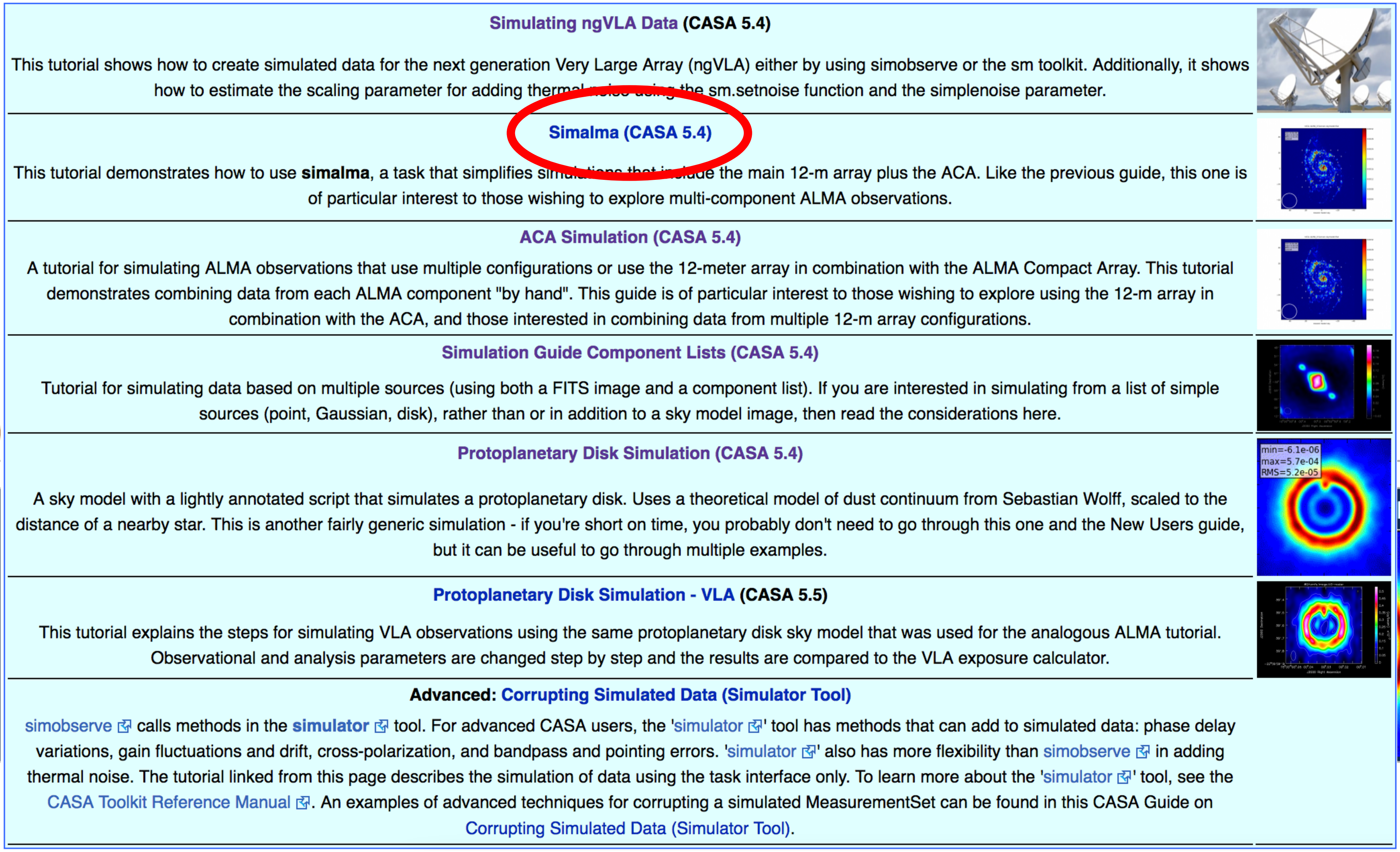
More information on ALMA simulations: Tutorials



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SIMALMA

CASA Guides:
https://casaguides.nrao.edu/

```
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os.system('curl https://casaguides.nrao.edu/images/3/3f/M51ha.fits.txt -f -o M51ha.fits')
skymodel          =  "M51ha.fits"
```

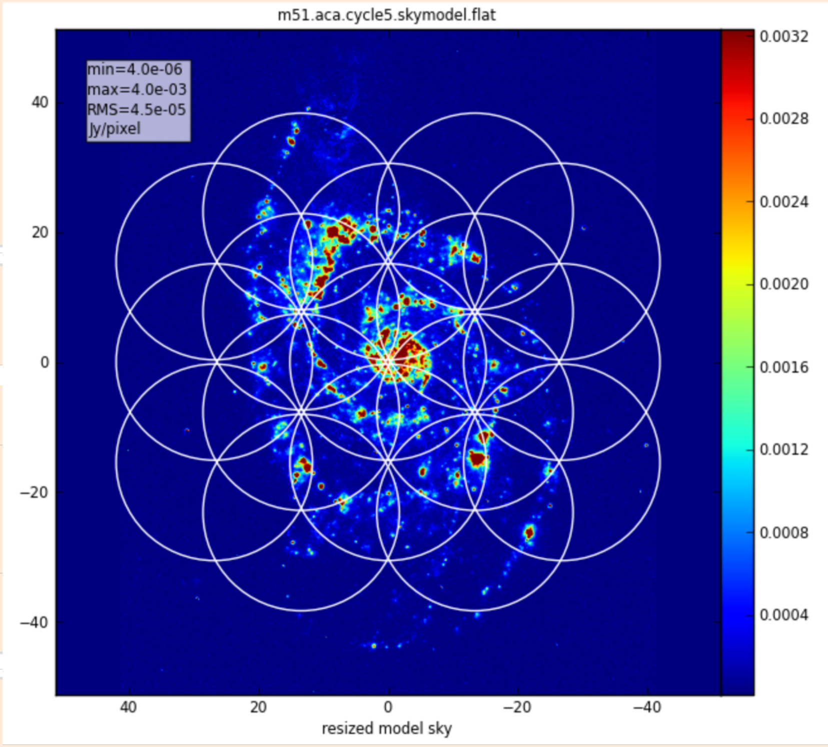
```
# Set model image parameters:
indirection="J2000 23h59m59.96s -34d59m59.50s"
incell="0.1arcsec"
inbright="0.004"
incenter="330.076GHz"
inwidth="50MHz"
```

```
antennalist=["alma.cycle6.3.cfg","aca.cycle6.cfg"]
```

```
totaltime="1800s"
tpnant = 2
tptime="7200s"
pwv=0.6
mapsize="1arcmin"
```

```
inp
```

```
go
```



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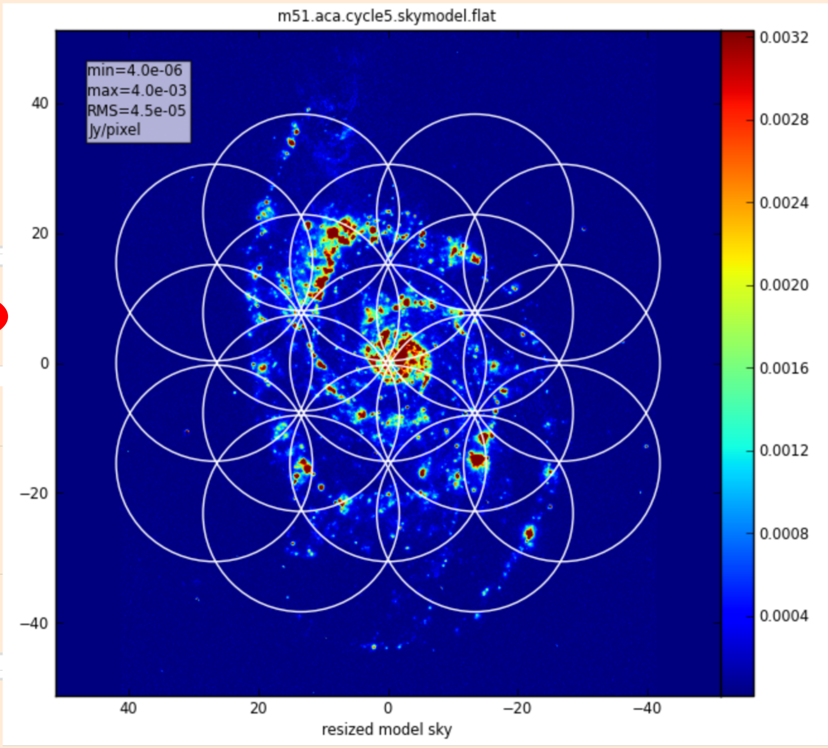
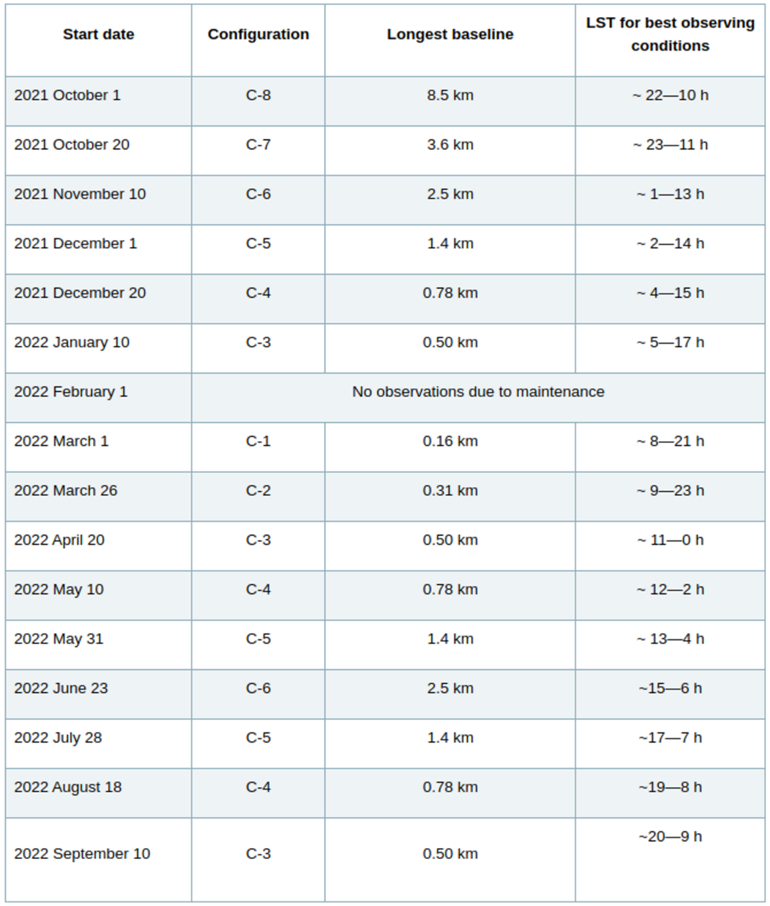
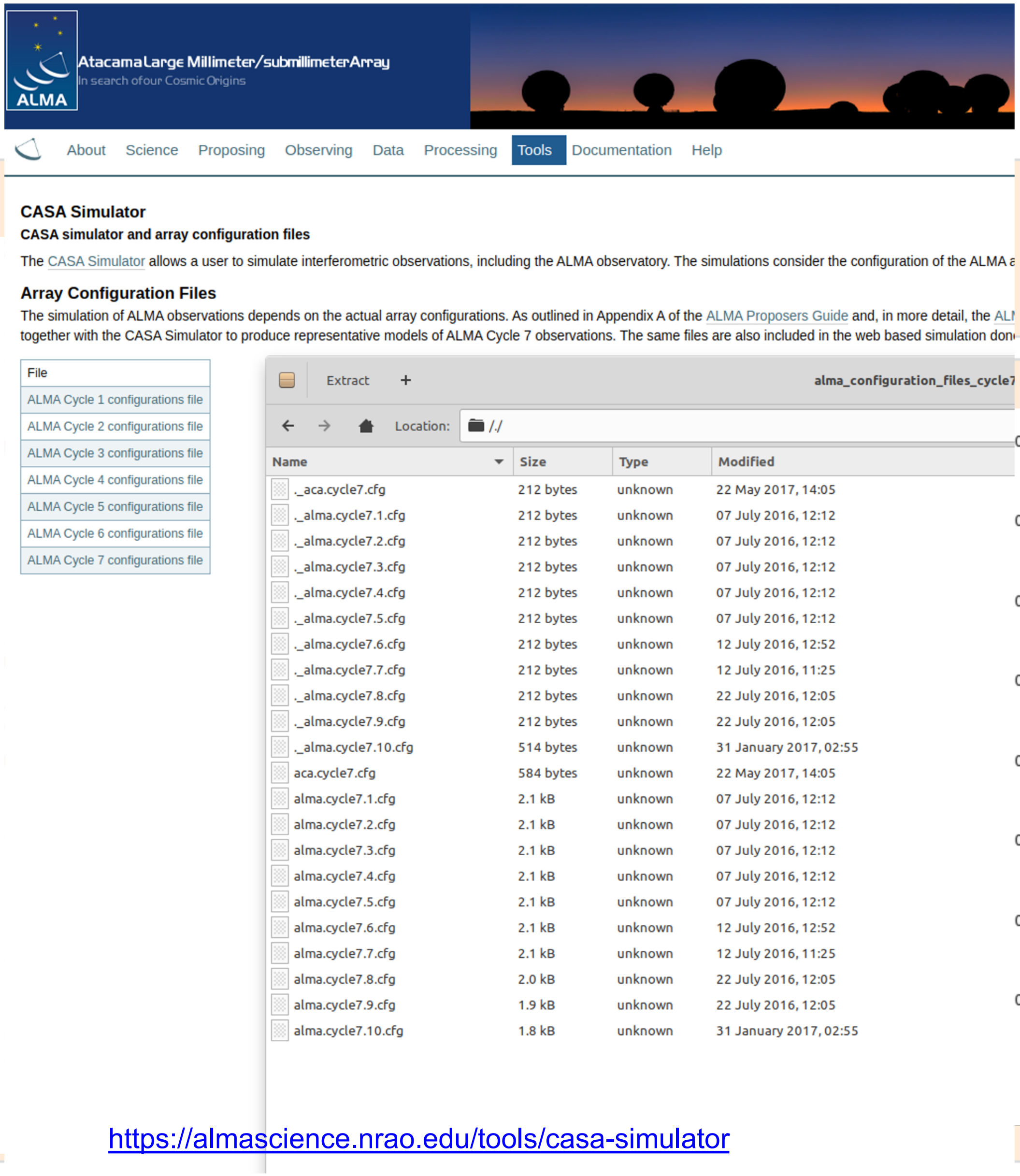


SIMALMA: Antenna Position Lists

```
# Model sky = Halpha image of M51
```



Start date	Configuration	Longest baseline	LST for best observing conditions
2021 October 1	C-8	8.5 km	~ 22—10 h
2021 October 20	C-7	3.6 km	~ 23—11 h
2021 November 10	C-6	2.5 km	~ 1—13 h
2021 December 1	C-5	1.4 km	~ 2—14 h
2021 December 20	C-4	0.78 km	~ 4—15 h
2022 January 10	C-3	0.50 km	~ 5—17 h
2022 February 1	No observations due to maintenance		
2022 March 1	C-1	0.16 km	~ 8—21 h
2022 March 26	C-2	0.31 km	~ 9—23 h
2022 April 20	C-3	0.50 km	~ 11—0 h
2022 May 10	C-4	0.78 km	~ 12—2 h
2022 May 31	C-5	1.4 km	~ 13—4 h
2022 June 23	C-6	2.5 km	~15—6 h
2022 July 28	C-5	1.4 km	~17—7 h
2022 August 18	C-4	0.78 km	~19—8 h
2022 September 10	C-3	0.50 km	~20—9 h



AtacamaLarge Millimeter/submillimeterArray
In search of our Cosmic Origins
ALMA
About Science Proposing Observing Data Processing Tools Documentation Help

CASA Simulator

CASA simulator and array configuration files

The CASA Simulator allows a user to simulate interferometric observations, including the ALMA observatory. The simulations consider the configuration of the ALMA a

Array Configuration Files

The simulation of ALMA observations depends on the actual array configurations. As outlined in Appendix A of the ALMA Proposers Guide and, in more detail, the ALI together with the CASA Simulator to produce representative models of ALMA Cycle 7 observations. The same files are also included in the web based simulation don

File
ALMA Cycle 1 configurations file
ALMA Cycle 2 configurations file
ALMA Cycle 3 configurations file
ALMA Cycle 4 configurations file
ALMA Cycle 5 configurations file
ALMA Cycle 6 configurations file
ALMA Cycle 7 configurations file

Name	Size	Type	Modified
._aca.cycle7.cfg	212 bytes	unknown	22 May 2017, 14:05
._alma.cycle7.1.cfg	212 bytes	unknown	07 July 2016, 12:12
._alma.cycle7.2.cfg	212 bytes	unknown	07 July 2016, 12:12
._alma.cycle7.3.cfg	212 bytes	unknown	07 July 2016, 12:12
._alma.cycle7.4.cfg	212 bytes	unknown	07 July 2016, 12:12
._alma.cycle7.5.cfg	212 bytes	unknown	07 July 2016, 12:12
._alma.cycle7.6.cfg	212 bytes	unknown	12 July 2016, 12:52
._alma.cycle7.7.cfg	212 bytes	unknown	12 July 2016, 11:25
._alma.cycle7.8.cfg	212 bytes	unknown	22 July 2016, 12:05
._alma.cycle7.9.cfg	212 bytes	unknown	22 July 2016, 12:05
._alma.cycle7.10.cfg	514 bytes	unknown	31 January 2017, 02:55
aca.cycle7.cfg	584 bytes	unknown	22 May 2017, 14:05
alma.cycle7.1.cfg	2.1 kB	unknown	07 July 2016, 12:12
alma.cycle7.2.cfg	2.1 kB	unknown	07 July 2016, 12:12
alma.cycle7.3.cfg	2.1 kB	unknown	07 July 2016, 12:12
alma.cycle7.4.cfg	2.1 kB	unknown	07 July 2016, 12:12
alma.cycle7.5.cfg	2.1 kB	unknown	07 July 2016, 12:12
alma.cycle7.6.cfg	2.1 kB	unknown	12 July 2016, 12:52
alma.cycle7.7.cfg	2.1 kB	unknown	12 July 2016, 11:25
alma.cycle7.8.cfg	2.0 kB	unknown	22 July 2016, 12:05
alma.cycle7.9.cfg	1.9 kB	unknown	22 July 2016, 12:05
alma.cycle7.10.cfg	1.8 kB	unknown	31 January 2017, 02:55

032
028
024
020
016
012
008
004

https://almascience.nrao.edu/tools/casa-simulator

```
go
```

SIMALMA

```
# Model sky = Halpha image of M51
os.system('curl https://casaguides.nrao.edu/image
skymodel             =  "M51ha.fits"
```

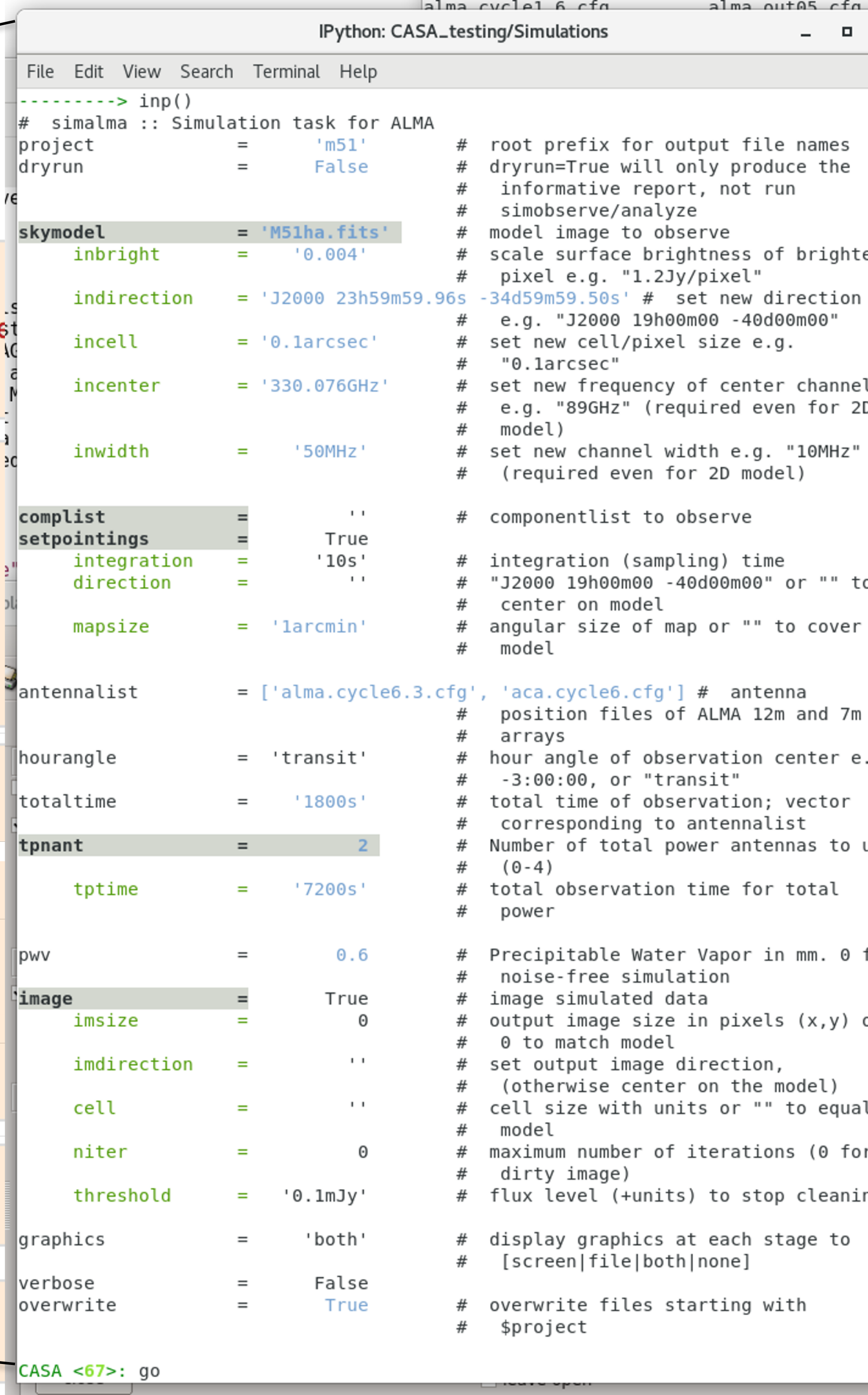
```
# Set model image parameters:
indirection="J2000 23h59m59.96s -34d59m59.50s"
incell="0.1arcsec"
inbright="0.004"
incenter="330.076GHz"
inwidth="50MHz"
```

```
antennalist=["alma.cycle6.3.cfg","aca.cycle6.cfg"
```

```
totaltime="1800s"
tpnant = 2
tptime="7200s"
pwv=0.6
mapsize="1arcmin"
```

```
inp
```

```
go
```

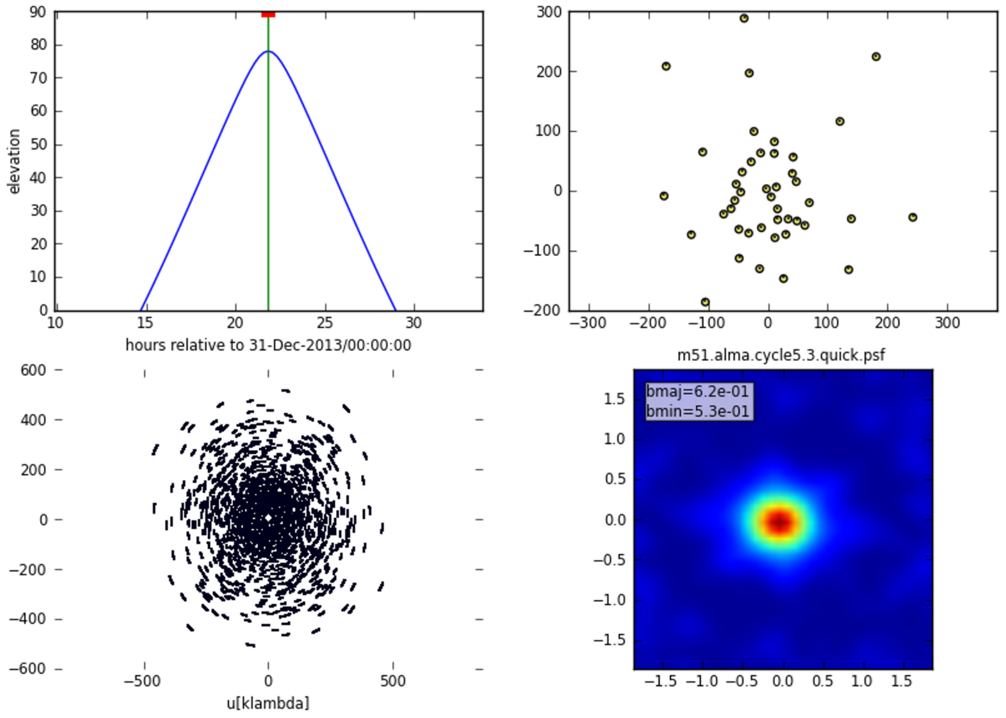

IPython: CASA_testing/Simulations
File Edit View Search Terminal Help

```
---------> inp()
#  simalma :: Simulation task for ALMA
project             =      'm51'        #  root prefix for output file names
dryrun              =      False        #  dryrun=True will only produce the
                                        #   informative report, not run
                                        #   simobserve/analyze
skymodel            = 'M51ha.fits'      #  model image to observe
     inbright       =     '0.004'       #  scale surface brightness of brighte
                                        #   pixel e.g. "1.2Jy/pixel"
     indirection    = 'J2000 23h59m59.96s -34d59m59.50s' #  set new direction
                                        #   e.g. "J2000 19h00m00 -40d00m00"
     incell         = '0.1arcsec'       #  set new cell/pixel size e.g.
                                        #   "0.1arcsec"
     incenter       = '330.076GHz'      #  set new frequency of center channel
                                        #   e.g. "89GHz" (required even for 2D
                                        #   model)
     inwidth        =     '50MHz'       #  set new channel width e.g. "10MHz"
                                        #   (required even for 2D model)

complist            =         ''        #  componentlist to observe
setpointings        =       True
     integration    =      '10s'        #  integration (sampling) time
     direction      =         ''        #  "J2000 19h00m00 -40d00m00" or "" to
                                        #   center on model
     mapsize        =    '1arcmin'      #  angular size of map or "" to cover
                                        #   model

antennalist         = ['alma.cycle6.3.cfg', 'aca.cycle6.cfg'] #  antenna
                                        #   position files of ALMA 12m and 7m
                                        #   arrays
hourangle           =    'transit'      #  hour angle of observation center e.
                                        #   -3:00:00, or "transit"
totaltime           =     '1800s'       #  total time of observation; vector
                                        #   corresponding to antennalist
tpnant              =          2        #  Number of total power antennas to u
                                        #   (0-4)
     tptime         =     '7200s'       #  total observation time for total
                                        #   power

pwv                 =        0.6        #  Precipitable Water Vapor in mm. 0 f
                                        #   noise-free simulation
image               =       True        #  image simulated data
     imsize         =          0        #  output image size in pixels (x,y) o
                                        #   0 to match model
     imdirection    =         ''        #  set output image direction,
                                        #   (otherwise center on the model)
     cell           =         ''        #  cell size with units or "" to equal
                                        #   model
     niter          =          0        #  maximum number of iterations (0 for
                                        #   dirty image)
     threshold      =    '0.1mJy'       #  flux level (+units) to stop cleanin

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

CASA <67>: go
```

SIMALMA

1. Simobserve

Simulate visibilities (MS) for each configuration



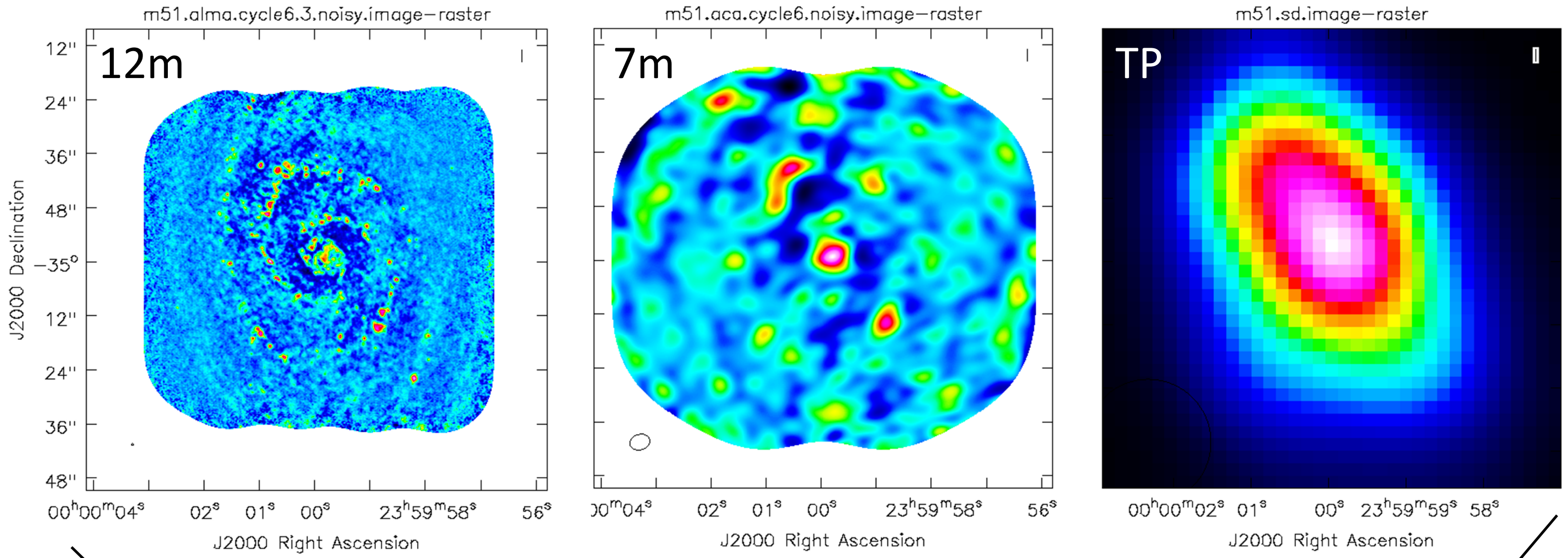
2. Simanalyze

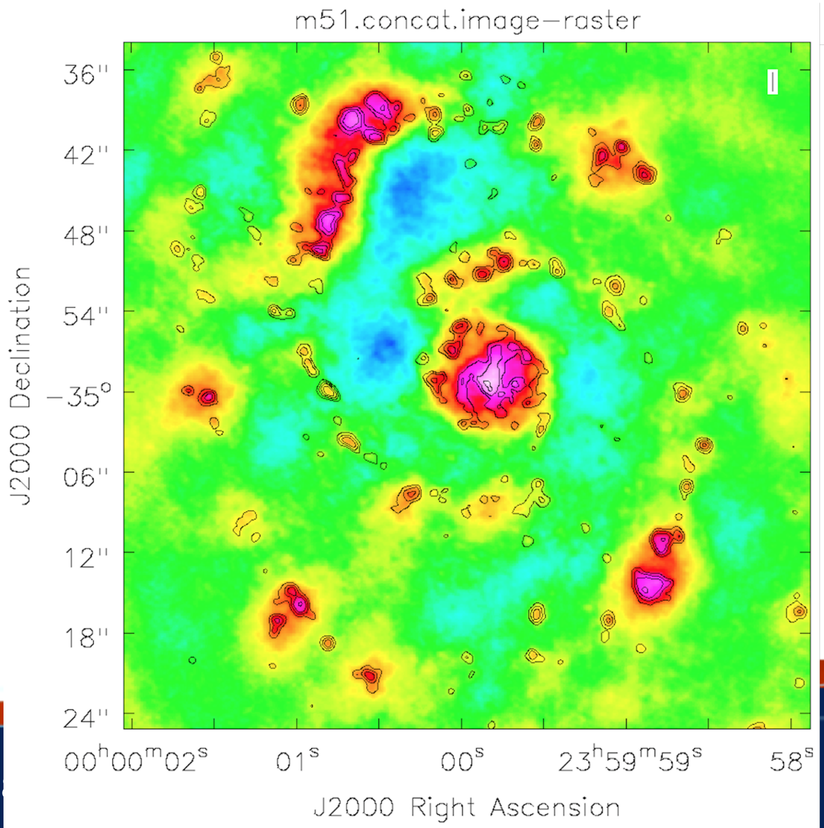
Imaging using simulated MSs

SIMALMA

1. Simc

Simula
each c

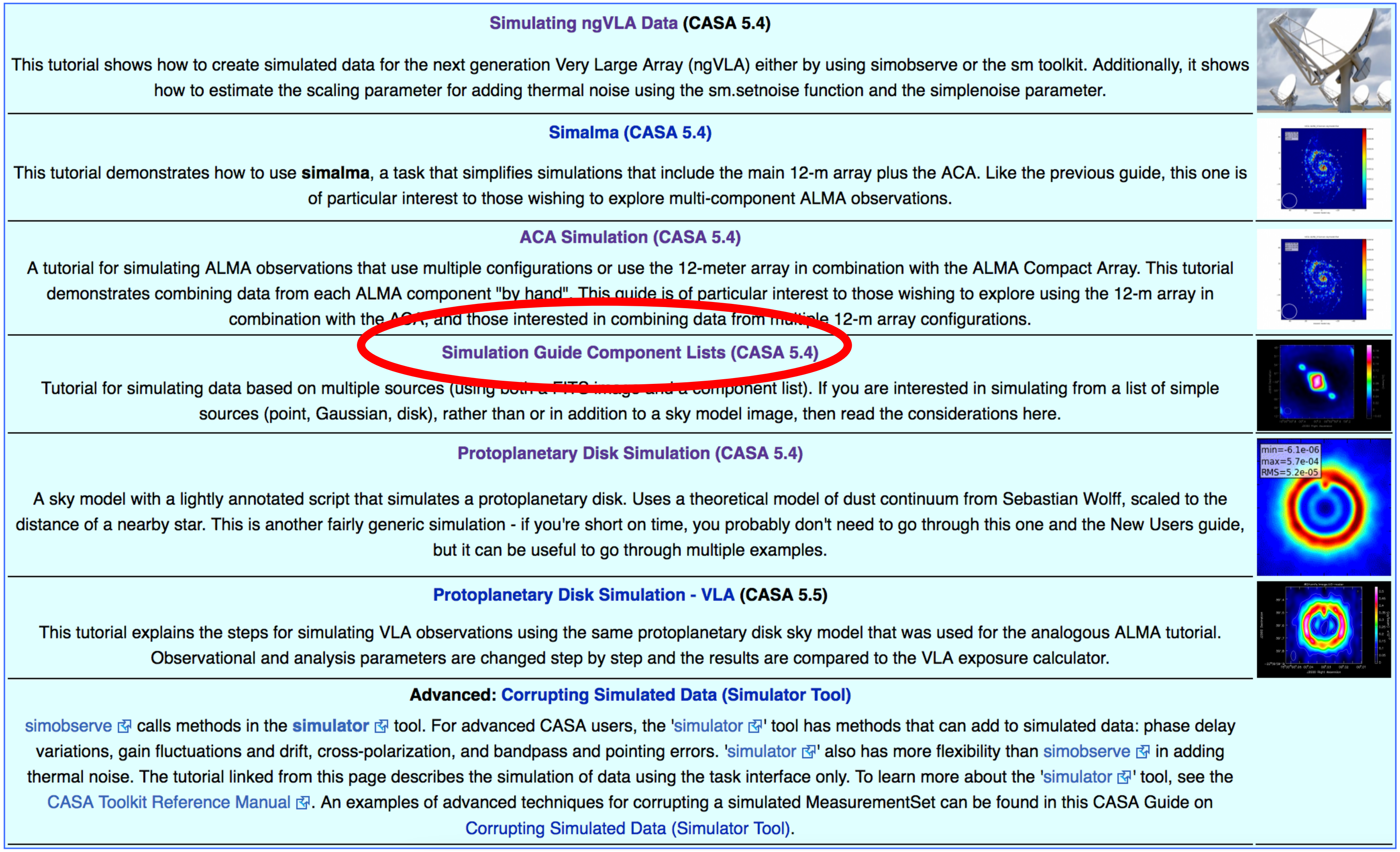




2. Simanalyze

Imaging using
Simulated MSs

More information on ALMA simulations



Simulating ngVLA Data (CASA 5.4)

This tutorial shows how to create simulated data for the next generation Very Large Array (ngVLA) either by using simobserve or the sm toolkit. Additionally, it shows how to estimate the scaling parameter for adding thermal noise using the sm.setnoise function and the simplenoise parameter.

Simalma (CASA 5.4)

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.

ACA Simulation (CASA 5.4)

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.

Simulation Guide Component Lists (CASA 5.4)

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.

Protoplanetary Disk Simulation (CASA 5.4)

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.

Protoplanetary Disk Simulation - VLA (CASA 5.5)

This tutorial explains the steps for simulating VLA observations using the same protoplanetary disk sky model that was used for the analogous ALMA tutorial. Observational and analysis parameters are changed step by step and the results are compared to the VLA exposure calculator.

Advanced: Corrupting Simulated Data (Simulator Tool)

simobserve calls methods in the **simulator** tool. For advanced CASA users, the 'simulator' tool has methods that can add to simulated data: phase delay variations, gain fluctuations and drift, cross-polarization, and bandpass and pointing errors. 'simulator' also has more flexibility than simobserve in adding thermal noise. The tutorial linked from this page describes the simulation of data using the task interface only. To learn more about the 'simulator' tool, see the CASA Toolkit Reference Manual. An examples of advanced techniques for corrupting a simulated MeasurementSet can be found in this CASA Guide on Corrupting Simulated Data (Simulator Tool).

Simulating Component Lists

CASA Guides:
https://casaguides.nrao.edu/

```
# In CASA
direction = "J2000 10h00m00.0s -30d00m00.0s"
cl.done()
cl.addcomponent(dir=direction, flux=1.0, fluxunit='Jy', freq='230.0GHz', shape="Gaussian",
                majoraxis="0.1arcmin", minoraxis='0.05arcmin', positionangle='45.0deg')
#
ia.fromshape("Gaussian.im",[256,256,1,1],overwrite=True)
cs=ia.coordsys()
cs.setunits(['rad','rad','','Hz'])
cell_rad=qa.convert(qa.quantity("0.1arcsec"),"rad")['value']
cs.setincrement([-cell_rad,cell_rad],'direction')
cs.setreferencevalue([qa.convert("10h",'rad')['value'],qa.convert("-30deg",'rad')['value']],type="direction")
cs.setreferencevalue("230GHz",'spectral')
cs.setincrement('1GHz','spectral')
ia.setcoordsys(cs.torecord())
ia.setbrightnessunit("Jy/pixel")
ia.modify(cl.torecord(),subtract=False)
exportfits(imagename='Gaussian.im',fitsimage='Gaussian.fits',overwrite=True)
```

```
# In CASA
os.system('rm -rf point.cl')
cl.done()
cl.addcomponent(dir="J2000 10h00m00.08s -30d00m02.0s", flux=0.1, fluxunit='Jy', freq='230.0GHz', shape="point")
cl.addcomponent(dir="J2000 09h59m59.92s -29d59m58.0s", flux=0.1, fluxunit='Jy', freq='230.0GHz', shape="point")
cl.addcomponent(dir="J2000 10h00m00.40s -29d59m55.0s", flux=0.1, fluxunit='Jy', freq='230.0GHz', shape="point")
cl.addcomponent(dir="J2000 09h59m59.60s -30d00m05.0s", flux=0.1, fluxunit='Jy', freq='230.0GHz', shape="point")
cl.rename('point.cl')
cl.done()
```

```
# In CASA
default("simobserve")
project = "FITS_list"
skymodel = "Gaussian.fits"
inwidth = "1GHz"
complist = 'point.cl'
compwidth = '1GHz'
direction = "J2000 10h00m00.0s -30d00m00.0s"
obsmode = "int"
antennalist = 'alma.cycle6.1.cfg'
totaltime = "28800s"
mapsize = "10arcsec"
thermalnoise = ''
simobserve()
```

Simulating Component Lists

CASA Guides:
https://casaguides.nrao.edu/

```
# In CASA
direction = "J2000 10h00m00.0s -30d00m00.0s"
cl.done()
cl.addcomponent(dir=direction, flux=1.0, fluxunit='Jy', freq='230.0GHz', shape="Gaussian",
                majoraxis="0.1arcmin", m                                gle='45.0deg')
#
ia.fromshape("Gaussian.im",[256,256,1,1
cs=ia.coordsys()
cs.setunits(['rad','rad','','Hz'])
cell_rad=qa.convert(qa.quantity("0.1arcs
cs.setincrement([-cell_rad,cell_rad],'d
cs.setreferencevalue([qa.convert("10h",                                ",'rad')['value']],type="direction")
cs.setreferencevalue("230GHz",'spectral')
cs.setincrement('1GHz','spectral')
ia.setcoordsys(cs.torecord())
ia.setbrightnessunit("Jy/pixel")
ia.modify(cl.torecord(),subtract=False)
exportfits(imagename='Gaussian.im',fitsimage='Gaussian.fits',overwrite=True)
```

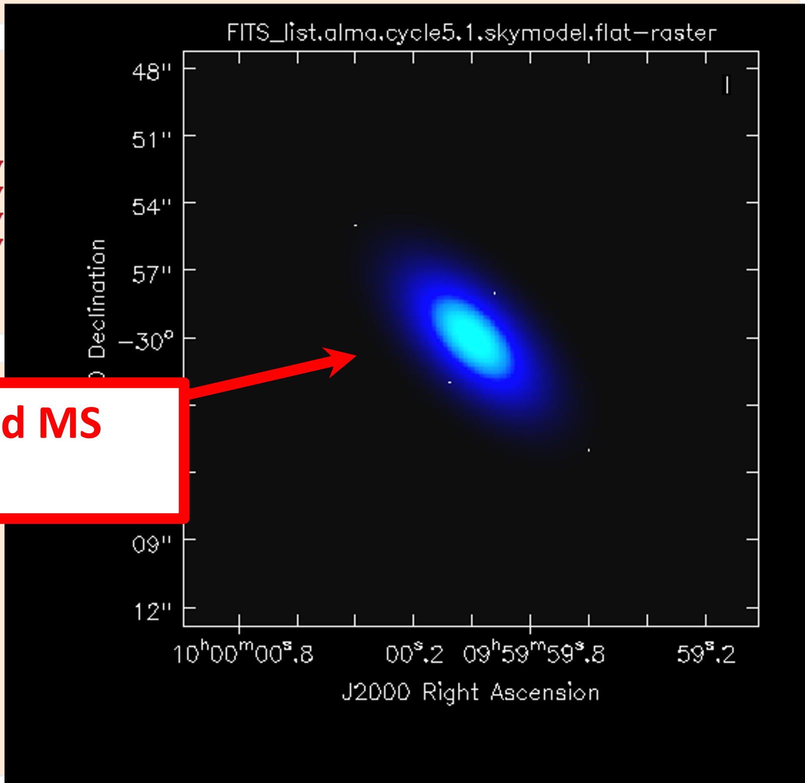
Use CASA tools to create FITS file of Gaussian

```
# In CASA
os.system('rm -rf point.cl')
cl.done()
cl.addcomponent(dir="J2000 10h00m00.08s                                ='Jy
cl.addcomponent(dir="J2000 09h59m59.92s -29d59m58.0s", flux=0.1, fluxunit='Jy
cl.addcomponent(dir="J2000 10h00m00.40s -29d59m55.0s", flux=0.1, fluxunit='Jy
cl.addcomponent(dir="J2000 09h59m59.60s -30d00m05.0s", flux=0.1, fluxunit='Jy
cl.rename('point.cl')
cl.done()
```

Create component list

```
# In CASA
default("simobserve")
project = "FITS_list"
skymodel = "Gaussian.fits"
inwidth = "1GHz"
complist = 'point.cl'
compwidth = '1GHz'
direction = "J2000 10h00m00.0s -30d00m00.0s"
obsmode = "int"
antennalist = 'alma.cycle6.1.cfg'
totaltime = "28800s"
mapsize = "10arcsec"
thermalnoise = ''
simobserve()
```

Create simulated MS of "skymodel"



Simulating Component Lists

CASA Guides:
https://casaguides.nrao.edu/

```
# In CASA
direction = "J2000 10h00m00.0s -30d00m00.0s"
cl.done()
cl.addcomponent(dir=direction, flux=1.0, fluxunit='Jy', freq='230.0GHz', shape="Gaussian",
```

```
default("simanalyze")
project = "FITS_list"
vis="FITS_list.alma.cycle6.1.ms"
imsize = [256,256]
imdirection = "J2000 10h00m00.0s -30d00m00.0s"
cell = '0.1arcsec'
niter = 5000
threshold = '10.0mJy/beam'
analyze = True
simanalyze()
```

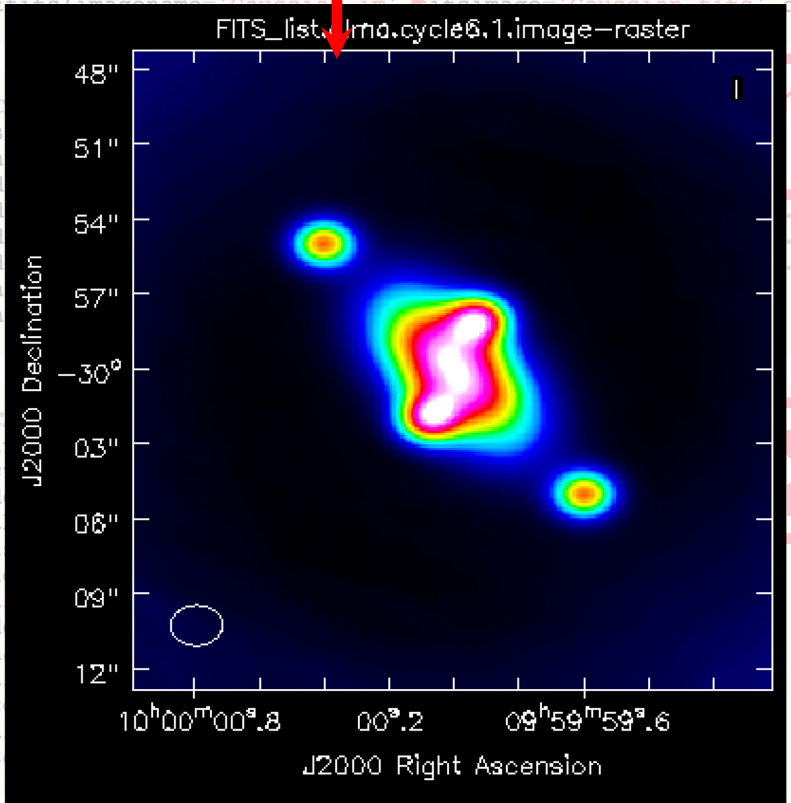
```
ia.modify(cl.torecord(),subtr ct=Fal se)
export                                         overwrite=True)
```

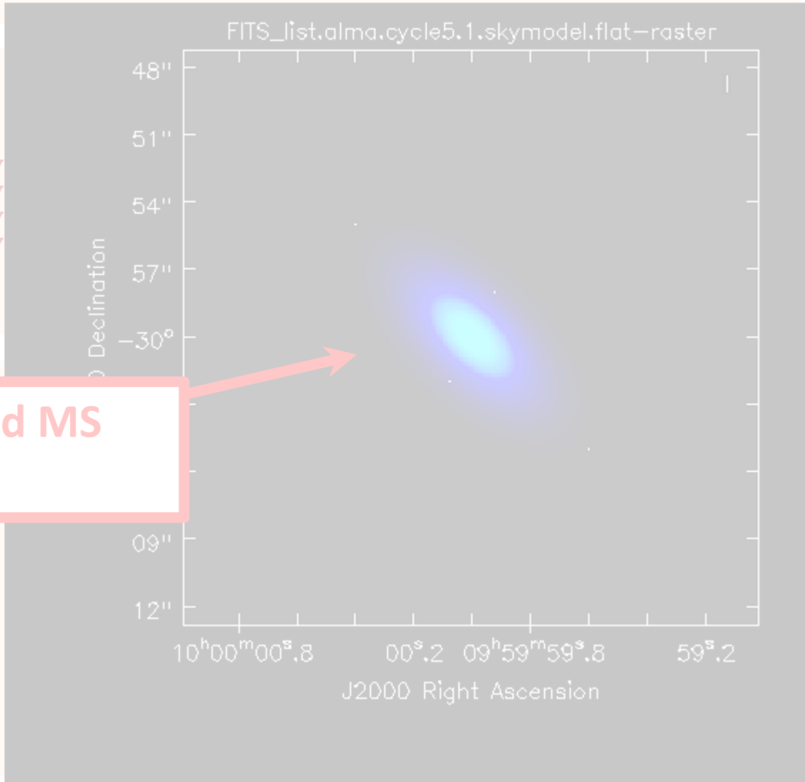
```
# In C
os.sys
cl.don
cl.add                                   ='Jy
cl.add                                  1, fluxunit='Jy
cl.add                                  1, fluxunit='Jy
cl.add                                  1, fluxunit='Jy
cl.ren
cl.don
```

nent

te simulated MS
kymodel”

```
# In C
defaul
projec
skymod
inwidt
compli
compwi
direct
obsmod
antenn
totalt
mapsiz
therma
simobs
```





Simulating Component Lists

CASA Guides:
https://casaguides.nrao.edu/

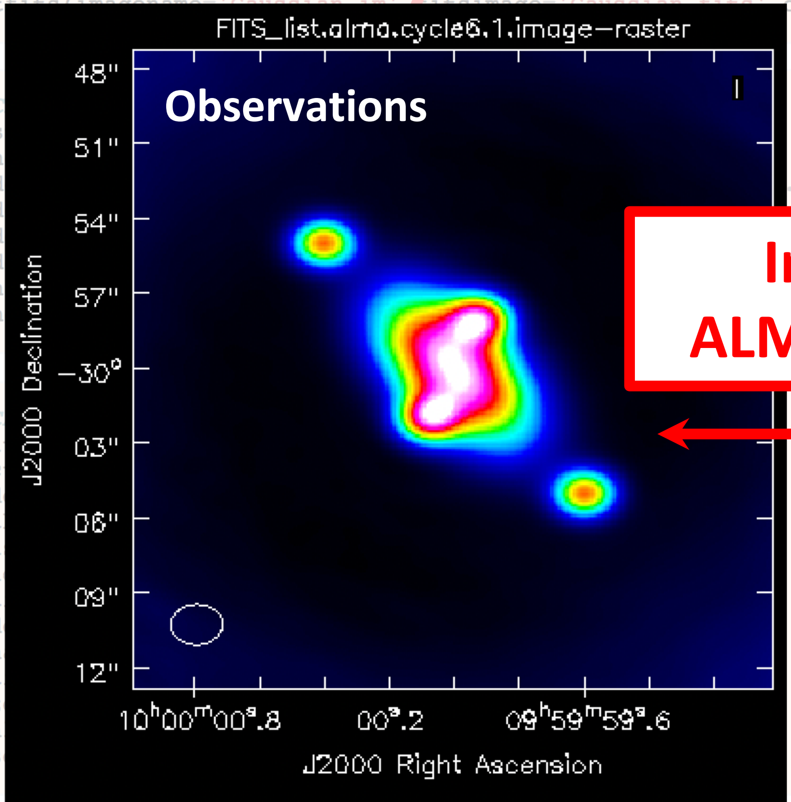
```
# In CASA
direction = "J2000 10h00m00.0s -30d00m00.0s"
cl.done()
cl.addcomponent(dir=direction, flux=1.0, fluxunit='Jy', freq='230.0GHz', shape="Gaussian",
```

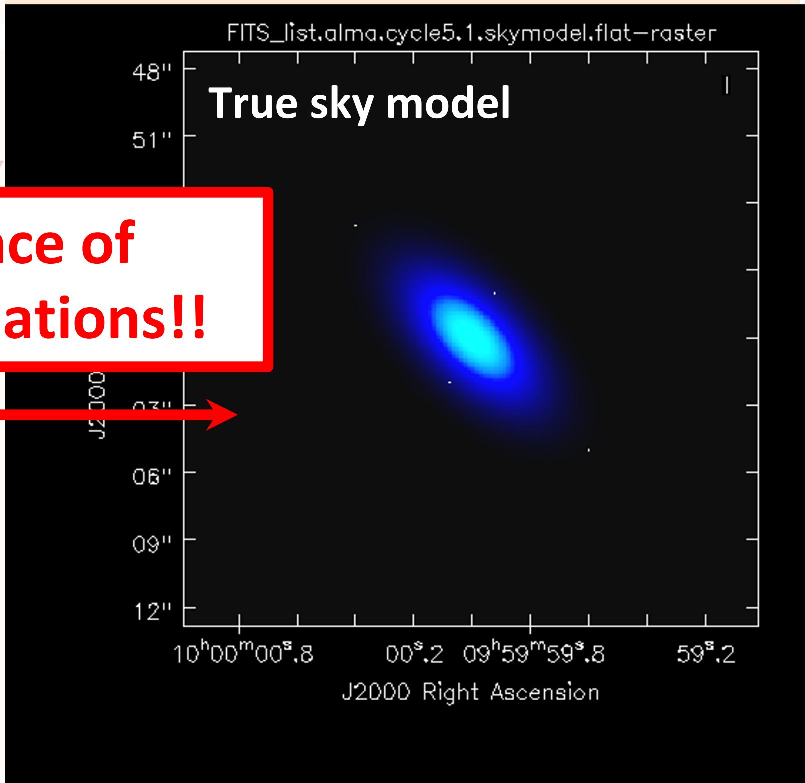
```
default("simanalyze")
project = "FITS_list"
vis="FITS_list.alma.cycle6.1.ms"
imsize = [256,256]
imdirection = "J2000 10h00m00.0s -30d00m00.0s"
cell = '0.1arcsec'
niter = 5000
threshold = '10.0mJy/beam'
analyze = True
simanalyze()
```

```
ia.modify(cl.torecord(),subtract=False)
exportfits(imagename='Gaussian.im',fitsimage='Gaussian.fits',overwrite=True)
```

```
# In C
os.sys
cl.don
cl.add                                     1, fluxunit='Jy
cl.add
cl.add
cl.add
cl.ren
cl.don
```

```
# In C
defaul
projec
skymod
inwidt
compli
compwi
direct
obsmod
antenn
totalt
mapsiz
therma
simobs
```





Importance of ALMA simulations!!

Questions?

Five Minute Break

Hands on
SIMALMA DEMO

SIMALMA

- simalma — simulate an ALMA observation including multiple configurations of the 12-m interferometric array, the 7-m ACA, and total power measurements by streamlining the capabilities of both *simobserve* and *simanalyze*.

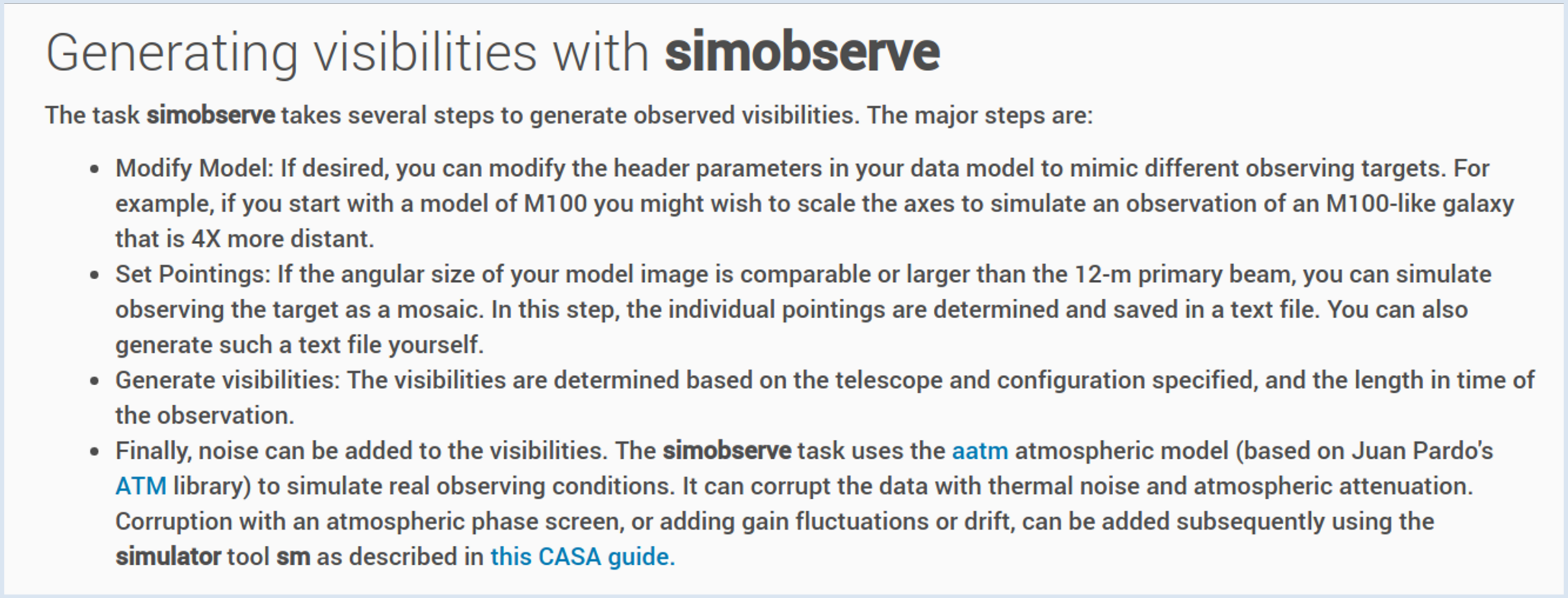
- Simulating interferometric observations using the simobserve and simanalyze tasks proceeds in the following steps:

SIMALMA

1. Make a model image or component list. The model is a representation of the sky brightness distribution that you would like to simulate observing.
   - Existing previous image of your target or similar target
   - Component list (point sources, Gaussians, disks, and limb-darkened disks)

1. Uses the **simobserve** task to create a Measurement Set (uv data) that would be measured by a telescope observing the specified input model of sky brightness. simobserve can also introduce corruption modeling thermal noise or atmospheric effects.

SIMOBSERVE

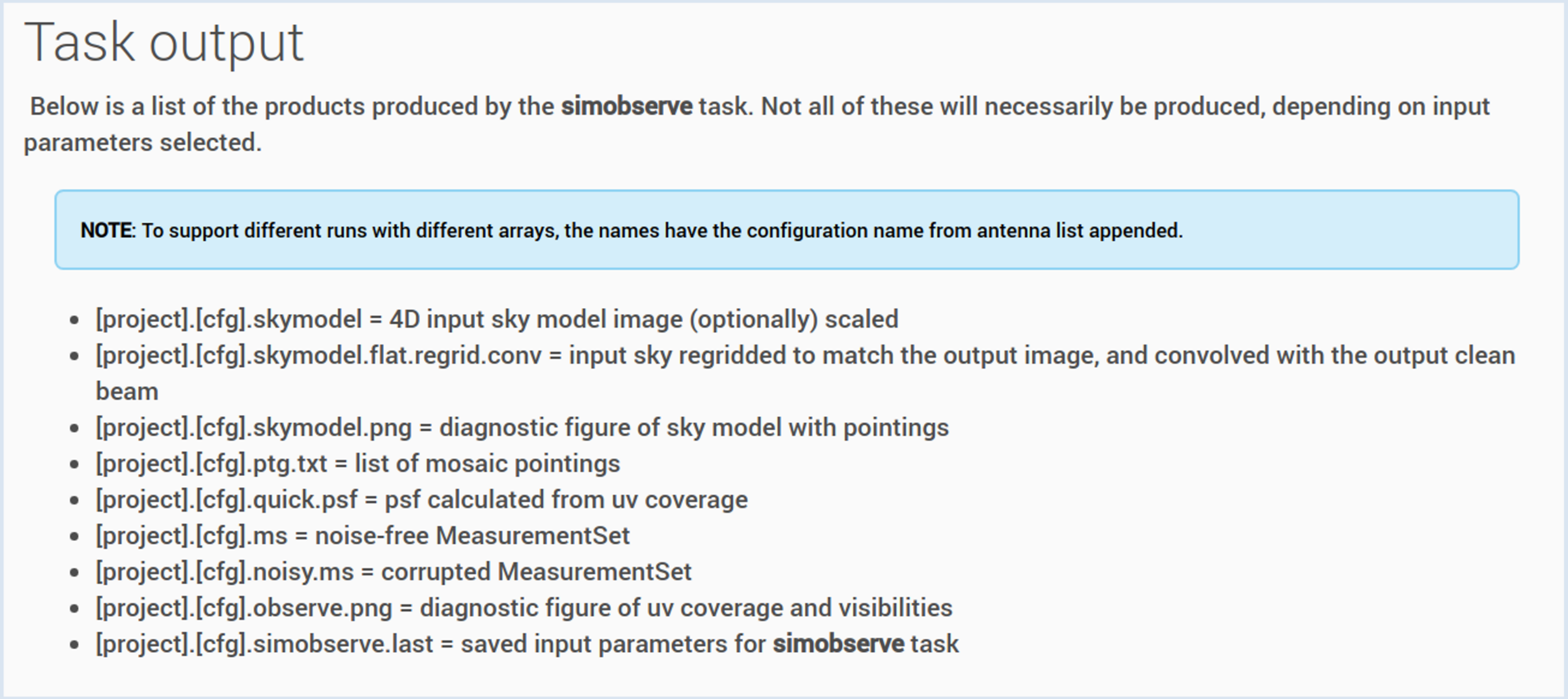


Generating visibilities with **simobserve**

The task **simobserve** takes several steps to generate observed visibilities. The major steps are:

- Modify Model: If desired, you can modify the header parameters in your data model to mimic different observing targets. For example, if you start with a model of M100 you might wish to scale the axes to simulate an observation of an M100-like galaxy that is 4X more distant.
- Set Pointings: If the angular size of your model image is comparable or larger than the 12-m primary beam, you can simulate observing the target as a mosaic. In this step, the individual pointings are determined and saved in a text file. You can also generate such a text file yourself.
- Generate visibilities: The visibilities are determined based on the telescope and configuration specified, and the length in time of the observation.
- Finally, noise can be added to the visibilities. The **simobserve** task uses the aatm atmospheric model (based on Juan Pardo's ATM library) to simulate real observing conditions. It can corrupt the data with thermal noise and atmospheric attenuation. Corruption with an atmospheric phase screen, or adding gain fluctuations or drift, can be added subsequently using the **simulator** tool **sm** as described in this CASA guide.

SimObserve: Files Created



Task output

Below is a list of the products produced by the **simobserve** task. Not all of these will necessarily be produced, depending on input parameters selected.

NOTE: To support different runs with different arrays, the names have the configuration name from antenna list appended.

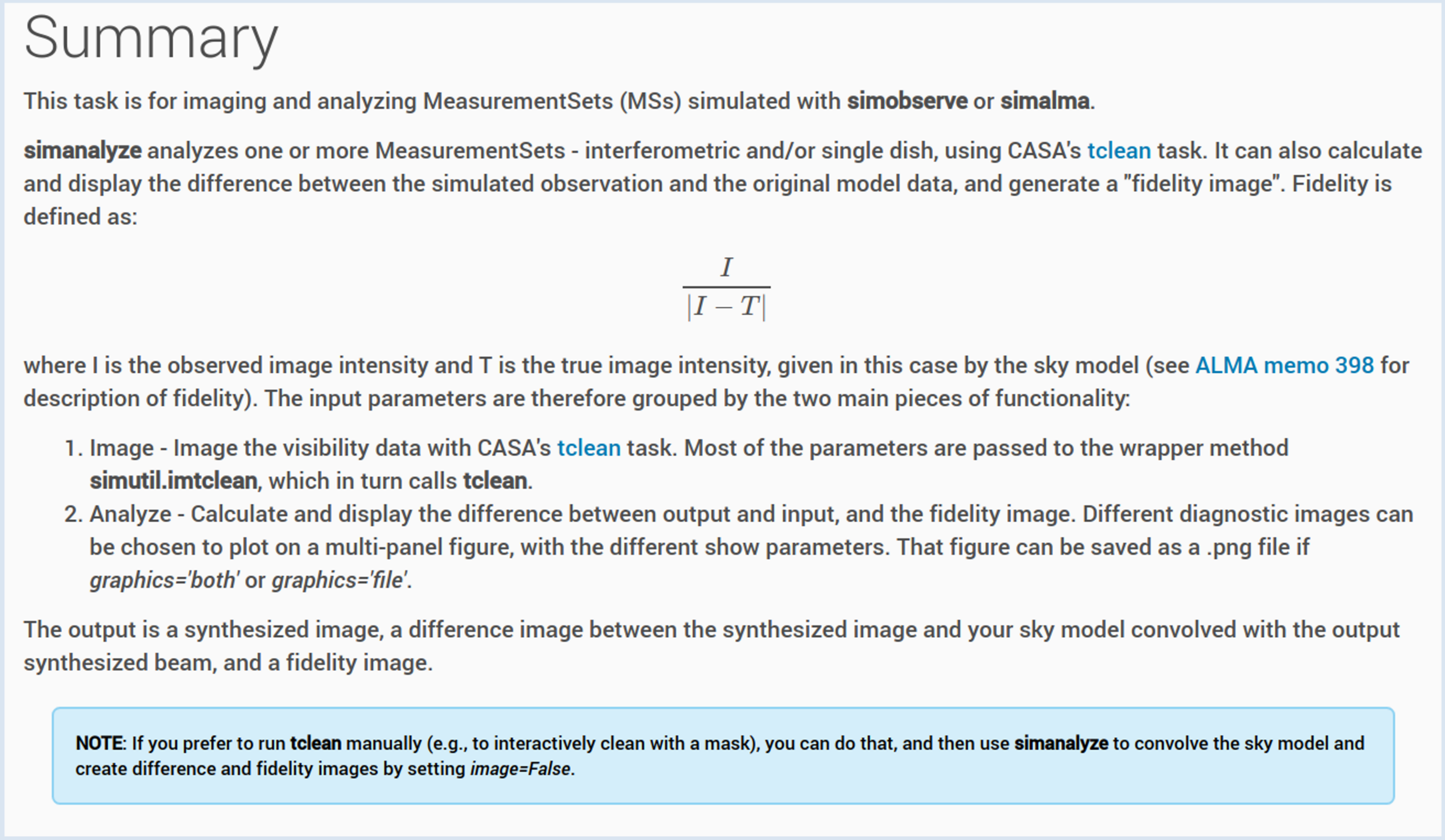
- [project].[cfg].skymodel = 4D input sky model image (optionally) scaled
- [project].[cfg].skymodel.flat.regrid.conv = input sky regridded to match the output image, and convolved with the output clean beam
- [project].[cfg].skymodel.png = diagnostic figure of sky model with pointings
- [project].[cfg].ptg.txt = list of mosaic pointings
- [project].[cfg].quick.psf = psf calculated from uv coverage
- [project].[cfg].ms = noise-free MeasurementSet
- [project].[cfg].noisy.ms = corrupted MeasurementSet
- [project].[cfg].observe.png = diagnostic figure of uv coverage and visibilities
- [project].[cfg].simobserve.last = saved input parameters for **simobserve** task

SIMALMA

3. Image (grid, invert, and deconvolve) the simulated observation(s) with the simanalyze task. **simanalyze** can also compare the simulated image with your input (convolved with the output clean beam) and then calculate a "fidelity image" that indicates how well the simulated output matches the convolved input image.

- Alternately, you can create an image yourself with the tclean task, and then use **simanalyze** to compare that to the sky model input.

SIMANALYZE



Summary

This task is for imaging and analyzing MeasurementSets (MSs) simulated with **simobserve** or **simalma**.

simanalyze analyzes one or more MeasurementSets - interferometric and/or single dish, using CASA's tclean task. It can also calculate and display the difference between the simulated observation and the original model data, and generate a "fidelity image". Fidelity is defined as:

$$\frac{I}{|I-T|}$$

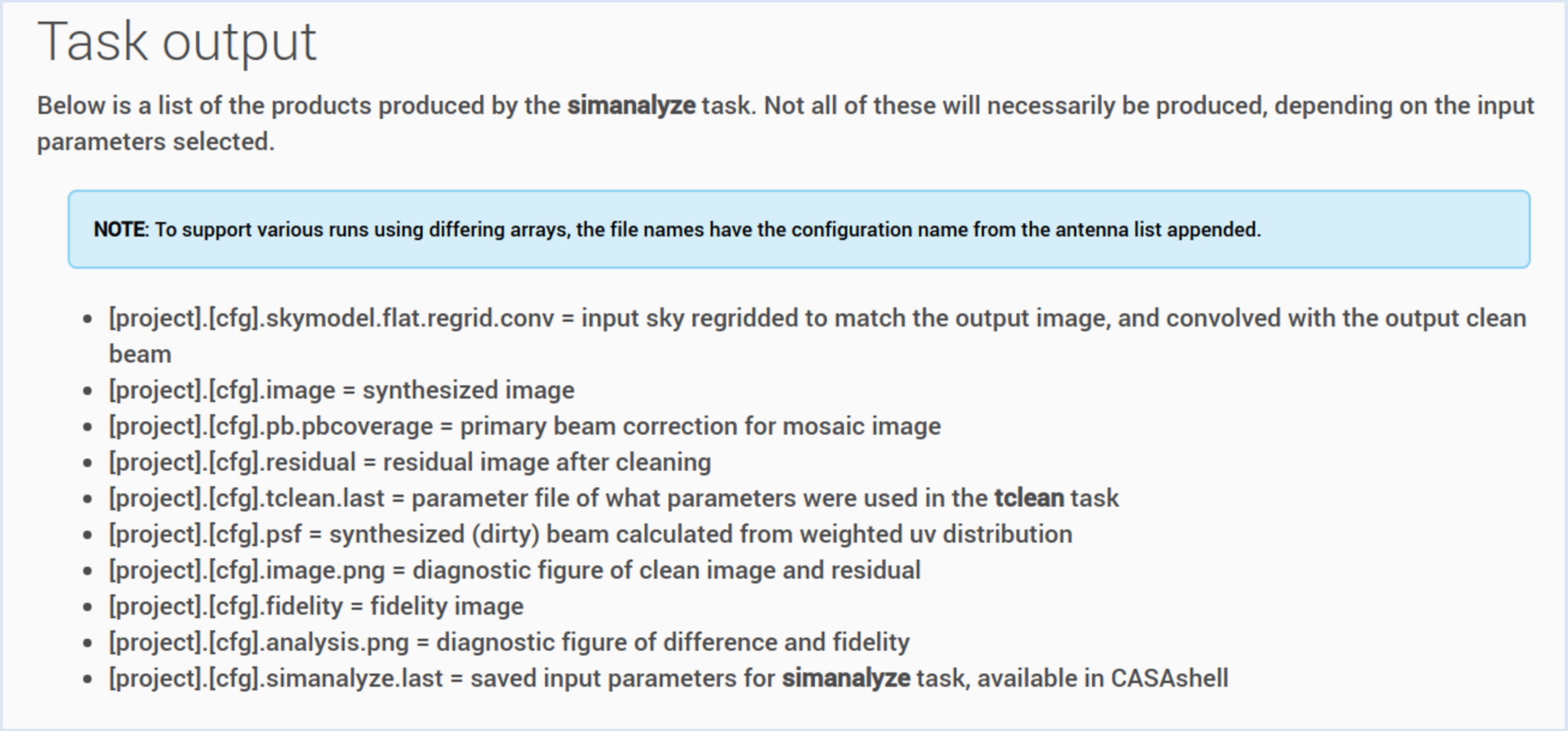
where I is the observed image intensity and T is the true image intensity, given in this case by the sky model (see ALMA memo 398 for description of fidelity). The input parameters are therefore grouped by the two main pieces of functionality:

1. Image - Image the visibility data with CASA's tclean task. Most of the parameters are passed to the wrapper method **simutil.imtclean**, which in turn calls **tclean**.
2. Analyze - Calculate and display the difference between output and input, and the fidelity image. Different diagnostic images can be chosen to plot on a multi-panel figure, with the different show parameters. That figure can be saved as a .png file if *graphics='both'* or *graphics='file'*.

The output is a synthesized image, a difference image between the synthesized image and your sky model convolved with the output synthesized beam, and a fidelity image.

NOTE: If you prefer to run **tclean** manually (e.g., to interactively clean with a mask), you can do that, and then use **simanalyze** to convolve the sky model and create difference and fidelity images by setting *image=False*.

Simanalyze: Files Created



Task output

Below is a list of the products produced by the **simanalyze** task. Not all of these will necessarily be produced, depending on the input parameters selected.

NOTE: To support various runs using differing arrays, the file names have the configuration name from the antenna list appended.

- [project].[cfg].skymodel.flat.regrid.conv = input sky regridded to match the output image, and convolved with the output clean beam
- [project].[cfg].image = synthesized image
- [project].[cfg].pb.pbcoverage = primary beam correction for mosaic image
- [project].[cfg].residual = residual image after cleaning
- [project].[cfg].tclean.last = parameter file of what parameters were used in the **tclean** task
- [project].[cfg].psf = synthesized (dirty) beam calculated from weighted uv distribution
- [project].[cfg].image.png = diagnostic figure of clean image and residual
- [project].[cfg].fidelity = fidelity image
- [project].[cfg].analysis.png = diagnostic figure of difference and fidelity
- [project].[cfg].simanalyze.last = saved input parameters for **simanalyze** task, available in CASAshell

casa-feedback@nrao.edu

CASA website: https://casa.nrao.edu/
CASA Docs: https://casa.nrao.edu/casadocs/
CASA Guides: https://casaguides.nrao.edu/

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