Simulating ALMA Observations

How to get started and what to expect

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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)

2. Use 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

For more info:

https://almascience.nrao.edu/

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC), and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI), and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction and operation of ALMA.

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