# Advance of ALMA simulation at IRAM

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With the prospect of Japan joining the ALMA project in a 3-way partnership, we have to explore what are the best scientific options for possible extensions of the baseline ALMA projects. These include a compact array (ACA) of smaller antenna to provide (hopefully) better wide field imaging performances. The open questions are

- What antenna size should the ACA consider ?
- What number of antennas is required ?
- What operation modes are foreseen ?
- What are the antenna specifications to improve the imaging quality ?
- What are the desirable configurations ?

To make this evaluation, we are developping a realistic simulation of an heterogeneous interferometer which follows the ALMA specification. Since the probleme involves numerous aspect, the simulation has to be fast, and as close as possible to a standard reduction pipeline.

## 1 Present state of the simulation

As of today, we have a *running* simulation of ALMA. From a single input image which features the sky brightness, the following steps are made:

- Simulation of single-dish on-the-fly observations with thermal and calibration noise.
- Simulation of interferometry observations, including pointing errors, phase noise and thermal noise. The result is a UV table whose visibilities have been computed along the tracks for each pair of antennas. Depending on the input image size, the simulator automatically shifts between single field and mosaic modes. The interferometry simulation can be made at the same time for two antenna diameters giving two independent UV tables. Alternatively, separate hour angle coverage for the two arrays can also be specified.
- Possible generation from the single-dish map of a UV table containing short spacings. This table is then merged to the smallest antenna UV table in order to fill the short baseline space in the Fourier plane.
- Deconvolution using the CLEAN algorithm.
- Comparison of the original and cleaned image. In this step, image quality indicators are such as dynamic range, fidelity range, fidelity index, can be computed. The comparison between the model and simulated observation is automatically performed by proper resampling and convolution with the Clean beam of the original model. No ad-hoc scaling factor is used here.

In the absence of errors, the result would depend on the accuracy of the simulation process, and on the quality of the imaging methods. Calibration errors (phase & amplitude, but mostly pointing errors) greatly influence the image quality, and are often the major limiting factor. These are inherently statistical errors, requiring several simulations to provide a representative sample of problems. Computational speed becomes an issue.

Thus, we have chosen to use a fast, but approximate, method to simulate the visibilities from an input image model. Our method uses the fact that for a single field, the visibility is the Fourier Transform of the sky brightness multiplied by the primary beam of the antenna. For an ensemble of pointings, we can thus derive the true visibility from the convolution of the Fourier Transform of the sky brightness by the Fourier transform of the primary beam. This is a local operation in the Fourier plane. Pointing errors can be handled in a similar way, by applying the appropriate phase shifts in addition to this convolution problem. The accuracy of the method is limited by the finite sampling of the Fourier transform of the sky brightness. We use image sizes of 4096 x 4096 pixels to obtain precisions of order 0.3 %. This limits our fidelity to 300:1, but this limitation is not important since pointing errors contribute more significantly. Note also that a 1% calibration error would limit the image fidelity to 100:1 ...

A thorough pointing model was developed. It takes into account different timescales and amplitudes for the following origins:

- tracking uncertainty;
- bearing error;
- errors due to structure changes following temperature variation;
- errors due to wind;
- errors of measurement at each pointing calibration.

The wind and thermal errors are assumed to be correlated among antennas (the correlation factor can be adjusted). The time between two pointing calibrations is typically set to 30 minutes but can be modified.

# 2 Missing points

To evaluate the performances of the heterogeneous array, we still have to solved the simultaneous deconvolution of the images obtained by the interferometers with different antenna diameters. Morita has used MEM-based tools in the SDE environment to solve this problem. We follow a different approach using CLEAN-based techniques. By comparing both results, we hope to get algorithm-independent conclusions on the usefulness of the compact array. Two possibilities are studied for this convolution:

- The first method directly operates in the Fourier space. It applies a convolution to the ACA visibilities to bring them at the same effective resolution (in the UV plane) than the ALMA visibilities. The usual mosaic CLEAN deconvolution algorithm is then applied on the resulting UV table.
- The second possibility operates in the image space, using a multi-scale deconvolution method, based on CLEAN.

The simulation can also incorporate a rudimentary model of phase noise. A foreseen enhancement is to make a more realistic model.

# 3 Foreseen schedule

All simulation tools are in place. Examples of user interfaces are shown in Fig.1-2. An example of the current simulation output is shown in Fig.3. The running time information is quite interesting: a complete, single-field simulation takes about 2 min of running time on a 800 MHz Pentium-III with 512 Mbytes of memory. The time only slightly increase with the hour angle coverage, getting up to 3 min for 4 hours UV coverage including pointing errors. For mosaic, the model generation time is similar, but the deconvolution step becomes much longer (typically 1-2 min per field).

Our schedule is to complete the CLEAN deconvolution tools by end of December, and spend the January month running the simulation.

In parallel with the simulation, the calibration problem (bandpass, phase, pointing, etc...) is being studied. Calibration may become a limiting factor when the ACA is operated as a stand alone array, and will constrain the antenna size-number tradeoff.

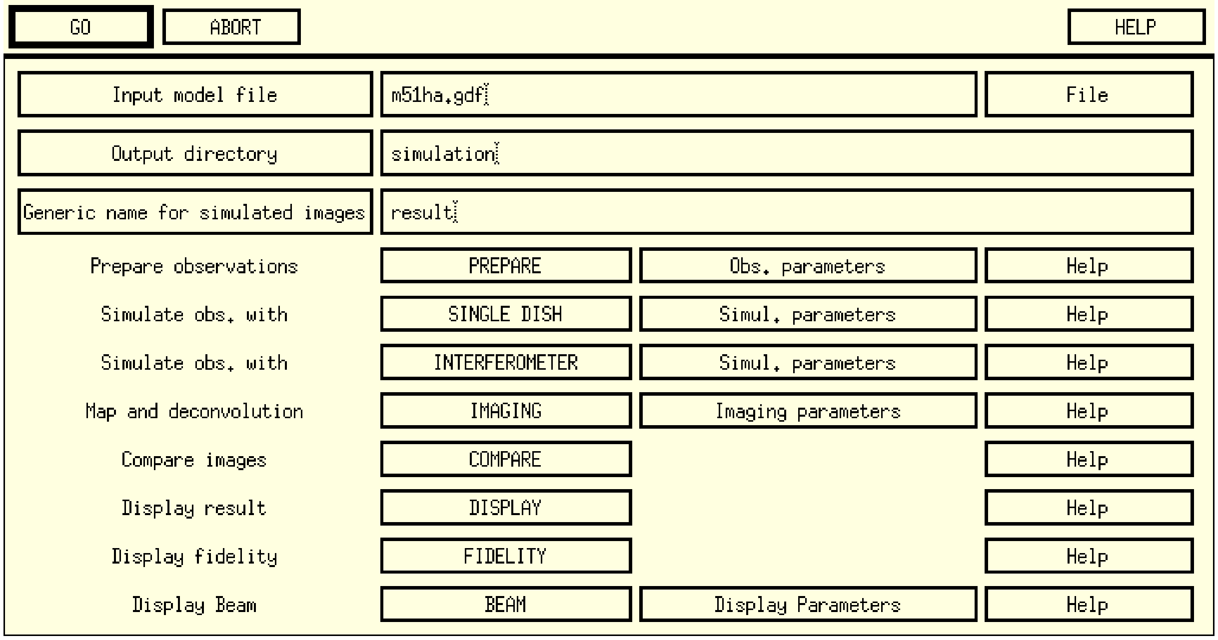


Figure 1: Main control widget

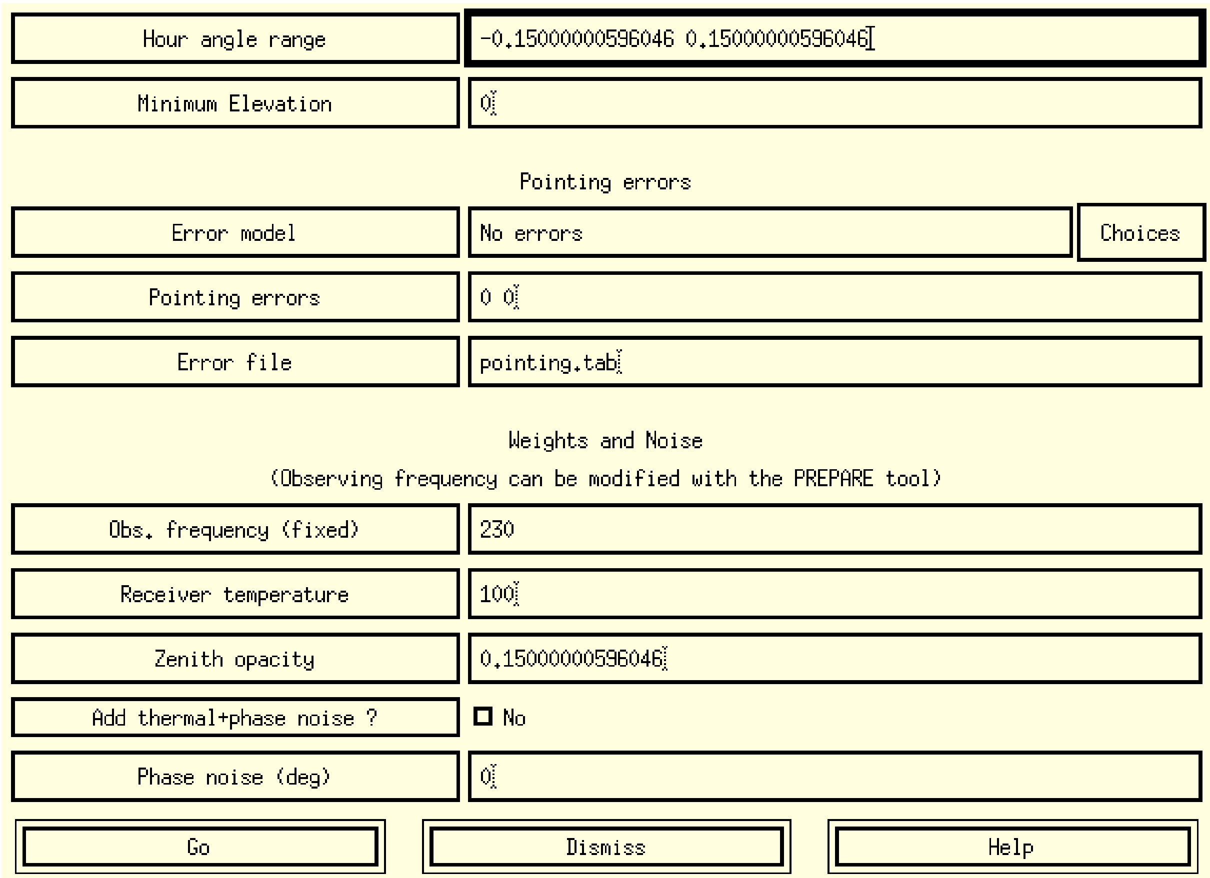


Figure 2: One of the sub-panels activated by the main widget

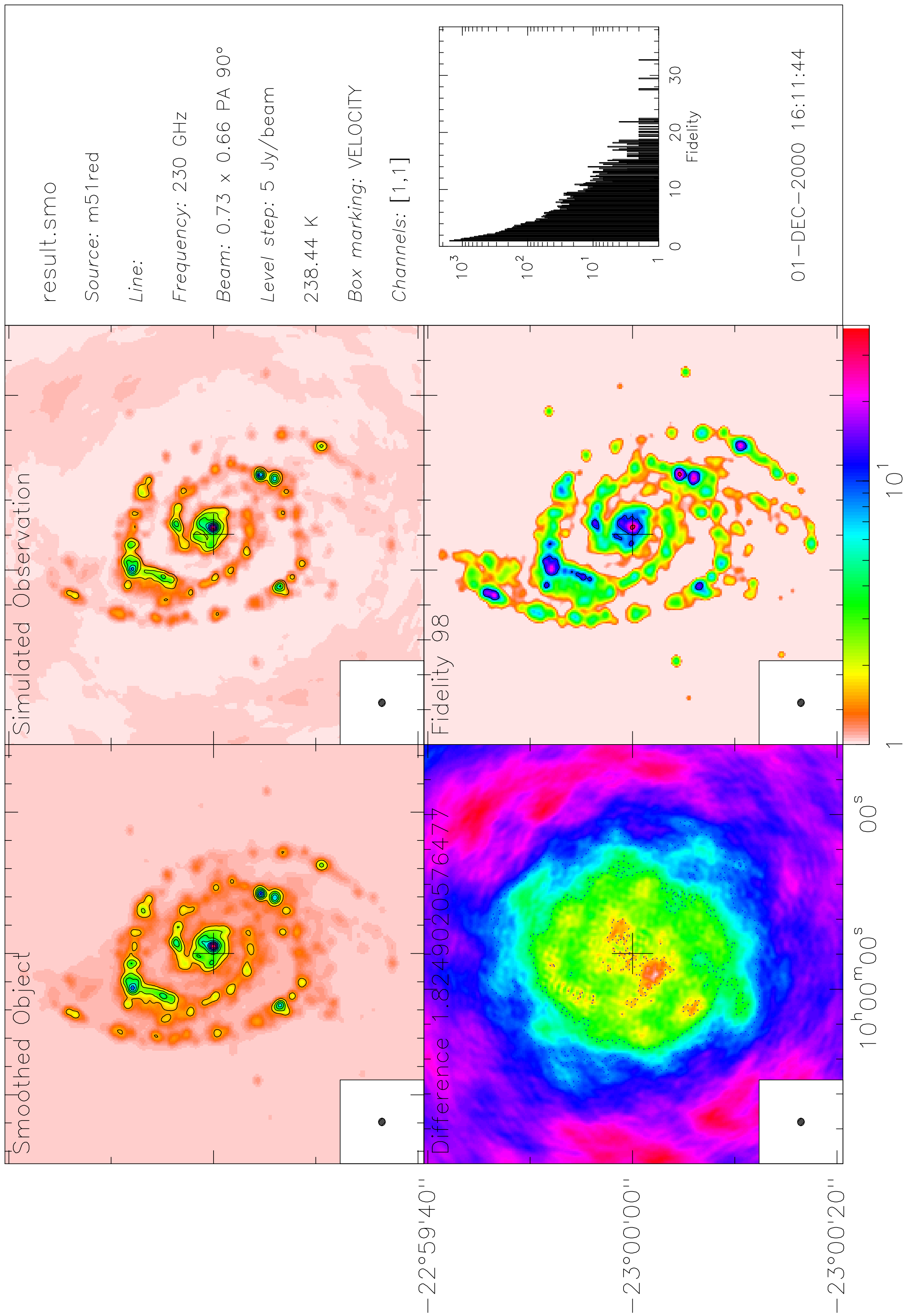


Figure 3: Example of output result