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A simulator of interferometric *On-the-fly* observations[1]

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1. Introduction

We have developed a simulator of interferometric on-the-fly observations in the framework of our research on image synthesis for mosaics observed in the on-the-fly (OTF) mode, in which the interferometer takes data at the same time that the antennas move continuously across the source. The characteristics of this observing mode and the advantages with respect to classical "point-and-shoot" or "stop-and-go" mosaics have been discussed in Rodriguez-Fernandez, Pety & Gueth (2009). In that memo, we have also discussed observing time and size limitations for OTF mosaics and three possible schemes to image OTF mosaic data. The first one is similar to that currently used for point-and-shoot mosaics, i.e., each mosaic field is processed independently to compute a dirty image and afterwards all those dirty images are combined linearly before doing a joint deconvolution of the mosaic dirty image. In the case of OTF observations a "mosaic field" is the region covered by the antennas primary beams in the time of one integration or dump. The two other methods discussed in Rodriguez-Fernandez, Pety & Gueth (2009) consist in imaging the whole mosaic at once after constructing a global *uv*-plane that contains the information of all the mosaic fields. These new methods are based on the analysis by Ekers & Rots (1979) that has also been discussed by Cornwell (1987, 1988).

The OTF interferometric data simulator has been developed to allow for development, testing, and comparison of algorithms for processing interferometric OTF data. The present version of the simulation tool uses the following (minor) approximations:

- The *uv* coordinates are independent of the actual pointing position. This is perfectly justified up to very large fields-of-view (a few square degrees)
- The broadening of the effective primary beam, during the scanning motion of the antennas, is not taken into account. As discussed in Rodriguez-Fernandez, Pety & Gueth (2009), the effective beam when observing on-the-fly is almost indistinguishable to the primary beam of the antennas when the sampling rate in the scanning direction is better than Nyquist. Since one wants a good sampling (typically four integrations per FWHM of the primary beam) to allow an accurate data processing, it is possible to assume that the effective beam is equal to the primary beam of the antennas.

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In the following we describe the current version (0.6; mars 2009) of the OTF interferometric data simulator.

2. A simulator of interferometric On-The-Fly simulator

The interferometric OTF simulator tool has been developed on the basis of the IRAM/GILDAS ALMA+ACA simulation tool (Pety, Gueth & Guilloteau 2001). Figure 1 shows the main widget of the OTF simulator tool. Each row correspond to a major step in the processing:

- the setup of the observations
- the actual simulation of the interferometric observations
- computation of a dirty image of the whole mosaic as a linear combination of dirty images, each one computed from each OTF dump or integration (the equivalent to a *field* in the context of pointed *stop-and-go* mosaics)
- deconvolution of the dirty image of the mosaic using the Hogbom algorithm (CLEAN)
- an alternative method to image the mosaic as a whole after computation of a global uv plane containing all the information of the mosaic (this method is still under development)

The user interface has three buttons per step: “GO” to execute, “Parameters” in order to change the default parameters, and “HELP”, which displays information on the different operations to be performed at each step and the meaning of the parameters that can be changed be the user.

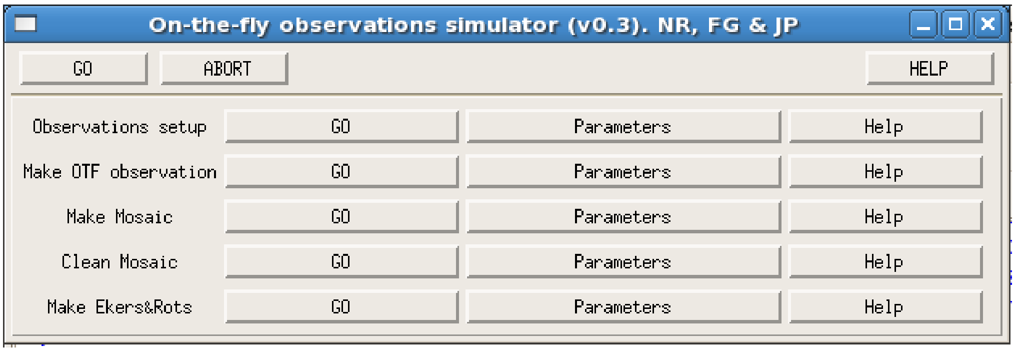
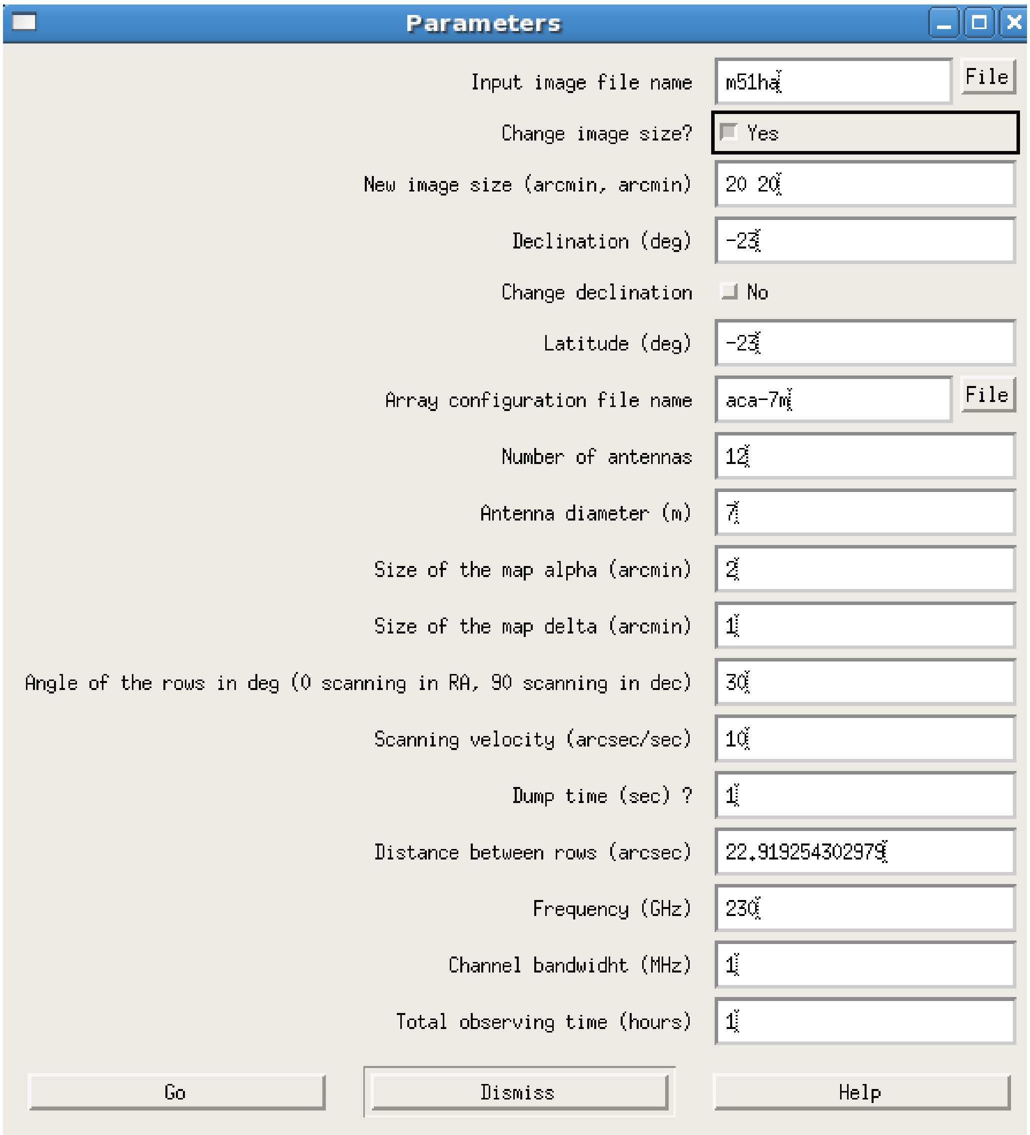


Figure 1 – Screenshot of the main user interface of the interferometric OTF simulator. The different rows allow the user to perform various actions, namely: define the observation setup (array configuration, scanning pattern, integration time, etc.); run the actual simulator; reconstruct an image using the classical mosaicing technique; deconvolve (clean) that mosaic; and reconstruct an image using the Ekers & Rots algorithm (under development). The “Parameters” buttons open a another window allowing one to modify the input parameters of each of these actions.

2.1. Observations setup

The user can select the parameters of the OTF observation as shown in Fig. 2. First, the observer should provide the simulator tool with a model source in FITS or GDF format. If the header of the image does not contain information on the physical size of the image, or if the observer wants to change the physical size of the image, he/she can specify a new physical size and the declination of the source. The next four rows correspond to the array characteristics (latitude, array configuration, antenna diameter and number of antennas, which should be in agreement with the array configuration file).

Aferwards, in the next six rows, the observer should give the parameters of the OTF observation. The observation will be performed following a Cartesian grid pattern. The observer should specify the size of the rectangle to be observed and the inclination. In addition, he/she should specify the scanning velocity and the dumping time. The row separation is indeed fixed to half the FWHM (Full Width at Half Maximum) of the primary beam of the interferometer antennas as computed from the antenna diameter and the frequency of the observations. Finally the observed should give the channel width and the total observing time, which is assumed to be distributed symmetrically around the time at which the source is on the zenith. Other parameters are fixed in the current version, as the zenith opacity (0.8) of the receiver temperature (100 K).



Input image file name	m51ha
Change image size?	☑ Yes
New image size (arcmin, arcmin)	20 20
Declination (deg)	-23
Change declination	☐ No
Latitude (deg)	-23
Array configuration file name	aca-7m
Number of antennas	12
Antenna diameter (m)	7
Size of the map alpha (arcmin)	2
Size of the map delta (arcmin)	1
Angle of the rows in deg (0 scanning in RA, 90 scanning in dec)	30
Scanning velocity (arcsec/sec)	10
Dump time (sec) ?	1
Distance between rows (arcsec)	22.919254302979
Frequency (GHz)	230
Channel bandwidht (MHz)	1
Total observing time (hours)	1

Figure 2 – Parameters that can be changed at the “Observation setup” step

Figure 3 shows the output of the “Observations setup” tool. The region to be observed is plotted as blue rectangle. The OTF scan begins in the upper left corner to the right before scanning the next row in the opposite direction and so on. As explained in Rodriguez-Fernandez, Pety & Gueth (2009), OTF mosaics are similar to stop-and-go mosaics but with an effective beam that can be different to the primary beams of the interferometer antennas. Assuming a constant scanning velocity, the effective beam points to the sky position where the primary beam of the antennas point at the middle of each dump or integration. Therefore to have an effective integration at the upper left corner of the blue rectangle, the first pointing of the antennas is actually located at a distance of $v_{scan} \cdot t_{dump}/2$ outside the rectangle. In Fig. 3, the pointings of the antennas at the start and the end of each integration are represented by small bars perpendicular to the scanning direction while the pointing position of the effective beam is represented by a star.

Regarding the shape of the effective beam, it is very close to the shape of the primary beam of the antennas when there is more than two integrations per FWHM of the primary beam (i.e., when the sampling rate in the scanning direction is better than Nyquist). When observing on-the-fly, scanning velocities and dumping times are chosen to give typically three or four integrations per FWHM of the primary beam, therefore one can assume that the effective beam is given by the same function as the primary beam of the antennas. In the exemple shown in Fig. 3, there are four integrations per FWHM of the primary beams and the white dashed circles represent the FWHM of the effective beam. Note that in the exemple shown in Fig. 3, a fourth row has been planned to be observed in order to fully sample with a good sensitivity the region defined by the blue rectangle, even if the rectangle surface is already covered with only three rows.

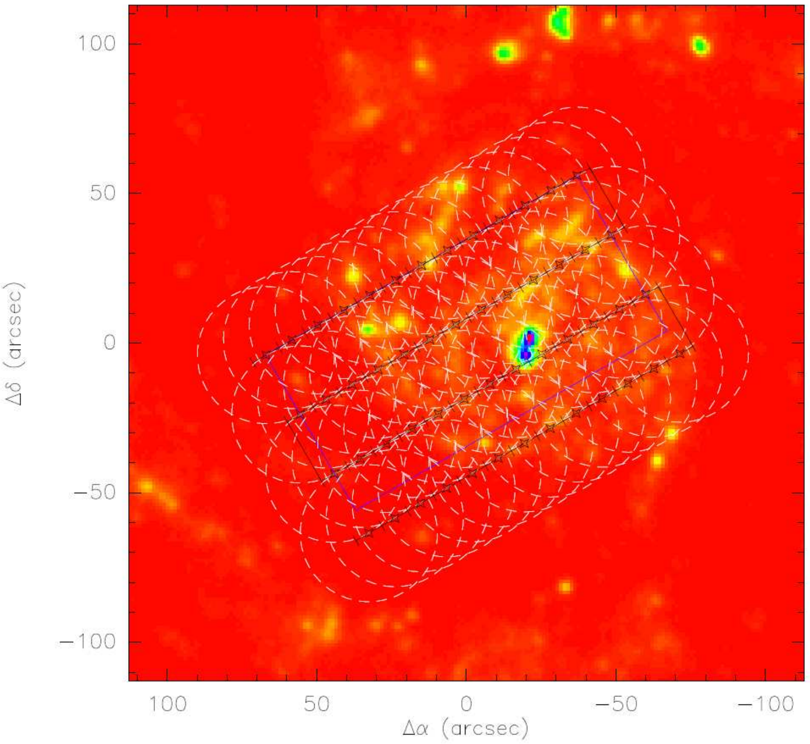
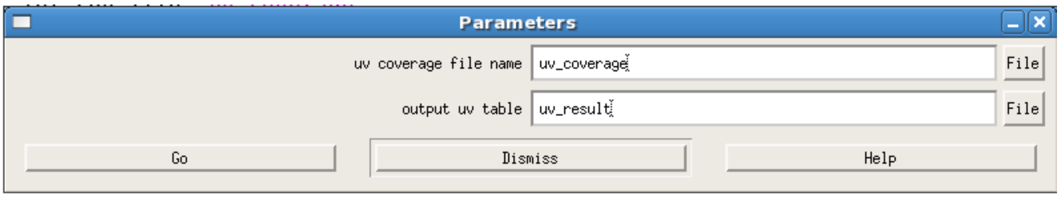


Figure 3 – Output of the setup tool of the OTF simulator. The observations have been simulated using the ACA array. The field requiered by the observer is indicated by a blue rectangle. The field is scanned on-the-fly starting in the upper-left corner and following the black lines. The small perpendicular bars indicate the beginning and the end of each on-the-fly integration. The white dashed circles represent the FWHM of the effective beam, while the effective pointing is indicated by a cross.

2.2. *Make OTF observation*

Once the observer has accepted or changed the parameters that define the required observations, the OTF simulator tool computes the time needed to observe one full coverage of the mosaic and the total number of full coverages that can be observed within the total observing time. In addition, it computes the *uv*-tracks defined by the array configuration and the *uv* points at which the visibility of the source is measured for each time dump. Afterwards, it computes the Fourier transform of the sky brightness distribution and the value of the source visibility at those *uv* points.

The parameters that can be changed at this step is the name of the *uv* table where the computed *uv* points will be stored and the name of the *uv* table where the visibilities have already been computed. In order to deal with OTF mosaics we have added two columns to the standard *uv* table format (see the MAPPING manual in the GILDAS documentation page). These two columns contain the pointing information in order to directly associate a given visibility with the corresponding effective beam pointing.



uv coverage file name: uv_coverage
output uv table: uv_result

Figure 4 – Parameters that can be changed at the "Make OTF observation" step

2.3. *Make Mosaic*

As already mentioned in Sect. 1, it is possible to produce a dirty image of the OTF mosaic computing a one dirty image per OTF dump and a linear combination of those dirty images (see for instance Gueth 2000). This can be done in the "Make mosaic" step of the simulator. Figure 5 shows the "Parameters" window, in which the user can chose the mosaic image size in pixels, the physical size of the pixels and the truncation threshold for the primary beam used to weight the individual fields dirty images.

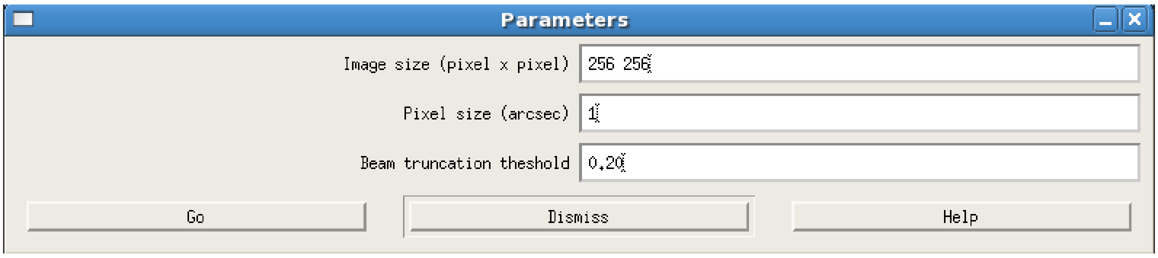


Image size (pixel x pixel): 256 256
Pixel size (arcsec): 1
Beam truncation theshold: 0.20

Figure 5 – Parameters that can be changed at the "Make mosaic" step

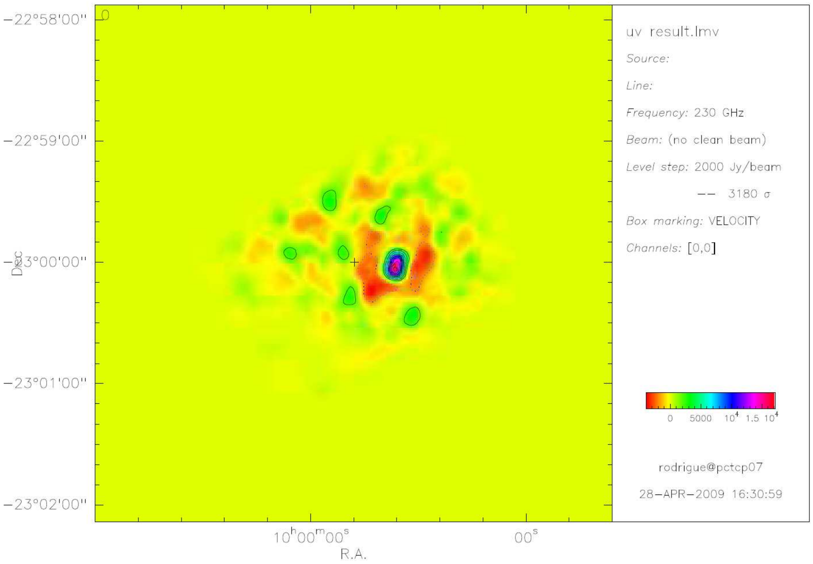
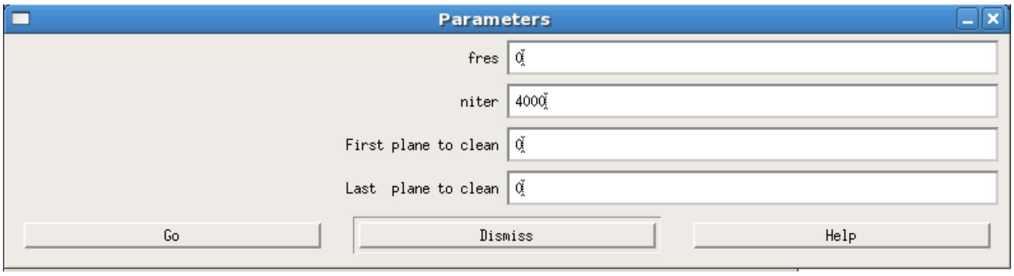


Figure 6 – Dirty image of the OTF mosaic observation of M51 shown in Fig. 3

2.4. *Clean Mosaic*

Once a dirty image of the whole mosaic has been computed, it is possible to do a joint deconvolution. In the current version of the OTF simulator, the deconvolution is done using the Hogbom CLEAN algorithm. Figure 7 shows the corresponding “Parameters” widget. The user can fine tune some parameters as the number of iterations and the minimal fraction of the peak flux in the dirty image that the program will consider as significant (setting the input values to zero makes de program to guess reasonable values or to use the defaults). As an example, Fig. 8 shows the CLEANed version of the map shown in Fig. 6 (the short spacing information has not been added).



fres 0

niter 4000

First plane to clean 0

Last plane to clean 0

Figure 7 – Parameters that can be changed at the “Clean mosaic” step

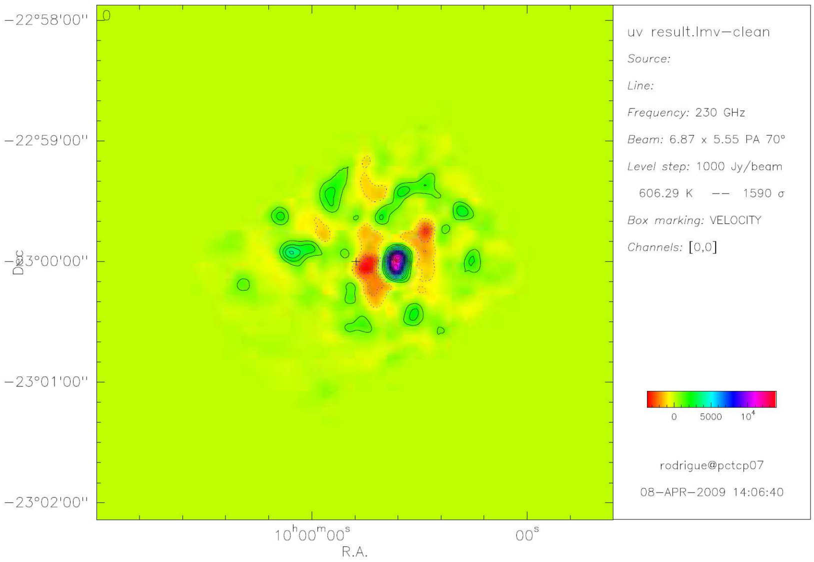


Figure 8 – CLEAN image of the full field of the on-the-fly mosaic. The imaging has been done computing one dirty-image per effective field and doing a linear combination of dirty images before applying a deconvolution. Note that this is a pure interferometric image without the addition of short-spacings.

2.5. Make Ekers & Rots

As mentioned in Sect. 1, one of the goals of the OTF simulator is to produce OTF datasets that can be used to test new imaging algorithms. The “Make Ekers & Rots ” section of the OTF simulator should compute the mosaic image at once from a global *uv*-plane that contains all the information of the mosaic. The global uv-plane will be computed using a completely new algorithm inspired in the Ekers & Rots (1979) scheme. This algorithm is still not implemented in the current version of the simulator.

References

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