Simulation of radio observations of Cygnus A

Patrizia Bussatori

patrizia.bussatori@studenti.unipd.it

1 Introduction

In this brief report I would like to discuss results obtained from simulation of radio observations with APerture SYNthesis SIMulator (APSYNSIM), program by Ivan Marti-Vidal. In particular, the simulation is made assuming two different VLA configurations, the A and B ones, and the radio galaxy Cygnus A.

2 Target

The target is the radio galaxy Cygnus A, also known with the code $3C405$. It is one of the most powerful radio sources in the sky, located in the homonymous constellation and distant 232 Mpc. This concentrated radio source, discovered in 1939, is an elliptical galaxy with apparent magnitude in V band of 16.22.

Like all radio galaxies, it contains an Active Galactic Nucleus (AGN) with a supermassive black hole in the core of mass $(2.5 \pm 0.7) \times 10^9\ M_\odot$. What is really intresting of this source are the two jets protruding in opposite direction from the center with two hot spots in the final part of the two lobs. These hot spots are created from collision of ejected material with the surrounding interstellar medium. These two structure are the main ones observable inside the following simulation.

3 Configuration A

A configuration is characterized by a maximum baseline $B_{max} = 36\ km$ and a minimum baseline $B_{min} = 0.68\ km$. The VLA Array Design and the corresponding overhead snapshot of the UV plane are visible in image 1.

Assuming this configuration, I load the model for the target. Here there are different parameters that can be changed. I assume default latitude (33.9 h) and default declination (45.0 h). They will be the same for the entire simulation. Then I assume recommended observations times: $H_0 = -1.27\ h$ and $H_1 = 1.47$ h for a total observation of 2.8 hours, quite reasonable. Moreover I reduce the wavelength λ to $\sim 100\ mm$ in order to have a better dirty image but I can

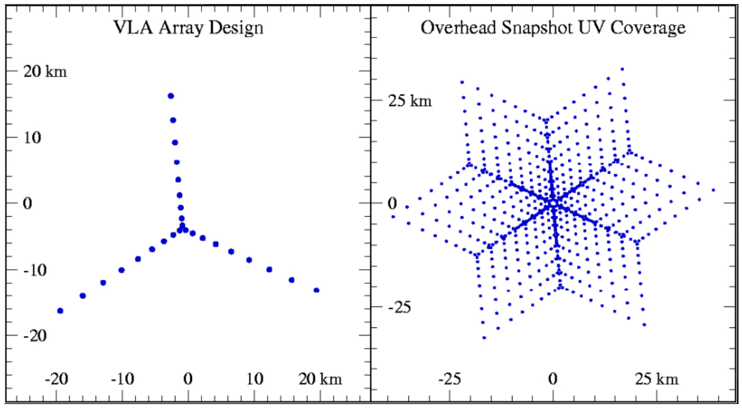

Figure 1: *Panel on left*: VLA Array Design. *Panel on right*: corresponding UV plane coverage given by the Array Design.

reduce up to a limit. Indeed, if the wavelength is too small, the PSF is also very small and, as consequence, it is not possible to apply the deconvolution (the so-called "CLEAN" function on the python program).

Assuming these parameters, I reduce the data and then I clean the image three times, the first one with 0.1 of gain for 100 iterations and the other two times with 0.3 of gain for 800 iterations. However, also after many iterations, has a peak of residuals of 3.26 $Jy/beam$ and the cleaned image does not show clearly the hot spots (see figure 2).

Due to these problems, I conclude that A configuration is not the best one to observe Cygnus A. The true source convolved is visible in figure 3.

4 Configuration B

B configuration is characterized by a maximum baseline $B_{max} = 11.0\ km$ and a minimum baseline $B_{min} = 0.24\ km$. Assuming same latitude and declination as before, I analysed two different combination of parameters.

4.1 First combination

To have a good coverage of the UV plane, the simulator suggests $H_0 = -1.44$ h and $H_1 = 1.63\ h$. As before, decreasing the wavelength, the dirty image becomes more clear and the PSF much resolved. However, as before, there is a limit, even it is bigger for this configuration. The wavelength I choose is 53.0 mm. Then I reduce data and I apply the deconvolution for gain equal to 0.2 and for 3000 iterations.

In this case, the result is a clear image with dynamical range of $32,26$ but there are still big residuals with a peak around 2.15 $Jy/beam$, as visible in image 4.

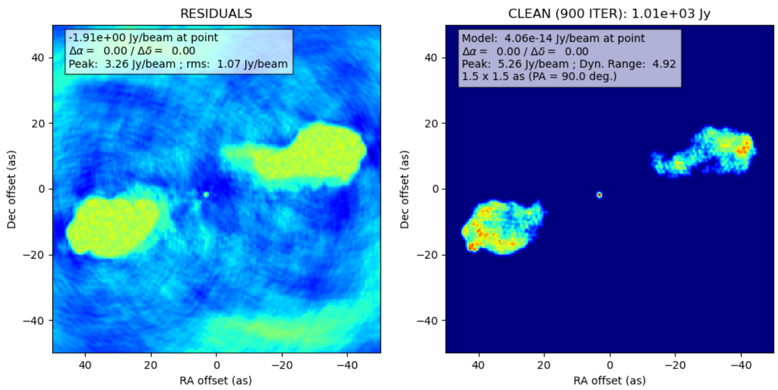

Figure 2: *Panel on left*: Residuals of the reduce data. *Panel on right*: cleaned image, the one on which deconvolution has been applied.

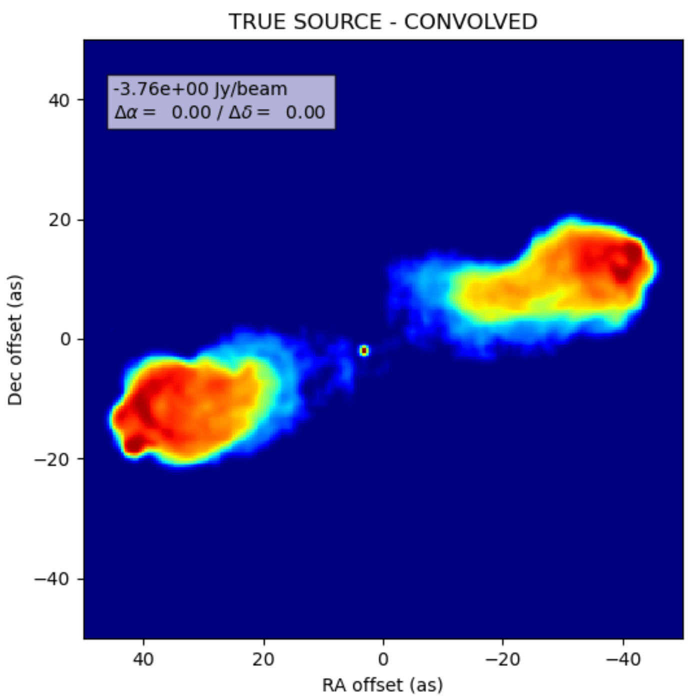

Figure 3: True source for configuration A.

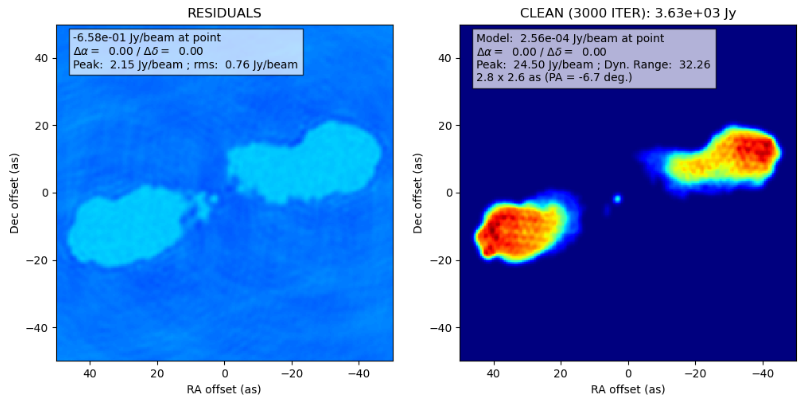

Figure 4: *Panel on left*: Residuals of the reduce data. *Panel on right*: cleaned image, the one on which deconvolution has been applied.

The true source convolved is visible in figure 5.

4.2 Second configuration

In this second case, to have a better and bigger coverage of the UV plane, I set $H_0 = -2.4\ h$ and $H_1 = 2.91\ h$. I also choose to have a bigger wavelength $\lambda = 77.4\ mm$ in order to have a bigger PSF to deconvolve, even if less resolved. Now I reduce the data applying a gain of 0.3 for 300 iterations and then a gain of 0.4 for 1200 iterations. The result is figure 6.

The final result is, instead, figure 7.

5 Conclusion

Looking at previous results, it is clear that the VLA B configuration in the second case is the better chose. Indeed it has relatively low residuals, for being an extended and complex sources, for a reasonable number of iterations of deconvolution and observable in a reasonable amount of time ($\sim 5.3\ h$). The final cleaned image shown in figure 7, can be compered with one obtained by VLA observing at 5 GHz (corresponding to $\lambda = 0.06m = 6 \times 10^3 mm$). In this last case the wavelength is three order smaller than the one used inside the simulation, indeed it is characterized by a very high spatial resolution, but the entire structure is quite similar to the one obtained with the APSYNSIM simulation.

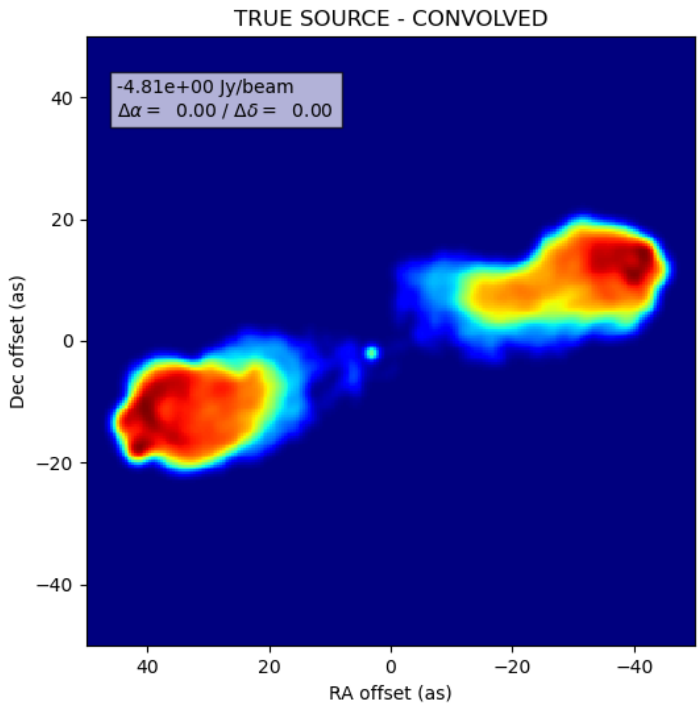

Figure 5: True source for configuration B (first case).

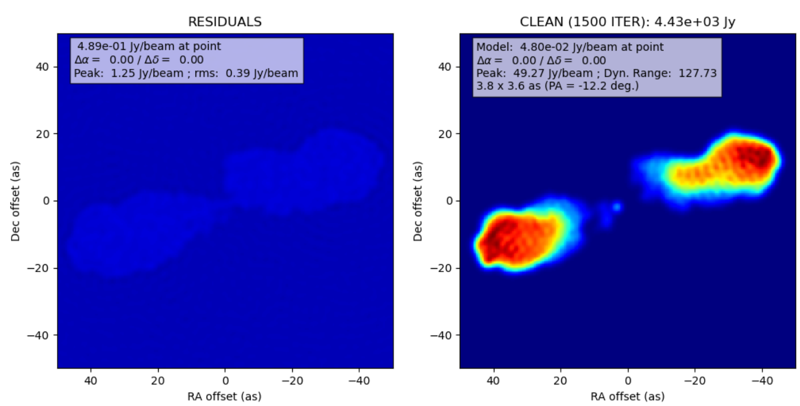

Figure 6: *Panel on left*: Residuals of the reduce data. *Panel on right*: cleaned image, the one on which deconvolution has been applied.

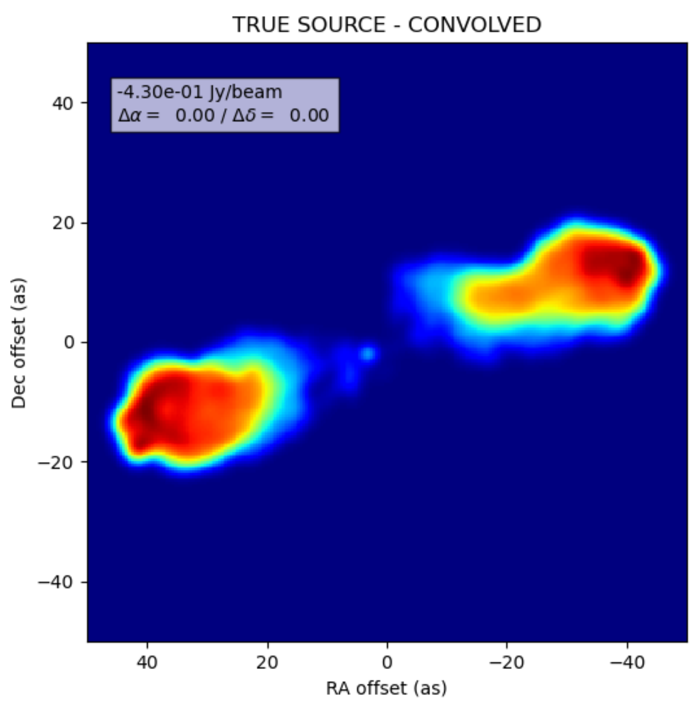

Figure 7: True source for configuration B (second case).

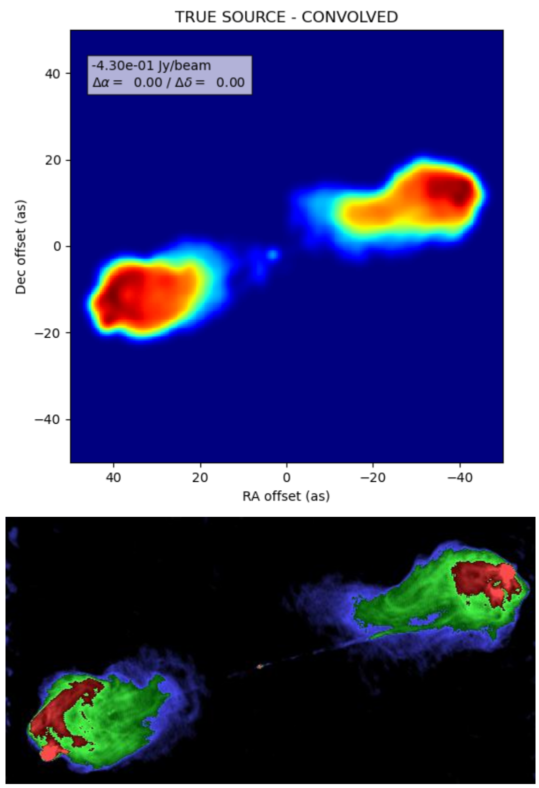

Figure 8: **Simulation VS real image**- *Panel above*: Final image obtained with simulation assuming VLA B configuration in the second case treated before. *Panel below*: A real VLA image at frequency 5 GHz.