Addendum to Next Generation Very Large Array Memo #89

Imaging Molecular Gas in Nearby Galaxies with the RevD Configuration of the ngVLA

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Abstract

To explore the capabilities of the Next Generation Very Large Array (ngVLA) in imaging molecular gas in nearby galaxies, we made a representative simulation of CO(1–0) line (115 GHz) observations at 100 mas resolution of a NGC 4321-like galaxy for Key Science Goal 3 (driving case NGA8). We employ the ngVLA image fidelity pipeline presented in Memo #89 to compare the imaging fidelity achieved with the RevC and RevD of the ngVLA antenna configuration using several components of the array. We find that the RevC and RevD configurations lead to a high imaging fidelity of ≈ 0.994. The radial profiles of the imaging fidelity obtained from both configurations differ by $\lesssim 2\%$ at all radii.

1 Introduction

The performance of the ngVLA for imaging molecular gas in nearby galaxies (driving case NGA8), was explored in depth in the ngVLA memo #89 using the antenna configuration RevC. During the Fall of 2021, a revision for the ngVLA configuration reference design was introduced (RevD) and reported in ngVLA memo #92. For the specific components of the ngVLA used for the simulations of driving case NGA8, the main difference with respect to RevC is related with the redistribution of 27% of the antennas from the Spiral[1] subarray to the Core subarray. In this document, our main goal is to compare the imaging fidelity results obtained with the RevC and RevD configurations of the ngVLA.

[1] The Spiral subarray, formerly known as the Plains subarray.

2 Simulations

We employ the ngVLA image fidelity pipeline[2] (version 1.0), which procedure is summarized below:

- An input model and antenna configuration files are provided to generate visibilities with the task `simobserve`. Given the requirements of the NGA8 use case (i.e., 100 mas resolution, LAS=120 arcsec), three components of the ngVLA have been adopted: the Spiral+Core subarray of the Main configuration, the Short Baseline Array, and the Total Power antennas. A mosaic pattern is implemented for the Spiral+Core and SBA configurations to cover the large angular size of nearby galaxies. Thermal noise is also added, based on the science requirements of KSG 3 (NGA8).

- The Spiral+Core and SBA mock observations are combined with the task `concat`. An interferometric image is created using the CASA task `tclean`. Then, the resulting mosaic is combined with the Total Power image using the task `feather`.

- The imaging fidelity is estimated using the feathered (final) image and the input model, using the definition presented in the ngVLA Science Requirements document.

We execute the ngVLA fidelity pipeline with CASA version 5.6 using the ngVLA RevC and RevD[3] antenna configurations. For both revisions, we adopt the input model, fidelity region file, observational setup, and imaging parameters presented in ngVLA memo #89. We refer the reader to the latter document for a detailed description of the simulations. Here, we limit ourselves to restate the most important aspects of the pipeline setup. Namely, we use a central frequency of 115 GHz and a total integration time of 3.9 hr

[2] `https://gitlab.nrao.edu/vrosero/ngvla-fidelity-pipeline`.
Note: The file `run_all.py` in the fidelity pipeline contains all the user-configurable imaging setup.

[3] RevD configuration files are available at `https://gitlab.nrao.edu/jcarilli/ngvla-configurations/`.
Note: To match the designations of the CASA configuration files from the RevC configuration, we merge the `ngvla-revD.spiral.cfg` and `ngvla-revD.core.cfg` files into `ngvla-revD.plains+core.cfg`, an analog to the previously used `plains+core.cfg` file from the RevC configuration.

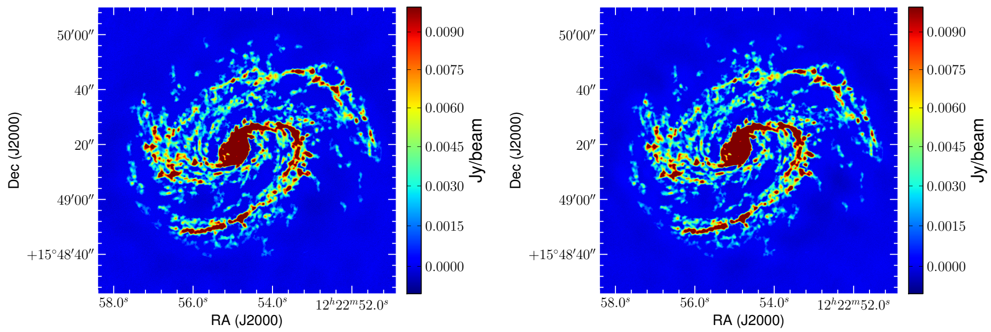

Figure 1: Simulated CO(1-0) line observations of a NGC4321-like galaxy with the ngVLA with the RevC (*right*) and RevD (*left*) configurations. Both images were obtained using auto-multithresh masking and adopting the same cleaning threshold of 1mJy. The rms of the RevC and RevD images obtained via sigma clipping is 0.144 and 0.142 mJy, respectively.

and 8.6 hr for Spiral+Core and SBA, respectively. We employ multiscale imaging with robust=0 and taper=79.2 mas, image size of 12288 pixels, and cell size of 20 mas.

For the results presented in this document, we adopt the auto-multithresh option that implements an automated masking algorithm. We also choose a common threshold of 1 mJy and 500,000 iterations to ensure that this limit is reached, which allows us to clean down to the same peak residual and perform a more direct comparison between the images obtained from the RevC and RevD configurations.

3 Results

The simulated images of an NGC4321-like galaxy obtained with the RevC and RevD configuration are presented in Figure 1. The FWHM of the synthesized beam achieved with these observational setups is 108×100 mas and 110×94 mas respectively. A visual inspection does not reveal significant differences between the two images. Indeed, the imaging fidelity derived from the RevD configuration of 0.9940 is only 0.03% lower than that obtained using the RevC one (0.9943). We verify that the imaging fidelity obtained from the RevD configuration is always consistent (or even better) than that obtained

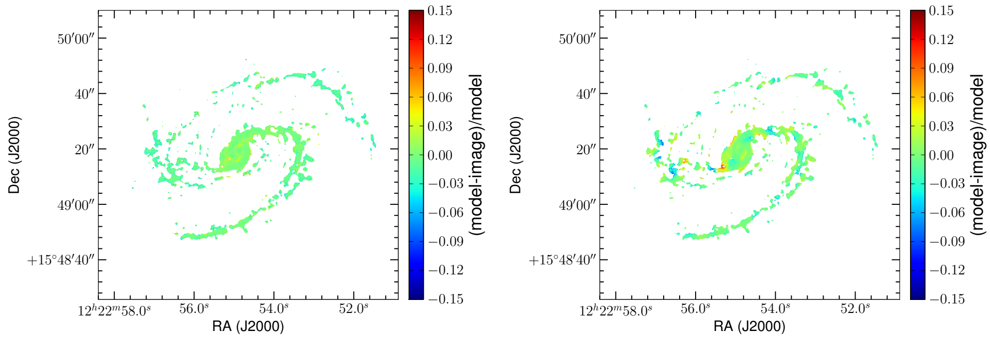

Figure 2: Relative residuals, i.e., (model-image)/model, obtained with the RevC (*right*) and RevD (*left*) configurations. Both images were obtained using auto-multithresh masking and adopting the same cleaning threshold of 1mJy. The area shown here corresponds to the cutout region used to estimate the fidelity, which includes the non-zero pixels of the input model and avoids the areas of model zero-padding.

from RevC if no masking nor stopping threshold is adopted in tclean.

To explore the spatial variations of the reconstructed image quality with the RevC and RevD configurations, in Figure 2 we present the relative residual maps, [(model-image)/model], that are a proxy for the fidelity per pixel. A visual comparison reveals subtle differences, particularly in the outer regions of the core and the spiral arms. To confirm this, we derive the radial profiles of the relative residuals from the RevC and RevD configuration outputs presented in Figure 2. We employ a set of circular annulus (3 arcsec width) that span out to a radius of 51 arcsec, covering the full extent of the simulated image. We present the mean relative residuals as a function of radius in Figure 3. As anticipated from the 2D distributions, we find that the imaging fidelities achieved with the RevD and RecC configuration are consistent at all radii. Some marginal differences, however, exist. While at radii < 20 arcsec the RevC configuration leads to better imaging fidelity, in the outer regions of the galaxy's spiral arms, radius=40-50 arcsec, the RevD configuration marginally improves (by $\lesssim 1\%$) the imaging fidelity.

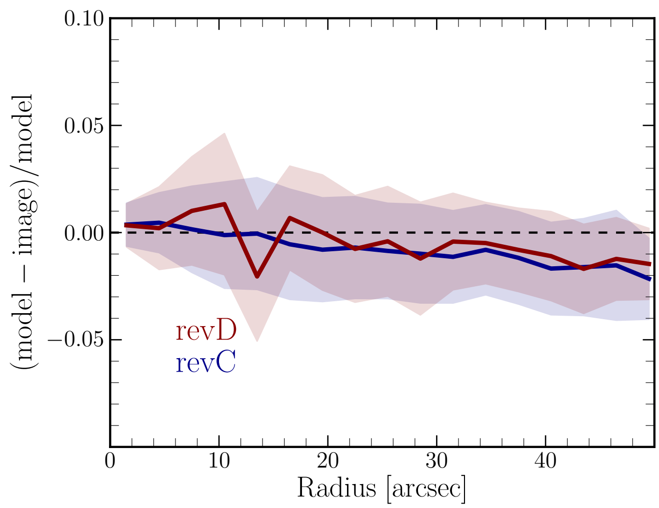

Figure 3: Relative residuals, i.e., (model-image)/model, as a function of distance to the galaxy's center. The red (blue) line shows the average residuals obtained with the RevD (RevC) configuration. The shaded regions illustrate the dispersion of the respective distribution. Auto-multithresh masking has been adopted. We use the same cleaning threshold of 1mJy for both configurations.

4 Conclusion

Using ngVLA mock observations of an NGC 4321 galaxy, we find that both the RevD and RevC configurations lead to an imaging fidelity of ≈ 0.994. The radial profiles of the imaging fidelity obtained from both configurations differ by $\lesssim 2\%$ at all radii. This finding reinforces the results presented in Memo #89, where it was shown that ngVLA will be able to produce the high fidelity images required to meet the Key Science Goal 3 and, in particular, the driving case NGA8.