Calibration of BIMA Data in AIPS++

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Abstract. We summarize the general approach adopted for the calibration of millimeter interferometer data from the BIMA telescope using AIPS++ and illustrate the use of the relevant software tools. In particular, we will discuss flagging, phase calibration, flux calibration, and polarization calibration, and we will show how we take advantage of the unique capabilities of AIPS++ to meet the special needs of BIMA data. We will show how BIMA calibration tools can be used to hide some of the complexity of the processes while still allowing access to specialized variations if desired. We will illustrate how these tools are pipelined together for end-to-end processing both within the BIMA Image Pipeline and on the user's desktop. Finally, we will present a comparison of data calibrated in MIRIAD and AIPS++.

1. Introduction

We present the results of a comparison of calibrated millimeter data from the Berkeley-Illinois-Maryland Association (BIMA) Array using both AIPS++ and MIRIAD. In addition, we discuss the unique calibration capabilities of AIPS++ in calibrating BIMA data both on the user's desktop and in an end-to-end (e2e) pipeline. In particular we present:

- A brief discussion of calibration of BIMA data using AIPS++;
- A qualitative comparison of data calibrated and cleaned in AIPS++ and MIRIAD;
- A quantitative comparison of the RMS and dynamic range of data calibrated and cleaned in AIPS++ and MIRIAD.

2. Calibration of BIMA Data with AIPS++

AIPS++ allows for the concealment of some of the complexity of calibrating BIMA data through the use of custom tools. The *bimacalibrater* tool in AIPS++ is such a tool. *bimacalibrater* contains several functions needed in the calibration process, many of which are friendly wrappers around functions of the AIPS++ *calibrater* tool. These wrappers hide parameters not normally needed in the calibration of BIMA data and provide more suitable defaults for other parameters.

195

The *bimacalibrater* functions hide much of the complexity of the calibration process while still allowing a high degree of customization for varied data.

One of the important aspects of the calibration process is the ability to view the antenna based gain solutions, flag bad data in the solution, and fit the solutions. Gain solutions are written to a gain table that can be accessed by the AIPS++ table tool, allowing for a high level of accessibility to the data. Once this has been done, an interactive user can use the *plotcal* function of the *bimacalibrater* tool to examine the gain table. If any bad data were noted after examining the gain table, a user could simply flag the bad data using the *autoflag* tool, or, interactively using the *msplot* tool (both part of AIPS++). In addition, it is also possible to flag and fit gain table solutions using the *gainpolyfitter* tool.

2.1. Calibration Process

The calibration process consists of three primary steps:
1. Filling;
2. Flagging/Editing;
3. Calibration.

All of these steps can be carried out interactively on the user's desktop using the AIPS++ GUI, interactively using the Glish (the scripting language front end to AIPS++) command line interface, or in an automated fashion using custom Glish scripts. The BIMA Image Pipeline currently employs the *bimacalibrater* tool to do automated calibration of BIMA data.

3. Comparison of Data Calibration with AIPS++ and MIRIAD

In order to assess the robustness of calibration of BIMA data within AIPS++, several comparisons were made between data calibrated with and cleaned within AIPS++ and MIRIAD. Great care was taken at each step of the calibration process to ensure we were comparing "apples to apples" – data that were flagged in one data set were flagged in the other, the same clean algorithms were used in both cases, gain solution fits were both two point interpolations, etc. The following comparisons were carried out:
- Peak fluxes of calibrated versions of the calibrator were compared;
- Antenna based gain solutions were compared;
- Contour maps with the contours chosen to highlight the noise levels were made for qualitative comparison;
- The data were cleaned using the same number of iteration and noise and dynamic range calculations were made;
- The data were cleaned to the same peak residual level and the number of iterations needed to reach that level was noted and subsequent image noise and dynamic range measurements were made.

As a check on the flux density calibration, images of the calibrator 1733-130 were made. The specified flux density of this source during calibration was 2.8 Jy. The flux densities of the dirty maps were compared. The MIRIAD image produced a peak flux density of 2.66 Jy, while the AIPS++ data yielded a flux density of 2.81 Jy. In this particular case, AIPS++ did a better job in reproducing the correct flux density during calibration.
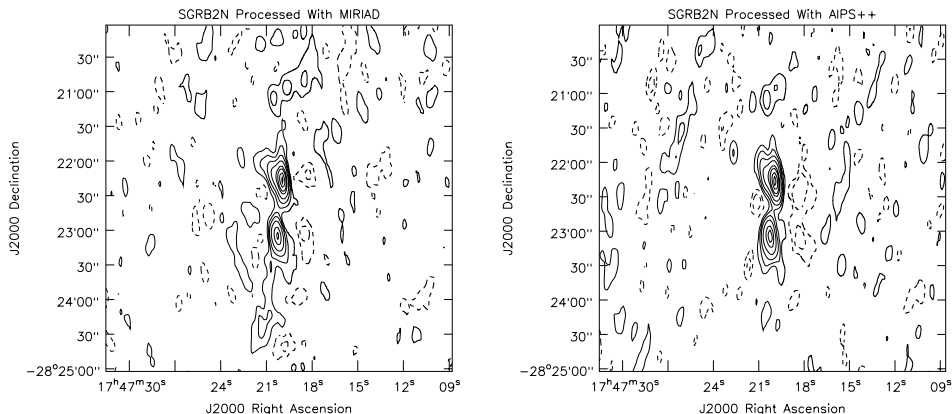
Figure 1.   SGRB2N calibrated and cleaned in MIRIAD and in AIPS++.

The next step in the calibration comparison was to examine the gain solutions produced in the two packages. There was no noteworthy difference in the gain solutions other than the fact that gain solution amplitudes in MIRIAD are the reciprocals of their AIPS++ counterparts.

A qualitative comparison of the images after a 1000 iteration clean (using the Clark clean algorithm) was then performed. The same data were calibrated and cleaned in AIPS++ and MIRIAD and then imaged. Figure 1 shows the results. In both cases, contour levels were chosen to highlight the background noise levels so qualitative comparisons between the calibrations could be seen more clearly. The contour levels are the same for both images.

Using the *imstat* command in MIRIAD and the image analysis tool in AIPS++, the RMS noise level for each cleaned image was measured. In both cases, the same off-source region was used. The results of this comparison are summarized in Table 1.

Table 1.   Image quality after calibration and cleaning (1000 iterations)

	AIPS++	MIRIAD
RMS (Jy/beam)	0.06	0.06
Peak Flux (Jy/beam)	5.50	5.25
Dynamic Range	91	90

Lastly the data were cleaned to a maximum residual cutoff of 0.115 Jy/beam and a similar comparison of background noise done. It should be noted that AIPS++ cleaned to that level faster than MIRIAD – 1437 iterations in AIPS++ and 4451 iterations in MIRIAD. The results are summarized in Table 2.

Table 2.   Image quality after calibration and cleaning (maximum residual cutoff of 0.115 Jy)

	AIPS++	MIRIAD
NITER	1437	4451
RMS (Jy/beam)	0.05	0.05
Peak Flux (Jy/beam)	5.5	5.4
Dynamic Range	112	117

4.   Summary

Comparison of calibration of BIMA Array data in MIRIAD and in AIPS++ has been carried out. We found no significant difference in the gain solutions and images made from calibrated data from either package. Specifically we found the following:

- The AIPS++ *bimacalibrater* tool and associated functions provide a useful interactive GUI, command line, or pipeline solution for calibrating BIMA data;
- In comparing antenna based gain solutions, it was found that gain solution amplitudes in MIRIAD are the recipricals of their AIPS++ counterparts;
- In comparing flux densities of the phase-calibrator from maps made using each package, AIPS++ did a better job reproducing the correct density;
- When the target data were calibrated and cleaned using the same number of iterations, the dynamic range of the image is roughly 2% higher in the AIPS++ image;
- When the target data were calibrated and cleaned to the same intensity cutoff whilst AIPS++ required fewer iterations, the dynamic range of the MIRIAD image was 4% higher than the AIPS++ image.