Astronomical Data Analysis Software and Systems XVII **P8.3**
ASP Conference Series, Vol. 394, © 2008
R. W. Argyle, P. S. Bunclark, and J. R. Lewis, eds.

The Common Astronomy Software Application (CASA)

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Abstract. This paper describes the Common Astronomy Software Application (CASA) for analysis of radio astronomy data. The initiative behind the CASA software is driven by the data processing needs of the ALMA and EVLA telescopes; However, the intention is to build a general purpose data analysis software for data from radio, millimeter, and submillimeter telescopes.

1. Introduction

The Common Astronomy Software Application (CASA) is a suite of tools for calibration and analysis of radio astronomy data, both interferometric and single-dish. In this document we describe what is available in the CASA software.

CASA builds upon the libraries developed by the AIPS++ consortium, but with some major differences! Gone is glish and in its place is Python. Other changes include: using the matplotlib library instead of pgplot for plotting, binding with the SciPy python library, and using TrollTech's Qt libraries for the GUIs. These changes has allowed CASA to extend the user interface facilities while maintaining the old!

2. CASA Tasks and Tools

The functionality within CASA has been divided into tasks and tools; tasks are more user-friendly; the tools offer the users more flexibility and functionality but are much more tedious to use. The CASA tasks are Python scripts which use the CASA tools and are intended to be tasks that are commonly performed when analyzing astronomical data.

2.1. Supported Data Types

The first step in using CASA is getting the data into a usable format. CASA uses its own internal data structure, called a Measurement Set which is nothing more then a set of tables containing the data from the observation(s). Specialize import facilities allow users to import ALMA and EVLA/VLA data as well as more generic facilities for importing UVFITS. In addition to the import facilities there are facilities for creating, querying, viewing, editing, and destroying both measurement sets and tables at the tool level.

Both interferometric and single-dish data are supported in CASA. Interferometric support comes and the original AIPS++ software and single-dish support by adapting ATNF's Spectral Analysis Package (ASAP) into CASA.

Although not observational data, but data of a sort are astronomical measurements and quantities are also supported at the CASA tool level. For example, there are facilities for converting B1950 positions to J2000, knows of constant values such as the speed of light, position of planets and many, many more helpful tidbits.

2.2. Data Flagging

Bad data can be flagged: automatically; manually through a task, or interactively with either the plotter and/or viewer GUIs.

Auto-flagging algorithms supported at the tool level include: time-median filtering, and frequency-median filtering. Manual flagging allows users to specify some subset of the data to be flagged, for example flagging all data from a single antenna. Interactive flagging allows users to select and flag areas on the CASA viewer (see Section 3.3.) and plotter (see Section 3.2.).

2.3. Calibration

The next step in data processing is calibration. In the calibration process correction factors are applied in order to make the measured quantities to values as close as possible to the ideal measurements for interferometric data.

Often pre-processing steps are applied before the calibration begins to correct the data. CASA intends to have support for temperature correction, applying antenna gain-elevation dependencies, atmospheric corrections, and modelling flux density; the Beta version does not fully support all of these.

The calibration facilities include solvers for basic gain (amp and phase), bandpass, and polarization effects, antenna-based and baseline-based solutions, incremental solving and smoothing/interpolation of solutions. In addition, single component UV model fitting and UV continuum subtraction are supported.

2.4. Imaging

In CASA there are facilities for creating and manipulating images from from calibrated data (measurement sets). Typically image creation involves stages of Fourier transforming observed interferometric data (visibilities) or images and image based deconvolution. Before Fourier transforming the visibilities a variety of weighting schemes is allowed (natural, uniform, superuniform and Briggs) to be applied on the visibilities. The resulting dirty images are then deconvolved. Deconvolution algorithms available are multiple flavors of CLEAN, Maximum entropy methods and Non-negative Least Square (NNLS) based deconvolution.

CASA supports a non-interactive and interactive clean modes, the difference being that users can make selections during the cleaning process. The clean algorithms supported by CASA are: Hogboom CLEAN (classic cleaning algorithm), Clark CLEAN (minor/major cycles), Cotton-Schwab CLEAN (Clark algorithm, with altered major cycle), and Multi-scale CLEAN (delta-functions and circular Gaussians). These algorithms can be applied to a single field or mosaic fields or even wide fields (non co-planar array imaging). In addition UV-base feathering and joint deconvolution allows single dish and interferometric image data to be combined for the cleaning process.

2.5. Simulator

There are facilities in CASA for simulating observations from the EVLA and ALMA telescopes; it has also been used to simulate SKA observations. The simulator takes an input model for a patch of sky and turns it into an observation from multiple points, or deconvolved mosaic. There are facilities for adding noise to the observation too. The simulator facilities are under construction and not fully developed in the beta version of CASA.

3. User Interface

For the most part users will interact through the interactive IPython shell. However, there are a number of graphically user interfaces; viewer, plotter, logger and table browser. The logger displays any messages reported by the CASA software, and the table browser is used to investigate the contents of a table. The remainder of the interfaces are described in more detail in this section.

3.1. Python

IPython was chosen to be used as the command-line interface. IPython has facilities for: executing shell commands, command-line history maintenance, defining macros, and auto-parenthesizing input. These features are in addition to what is already found in Python. User's can easily import any 3rd-party Python libraries into the CASA environment and use them from within CASA. It was felt that the SciPy and PyLab (matplotlib) packages would be so widely used that these libraries are distributed with CASA.

From the CASA interactive shell, *casapy* all of the CASA tasks and tools (see Section 2.) can be executed. In-line help is provided, further resources, cookbook and manual, can be found at the CASA website, **http://casa.nrao.edu**.

3.2. Plotting

The plotting facilities in CASA uses the PyLab (matplotlib) Python library. The plotter plots calibration data, measurement sets, and simple tables. There are facilities for creating plots with multiple panels of varying sizes, virtually unlimited colour selection and a variety of plot symbols, the ability to overplot, interactive data flagging, and iterative plots. Iterative plots allow users to make a particular plot while automatically iterating (looping over) a particular data descriptor, such as field, channel, or spectral window.

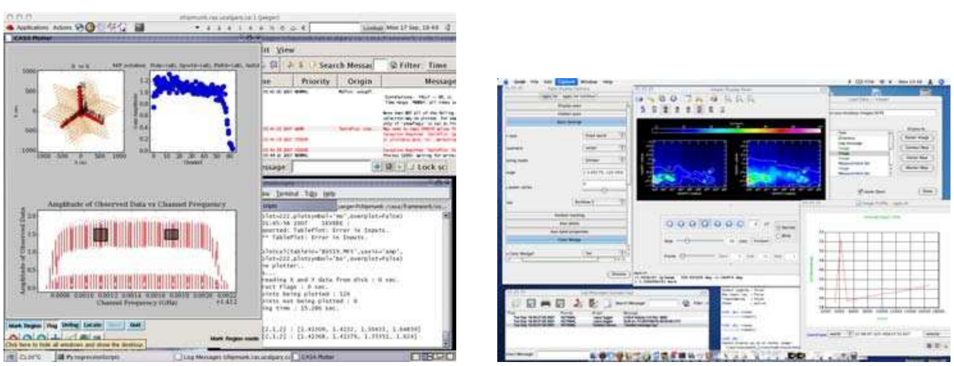

Figure 1. Fig 1 (left) **top-left**: UV coverage **top-right**: base-line based bandpass calibration solution, and **bottom**: observed frequencies (black), averaged frequencies (orange), and flagged data (holes). Fig 2 (right) **middle**: two panels show different slices of the contour image is overplotted on the raster image, **bottom-right**the spectral profile of the selected region, and **top-left** option selections

3.3. Viewer

CASA has a powerful image viewer, and despite its name it can be used to view images (CASA and FITS formats) and visibility data (CASA measurement sets).

There are a number of viewer controls which allow users to adjust the colour scheme, the data associated with the x, y, and z axes, animation speed, the number of panels displayed, and many, many more options.

A feature of the CASA viewer is that it can handle a large number of frequency channels. The viewer can play animations by stepping through the z axis, typically the z-axis is set at frequency, while the x and y axes are set to be positions. Images can be overlaid on top of each other, a common use of this feature is to overlay the contour map onto the raster image. Finally the spectral profile of a selected point or region in the image, can be plotted in a separate window.

4. Concluding Remarks

Work is ongoing for this project. At the time of writing this paper, a beta version of CASA is available and by the time next years ADASS conference there will be a fully supported version of the CASA. The support 32bit operating systems are: Red Hat Enterprise, Scientific Linux, Fedora, and Mac OSX.

For more information on the CASA software please visit: http://casa.nrao.edu

4.1. Acknowledgements

CASA is the result of team effort, a great team of software developer and scientist that I am proud to be a part of. Our fearless leader is Joe McMullin who will be moving on to a new project in Chile at the ALMA observatory. His absence will be felt by all of the team members. The other developers, in alphabetical order are: Sanjay Bhatnagar, Laura Glendenning, Kumar Golap, David King, George Moellenbrock, Urvashi Rau, Darrell Schiebel, Boyd Waters, Honglin Ye, and Wes Young (NRAO); Raymond Rusk (NRC Canada); Shannon Jaeger (University of Calgary); Tak Tsutsumi (NAOJ).

We also owe a great deal of thanks to our advisors/testers which is a suite scientists from around the world as well as the NRAO Applications User Group. Thanks to the collaborators of CASA's predecessor, AIPS++, and the ATNF and the ASTRON Technical Lab who have contributed to the CASA software as well.