ALMA

The Atacama Large Millimeter/submillimeter Array (ALMA) is a major new facility for world astronomy. ALMA will consist of an array of 50 12-m antennas, with baselines up to 16 km, and an additional complement of 12 7-m and 14 12-m antennas to greatly enhance ALMA’s ability to image extended targets. ALMA is outfitted with modern receivers that cover atmospheric windows from 300 to 350 GHz with additional bands in preparation. Construction of ALMA started in 2003. Early Science observations started in 2011 with 16 antennas and 4 receiver bands. The inauguration of the complete instrument took place in March 2013. Commissioning and some construction work is still in progress.

The ALMA project is an international collaboration between Europe, East Asia, and North America in cooperation with the Republic of Chile.

For more information see http://almascience.eso.org/

ALMA Proposal Cycles 0 and 1

The first call for ALMA proposals went out on 31 March 2011 (Cycle 0). Observations were completed end of 2012. More than 50 refined papers were already published based on the data obtained by ALMA. Cycle 1 observations started in January 2013.

ALMA Data Quality Assurance (QA)

AlMA PIs propose for science goals, not for a specific amount of time. One proposal can have several science goals.

The goal of ALMA Quality Assurance (QA) is to deliver to the PI a reliable final data product that has reached the desired control parameters outlined in the science goals, that is calibrated to the desired accuracy and free of calibration or imaging artifacts. The observations are organised by science goal into observing units (OUs). Within each OU, the smallest separately observable block (SRB) duration 30-60 min. The SBIs for one OU can be repeatedly executed until the performance criteria of the science goal have been met. This is verified by QA at four levels:

1) Real-time near-arrival verification of weather and hardware issues carried out on each SB execution (execution block, EB) immediately after the EB (on-site).
2) Verification of longer-term observational health issues like absolute pointing and flux calibration.
3) Offline calibration and imaging (using CASA) of a completely observed SB. Performed by expert analysis distributed at the JAO and the ARCs with the help of a semi-automatic QA2 pipeline. The automation of the pipeline is planned to be extended over the next cycles. Results the science-grade standard ALMA data products. The PI may use CASA to further improve on these.
4) (optional): PIs may request re-calibration and problem fixes.

See http://almascience.eso.org/documents-and-tools/alma-technical-handbook

ALMA Standard Data Products in Cycle 0

1) Images:
   a) MS including only the science spectral windows, with Tsys, WVR and antenna positions corrected and binned to a resolution of 16".
   b) The fully calibrated MS (FCMS).
2) Imaging Products (all images are delivered as FITS files):
   a) Datasets: MS, immediate after the EB observation.
   b) Verification of all sidebands.
   c) A set of high-level data processing procedures (“tasks”) from the CASA project.
   d) The fully calibrated MS.

3) Calibration Tables:
   a) All calibration tables (Tsys, WVR, bandpass, gain, flux).
   b) All flagging tables.
   c) All US tables.
   d) All flux tables.
4) Support Information:
   a) Detailed explanation of constructing data tables.
   b) CASA reduction scripts (including QA2)
   c) Reduction logs
   d) Add-on task images/plots as needed.

CASA main facts

CASA = Common Astronomy Software Applications
- Development started in the 90s, now > 1.5 Min. lines of code (C++)
- Designed in 2005 to be the ALMA/vla analysis package
- Both for official observatory work and for ALMA users
- Has the intention to be a general software package to reduce both interferometric and single-dish data
- Internally consists of two parts:
  1) casa noncore – user interface, higher-level analysis routines, GUIs
  2) casacore – general physical and astronomical utilities, infrastructure
- Developed in collaboration with ASTRON, ATNF, and others.
- Implements the “Measurement Equation” (Hanaker, Bregman & Sault 1996) for calibration in full polarisation
- Science data format: the “Measurement Set” (Kemball & Wieringa 2000)
- Scriptable via Python (“casapy”)

5) ALMA Observing Cycle 0 (2011 – 2013) 8000 hours.

6) One proposal can have several science goals.

A typical analysis workflow for ALMA data*

1) “Heterodynes data in this case, but CASA also has a complete list for ‘single dish’ analysis which relates to the entire ALMA Science Processing Handbook (ASPH)
2) CASA reduction script(s) including QA2
3) Calibration and imaging with CASA to produce images for science.
4) A set of high-level data processing procedures (“tasks”)
5) A programmable command line interface with scripting
6) Documentation: an extensive cookbook (380 pages)
7) + documentation through built-in help + online help pages

CASADesign and implementation

1) A data structure (Tables: Images, Caltables, the MeasurementSet)
2) A set of data input/export facilities supporting (ASDM, UVFRS, FITS-IDE, YLA archive, SPFIT, FITS)
3) A toolkit with more than 1000 methods for
   a) data access, display, transformation, and editing
   b) radio astronomical calibration, imaging, and simulation
   c) A set of high-level data processing procedures (‘tasks’)
4) A programmable command line interface with scripting
5) Python (augmented by IPython) gives a MATLAB-like environment
6) Documentation: an extensive cookbook (380 pages)
   + documentation through built-in help + online help pages

See http://casa.nrao.edu/ and http://casaguides.nrao.edu

The CASA user interface

Pictures from a typical interactive analysis session.

1) A typical analysis workflow for ALMA data*

1) Datasets: QA3 data products. The PI may use CASA to produce images for science.
2) Calibration and imaging with CASA to produce images for science.
3) A set of high-level data processing procedures (“tasks”)
4) Data products for each observation block (SB).
5) The observations are organised by science goal into observing units (OUs).
6) All flagging tables.

A typical analysis workflow for ALMA data*

1) Datasets: QA3 data products. The PI may use CASA to produce images for science.
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CASA in ALMA Cycle 0

During Early Science, i.e. the first few proposal cycles until all planning and implementation capabilities have been revealed, also the data reduction pipeline is under construction. As the experience in the “Measurement Equation” is building up, the data reduction will be more and more automated.

For Cycle 0, a script generator tool was developed. Based on a given MS, it creates a nearly complete CASA reduction script which can then be fine-tuned and refined by the analyst. The script generator approach proved to be highly effective. It will also be used in cycle 1 and beyond for complicated cases and verification of the automated pipeline.

Examples from http://casaguides.nrao.edu

ALMA VLA data from April 2013: 8 antennas in compact configuration, ca. 3 hours of total on-source time.

The CO (1-0) velocity field of NGC253, with contours of the total line emission map overlaid.

The CO (1-0) “moment 0” total intensity map of NGC253 overlaid with the contours of the velocity field overlaid.

CASA is a deliverable by NRAO to the ALMA collaboration.

It is developed at NRAO and under NRAO management with major contributions from ESO and NAIC.

Manager: Jeff Kerr (NRAO), project scientist: Jacques Orr (NRAO).

ALMA-CASA subsystems: Craig Conley (NRAO), DovSha Finkelman and Toshihiko Nonaka.

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