



Analysing ALMA data with CASA



ALMA

The Atacama Large Millimeter/submillimeter Array (ALMA) is a major new facility for world astronomy. When completed in 2013, ALMA will consist of a giant array of 12-m antennas, with baselines up to 16 km, and an additional compact array of 7-m and 12-m antennas to greatly enhance ALMA's ability to image extended targets. ALMA in Cycle 0 is outfitted with state-of-the-art receivers that cover atmospheric windows from 84–720GHz (3mm – 420 micron). Construction of ALMA started in 2003 and will be completed in 2013. Science observations are ongoing since end of September 2011 with 16 antennas and four receiver bands. 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://www.almascience.org/>

ALMA Proposal Cycles

The first call for ALMA proposals went out on 31 March 2011. The deadline for proposal submissions was 30 June 2011. More than 900 proposals were received out of which 112 were accepted.

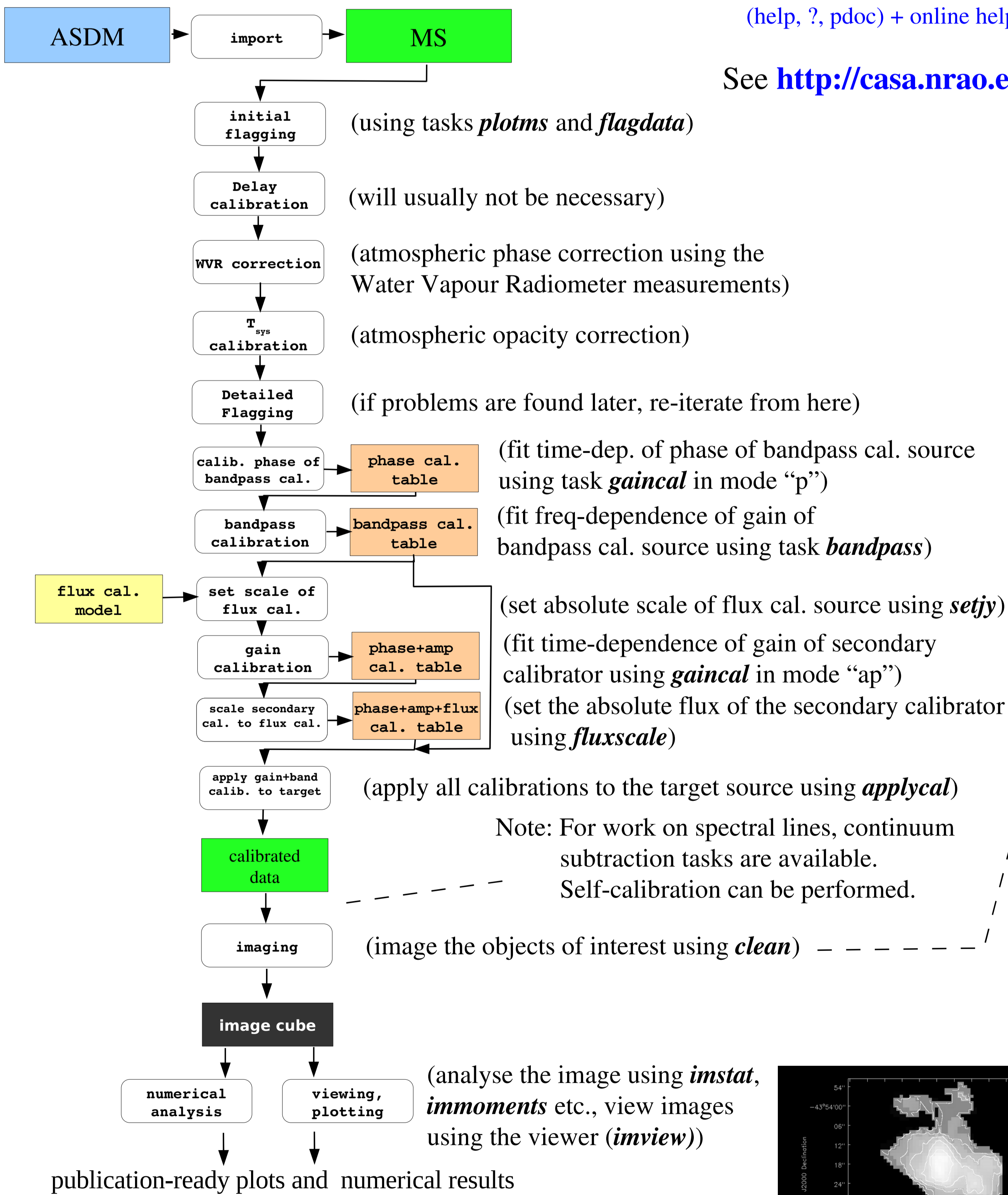
Observations based on these proposals have started on 30 September 2011 and are planned to be completed in June 2012. The call for cycle 1 proposals is planned to be issued on 1 February 2012.



19 ALMA antennas at the observatory site (5000 m a.s.l.)
Credit: W. Garnier (ALMA)

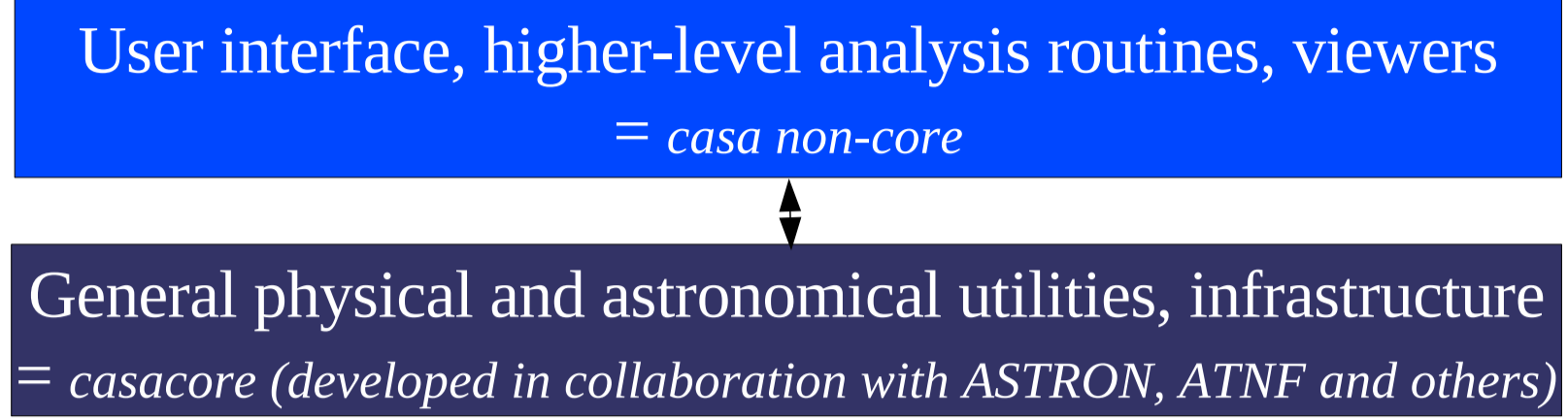
A typical analysis workflow for ALMA SV data*

*interferometric data in this case, but CASA also has a complete kit for "single dish" analysis which includes the entire ATNF Spectral Analysis Package (ASAP)



CASA main features

- CASA = Common Astronomy Software Applications
- Development started in the 90s
- Designated in 2003 to be the ALMA/EVLA analysis package
- Has the intention to be a general software package to reduce both interferometric and single-dish data
- Internally consists of two parts:



- Implements the "Measurement Equation" (Hamaker, Bregman & Sault 1996) for calibration in full polarisation
- Internal data format is the "Measurement Set" (Kemball & Wieringa 2000)
- more than 1.5 Million lines of code (mostly C++)
- In public release under GNU Public License since December 2009

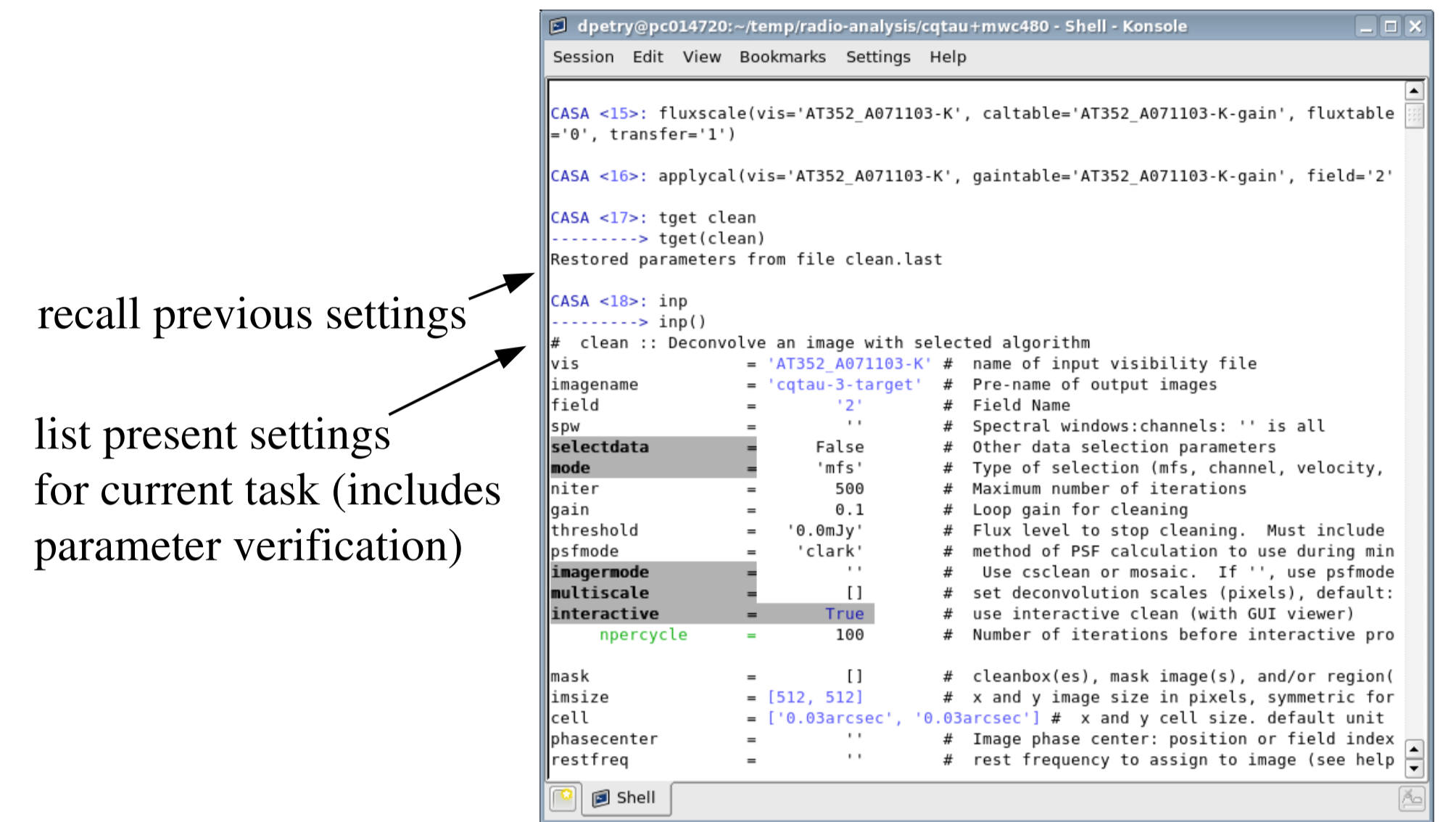
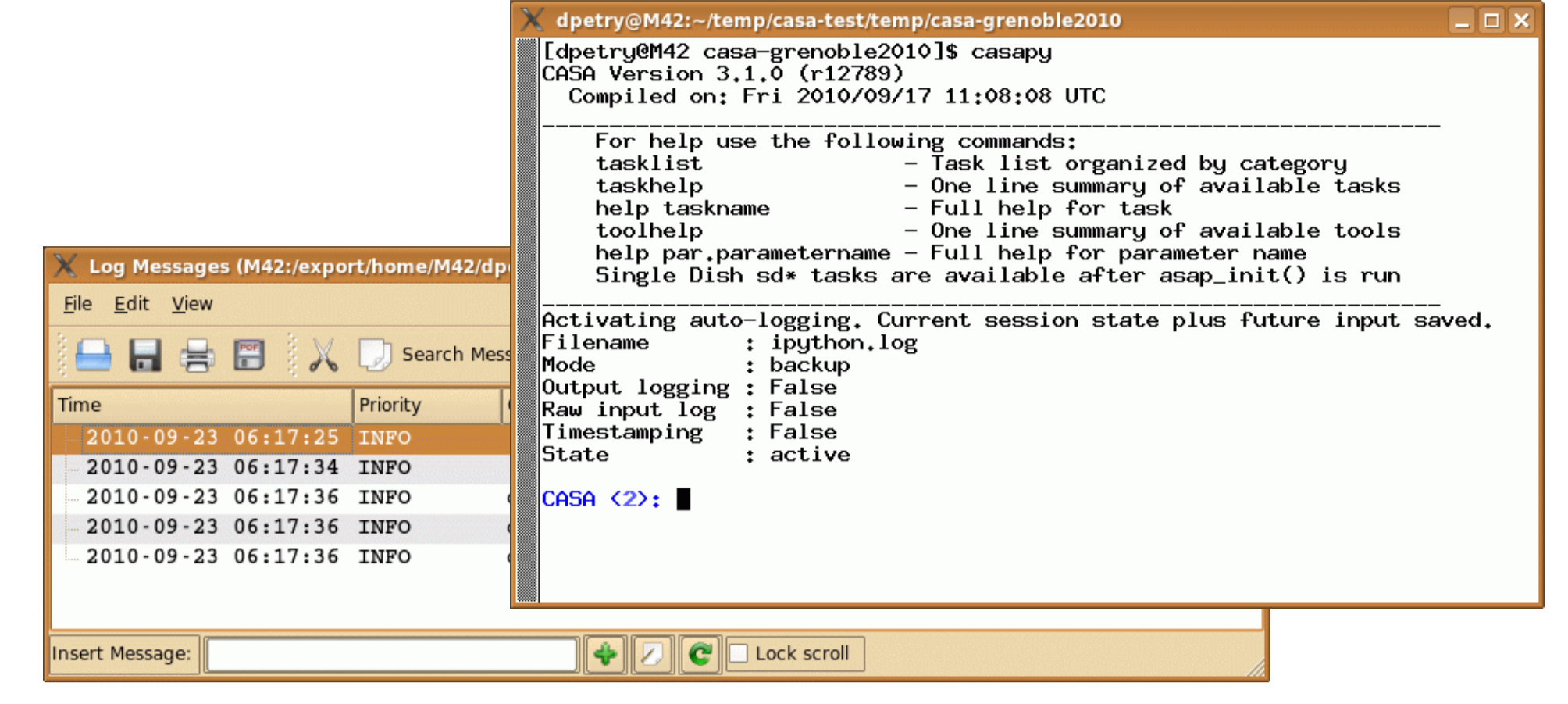
CASA design and implementation

- 1) A data structure
 - Tables: *Images*, *Caltables*, and the *Measurement Set* (MS)
- 2) A set of data import/export facilities supporting ASDM, UVFITS, FITS-IDI, VLA archive, SDFITS, FITS
- 3) A toolkit with more than 1000 methods for
 - a) data access, display, and editing
 - load/write data into/from casacore data types, table browsing, image viewing, x/y plotting
 - b) science analysis
 - providing access to most commonly used and many new algorithms for radio astronomical calibration, imaging, and simulation
- 4) A set of high-level data processing procedures ("tasks") user-friendly solutions for all common analysis problems
- 5) A programmable command line interface with scripting *Python* (augmented by *IPython*) gives a MATLAB-like environment
 - an extensive cookbook (500 pages)
 - + documentation through help commands (help. ?, pdoc) + online help pages
- 6) Documentation

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

Pictures from a typical analysis session

Startup:
open terminal and start casapy



recall previous settings
list present settings for current task (includes parameter verification)

Where needed, tools have GUIs:

plotxy, plotcal, browsetable, viewer, clean, plotms

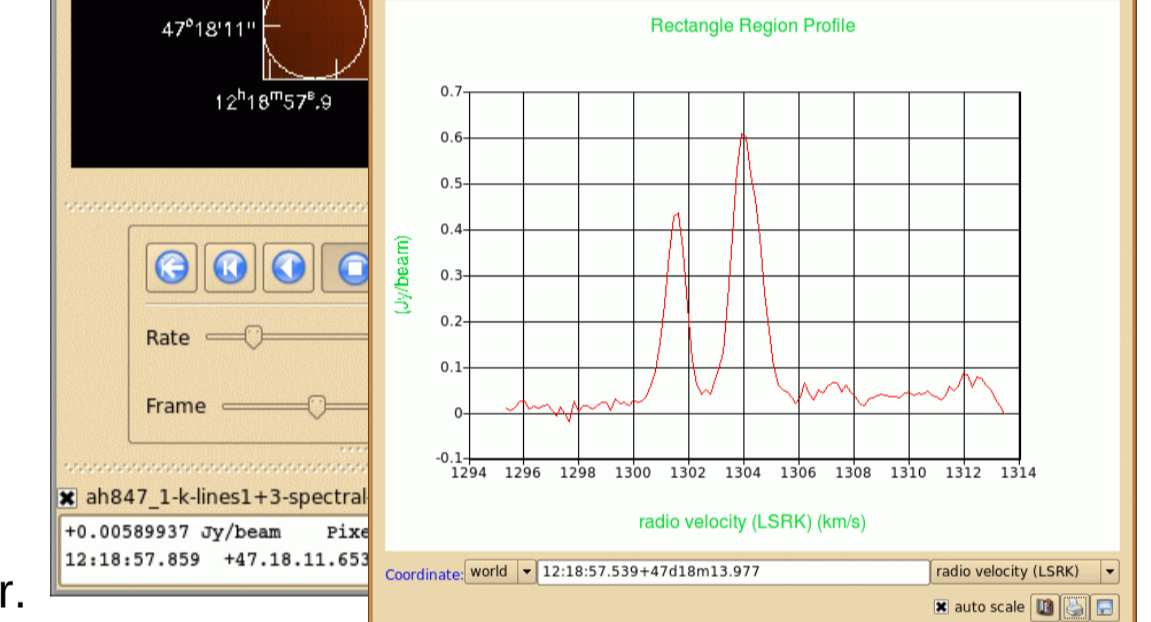
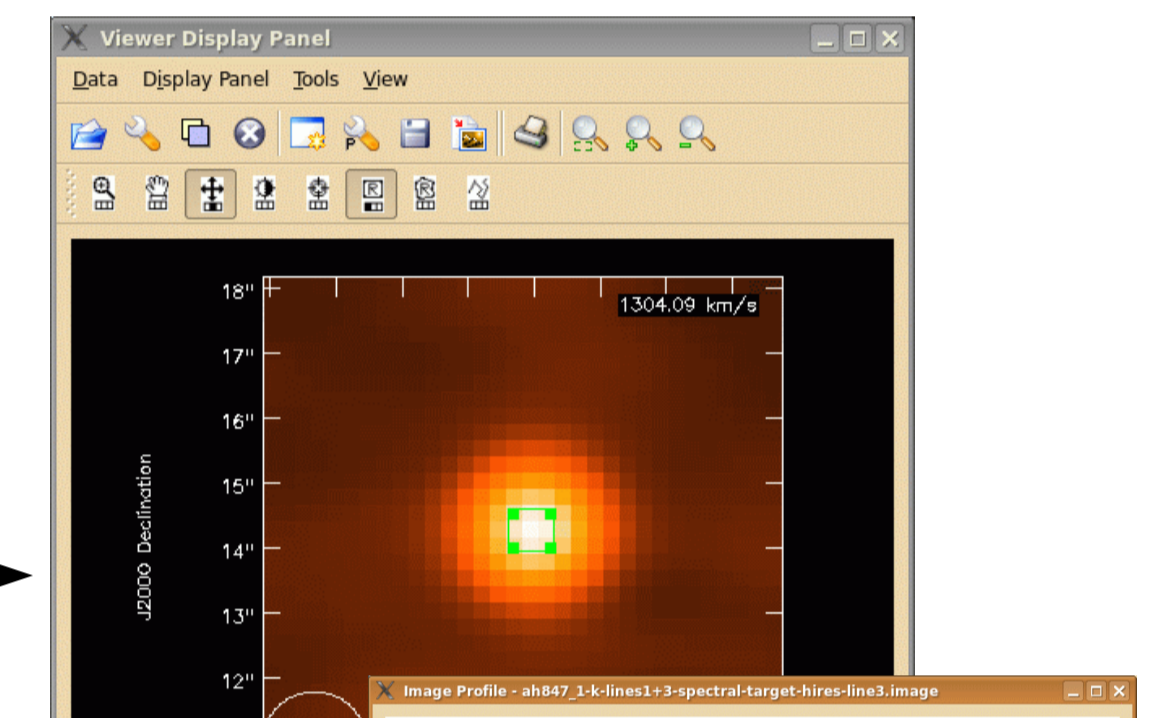
(started in separate threads)

The **viewer** is a powerful multi-function tool for data analysis and visualization.

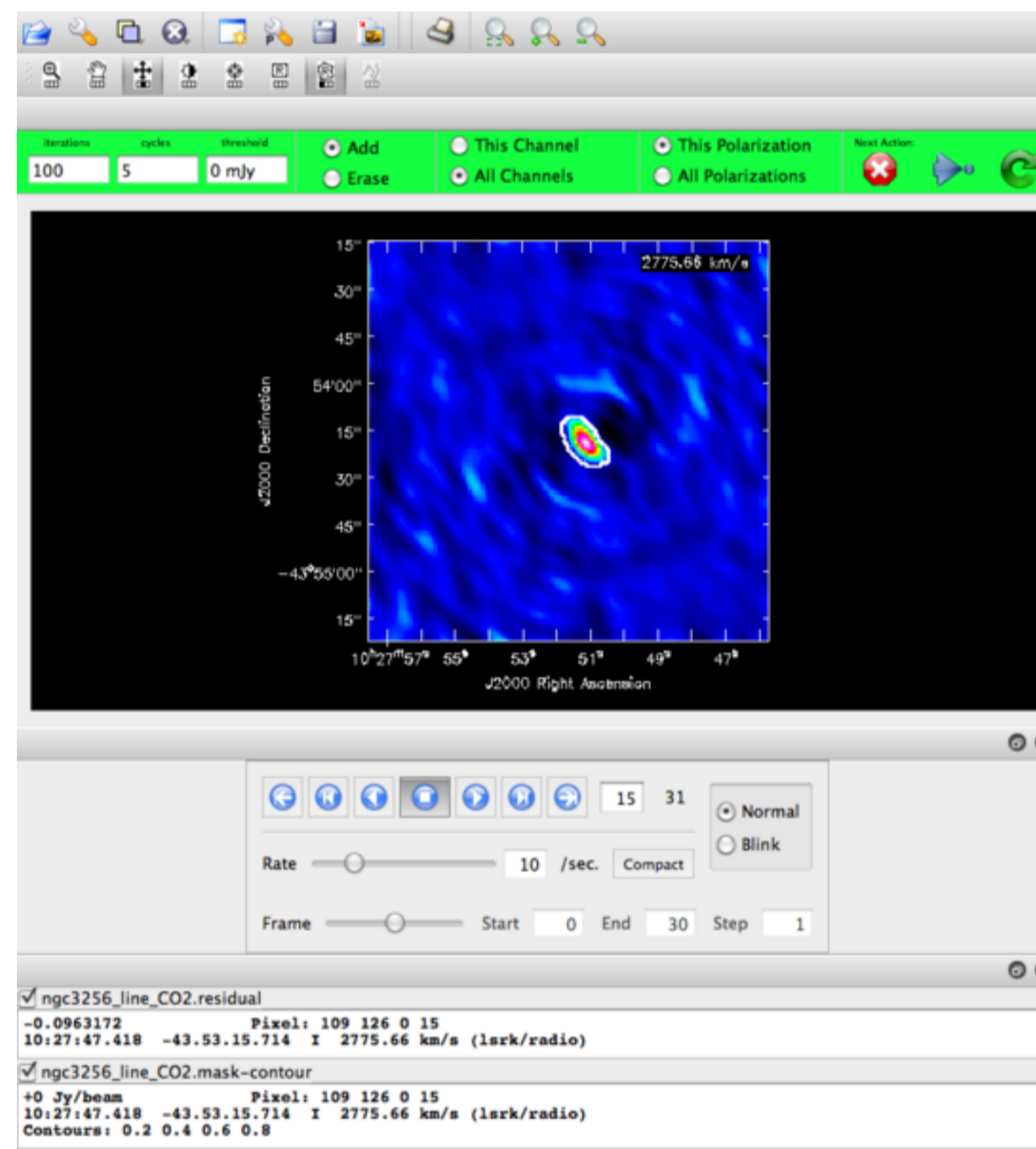
Uses Qt widget set (but 80% independent)

Rendering based on pplot

plotms provides fast xy plotting of large datasets. Still under development. Will replace the older plotxy and plotcal. plotms is Qt-based like the viewer.

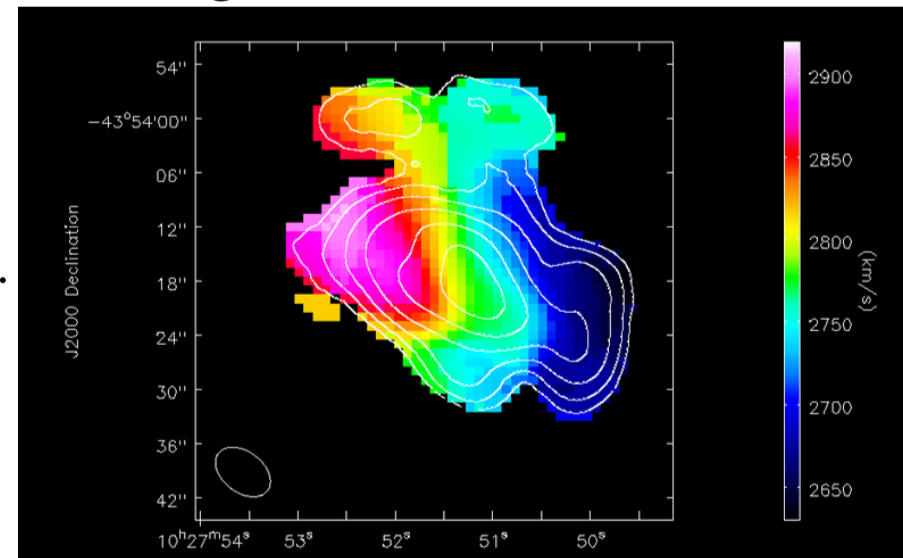


The GUI for interactive cleaning

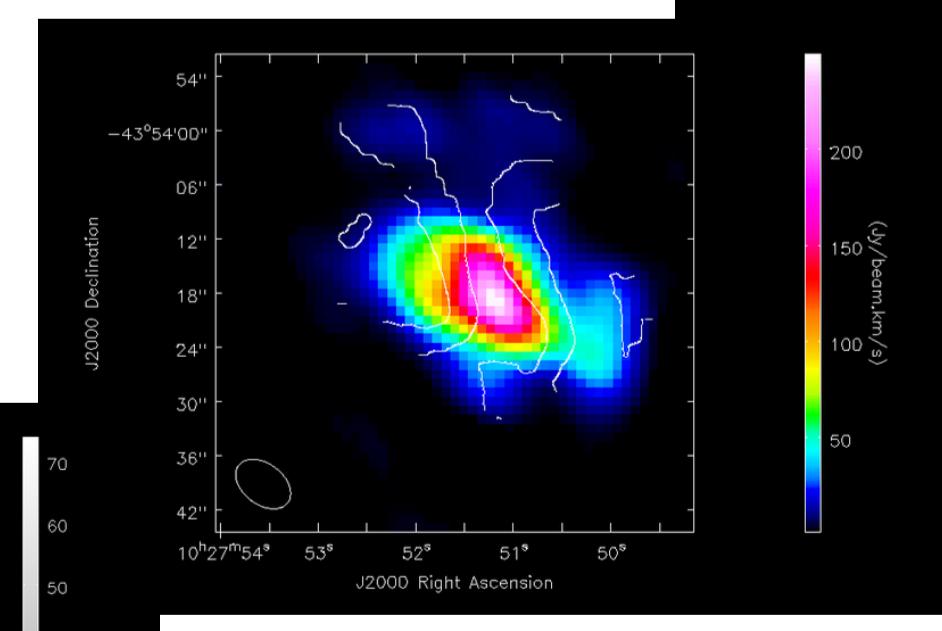


Examples from http://casaguides.nrao.edu

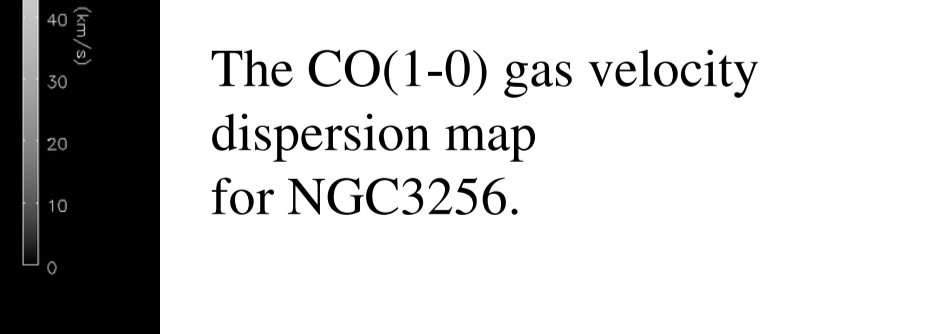
ALMA SV data from April 2011: 8 antennas in compact configuration, ca. 3 h obs. time at 114 GHz. The CO(1-0) velocity field of NGC3256, with contours of the total line emission map overlaid.



The CO(1-0) "moment 0" total intensity map of NGC3256 with the contours of the velocity field overlaid.



The CO(1-0) gas velocity dispersion map for NGC3256.



Imaging in CASA

Combinations of Major and Minor Cycle Algorithms

Imaging (Major Cycle):

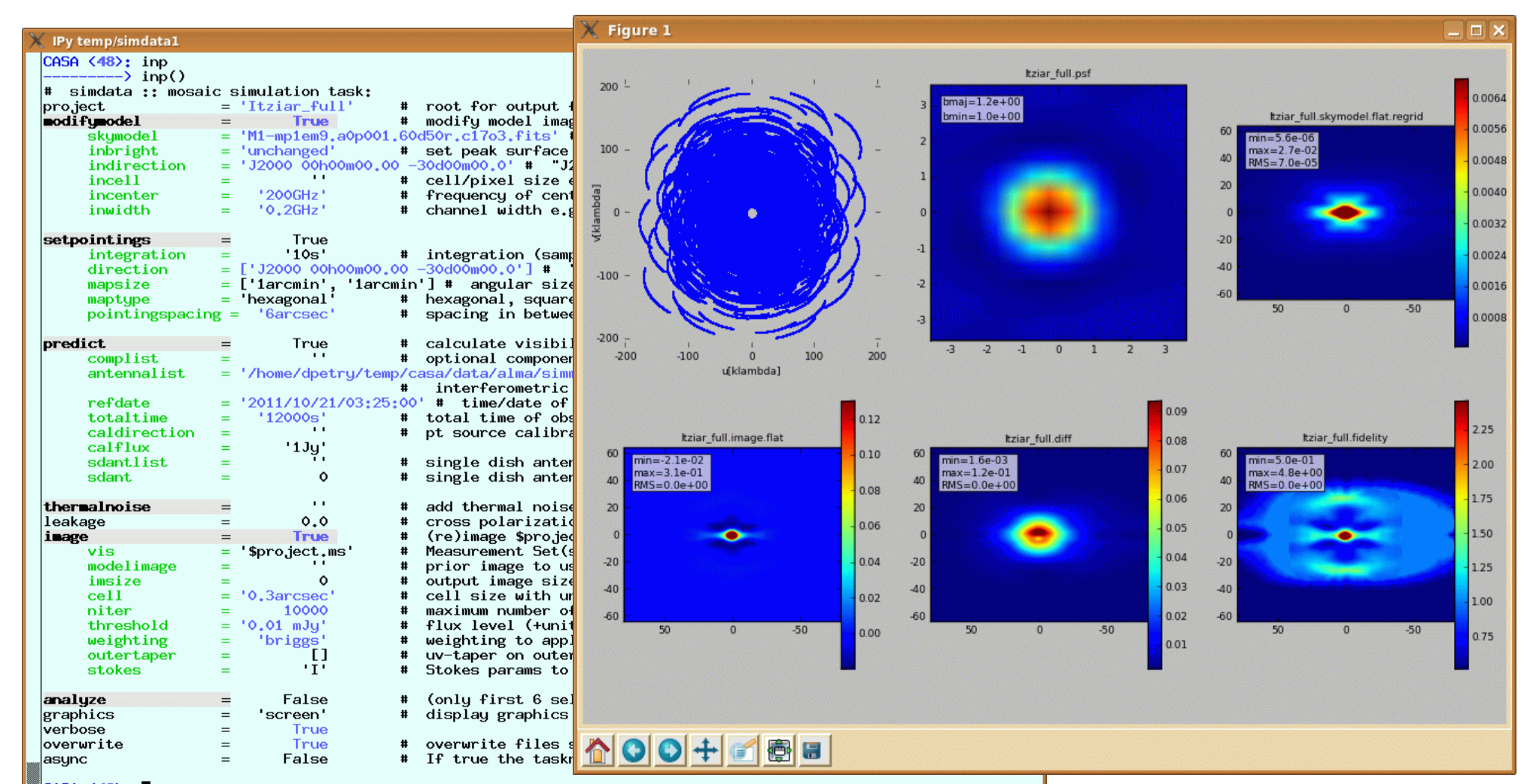
- 1) Standard (no direction-dependent effects, uv-grid sampling uses convolutional regridding)
- 2) with direction-dependent effects:
 - a) W-term (image domain faceting, uv domain faceting, W projection)
 - b) PB correction (image domain, A projection)
 - c) Pointing Offset correction by phase gradient
 - d) Mosaicing (linear (separate) deconvolution, joint deconvolution of combined dirty images, mosaicing by regridding all uv data onto one grid)

Deconvolution (Minor Cycle):

- 1) CLEAN (delta function model)
- 2) MS-CLEAN (inverted tapered paraboloid (ITP) model)
- 3) MSFMS CLEAN (model of ITPs with polynomial spectrum)
- 4) MEM (maximum entropy method using prior image and delta function model)

The CASA algorithm development group is actively extending this list. Some of the above algorithms are presently only available in CASA. see overview at <http://www.aoc.nrao.edu/~urvasi/ImagingAlgorithmsInCASA/>

CASA also includes a sophisticated radio-astronomical data simulator: *simdata*



ALMA, a worldwide collaboration



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 NAOJ. Manager: Jeff Kern (NRAO), project scientist: Juergen Ott (NRAO), ALMA CASA subsystem scientist: Crystal Brogan (NRAO), developers at NRAO: Sanjay Bhatnagar, Kumar Golap, Remy Indebetouw, Jim Jacobs, Dave Mehringer, George Moellenbrock, Scott Rankin, Urvasi Rau, Rob Reid, Darrell Schiebel, Tak Tsutsumi, Honglin Ye, Wes Young, developers at ESO: Michel Caillat, Sandra Castro, Justo Gonzales, Martin Kuummel, Dirk Petry, developers at NAOJ: Shinosuke Kawakami, Wataru Kawasaki, Kanako Sugimoto, Takeshi Nakazato, ALMA Regional Center CASA leads: Dirk Petry, Martin Zwaan (ESO), Daniel Espada (NAOJ)

If you want to work on ALMA science, contact your ALMA Regional Centre via <http://www.almascience.org>

Dirk Petry (European ALMA Regional Center, ESO), 2011