

Imaging on-the-fly ALMA observations

N. Rodríguez-Fernández, J. Pety, M. Lonjaret,
JC. Roche, F. Gueth
IRAM, France



Attending the ADASS 2011 conference



nemesio.rodriguez
@gmail.com



lonjaret@iram.fr



roche@iram.fr

Abstract

We present R&D work on imaging algorithms for observations of fields larger than the field-of-view of a radio interferometer, in particular when the sky is scanned in on-the-fly mode. We discuss a new algorithm to image such observations and we describe the implementation in GILDAS (IRAM software for analysis of radio astronomy observations) and CASA (software package developed by NRAO and used by the ALMA project).

Context

- **ALMA** is a millimeter and submillimeter interferometer composed of 66 antennas that is under construction in the Atacama desert (Chile) at 5000 meters altitude.
- The “**ALMA enhancement**” program is an ESO-coordinated initiative to work on possible enhancements of the current capabilities of the ALMA observatory [1].
- Within this program, IRAM [2] is in charge of a R&D project on **imaging algorithms for the observations of large fields in on-the-fly (OTF) mode**.
- In OTF mode, the antennas get data as they map the astronomical source, in contrast to “standard” (stop-and-go) mosaics for which the array antennas are pointed and they take data before being pointed to a new position.

Wide Field Interferometric Synthesis (WIFISYN) algorithm

- Classical algorithms to image mosaics consist of computing a *dirty* image field by field and combining the images before or after a final deconvolution.
- The new interferometric OTF mode of ALMA will allow to observe larger fields, in the same amount of time, than with stop-and-go mosaics and will allow to explore new imaging algorithms.
- We have published in Pety & Rodriguez-Fernandez [3] a new algorithm (**WIFISYN, Wide Field Synthesis**) in which all the data corresponding to observations of different regions of the source are combined in the Fourier plane.
- The algorithm shares some similarities with the “uv-convolution” method developed by NRAO [5], which also computes the mosaic in the Fourier plane.
- The WIFISYN algorithm is based on the Ekers & Rots [4] scheme to compute the values of the wide field visibility function by Fourier transforming with respect to the scanning coordinates.

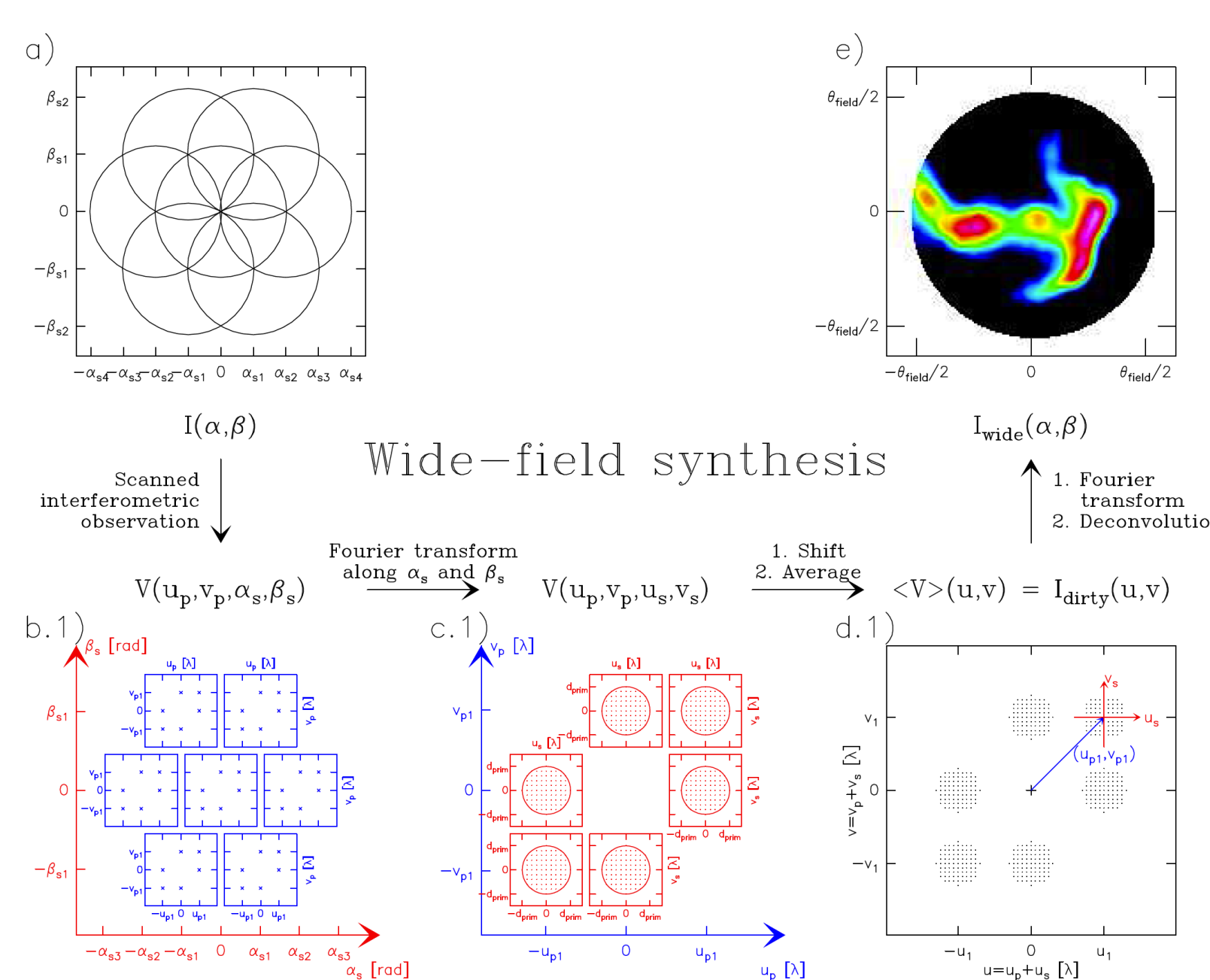


Fig. 1 Steps of the WIFISYN algorithm.

- Fields of view of the array on the sky for a 7 field mosaic.
- For each field, the visibility function is sampled at some points of the Fourier plane. The WIFISYN algorithm works with 4D tables that give the visibility V for each spatial frequency (u, v) and position offset (α, β) .
- For all spatial frequencies, the data are Fourier transformed with respect to the position coordinates to get the wide field visibility function around each nominal (u, v) point.
- In general, the circles in the previous panel overlap, therefore one must average different estimates of V coming from different circles.
- The data are Fourier transformed with respect to the spatial frequency to get a *dirty* image.

GILDAS prototype

- The Grenoble Image and Line Data Analysis System (GILDAS) [6] is a collection of tools developed at IRAM and dedicated to the reduction and analysis of radioastronomical data. It is written mostly in Fortran, with bits of C and some Python.
- Tools and functionalities are gathered into packages. Among them, the new **WIFISYN package** implements the wide field synthesis algorithm in order to produce wide field images, with an emphasis on so called on-the-fly observations.
- This implementation can be summarized as 6 steps:
 1. Convert the data to the required GILDAS format if necessary, then read and store them as a UV table.
 2. Set up and initialize all the required data structures, such as axes, convolution kernel, user parameters...
 3. Convolution and regular resampling to grid the visibilities.
 4. Fourier transform along the scanned sky coordinates to synthesize the wide-field visibilities.
 5. Apply a shift-and-average operator to obtain the wide-field UV plane.
 6. Inverse Fourier transform to yield the dirty image.

CASA

- The Common Astronomy Software Applications (CASA) [6], developed mainly by the NRAO, is the official data reduction and analysis software for radio astronomical telescopes such as the EVLA and ALMA.
- The various functionalities/algorithms are grouped as packages, implemented in C++ as well as in C and Fortran for some of the highly optimized engines. Those packages are exposed through a set of C++ *tools*, which are in turn bundled together under an iPython interface as a set of data reduction *tasks*.
- Data are handled in CASA via a system of tables. In particular, visibility data are stored in a set of CASA tables grouped and referencing each other, known as a Measurement Set (MS). It is a very flexible and generic system, albeit fairly complex.

WIFISYN implementation in CASA

Porting the GILDAS WIFISYN package to the CASA framework was articulated into 4 steps:

1. Read the relevant data from a CASA MS.
2. Set up the WIFISYN data structures and initialize them with the data through a C++/Fortran interface.
3. Extract the WIFISYN Fortran engines from GILDAS and integrate them into the CASA architecture. This required to identify some dependencies specific to the GILDAS data format, or other undesired parts of GILDAS, and to replace them with a suitable counterpart from the CASA framework or with a placebo made from scratch. This process was then partially automated with a suite of extraction tools coded in python and based on ad-hoc rules.
4. Export the dirty image produced to the image structure format of CASA, in order to (among other things) display it with the CASA image viewer.

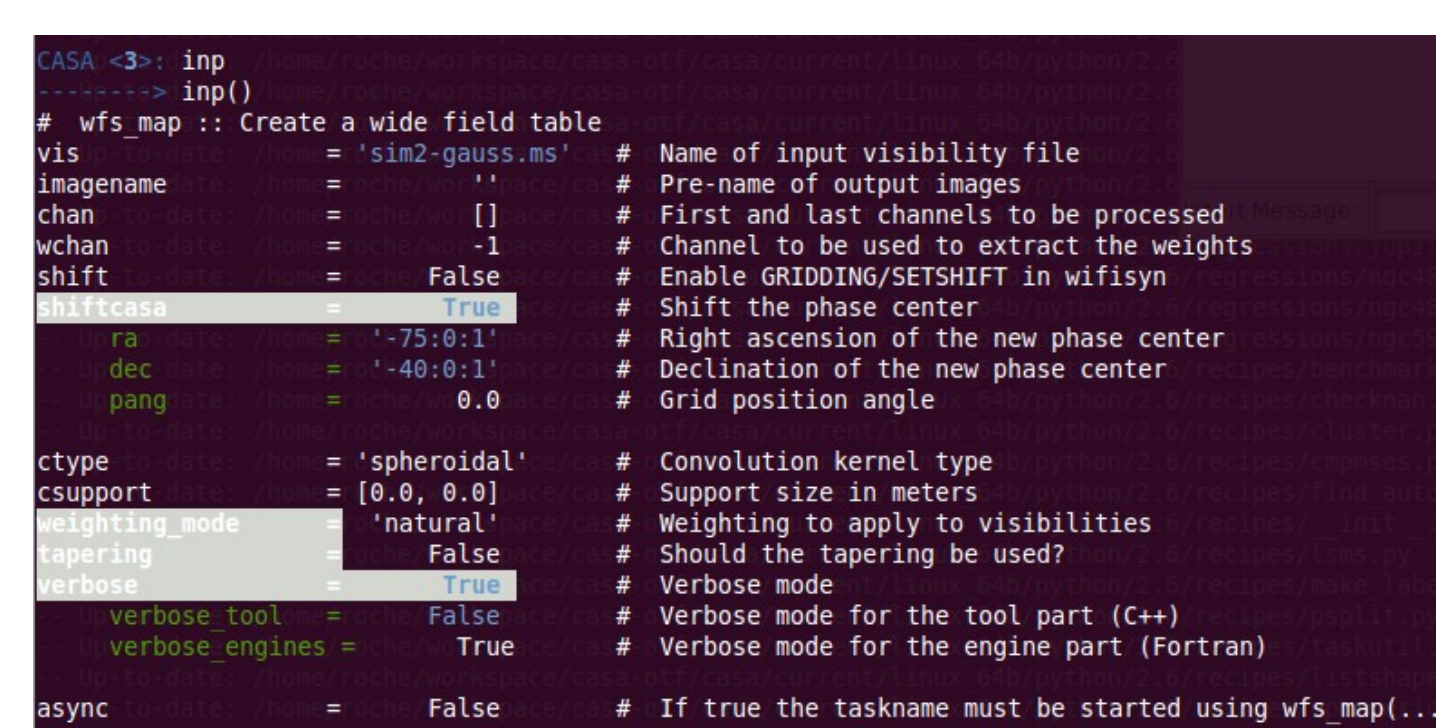


Fig. 2 The wfs_map task is the user interface to the WIFISYN algorithm in CASA

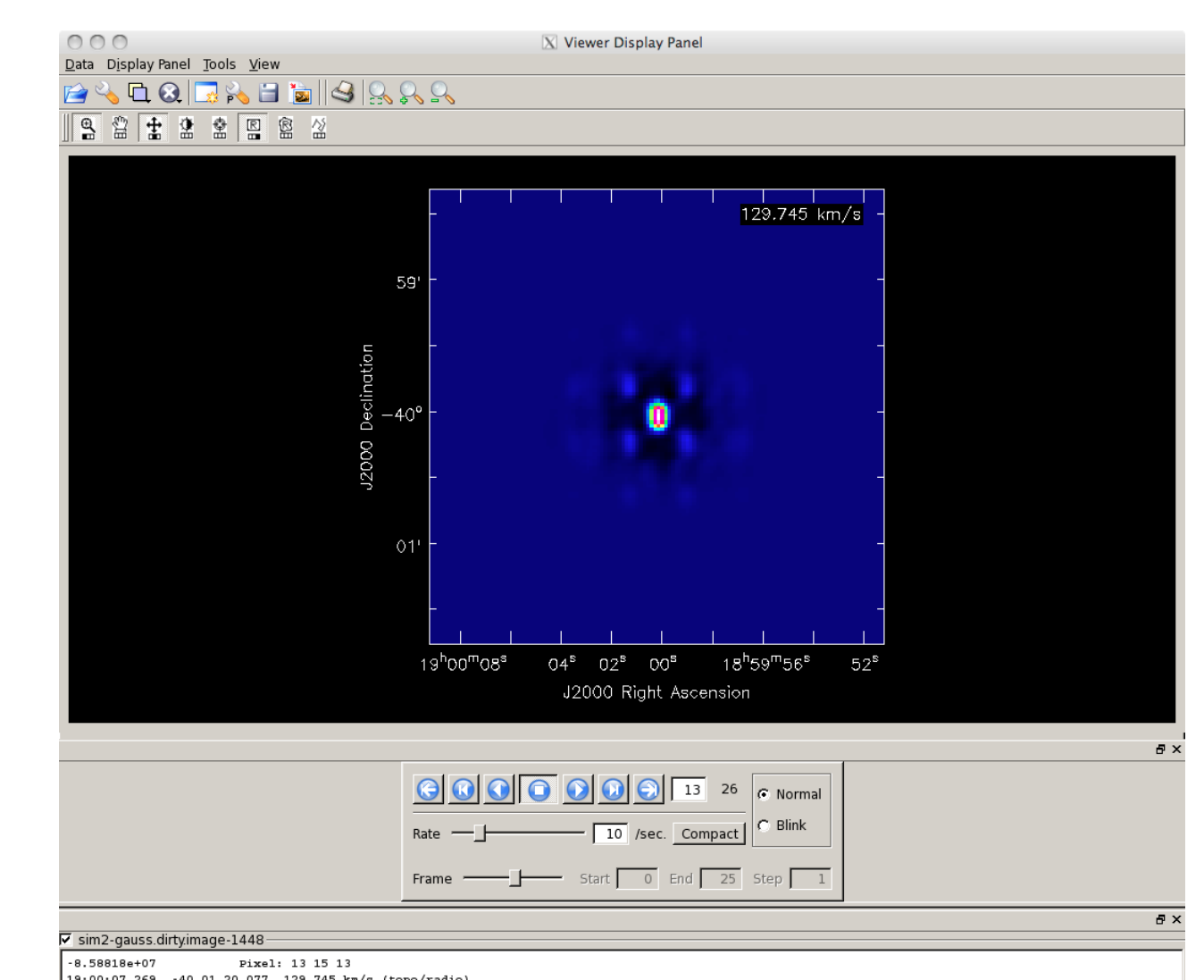


Fig. 3 Dirty image of a Gaussian source using the wfs_map task

References

- [1] ALMA <http://www.almaobservatory.org>
- [2] IRAM <http://www.iram-institute.org>
- [3] Pety & Rodriguez-Fernandez, 2010, A&A 517, A12
- [4] Ekers & Rots, 1979, IAU 49, ASCL Vol 76, 61
- [5] Rau, Bhatnagar, Voronkov, Cornwell, 2009, IEEE 97, 1472
- [6] GILDAS <http://www.iram.fr/IRAMFR/GILDAS/>
- [7] CASA <http://casa.nrao.edu/>