New−generation radioastronomy algorithms

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CONTEXT

A new generation of radio telescopes is almost upon us:

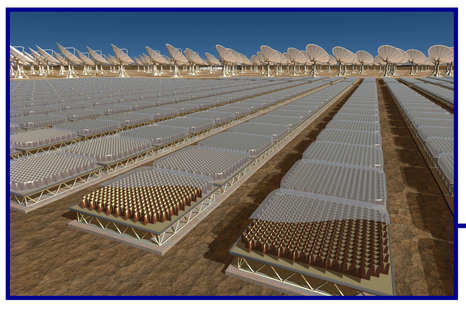
► The Atacama Large Millimetre Array (ALMA) in Chile is expected to surpass the capabilities of previous millimetre-wave interferometers by many orders of magnitude. The array of 60 antennae is to be completed around 2012.

► The UK-based e-MERLIN interferometer will provide complementary high-resolution data at longer wavelengths.

► The Low-Frequency Array (LOFAR), initiated by the Netherlands, with a contribution from the UK, has already seen first light and, when completed, will be a major tool to probe the deep radio universe.

► The Square-Kilometer Array (SKA) is a European project that should be completed by 2020, and among whose goals are the detection and mapping of neutral hydrogen at high redshift.

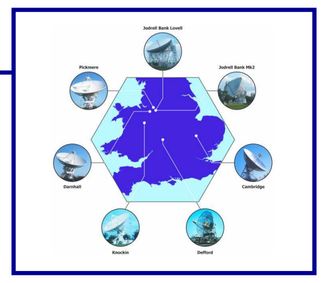
These instruments are expected to provide transformational science provided the data can be calibrated in the face of the many different ways in which the atmosphere and instrument may corrupt the incoming wavefronts from astronomical sources. These are tremendous challenges requiring state-of-the-art techniques in high-performance computing.



ALMA

SKA

e−MERLIN



LOFAR

PROJECT DESCRIPTION

The provisional breakdown of tasks for this project is the following:

1. Use a matrix formulation encoding these atmospheric and instrumental corruptions, to develop efficient simulation tools for ALMA and eMERLIN.

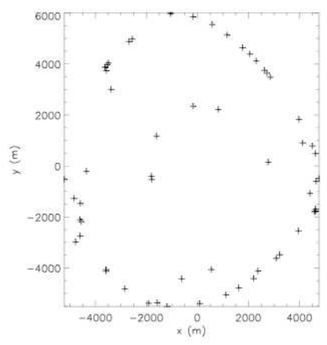
2. As astronomical calibration is the inverse problem to simulation, work on the basis of **1.** to develop new calibration tools for use with ALMA and eMERLIN.

3. Commission such software on site in Chile and Manchester, and hence be involved in the first attempts to extract new science from these facilities.

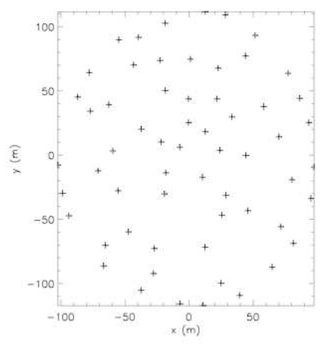
4. Collect a PhD, and hopefully go on to a glorious career in astrophysics or computing.

BUILDING DATA SETS

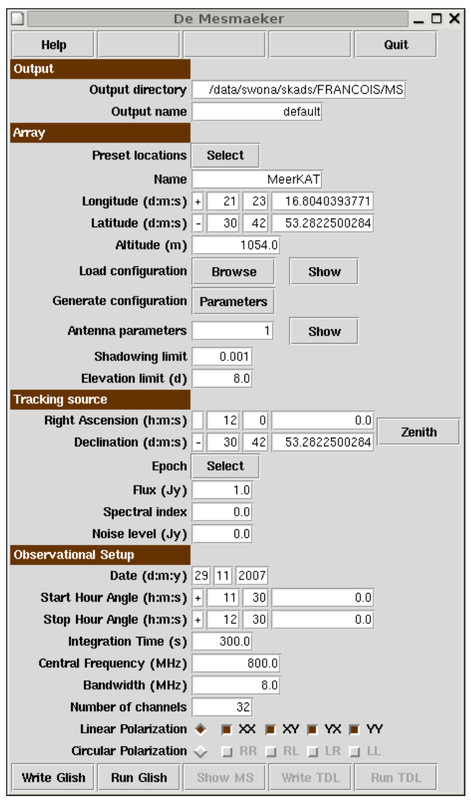
De Mesmaeker (The MS Maker) is a python tool designed to simplify the life of the radio-astronomy simulation scientist, by unifying the data format for multiple instruments. In this project, it will be used to build the skeletons of simulated data sets, as if they'd actually been observed by either ALMA or e-MERLIN.



ALMA (extended)

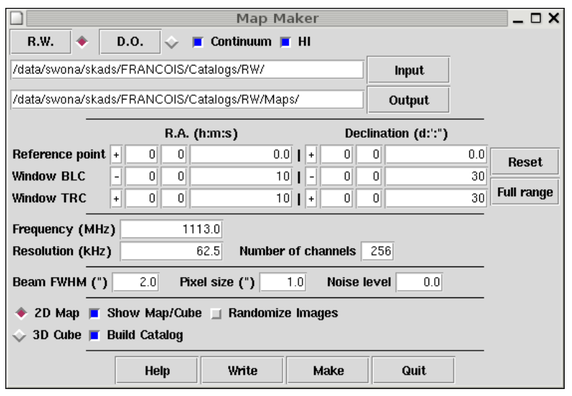


ALMA (compact)

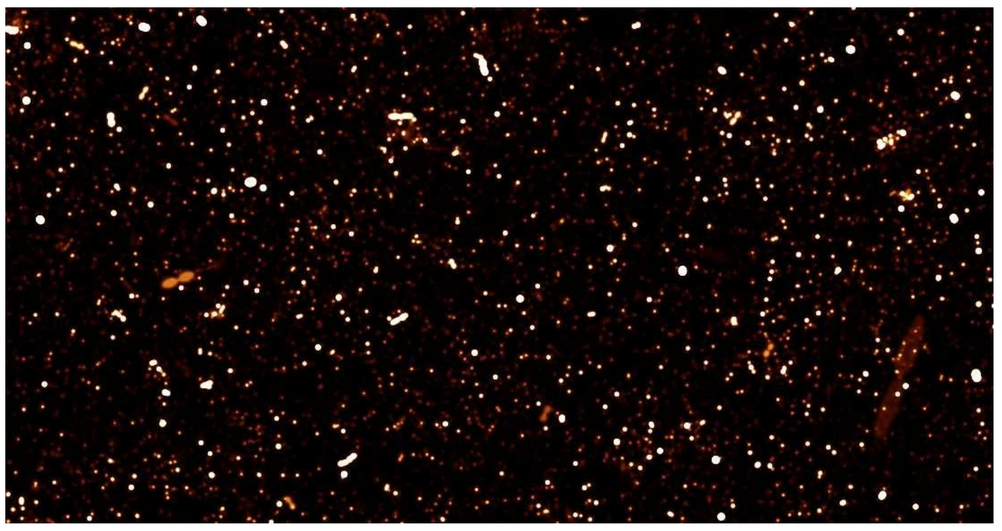


The frontend to De Mesmaeker

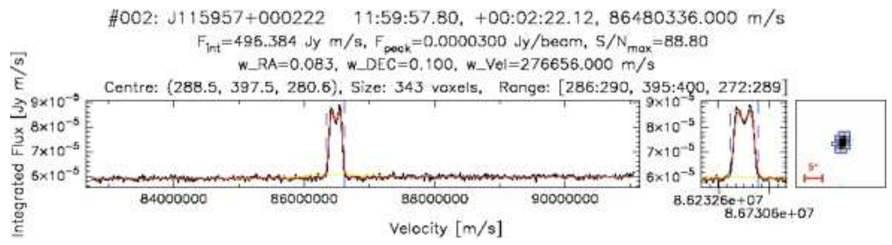
BUILDING REALISTIC RADIO SKIES



MapMaker is a tool developed in python to build images and data cubes out of the hundreds of millions of sources contained in the simulated source catalogues devised at Oxford Astrophysics.



Two square-degree patch of a simulated radio sky: A possible test-case

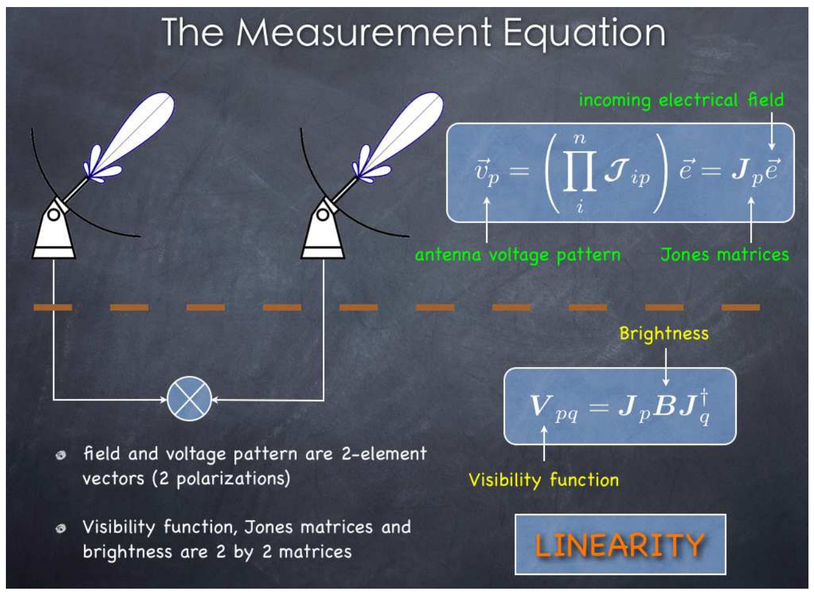


HI profile for one of the sources in the above field

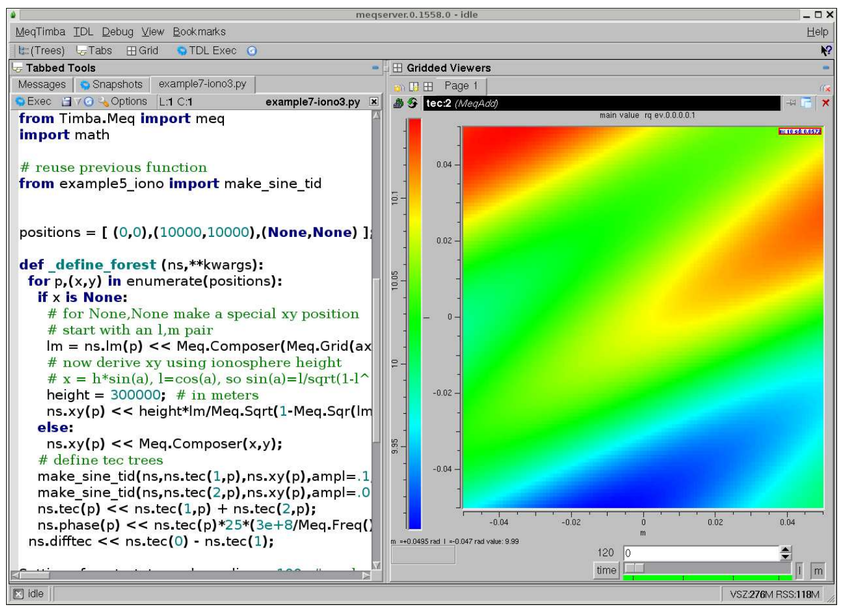
SIMULATING INSTRUMENTS

The Measurement Equation (ME) matrix-based formalism is a very elegant approach to radio-interferometry that naturally encompasses polarization, an aspect of radiation coming from astronomical sources that has been quite neglected so far, and which may soon prove of utmost importance, for instance to detect primordial gravitational waves in studies of the Cosmic Microwave Background (CMB).

MeqTrees is a package currently in development at ASTRON in the Netherlands. It is being specifically designed, with a C++ kernel and python interface, to handle data from large, new-generation radio-interferometers in the formalism of the measurement equation. Its primary task is to handle the calibration of LOFAR data. One of this project's goals is to assess the ability of MeqTrees to go beyond that and serve as a simulation and calibration package for a wider range of instruments.



The Measurement Equation in a nutshell



The frontend to MeqTrees, showing a patch of ionospheric disturbance over the instrument

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http://www.eso.org/alma/ http://www.skatelescope.org/ http://www.lofar.org/ http://www.merlin.ac.uk/e−merlin/