The Square Kilometer Array (SKA) : science and image reconstruction

The Square Kilometer Array (SKA) will be the world's largest telescope in the next decades. The discovering capabilities of SKA will be unique. SKA will most probably impact several domains of astrophysics, like Epoch of Reionization, galaxy evolution, cosmic magnetism, cosmology and dark energy, transient phenomena, tests of gravity and astrobiology. This METEOR will 1) present the instrument and how SKA will be able to provide new insight on these fields; 2) introduce the student to some specific data processing techniques required by such radio arrays.

The SKA

The SKA will collect light in radio wavelengths by means of dishes (top figure) and dipole antennes (bottom figure). It will be built in two phases and on two sites, South Africa and Australia. The first phase (2018-2023) will make operational 130 000 dipoles antennas over 80 km in Australia, and 200 15m dishes over 150 km in South Africa. After phase 2 (2025-2033), these numbers will reach 500 000 dipoles over 250 km, and 2500 dishes over 3500 km. The scale of such an instrument is unprecedented.

Compared with current radio observatories, the SKA will allow to: 1. increase the angular resolution: the larger the dimension of the collecting aperture, the smaller the resolution; 2. the sensitivity: a large number of dishes and dipole antennas results in a large collecting aperture allowing to observe faint sources; 3. a much better survey speed (which is the ability to observe large portions of the sky in a small amount of time) : groups of dipole antennas can be pointed very quickly, leading to a so-called "software telescope".

Science with the SKA

by C. Ferrari

We will firstly review the main physical mechanisms responsible for the celestial emission of electromagnetic radiation at radio frequencies.

Example of galactic and extragalactic radio sources will be described, with a particular attention to those research fields that will be specifically opened or largely widened by the SKA. These include the study of: 1. the Epoch of Reionisation, 2. the evolution of the gas content of galaxies as a function of time along the history of the Universe, 3. the magnetized plasma in the cosmic web and the largest structures in the Universe (galaxy clusters and super-clusters), 4. the transient objects in the Universe, 5) the study of fundamental physics through sets of highly magnetized, rotating neutron stars ("pulsars").

At the end of this part of the METEOR, students will write a short proposal to get observing time with one of current radio facilities. They will be guided to learn how to summarize the scientific objectives of their project and to estimate the observation time requested to fulfill them.

Data processing

by A. Ferrari and D. Mary

The SKA, relies heavily on advanced data processing techniques all along the signal path. The main steps are: 1. the modification of the directionality of the array of dipoles. This is achieved by the beamforming of the phased array; 2. the calibration of the individual antenna signals for gain and phase differences; 3. propagation through the ionosphere causes additional phase delays which must be calibrated on bright sources and feed 2D time variant ionospheric model; 4. finally, the image reconstruction relies on the resolution of an inverse problem. In view of the objectives of SKA wrt sensitivity, resolution and large fields of view, this last step is a very challenging large scale computation problem with extreme performances.

The objective of the data processing part of the meteor is to familiarize the students with the main stages of the data processing pipeline and the associated reference algorithms. A large part of the course is devoted to practical projects where the student will evaluate the performances of these techniques.

See also

SKA project website,

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