Applying State-of-the-art Deconvolution methods to ALMA data: towards a High Dynamic Range vision of the cold Universe

Context

The world's largest scale telescope, ALMA, has started its scientific operations in 2012, revolutionizing our vision of the cold and/or distant universe. It consists of a giant array of more than 50 12-m antennas, with baselines up to 16 km, opening astronomical windows from 0.3 mm to 3 mm, and located on the Chajnantor plateau at 5000m altitude in the Atacama desert. With high sensitivity, position, frequency information, and large bandwidth, ALMA data are intrinsically very rich. Although the spatial coverage provided by the array is an order of magnitude better than previous interferometers, also thanks to the additional compact array of 7-m antennas that greatly enhance ALMA's ability to image extended targets, ALMA data still represent sparse dataset with incomplete frequency sampling of the sky Fourier Transform. Moreover, the impact of the atmosphere at far-infrared wavelengths is quite important, especially when considering long baselines where loss of coherence can be quite dramatic.

The Cosmostat group in Saclay (`https://www.cosmostat.org`) has been developing innovative methods of image reconstruction (deconvolution) based on sparse representation of the signal (inverse problems). Sparse recovery has been shown to allow reconstructing an image with a resolution increased by up to a factor two in the case of low-frequency radio dataset. This has been shown by comparing the image of the Cygnus A radio jet obtained with the LOFAR instrument, reconstructed using sparsity, and the map of the same object obtained using Very Large Array at a higher frequency with a better resolution (Garsden et al., A&A, 2015).

Goals and requirements

SASIR is a deconvolution algorithm, written in C++ and Python, dedicated to radio interferometric imaging and based on the convex optimization using sparse representations (refered to the framework of Compressed Sensing). As an alternative to CLEAN, it allows a robust reconstruction of the sky brightness composed of a mix of extended emission and point sources, with improved image resolution and fidelity. It has been developed and tested in the context of the giant radio interferometer LOFAR. It is being adapted on recent imagers use for LOFAR and other SKA pathfinders/precursors.
The goal of the studentship will be to apply these innovative algorithms based on machine-learning, both to ALMA interferometric data and synthetic skies from MHD numerical simulations, to characterize the improvement of the image fidelity and the minimization of calibration errors that can be gained by using such state-of-the-art deconvolution methods on far-infrared data.

This studentship requires basic knowledge of signal processing methods, interferometry principles and python coding (Master 2 or beyond). The proposed work will allow the student to learn about inverse problems, deconvolution, sparse signal representation and their application to astronomical problems, using the most advanced techniques on state-of-the-art astrophysical dataset.

Supervision

The studentship will be carried out in the Astrophysical department of Irfu at CEA Saclay (`http://irfu.cea.fr/Sap`), at the interface of the Star Formation group and the Cosmostat group. Supervision will be jointly performed by Dr. Anaëlle Maury (ALMA expert) and Dr. Jean-Luc Starck (head of the Cosmostat group).

The studentship can start as soon as March 2018, and will be funded for up to 4 months. If satisfactory results are obtained, a subsequent PhD thesis could be funded to apply the methods to weak signal (polarization) in the framework of the MagneticYSOs european project (ERC).

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