Estimating the microwave sky from data of multi-kilo-pixel CMB experiments

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The current inflationary paradigm of early universe cosmology predicts the existence of primordial gravitational waves. These gravitational waves leave a specific imprint on the polarization anisotropies of the Cosmic Microwave Background (CMB), and their detection would deeply impact our understanding of cosmology and fundamental physics. The search for this faint signal as well as its precise characterization require increasingly better sensitivities, which in turn leads to an exponential growth in the size of the data sets being collected by the experiments. Processing these data efficiently requires better numerical tools, able to fully capitalize on the computational power of massively parallel supercomputers. The aim of my current work is to develop novel numerical techniques and code for the first stage of the data analysis pipeline of CMB experiments: we turn the raw data measured by the detectors into estimates of the sky maps (combining signals of different astrophysical origins), where unwanted temporal patterns have been filtered, the noise averaged out, and the loss of cosmological information is minimal. This process is referred to as map-making; it consists in solving a generalized least square problem with non-diagonal weights, and it is a central operation in the CMB analysis for which the main challenge consists in the size and complexity of the full raw data set that we need to process, which is soon expected to reach the Petabytes scale in the forthcoming experiments. At this scale, such an operation can only be performed on massively parallel computing platforms, and the underlying algorithm need to have minimal complexity and to be properly scalable finding suitable solutions to the communication bottleneck problem. I will present my ongoing work on the development of a map-making framework for the next generation of CMB polarization ground experiments (such as Simons Array and Simons Observatory) based on conjugate gradient iterative methods.