Preface

Cosmology, intended as the study of the origin and evolution of the Universe and its components, has advanced from being a philosophical discipline to a data-driven science. Much of this progress was achieved in the past few decades thanks to the wealth of cosmological data from Earth and space-based experiments. The abundance of observational constraints has considerably narrowed the space for theoretical speculation, to the point that now most of the cosmological community agrees on a *standard model of cosmology*.

A crucial assumption of this model is that the structure observed in the Universe, such as planets, stars and galaxies, can be ultimately traced back to tiny density perturbations in the early Universe. Therefore, a huge theoretical and experimental effort is being made by cosmologists and particle physicists to gain insight into the mechanism of generation of these primordial fluctuations, which remains still largely unknown. The bispectrum of the cosmic microwave background (CMB) has been recently recognized as a powerful probe of this mechanism, as it is sensitive to the non-Gaussian features in the seed fluctuations, which in turn are generated by nonlinear processes such as the interactions between the fields present in the primordial Universe.

The non-Gaussianity of the CMB, therefore, opens a window to the nonlinear physics of the early Universe; the CMB bispectrum is the observable that allows us to look through this window. However, not all of the observed non-Gaussianity is of primordial origin. Indeed, a bispectrum arises in the CMB even for Gaussian initial conditions due to nonlinear dynamics, such as CMB photons scattering off free electrons and their propagation in an inhomogeneous Universe. This *intrinsic bispectrum* is an interesting signal in its own right as it contains information on such processes. Furthermore, if not correctly estimated and subtracted from the CMB maps, it will provide a bias in the estimate of the primordial non-Gaussianity.

The main purpose of my doctorate has been to quantify the intrinsic bispectrum of the CMB and compute the bias it induces on the primordial signal. In doing so, I have developed, a new and efficient code for solving the second-order

Einstein-Boltzmann equations and compute primordial and intrinsic bispectra, including polarization.[1] While this project might sound eminently technical, it allowed me to gain deep insight into some of the most important aspects of modern cosmology. The purpose of this Ph.D. thesis is to share such insight with the reader, in a plain and accurate way, avoiding the technicalities when possible and making those that cannot be avoided as digestible as possible.

In writing my thesis I employed a pedagogic approach and strived to make it comprehensible to a first-year Ph.D. student with a basic background in physics and statistics. The first four chapters, complemented with the appendices, review the state of the field, while the last chapters detail the original research that I conducted during my Ph.D. at the Institute of Cosmology and Gravitation, University of Portsmouth, UK, which led to the publication of the following paper:

G.W. Pettinari, C. Fidler, R. Crittenden, K. Koyama, and D. Wands. "The Intrinsic Bispectrum of the Cosmic Microwave Background". J. Cosmology Astropart. Phys., 04(2013)003, doi: 10.1088/1475-7516/2013/04/003, http://arxiv.org/abs/1302.0832, April 2013.

Since I obtained my Ph.D. in 2013, my collaborators and I have carried out further research on the topic, extending the work presented in this thesis. In particular, we have found the polarized intrinsic bispectrum to be strongly enhanced with respect to the temperature one; developed a formalism to treat all propagation effects, including lensing, at second order; computed the power spectrum of the second-order B-modes; quantified the CMB spectral distortions in both temperature and polarisation. These works are all published in peer-reviewed journals, and can be freely accessed as preprints; their bibliographical references are, respectively:

G.W. Pettinari, C. Fidler, R. Crittenden, K. Koyama, A. Lewis, and D. Wands. "Impact of polarisation on the intrinsic CMB bispectrum". Phys. Rev. D, 90, 103010, doi: 10.1103/PhysRevD.90.103010, http://arxiv.org/abs/1406.2981, November 2014.

C. Fidler, K. Koyama, G.W. Pettinari. "A new line-of-sight approach to the non-linear Cosmic Microwave Background". J. Cosmology Astropart. Phys., 04 (2015)037, doi: 10.1088/1475-7516/2015/04/037, http://arxiv.org/abs/1409.2461, July 2014.

C. Fidler, G.W. Pettinari, R. Crittenden, K. Koyama and D. Wands. "The intrinsic B-mode polarisation of the Cosmic Microwave Background". J. Cosmology Astropart. Phys., 07(2014)011, doi: 10.1088/1475-7516/2014/07/011, http://arxiv.org/abs/1401.3296, July 2014.

S. Renaux-Petel, C. Fidler, C. Pitrou and G.W. Pettinari. "Spectral distortions in the cosmic microwave background polarization". J. Cosmology Astropart. Phys., 03 (2014)033, doi: 10.1088/1475-7516/2014/03/033, http://arxiv.org/abs/1312.4448, March 2014.

[1]SONG is open-source and available since August 2015 on the website https://github.com/coccoinomane/song.

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