STEP'UP
COMPOSANTE PHYSIQUE DE L'UNIVERS

Titre : Inflationary non-Gaussianities

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Financement (ou demi-financement) possible hors contrat doctoral : Non

Inflation is an important theory of the primordial universe that explains amongst other things the origin of the fluctuations observed in the cosmic microwave background (CMB) and of the large-scale structure of galaxy clusters. However, there are many different inflation models and one of the challenges of modern cosmology is to find ways to distinguish these models at the level of their predictions for observables, in order to confront them with experimental data. A very important way to distinguish between the models is based on studying the amplitude and the type of the non-Gaussianities that are produced during inflation due to second-order perturbations. With the results of the Planck satellite, non-Gaussianities have become a quantitative and topical area of research. The official publications of the Planck collaboration have only scratched the surface of the large subject of non-Gaussianity: there are still many avenues to explore. There are also new experiments in preparation to observe the CMB and the large-scale structure with even higher precision.

In this thesis proposal there are multiple related research directions possible (that do not necessarily all have to be taken up by the candidate). Regarding the internship proposal, it consists of the beginning of project no.~1.

- Use the data of the Planck satellite (power spectrum and bispectrum) to constrain the space of viable inflation models.

The large quantity of precise data from the Planck satellite opens for the first time the possibility to test the predictions of inflation models quantitatively, both for the linear perturbations in the power spectrum and for the non-Gaussianities in the bispectrum (three-point correlator). In this way we hope to be able to exclude certain (classes of) inflation models and constrain the parameter space of other models. B.~van Tent and his collaborators have developed an estimator (the binned bispectrum estimator) and the associated computer code to determine the primordial non-Gaussianities from the Planck data. This project consists of a data analysis part, a numerical part (extension of the code to combine the power spectrum and the bispectrum), and a theoretical part (determining the implications for the inflation models).

- Development of a code to determine the primordial trispectrum from the Planck data.

The trispectrum is the Fourier transform of the four-point correlator and is another observable that can help to constrain and distinguish inflation models. At the moment we have barely started the trispectral analysis of the Planck data, and having a ``binned trispectrum estimator'' would be an important step forward.

- Extend the existing know-how about bispectrum analysis from the CMB to large-scale structure experiments.
Many large-scale structure experiments of the next generation will produce data in the coming years. While extracting information about primordial non-Gaussianity from these data will be harder than for the CMB, because the fluctuations cannot be treated as a small perturbation, the reward is potentially much larger, as these experiments probe a 3D volume of data instead of a 2D surface. It will be very interesting and important to study how our knowledge about CMB bispectrum analysis, and the binned bispectrum code, can be translated to this new field.

- Study the evolution of the linear and non-linear fluctuations during the transition at the end of inflation and during the consecutive period of (p)reheating.
In single-field inflation models the fluctuations stay constant on super-horizon scales and the quantities computed during inflation can be extrapolated without any problem to the period of recombination and the formation of the CMB. In multiple-field inflation models this is no longer necessarily the case and the evolution of the perturbations during the end of inflation and afterwards, in particular during the period of (p)reheating, becomes non-trivial. This is an area of research with many open questions.

A good knowledge of cosmology as well as an interest and experience in programming (Python and/or C) is essential for the candidate. For the theoretical aspects related to inflation, a good knowledge of general relativity and quantum field theory is also required.