Intepretable and higher-order statistics for late-time cosmology

Report of Contributions

https://indico.sissa.it/e/hos_lss

Contribution ID: **1** Type: **not specified**

Introduction to the Workshop

Monday, June 27, 2022 10:00 AM (30 minutes)

Presenters: COLE, Alex (University of Amsterdam); BIAGETTI, Matteo (SISSA)

Contribution ID: **2** Type: **not specified**

Large Scale Structures in an hour or so

Monday, June 27, 2022 10:30 AM (1h 30m)

The goal of this lecture is to provide a pedagogical introduction to the standard cosmological model, with a particular focus on large-scale structure formation at late times.

Presenter: SEFUSATTI, Emiliano (OATs)

Contribution ID: **3** Type: **not specified**

Introduction to the Data Challenge

Monday, June 27, 2022 12:00 PM (30 minutes)

Presenters: CALLES HANSEN, Juan Manuel (Pontificia Universidad Católica de Valparaíso); BIAGETTI, Matteo (SISSA)

Contribution ID: **4** Type: **not specified**

Practical, Informative, Spatial Statistics with Applications to Cosmological Large Scale Structure

Monday, June 27, 2022 2:00 PM (1h 30m)

Presenter: ABEL, Tom

Contribution ID: **6** Type: **not specified**

TBA

Presenter: COLE, Alex (University of Amsterdam)

Contribution ID: **8** Type: **not specified**

Constraining Cosmology with Persistent Homology

Tuesday, June 28, 2022 11:00 AM (1 hour)

Persistent homology naturally addresses the multi-scale characteristics of the large scale structure. I will discuss the specifics of its application to mock galaxy catalogues to construct a simple and interpretable summary statistic. With the Fisher matrix formalism, I will show that our approach outperforms the momentum-space statistics in constraining cosmological parameters and offers robustness against marginalization over nuisance parameters.

Presenter: YIP, Jacky (University of Wisconsin-Madison)

Contribution ID: **9** Type: **not specified**

Scattering transforms, recent applications in astrophysics and cosmology

Wednesday, June 29, 2022 2:00 PM (1 hour)

New statistical descriptions related to the so-called Scattering Transform recently obtained attractive results for several astrophysical applications. These statistics share ideas with convolutional neural networks, but do not require to be learned, allowing for a direct characterization of interactions between scales in non-linear processes. In this talk, I will present these statistical descriptions, and give an overview of their recent successful applications to astrophysics. After highlighting in particular the results that have been obtained on LSS studies, I will also discuss the ongoing promising work on components separation.

Presenter: ALLYS, Erwan

Contribution ID: **10** Type: **not specified**

Higher-order statistics in cosmic shear

Tuesday, June 28, 2022 2:00 PM (1 hour)

The weak gravitational lensing effect is a powerful tool to study the structure and evolution of our Universe and, according to the Dark Energy Task Force, one of the most promising methods to constrain the equation of state of dark energy. In this talk, I will present two higher-order shear statistics: the third-order aperture masses and persistent homology. I will discuss their potential uses, their advantages and disadvantages, and preliminary results from their application.

Presenter: HEYDENREICH, Sven

Contribution ID: **11** Type: **not specified**

An introduction to persistent homology

Tuesday, June 28, 2022 9:30 AM (1 hour)

In this talk, I will first give a gentle introduction to persistent homology with an emphasis on certain theorems that will be referenced in Mathieu's talk later in the day. After this, I will discuss some recent advances in multiparameter persistent homology.

Presenter: BOTNAN, Magnus

Contribution ID: **12** Type: **not specified**

Antifragile Persistent Homology using Fisher Information

Wednesday, June 29, 2022 11:00 AM (1 hour)

Antifragility is a property of systems in which they increase their capability to thrive in the presence of volatility and noise. I will present how persistent homology can be made adaptive by learning the optimal filtration that is resilient to noise in data. This is done by maximizing the Fisher Information among a variational family of filtration parameters using gradient descent. By doing so, we construct an informative persistence diagram and consequently, a compressed summary of the input data that is sensitive to the input parameters. I will illustrate this with a few examples and compare the performance with the other standard filtrations.

Presenter: VISWANATHAN, Karthik

Contribution ID: **13** Type: **not specified**

Introduction to Topological Machine Learning

Wednesday, June 29, 2022 9:30 AM (1 hour)

In this talk, I will show through several examples and applications how persistence theory can be used to build relevant topological descriptors/signatures from data sets, that encode useful topological information that is often complementary to other usual descriptors. Then, we will show how these signatures can be converted into features for further data analysis and machine learning tasks, by using either finite or infinite-dimensional vectorizations into reproducing kernel Hilbert spaces, i.e., kernel methods. We will finally present several recent applications of topological data analysis in deep learning, involving differentiating persistence (in order to, eg, being able to incorporate topological penalties in the loss functions of classifiers) and mimicking persistence computations with deep neural networks.

Presenter: CARRIERE, Mathieu

Contribution ID: **14** Type: **not specified**

Analysing the PDF of density fluctuations - can it work in real data?

Thursday, June 30, 2022 2:00 PM (1 hour)

Key analyses of the cosmic large-scale structure only capture the “scale-dimension” of the cosmic web: they measure the variance of fluctuations as a function of scale. A powerful way to complement this vast compression of data is to add the “density-dimension”: at a fix smoothing scale one can analyse the entire shape of the probability density function (PDF) of density fluctuations (cf. Cora Uhlemann’s talk). I will give an overview on a number of efforts (arxiv.org/abs/1710.05162 ; arxiv.org/abs/1912.06621 ; arxiv.org/abs/2107.02300 ; and more) that have helped PDF-analyses to catch up with 2-point functions, and I will discuss how to employ these techniques in real data.

Presenter: FRIEDRICH, Oliver

Contribution ID: **15** Type: **not specified**

Joint power spectrum-bispectrum covariance and the squeezed configurations

Thursday, June 30, 2022 11:00 AM (1 hour)

Predictions from single-field inflation are consistent with CMB observations. Large-scale structure observations will improve our knowledge of the early universe. In particular, we can learn much about the inflationary era by testing for primordial non-Gaussianity (PNG). The upcoming galaxy surveys promise to improve such constraints by mapping the 3-dimensional distribution of matter and galaxies in the universe to scales of the order of the Hubble horizon. Then, to extract information about the early universe, we need to compute observables with the same precision as the observations, for example, the galaxy Power Spectrum and Bispectrum. A precise estimation for the covariance is a relevant ingredient in determining the information content of a given observable. The main goal of the talk is to study how the modelling of the joint power spectrum-bispectrum covariance is improved by including non-Gaussian terms that agree with N-body simulations at a 20% level. We will see that the non-Gaussian terms in the covariance are significant for observables evaluated at the squeezed limit, as in the case of the local PNG factor. Then, by doing a Fisher analysis on the constraining power of PNG, it is confirmed that non-Gaussian terms have to be taken into account, as they degrade the constraint by more than a factor of 2. Finally, I will talk about a work in progress where we want to include shot noise contribution and use the theoretical covariance to estimate the uncertainty in measuring PNG from the power spectrum response function.

Presenter: CASTIBLANCO, Lina

Contribution ID: **16** Type: **not specified**

Cosmology beyond the average with one-point statistics

Thursday, June 30, 2022 9:30 AM (1 hour)

One-point statistics such as counts-in-cells capture essential non-Gaussian properties of the cosmic web, including peculiar regions of high and low density. I will show that those statistics not only provide information complementary to common two-point statistics, but also allow for accurate theoretical predictions. I will explain how matter counts-in-cells statistics and their dependence on cosmological parameters can be predicted from first principles. I demonstrate the power of the matter PDF and its complementarity to the matter power spectrum at mildly nonlinear scales for constraining wCDM parameters, the total neutrino mass, the primordial skewness and modified gravity parameters. Finally, I will give an outlook on how predictions for the matter PDF can be adapted to predict survey observables related to galaxy clustering and weak lensing.

Presenter: UHLEMANN, Cora

Contribution ID: **17** Type: **not specified**

Amplitudes meet the Swampland

Thursday, June 30, 2022 4:00 PM (1 hour)

This talk is hosted by ICTP

Presenter: SHIU, Gary

Contribution ID: **18** Type: **not specified**

The Quijote PNG simulations - A test bed for higher order statistics and primordial non-Gaussianity

Friday, July 1, 2022 9:00 AM (1 hour)

Constraints on primordial non-Gaussianity (PNG) provide powerful insights into the early universe. To date, the CMB has been the leading source of information and I will briefly overview what more we expect to gain from upcoming experiments. Large scale structure measurements potentially have a wealth of information that could surpass the CMB. However, due to the non-linear nature of structure formation, fully accessing this is challenging. To help address this issue, my collaborators and I present the Quijote-PNG simulations. This is a suite of large scale structure simulations which contain three types of primordial non-Gaussianity. These simulations are designed to complement the existing Quijote simulations, which varied the ΛCDM cosmological parameters, and are a useful test bed for developing new PNG estimators. We present an example of their utility by exploring the information content in measurements of the bispectrum on non-linear scales. As a bonus I will also discuss a new method for improving the estimation of the Fisher information, when you only have access to simulations. This new method provides a test of the stability of numerical Fisher estimates and can also dramatically reduce the number of simulations required to have robust results.

Presenter: COULTON, William

Contribution ID: **19** Type: **not specified**

Dark Matter Dynamics

Friday, July 1, 2022 11:00 AM (1 hour)

IFPU Colloquium

Presenter: ABEL, Tom

Contribution ID: **20** Type: **not specified**

Cosmology with Cosmic Voids

Friday, July 1, 2022 2:00 PM (1 hour)

Voids in the large-scale structure of the Universe are currently entering the realm of precision cosmology. Most ongoing and planned surveys are considering them as a cosmological probe in various ways. The aim is to extract information that is complementary to what is already accessible via the traditional probes. I will present some recent highlights from the analysis of cosmic voids in both simulated, as well as observational data. These include constraints on cosmological parameters from dynamic and geometric distortions of voids in SDSS with prospects for Euclid, measurements of gravitational lensing around voids in DES, and their expected signatures from primordial non-Gaussianity and massive neutrinos based on simulations.

Presenter: HAMAUS, Nico (LMU Munich)

Contribution ID: **21** Type: **not specified**

The Initial Shape of the Universe

Friday, July 1, 2022 3:00 PM (1 hour)

We want to explore the potential of topological data analysis in detecting primordial non-Gaussianity through observations of the large scale structures of the universe. As a proof of concept, we estimate the Fisher information content on primordial non-Gaussianity using halo catalogs generated from N-body simulations run with both Gaussian and non-Gaussian initial conditions. We perform several tests to verify the reliability of our Fisher matrix calculation. We find promising figures for the estimated uncertainties on primordial non-Gaussianity of the local and equilateral type, proving that TDA is indeed a promising tool for analysing galaxy surveys in search for primordial non-Gaussianity.

Presenter: CALLES HANSEN, Juan Manuel (Pontificia Universidad Católica de Valparaíso)

Contribution ID: **22** Type: **not specified**

Closing Remarks

Presenters: COLE, Alex (University of Amsterdam); BIAGETTI, Matteo (SISSA)

Contribution ID: **23** Type: **not specified**

Towards optimal likelihood-free inference for cosmology with deep learning

Monday, June 27, 2022 3:30 PM (1 hour)

In this talk I will first show with toy examples how deep learning can find optimal summary statistics to extract the maximum information from cosmological data. I will then show how it can also perform really complex tasks like extracting information from very small, highly non-linear, scales while marginalizing over baryonic effects at the field level. I will also present the major challenges this method needs to overcome to achieve its goals.

Presenter: Dr VILLAESCUSA-NAVARRO, Francisco (CCA, Flatiron)

Contribution ID: **24** Type: **not specified**

Introduction to the Data Challenge

Presenters: CALLES HANSEN, Juan Manuel (Pontificia Universidad Católica de Valparaíso); BIAGETTI, Matteo (SISSA)