

# **Applications of Topological Data Analysis to Cosmology and Beyond**

## **Report of Contributions**

Contribution ID: 1

Type: **not specified**

## Introduction to Workshop

*Monday, June 5, 2023 10:00 AM (15 minutes)*

**Primary author:** BIAGETTI, Matteo (SISSA)

**Presenter:** BIAGETTI, Matteo (SISSA)

Contribution ID: 2

Type: **not specified**

# Information Maximizing Persistent Homology

*Monday, June 5, 2023 11:00 AM (1 hour)*

**Presenter:** VISWANATHAN, Karthik

Contribution ID: 3

Type: **not specified**

## Parameter inference using persistent homology

*Tuesday, June 6, 2023 9:30 AM (1 hour)*

**Presenter:** BOUCHÉ, Sibilla

Contribution ID: 4

Type: **not specified**

## Quasars and/or dimensionality reduction

*Tuesday, June 6, 2023 2:00 PM (1 hour)*

**Presenter:** CONTARDO, Gabriella

Contribution ID: 5

Type: **not specified**

## An introduction to Topological Data Analysis

*Wednesday, June 7, 2023 9:30 AM (1 hour)*

Topological Data Analysis (TDA) is a growing field of research at the intersection of data science and computational geometry and topology. It has encountered key successes in several different applications (ranging from cancer subtype identification in bioinformatics to shape recognition in computer vision, just to name a few), and become the landmark product of several companies in the recent years. Indeed, many data sets nowadays come in the form of point clouds embedded in very large dimensional spaces, yet concentrated around low-dimensional geometric structures that need to be uncovered. Unraveling these structures is precisely the goal of TDA, which can build descriptors that can reliably capture geometric and topological information (connectivity, loops, holes, curvature, etc.) from the data sets without the need for an explicit mapping to lower-dimensional space. This is extremely useful since the hidden, non-trivial topology of many data sets can make it very challenging to perform well for classical techniques in data science and machine learning, such as dimensionality reduction.

In this talk, I will provide a global overview of TDA, by introducing its main descriptors and by presenting the theoretical guarantees that they enjoy. I will also show how they can be efficiently computed in practice with the dedicated, open-source library GUDHI, and describe some applications where TDA proved useful.

**Presenter:** CARRIÈRE, Mathieu

Contribution ID: 6

Type: **not specified**

## **On the geometry of large transformers representations**

*Wednesday, June 7, 2023 11:00 AM (1 hour)*

**Presenter:** CAZZANIGA, Alberto

Contribution ID: 7

Type: **not specified**

## Barcodes for multiparameter persistence

*Wednesday, June 7, 2023 12:00 PM (1 hour)*

Multiparameter persistence is a generalization of persistent homology that allows for more than a single filtration function. Such constructions arise naturally when considering data with outliers or variations in density, time-varying data, or functional data.

In single-parameter persistence, the barcode is equivalent to the “rank invariant”: the function that associates the rank of the corresponding linear map to every pair of comparable points. However, nearly all of the tools developed in persistent homology are based on the barcode. This is because it is a concise and geometric descriptor that lends well to data analysis and visualization. Therefore, it is crucial, and perhaps imperative, to construct a generalized barcode to work with the rank-invariant for multiparameter persistence efficiently.

Perhaps surprisingly, recent work has shown that if we allow the elements of the barcode to be signed intervals, then such a generalization is possible. I will discuss how one can use homological algebra to obtain a signed barcode in a stable manner. Furthermore, I will discuss how signed barcodes can be used in machine learning and report on recent computational results.

**Presenter:** BOTNAN, Magnus



Contribution ID: 8

Type: **not specified**

## Coffee break and discussion

Contribution ID: 9

Type: **not specified**

## Multiparameter persistence

*Thursday, June 8, 2023 9:30 AM (1 hour)*

**Presenter:** EL ELA, Sliem

Contribution ID: **10**

Type: **not specified**

# Inverse optimization

*Thursday, June 8, 2023 3:00 PM (30 minutes)*

**Presenter:** EL ELA, Sliem

Contribution ID: **11**

Type: **not specified**

# **Generative models for cosmological simulations**

*Friday, June 9, 2023 9:30 AM (1 hour)*

**Presenter:** CARRIÈRE, Mathieu

Contribution ID: **12**

Type: **not specified**

## Closing remarks

*Friday, June 9, 2023 2:00 PM (30 minutes)*

Contribution ID: 13

Type: **not specified**

# **Unsupervised learning methods in quantum computers and simulators: why we do it and which methods have been used**

*Monday, June 5, 2023 2:00 PM (1 hour)*

**Presenter:** DALMONTE, Marcello

Contribution ID: **14**

Type: **not specified**

## Graph-based algorithms

*Thursday, June 8, 2023 2:00 PM (1 hour)*

Contribution ID: 15

Type: **not specified**

# What Every Physicist Should Know About String Theory

*Wednesday, June 7, 2023 2:00 PM (1 hour)*

This event is organized by ICTP.

**Presenter:** WITTEN, Edward



Contribution ID: 16

Type: **not specified**

# **Our Attempts to Use Unsupervised Learning in Soft-Matter Physics**

*Tuesday, June 6, 2023 3:00 PM (1 hour)*

**Presenter:** HASSANALI, Ali

Contribution ID: 17

Type: **not specified**

# **Machine learning you can trust for cosmology and astrophysics**

*Wednesday, June 7, 2023 4:00 PM (1 hour)*

**Presenter:** TROTTA, Roberto

Contribution ID: **18**

Type: **not specified**

# **Persistent Homology of Cosmic Structures**

*Monday, June 5, 2023 10:15 AM (45 minutes)*

**Presenter:** BIAGETTI, Matteo