# SOCIAL SCIENCES AND MATHEMATICS

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**MARTA MENCI, GABRIELLA PUPPO, THIERRY PAUL ORG.**

## TITLES AND ABSTRACTS

**Elisa Calzola** (Università degli studi di Verona)

*Emergence of condensation patterns in kinetic equations for opinion dynamics*

**Riassunto/Résumé** : In this talk a class of models is defined, with the aim to understand the impact of population size on opinion formation dynamics, a phenomenon usually related to group conformity. To this end, a new kinetic model is introduced, in which the interaction frequency is weighted by the kinetic density. In the quasi-invariant regime, this model reduces to a Kaniadakis-Quarati-type equation with nonlinear drift, originally introduced for the dynamics of bosons in a spatially homogeneous setting. From the obtained PDE for the evolution of the opinion density, it is possible to determine the regime of parameters for which a critical mass exists and triggers blow-up of the solution. Therefore, the model is capable of describing strong conformity phenomena in cases where the total density of individuals holding a given opinion exceeds a fixed critical size. In the final part, several numerical experiments are shown, demonstrating the features of the introduced class of models and the related consensus effects. Joint work with Giacomo Dimarco, Giuseppe Toscani and Mattia Zanella.

**Emiliano Cristiani** (IAC-CNR) with G. G. Amaro, L. Bartoli, S. Cacace, A. Malagnino, M. Menci, R. Ferretti

*Microscopic and macroscopic pedestrian models with variable maximal density*

**Riassunto/Résumé** : In this talk we present two models for pedestrian traffic, both suitable for modelling crowds in low and high density regimes. The first model is microscopic (agent-based), while the second is macroscopic (fluid-dynamic). Both models are characterized by a variable maximal density accounting for the effects of psychological/physical pushing forces, whose evolution is described by some additional terms (e.g., a Burgers-like PDE in the macroscopic setting).

**Paola Goatin** (INRIA, Université Côte d'Azur)

*Multi-class and multi-population traffic flow models on networks*

**Résumé/Riassunto**: We propose a general framework for modeling and simulating multi-class (e.g., different vehicle types) and multi-population (e.g., various routes) traffic flows across road networks. Our model consists of systems of conservation laws, coupled through the flux function's speed component, to accommodate overtaking and creeping among different vehicle types. At junctions, class-specific coupling conditions facilitate the design of Godunov-type numerical schemes, leveraging the supply-demand approach. This simulation can be further integrated with routing strategies at junctions, representing the route choices of the different driver populations. Numerical tests illustrate the impacts of these interactions, along with control strategies designed to mitigate adverse effects.

**Elisa Iacomini** (Università degli studi di Ferrara)

*Investigating Uncertainty in Traffic Flow Modeling: Multi-Level Monte Carlo and Multi-Fidelity Approaches*

**Riassunto/Résumé** : In traffic flow modeling, incorporating uncertainty is crucial for accurately capturing the complexities of real-world systems. In this talk, we deal with kinetic models of traffic flow, employing a non intrusive Monte Carlo approach both on the physical space, to solve the kinetic equation, and on the stochastic space, to investigate the uncertainty. In order to address the high dimensional problem given by this coupling, control variate approaches, as multi level and multi fidelity Monte Carlo methods, are particularly effective. Here, accurate models provide high-fidelity representations but require high computational cost, while simplified models, as low-fidelity surrogates, offer approximate solutions at a lower computational cost. Numerical simulations show that the multi-fidelity approach offers significant accuracy improvements over standard Monte Carlo methods.

**Vittorio Loreto** (Università di Roma La Sapienza)

*New scenarios for inclusive and sustainable cities*

**Riassunto/Résumé** : Modern cities are at the centre of a passionate debate about their future. The recent pandemic exacerbated the existing challenges and made clear the urgent need for a radical rethink of our lifestyles: from the organisation of our societies and cities to the relationship between urban and rural areas, from our production systems to the breaching of ecological ceilings. Thus, tackling urban areas' challenges beyond pure optimisation schemes is paramount, keeping instead a transformative eye. New tools are therefore needed, allowing for a tomography of the current situation and "what-if" machines to assess how a change in the current conditions can affect and modify future scenarios, with an eye to inclusivity and sustainability. In this talk, I will present several scenarios and discuss their applicability and sustainability. The notion of proximity-based cities will be the starting point of a little journey to explore whether a universal model exists for future cities and how it is possible to summarise what is known to plan the next steps.

**Marialuisa Mongelli** (ENEA)

*Digital Twins for the safeguarding and conservation of Cultural Heritage: case studies*

**Riassunto/Résumé** : Digital twins are increasingly utilized in the field of cultural heritage to create virtual replicas of artifacts, structures, and archaeological sites. This innovation fundamentally relies on point cloud data, which is generated through advanced scanning techniques such as photogrammetry, laser and structured light. These methods capture detailed spatial information and geometric features, allowing for the accurate reconstruction of physical objects in a digital format. Photogrammetric reconstruction using the Structure from Motion technique enables the definition of high-resolution 3D models from a series of 2D images in a fast, easy, and cost-effective manner. Once the 3D model is created, it can be integrated with Finite Element Method numerical models to simulate stresses, structural weaknesses, and damage evolution over time. Finite element analysis provides valuable insights into the structural integrity of heritage assets, enabling preventive measures and targeted interventions to protect invaluable pieces of history. Together, these digital tools offer a comprehensive approach to safeguarding and conserving cultural heritage by enhancing our understanding about the physical conditions of the objects, predicting future risks, and supporting informed conservation strategies. The presentation shows different case studies, including both movable and immovable elements of artistic heritage assets.

**Immacolata Oliva** (Università di Roma La Sapienza)

*Optimal portfolio choice in complete jump-diffusion markets with longevity risk*

**Riassunto/Résumé** : In the present paper, we provide optimal portfolio choice for an investment strategy endowed with Target-date funds. The proposal must ensure a minimum level of gain from the investment at maturity, and hypothesizes uncertainty in interest rate, contribution rate, and mortality. Moreover, the financial setting assumes the presence of discontinuities in the risky asset dynamics to reflect the occurrence of market crashes. To hedge against investment, longevity and event risks, we complete the market by using a zero-coupon bond, a longevity zero-coupon bond, and a derivative. We apply standard dynamic programming techniques and obtain closed-form solutions to the stochastic control problem with the objective of maximizing the expected utility of terminal wealth. We complete the picture by performing an extensive numerical analysis on real data, to measure the impact of market crashes and the effect of hedging tools.

**Elia Onofri** (IAC-CNR)

*An all-around perspective on the management of Pedestrian Flows in Crowded Museums*

**Résumé/Riassunto**: In this presentation, we discuss a comprehensive analysis of visitor movement patterns in crowded museums. By combining Lagrangian field data with statistical methods, we create stochastic digital models of visitor flows to support improvements in comfort and safety. In our novel approach, we adopt a Lagrangian IoT-based tracking system that incorporates Raspberry Pi devices positioned throughout the museum and portable Bluetooth Low-Energy (BLE) beacons given to visitors. In this setup, BLE signal strength (RSSi) can be used to estimate the distance from each antenna to approximate visitor locations though RSSi signals are known to be noisy even under ideal conditions (dense antenna placement, unobstructed paths, absence of crowds). To address this challenge, we introduce a cascaded AI classifier approach that enhances RSSi-based tracking accuracy even when the antennas are few and sparse. This enables the reconstruction of visitor paths across rooms, in particular supported by a practical encoding of the museum layout as a fully-coloured graph. Through clustering analysis based on a Wasserstein-inspired trajectory-space metric, we gain insights into visitor behaviour, identifying common movement patterns. From these findings, we build a transition matrix that probabilistically models room-to-room visitor flows, forming the basis of a stochastic model that can simulate visitor paths in silico. Finally, we apply this simulation to optimise the museum experience, balancing visitor access with logistical and safety needs through improved ticketing and entry/exit flow management. Our case studies include data collected at the Galleria Borghese Museum in Rome and the Peggy Guggenheim Collection in Venice, where our experimental trials proved highly successful. In both cases, the museums adopted and implemented recommendations from our study, resulting in tangible improvements, as confirmed by subsequent measurements.

**Lorenzo Pareschi** (Heriot Watt University, Edinburgh & Università degli Studi di Ferrara)

*The mathematics behind wealth distributions and economic inequality*

**Riassunto/Résumé** : A study by the World Institute for Development Economics Research at United Nations University reports that the richest 1% of adults alone owned 40% of global wealth, and that the richest 10% of adults accounted for 85% of the world total. The bottom half of the world's adult population owned 1% of global wealth. Other studies have confirmed this analysis by reporting a further increase in inequality as a result of the economic crisis caused by the pandemic. But what are the origins of such inequalities? Can mathematics help us better understand the nature of such phenomena? In this lecture we will briefly attempt to venture into the mathematical modeling of wealth distribution, starting with Vilfredo Pareto's early ideas from the beginning of the last century to more recent developments based on a statistical physics approach inspired by the kinetic theory of rarefied gases.

**Giulia Poce** Euronext

*Quantitative assessment of market risk in a pan-European CCP*

**Riassunto/Résumé** : Finance beyond trading: the presentation will explain the role of a CCP into the international market context, with a focus on the most famous quantitative model adopted by Euronext Clearing to assess market risk in line with international market standards and regulatory requirements

**Yvain Quéau** (CNRS- Caen)

*Towards a more inclusive access to medieval tapestries through semi-automatic 3D object generation*

**Résumé/Riassunto**: The issue of accessibility to museum works for blind and partially-sighted people is regularly raised by associations and museums. By their very nature, some works, such as medieval tapestries, cannot be touched and are often not accessible via audio-description. In addition, the manual creation of tactile representations is costly and complex, limiting their availability in museums. The Apocalypse Tapestry and the Bayeux Tapestry are two emblematic examples. This work will provide an overview of artificial intelligence techniques which we recently developed in order to ease the accessibility of these two large-scale works of art - 104m by 4.5m for the former and 70m by 50cm for the latter. In particular, we introduce an innovative methodology for the semi-automatic creation of 3D objects from a simple photograph. Using artificial intelligence tools such as zero-shot segmentation algorithms and generative adversarial networks (GANs), we are able to generate 3D-printed bas-reliefs quickly and inexpensively, enabling tactile exploration of the works. This solution offers greater autonomy in art appreciation, enhancing the satisfaction and motivation of blind and partially-sighted people to discover these cultural treasures.

**Walter Quattrociocchi** (Università di Roma La Sapienza)

*Polarization, Opinions and Other Monsters*

**Riassunto/Résumé** : Do echo chambers exist on social media? By focusing on how both Italian and US Facebook users relate to two distinct narratives (involving conspiracy theories and science), we offer quantitative evidence that they do. The explanation involves users' tendency to promote their favored stories and hence to form polarized groups. Confirmation bias helps to account for users' decisions about whether to spread content, thus creating informational cascades within identifiable communities. At the same time, aggregation of favored information within those communities reinforces selective exposure and group polarization. We provide empirical evidence that users tend to assimilate only confirming claims and ignore apparent refutations because they focus on their preferred narratives.

The COVID-19 pandemic was the perfect storm for this phenomenon and the WHO coined the term infodemics to refer to the overabundance of information. We explored these processes during the pandemics' initial phase finding that reliable and questionable information spread similarly. We conclude the presentation by showing how different social media platforms elicit very different polarization dynamics but similar conversational patterns.

**Matteo Semplice** (Università degli studi dell'Insubria)

*Differential models for cultural heritage*

**Riassunto/Résumé** : We present few examples of predictive models for the damage of stones in works of art. Most are based on reaction-diffusion differential models that describe the diffusion of a liquid or gas pollutant inside the pores of the stone and a reaction with the stone material that transforms it into a weaker or soluble material, leading to permanent damage.

We will also focus on the need of acquiring the exact geometry of the work of art under consideration and use it in the numerical simulations. We propose a levelset approach and discuss a complete workflow starting from a point cloud acquired by laser scanning to the computation of the levelset and the numerical solution of the partial differential equation via ghost-fluid methods.

Joint work with Silvia Preda (Università dell'Insubria), Armando Coco (Univeristà di Catania)

**Giuseppe Visconti** (Università di Roma La Sapienza)

*Stop-and-go waves in kinetic models for traffic flow*

**Riassunto/Résumé** : We study space non-homogeneous kinetic models for vehicular traffic flow. Kinetic models are characterized by a statistical description of the microscopic states, position and velocity, of vehicles, and, therefore, are very useful to link collective dynamics to pairwise interactions occurring at a smaller microscopic scale.

Many kinetic models succeed in reproducing space homogeneous, i.e. at equilibrium, features of a flow of vehicles. However, the extension of these models to the space non-homogeneous case, in order to reproduce off equilibrium phenomena, requires more attention. We show that classical kinetic formulations, as for instance the Bhatnagar-Gross-Krook (BGK) model, lead to unconditionally unstable solutions when used in high density regimes of traffic flow. The stability of the kinetic model is performed by a Chapman-Enskog expansion yielding a backward advection-diffusion equation in dense traffic.

We address this issue by deriving the correct formulation of the BGK-type model for vehicular traffic. The goal is achieved by linking traffic descriptions at different scales. In fact, the proposed space non-homogeneous kinetic model is obtained as limit of the microscopic Follow-the-Leader (FtL) model, and therefore offers a mesoscopic description between the FtL and the macroscopic Aw-Rascle and Zhang models. We show that the new kinetic model allows to reproduce conditionally stable solutions in dense traffic: these are bounded backward-propagating signals occurring in bounded regimes of the density where the model is unstable and can be regarded as stop-and-go waves.