CCS/ITALY

ITALIAN REGIONAL CONFERENCE ON COMPLEX SYSTEMS

Italian Regional Conference on Complex Systems

Naples, Italy

October 9 – 11, 2023

WELCOME TO CCS/ITALY 2023

The Second Italian Regional Conference on Complex Systems is the flagship event of CSS/Italy – the Italian Chapter of the Complex Systems Society – to disseminate Complexity Science and to promote interdisciplinary scholarly exchange between scientists and practitioners, fostering active participation by post-doctoral researchers, PhD students, and undergraduate students.

CCS/Italy 2023 will focus on the interaction between Complexity and Risk in their multiple dimensions, moving across fundamental and applied sciences, with special emphasis on Physics and Engineering. Cutting-edge studies will be presented through keynote lectures, oral presentations, and posters, which will deal with the following topics: nonlinear dynamics, modelling, control, robustness, and resilience of complex systems, ranging across biological, ecological, social, communication, financial, and urban networks; modelling of natural, accidental and anthropic hazards, accounting for climate change; risk assessment and mitigation of people, buildings, bridges, and industrial sites under single or multiple hazards; robustness and disaster resilience of critical infrastructure, historical urban centres, and metropolitan areas; data-driven complexity and machine learning.

The conference will be held on October 9 to 11, 2023, in two major cultural venues located in the ancient centre of Naples, Italy: the Monastery of Saints Marcellinus and Festus, which is a historic congress venue of the University of Naples Federico II; and the Italian Institute for Philosophical Studies. In addition to such institutions, the conference will be mostly supported by the Department of Structures for Engineering and Architecture of the University of Naples Federico II, as well as Scuola Superiore Meridionale, which are gratefully acknowledged.

In such a spirit, we are delighted to welcome all conference delegates to CCS/Italy 2023.

Fulvio Parisi
University of Naples Federico II
Chair

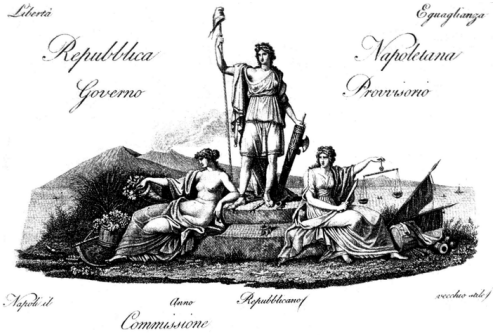
Antonio Scala
National Research Council of Italy
Co-Chair

SUPPORTING INSTITUTIONS

University of Naples Federico II

Department of Structures for Engineering and Architecture
(through programme "Dipartimenti di Eccellenza 2023-2027"
funded by Italian Ministry for University and Research)

Scuola Superiore Meridionale



Istituto italiano per gli Studi Filosofici

Italian Society for Chaos and Complexity

ORGANIZATION

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Antonio Scala (CNR - National Research Council of Italy)

Program Chairs
Mario di Bernardo, Mario Nicodemi (University of Naples Federico II)

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TOPICS

1. Foundations of Complex Systems
Complex networks, self-organization, nonlinear dynamics, statistical physics, mathematical modeling and simulation

2. Infrastructure, Planning and Environment
Critical infrastructures, urban planning, mobility, transport and energy, smart cities

3. Disaster Risk
Single-hazard and multi-hazard risk assessment, disaster risk mitigation, risk perception

4. Data-Driven Complexity Science
Data science, artificial intelligence, statistical methods for complex systems

5. Information and Communication Technologies
Internet, WWW, search, semantic web, blockchain

6. Economics and Finance
Social networks, game theory, stock market and crises

7. Biological and (Bio)Medical Complexity
Biological networks, systems biology, evolution, natural science, medicine and physiology

8. Socio-Ecological Systems
Global environmental change, green growth, sustainability and resilience

9. Language, Linguistics, Cognition and Social Systems
Evolution of language, social consensus, artificial intelligence, cognitive processes

PROGRAMME AT A GLANCE

October 9, 2023

08.30 – 09.30 Registration

09.30 – 10.00 Opening Ceremony

Fulvio Parisi and Antonio Scala
Conference Chairs

Mario di Bernardo and Mario Nicodemi
Program Chairs

Matteo Lorito, *Rector of University of Naples Federico II*

Arturo De Vivo, *Responsible of Scuola Superiore Meridionale*

Andrea Prota, *Head of Department of Structures for Engineering and Architecture*

Giovanni Piero Pepe, *Deputy Head of Department of Physics*

Fabio Villone, *Head of Department of Electrical Engineering and Information Technologies*

Morning Session (Chair: Fulvio Parisi)

10.00 – 10.30 Keynote: Juergen Kurths

10.30 – 11.00 Keynote: Iunio Iervolino

11.00 – 11.30 Coffee break

11.30 – 13.00 Contributed talks

13.00 – 13.30 Keynote: Ginestra Bianconi

13.30 – 14.30 Lunch break

Afternoon Session (Chair: Mario Nicodemi)

14.30 – 15.00 Keynote: Andrea Pagnani

15.00 – 16.30 Contributed talks

16.30 – 17.00 Coffee break

17.00 – 17.30 Keynote: Duccio Fanelli

17.30 – 19.00 Contributed talks

October 10, 2023

Morning Session (Chair: Mario di Bernardo)
09.00 – 09.30 Keynote: Enrico Zio
09.30 – 10.30 Contributed talks
10.30 – 11.00 Coffee break
11.00 – 11.30 Keynote: Alessandro Rizzo
11.30 – 12.30 Contributed talks
12.30 – 13.00 Keynote: Mattia Frasca

13.00 – 14.00 Lunch break

Afternoon Session (Chair: Antonio Scala)
14.00 – 14.30 Keynote: Almerinda di Benedetto
14.30 – 16.00 Contributed talks
16.00 – 16.30 Coffee break
16.30 – 17.00 Keynote: Constantinos Siettos
17.00 – 18.30 Contributed talks

18.30 – 19.00 Closing Ceremony
Fulvio Parisi and Antonio Scala
Conference Chairs
Mario di Bernardo and Mario Nicodemi
Program Chairs
Manlio De Domenico
Coordinator of CSS/Italy Chapter

October 11, 2023 – Public event

10.00 – 10.45 Public lecture: Guido Caldarelli (Ca' Foscari University of Venice)
10.45 – 11.30 Public lecture: Andrea Prota (University of Naples Federico II)
11.30 – 12.30 Round Table
12.30 – 13.00 Closing remarks
Fulvio Parisi and Antonio Scala
Conference Chairs
Mario di Bernardo and Mario Nicodemi
Program Chairs

Keynote and Public Speakers

Ginestra Bianconi (Queen Mary University of London)

Guido Caldarelli (University of Venice Ca' Foscari)

Almerinda Di Benedetto (University of Naples Federico II)

Duccio Fanelli (University of Florence)

Mattia Frasca (University of Catania)

Juergen Kurths (Humboldt Universitaet)

Iunio Iervolino (University of Naples Federico II)

Andrea Pagnani (Politecnico di Torino)

Andrea Prota (University of Naples Federico II)

Alessandro Rizzo (Politecnico di Torino)

Constantinos Siettos (University of Naples Federico II)

Enrico Zio (Politecnico di Milano)

PROGRAMME

October 9, 2023

08.30 – 09.30 Registration

09.30 – 10.00 Opening Ceremony

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Morning Session (Chair: Fulvio Parisi)

10.00 – 10.30 Keynote: Juergen Kurths | *Stability of power grid concerning tropical cyclones: Increasing resilience by protecting critical lines*

10.30 – 11.00 Keynote: Iunio Iervolino | *Seismic risk vs seismic design*

11.00 – 11.30 Coffee break

11.30 – 13.00 Contributed talks

11.30 – 11.45 S. Mancini, W. Marzocchi | *SimplETAS: a Reference Earthquake Forecasting Model Suitable for Operational Purposes and Seismic Hazard Analysis*

11.45 – 12.00 G. Petrillo, J. Zhuang | *Testing the existence of magnitude dependence in earthquake clusters*

12.00 – 12.15 A. Fumai, N. Caterino, F. Parisi, I. Iervolino | *National risk-informed prioritization for seismic loss mitigation of Italian strategic buildings*

12.15 – 12.30 V. Buonocunto, F. Parisi | *Enhancing Seismic Resilience at Territorial Scale through vulnerability Mitigation of Unreinforced Masonry Buildings*

12.30 – 12.45 M. Spizzuoco, T. De Stefano, F. Cavuoto, G. Bovio, G. Serino | *Structural Health Monitoring of a historical monument case study: Monument to Four Days of Naples*

12.45 – 13.00 T. Scagliarini, O. Artime, M. De Domenico | *Assessing the risk of infrastructural networks to natural catastrophes*

13.00 – 13.30 Keynote: Ginestra Bianconi | *Learning the topology of complex systems from their dynamics*

13.30 – 14.30 Lunch break

Afternoon Session (Chair: Mario Nicodemi)

14.30 – 15.00 Keynote: Andrea Pagnani | *Protein fitness landscapes from screening experiments*

15.00 – 16.30 Contributed talks

15.00 – 15.15 D. Giaquinto, W. Marzocchi, J. Kurths | *Exploring meteorological droughts spatial patterns across Europe through complex network theory*

15.15 – 15.30 A. Miano, F. Parisi, A. Prota | *Disaster resilience assessment of an urban road network in the city of Naples*

15.30 – 15.45 L. A. Grieco, N. Scattarreggia, R. Monteiro, F. Parisi | *An index-based approach for multi-hazard risk assessment of existing bridge portfolios*

15.45 – 16.00 G. Mucedero, R. Couto, R. Monteiro | *Seismic and energy performance upgrading of existing buildings in Italy: seismicity vs. climatic conditions*

16.00 – 16.15 A. Masi, F. Parisi, V. Manfredi, E. Acconcia | *Analytical vulnerability assessment of RC framed buildings considering ground shaking and earthquake-induced slope displacements*

16.15 – 16.30 M. Scalvenzi, S. Ravasini, E. Brunesi, F. Parisi | *Progressive collapse vulnerability assessment of precast buildings subjected to extreme hazards*

16.30 – 17.00 Coffee break

17.00 – 17.30 Keynote: Duccio Fanelli | *Machine learning in spectral domain*

17.30 – 19.00 Contributed talks

17.30 – 17.45 G. Fabiani, N. Evangelou, C. Siettos, I. G. Kevrekidis | *Tipping Points via Machine Learning: Comparing Data-driven Global PDE and Local SDE surrogates*

17.45 – 18.00 A. Della Pia, T. Michelis, M. Chiatto, M. Kotsonis, L. de Luca | *Synchronized oscillations in two-phase wake-mixing layer flows*

18.00 – 18.15 S. Stramaglia | *Higher order informational circuits in complex systems*

18.15 – 18.30 O. Artime, M. Grassia, M. De Domenico, J. P. Gleeson, H. A. Makse, G. Mangioni, M. Perc, F. Radicchi | *Robustness and resilience of complex networks*

18.30 – 18.45 H. Sun, F. Radicchi, J. Kurths, G. Bianconi | *The dynamic nature of percolation on networks with triadic interactions*

18.45 – 19.00 L. Bellantuono, M. Parihar, J. Kleinman, J. H. Shin, T. Hyde, D. R. Weinberger, G. Pergola | *Liquidity of gene co-expression patterns across age, brain regions and diseases with complex heritability*

October 10, 2023

Morning Session (Chair: Mario di Bernardo)

09.00 – 09.30 Keynote: Enrico Zio | *The complexity of risk, the risk of complexity*

09.30 – 10.30 Contributed talks

09.30 – 09.45 F. Ferriero, W. Marzocchi, G. Urciuoli, S. Mancini | *A full probabilistic approach to landslide forecast*

09.45 – 10.00 D. Losanno, F. Parisi | *Vulnerability of existing concrete bridges to traffic loads*

10.00 – 10.15 A. Lama, M. di Bernardo | *Utilising complex systems for control: the shepherding problem*

10.15 – 10.30 P. Castaldo, E. Miceli | *Seismic design of reinforced concrete frames by including the confinement*

10.30 – 11.00 Coffee break

11.00 – 11.30 Keynote: Alessandro Rizzo | *Incorporating human behavior into network epidemic models*

11.30 – 12.30 Contributed talks

11.30 – 11.45 D. Cialfi | *Urban amenities complexity and their urban locations*

11.45 – 12.00 M. Faccin, E. Schultz, F. Gargiulo | *International topic distribution in the HCQ controversy on Twitter*

12.00 – 12.15 M. Coraggio | *Data-driven selection of the structure of a complex network*

12.15 – 12.30 D. Russo, A. Di Benedetto | *Machine Learning for Complex Chemical System Optimization: an overview of recent applications of Gaussian Processes surrogates*

12.30 – 13.00 Keynote: Mattia Frasca | *Synchronization in dynamical systems coupled via multi-body interactions*

13.00 – 14.00 Lunch break

Afternoon Session (Chair: Antonio Scala)

14.00 – 14.30 Keynote: Almerinda Di Benedetto | *Risk analysis of H2 accidental release*

14.30 – 16.00 Contributed talks

14.30 – 14.45 S. Polizzi, D. Remondini, E. Fonzi, A. Ghelli Luserna di Rorà, G. Castellani | *Laplacian Diffusion for Synthetic Lethality*

14.45 – 15.00 S. Suweis, F. Ferraro, S. Azaele, A. Maritan | *Generalized Lotka-Volterra Systems with Time Correlated Stochastic Interaction*

15.00 – 15.15 J. Nauta, M. De Domenico | *Dispersal and network topology strongly influence stability of meta-ecosystems*

15.15 – 15.30 P. De Lellis, F. Della Rossa, D. Liuzza, F. Lo Iudice | *Synchronization and control in networks with higher-order interactions*

15.30 – 15.45 J. A. Dueñas Santana, A. Di Benedetto, E. Salzano | *Using a system thinking approach for hydrogen safety management*

15.45 – 16.00 M. Calabrese, D. Russo, G. Capone, R. Andreozzi, R. Marotta, A. Di Benedetto | *Safe hydrogen storage in aqueous formate solutions: risk analysis*

16.00 – 16.30 Coffee break

16.30 – 17.00 Keynote: Constantinos Siettos | *To learn or not to learn surrogate machine learning models, that is the question*

17.00 – 18.30 Contributed talks

17.00 – 17.15 S. Bianco | *Physics mechanisms of the genome spatial organization*

17.15 – 17.30 A. Esposito, S. Bianco A. M. Chiariello, A. Abraham, L. Fiorillo, M. Conte, R. Campanile, M. Nicodemi | *Decoding chromosome 3D folding: a hybrid Polymer Physics*

17.30 – 17.45 C. Corridori, S. Azaele, S. Suweis, M. Romeike, C. Buecker, G. Martello | *Inferring Gene Regulatory Networks in Differentiating Pluripotent Stem Cells*

17.45 – 18.00 E. Pigani, L. Campese, S. Azaele, S. Suweis, D. Iudicone | *Unveiling Gene Expression Dynamics in Microbial Communities: Insights from Metagenomics and Stochastic Modeling*

18.00 – 18.15 G. C. Maffettone, M. di Bernardo, M. Porfiri | *Continuification control of large-scale multiagent systems*

18.15 – 18.30 G. D'Agostino, A. De Nicola | *Monitoring the Women's empowerment in the Italian Information System Community*

18.30 – 19.00 Closing Ceremony

Fulvio Parisi and Antonio Scala,
Conference Chairs

Mario di Bernardo and Mario Nicodemi,
Program Chairs

Manlio De Domenico,
Coordinator of CSS/Italy Chapter

October 11, 2023 | Public event (in Italian)

10.00 – 10.45 Public lecture: Guido Caldarelli | *Le Reti come strumento di lettura del mondo*

10.45 – 11.30 Public lecture: Andrea Prota | *Framework multi-rischio nella sfida per una transizione sostenibile in un clima che cambia*

11.30 – 12.30 Round Table

12.30 – 13.00 Closing remarks

Fulvio Parisi and Antonio Scala
Conference Chairs

Mario di Bernardo and Mario Nicodemi
Program Chairs

Posters (October 9 and 10, 2023)

P1 D. Cialfi | *Investigating the information access over Nash network formation: An algorithmic representation*

P2 S. K. Joshi | *Synchronization Analysis of Biomolecular Oscillators*

P3 V. Centorrino, G. Russo, F. Bullo | *Contractivity of Symmetric Neural Networks for Non-negative Sparse Approximation*

P4 W. Marzocchi, L. Sandri, S. Ferrara, J. Selva | *From the detection of monitoring anomalies to the probabilistic forecast of the evolution of volcanic unrest: an entropy-based approach*

P5 A. Piscopo, N. Esposito, B. Castanier, M. Giorgio | *Condition based estimation of residual reliability of gamma degrading units characterized by a bathtub-shaped degradation rate in the presence of random effect and measurement error*

P6 C. C. Graciani Rodrigues, T. De Angelis, P.Tankov | *Green Investment model for pollution reduction*

P7 A. Grotta | *Enhancing Complex Human Group Coordination in Hybrid Spaces: The Role of Autonomous Avatars and Cognitive Architectures*

P8 K. K. Hanumanthappa Manjunatha, G. Baron, D. Benozzo, E. Silvestri, M. Corbetta, A.Chiuso, A. Bertoldo, S. Suweis, M. Allegra | *Controlling target brain regions by optimal selection of input nodes*

P9 I. Stanzani, G. Ratto, D. Pretolesi, A. Vian, A. Barla | *Capturing the landscape of neurological research through machine learning and data visualization*

P10 K. Kovalenko, X. Dai, K. Alfaro-Bittner, A. M. Raigorodskii, M. Perc, S. Boccaletti | *Contrarians Synchronize beyond the Limit of Pairwise Interactions*

P11 A. Mira | *The ABC of ABC with application to complex network metapopulation epidemiological model to assess COVID-19 travel restrictions*

P12 H. V. Alvarez, G. Viola, L. Russo, C. Siettos | *Learning macroscopic models in form of PDEs from crowd dynamics' agent-based simulations using Machine Learning*

P13 G. Nicoletti, P. Padmanabha, S. Azaele, S. Suweis, A. Rinaldo, A. Maritan | *Emergent encoding of dispersal network topologies in spatial metapopulation models*

P14 Prajwal Padmanabha | *Survivability near extinction through response to perturbations*

P15 M. Sartore, S. Azaele, A. Maritan, C. Poletto | *Modeling pathogen-pathogen competition in a multi-pathogen ensemble: application to the co-circulation of seasonal respiratory viruses*

P16 Mansouri, Durazzi, Pasquini, Pasquali, Van der Putten, Schultsz, Britto, Malhotra, Remondini | *Identification of antimicrobial resistance modules in E. coli through network diffusion*

P17 A. Tawalo, M. Pirone, G. Urciuoli | A*ssessing the land displacements induced by rainfall infiltration (Miscano landslide)*

P18 G. Tremontini | *Macroeconomic Disruption under Environmental Shocks: discrete-time Equilibria and Predator-Prey dynamical Models*

P19 L. Bellantuono, F. Palmisano, N. Amoroso, A. Monaco, V. Peragine, R. Bellotti | *Detecting the socio-economic drivers of confidence in government with eXplainable Artificial Intelligence*

P20 L. Bellantuono | *Structural biases in university rankings: a complex network approach to bridge the gap*

P21 P. Frasca, M. Castaldo, F. Gargiulo, T. Venturini | *Attention Dynamics and Disorders on YouTube*

P22 J. G. Oliveira, S. N. Dorogovtsev, J. F. F. Mendes | *Statistics of remote regions of networks*

P23 G. Di Bona, A. Bellina, G. De Marzo, A. Petralia, I. Iacopini, V. Latora | *The dynamics of higher-order novelties*

KEYNOTE LECTURES

Juergen Kurths (Potsdam Institute for Climate Impact Research and Humboldt University Berlin)

"*Stability of power grid concerning tropical cyclones: Increasing resilience by protecting critical lines*"

Power grids are characterized by multistability. For power grids, the strongly ongoing transition to distributed renewable energy sources leads to a proliferation of dynamical actors. The desynchronization of a few or even one of those would likely result in a substantial blackout. Thus, the dynamical stability of the synchronous state has become a leading topic in power grid research, in particular for rather strong perturbations where traditional linearization-based concepts are not appropriate. First, we discuss the concept of basin stability and its estimation even in high-dimensional systems. Considering the vulnerability of power grids against extreme wind loads and, consequently, increasing its robustness to withstand these events is of great importance. Here, we combine a detailed model of the climatic drivers of extreme events, and a cascadable model of the transmission network to provide a holistic co-evolution model to consider wind-induced failures of transmission lines in the Texan electrical network. The proposed modelling approach could be a tool so far missing to effectively strengthen the power grids against future hurricane risks even under limited knowledge.

Iunio Iervolino (University of Naples Federico II and IUSS Pavia)

"*Seismic risk vs seismic design*"

Modern era building codes generally state accepted levels of structural reliability. However, in the case of seismic action, design is often performed via a (largely) simplified version of performance-based design, in which only the design ground motion intensity is established based on an explicit probabilistic approach. It follows that, not only the reliability achieved by design is not known to the practitioner, but also that structures of different typologies and/or with different construction site, may show failure probabilities differing by orders of magnitude. In the seminar this is shown with reference to the case of structures (i.e., buildings and bridges) designed according to the current Italian building code, which has large similarities with Eurocode 8. It is also discussed that the main causes are to be searched in the lumped use of site-specific probabilistic seismic hazard, and the code-prescribed minima (including in this the effect of gravity-load design) in areas of low-to-moderate seismicity. Nevertheless, despite these known limitations, it is also shown that the current approach to seismic design has led to a systematic improvement of structural reliability with respect to the approaches pursued in now-obsolete building codes. Finally, the current trends toward the evolution of seismic design are briefly highlighted.

Ginestra Bianconi (Queen Mary University of London)

"*Learning the topology of complex systems from their dynamics*"

From the brain to the climate, complex systems constitute a real challenge for scientists and mathematicians as they are giving rise to dynamical phenomena notoriously difficult to understand, model and predict.
In the last twenty years the scientific community has made unprecedented progress in unveiling the structure of complex systems encoded in their network skeleton describing the set of their pairwise interactions. However networks are not able to characterize the ubiquitous higher-order interactions between more than two nodes that give rise to the higher-order complex systems topology.
Here we reveal how non-linear dynamical processes can be used to learn the topology, by defining Topological Kuramoto model and Topological global synchronization. These critical phenomena capture the synchronization of topological signals, i.e. dynamical signal defined not only on nodes but also on links, triangles and higher-dimensional simplices in simplicial complexes. Moreover will discuss how the Dirac operator can be used to couple and process topological signal of different dimensions, formulating Dirac synchronization and Dirac signal processing. Finally we will reveal how non-linear dynamics can shape topology by formulating triadic percolation. In triadic percolation triadic interactions can turn percolation into a fully-fledged dynamical process in which nodes can turn on and off intermittently in a periodic fashion or even chaotically leading to period doubling and a route to chaos of the percolation order parameter. Triadic percolation changes drastically our understanding of percolation and can describe real systems in which the giant component varies significantly in time such as in brain functional networks and in climate.

Andrea Pagnani (Politecnico di Torino)

"*Protein fitness landscapes from screening experiments*"

In the last few years, the development of increasingly accurate high-throughput biochemical assays with massively parallel sequencing techniques has established large-scale genetic screening as a fundamental tool for the investigation of the relationship between evolution, fitness, and other critical biological concepts that are behind experimental research. I will describe the two main types of screening experiments - deep mutational scanning, and directed evolution - and the different inference frameworks we developed to analyze them.

Duccio Fanelli (University of Florence)

"Machine learning in spectral domain"

Machine learning (ML) technologies are becoming increasingly popular due to their inherent degree of transversal adaptability, which transcends different realms of applications. ML seeks at solving an optimization problem, upon minimization of a suitably defined loss function which confronts the expected target to the output produced at the exit layer, after a nested sequence of linear (across layers) and non-linear (punctually localized on the nodes) manipulations of the data supplied as an entry. The target of the optimization are the weight of the links that connect pair of nodes belonging to adjacent stacks of the multi-layered arrangement. In this talk, I will discuss an alternative training approach which anchors the learning to reciprocal domain. The eigenvalues and the eigenvectors of suitable transfer operators get self-consistently adjusted by the optimization, with no increase in terms of computational and complexity load, as compared to standard training algorithms. Importantly, eigenvalues act as veritable parameters to assess the nodes' relative importance. Indeed, by sorting the nodes based on their associated eigenvalues, enables effective post-processing pruning strategies to yield massively compacted networks (in terms of the number of composing neurons) with virtually unchanged performance. Building on a variant of the spectral methodology, one can also accommodate for a dynamical variant of the usual learning paradigms, paving the way for a novel class of algorithms of biomimetic inspiration.

Enrico Zio (MINES Paris-PSL University and Politecnico di Milano)

"*The complexity of risk, the risk of complexity"*

Risk can be complex to assess and manage. Scenarios must be imagined and postulated, and evaluations must be performed in the presence of uncertainties, possibly very deep. The outcomes of the evaluations inform decisions to prevent undesired events and, were they to occur, mitigate and recover from their consequences. On the other hand in our modern technological society, complex systems and systems of systems are being designed, built and operated to meet the numerous and increasingly challenging objectives of efficiency, sustainability etc. In this world of continuous transitions, the innovations that are being developed for better-being and more benefits for all, also deepen uncertainty related to new and unknown hazards and dangers, due also to new and unknown functional and structural dependencies and interdependences in the complex systems and systems of systems. This calls for new and enhanced ways of analysis, assessment and management of risk. In this lecture, directions of development are presented, including the use of simulation for accident scenario identification and exploration, the exploitation of monitoring data for the dynamic updating of risk assessment to condition monitoring-based risk assessment, and the extension of the framework to resilience.

Alessandro Rizzo (Politecnico di Torino)

"Incorporating human behavior into network epidemic models"

The spreading dynamics of an epidemic and the collective behavioral pattern of the population over which it spreads are deeply intertwined, and the latter can critically shape the outcome of the former. Motivated by this, my research group is engaged in devising parsimonious yet dynamically rich models that, despite their simplicity, are able to faithful reproduce complex epidemic phenomena, including successful collective responses, periodic oscillations, and resurgent epidemic outbreaks. In this talk, I will outline some of these models and present our recent results.

Mattia Frasca (University of Catania)

"Synchronization in dynamical systems coupled via multi-body interactions"

In this keynote presentation I will discuss the main aspects of synchronization in those complex systems where the elementary interactions occur not only between pairs of units, but also involve a larger number of units. To model this type of interactions, hypergraphs and simplicial complexes, which extend the paradigm of classical complex networks, are in fact necessary. Using the mathematical representation provided by these tools, I will first review the general model of coupled dynamical systems and, then, illustrate the conditions for stability of synchronization in such model. I will then discuss the typical collective behaviors that can arise in hypergraphs and simplicial complexes of chaotic oscillators, focusing on the effect of some important topological properties of the structure, such as directionality of the interaction and degree of overlap of the hyperedges.

Almerinda Di Benedetto (University of Naples Federico II)

"Risk analysis of H2 accidental release"

Hydrogen (H2) is considered the clean fuel essential to achieve the decarbonization goal set by 2050. The development of H2 related technologies (production, transportation, storage, and use) is quite challenging in terms of both performances and safety. Hydrogen poses significant safety issues due to its flammability/explosion properties. The minimum ignition energy of H2 (≈ 0.02 mJ) is much lower (≈ 0.2 mJ) and the flammability range (4–75% in air) is much wider, compared to traditional fuels.

In this framework, the risk coming from accidental H2 release must be evaluated and quantified. Due to the peculiar properties of H2 (very low density with respect to air, high diffusion coefficient) the available models for dispersion calculation and risk map development, are not suitable.

To correctly compute the spatial/temporal maps of the H2 concentration in the atmosphere after accidental release, the interaction between momentum induced by the release, buoyancy, and turbulent motion in the atmosphere must be modelled. To this end, the solution of the Navier-Stokes equations coupled to the mass balance equations is mandatory. The solution of the Navier-Stokes equations in highly turbulent flow and in combination with peculiar properties of the species (H2) is rather complex.

In this lecture, the analysis, and the main results of the advanced models of the H2 dispersion into the atmosphere will be discussed, highlighting the complexity of fully describing the interaction between H2 dispersion in a turbulent flow and the consequences on the risk maps.

Constantinos Siettos (University of Naples Federico II)

“To learn or not to learn surrogate machine learning models, that is the question”

Complex systems span multiple space and time scales, ranging from the microscopic scale where individual/discrete units interact and evolve and the mesoscopic and macroscopic scales where the coarse-grained/emergent behaviour arise and the numerical analysis and control is usually sought. Towards this goal, high-dimensional agent-based models (ABM) have become the backbone for creating physics-based digital twins of real-world systems. What is usually done with such detailed large-scale models for the study of the emergent behavior is ``brute force'' temporal simulations: one usually sets up many initial (macroscopic) conditions, for each one of them generates many ensemble (microscopic) realizations, probably changes some of the evolution rules and then runs the detailed dynamics for a long time and process the corresponding statistical distributions. However, such high-dimensional simulations are insufficient for the systematic numerical analysis, optimization and the design of controllers. An alternative path is the statistical mechanics approach, aiming at extracting macroscopic evolution laws in the form of ODEs or Integro-PDEs, where the gap between the high-dimensional ambient space and the low-dimensional emergent/macroscopic scale is bridged through closures, relating higher-order, moments to a few, low-order moments of the underlying detailed distributions. However, the derivation of such closures are based on assumptions (e.g. infinite size of population, homogeneous agents, homogeneous interaction networks) that may bias the analysis at the density/collective level. Thus, bridging systematically the scales constitutes an important, open challenge problem in the contemporary complex systems modeling, numerical analysis and control. If the coarse-variables are known, the Equation-free (EF) approach offers an efficient alternative for learning “on demand” black-box local coarse-grained maps for the emergent dynamics on an embedded low-dim-

ensional subspace; this bypasses the need to construct (global, generalizable) surrogate models, focusing on the numerical task we need to perform, and not on constructing a predictive and generalizable model. Another option is the data-driven identification of surrogate models in the form of ordinary, stochastic or partial differential equations via machine learning. For such machine learning models, the knowledge of an appropriate set of collective variables is necessary, while their approximation accuracy clearly depends very strongly on the quality of the training data. Last but not least, one confront with the "curse of dimensionality".

In this talk, I will present a next-generation Equation-free framework bridging state-of-the-art EF numerical analysis methods, and machine learning approaches for the modelling, analysis and control of the emergent dynamics of complex and large-scale multiscale systems. The keystones of the proposed framework are (Physics-Informed) Neural Networks (PINNs), Equation-free computations, and Manifold Learning. I will present how one can apply this machinery when the physics at the macroscopic level, i.e. when the emergent variables, are unknown. This is an Equation-free/Variable free (or Next Generation Equation-free) approach that bypasses the current practice, i.e. the construction of surrogate machine-learning models (using e.g. ANNs) that introduce de facto biases and may fail for the tasks that are supposed to deal with. I will demonstrate the proposed framework via a benchmark high-dimensional ABM model approximating a financial market model with mimesis. The benchmark paradigm reveals the need and importance for selecting the correct modelling approach for engineering complex systems via machine learning, bewaring the "gifts" including pitfalls that different types of such modeling approaches bear across scales.

KEYNOTE LECTURES OPEN TO THE PUBLIC (in Italian)

Guido Caldarelli (University of Venice Ca' Foscari)

"Le Reti come strumento di lettura del mondo"

In un'epoca dominata dall'iperconnessione e dalla frenetica diffusione delle informazioni, la nostra società si confronta con una complessità crescente. Tale complessità, manifestandosi attraverso interazioni su piattaforme social come Facebook, l'affollamento delle megalopoli e i mercati finanziari globali, richiede una descrizione adeguata. In questa prospettiva, vari gruppi di ricerca si dedicano a sviluppare modelli fisici, matematici e informatici per affrontare tale sfida. Sebbene una definizione formale di complessità sia ancora mancante, l'utilizzo delle reti emerge come uno strumento cruciale per affrontare e comprendere questa complessità.

Andrea Prota (University of Naples Federico II)

"*Framework multi-rischio nella sfida per una transizione sostenibile in un clima che cambia"*

L'Italia è tra i Paesi maggiormente esposti ai disastri naturali e gli effetti dei cambiamenti climatici richiedono di intervenire in maniera sistematica per prevenire e mitigare gli impatti. In questo contesto, il partenariato esteso RETURN, finanziato dal PNRR sulla tematica dei Rischi Ambientali, Naturali e Antropici, ha lo scopo di migliorare la comprensione di tali rischi, considerandone l'interrelazione con i cambiamenti climatici e adottando approcci multi-rischio per la previsione, prevenzione, adattamento, mitigazione e monitoraggio. L'impostazione multi-disciplinare per la gestione olistica dei rischi consente di definire scenari di transizione che dalla pianificazione strategica prevedano il passaggio ad azioni efficaci e strutturali, prevedendo tra l'altro azioni di coprogettazione e condivisione che aumentino la percezione dei rischi e la collaborazione delle comunità.

9 – 10 OCTOBER

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NOTES

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