# 54th Winter School of Theoretical Physics

**http://ift.uni.wroc.pl/~karp2018**

**email:** karp2018@ift.uni.wroc.pl

February 18-24th 2018

Lądek Zdrój

Poland

**Organizing committee**

Dariusz Grech

Janusz Miśkiewicz

Remigiusz Durka

# Simplicity of Complexity in Economic and Social Systems

## Invited Lecturers

Marcel Ausloos (Leicester)
Janusz Hołyst (Warsaw)
Joseph Indekeu (Leuven)
Rosario Mantegna (Palermo)
Tiziana Di Matteo (London)
Paweł Oświęcimka (Cracow)
Katarzyna Sznajd-Weron (Wrocław)
Boris Podobnik (Rijeka)
Hideki Takayasu (Tokyo)
Misako Takayasu (Tokyo)

Main Organizers

Institute of Theoretical Physics
Faculty of Physics and Astronomy
University of Wrocław

FENS
Physics in Economy and Social Sciences (FENS)

Sponsors

Uniwersytet Wrocławski

Ministry of Science and Higher Education
Republic of Poland

Polish Physical Society

# Lecturers

1. Marcel Ausloos (University of Leicester)
2. Janusz Hołyst (Warsaw University of Technology)
3. Joseph Indekeu (KU Leuven)
4. Ladislav Kristoufek (Charles University, Prague)
5. Ryszard Kutner (Faculty of Physics University of Warsaw)
6. Rosario Mantegna (Central European University & Palermo University)
7. Paweł Oświęcimka (Institute of Nuclear Physics Polish Academy of Sciences, Kraków)
8. Boris Podobnik (University of Rijeka, ZSEM)
9. Katarzyna Sznajd-Weron (Wrocław University of Science and Technology)
10. Marek Szydłowski (Jagiellonian University)
11. Hideki Takayasu (Sony Computer Science Laboratory)

# Abstracts

**Marcel Ausloos**

- ***On fat tails, kurtosis, and skewness of socio-economic data distributions***

The fat tails of socio-economic distributions is recalled: the distributions of returns of assets are known to be leptokurtic, showing fat tails, indeed. The Geometric Brownian Motion is recalled to provide an unsatisfactory description of such distribution tails of returns, i.e. asset price distributions given by stock market indices.

The Irrational Fractional Brownian Motion is introduced and shown to lead to a much better description of the fat tail(s) of such distributions. Through an econometric model specification analysis, the empirical kurtosis of such returns distribution is thereafter modeled. Moreover, it is shown that a "simple relation", but *a priori unexpected*, may exist between high order moments of socio-economic data distributions, like the skewness and kurtosis. This allows to point to theoretical models with understandable structural parameters based on a preferential attachment process.

**Janusz Holyst**

- ***Detecting and modelling of collective emotions in on-line communities***

Emotions are part of what makes us human. We cannot escape from them since they belong to the core of our human nature. With information technology occupying such a central part in all our lives, it's important to ask whether there are emotions in cyberspace too?

During the lecture I will introduce the reader to fundamental definitions, key concepts and case studies addressing the following issues of rapidly growing relevance for online communities:

- What are emotions ? How do they emerge, how are they transmitted?
- How can one measure emotional states?

- What are cyberemotions?
- When do emotions and cyberemotions become collective phenomena?
- How can one model emotions and their changes?
- What role do emotions play for on-line communities?

I will show you how machine learning methods can become an efficient tool for large scale sentiment analysis and how data-driven agent-based models of virtual emotional human can describe live and death of on-line communities. I will demonstrate interactive affective systems that communicate directly with users and are examples of next generation of emotionally-intelligent ICT services.

More more details see the book *Cyberemotions - Collective Emotions in Cyberspace*, Editor: Janusz A. Hołyst, Springer 2017, Series Title: Understanding Complex Systems, ISBN: 978-3-319-43639-5; DOI: 10.1007/978-3-319-43639-5

**Joseph Indekeu**

- ***Interdisciplinary applications and undisciplined intimations of statistical physics***

The subject of this lecture are two hitherto unpublished pieces of ongoing research and the purpose of this lecture is twofold.

*Exploratory:* Interdisciplinary applications of statistical physics are illustrated in two directions: one is sociophysics and the other is computational physics. The application to sociophysics proposes an analogue of wetting phase transitions in the context of interactions between social groups. The application to computational physics proposes an unconventional use of solutions of nonlinear differential equations originally relevant to diffusive and convective growth of populations.

*Methodological:* The process of obtaining new results starts from an imitation step and proceeds through an intimation step. As is well known, imitation alone does not lead to creation but to plagiarism. However, if imitation is followed by intimation, new results are being hinted or suggested (in the mind of the scientist) and can be developed into a creation. This sometimes involves an undisciplined process (similar to an artistic effort), the outcome of which is beyond what could rationally have been envisaged.

**Ladislav Kristoufek**

- **From long-range dependence to scale-specific correlations, regressions and power-law coherency: Review, utility and challenges**

Analysis of long-range dependence in financial time series was one of the initial steps of econophysics into the domain of mainstream finance and financial economics in the 1990s. Since then, many different financial series have been analyzed using the methods standardly used outside finance to deliver some important stylized facts of the financial markets. In the late 2000s, these methods have started being generalized to bivariate settings so that the relationship between two series could be examined in more detail. It was then only a single step from bivariate long-range dependence towards scale-specific correlations and regressions as well as power-law coherency as a unique relationship between power-law correlated series. Such rapid development in the field has brought some issues and challenges that need further discussion and attention. The two lectures will review

the development and historical steps from long-range dependence to bivariate generalizations and connected methods, focus on its technical aspects, summarize their use in the empirical literature and discuss problematic parts and challenges for future directions in this specific subfield of econophysics.

**Ryszard Kutner**

- ***Continuous-time random walk in real complex systems: Anomalous transport & diffusion, extreme value theory, fractional evolution vs econophysic applications"***

We demonstrate the very inspiring role of the continuous-time random walk (CTRW) formalism, the numerous modifications permitted by its flexibility, its various applications, significant achievements, and the promising perspectives in the different fields of knowledge [1]. This formalism assumes the interevent-times continuous and fluctuating. This times are characterized by some distribution associated with a stochastic process, quite often by the broaden one, giving an inside into the process activity. We focused on the pivotal role of CTRWs mainly in anomalous stochastic processes discovered in physics and beyond. Thus we show incredible possibilities of the CTRWs.

My talk consists of three lectures:

- **Lecture 1:** where in a systematic way the birth of CTRW is presented together with its first very successful applications to description of anomalous transport and diffusion in such amorphous systems as vitrous (glossy) solids and light-emitting organic polymers.
- **Lecture 2 and 3:** showing the links to the memory, telegraph equation, discrete-scale invariance, extreme value theory, and fractional evolution equation. Moreover, the link to financial markets is also established.

Reference:
*[1] Ryszard Kutner and Jaume Masoliver: "The continuous time random walk, still trendy: fifty-year history, state of art and outlook", Eur. Phys. J. B (2017) 90:50; DOI: 10.1140/epjb/e2016-70578-3, and refers therein.*

**Rosario Mantegna**

- ***Properties of Financial and Economic Networks***

We discuss properties of a broad class of financial and economic networks. Typical examples are Interbank networks investigated in studies of systemic risk that arise from banks mutual exposures. These exposures originate from many channels. The primary channel arises from the credit relationships of interbank lending. In addition to this direct channel, indirect impact might be felt due to common holdings of the same asset classes, that can lead to common shocks in some instances. Finance and economics are therefore presenting complex systems where different types of networks can be simultaneously present and can affect the dynamics, robustness, and resilience of the system.

We will explicitly discuss the nature and role of (i) event or relationships network, (ii) proximity based network, i.e. networks obtained starting from a proximity measure sometime filtered with a network filtering methodology, (iii) association network, i.e. networks where a link between two actors of the complex system is set if a statistical test again a null hypothesis is rejected, and (iv) statistically

validated network, i.e. event or relationship networks where a subset of links is selected according to a statistical validation associated with the rejection of a random null hypothesis.

- **Lecture 1:** *Financial and economic networks. Different types of networks. Event or relationship networks, Proximity based networks, association networks. Role of heterogeneity in financial and economic complex systems and statistically validated networks.*

- **Lecture 2:** *Problems with the construction of financial networks. Different approaches and methodologies in construction of financial networks. Maximum entropy method. Minimum density method. An application about systemic risk in finance.*

- **Lecture 3:** *Bootstrap validation of proximity based networks. Statistical validation of event networks in heterogeneous systems.*

**Paweł Oświęcimka**

- ***Multiscaling in financial time series***

Many natural phenomena and systems can quantitatively be described within the framework of the fractal geometry which brings such characteristics like the fractal dimension, scaling exponents, self-similarity and cascade effects. This interdisciplinary concept, proposed by Mandelbrot, is especially useful for grasping the principal characteristics of complexity. Complex systems reveal a highly convoluted organization that escapes an appropriate description by means of the standard methods. The most vivid example of complexity are the financial markets. One approach to study them is to analyze the time series of the financial observables. By now there exists a convincing evidence that the financial fluctuations develop even the multifractal patterns, quantitatively characterized by the whole spectrum of the scaling exponents whose estimation often demands quite sophisticated computational methods.

During the lectures I will introduce the basic theoretical concepts that serve description of the multifractal patters with a particular focus on their application to the time series analysis. I will present both, the more conventional methods of quantifying the scaling properties of the time series as well as some more advanced algorithms of the nonstationary time series analysis. I will also present a novel concept of the multifractal cross-correlation and point to its utility in filtering out such effects among the different financial time series.

- **Lecture 1:** *Fractals and Multifractals*

*Material:* nonrandom fractals, scaling, fractal functions, Hurst exponent, spectral analysis, fractional Brownian motion (fBm), multifractal (singularity) spectrum, multifractality of financial fluctuations.

- **Lecture 2:** *Multifractal analysis of the time series and multifractal models*

*Material:* wavelet transform modulus maxima (WTMM), multifractal detrended fluctuation analysis (MFDFA), surrogate time series, binomial multifractal cascade, multifractal model of asset returns (MMAR), examples of multifractal natural systems.

- **Lecture 3:** *Multiscale cross-correlations between the different time series*

*Material:* multifractal cross-correlation analysis (MFCCA), q-dependent detrended cross-correlation coefficient, q-dependent minimum spanning trees (qMSTs), examples of analysis of financial data.

**Boris Podobnik**

- ***Biological conservation law as an emerging functionality in dynamical neuronal networks***

Scientists strive to understand how functionalities, such as conservation laws, emerge in complex systems. Living complex systems in particular create high-ordered functionalities by pairing up low-ordered complementary processes, e.g., one process to build and the other to correct. We propose a network mechanism that demonstrates how collective statistical laws can emerge at a macro (i.e., whole-network) level even when they do not exist at a unit (i.e., network-node) level. Drawing inspiration from neuroscience, we model a highly stylized dynamical neuronal network in which neurons fire either randomly or in response to the firing of neighboring neurons. A synapse connecting two neighboring neurons strengthens when both of these neurons are excited and weakens otherwise. We demonstrate that during this interplay between the synaptic and neuronal dynamics, when the network is near a critical point, both recurrent spontaneous and stimulated phase transitions enable the phase-dependent processes to replace each other and spontaneously generate a statistical conservation law: the conservation of synaptic strength. This conservation law is an emerging functionality selected by evolution and is thus a form of biological self-organized criticality in which the key dynamical modes are collective.

- ***Predicting the rise of EU right-wing populism in response to unbalanced immigration***

Among the central tenets of globalization is the free migration of labor. Although much has been written about the benefits of globalization, little is known about its limitations and how anti-globalist sentiment can be strongly affected by high levels of immigration. Analyzing poll data from a group of EU countries affected by the recent migrant crisis, we find that over the last three years the percentage of right-wing (RW) populist voters in a given country depends on the prevalence of immigrants in this country's population and the total immigration inflow into the entire EU. The latter is likely due to the perception that the EU functions as a supranational state in which a lack of inner borders means that "someone else's problem" can easily become "my problem".

We find that the increase in the percentage of RW voters substantially surpasses the percentage of immigration inflow, implying that if this process continues ongoing democratic processes will cause RW populism to prevail and globalization to rapidly decrease. We locate tipping points between the fraction of immigrants and the rise of RW populism, and we model our empirical findings using a complex network framework in which the success of globalization rests on a balance between immigration and immigrant integration.

**Katarzyna Sznajd-Weron**

- ***Statistical physics of opinion formation***

Among many different subjects, opinion dynamics is one of the most studied in the field of sociophysics. In my opinion there are at least two important reasons why physicists study this topic. The first motivation comes from social sciences and can be described as a temptation to build a bridge

between the micro and macro levels in describing social systems. Traditionally, there are two main disciplines that study social behavior - sociology and social psychology. Although the subject of the study is the same for both disciplines, the usually taken approach is very different. Sociologists study social systems from the level of the social group, whereas social psychologists concentrate on the level of the individual. From the physicist's point of view this is similar to the relationship between thermodynamics and statistical physics. This analogy raises the challenge to describe and understand the collective behavior of social systems (sociology) from the level of interpersonal interactions (social psychology). The second motivation to deal with opinion dynamics is related to the development of non-equilibrium statistical physics, because models of opinion dynamics are often very interesting from the theoretical point of view. A good example of such an interesting model is a broad class of voter models, including linear voter model and nonlinear q-voter model introduced in along with its modifications.

During this tutorial I will try to cover two aspects of opinion dynamics models – usefulness for interdisciplinary applications and theoretical challenges, that make these models interesting for physicists. Therefore, I will start with presenting the social background, then I will move to theoretical results and finally I will provide examples where such models can be used. I will summarize with open questions and guidelines for further studies.

Further reading:
[1] *C. Castellano, S. Fortunato, V. Loreto, Statistical physics of social dynamics. Rev. Mod. Phys. 81, 591–646 (2009)*
[2] *P. Nyczka and K. Sznajd-Weron, Anticonformity or Independence? - Insights from Statistical Physics, Journal of Statistical Physics 151, 174–202 (2013)*
[3] *A. Jędrzejewski and K. Sznajd-Weron, Person-Situation Debate Revisited: Phase Transitions with Quenched and Annealed Disorders, Entropy 16, 415 (2017)*

**Marek Szydłowski** *[in collaboration with Adam Krawiec]*

- ***Complex dynamics of economics models with time delay I: Introduction to delay differential equations***

We present the introduction to the delay differential equation. The development of mathematical methods in the functional analysis as well as numerical methods have triggered off an increasing interest in modeling physical, biological as well as economic phenomena with time delay differential equations. Especially in economic applications, the time delay is a convenient way to study present responses on some past stimuli. The delay differential equation is equivalent to a system of infinite ordinary differential equations. We use the qualitative theory of dynamical systems to analyze the delay differential equation or a system of delay differential equations. To study the stability of critical points of dynamical systems we use the local stability analysis. We also use the bifurcation theory for detecting cyclic behavior in an economic system through the Hopf bifurcation mechanism.

- ***Complex dynamics of economics models with time delay II: Business cycles and economic growth models with time delay***

We present how Kalecki's idea of the time required for building investment goods was exploited to formulate a simple model of business cycle as a differential equation with time delay. We show that

it is a universal mechanism for inherent cyclic behavior of the economy. It is a prototype of business cycle model with cycles of a self-sustainable character. As an example of a model in the form of a two-dimensional system of differential equations with a time delay, we present the Kaldor-Kalecki model of business cycle. This model can be further extended by incorporating an exponential growth term to form the Kaldor-Kalecki economic growth model, which exhibit a cyclic behavior known as growth cycles.

# Poster Session

1. *Multiple propagation paths in locating the source of diffusion in complex networks*

   **Łukasz Gajewski**

2. *Quantum finance methods in vanilla option pricing*

   **Pavel Irinkov**

3. *Pair approximation for the q-voter model with independence on complex networks*

   **Arkadiusz Jędrzejewski**

4. *Asymmetry of stock market trends and the long memory effect*

   **Grzegorz Link**

5. *The business cycle 'clock': predicting market tops based on investor sentiment*

   **Grzegorz Link**

6. *Exact combinatorial approach to finite coagulating systems*

   **Michał Łepek**

7. *The q-voter model with nonconformity in freely forming groups: does the size distribution matters?*

   **Wojciech Radosz**

8. *The Effect of Support and Resistance Levels Breaking for chosen Currency Pairs Prices*

   **Adam Szmagliński**

9. *New constant of motion for coevolving voter model*

   **Joanna Toruniewska**

10. *Cross-correlations between financial time series on different time scales*

    **Marcin Wątorek**

11. *Unified multifractal analysis: An application to study tkhe series of interevent times*

    **Jarosław Klamut**

12. *Two economic models as examples of dynamical systems with time delay*

    **Marek Szydłowski**

# List of Participants

- Adam Szmagliński (Cracow University of Technology)
- Alessandro Maria Solda (University of Padova, Italy)
- Arkadiusz Jędrzejewski (Wrocław University of Science and Technology)
- Boris Podobnik (University of Rijeka, ZSEM)
- Dariusz Grech (University of Wrocław)
- Giada Bruni (University of Macerata, Italy)
- Grzegorz Link (University of Warsaw)
- Hideki Takayasu (Sony Computer Science Laboratory)
- Janusz Hołyst (Warsaw University of Technology)
- Janusz Miśkiewicz (University of Wrocław)
- Jarosław Klamut (University of Warsaw)
- Jessica Riccioni (University of Macerata, Italy)
- Joanna Toruniewska (Warsaw University of Technology)
- Joseph Indekeu (KU Leuven)
- Katarzyna Sznajd-Weron (Wrocław University of Science and Technology)
- Ladislav Kristoufek (Charles University, Prague)
- Łukasz Gajewski (Warsaw University of Technology)
- Marcel Ausloos (University of Leicester)
- Marcin Lebiedź (University of Warsaw)
- Marcin Wątorek (Wątorek (Institute of Nuclear Physics, Polish Academy of Sciences, Kraków)
- Marek Szydłowski (Jagiellonian University, Cracow)
- Marta Bigus-Kwiatkowska (Warsaw University of Technology)
- Marta Brzezińska (Wrocław University of Science and Technology)
- Mateusz Denys (University of Warsaw)
- Michał Łepek (Warsaw University of Technology)
- Michał Sawa (University of Wrocław)
- Pavel Irinkov (Charles University, Prague)
- Paweł Oświęcimka (Institute of Nuclear Physics Polish Academy of Sciences, Kraków)
- Prakash Kandel (Tribhuvan University, Nepal)
- Remigiusz Durka (University of Wrocław)
- Rosario Mantegna (Central European University & Palermo University)
- Ryszard Kutner (University of Warsaw)
- Valerio Ficcadenti (University of Macerata, Italy)
- Wojciech Radosz (Wrocław University of Science and Technology)

**Winter School of Theoretical Physics 2018 -** Simplicity of Complexity in Economic and Social Systems

| *DATE/TIME* | MON., Feb. 19 | TUE., Feb. 20 | WED., Feb. 21 | THUR., Feb. 22 | FRI., Feb. 23 | SAT., Feb. 24 |
|---|---|---|---|---|---|---|
| 8:00 - 9:00 | *Breakfast* | *Breakfast* | *Breakfast* | *Breakfast* | *Breakfast* | *Breakfast* |
| 9:00 - 9:15 | *OPENING* | | | | | |
| 9:15 - 10:15 | **Ausloos** | **Mantegna** | **Mantegna** | **Mantegna** | **Indekeu** | **Indekeu** |
| 10:15 - 11:15 | **Kutner** | **Ausloos** | **Ausloos** | **Hołyst** | **Hołyst** | **Hołyst** |
| 11:15 - 11:45 | *Coffee Break* | *Coffee Break* | *Coffee Break* | *Coffee Break* | *Coffee Break* | *Coffee Break* |
| 11:45 - 12:45 | **Szydłowski** | **Kutner** | **Oświęcimka** | **Sznajd-Weron** | **Kristoufek** | **Sznajd-Weron** |
| 12:45 - 13:00 | | | | | | *CLOSING* |
| 13:00 - 14:00 | *LUNCH* | *LUNCH* | *LUNCH* | *LUNCH* | *LUNCH* | *LUNCH* |
| 14:00 - 14:30 | | | | | | *BUS to WROCŁAW* |
| 14:30 - 15:30 | Poster Session I *Coffee* | **Szydłowski** | *EXCURSION (Bear Cave)* | **Indekeu** | **Sznajd-Weron** | |
| 15:30 - 16:30 | *WALK TO THE CENTER OF LĄDEK ZDRÓJ* | **Oświęcimka** | | **Oświęcimka** | **Kristoufek** | |
| 16:30 - 18:00 | | Poster Session II *Coffee* | | *LIVE MUSIC* | *Coffee* | |
| 18:00 - 19:00 | *DINNER* | *DINNER* | *DINNER* | *DINNER PARTY* | *DINNER* | |
| 19:00 - ? | BAR | BAR | BAR | BAR | BAR | |