NIKOLA BURIĆ MEMORIAL WORKSHOP

9 December 2016, Institute of Physics Belgrade, Serbia

Book of Abstracts

Workshop chair

Antun Balaž

Co-chairs

Igor Franović

Slobodan Prvanović

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Welcome

to Nikola Burić Memorial Workshop

We would like to cordially welcome you to a workshop that will be held at the Institute of Physics Belgrade on December 9, 2016. Deeply saddened by Nikola's early passing away in January this year, as his friends and colleagues, we have decided to host a workshop that will honor his life and scientific achievements, keeping up the memory of Nikola and the legacy of his work. The workshop is intended to become an annual gathering of his distinguished colleagues and successors, where they would have the opportunity to present the most recent results from the general field of dynamics of classical and quantum complex systems.

We wish you all a pleasant time in Belgrade.

Antun Balaž, Igor Franović and Slobodan Prvanović

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NIKOLA BURIĆ

BIOGRAPHY

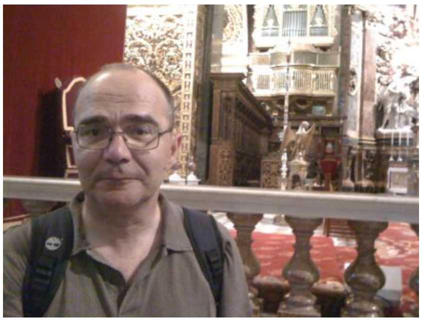
Prof. Dr Nikola Burić was born in 1959 in Belgrade. He graduated Theoretical Physics at the Faculty of Physics, University of Belgrade, and has completed his PhD thesis in Applied Mathematics in 1990 at the University of London under supervision of Professor Ian C. Percival. Nikola began his scientific career as a Researcher at the Institute of Physics Belgrade, where he worked in the period 1983-1993. Nikola spent several years in England, from 1987 to 1993, first obtaining his PhD degree, and then remaining for additional two years as a postdoctoral fellow at the School of Mathematics, Queen Mary and Westfield College, University of London. From 1993 to 2006 he worked as an Assistant Professor, then as Associate Professor and finally as full Professor of Physics at the Faculty of Pharmacy, University of Belgrade. In 2006, Nikola returned to the Institute of Physics Belgrade, where he worked as a Research Professor, first within the Photonics Centre, and then having become a member of the Scientific Computing Laboratory, the Centre for the Study of Complex Systems. In parallel to his research work, Nikola held a course in Nonlinear Dynamical Systems at the PhD studies on the Faculty of Physics, University of Belgrade. Apart from the stay in England, Nikola had a number of long stays at the leading universities and institutes abroad, becoming a fellow of DAAD, OeAD and University of Bologna. During his research career, Nikola has also been an associate member of the International Centre for Theoretical Physics "Abdus Salam" in Trieste.

Professor Burić has supervised the completion of three PhD theses in Physics, and has also been a co-adviser on two Doctoral Theses in Mathematics, as well as a mentor on two Master's Thesis in Physics and a co-adviser on two Master's thesis in Mathematics.

Area of scientific interest of Professor Burić was related to the application of the theory of dynamical systems in Physics. His most important results concern the three following topics:

- Efficient description of the fractal structure and dynamics of Hamiltonian systems,
- Modelling and analysis of the dynamics of neuronal systems
- Hamiltonian formulation of quantum mechanics.

Within the first topic, Prof. Burić formulated the novel theory of modular smoothing that allows one to approximate the complex fractal structure of phase portraits of typical Hamiltonian systems via simple smooth functions. The main contribution within the field of neurodynamics is associated to understanding the fundamental role that the coupling delays play in rhythmogenesis and synchronization of neuronal activities, with his later studies extended to qualitative analysis of stochastic stability and bifurcations of delay-coupled excitable systems. The third main field of Nikola's work concerns the different aspects of formulation of quantum dynamics and its generalizations as specific types of Hamiltonian systems. The first article regarding the Hamiltonian formulation of quantum mechanics, which Professor Burić published in Annals of Physics, was selected as the one that illustrates the intellectual vitality of physics in 2007. In addition to the three main topics indicated above, Prof. Burić has also worked on the following problems: chaotic dynamics of the Bianchi IX cosmological model, the complex dynamics of mappings of the circle, modelling the immune response, as well as the application of stochastic equations in modelling of the dynamics of open quantum systems.



Professor Burić has collaborated with prominent scientists, including F. R. Ellis, I. C. Percival, G. Turchetti, G. Ghirardi, Č. Brukner, H. T. Elze and others. Professor Burić has published 97 articles that have been cited 425 times (not including the self-citations), whereas his h-factor is 15.

For his outstanding achievements in the field of dynamics of classical and quantum complex systems and the contribution to introducing and the development of novel scientific methods in Serbia, Professor Burić has received an Award of the Serbian Academy of Sciences and Arts for the field of Physics and Associated Disciplines in 2015.

NIKOLA BURIĆ

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WORKSHOP PROGRAM

Morning Session: Foundations of Quantum Mechanics and Quantum Complexity

9:45-10:00	**Opening of the Workshop**	**Antun Balaž Đorđe Šijački Branislav Jelenković**
10:00-10:30	**Quantum-to-classical Transition Through Coarse-grained Measurements**	**Časlav Brukner**
10:30-11:00	**Full Symmetry Implementation in Condensed Matter and Molecular Physics – Modified Group Projector Technique**	**Milan Damnjanović**
11:00-11:30	**Exploring the Boundaries of Quantum Mechanics**	**Hans-Thomas Elze**
11:30-11:45	**COFFEE BREAK**	
11:45-12:15	**Quantum Cryptography Beyond Key Distribution: Bit Commitment and Secure Multiparty Computation**	**Nikola Paunković**
12:15-12:45	**Hamiltonian Formulation of Hybrid Quantum-classical Systems**	**Milan Radonjić**
12:45-13:15	**Benefits of Generalizations in Different Topics**	**Dušan Arsenović**

LUNCH BREAK 13:15-14:30

Afternoon Session: Emergent Dynamics in Classical Complex Systems

14:30-15:00	Partial Integrability	Božidar Jovanović
15:00-15:30	The Spark of Life: the Physics of How the Earth Went From Geology and Chemistry to Biology	Julyan Cartwright
15:30-16:00	Geometric Phases in Discrete Dynamical Systems	Oreste Piro
16:00-16:30	Self-organized Dynamics of Neuronal Systems Influenced by Noise and Coupling Delays	Igor Franović
16:30-17:00	COFFEE BREAK	
17:00-17:30	Note on Higher-dimensional Symmetric Euler Top	Borislav Gajić
17:30-18:00	Time and Times: Some Things I learnt from Nikola Burić	Luis Fariña-Busto

CLOSING OF THE WORKSHOP

ABSTRACTS

MORNING SESSION

FOUNDATIONS OF QUANTUM MECHANICS

AND QUANTUM COMPLEXITY

Quantum-to-classical Transition Through Coarse-grained Measurements

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The descriptions of the quantum realm and the macroscopic classical world differ significantly not only in their mathematical formulations but also in their foundational concepts and philosophical consequences. When and how physical systems cease to behave quantumly and begin to behave classically is still heavily debated in the physics community and subject to theoretical and experimental research. A possible approach to classicality from within quantum theory focuses on the limits of observability of quantum effects for macroscopic objects, i.e. on the required precision of our measurement apparatuses such that quantum phenomena can still be observed. In my talk, I recall on my collaboration on understanding quantum-to-classical transition through coarse-grained measurements and friendship with Nikola Burić.

Full Symmetry Implementation in Condensed Matter and Molecular Physics — Modified Group Projector Technique

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Symmetry is well established as one of the fundamental concepts in physics, accurately extracting relevant characteristics of the studied object, giving deep and transparent insight to its properties. In the solid state and molecular physics the most abundant application is reduction of the dimension of the eigenproblem of the Hamiltonian, with the resulting eigenvectors labeled by good quantum numbers, forming the so called symmetry adapted basis. Such a basis is the starting point for subsequent analysis of the physical properties of the system, performed usually by applying adequate perturbation technique. Standard procedure for finding a symmetry adapted basis involves Wigner operators, which are sums of the operators acting in the quantum state space (Hilbert space, most usually) over all elements of the symmetry group of the systems. However, both the dimension of the state space and the number of the symmetry transformations are infinite even in the simplest approximate models in crystal physics making obstacles for direct application of the standard Wigner projector technique, and its numerical implementation. On the other hand, there is a minimal part of the system, the full symmetry elementary cell (symcell), from which the whole system can be built by action of the full symmetry group elements on it.

A clear heuristic idea, that symcell and full symmetry group, determine the properties of the entire system, is fully realized within modified group projector technique. Namely, when applying this technique, the full symmetry of the system is used to provide reduction of calculations to the symcell only, singling out its state space (of a finite dimension!) as the effective state space to be worked in. Physical observables, expressed through their irreducible tensor components, obtain their counterparts in this finite-dimensional space of a symcell. It remains to consider only the symmetry transformations which leave the symcell invariant. This is absolutely sufficient for the complete information on the properties of the system.

Generality of the method allows unified treatment of the most important dynamical models for ions (lattice dynamics within harmonic approximation), electrons (tight-binding method for the quantum states) and spin subsystem (spin waves in quasi classical approach), with specific details considered separately. Prescription for theoretically minimal relaxation procedures and calculation of the transition amplitudes are developed.

Exploring the Boundaries of Quantum Mechanics

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I will begin by recalling how I met Nikola Burić and how our friendship developed in the short time we were given. Motivated by quite different interests in the transition between quantum and classical mechanics, at first, we both were studying possibilities for a theory of quantum-classical hybrid systems, which became the focus of our discussions. This has recently led me to explore cellular automata (CA) which, quite surprisingly, show well known features of quantum mechanics (QM). Such as a linear updating rule that resembles a discretized form of the Schrödinger equation together with its conservation laws. In particular, a whole class of natural Hamiltonian CA, which are based entirely on integer-valued variables and couplings and derived from an action principle, can be mapped reversibly to continuum models with the help of sampling theory [Shannon]. This results in ”deformed” quantum mechanical models with a finite discreteness scale l, which for $l \to 0$ reproduce the familiar continuum limit. Such CA can form multipartite systems consistently with the tensor product structures of many-body QM, while maintaining linearity. Interestingly, discreteness necessitates a many-time formulation reminding of relativistic dynamics. We conclude that the superposition principle is fully operative already on the level of such primordial discrete deterministic automata, including the essential quantum effects of interference and entanglement and might offer a primitive understanding of the Born rule.

Quantum Cryptography Beyond Key Distribution: Bit Commitment and Secure Multiparty Computation

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We give a brief overview of cryptography, with special emphasis on secure multiparty computation protocols, such as e-voting, private data mining, etc. We present oblivious transfer and bit commitment, computational primitives used to build up more complex schemes, and analyze classical reductions between various versions of such primitives and the corresponding no-go theorems. We then move to the quantum realm and discuss possible advantages over the classical counterparts, offered by the laws of quantum mechanics. Finally, we present a practical quantum bit commitment protocol, and analyze its security against various cheating strategies performed by dishonest agents.

Hamiltonian Formulation of Hybrid Quantum-classical Systems

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In this talk an overview of the dynamical description of interacting quantum-classical systems will be given, based on a novel approach recently introduced by N. Burić and co-workers. General constrained Hamiltonian framework is applied to quantum systems in order to tackle the emergence of classical systems and their consistent joint treatment. Some results and emerging issues will be presented by following the development time-line of the approach.

Benefits of Generalizations in Different Topics

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Well known results in theoretical physics are often special cases of more general properties. Knowing these universal statements gives one a new research tool. Standard distributions on a phase space can be extended to spin to define its classical-like states. While self-adjoint operators have orthogonal spectral decomposition, another mathematical notion is also suitable in quantum mechanics. That is positive operator value measure which need not be orthogonal. It is a candidate for description of the phase observable. Peculiar fact is that quantum dynamics can be understood as a classical dynamics on a scalar product of wave function with some basis. For them to be fully equivalent constraint on the observables should be imposed. Relaxing this constraint enables the analysis of a possibility of a cloning in nonlinear Hamiltonian systems. Time can be added to usual phase space variables. New formulation is equivalent to the initial with one more constraint. This result from a classical theory enables the formulation of quantum dynamics with space, spin and time on the same footing.

AFTERNOON SESSION

EMERGENT DYNAMICS IN

CLASSICAL COMPLEX SYSTEMS

Partial Integrability

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Consider the Hamiltonian flow of a time-independent Hamiltonian H on a $2n$-dimensional symplectic manifold P. We prove a variant of complete integrability, where n integrals commute only on an isoenergetic surface $M = \{H = h\}$: the trajectories of the system are quasi-periodic on M. If we interchange the role of the Hamiltonian with some other integral F and consider the invariant surface $N = \{F = c\}$, we get that N is foliated on invariant tori, but the dynamics not need to be periodic. The examples of the later statement are Hess-Appelrot type systems studied by Dragović and Gajić (joint work with Vladimir Jovanović, University of Banja Luka).

The Spark of Life: the Physics of How the Earth Went From Geology and Chemistry to Biology

Julyan Cartwright[1,a)]

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More than 3.5 billion years ago, something interesting happened on Earth. Somewhere matter self-organized so that it was able to reproduce its complex state. Life had begun. Where and how that happened are questions whose answers, after many centuries, seem at last within reach. About four decades ago there were discovered hydrothermal vents at the bottom of the oceans; for 25 years there has been increasing evidence that they were the cradle of life on Earth. We shall examine how physics can help explain how life started.

Geometric Phases in Discrete Dynamical Systems

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In order to study the behaviour of discrete dynamical systems under adiabatic cyclic variations of their parameters, we consider discrete versions of adiabatically-rotated rotators. Parallelling the studies in continuous systems, we generalize the concept of geometric phase to discrete dynamics and investigate its presence in these rotators. For the rotated sine circle map, we demonstrate an analytical relationship between the geometric phase and the rotation number of the system. For the discrete version of the rotated rotator considered by Berry, the rotated standard map, we further explore this connection as well as the role of the geometric phase at the onset of chaos. Further into the chaotic regime, we show that the geometric phase is also related to the diffusive behaviour of the dynamical variables and the Lyapunov exponent.

Self-organized Dynamics of Neuronal Systems Influenced by Noise and Coupling Delays

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Self-organization mediated by synchronization of neuronal activities provides the dynamical paradigm for cooperative dynamics in the human brain, underlying on one hand the different stages of information processing, and on the other hand supporting our cognitive abilities, such as perception, attention, learning and memory. The fascinating plethora of different synchronization patterns may involve asymptotic synchronization that contributes to rhythmogenesis or the transient synchrony, then the instances of exact synchronization or (chaotic) phase synchronization, the cluster synchrony or partial synchronization, as well as coexistence between the synchronous and disordered phases. Given that the neuronal systems typically comprise multiple characteristic spatial and temporal scales, building the physically relevant models necessarily requires one to incorporate noise and explicit coupling delays as important ingredients. Noise is naturally associated to fluctuations in the embedding environment and the variability of intrinsic parameters derived from essentially coarse-grained descriptions, whereas the coupling delays account for the finite signal propagation velocities and the latency in neuronal responses to the arriving input.

The first part of my talk will concern the results obtained by Nikola Burić and his collaborators on motifs of delay-coupled excitable or bursting neurons, including the fundamental problems of (*i*) stability and bifurcation analysis of systems of coupled delay-differential equations, and (*ii*) the stochastic stability of the synchronization manifold. Apart from considering the interesting phenomenon of amplitude death and the facilitatory role of delay in giving rise to oscillations and the exact synchronization, it will be shown that the sensitivity of synchronization manifold to noise is crucially affected by the linear or nonlinear form of coupling between the neurons.

The latter part of my talk will address the issue of self-organization in networks of delay-coupled noisy excitable neurons. The focus will be on the use of approximate mean-field models in qualitative analysis of stability and stochastic bifurcations exhibited by the collective network dynamics, both in terms of globally coupled networks and the extension to certain paradigmatic modular networks. The other goal will be to demonstrate some of the less standard applications of the mean-field model with regard to the macroscopic excitability feature and the dynamics of the noise-driven activation processes. For an outlook, I shall point out some of the intricate aspects of how the mean-field approximation may be generalized to more complex scenarios that I have discussed with Nikola.

Note on Higher-dimensional Symmetric Euler Top

Borislav Gajić[1,a)], Vladimir Dragović[1] and Bozidar Jovanović[1]

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We consider the motion of a free symmetric n-dimensional rigid body around a fixed point, restricted to the invariant subspace given by the zero values of the linear Noether integrals. In the case of the $SO(n2)$-symmetry, we show that the motion can be expressed in terms of elliptic functions. In the case of the $SO(n3)$-symmetry, we prove the solvability of the problem by using a recent Kozlov's result on the Euler-Jacobi-Lie theorem.

Time and Times: Some Things I learnt from Nikola Burić

Luis Fariña-Busto[1,a)]

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Is my time your time? Is my past your past? Can you influence my future? Can I influence your past? Some fascinating and disturbing questions will be echoed, together with attempts to answer them and explore other related phenomena. This talk will evoke some memories of conversations with Nikola and tie them with some personal considerations on current research directions in quantum physics with reference to projects funded by ERC.

LIST OF LECTURERS
(in alphabetical order)

Dušan Arsenović, Research Professor, Institute of Physics Belgrade

Antun Balaž, Research Professor, Instute of Physics Belgrade

Časlav Brukner, Professor, Faculty of Physics, University of Vienna, Austria; Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences,Vienna, Austria

Julyan Cartwright, Senior Investigator with the Consejo Superior de Investigaciones Cientificas (CSIC), Instituto Andaluz de Ciencias de la Tierra, Facultad de Ciencias, Granada, Spain

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