ANNUAL REPORT 2010

Physics of Physiological Processes Faculty of Physics, University of Vienna

STAFF

Group speaker:	Ao. Univ. Prof. Dr. Karl W. Kratky
Guest scientist:	Univ. Doz. Dr. Karl E. Kürten
Lecturers:	Mag. Werner Gruber, Univ. Doz. Dr. Karl E. Kürten, Mag. Dr. Hans Günter Löw
Volunteers:	Mag. Werner Gruber, Mag. Dr. Hans Günter Löw
Administration:	Andrea Hnizdo
Diploma students:	Matthias Fukac, Lukas Geyrhofer, Martina Hatzl, Jasmin Kölndorfer, Marvin Kovacs
PhD students:	Mag. Werner Gruber, Dr. Said Ibrahim, Mag. Ivan Lucić, Rozhin Penjweini MSc

RESEARCH

The research group "Physics of Physiological Processes" deals with complex dynamical systems (chaos and systems research) in general and with the physics of the human body in particular. The following topics are considered: nonlinearity and feedback, chaos and fractals, self-organization and synchronization, neuronal and neural networks as well as cellular automata. These areas are interdisciplinary, connecting physics especially with biology, psychiatry/ medicine, economy and ecology. They are treated in various ways: from a fundamental point of view, studying computer experimental results and interpreting experimental data. The group's fields of research in more detail:

Overview: Inter- and transdisciplinary aspects of the physics of physiological processes

By means of studying complex dynamical systems, bridges to other sciences can be built, in research as well as in teaching. Attention is focused on biology and medicine. Among other things, it is investigated how chaos control is used by organisms to regulate their body functions efficiently. Furthermore, several therapies in complementary medicine are interpreted from the view-point of complex dynamical systems.

Interconnected dynamical systems: From cellular automata to genetic and artificial neural network models

Physical, biological, ecological and economical processes are treated using mathematical modeling and computer visualization. Topics:

- Pattern recognition, memorization and retrieval of information
- Self-organizing systems at the borderline between order and chaos
- Evolutionary economics and econophysics
- Neural network applications for computer-aided tomography

For details, see the project of K.E. Kürten and the diploma thesis of L. Geyrhofer.

Neurophysics

The aim of the research is to build up a programming environment to create better biological neuronal networks in order to verify medical and psychological theories of the brain. With this programming environment, it is possible to build up very complex simulations by use of few neurons in order to only of few neurons to describe synchronization of neurons as well as of complex neural systems just by few clicks. Thus, different problems of theoretical neuroscience, as cognitive learning, stammering or the perception of speech can be easily tackled.

The response of heart-rate variability (HRV) to various influences and stimuli

- Humans were exposed to light of different spectral composition and of different and varying intensity. In a further step, three kinds of sound were presented to humans. Data of biophysical parameters (e.g. ECG, EMG, breath) were acquired and then analyzed by nonlinear time series and other methods. Heart-rate variability (HRV) is a major aspect in these investigations.
- Calculating the breathing rate via HRV (utilizing the respiratory sinus arrhythmia) yields another interesting variable that makes new interpretations possible.
- This may be compared to direct measurements of the breathing rate, which also allows considering the breathing rate variability BRV, the counterpart of HRV. This is now under investigation.
- HRV (and BRV) are not only influenced by external stimuli, but also by internal ones, e.g., Hathayoga breathing techniques. For details, see the diploma thesis of M. Kovacs.

Biophysics and Medical Physics

The following topics are dealt with:

- Energetic metabolic parameters of muscle tissue during electrostimulation
- Miniaturized fluorescence diagnostic components using single cellular and molecular spectroscopy methods
- Effects of laser beams and LED radiation in annihilation of mould fungus using spectrophotometry analysis.
- Biophysical investigations of photosensitization within mitotic cell cycle. Electromagnetically induced nonlinear dose-effect relations monitored by novel optical detection methods

For details, see the projects of H.G. Löw and the doctoral thesis of R. Penjweini.

In addition to the research, several courses are offered, e.g., "Complex dynamical systems", "Properties of biophysical systems in theoretical models and experiments", "Physics of physiological processes", "Complementary medicine" and "Theory of complex interconnected systems I & II".

REFEREED PROJECTS

K.E. Kürten

<u>Theory of interconnected systems: from cellular automata to genetic, social, and neural network</u> <u>models</u> (supported by the Royal Society (London) International Joint Projects 2009/R3, European Science Foundation Network-Programme, AQDJJ and by EPSRC Grant, EP/F005482/1)

We study phase transitions from ordered to chaotic behavior applicable to various real-word networks such as gene regulation networks, social networks, multi-agent networks, majority voter networks, epidemic networks, chemical reaction networks, and neural network models. One focus of this study is the determination of critical parameters, where the network is placed "at the edge of chaos", i.e. at a subtle compromise between stability and flexibility, where biological systems have both, the necessary stability and the potential for evolutionary improvements.

Another focus of the project is to give possible explanations for social behaviour, in particularly for the stability or instability of the individual and global opinion during an electoral campaign. We study a mathematical model for the emergence of collective decision making, consisting of N interacting agents, whose opinions are described by Ising spin variables. One focus of this study is the determination of critical parameters, where due to a subtle balance of opportunistic and contrarian behaviour the network can be placed "at the edge of chaos", i.e. at a subtle compromise between stability and flexibility, where the system has both, the necessary stability and the potential for "evolutionary" improvements.

The suggested study extends various Galam models to damage spreading analysis which has successfully been applied earlier to the theory of genetic and neural networks as well as spin models. We study this model on a scale free topology, where the individual agents are not constrained to have the same fixed number K of neighbours. Here we will explore the extent to which the stable regime can be expanded by adjusting the power-law coefficient of the scale free probability distribution. For these more realistic models a substantial increase of the ordered regime at the expense of the disordered regime is to be expected 10 such that even in the case of a "tie" the networks eventually will be stable and can be placed into the ordered phase.

The last major topic of the project is the application of methods of statistical mechanics to wealth distributions in a free economy situation. We find that distributions of money or income usually take the form of a general Bose-Einstein. In analogy to kinetic energy exchange models in physics the market can be described by three parameters: temperature, chemical potential and the space dimensionality. Numerical simulations and a detailed analysis of generic models confirm these findings.

H.G. Löw

• <u>Biophysical investigation of energetic metabolic parameters of muscle tissue during electrostimulation: papillary- and skeletal muscles as examples</u> (cooperation-project with the Institute for Toxicology, University of Vienna)

Based on the physical developments during the refereed project "Continuous fluorescence-optical detection of energetic metabolic parameters of cardiomyocytes during stress induction by electrostimulation" (University of Vienna and Facultas Verlag), further developments are performed. Primary specific aim of this project is to investigate biophysical parameters in vital muscular biomolecules under presence of short pulsed magnetic fields. Modulating the chemical and environmental conditions of the buffer solutions as well as coil-conformations and current pulse shapes studies are focused on influences of dynamic contraction-force-development as well as on autofluorescence, oxygen demand, calcium-fluorescence which represent ionic channel activities under pulsed magnetic stress induction. Force-frequency relations under presence of ionic channel blockers as well as under normoxic and hypoxic conditions are measured. Influences of spectral components of magnetic pulses on penetration depth and biomechanical transduction efficiency are studied using a novel type organ bath. This instrument allows combining fluorescence excitation, optical detection of muscle tissue as well as simultaneous measurement of muscle-tension. All data are recorded and time-stamped within a datastream using LABVIEW-Software packages and a novel developed software protocol which allows minimizing stochastic signal deviations during acquisition. This application oriented project allows specifying the electrodynamic field-parameters influencing muscle contraction and characterizes a novel kind of muscle-stimulation from biophysical and biomedical point of view.

H.G. Löw

• <u>Fluorescence diagnosis, mini-FACS on chip research and development of miniaturized fluorescence diagnostic components using single cellular and single molecular spectroscopy methods</u> (cooperation-project with the Ludwig Boltzmann Institute for Andrology and Urology, KH Lainz, Vienna, and with the Max F. Perutz Laboratories, Campus Vienna Biocenter)

Based on the results of the refereed project 9675 (Austrian National Bank, see above), time-correlated methods for detection of molecular binding properties between biomolecules are applied to develop and construct a miniaturized fluorescence detection device for small liquid samples in context to establish binding assays for medical diagnosis. The aim of this project is focussed to construct an "easy to use+ low-cost" fluorescence device for diagnostic physicians, which allows performing prescreening-tests on patients blood and liquid samples. Incubation the novel developed tumor-targetting substance Photovidon (Hypericin-PVP-Complex derivative) urinary samples of potential bladder-wall cancer patients are investigated using a "mini-FACS" device as well as an ordinary standard fluorescence cell-sorter (FACS). The correlations between both methods are compared and related to the clinical data supplied by the hospital. The novel device is a contribution to early cancer diagnosis methods in biomedicine and may enhance diagnostic performance at low cost levels.

COOPERATIONS

a. INTERNATIONAL COOPERATIONS

K.W. Kratky

<u>CANADA</u>

• International Institute for Advanced Studies in Systems Research and Cybernetics, Tecumseh, Ontario (G.E. Lasker)

GERMANY

- Lehrstuhl für Medizintheorie und Komplementärmedizin der Universität Witten / Herdecke (D. Cysarz)
- Filderklinik, Filderstadt-Bonlanden (A. Schäfer)
- Department of Music Education and Music Therapy, Siegen University, Siegen (C.-L. Zhang)

K.E. Kürten

BELGIUM

• Laboratory of Physiology, Department of Molecular Cell Biology, Catholic University of Leuven (L. Raeymaekers)

FRANCE

• École Polytechnique, Paris (S. Galam)

HUNGARY

• Collegium Budapest (G. Kampis)

UK

• School of Mathematical and Physical Sciences, Loughborough University (F.V. Kusmartsev)

USA

• Department of Physics; Washington University, St. Louis (J.W. Clark)

H.G. Löw

<u>RUSSIA</u>

• Rostov State University, Biophysics Department, Rostov-on-Don (A. Uzdensky)

NORWAY

• Institute for Cancer Research, Montebello, Oslo (J. Moan)

USA

• Wellman Center for Photomedicine, Massachusetts General Hospital, Boston (M.R. Hamblin et al.)

W. Gruber

GERMANY

- Fachhochschule des Bundes FB Bundespolizei / Lübeck (M. Möllers)
- BV1 Bildungsverlag EINS, Troisdorf (D. Roland)
- ZDF Redaktion Markus Lanz (Th. Mau)

b. NATIONAL COOPERATIONS

K.W. Kratky

• Institute of Electrodynamics, Microwave and Circuit Engineering, Vienna University of Technology (group *Biomedical Sensors*, E. Kaniusas)

- Joanneum Research, Institut für Nichtinvasive Diagnostik, Weiz (M. Moser)
- Interuniversitäres Kolleg für Gesundheit und Entwicklung, Graz / Schloss Seggau (P.C. Endler)
- Akademie für Ganzheitsmedizin, Wien (W. Marktl)

H.G. Löw

- Department für Strukturbiologie und Computational Biology der Universität Wien (E. Gaubitzer, G. Grabner, G. Köhler)
- Institut für Physiologie der Medizinischen Universität Wien (D. Schmid)
- Institut für Medizinische Chemie der Medizinischen Universität Wien (P. Chiba)
- Geriatriezentrum Am Wienerwald, Lainz (H. Löw-Weiser, R. Werni)
- Department für Pharmakologie und Toxikologie der Universität Wien (C. Studenik)
- Ludwig Boltzmann Institut für Andrologie and Urologie, KH Lainz, Wien (H. Pflüger)

W. Gruber

- Wiener Volkshochschulen, Programm 'University meets public' (M. Ludwig)
- Atominstitut der Österreichischen Universitäten, Wien (H. Oberhummer)
- Kapsch Science to people (W. Stagl)
- KPH Krems (R. Binder)

R. Penjweini

- Department of Bioelectronics, Institute of Solid State Electronics, Vienna University of Technology (S. Saghafi, K. Becker)
- Institute of Cancer Research, Medical University of Vienna (M. Eisenbauer, P. Breit)

PUBLICATIONS

a. ALREADY ISSUED

• D. Schmid, D.L. Staudacher, C.A. Plass, **H.G. Löw**, E. Fritz, G. Steurer, P. Chiba, T. Möslinger, *Pinacidil-primed ATP-sensitive potassium channels mediate feedback control of mechanical power output in isolated myocardium of rats and guinea pigs*. Eur J Pharmacol **628** (2010) 116-127.

We tested the hypothesis, that ATP-sensitive potassium (K(ATP)) channels limit cardiac energy demand by a feedback control of mean power output at increased cardiac rates. We analysed the interrelationships between rising energy demand of adult rat and guinea pig left ventricular papillary muscle and down-regulatory electromechanical effects mediated by K(ATP) channels. Using the K(ATP)-opener pinacidil the stimulation frequency was increased stepwise and the mechanical parameters and action potentials were recorded. Power output was derived from force-length area or forcetime integral calculations, respectively. Simultaneously oxygen availability in the preparations was estimated by flavoprotein fluorescence measurements. ADP/ATP ratios were determined by HPLC. We found highly linear relationships between isotonic power output and the effects of pinacidil on isotonic shortening in both rat ($r^2 = 0.993$) and guinea pig muscles ($r^2 = 0.997$). These effects were solely observed for the descending limb of shortening-frequency relationships. In addition, a highly linear correlation between total force-time integral-derived power and pinacidil effects on action potential duration (APD(50), $r^2 = 0.92$) was revealed. Power output became constant and frequencyindependent in the presence of pinacidil at higher frequencies. In contrast, the K(ATP)-blocker glibenclamide produced a lengthening of APD(50) and increased force transiently at higher power levels. Pinacidil prevented core hypoxia and a change in ADP/ATP ratio during high frequency stimulation. We conclude, that pinacidil-primed cardiac K(ATP) channels homeostatically control power output during periods of high energy demand. This effect is associated with a reduced development of hypoxic areas inside the heart muscle by adapting cardiac function to a limited energy supply.

• S. Saghafi, R. **Penjweini**, K. Becker, **K.W. Kratky** and H.-U. Dodt, *Investigating the effects of laser beams (532 and 660 nm) in annihilation of pistachio mould fungus using spectrophotometry analysis.* J. Eur. Opt. Soc.- Rapid Publ. **5**, 10033s1-8 (2010).

When moulds are illuminated by visible electromagnetic-EM radiations, several effects on nucleus materials and nucleotides can be detected. These effects have a significant influence on mould generation or destruction. This paper presents the effects and implications of a red diode laser beam (660 nm), a second-harmonics of a Nd:YAG laser emitting green beam (532 nm), or the combination of both, on the eradication of Pistachio mould fungus. Incident doses (ID) of both beams are kept identical throughout the experiment. The absorption spectrums of irradiated mouldy samples and the bright-greenish-yellow-fluorescence (BGYF) of fungus occurring in mould texture due to electronic excitation are investigated. We found that a combination of a green and a red laser beam with an ID of 0.5 J/cm² provides the optimal effects on Pistachio mould fungus eradication.

• F.V. Kusmartsev and **K.E. Kürten**, *Chaotic modes in scale free opinion networks. In:* F.V. Kusmartsev (ed.), *Condensed Matter Theories. Vol. 24.* Proceedings of the 32nd International Workshop. World Scientific, Singapore 2010 (pp.65-84).

In this paper, we investigate processes associated with formation of public opinion in varies directed random, scale free and small-world social networks. The important factor of the opinion formation is the existence of contrarians which were discovered by Granovetter in various social psychology experiments long ago and later introduced in sociophysics by Galam. When the density of contrarians increases the system behavior drastically changes at some critical value. At high density of contrarians the system can never arrive to a consensus state and periodically oscillates with different periods depending on specific structure of the network. At small density of the contrarians the behavior is manifold. It depends primarily on the initial state of the system. If initially the majority of the population agrees with each other a state of stable majority may be easily reached. However when originally the population is divided in nearly equal parts consensus can never be reached. We model the emergence of collective decision making by considering N interacting agents, whose opinions are described by two state Ising spin variable associated with YES and NO. We show that the dynamical behaviors are very sensitive not only to the density of the contrarians but also to the network topology. We find that a phase of social chaos may arise in various dynamical processes of opinion formation in many realistic models. We compare the prediction of the theory with data describing the dynamics of the average opinion of the USA population collected on a day-by-day basis by varies media sources during the last six month before the final Obama-McCain election. The qualitative outcome is in reasonable agreement with the prediction of our theory. In fact, the analyses of these data made within the paradigm of our theory indicates that even in this campaign there were chaotic elements where the public opinion migrated in an unpredictable chaotic way. The existence of such a phase of social chaos reflects a main feature of the human being associated with some doubts and uncertainty and especially associated with contrarians which undoubtly exist in any society.

• M. Forrester, E. Kovacs, **K.E. Kürten** and F.V. Kusmartsev, *Astroid curves for a synthetic antiferromagnetic stack in an applied magnetic field. In:* F.V. Kusmartsev (ed.), *Condensed Matter Theories. Vol. 24.* Proceedings of the 32nd International Workshop. World Scientific, Singapore, 2010 (pp.85-194).

The interaction of two magnetic particles separated by an interlayer is illustrated through the "astroid" curves that represent regions in the magnetic field plane where different numbers of minima associated with stable or metastable states may exist. For a single particle, we describe the astroid curves of the Stoner-Wohlfarth model. The case of two particles is then examined and found to be much more complicated. The energy landscape of the two-particle system contains ferromagnetic, antiferromagnetic and canting states that emerge in response to the level of applied magnetic field. Because of this, up to four energy minima can exist in the system, depending upon the strength of the magnetic field and the material properties of the particles.

• J.W. Clark, A. Mandilara, M.L. Ristig and K.E. Kürten, *Entanglement properties of quantum many-body wave functions. In:* F.V. Kusmartsev (ed.), *Condensed Matter Theories. Vol. 24.* Proceedings of the 32nd International Workshop. World Scientific, Singapore 2010 (pp.105-121).

The entanglement properties of correlated wave functions commonly employed in theories of strongly correlated many-body systems are studied. The variational treatment of the transverse Ising model within correlated-basis theory is reviewed, and existing calculations of the one- and two-body reduced density matrices are used to evaluate or estimate established measures of bipartite entanglement, including the Von Neumann entropy, the concurrence, and localizable entanglement, for square, cubic, and hypercubic lattice systems. The results discussed in relation to the findings of previous studies that explore the relationship of entanglement behaviors to quantum critical phenomena and quantum phase transitions. It is emphasized that Jastrow-correlated wave functions and their extensions contain multi-partite entanglement to all orders.

• K.E. Kürten and F.V. Kusmartsev, *About distribution of money in a free market economy*. In: I. Spanulescu (ed.), ENEC 2010. Proceedings of the International Conference on Econophysics, New Economy and Complexity, 20-22 May 2010, Bucharest. Victor Publishing House, Bucharest, Romania 2010 (pp.7-21).

We study a sophisticated model of a market belonging to the class suggested originally by Angle et al. (see Review, and references therein) where a fixed number of trading agents exchange and transfer money. We show that the probability distribution of money, income or wealth resulting in the long-term trading process may take a specific form depending on the amount of money rotated in a single turnover process, where all agents are involved. These distributions are associated with a stable steady state of the macroscopic dynamical trading processes and may describe different market economies. The structure of these distributions depends crucially on average income, democracy, the standard of life and other features associated with political and economic structures of the market economy at equilibrium and may be described by a few parameters, only. One of these parameters can be called a temperature, which is similar to one introduced earlier by Yakovenko and collaborators and connected with an average money which economic agents have. Such parameter may separate hot and cold markets which behaviour is different. Specifically for some "cold" market economies when the temperature is smaller than average amount of money per agent we find the Boltzmann distribution found before by Yakovenko et al. In such market there is a large amount of goods flow and money and the market is associated with countries having a population with high average income and standard of life. However for hotter countries when the temperature tends to the average amount of money per agent this distribution is changing and may take both a Poisson form which gradually transformed from conventional Boltzmann form, when the level of life increases. On the other hand for very cool countries, when the temperature is significantly smaller than average amount of money per agent there arises another form of the money distribution – a Bose-Einstein one. That may arise for very cold market economies, when the most of money are accumulated only in a few economic agents. It is associated normally with not well developed countries having lower level of life, when only a small amount of money and goods flow taken part in the trading processes or in cases when financial crises arises.

• K.E. Kürten, Dynamical Stability of Scale-free Opinion Networks: Opportunists versus Contrarians. In: I. Spanulescu (ed.), ENEC 2010. Proceedings of the International Conference on Econophysics, New Economy and Complexity, 20-22 May 2010, Bucharest. Victor Publishing House, Bucharest, Romania 2010 (pp.277-289).

We present a dynamical binary opinion model for the emergence of collective decision making based on the majority and the minority principle. The network consists of N interacting agents, whose opinions are described by Ising spin variables. The connectivity structure of the network is flexible, specified by suitable probability distributions. Damage spreading techniques show how the dynamical stability of these models depends on the choice of these structures. We present critical network parameters, where the network undergoes a dynamical phase transition from ordered to disordered behaviour in analogy to earlier studied genetic and neural network models. Variation of the control parameters of the connectivity distributions can largely enhance the parameter range of the network stability. The model is meant to give possible explanations for social behaviour, in particular for the stability and instability of the individual and global opinion during an electoral campaign.

b. ACCEPTED

• **K.E. Kürten** and F.V. Kusmartsev, *Bose-Einstein distribution of money in a free market economy. II* (to be published in: Europhysics Letters **93**, 2011)

We argue apply methods of statistical mechanics to free economy (Kusmartsev F. V., Phys. Lett. A, 375 (2011) 966) and find that the most general distribution of money or income in a free market economy has a general Bose-Einstein distribution form. Therewith the market is described by three parameters: temperature, chemical potential and the space dimensionality. Numerical simulations and a detailed analysis of a generic model confirm this finding.

• D.M. Forrester, **K.E. Kürten** and F.V. Kusmartsev, *Fundamental design paradigms for systems of three interacting magnetic nanodiscs* (to be published in: Appl. Phys. Lett. **98**, 2011)

The magnetic properties of a system of three interacting magnetic elliptical discs are examined. For the various levels of shape anisotropy investigated a complicated series of phase transitions exists. These are marked by the critical lines of stability that are demonstrated in an applied magnetic field plane diagram.

c. SUBMITTED

• D. M. Forrester, **K.E. Kürten** and F.V.Kusmartsev, *Properties of nano-engineered materials made of magnetic particles* (submitted to the World Journal of Engineering)

The mono-domain magnetic particle is being incorporated into our technologies with breathtaking progress and the characteristics of such particles can be elucidated upon if you pay close attention to the shape anisotropy. The shape anisotropy is a measure of the difference between the energies associated with the magnetisation in the shortest and longest dimensions of the particle. We consider the particles as elliptic cylinders. A long cylinder has a greater magnetostatic energy associated with is magnetisation perpendicular to its major axis than that associated with its magnetisation parallel to the axis. Crudely this can be visualised by considering the closeness of the related but oppositely charged magnetic poles that appear upon the application of an external magnetic field that gives the net magnetisation. Parallel to the axis the poles have a wide separation and low magnetostatic energy. This means that the long axis is the easy axis of shape anisotropy. Axes perpendicular to this axis are hard axes of magnetisation. The energy difference in a cylinder is given in terms of the demagnetising factors. Exact values of these factors can be calculated for uniformly magnetised ellipsoids. Through the axial ratio a/b, where a is the length of the major semiaxis and b the length of the semi-axis perpendicular to it from the centre of the particle we find the demagnetisation factors and the corresponding shape anisotropy energies. K is made dimensionless and its value is zero for a perfectly circular cross section. K increases with the ratio of the semi-axes lengths.

d. ABSTRACTS IN CONFERENCE PROCEEDINGS

• **R. Penjweini**, F. Mohajer, A. Geranmayeh, **K.W. Kratky** and S. Saghafi, *Characterizing the Effects of Combinations of Visible-Infrared Laser Beam and Blue/Red-Led-Arrays on Albican Candida and Pityriasis Versicolor Destruction.* In: M. Musso (ed.), 60th Annual Meeting of the Austrian Physical Society, 6-10 September 2010, Salzburg (p.126).

This study presents the effects of combinations of non-ionizing coherent and non-coherent visible-near infrared light on destruction of *Albican Candida* and *Pityriasis versicolor in vivo*. Considering the absorption spectra of Candida obtained using Carry-500-scans spectrophotometer, a second harmonics of Nd:Yag laser (100 mW / 3 mm spot-size), a red diode laser (120 mW / 8 mm spot-size), an infrared diode laser (150 mW / 6 mm spot size), an array of 24 Blue-LED (72 mW) and array of 20 Red-LED-Array (80 mW) have been chosen as illuminating sources.

During the irradiation process, candida infections received 6, 10 and 14 J/cm² laser light incident doses (*ID*) of 532 nm, 660 nm and 980 nm coherent beams, respectively. Additionally, it received 2 J/cm² *ID* from LED arrays ($420 < \lambda < 470$ nm and $624 < \lambda < 660$ nm).

Patients with *Albican Candida* had 7 sessions of illuminations and the patients with *Pityriasis versi-color* had 15 sessions of illuminations. In addition to the ability of photons to produce electronic excitations in chromophores, light can induce a wave-like alternating electric field in Candida that interacts with polar structures. It produces dipole transitions at different cellular and biochemical processes. Furthermore, the Reactive Oxygen Species (ROS) production that is cytotoxic can be increased due to this processes and it can kill the Candida cells when the concentration becomes sufficiently high. The method is accurate, highly reproducible and relatively inexpensive.

• K.W. Kratky, *The health disc as an abstract space describing physiological and pathological states: Relation to heart and breathing rates and extension to higher dimensions* (Abstracts of the 3rd European Congress for Integrative Medicine, 3-4 December 2010, Berlin). European Journal of Integrative Medicine **2** (2010) 251-2.

Introduction and outline. In order to compare and integrate Eastern and Western methods of complementary medicine, the health disc was introduced [1]. This disc can be interpreted as an abstract phase space in the sense of nonlinear physics. The starting point had been a circle, which was extended to the disc. Physiological or pathological states can be interpreted as points on the disc: close to the centre and boundary are the healthy and diseased states, respectively. The direction of a point (as seen from the centre) has to do with the type of the person and the disease, the connection of these two being discussed.

Methods and results. The portions of the disc can most easily be described in terms of the three doshas (principles of regulation) in Ayurveda. Due to the comparison and integration done in [1], interpretations in terms of Traditional Chinese medicine TCM (yin, yang and qi) and homeopathy (three miasms) are also possible. In the following, the health disc is elaborated in order to enhance its Western scientific interpretation. This is done using Ayurvedic literature where the heart and breathing rates of the doshas are specified. Hence a mathematical attribution of the points of the disc to heart and breathing rates is developed. At last, an extension of the disc to higher dimension is proposed, where the Greek, Indian and Chinese elements are being taken into account.

Conclusion and discussion. In nonlinear physics, the starting point is usually a high-dimensional abstract space of the considered complex system. Using good approximations, the space is reduced as far as possible to yield a preferably low-dimensional state space. Our approach is a different one: We started with 1- and 2-dimensional spaces (health circle and disc) as first steps to describe the complex physiological and pathological states. In the present paper, the interpretation is refined by taking heart and breathing rates into account. Furthermore, higher-dimensional spaces are considered. By the way, measurements of heart-rate variability indicate that a 5-or 6- dimensional phase space would be sufficient in a very good approximation. This may be compared with the number of Greek, Indian and Chinese elements. Thus the conceptual integration of medicine systems moves forward.

Reference: [1] Karl W. Kratky, Complementary Medicine Systems. Comparison and Integration (Health and Human Development Series, ser. ed. Joav Merrick). Nova Science, NY 2008.

 K.W. Kratky, Integrative Medizin: nur ein Schlagwort? Vergleich und Integration medizinischer Richtungen im Fokus (Abstracts of the Congress "Menopause – Andropause – Anti-Aging 2010", 9-11 December 2010, Vienna). J Gynäkol Endokrinol 134 (2010) 37.

Von der "Integrativen Medizin" ist immer öfter die Rede. Es gibt inzwischen auch Kongresse und Zeitschriften, wo dieser Ausdruck vorkommt. Was ist damit aber gemeint? Darunter kann man sich nämlich verschiedenes vorstellen:

- Das Einbeziehen z.B. der Akupunktur in die (schul-) medizinische Praxis.
- Das "Mischen" mehrerer Therapien, die von verschiedenen Medizinsystemen stammen.
- Eine Erweiterung der Komplementärmedizin bzw. ein neuer Ausdruck für Ganzheitsmedizin.

- Die Kenntnis mehrerer (komplementär-) medizinischer Richtungen, die es einem erlaubt, die jeweils beste Methode anzuwenden bzw. bestimmte Fälle gezielt an Kolleginnen und Kollegen anderer Richtungen zu überweisen ("think global, act local").
- Ein geistiges Konzept, das versucht, die unterschiedlichen Medizinsysteme zu vergleichen und letztlich zu einem neuen Ganzen integrieren.

Vor allem mit dem letztgenannten Aspekt habe ich mich auch in meinem Buch über komplementäre Medizinsysteme [1-2] beschäftigt. Dabei hat sich gezeigt, dass es beim Vergleich der Systeme wesentliche Fortschritte gibt, die Integration aber "work in progress" ist und letztlich noch eine Zukunftsvision darstellt. Ich selber habe ein geometrisches Modell vorgestellt, das – vergleichbar mit einem Steuerrad oder einem Kompass – eine Zusammenschau verschiedener westlicher und östlicher Medizinsysteme darstellt. Auf dieses Modell wird am Schluss des Vortrags eingegangen.

- Literatur: [1] Karl W. Kratky, Komplementäre Medizinsysteme. Vergleich und Integration. Ibera / European University Press, Wien 2003 (ISBN 3-85052-148-6).
 - [2] Karl W. Kratky, Complementary Medicine Systems: Comparison and Integration. Nova Science, Hauppauge, New York 2008 (ISBN 1-60456-475-X)

e. BOOKS

• W. Gruber, H. Oberhummer und M. Puntigam, Wer nichts weiß, muss alles glauben. Ecowin, Salzburg 2010.

LECTURES, CONFERENCE CONTRIBUTIONS, POSTERS

a. LECTURES

K.W. Kratky

- Vergleich und Integration komplementärmedizinischer Verfahren (Modulbilanz für Gr. 32 & 36, Masterlehrgang für Komplementäre, Psychosoziale und Integrative Gesundheitswissenschaften, Interuniversitäres Kolleg für Gesundheit und Entwicklung, Schloss Seggau, Österreich), 22.1.2010
- Vergleich und Integration komplementärmedizinischer Verfahren (Modulbilanz für Gr. 29-31, Masterlehrgang für Komplementäre, Psychosoziale und Integrative Gesundheitswissenschaften, Interuniversitäres Kolleg für Gesundheit und Entwicklung, Schloss Seggau, Österreich), 23.1.2010
- Weltbilder komplementärmedizinischer Richtungen (Ringvorlesung "Komplementärmedizinische Methoden. Grundlagen, Möglichkeiten, Grenzen" an der Medizinischen Universität Wien), 3.3.2010
- Komplementäre Medizinsysteme (Weiterbildung "Energetische Modelle und Methoden Therapeutische Berührung", Zentrum – Lebensenergie, Wien), 5.3.2010
- Die Herzfrequenz-Variabilität als Indikator des autonomen Nervensystems (Workshop 35 der Med-Success 2010 der Österreichischen Medizinerunion; AKH Wien), 13.3.2010

K.E. Kürten

- Opinion dynamical networks: Coexistence of opportunists and contrarians on scale-free topologies (Collegium Budapest, Hungary), 23.01.2010
- Stoner- Wohlfahrt Theory extended to a stack of arbitrary numbers of interacting magnetic nanodiscs (Department of Physics, Loughborough University, UK), 26.4.2010
- Network stability: A subtle interplay between ferromagnetic and antiferromagnetic interactions in social networks (Department of Physics, Loughborough University, UK), 22.10.2010
- Meaningful biological Boolean interactions in genetic networks (Department of Molecular Cell Biology, <u>Catholic University of Leuven</u>, Belgium), 19.11.2010
- Wealth distribution models: generalized gamma distribution in physics (Collegium Budapest, Hungary), 24.11.2010

b. CONFERENCE CONTRIBUTIONS

- K.E. Kürten: Dynamical Properties of Opinion Networks at the Edge of Chaos: A Subtle Interplay between Opportunists and Contrarians (invited lecture at the International Conference "Econophysics, New Economics and Complexity" ENEC 2010, Hyperion University, Bucharest, Romania, May 20-22, 2010), 22.5.2010
- K.E. Kürten: Dynamical Properties of Networks at the Edge of Chaos (invited lecture at the International Conference on Computational Science ICCS 2010: "Celebrating 10 years of Advancing Computational Thinking", University of Amsterdam, The Netherlands, May 31 - June 2, 2010), 2.6.2010
- **R. Penjweini:** Characterizing the Effects of Combinations of Visible-Infrared Laser Beam and Blue/Red-Led-Arrays on Albican Candida and Pityriasis Versicolor Destruction (60th Annual Meeting of the Austrian Physical Society, September 6-10, 2010, University of Salzburg, Austria), 9.9.2010
- K.W. Kratky: Integrative Medizin: nur ein Schlagwort? Vergleich und Integration medizinischer Richtungen im Fokus (eingeladener Vortrag beim Kongress "Menopause, Andropause, Anti-Aging 2010", 9.-11. Dezember 2010, Hotel Hilton Vienna, Austria), 11.12.2010

c. POSTERS

• **K.W. Kratky**: The health disc as an abstract space describing physiological and pathological states: Relation to pulse and breathing rates (3rd European Congress for Integrative Medicine, December 3-4, 2010, Berlin), 3.12.2010.

DIPLOMA THESES – PHD THESES (Supervisor: K.W. Kratky, if not stated otherwise)

a. CURRENT DIPLOMA THESES

• M. Fukac

Simulation des menschlichen Sehsystems

• M. Hatzl

Die Wirkung von optischen und akustischen Reizen auf die HRV (heart-rate variabiltiy): Interpretation und Auswertung der Experimente

• J. Kölndorfer

Klassifizierung von Sprache und Geräuschen mittels eines Biologischen Neuronalen Netzwerks von Integrate-and-Fire Oszillatoren

• M. Kovacs

Die Auswirkung von Hathayoga-Atemtechniken auf die Herzfrequenzvariabilität

Abstract of the results up to now: ECG and breathing data of the measuring device NEXUS-10 (Mindmedia Company) were used. A whole session took one and a half hours for each of the 24 probands. There were alternating phases of relaxation (lying, sitting) and breathing exercises (Pranayama). In each session, 11 measurements of 3 minutes each took place. In the following, we stick to the variables P (pulse or heart rate), B (breathing rate), Q (quotient P/B) and SDNN, which is in essence the standard deviation of heart rate.

Comparison between the results of the different measurements (average of all probands): Concerning P, B and Q, there were highly significant differences between the lying periods at the beginning and the end of a session and all other phases.

As to the differentiation between the behavior of different subgroups of probands, the results are less impressive. In essence, only SDNN showed clear significances at some phases, viz. concerning the difference between yoga beginners and very experienced people as well as the difference between yoga disciples and experienced instructors.

b. COMPLETED DIPLOMA THESES

• L. Geyrhofer (Supervisor: K.E. Kürten)

Critical phenomena and dynamical phase transitions in Boolean networks

Abstract: Boolean Networks have been used as highly non-linear dynamical models in biology, sociology and economics. Together with the introduction as gene regulatory networks in the late 1960s, Stuart Kauffman established two different phases of the dynamics in Boolean Networks: the ordered phase, where eventual perturbations vanish rather quickly, and the disordered phase, where a small perturbation might spread over the whole network. In the 1980s statistical considerations by Bernard Derrida and coworkers vielded analytical results for the dynamical behavior of those networks, especially a statistical characterization of the critical condition for this phase transition was obtained. In this work, recent developments have been compiled and presented in a rather formal way, with special emphasis on this critical condition, which is important, because many networks in nature are believed to be close to this dynamical phase transition. An approach for the derivation of coupled iteration equations of the macroscopic parameters magnetization and Hamming distance is explained for arbitrary mixtures of Boolean functions and distribution of in-degrees. From these iteration equations the critical condition is derived, showing that this condition only depends on the average sensitivity of the mixture of Boolean functions. Furthermore, the equivalence of using higher sensitivities in the construction of the polynomial for the Hamming distance is established to be a restriction to the magnetization, which cannot be maintained over time, and therefore fails to predict the fixed point in the Hamming distance observed in computer simulations.

In the second part of this work, this formalism has been applied to Linear Threshold functions. They are a subclass of all possible Boolean functions and an explicit projection to Boolean functions is given. Complete phase diagrams have been calculated for several different Boolean Networks with all functions being Linear Threshold functions, where two parameters have been included, the threshold *h* and the asymmetry *p* in the distribution of weights, which is an additional degree of freedom compared to several earlier publications. Finally, it has been proven for a simple mixture of Linear Threshold functions that the parameter region corresponding to the ordered phase actually grows with increased connectivity *K*, and the parameter region of the disordered phase shrinks to a single value in the limit $K \to \infty$. This is contrary to the Kauffman model, where the opposite behavior is observed: the parameter region of the disordered phase spans the complete interval in the limit $K \to \infty$. This is an interesting result, because biological networks usually have a connectivity larger than the critical value $K_c = 2$ in the (unbiased) Kauffman model, so that a more realistic topology could be imposed on the Boolean Networks, where also nodes with a higher in-degree occur, without being restricted to extreme values of the external parameters.

c. CURRENT PHD THESES

• W. Gruber

Physikalische Beschreibung des menschlichen Gehirns: Verbände von Neuronen

• S. Ibrahim

Naturwissenschaftliche Grundlagen der medizinischen Systeme

• I. Lucić

Der Einfluss unterschiedlicher Frequenzen auf biologische Systeme

• **R. Penjweini** (Co-Supervisor: **H.G. Löw**)

Biophysical investigations of photosensitization within mitotic cell cycle. Electromagnetically induced nonlinear dose-effect relations monitored by novel optical detection methods

Abstract of the results up to now: During fluorescent live cell imaging it is critical to keep excitation light dose as low as possible, especially in presence of photosensitizer drugs which generate free radicals upon photobleaching. Stress by excitation and free radicals during fluorescent imaging induces serious cell damages that may arrest the cell cycle. This limits usefulness of the technique for drug discovery, when prolonged live cell imaging is necessary. Up to now, the fluorescence imaging of live

cells proliferation is limited to a few minutes' monitoring in the presence of dyes with low phototoxicity. Correspondingly, this method still has not been introduced to prolonged in-vitro photodynamic diagnostic and therapy in presence of PVP-Hypericin (a strong photosensitizer).

Now we present a strategy to provide experimental conditions for hours-long dynamic monitoring of the proliferation of human lung epithelial carcinoma cells (A549) in presence of PVP-Hypericin. The specific strategy of this project is based on the stringent environmental control, minimizing the excitation light dose by using a pulsed blue LED and improving the fluorescence signals by using an additional fluorescent dye (CFSE). To demonstrate the usefulness of this strategy, cell proliferation and fluorescence signals under excitation were compared for the following conditions:

- usual illumination by a tungsten halogen lamp for visual inspection
- continuous blue-LED excitation
- pulsed blue-LED excitation (pulse of 13 ms duration every 2 minutes)

In both cases of excitation, the cells were marked with CFSE and PVP-Hypericin, the experiments took 2 hours, and the light intensity at the focal plane was 9.83 mW/cm² during the live cell imaging. The results demonstrated strong fluorescence signals and reduced photobleaching and phototoxicity for the pulsed excitation, which enables experiments to be performed over longer time scales than with conventional continuous excitation.

PRIZES AND AWARDS

W. Gruber

- Golden book award for "Die Genussformel" given by Federal Minister for Science and Research Dr. B. Karl
- Golden book award for "Unglaublich einfach" given by Federal Minister for Science and Research Dr. B. Karl
- "Communicator of the year" given by Public Relations Verband Austria and by the Federal Ministry of Economy, Family and Youth

PRESENCE IN THE MEDIA

K.W. Kratky

Print media

- ernährung heute 3 (2010):
 - Artikel "auf den Blickwinkel kommt es an", S.3
 - Interview "Kleiner Reiz große Wirkung", S.4

W. Gruber

He features on all relevant media – as print, radio and television – in Austria, Germany and Switzerland. Some examples:

Print media

- "Formidabel", Süddeutsche Zeitung, Feuilleton, 1.10.2010
- "Wissen ist Zufall", taz, 2.11.2010
- "Berechnung über die 5. Jahreszeit", Salzburger Nachrichten, 10.9.2010
- "Die Gurke zum Glühen bringen", Die Zeit, 21.10.10
- "Ein schwarzes Loch im Goldfischglas", Süddeutsche Zeitung, 21.10.2010
- "Tanz der Moleküle", Die Welt, 6.9.2010
- "Die mit der Laserwurst", Hannoversche Allgemeine Zeitung, 18.11.2010

- "Die drei Musketiere der Physik", Salzburger Nachrichten, 1.9.2010
- "Die Welt im Strandkorb", Die Presse, 5.9.2010
- "Schwere Kost Lichtnahrung", Die Presse am Sonntag, 19.9.2010
- "Ein Physikbuch zum Zerkugeln", Kleine Zeitung, 20.9.2010
- "Von echten Skeptikern und falschen Wundern", Kärntner Tageszeitung, 3.10.2010
- "Wer nichts weiß muss alles glauben", dpa-Dossier Wissenschaft, 20. 9.2010
- "Wissen statt glauben", Thüringer Allgemeine, 4.9.2010
- "Schwarze Löcher und viel schwarzer Humor", Hamburger Abendblatt, 12.10.2010

Radio and television

- "Die Physik des Bodyscanners", Markus Lanz, ZDF, 13.1.2010
- "Der LHC", ZIB 3, ORF 1, 1.4.2010

MISCELLANEOUS

K.W. Kratky

- Member of the Scientific Board of the journals "Systeme" and "lebensweise".
- Member of the Editorial Board of the "Journal of Alternative Medicine Research" and reviewer of the journal "Research in Complementary and Classical Natural Medicine".
- Member of the Scientific Board of the Viennese International Academy of Holistic Medicine as well as the Institute of Ethno-music Therapy, Gföhl, Austria.
- Member of the Advisory Board of the Institute of Integrative Morphology, Hamburg, Germany.
- Fellow of the International Institute for Advanced Studies in Systems Research and Cybernetics, Tecumseh, Ontario, Canada.
- Member of the team of the Interuniversity College for Health and Development, Graz / Castle of Seggau, Austria. There, also lecturer at the European Master's Degree Program for Integrated Health Sciences.
- Member of the Board of Governors of the Scientific Society 'Dynamics Complexity Human Systems', Vienna, Austria.
- Member of the "Beirat für Traditionelle Asiatische Medizin im Bundesministerium für Gesundheit" (Vienna, Austria).

K.E. Kürten

- Guest Scientist and Lecturer.
- Visiting professor (Loughborough)
- Supervisor of the diploma thesis "Critical phenomena and dynamical phase transitions in Boolean networks" of L. Geyrhofer

W. Gruber

- Volunteer and Lecturer at the research group "Physics of Physiological Processes"
- General Editor at CISCI (Cinema and Science), an EU-Project for teaching physics.
- Lecturer at various adult evening classes ("Wiener Volkshochschulen") within the context of the project "University meets public".
- Member of the "ScienceBusters".
- Head of the jury for the "Red Bull paperwings" world championship
- Vorstandsmitglied der VHS Meidling, Wien, Austria.
- Wissenschaftlicher Beirat der KPH Krems, Austria.

H.G. Löw

- Volunteer and Lecturer.
- Co-supervisor of the PhD thesis "Biophysical investigations of photosensitization within mitotic cell cycle. Electromagnetically induced nonlinear dose-effect relations monitored by novel optical detection methods" of R. Penjweini

COURSES IN THE ACADEMIC YEAR 2009/10

K.W. Kratky

WS:	Physik Physiologischer Prozesse		VO,	2h
SS:	Umwelt- und Biophysik I – Physik Physiologischer Prozesse			2h
SS:	: Gemeinsamkeiten komplementärmedizinischer Methoden – aus naturwissenschaftlicher und interkultureller Sicht			
K.E.	Kürten			
WS: Einführung in die Theorie vernetzter Systeme I - Vom zellulären Automaten zu genetischen und neuronalen Netzwerkmodellen				2h
WS: Neuere Entwicklungen in der Theorie vernetzter Systeme				2h
SS:	Einführung in die Theorie vernetzter Systeme II - Vom zellulären Automaten zu genetischen und neuronalen Netzwerkmodellen			2h
SS:	Spezielle Anwendungen in der Theorie vernetzter Systeme II			2h
H.G	. Löw			
WS:	Biophysikalisches Praktikum für Vorgeschrittene	(als Mitveranstalter)	PR,	5h
W. (Gruber			
WS:	Biophysikalisches Praktikum für Vorgeschrittene	(als Mitveranstalter)	PR,	5h
WS:	Wie erkläre ich es meinen SchülerInnen?		VO,	2h
WS:	Fachdidaktische Vertiefung – Methoden der Physikdidaktik	(als Mitveranstalter)	SE,	1h
SS:	Praktikum für Schulversuche II	(als Mitveranstalter)	PR,	8h