DY 13: Cardiac dynamics and reaction-diffusion systems

Time: Tuesday 11:30–13:00 Location: MA 004

DY 13.1 Tue 11:30 MA 004

Different forms of alternans in the modified Beeler-Reuter model for cardiac dynamics and chaotic media — Georg Röder[1], Blas Echebarria[2], Jörn Davidsen[3], Steffen Bauer[4], and •Markus Bär[4] — [1]MPIPKS Dresden — [2]UPC Barcelona, Spain — [3]University of Calgary, Canada — [4]PTB Berlin

We investigate the phenomena of spatial period doubling and alternans of by numerical simulations and stability analysis of one-dimensional coherent structures in reaction-diffusion models. In general, the onset of alternans in different media can be related to a linear instability of periodic waves that is either a period doubling or a Hopf bifurcation. In chaotic media a period doubling of wavetrains is found, while in the modified Beeler-Reuter model of cardiac tissue period doubled wave trains stemming from a non-monotonous dispersion curve as well as Hopf bifurcations leading to temporary modulations of wave trains are observed. Period doubling bifurcations of wavetrains are related to real eigenvalues and lead to alternant wavetrains, whereas Hopf bifurcations correspond to purely imaginary eigenvalues displaying a frequency that is roughly half of the temporal frequency of the original wave train and produce . Implications for structures in higher dimensions are briefly discussed.

DY 13.2 Tue 11:45 MA 004

Pattern control in a two-dimensional model of cardiac tissue — •Philip Bittihn[1], Ulrich Parlitz[1], and Stefan Luther[2] — [1]Drittes Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Germany

Characteristic spatio-temporal patterns in cardiac tissue are plane waves and spiral waves. Spiral wave breakup may occur leading the system into defect mediated turbulence. In the heart, this transition may lead to a lethal electro-mechanical malfunction of the organ and sudden cardiac death. We demonstrate in a two dimensional numerical simulation that this chaotic spatio-temporal dynamics can be controlled and turned into a state of periodic activation using multiple delay feedback. The application of this approach to experiments and possible limitations will be discussed.

DY 13.3 Tue 12:00 MA 004

Inhibition of Tachyarrhythmic Activity by Local Pacing — •Ekaterina Zhuchkova and Harald Engel — Institute of Theoretical Physics, Technical University of Berlin, Berlin, Germany

Any abnormalities in the electrical activity of the heart are arrhythmias. Termination of arrhythmias occurring in the ventricles, particularly ventricular tachyarrhythmias, remains one of the most attractive research topics in view of application of physics and engineering to cardiology. Ventricular tachyarrhythmias are induced by rotation of a single or multiple re-entrant waves, which have spiral (in 2D) or scroll (in 3D) shapes.

Using the simplified ionic Fenton-Karma model of excitation in the heart we resolve the problem of termination of such dangerous re-entrant activity by local pacing of monophasic and biphasic waveforms. Although suppression efficiency nonlinearly depends on a number of parameters, in clinical context the local termination of spiral-wave dynamics would have an advantage: It would need low power of the stimulation and could be readily implemented with existing hardware - implantable cardioverter defibrillators.

DY 13.4 Tue 12:15 MA 004

Kinematical theory of rigidly rotating spiral waves — •Vladimir Zykov — TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A simplified kinematical description of a rigidly rotating spiral induced in a generic two-component reaction-diffusion medium is elaborated by application of a free-boundary approach. It is shown that all characteristics of a rigidly rotating spiral (including its rotation period) are determined by the value of the slow component near the spiral front. On the other hand, the same value determines the period of a periodic wave train. Since the rotation period represents simultaneously the period of the wave train generated by a spiral wave, a selected value of the rotation frequency is uniquely determined as a solution of a system of algebraic equations. The results obtained in the framework of the proposed approach are compared to asymptotics derived earlier in the limits of weak and high excitability.

DY 13.5 Tue 12:30 MA 004

Hysteresis in the selection of rotating wave patterns — •Hartmut Lentz, Vladimir Zykov, and Harald Engel — Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, D-10623 BERLIN

We study rotating wave patterns in an annular channel as spiral waves, rotating wave segments and boundary spots. Usually, a unique rotation period and wave shape are selected for given channel geometry and parameters of the medium. Within a modified kinematic approach that takes into account a boundary layer in the wave front, we derive a nonlinear eikonal equation with an unstable branch. Based on this equation we describe the transformation of rotating segments pinned to the inner boundary into a freely rotating spiral wave. Additionally, we specify a regime with hysteresis of the rotation frequency under variation of the inner radius. We conclude, that dispersion effects are not the crucial factor for the hysteresis in the rotation period. The theoretical predictions are compared with results obtained by numerical simulation of the underlying reaction-diffusion equations.

[1] G. Bordyugov and H. Engel: Continuation of spiral waves. 2007.
[2] A. Pertsov et. al.: Rotating spiral waves in a modified fitzhugh-nagumo-model, 1984.
[3] V. Zykov: Selection mechanism for rotating patterns in weakly excitable media, 2007.

DY 13.6 Tue 12:45 MA 004

Percolation effects in front propagation — •Sergio Alonso[1], Karin John[2], Raymond Kapral[3], and Markus Baer[1] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Université J. Fourier, Grenoble, France — [3]University of Toronto, Toronto, Canada

Waves and fronts propagate in nonlinear spatially extended systems. Normally extended systems present heterogeneities and deformations which hinder the stable propagation and which cannot be avoided. Numerical models do not usually consider any type of defects and they study homogeneous models. Here we study the propagation of a front in a bistable media for two different types of defects: some sites of the numerical grid do not propagate the front (site percolation), or some connections between the sites do not propagate (bond percolation). We calculate the velocity of both situations for different density of defects, and compare the results with an effective medium theory.