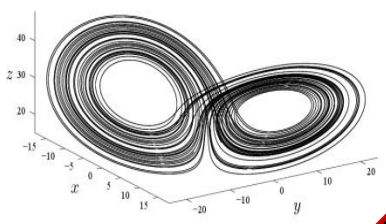# Nonlinear and Biomedical Physics

(A. Stefanovska & P. V. E. McClintock)
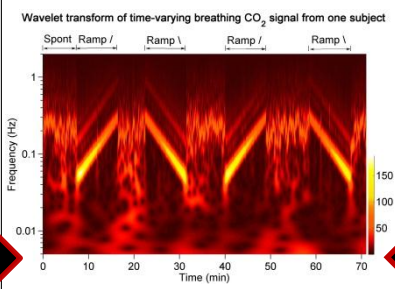
Oscillatory time-varying biodynamics

Theory of coupled oscillators & networks

- Phase dynamics
- Interactions
- Open, non-autonomous and chronotaxic systems
- Nonlinear & stochastic dynamics

Time series analysis methods

Wavelet transform of time-varying breathing CO_2 signal from one subject

- Inference of time evolving couplings
- Wavelet based methods
- Nonlinear time-dependent mode decomposition
- Surrogate testing

Functional measurements & imaging
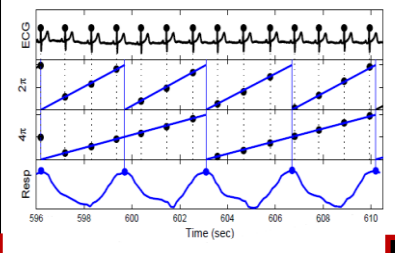
- Non-invasive multi-signal recording of cardiovascular interactions and brain waves
- Laser-based measurements and vascular imaging
- Recordings of cell membrane potential in vitro

Modelling: From the cell to the brain

Multi-ion conduction bands of Calcium ion channels
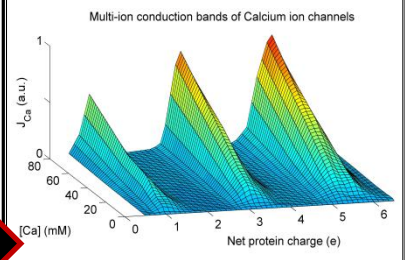
- Ion channel dynamics
- Networks of mitochondria
- Cardiorespiratory interactions and brain dynamics
- Virtual human as a collection of coupled oscillators

Applications

Cardiovascular system

- Physiological origins of cardiovascular oscillations
- Effect of perturbations i.e. exercise, heating, cooling, paced respiration, breath holds
- Ageing
- Hypertension
- Diabetes
- Cancer
- Spinal cord injury
- Heart failure
- Myocardial infarction
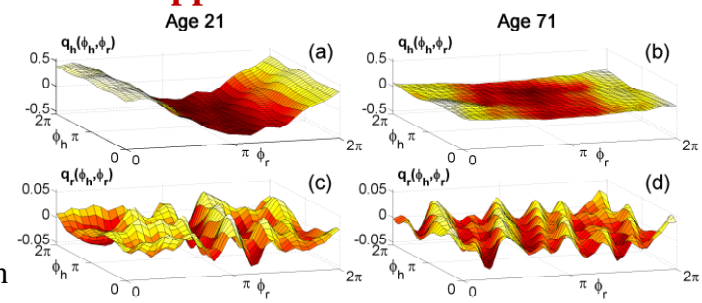
Brain function

- Anaesthesia
- Coma
- Autism

Other applications

- Low temperature phenomena
- Rogue waves

Prototypes

- Endotheliometer
- Anaesthesiometer

Inference of Time-Evolving Coupled Dynamical Systems in the Presence of Noise

- Complex systems with time-varying parametric and functional dynamics

- Interacting oscillators → phase dynamics decomposition:

$$\dot{\phi}_i = \omega_i + f_i(\phi_i) + g_i(\phi_i, \phi_j) + \xi_i$$

- Bayesian inference for SDE with particular information propagation

- The method can facilitate comprehensive analysis:

    - time-varying dynamics,

    - synchronization,

    - coupling direction and

    - inter-oscillator coupling functions.

- Example → cardiorespiratory interactions

- Coupling function of an open (biological) system can

themselves be a time-varying processes

Stankovski, Duggento, McClintock, Stefanovska, *Phys Rev Lett* **109**: 024101, 2012.