Coupled oscillators approach to data analysis

A foreword

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Terminological problem in interdisciplinary research

Many common special words have different meaning in different fields, in particular, in physics and in neuroscience!

We shall be very careful with the following words

- coupling
- synchronization
- locking
- phase

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Phase: what is it?

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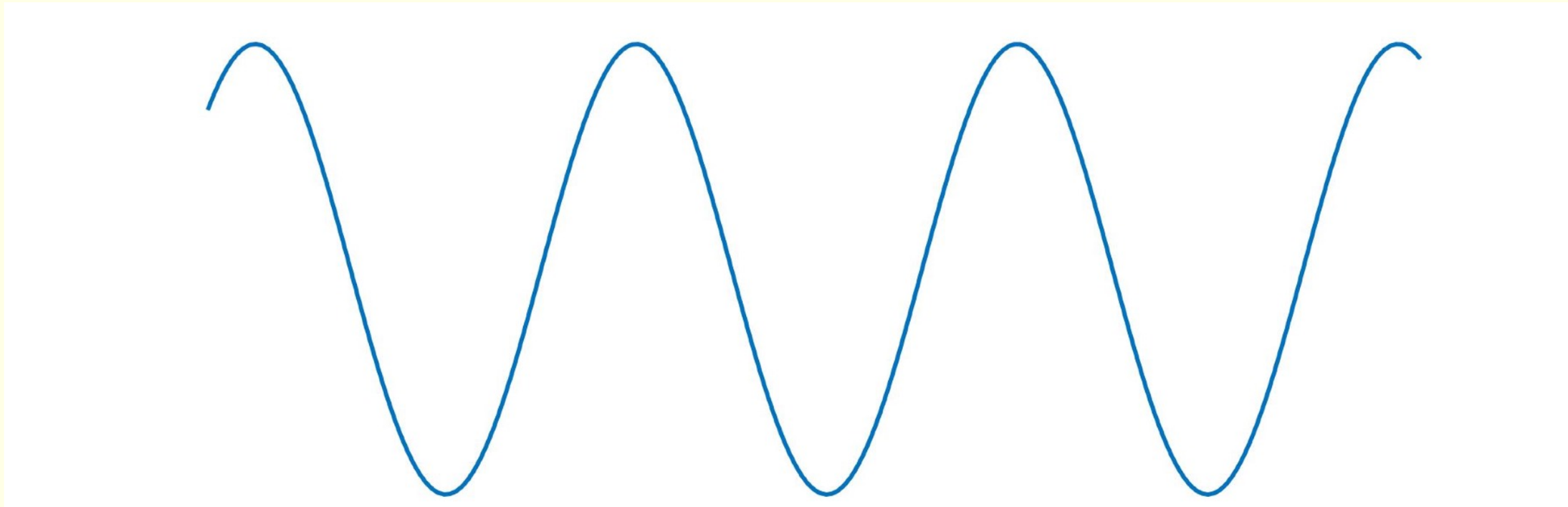
Is it the same quantity?

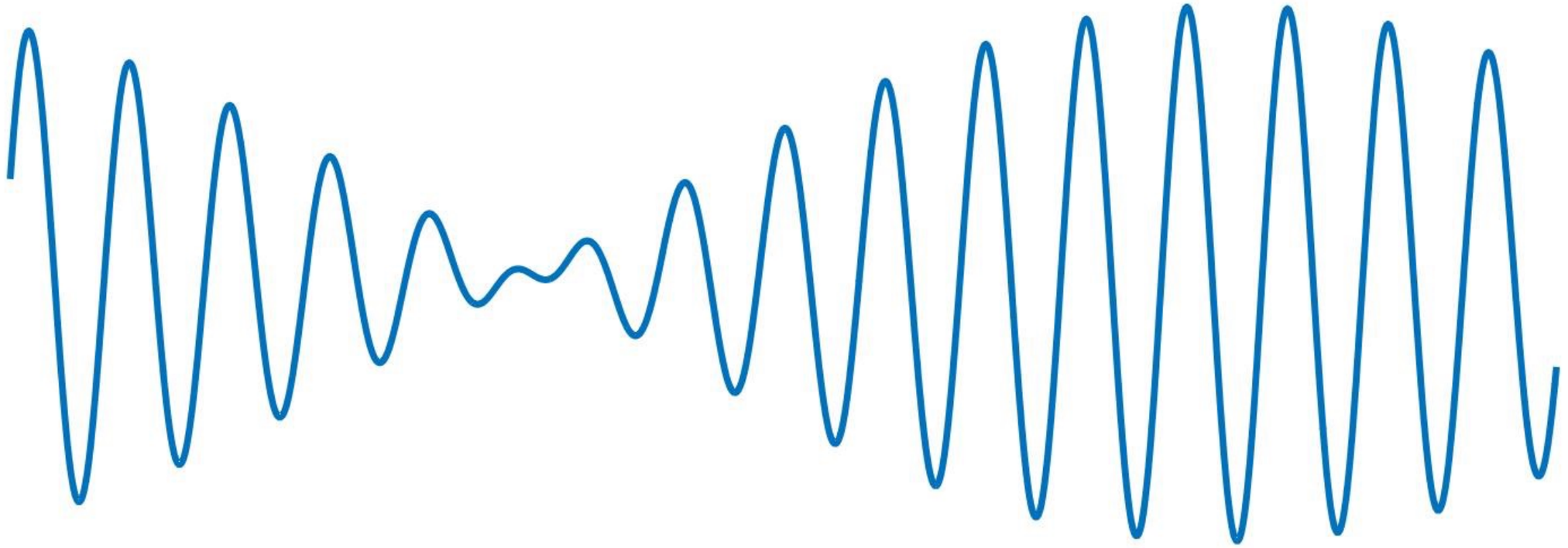
Phase: simple questions



$$x = A\sin(\omega t + \alpha)$$

What is phase here: α or $\omega t + \alpha$?

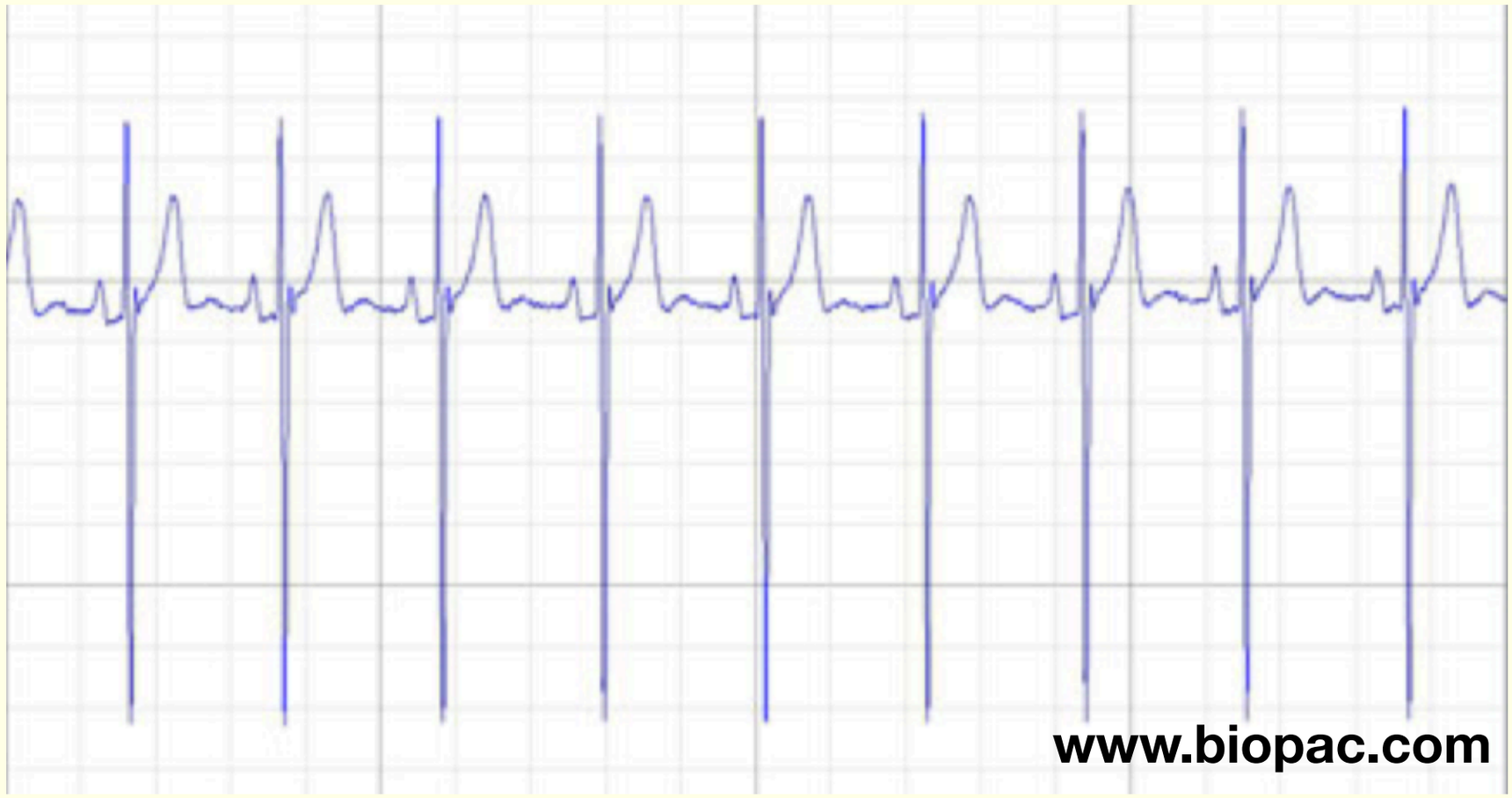
Phase: simple questions II



$$x = \sin(\omega_1 t + \alpha) + \sin(\omega_2 t)$$

What is phase here?

Phase: simple questions III



Human electrocardiogram: What is phase here?

Phase: simple questions IV

3-Lead ECG Recording

Human 3-Lead ECG Recording: What is phase here?

Shall different traces provide same or different phases?

If yes, how to achieve it?

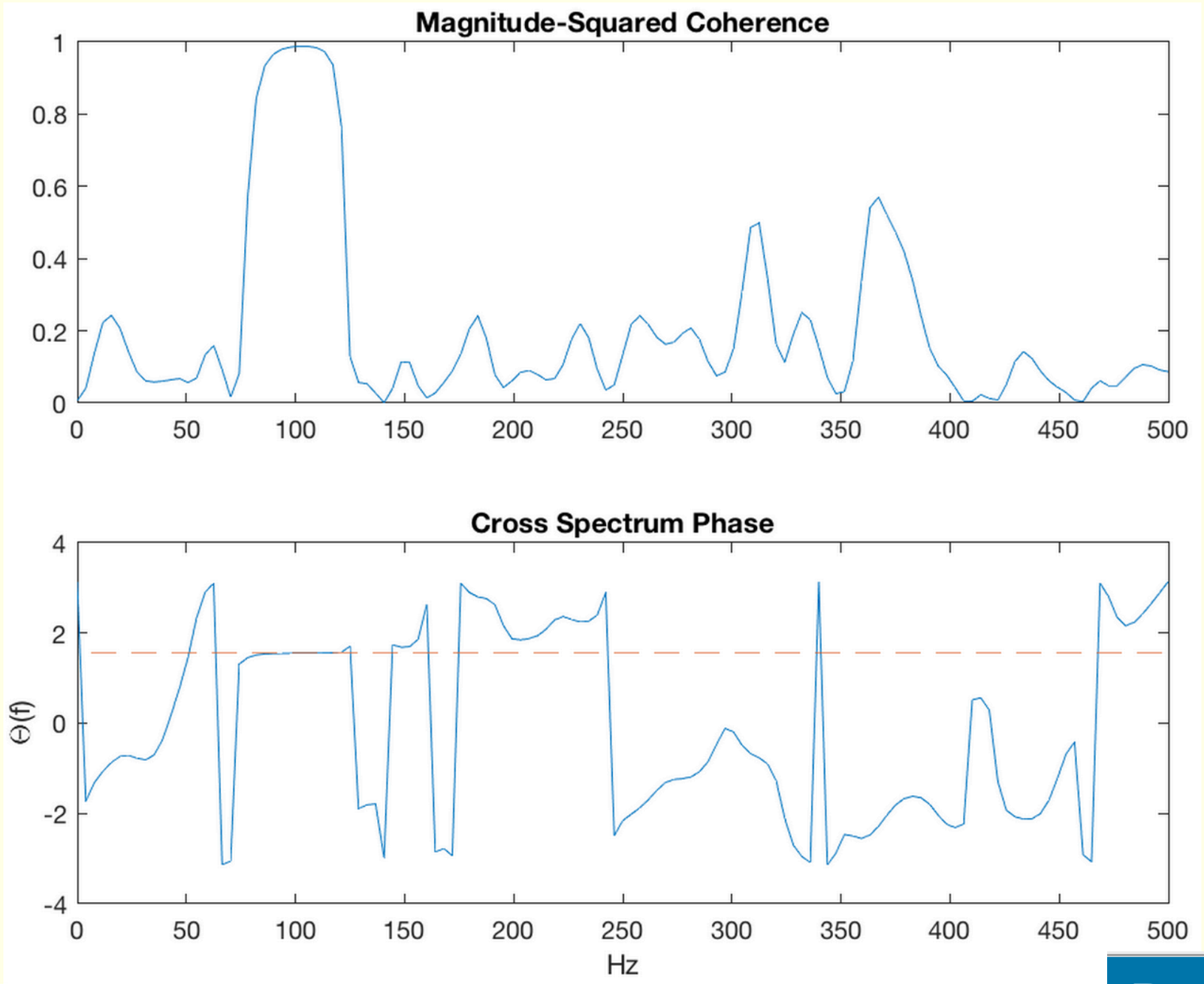
Phase: simple questions V

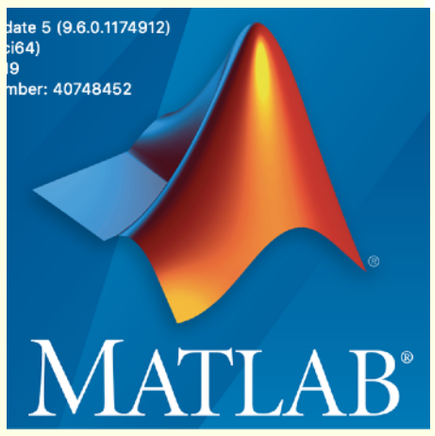
For computation of phase people use:

- Fourier Transform
- Hilbert Transform
- Complex Wavelet Transform
- …

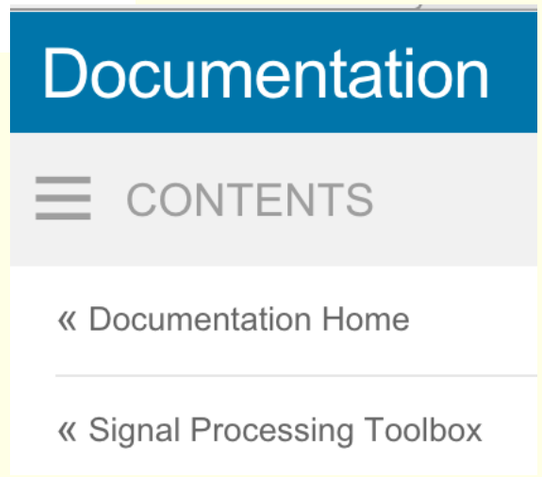
What is the relation between these approaches?

Phase: simple questions VI





What is this phase?



Phase: final question

Why exactly phase?

Phase: physical viewpoint

The word “phase” appears in many branches of physics (e.g. “phase transitions”)

We stick to the definition used in **nonlinear dynamics,** and, particularly, in

theory of coupled oscillators and their synchronization

Coupled oscillators and synchronization

In this theory we distinguish between phase of an **oscillator** and phase of a **signal**

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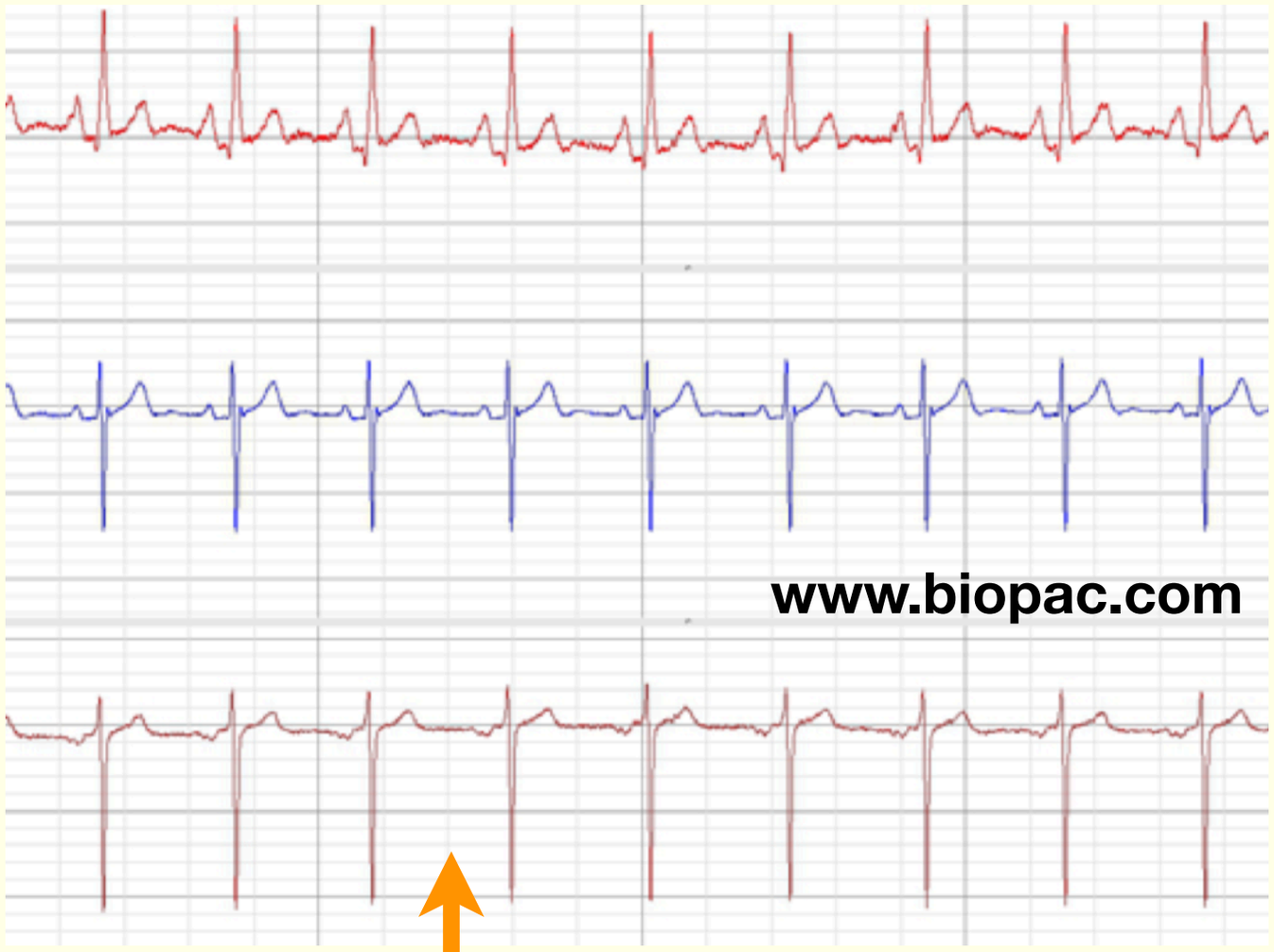
An example:



Oscillator

Measurement (signals, time series)

Coupled oscillators and synchronization II

In this theory we distinguish between phase of an **oscillator** and phase of a **signal**

Phase of an oscillator can be defined rigorously and unambiguously

Coupled oscillators and synchronization II

In this theory we distinguish between phase of an **oscillator** and phase of a **signal**

Phase of an oscillator can be defined rigorously and unambiguously

Computation of the oscillator's phase from time series remains a challenge, though a lot of progress has been achieved within last two decades

Coupled oscillators and synchronization III

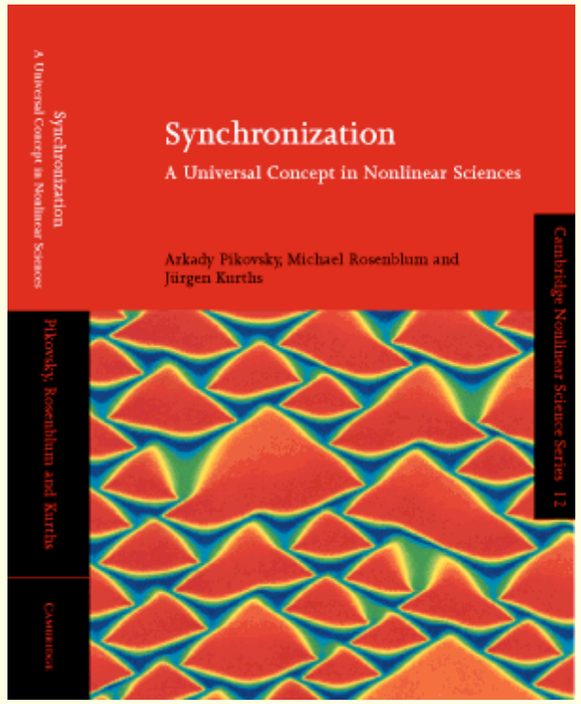
A very hot topic, with tenths of publications every month!!!

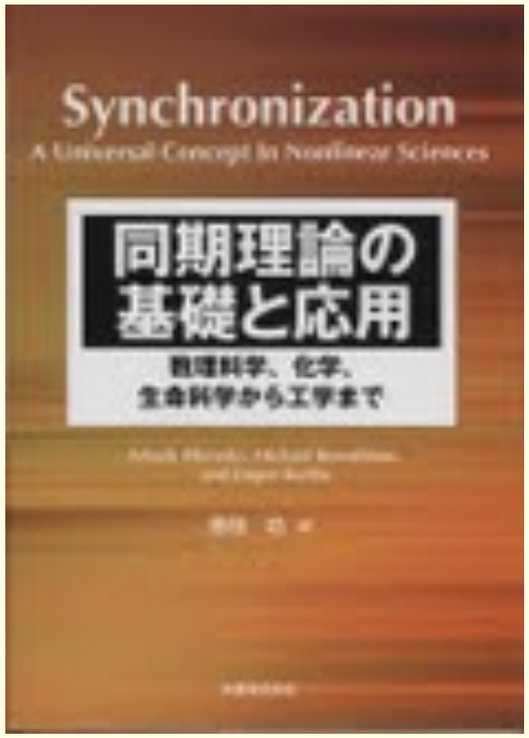
Applications in natural sciences and engineering

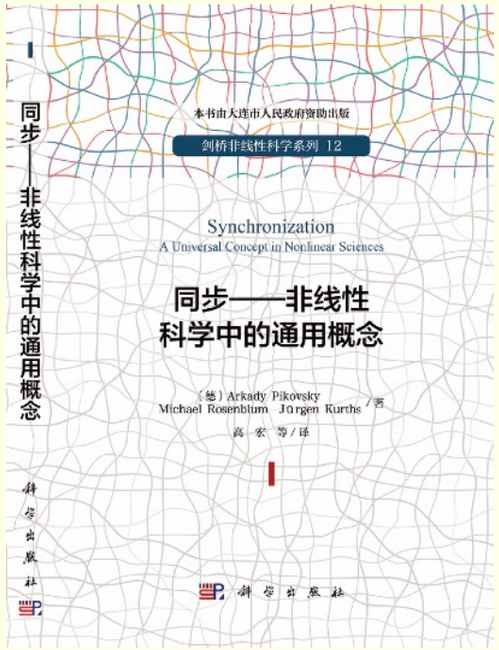
Many applications in life sciences: on the level of genes, cells, organs and physiological subsystems, and even on the level of human individuals

Coupled oscillators and synchronization: references

- A. Pikovsky, M. Rosenblum, J. Kurths, Synchronization. A Universal Concept in Nonlinear Sciences, 2001







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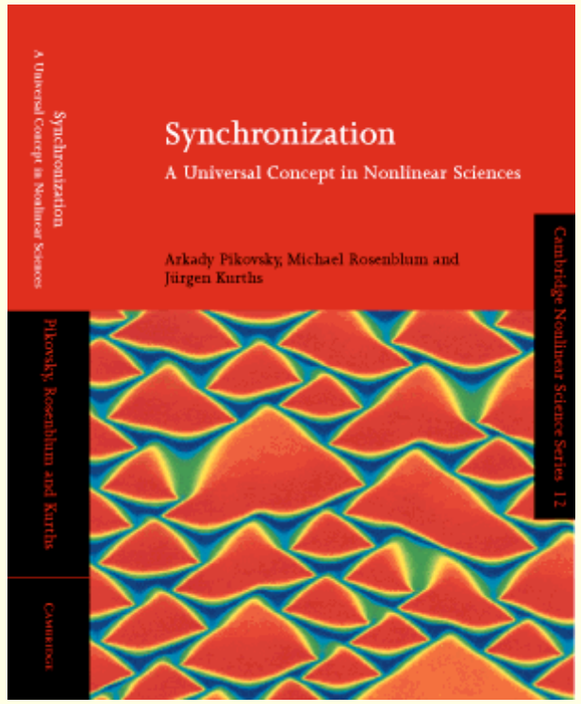
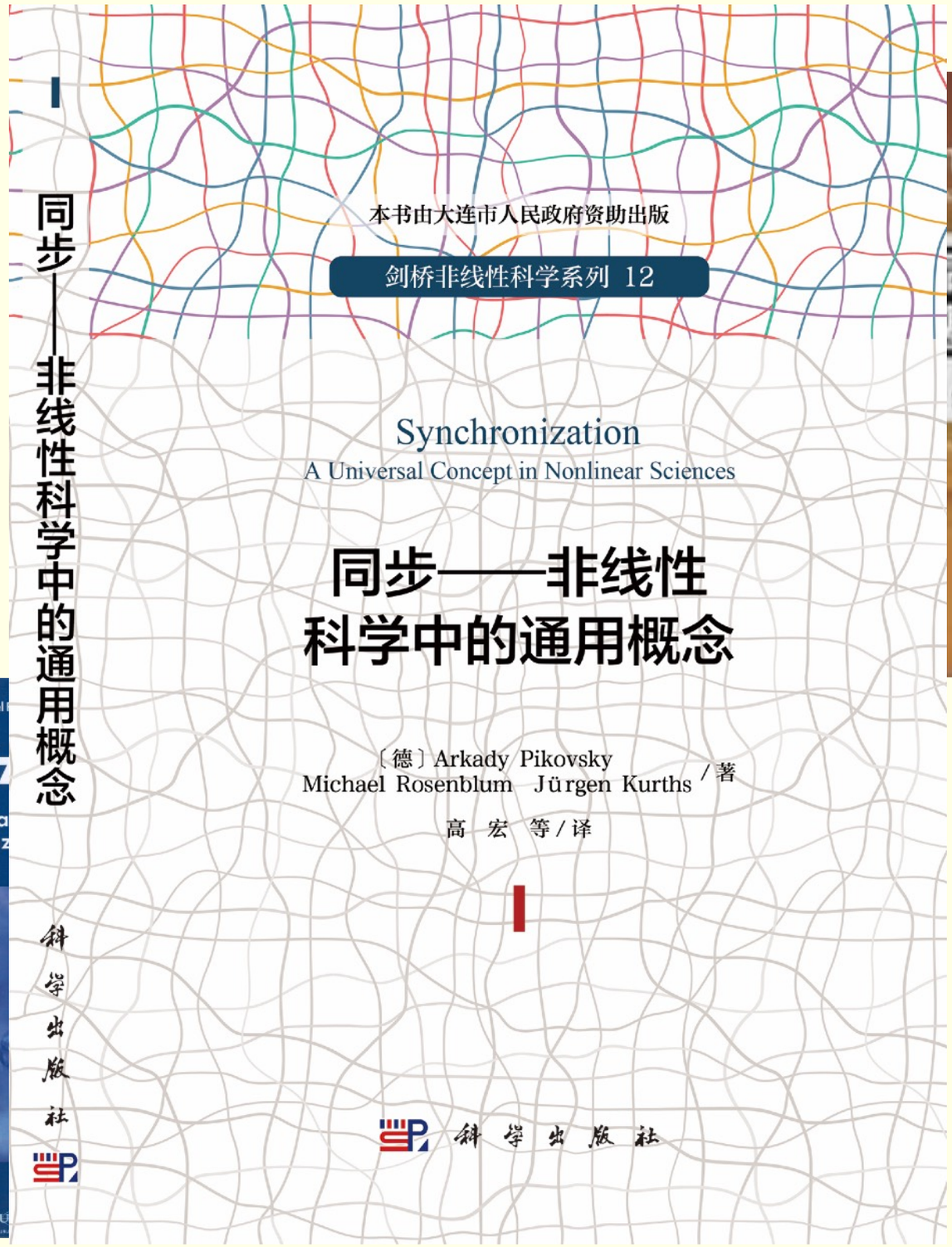
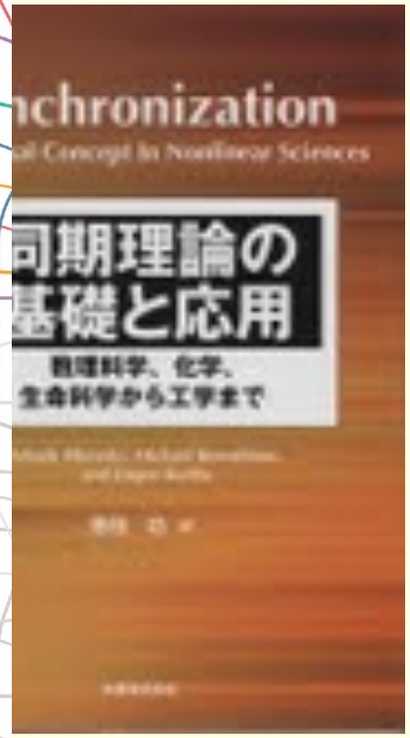
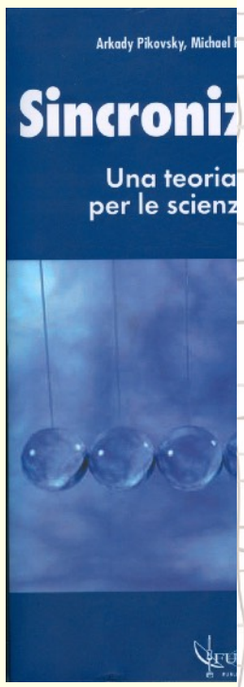


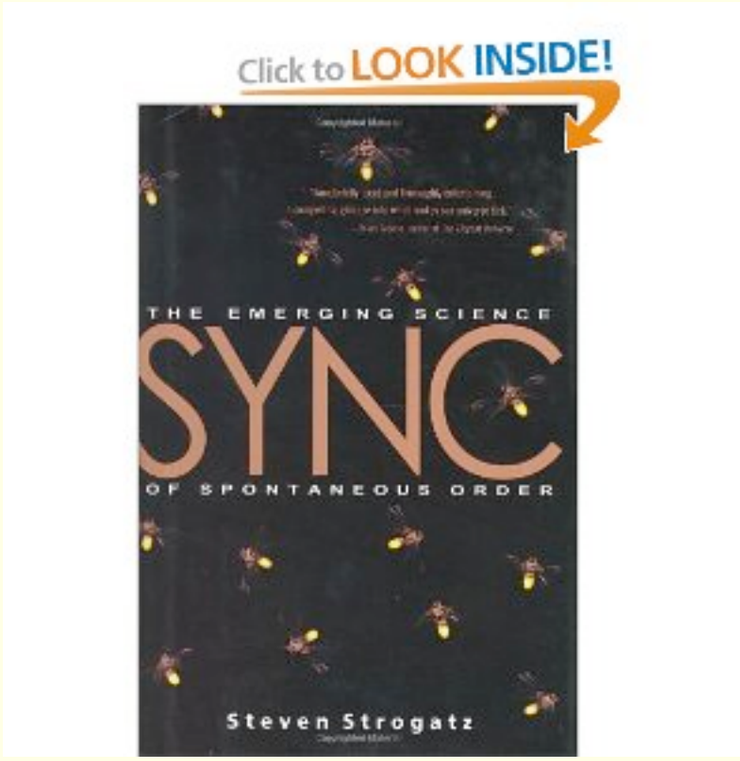






Coupled oscillators and synchronization: references

- S. Strogatz, Sync: The Emerging Science of Spontaneous Order, 2003



… and many review papers, e.g.

frontiers in
HUMAN NEUROSCIENCE

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Generative models of cortical oscillations: neurobiological implications of the Kuramoto model

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