MUNI SCI

Nonlinear Dynamics Team

Exploring Important Dynamic Changes

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Women in Science Day

Why Nonlinear Dynamics Matters

- Many real-world systems are governed by nonlinear interactions:
  - brain activity
  - epidemics
  - synchronized physical systems
  - climate and ecological dynamics

- Small parameter changes can trigger dramatic transitions.
- Mathematics helps us understand, predict and control such behavior.

Who We Are: NDteam

- Research group at Masaryk University focused on nonlinear dynamical systems
- Strong interdisciplinary orientation
- Combination of:
  - nonlinear dynamics and bifurcation theory
  - numerical methods
  - data-driven modeling
  - applications
- Core principle:

  Students are not assistants — they are junior researchers.

NDteam – People Behind the Science

Lenka Přibylová

Veronika Eclerová

Jakub Záthurecký

Jan Ševčík

Deeptajyoti Sen

Štěpán Zapadlo

NDteam – People Behind the Science

UFOs and ENDs – Neuroscience

Students

NDTeam with André Botha

What Is Nonlinear Dynamics?

- Systems where outputs are not proportional to inputs
- Typical phenomena:
  - oscillations
  - synchronization
  - sudden transitions
  - chaos
- Examples:
  - epidemic waves
  - neuronal firing
  - superconductive circuits

Main Research Pillars

Population Dynamics

- epidemic modeling
- seasonality
- data fitting

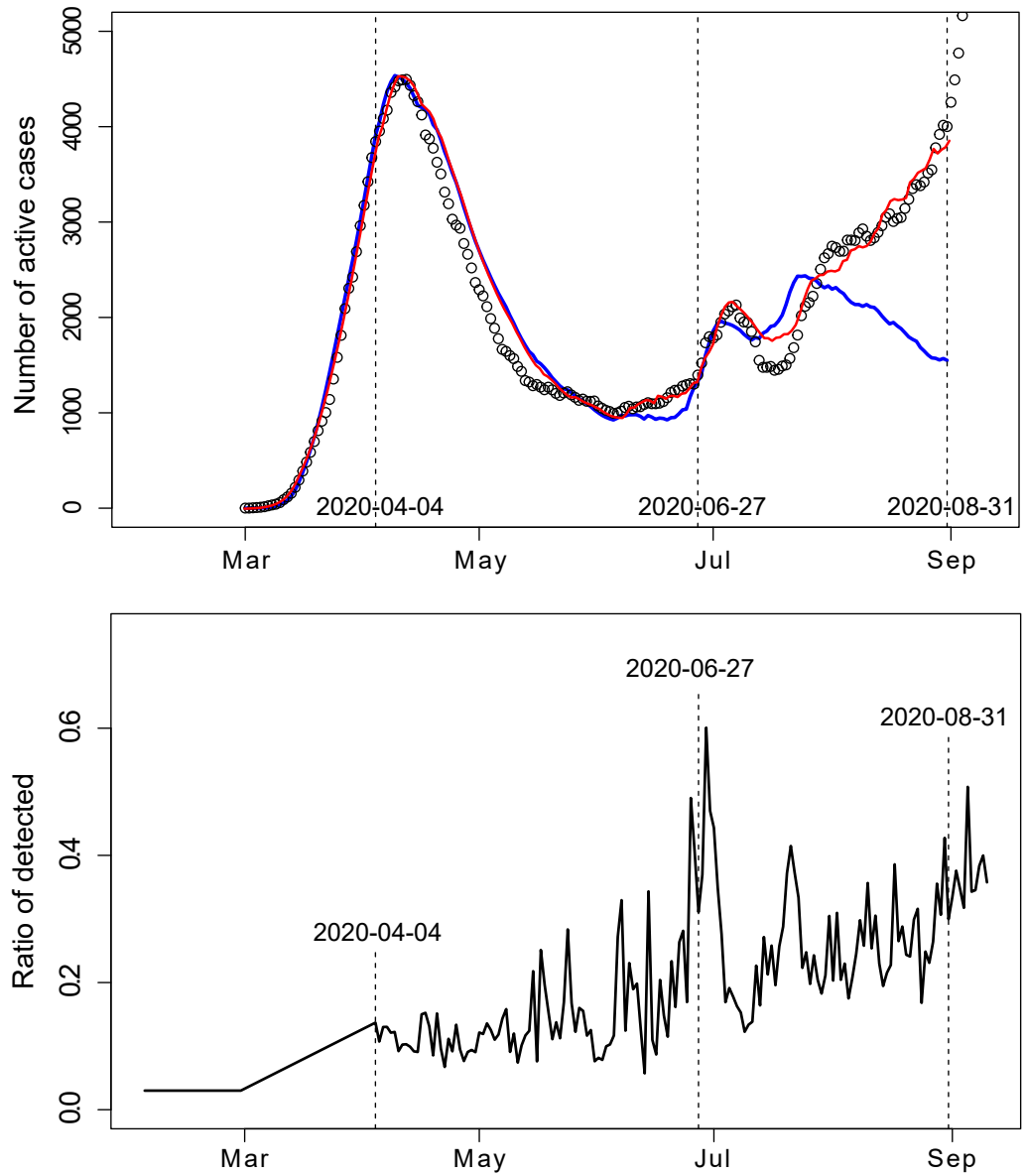
Neuroscience

- epilepsy
- Parkinson disease
- brain rhythms
- neuron models

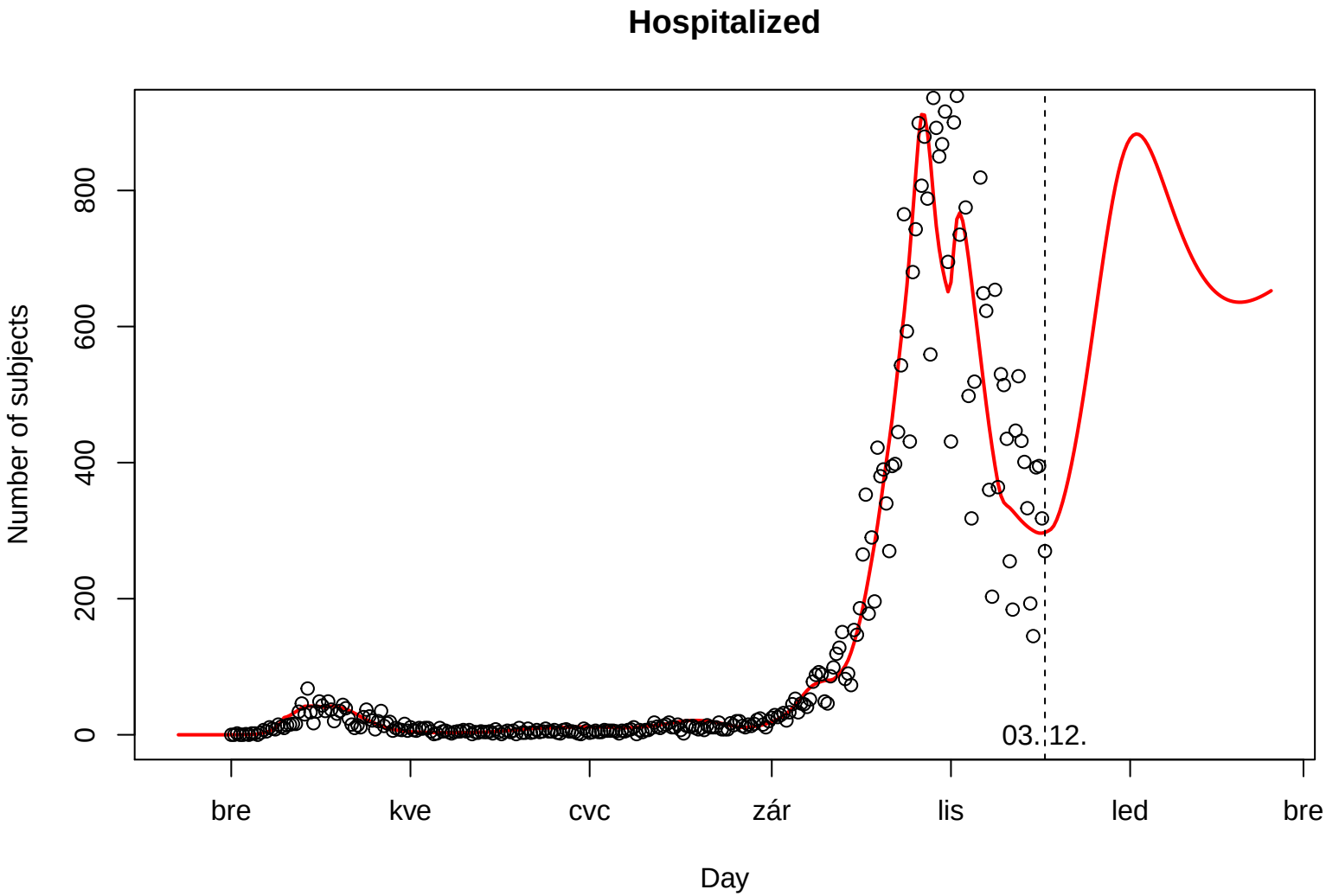
Physics

- synchronization
- coupled systems
- superconducting circuits
- lasers

Modeling COVID-19 and beyond

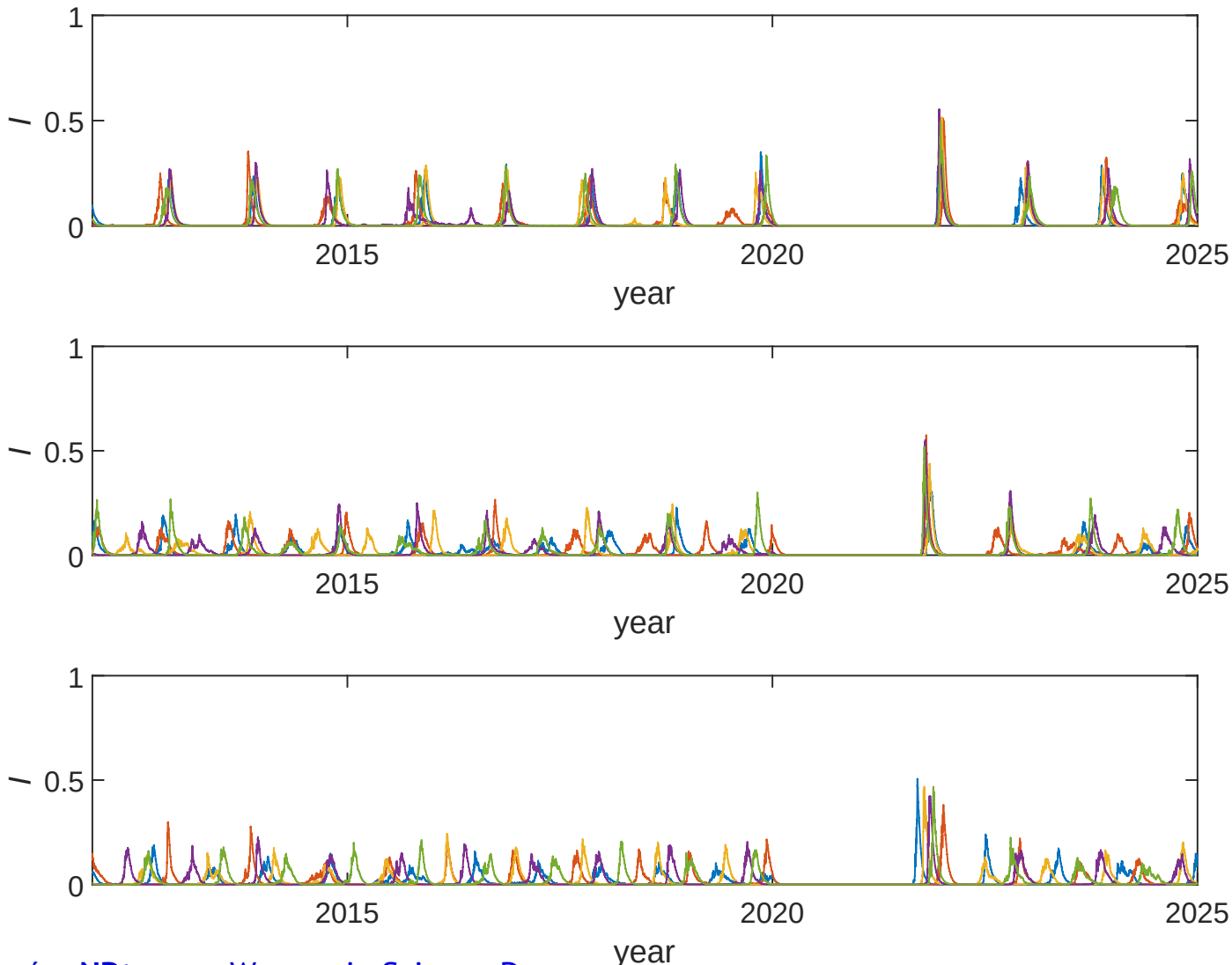


Modeling COVID-19 and beyond

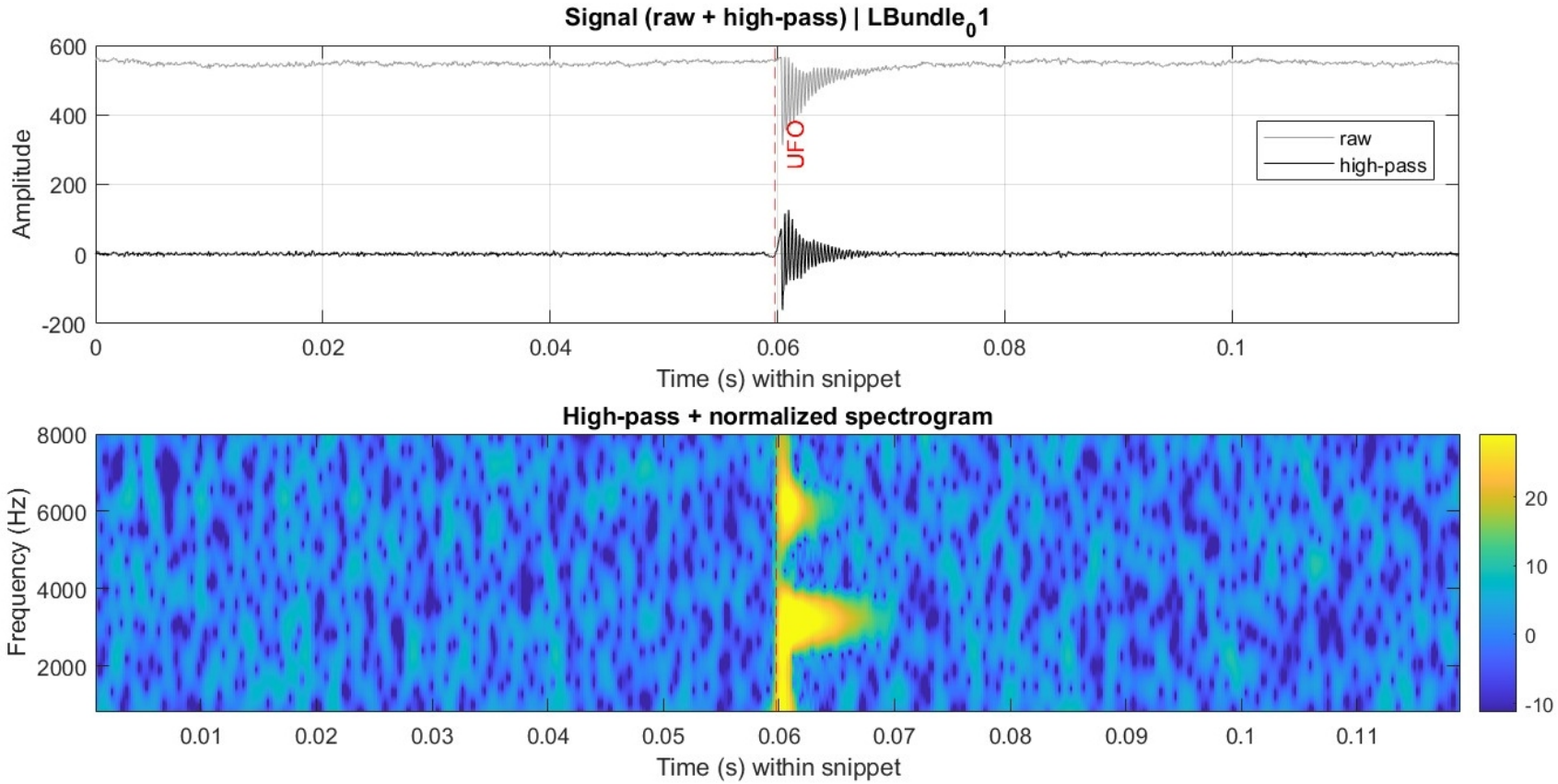


Modeling COVID-19 and beyond

Seasonality and influenza



From Mathematics to Clinical Relevance

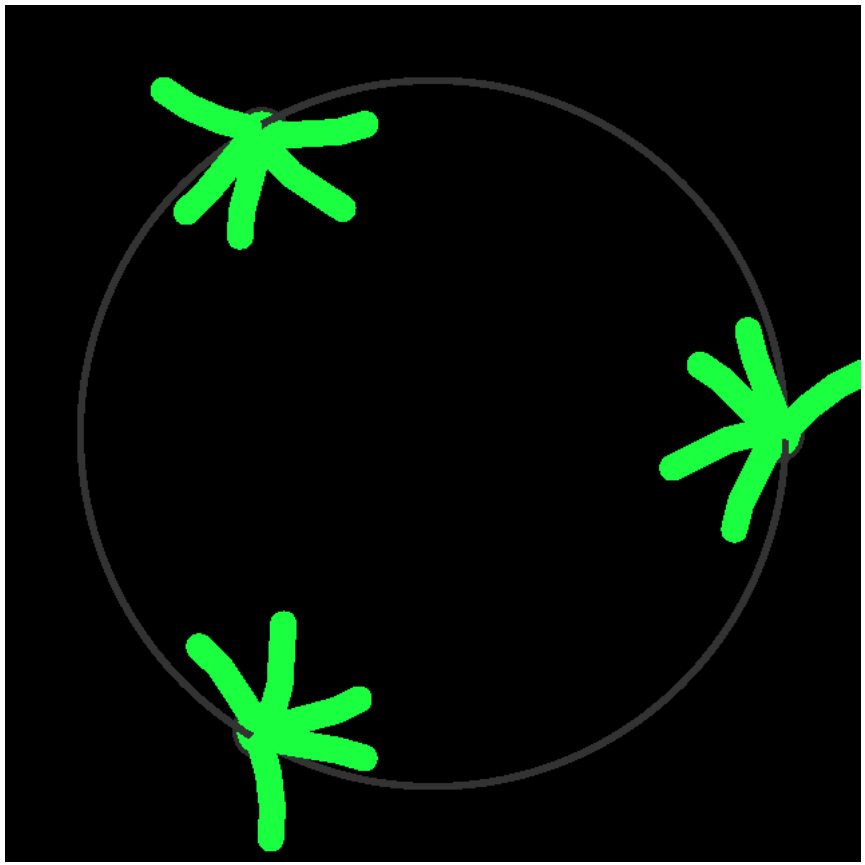


From Mathematics to Clinical Relevance

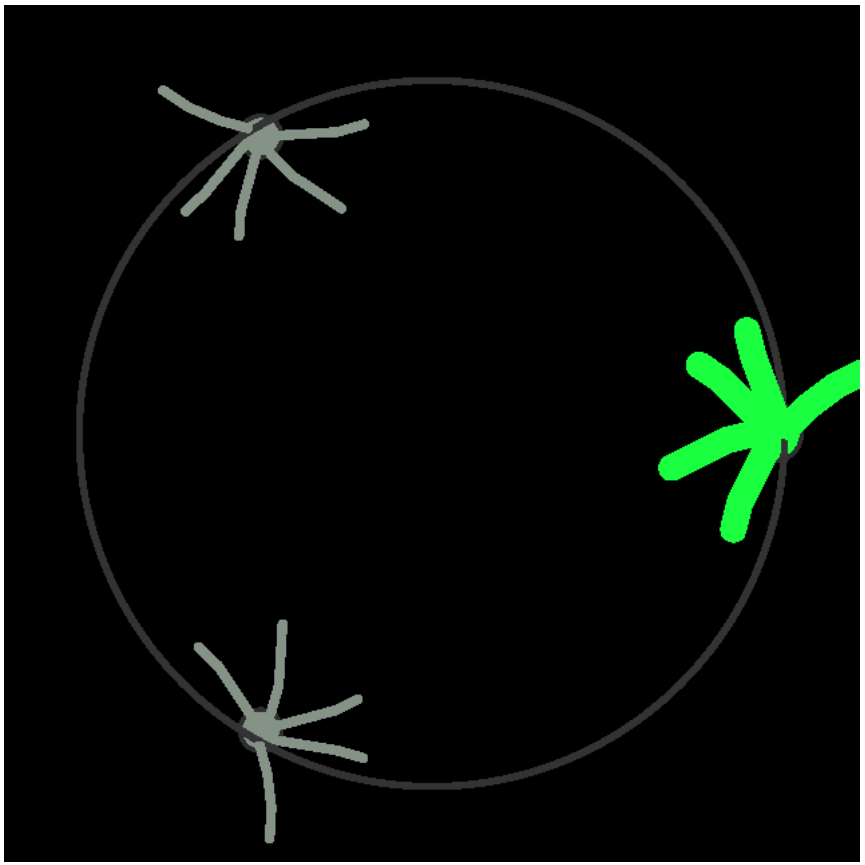
- Identification of biomarkers in iEEG and LFP signals
- Understanding very high-frequency oscillations
- Supporting interpretation of clinical data
- Long-term goal:

  Personalized modeling of neurological disorders

Possible mechanism

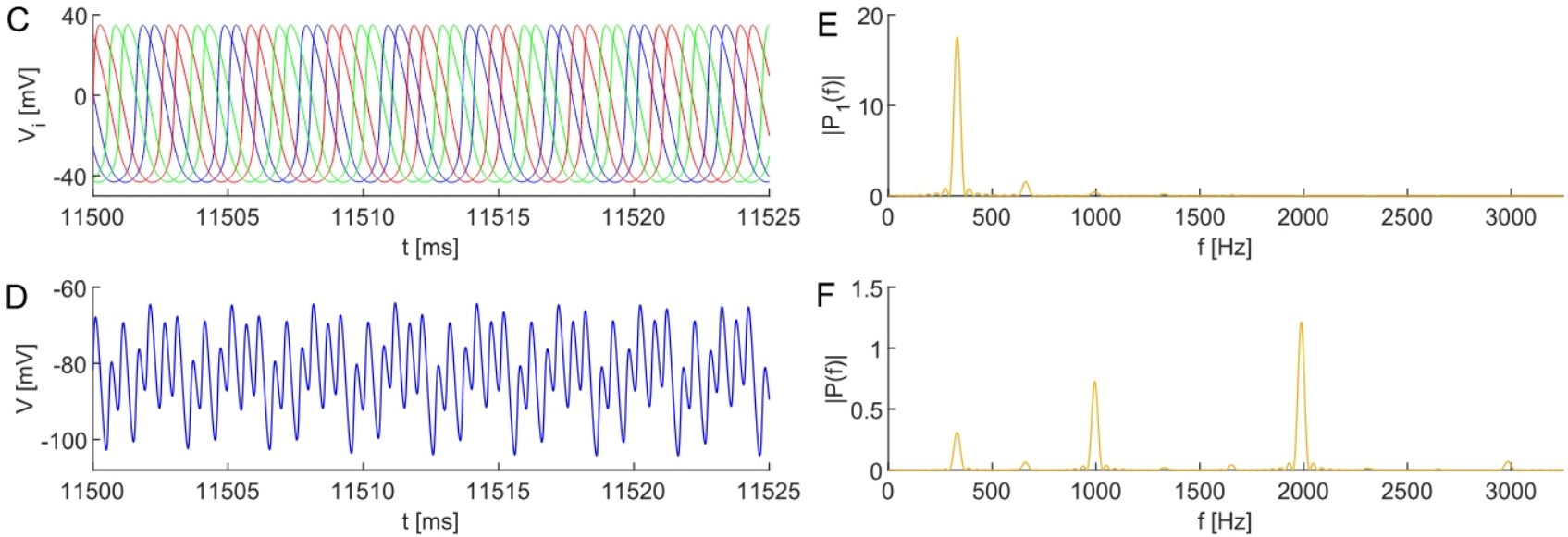


In-phase sync



Phase-shifted sync

We succeeded *in silico*!



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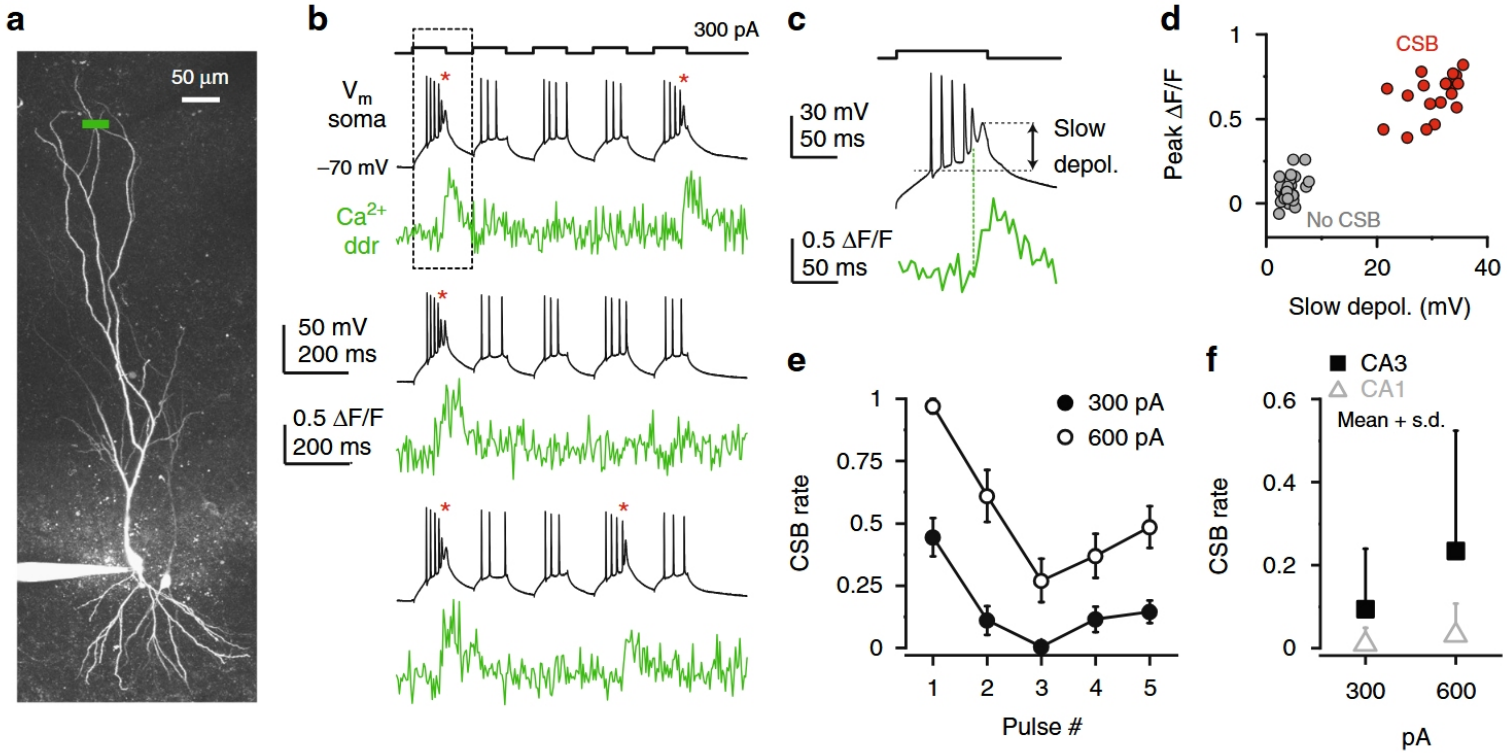
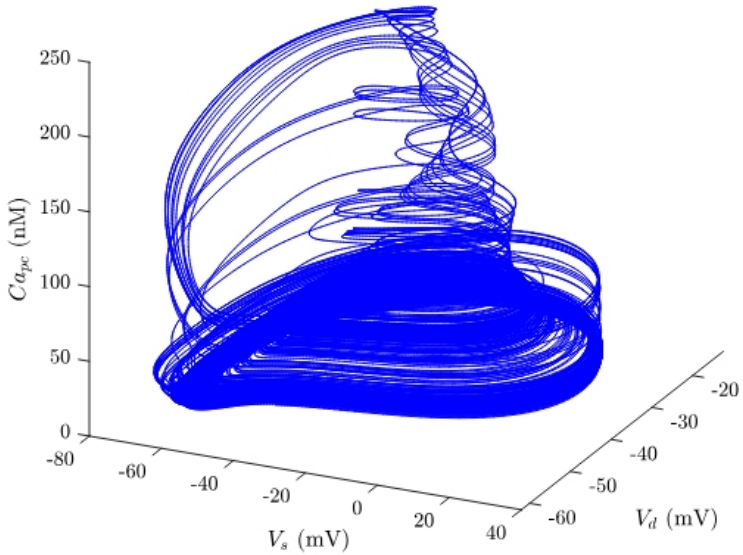
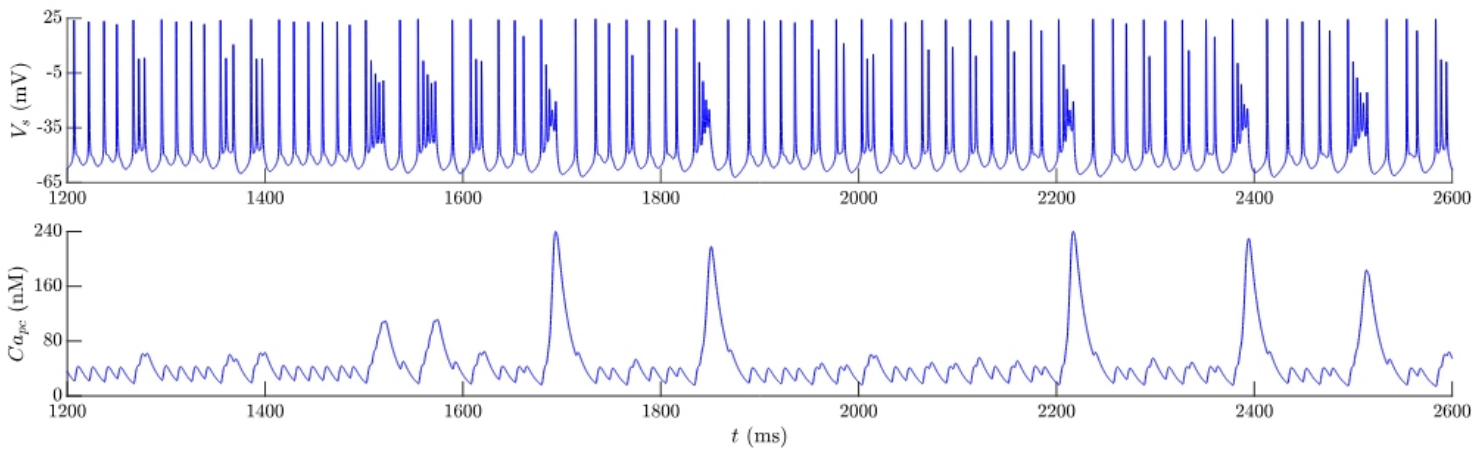


Real measurements

We succeeded *in silico*!





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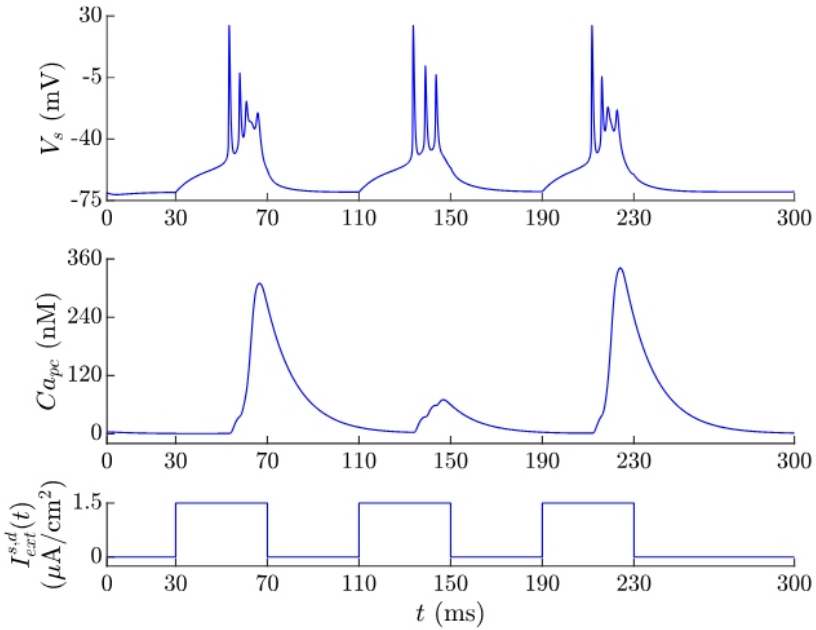
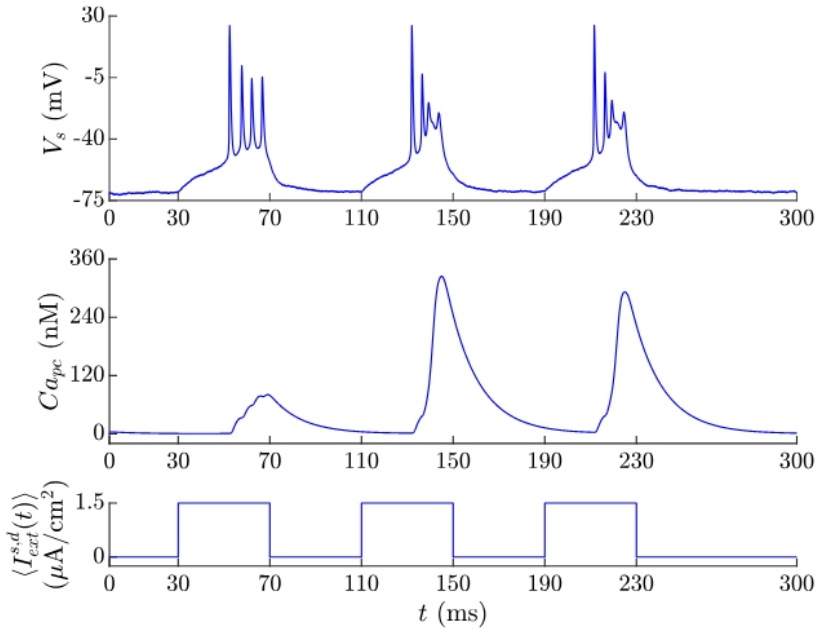
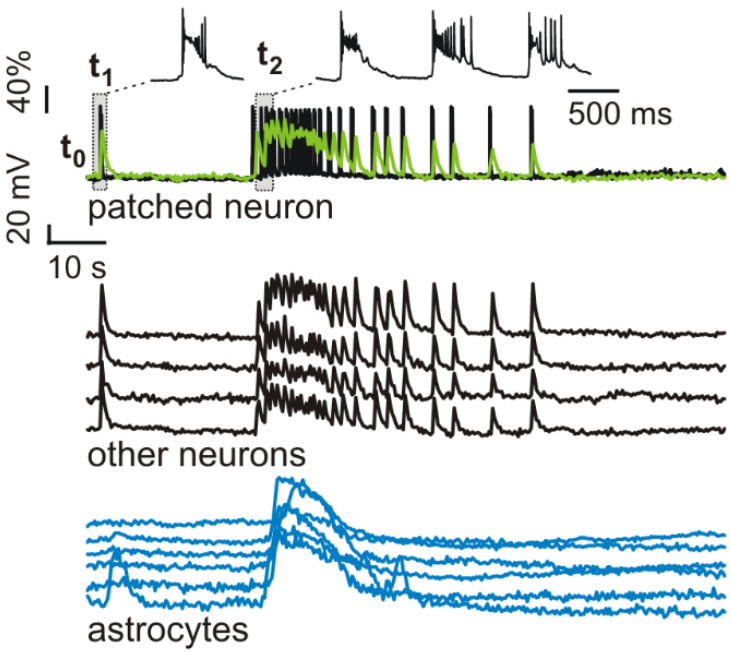


(a) Deterministic simulation via Euler method with time step $\Delta t = 10^{-4}$ ms



(b) Stochastic simulation via the Euler–Maruyama method with time step $\Delta t = 10^{-4}$ ms and Gaussian white noise WN $\left(0, 0.5^2\right)$

We succeeded *in silico*!



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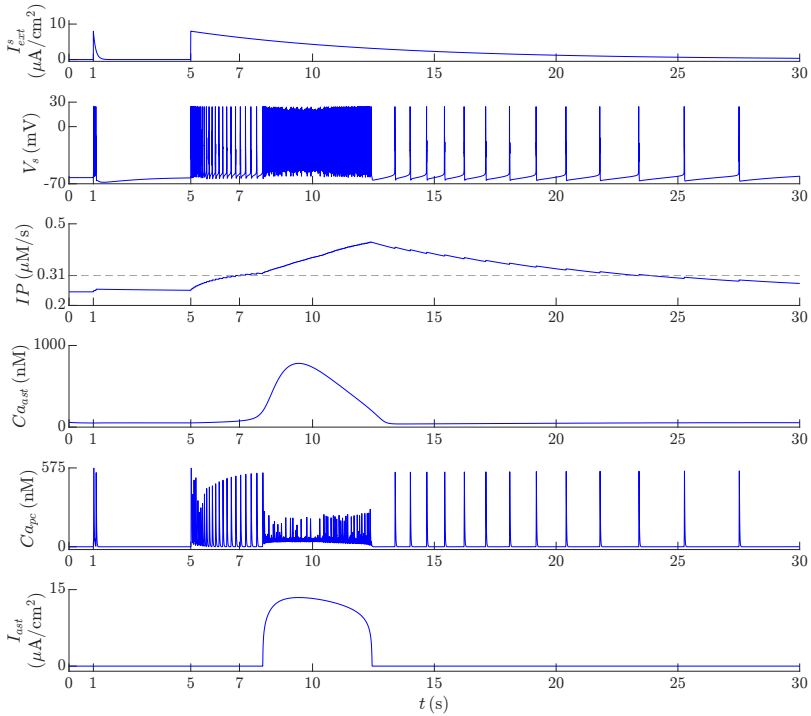
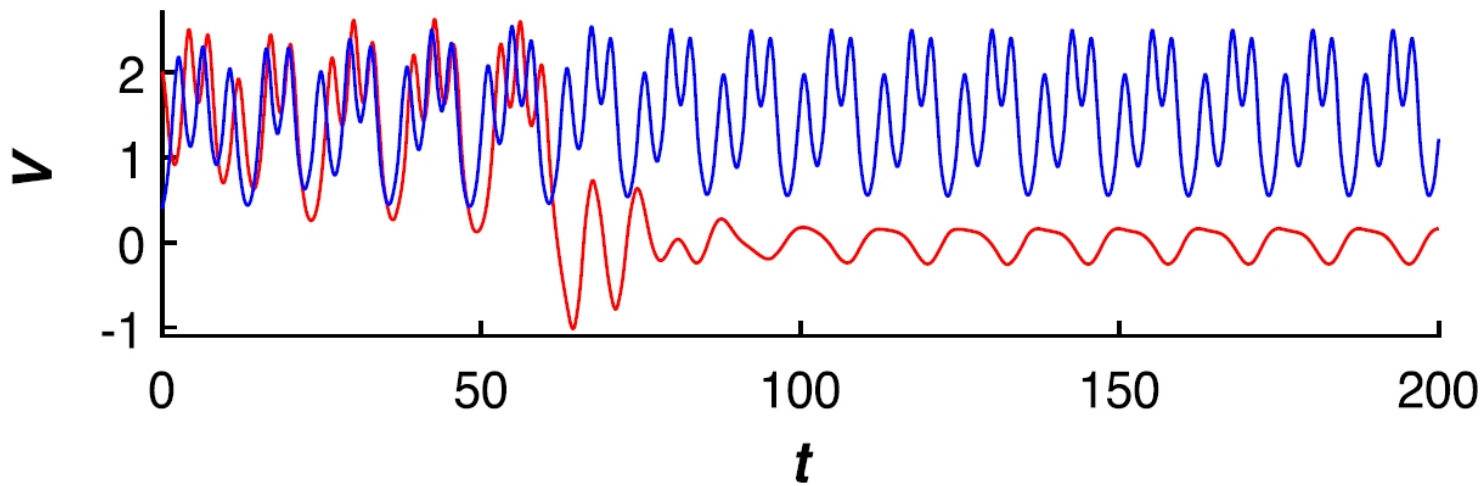


In silico replication

Superconductivity

High-Frequency vs Zero-Average Voltage Regimes



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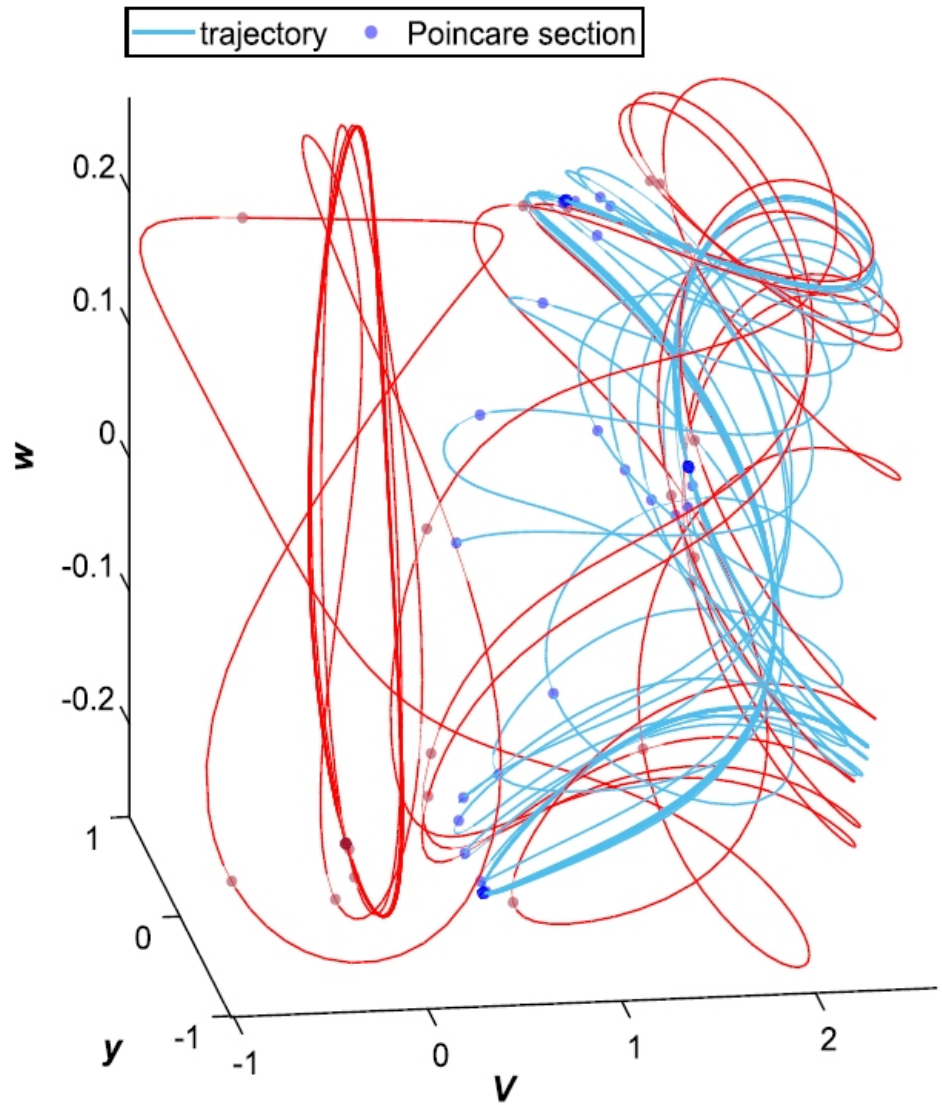

International Collaboration

- Strong network across Europe and beyond
- Cooperation with:
  - mathematicians
  - clinicians
  - healthcare institutions
  - computational neuroscientists
  - bio-engineers
  - physicists

Career Restart: Supporting Women in Science

- Veronika Eclerová received Career Restart funding
- Czech national nominee for the Heidelberg Laureate Forum
- Focus:
  - synchronization phenomena in physics
  - numerical methods for nonlinear dynamics
  - collaboration with André Botha, Univ. of South Africa
- Importance:
  - smooth return after career breaks
  - retaining talent in science
  - building diverse research teams

What Makes NDteam Different

- Strong link between theory and applications
- Mentoring-centered team culture
- Interdisciplinary environment
- Long-term collaborations

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WE KNOW THE MATHS BEHIND IT!

Thank you for your attention.

https://science.math.muni.cz/ndteam

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