Universität Rostock — Traditio et Innovatio

RETUNE — CRC TRR 295 Berlin-Würzburg

P 64 – Computational modelling and imaging in DBS . **E-mail: arash.golmohammadi@uni-rostock.de**

# Non-invertibility of basal ganglia network calls for new biomarkers

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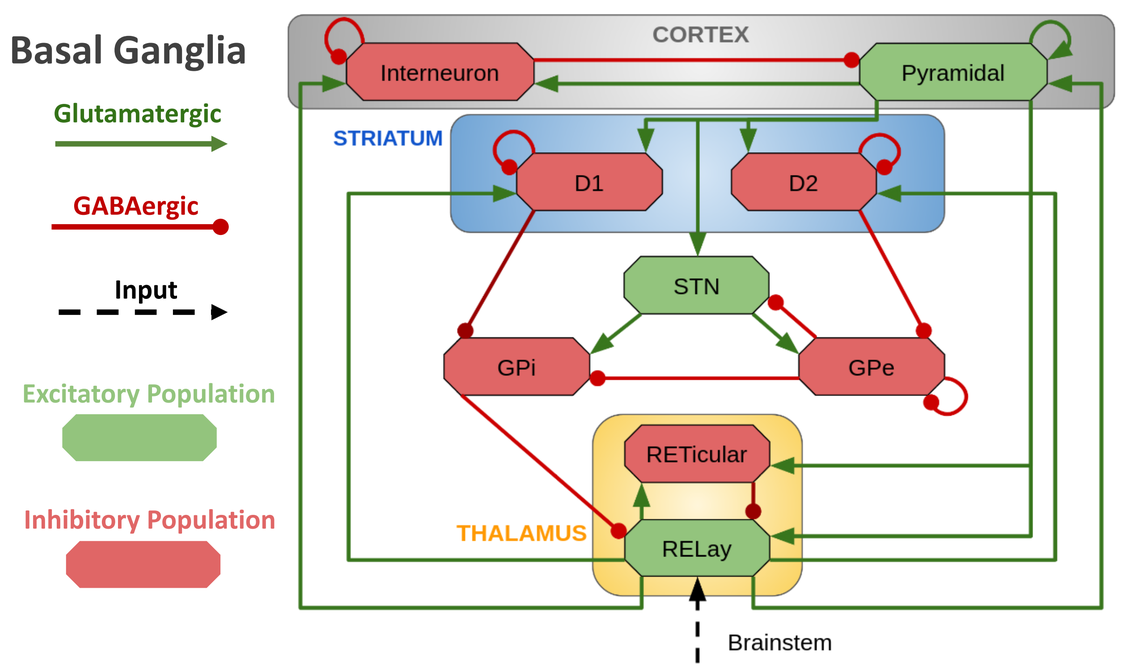
## INTRODUCTION

- Motivated by the role of synaptic processing in the basal ganglia, we explored the effect of the temporal synaptic characteristics on a parkinsonian biomarker.
- We demonstrate that one biomarker is not enough to determine the complete state of the brain.

## MODEL




### Mean-field model

Solved for voltage $V_k(t)$ and field $\phi_k(\boldsymbol{r},t)$ for each population k

$$\tau_r\tau_d\frac{d^2V_k}{dt^2}+(\tau_r+\tau_d)\frac{dV_k}{dt}+V_k=\sum_i \nu_{ki}\,\phi_i(t-\delta_{ki})+I_k^{ext}$$

$$\frac{1}{\gamma_a^2}\frac{\partial^2\phi_k}{\partial t^2}+\frac{1}{\gamma_a}\frac{\partial\phi_k}{\partial t}+\phi_k-r_a^2\nabla^2\phi_k=\frac{Q_k^{\max}}{1+\exp\left[-\frac{V_k-\theta_k}{r_k}\right]}$$

- Synaptic rise time $\tau_r$ and somatic decay time $\tau_d$
- Axonal pulse attenuation: damping rate $\gamma_a$
- Sigmoidal activation function: threshold $\theta_k$, steepness $r_k$, maximum firing rate of $Q_k^{\max}$
- Noise-free input $I_k^{ext}$ from brainstem to k=thalamus
- Spatially homogeneous neural field ($r_a^2\nabla^2\phi_k=0$)
- No axonal delay ($\delta_{ki}=0$)

### Healthy state

- Set according to the physiological steady-state firing rates [1,2]

### Parkinsonian state

- Unbalancing the direct/indirect pathways [4]
- Lower striatal thresholds → lower striatal signal-to-noise ratio [5]
- Weaker GPe-GPe link → Enhancing enkephalin release [6]
- Weaker intracortical links → mesocortical dopamine loss [7]

### Study

- Effect of synaptic-somatic temporal interaction
- Vary the time scale ($\tau_d$) on the emergence of *excess beta activity*

## RESULTS

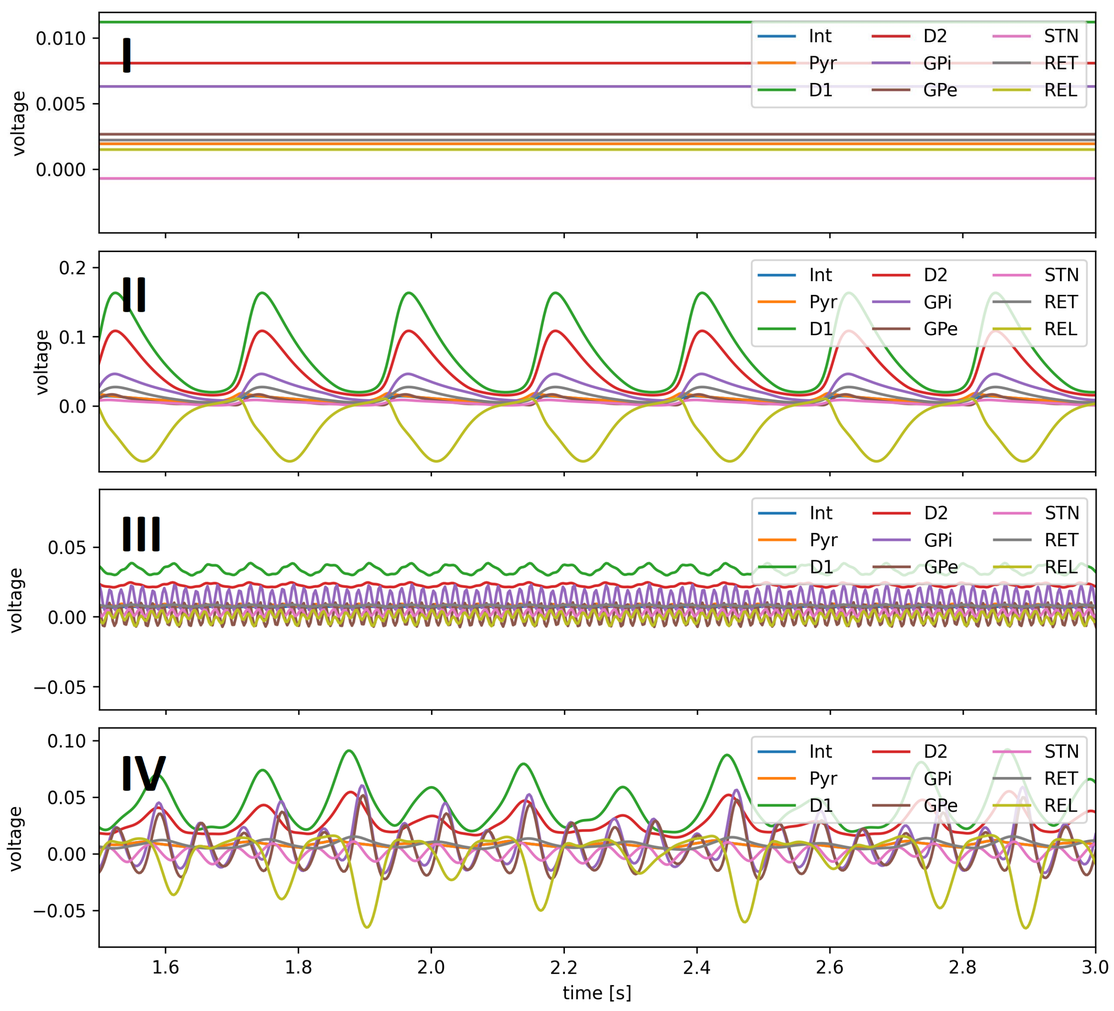



**Figure 1: Canonical response types of the model**

## RESULTS

- Model exhibits dynamically different response types (Fig.1)
  - *I. Stationary steady-state* → *[1,2], this work*
  - *II. Uni-modal oscillation* → *[3], this work*
  - *III. Multi-modal oscillations* → *this work*
  - *V. Chaotic* → *this work*

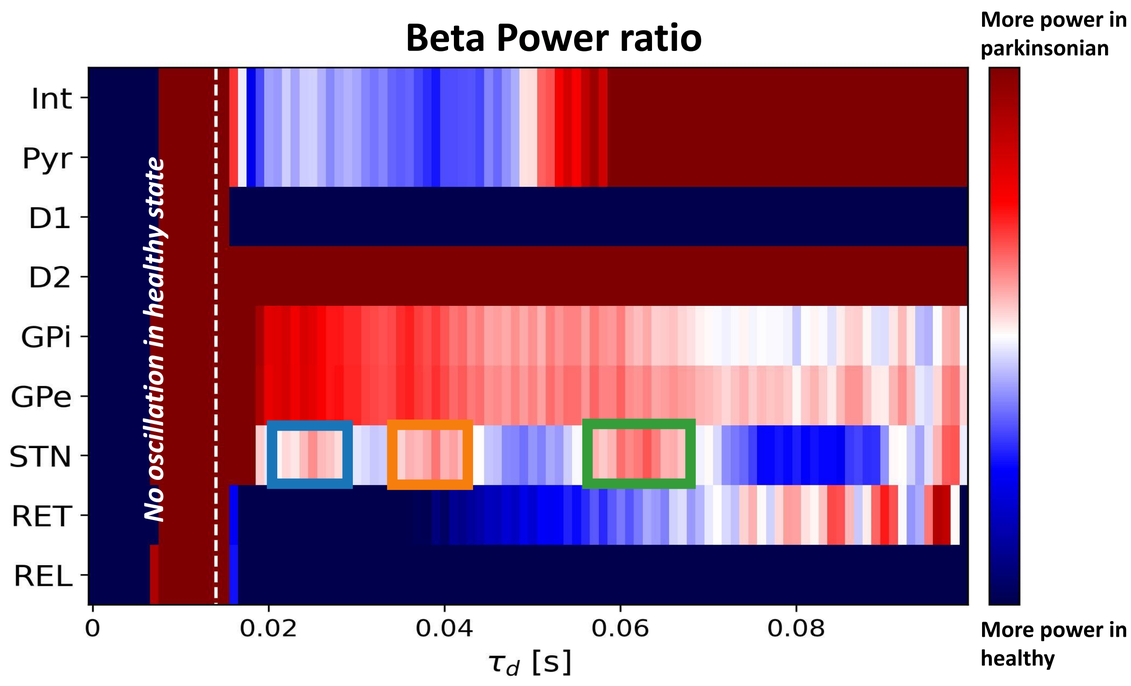



**Figure 2: Multitude of P-conformal parameter regions. Some STN windows are marked in blue, orange and green**

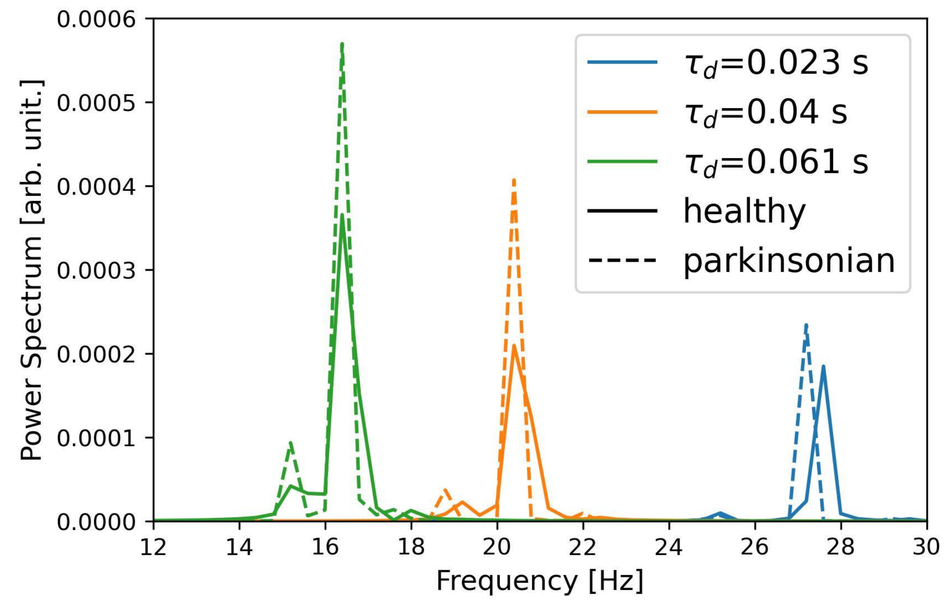



**Figure 3: STN power spectral density of the windows marked in Fig. 2 in beta frequency range**

## DISCUSSION

- Synaptic temporal characteristics are detrimental for exhibition or absence of parkinsonian-like responses
- Computational models discern p-conformal configurations
- Such discrimination should be compared with new biomarkers or brain recordings

## CONCLUSION

- Flexible computational model of the basal ganglia
- Varieties of dynamical responses depending on the "hidden" parameters
- Multitudes of distinguishable "p-conformal" parameter sets
- Network is non-invertible with few biomarkers
- Augmentation with EEG/ECoG/LFP is a must for an entire brain state specification

## FUTURE WORK

- Implementing the axonal delays
- Explore DBS-like and noisy inputs to the populations
- Use EEG/ECoG recordings and Bayesian inversion

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