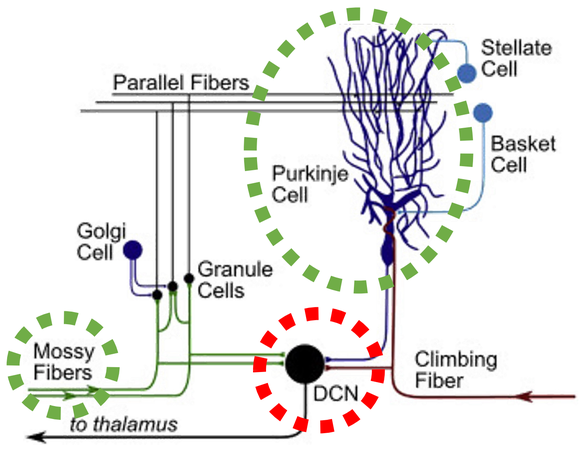
Multidimensional dynamics of the cerebellar output neurons encoding saccadic eye movement

Jisub Bae[1], Zong-peng Sun[2], Peter Thier[2] & Sungho Hong[1†]

[1]Center for Cognition and Sociality, Institute for Basic Science, South Korea; [2]Dept. of Cognitive Neurology, Hertie Institute for Clinical Brain Research, University of Tübingen, Germany; †sunghohong@ibs.re.kr

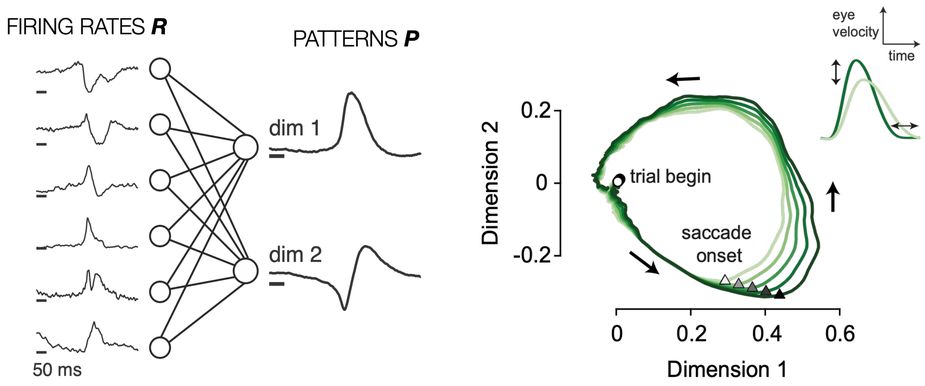
Introduction

Deep cerebellar nuclei (DCN)



- **Final output region of the cerebellum** (red) integrating the mossy fiber and Purkinje cell inputs (green),
- **Fastigial nucleus (FN)**, a DCN region involved in eye movement, remains poorly understood due to difficulty of recording from this area.
- We analyzed the recordings from **FN neurons** (**FNN**; *n*=67) by Sun et al. [1] in rhesus monkeys performing saccadic eye movement tasks (see below).

Neural manifold (in the cerebellum)

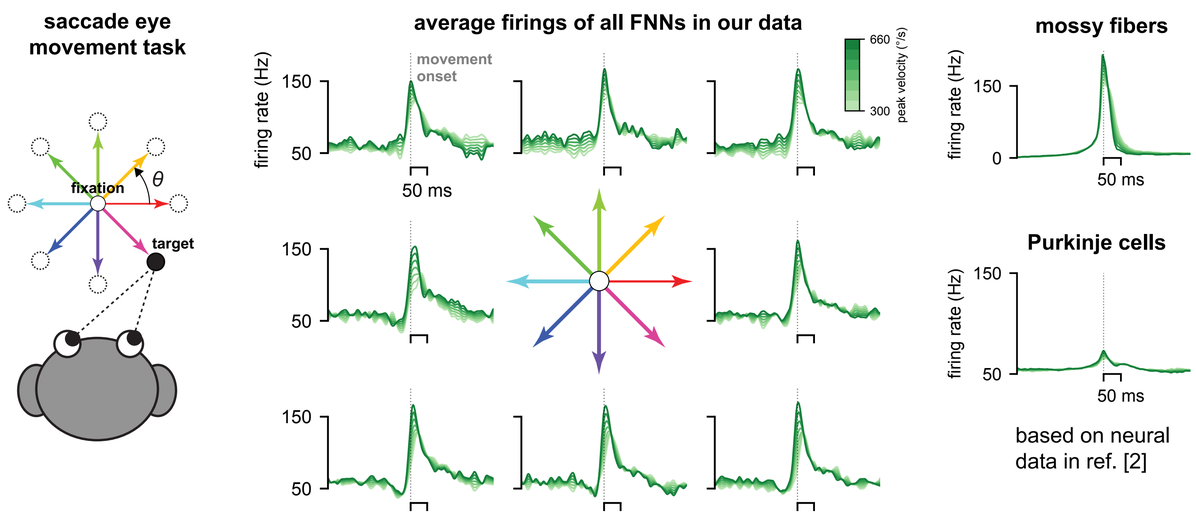


$\mathbf{R}(\mathbf{z},t) \approx \mathbf{W} \cdot \mathbf{P}(\mathbf{z},t)$ $\quad P_1(v_{\text{peak}},t)$ vs. $P_2(v_{\text{peak}},t)$

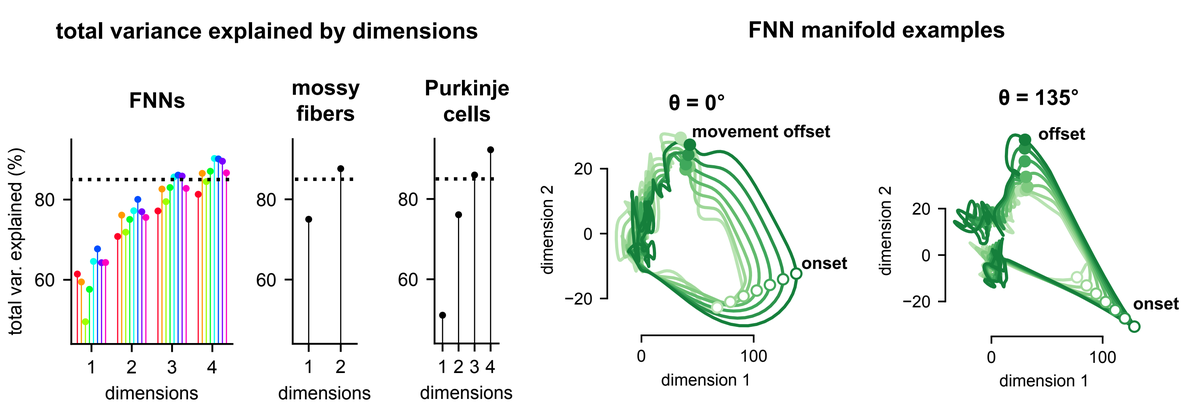
- A small number of patterns (dimensions) explaining a large fraction of cell-to-cell variability in the neural population activity,
- Highly successful at explaining the population activity of various neurons in many brain regions, including **mossy fibers** and **Purkinje cells** in the cerebellum [2] (figures above: Purkinje cell case).
- ***What about FNNs,*** *their common postsynaptic targets****?***

Results

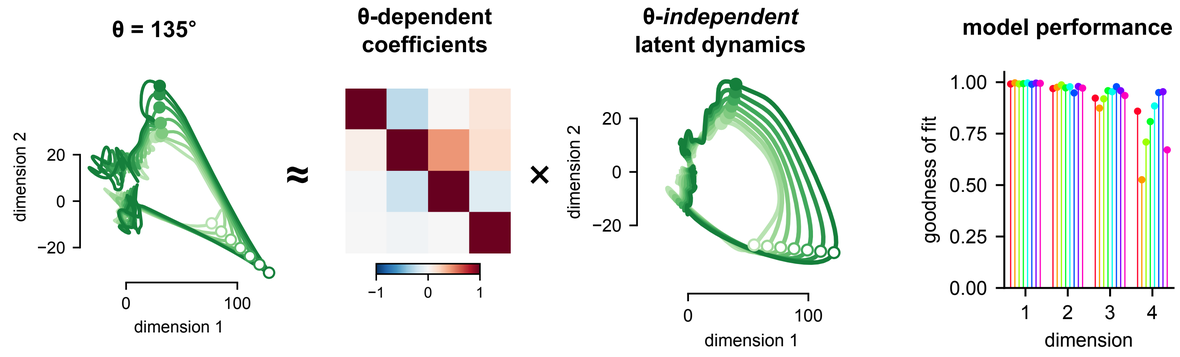
On average, FNNs prominently burst like mossy fibers



FNN activity dimensionally reduces like Purkinje cells



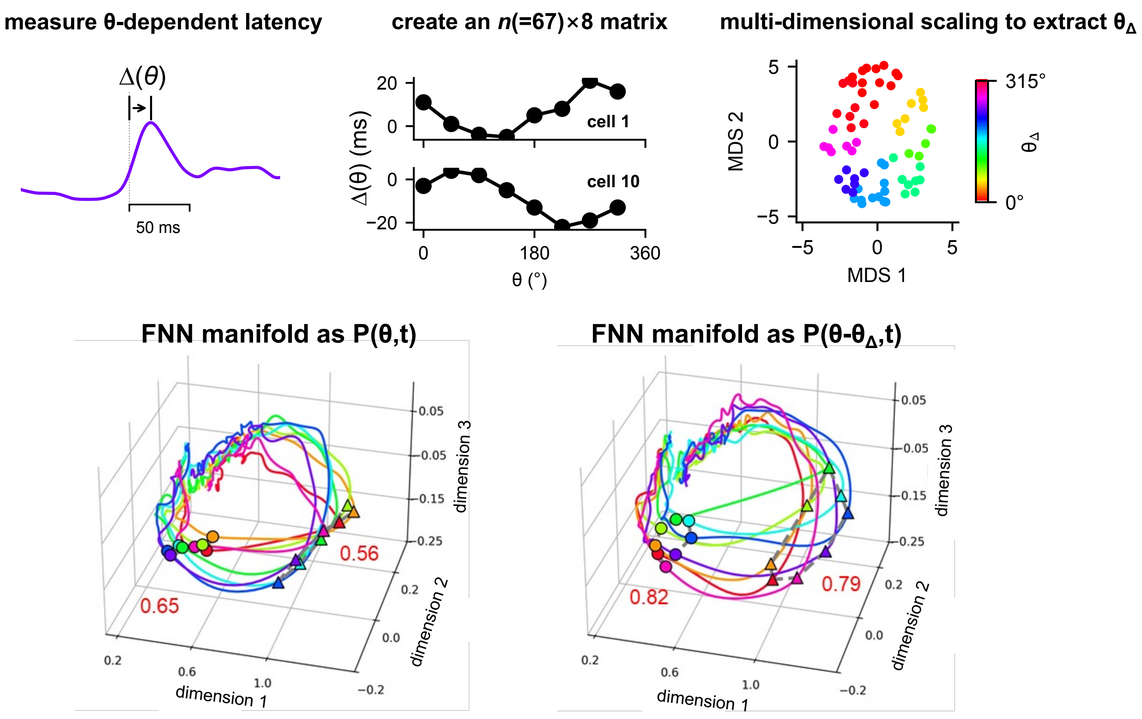
Direction-independent latent dynamics underlies FNN manifolds



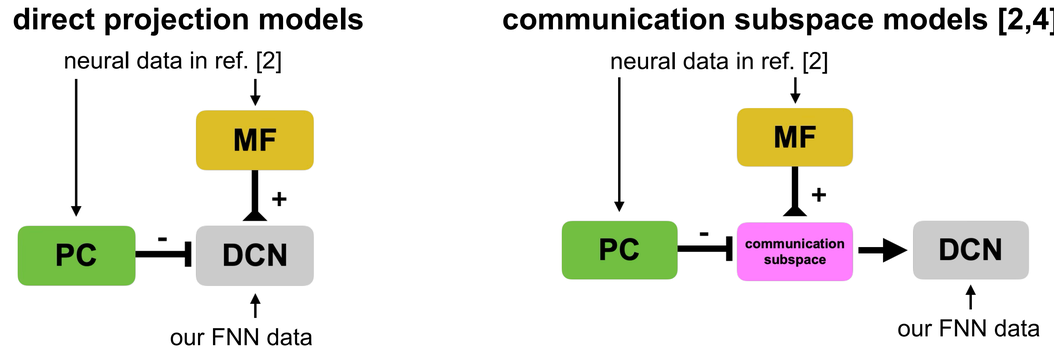
☞ $\mathbf{R}(\theta,t) \approx \mathbf{W} \cdot \mathbf{P}(\theta,t), \quad \mathbf{P}(\theta,t) = \mathbf{U}(\theta) \cdot \mathbf{L}(t)$

firing rate individual neurons | weight matrix | neural manifold | gain matrix | latent dynamics

FNNs have intrinsic reference directions [3] controlling their spike latency coding of eye movement directions



Data-driven network models show that FNN population activity is dominantly influenced by the Purkinje cell manifold



Acknowledgements

This work was supported by the Center for Cognition and Sociality (IBS-R001-D2), Institute for Basic Science, South Korea.

References

1. Sun et al. (2016) Eur J Neurosci *44*, 2531-42.
2. Markanday, Hong et al. (2023) Nat Commun *14*, 2548.
3. Fakharian et al. (2025) Science *388*, 869-75.
4. Semedo et al. (2019) Neuron *102*, 249-59.