Reservoir Computing with Nanostructured Magnetic Arrays

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1. Introduction

- Artificial Spin Vortex Ice presents itself as a strong candidate for reservoir computing

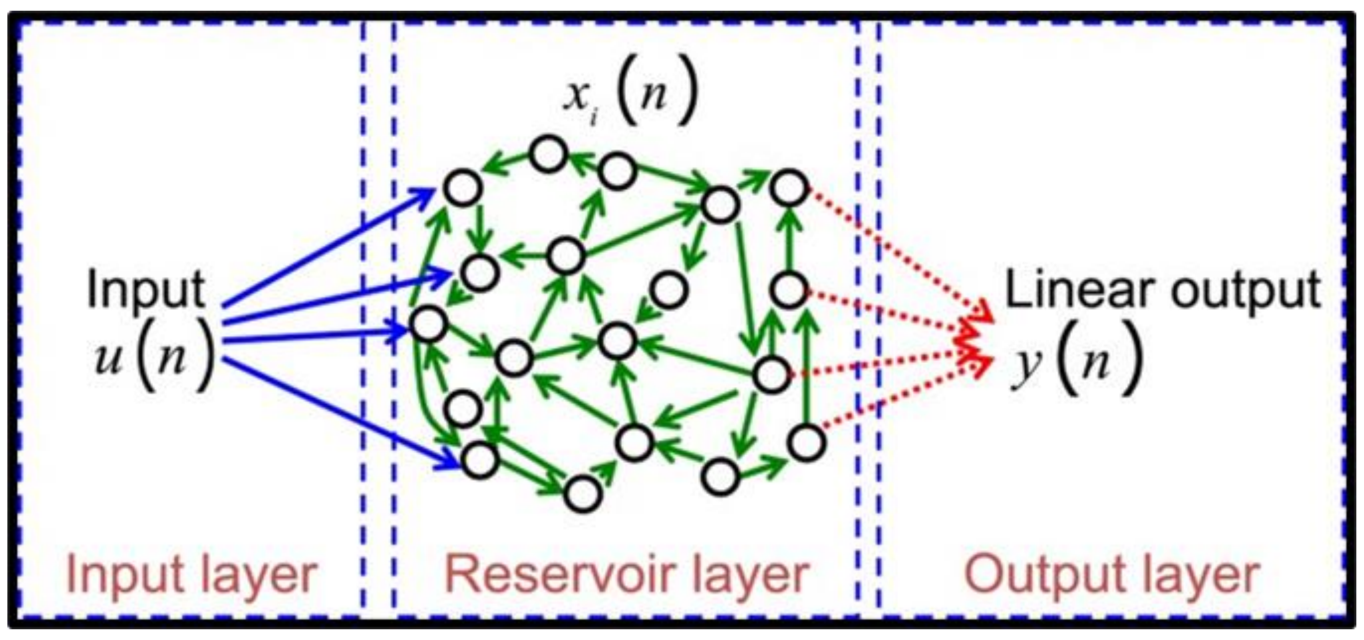
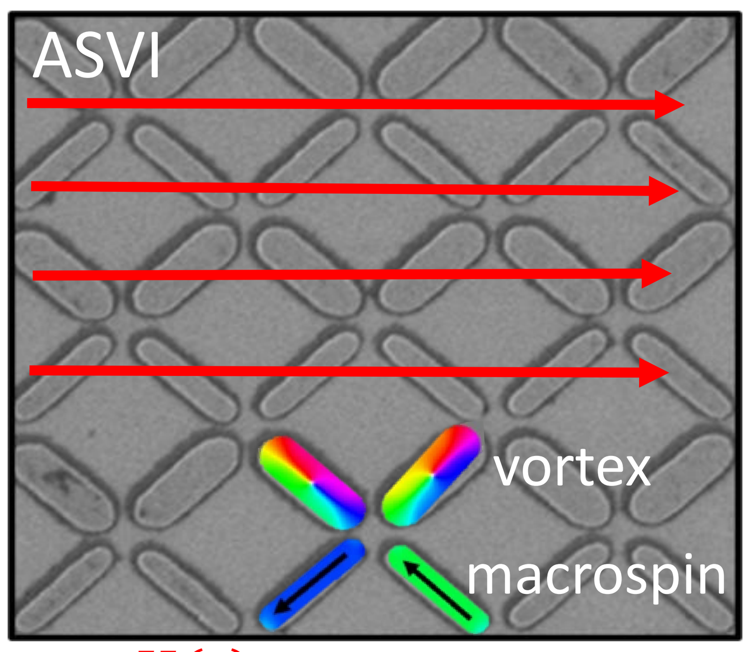


Fig. 1. Diagram illustrating reservoir computing [1].

2. Objective

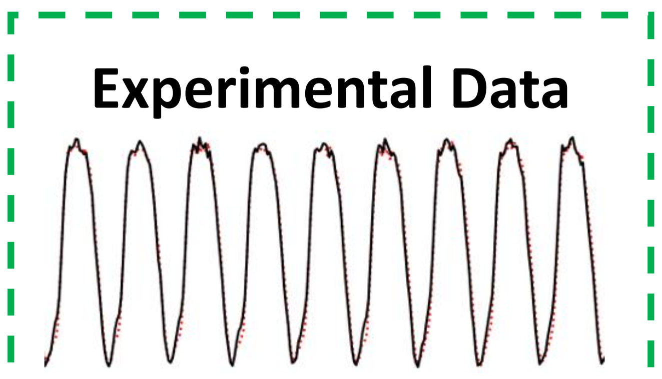
- Simulating the reservoir response to provide rapid insight into the system
- Evaluate properties of ASVI that make it suitable for reservoir computing



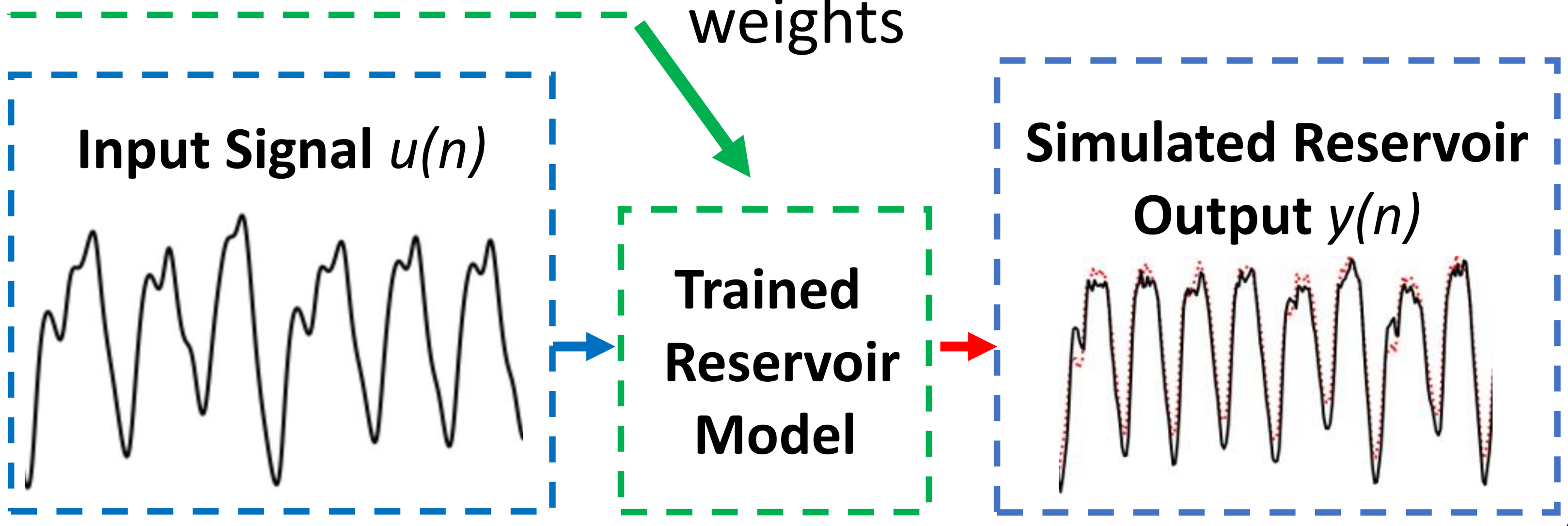
$\boldsymbol{H}(t)$: converts states

Fig. 2. Evolution in population of states (vortex/macrospin) can be used for reservoir computing [2].

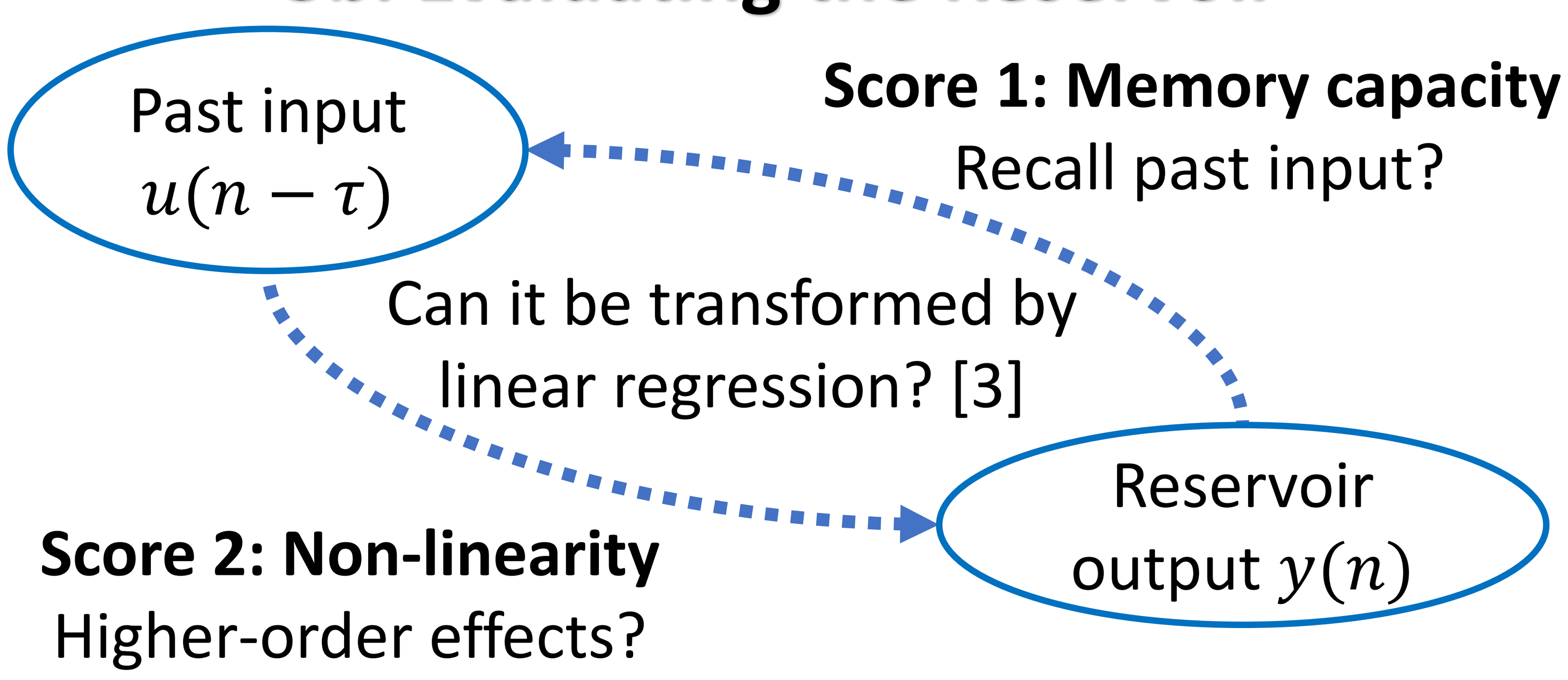
3a. Simulating the Reservoir



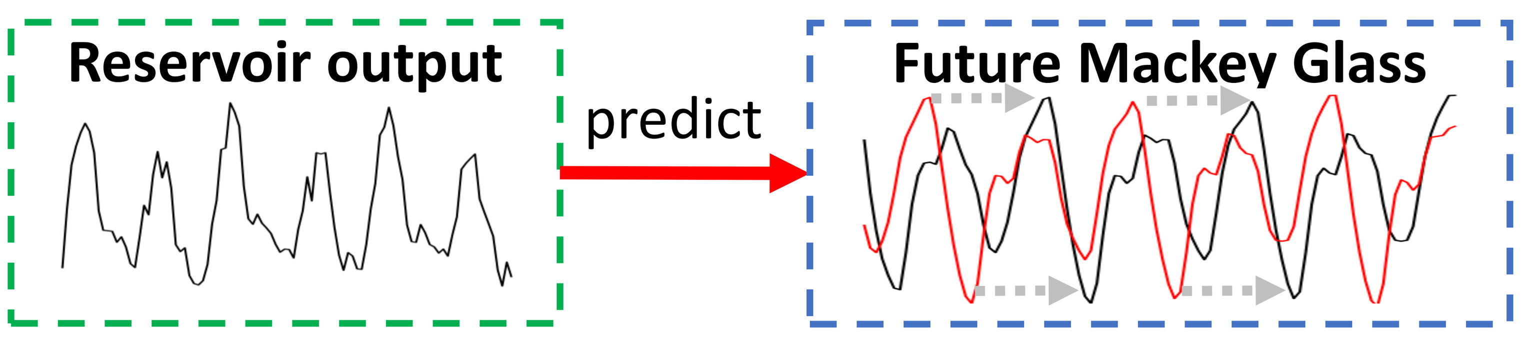
Train a linear regression model $y(n) = \sum w_n O_n$ where O_n are the past input/output values and w_n are their determined weights



3b. Evaluating the Reservoir



Goal: better forecast of Mackey Glass series



4. Results

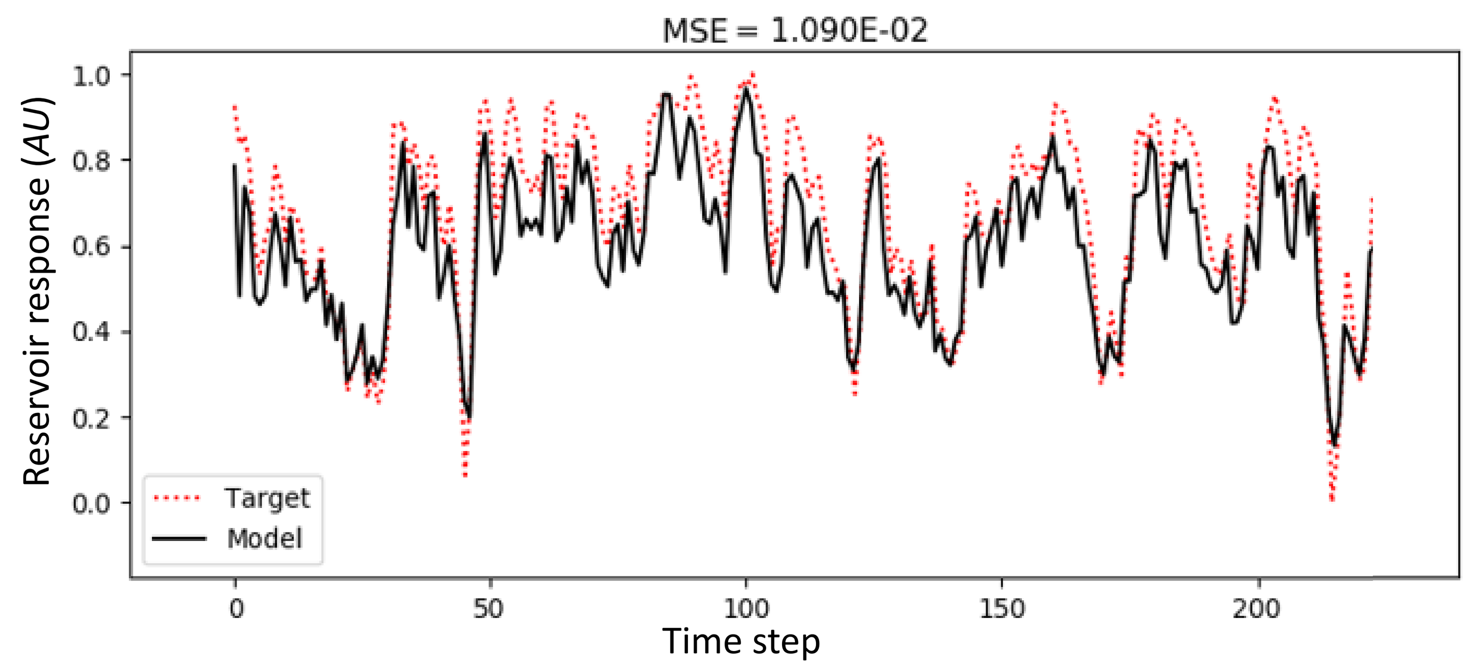
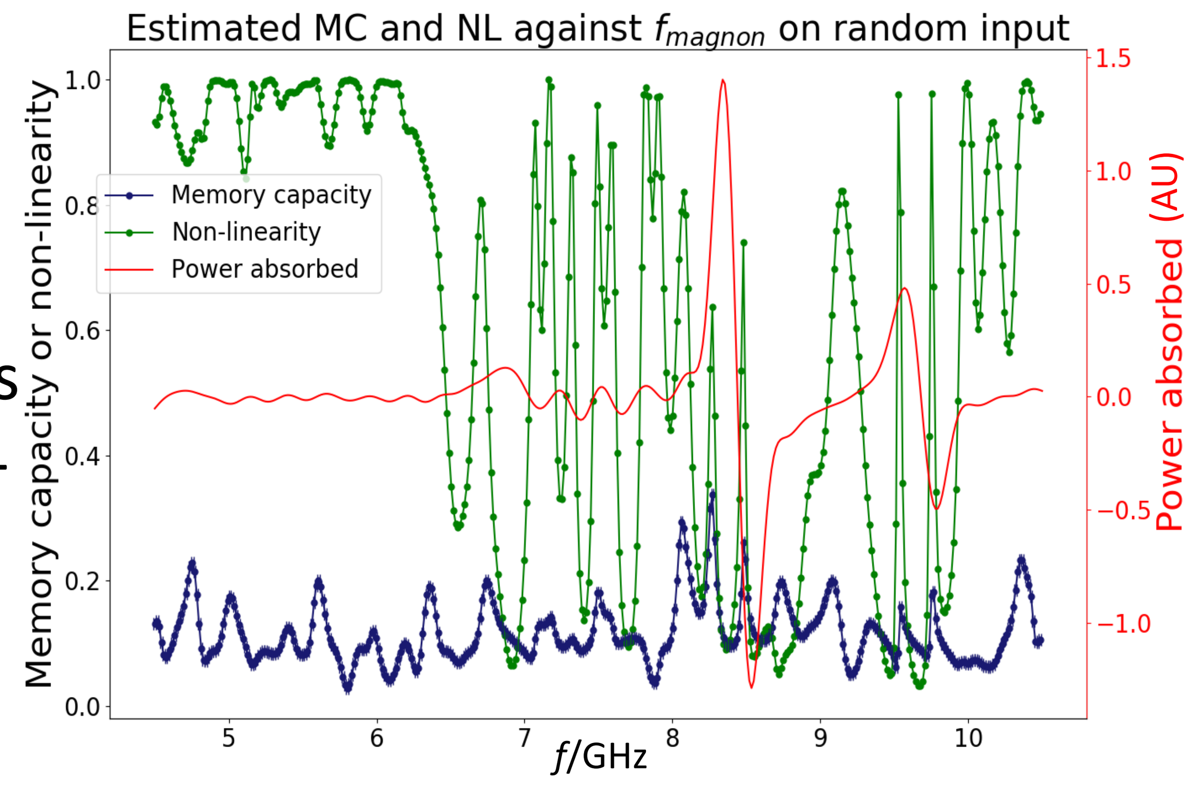


Fig. 3. Simulated reservoir response to a random input function, trained using experimental data from a sin, inverse saw and Mackey Glass input.

Fig. 4. Absorption spectrum encodes memory and non-linear effects.



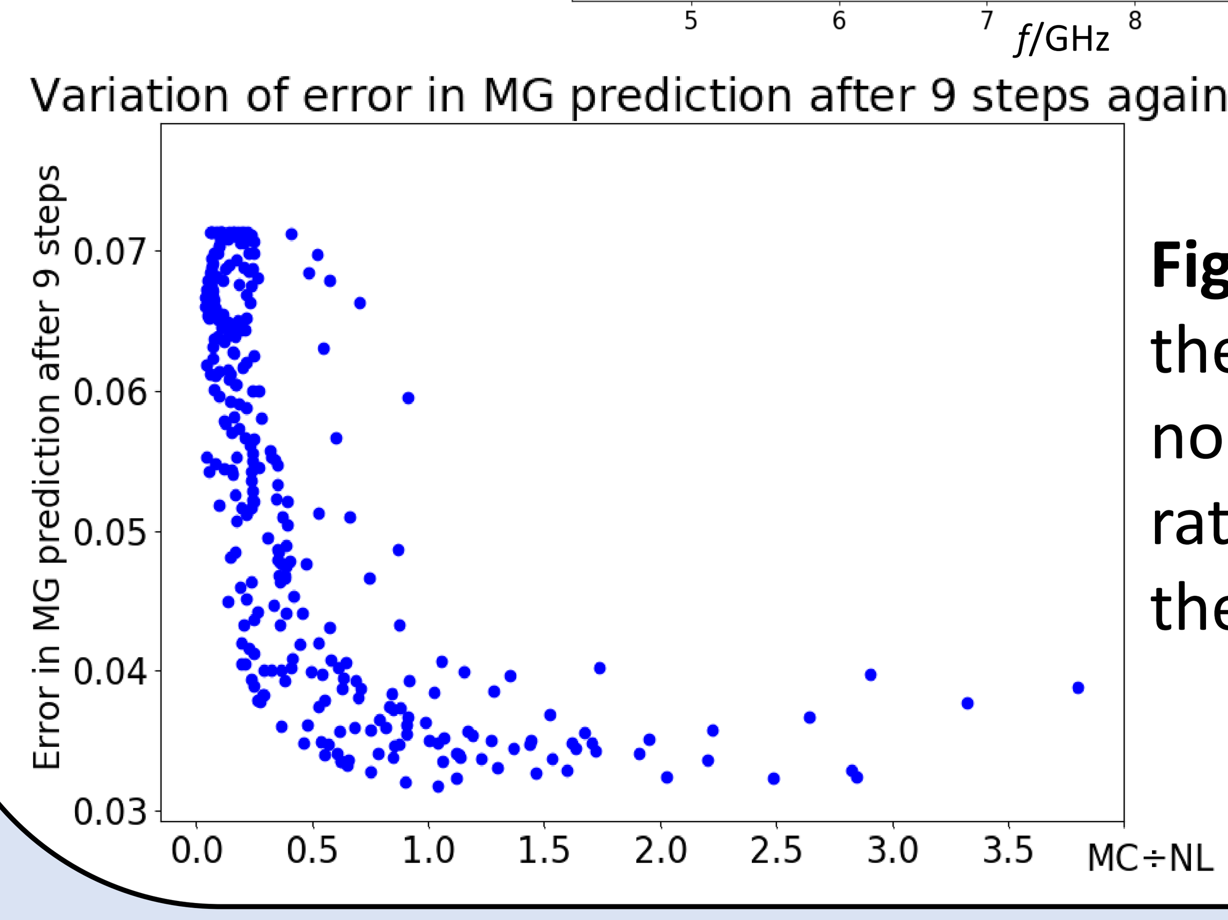


Fig. 5. The higher the memory to non-linearity ratio, the better the prediction!

5. Conclusions and Outlook

- Generated reservoir responses have mean squared error $\mathcal{O}(10^{-2})$ when tested against experimental data.
- The best frequencies in the spectrum to use for forecasting are the ones dominated by memory effects.
- Simulated output can be used to sample the reservoirs' ability to perform tasks like digit/vowel recognition and ECG classification.

[1] Duport, F., et al. (2016). Fully analogue photonic reservoir computer. *Scientific Reports*, *6*(1). https://doi.org/10.1038/srep22381

[2] Gartside, J., et al. (2022). Reconfigurable Training and Reservoir Computing in an Artificial Spin-Vortex Ice via Spin-Wave Fingerprinting. *arXiv.* http://arxiv.org/abs/2107.08941

[3] Love, J., *et al.* (2021). Task Agnostic Metrics for Reservoir Computing. arXiv:2108.01512.