

# Rodent - Relevant ODE identifier

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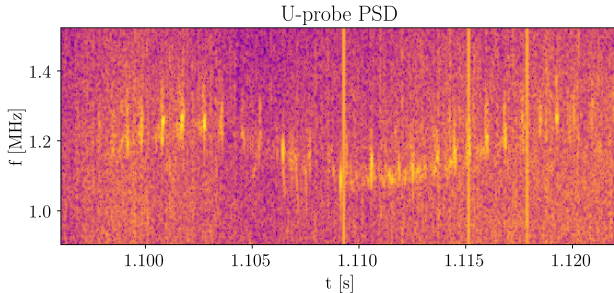
Artificial Intelligence Center

# Rodent



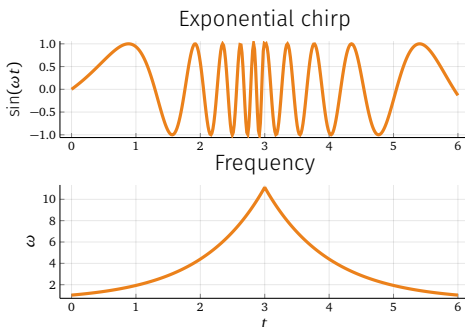
**Rodent:** Relevant ordinary differential equation identifier

# Chirping fusion plasmas



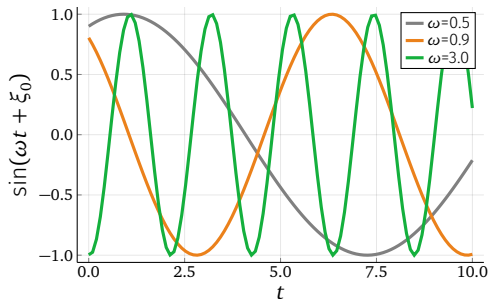
- scalar time-series that rarely contains **Alfven modes**
- Alfvens are poorly understood

# Chirping fusion plasmas



- **Model identification** of chirping modes
- First step: simplify the problem → harmonic signals

# Chirping fusion plasmas



## The simplified problem

- Learn generating model of harmonic signals
- varying frequency  $\omega$  and phase  $\xi_0$

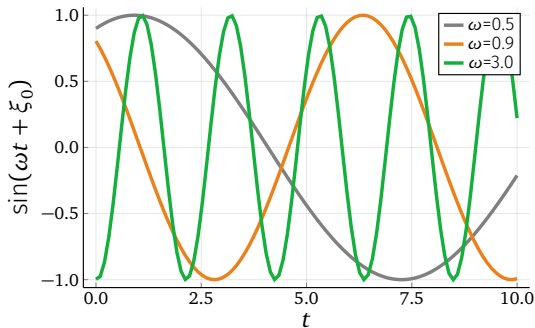
1. Explainability via ODEs
2. Sparsity of the ODE via *Automatic Relevance Determination* (ARD)
3. Generative Models for manifold learning

## Ordinary differential equations

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$$\frac{\partial \xi}{\partial t} = f(\xi, \theta, t) \approx \mathbf{W}\xi + b$$

## Example: Harmonic oscillator



### Scalar form

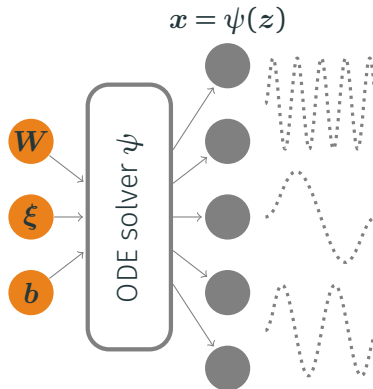
$$\ddot{\xi} = -\omega^2 \xi$$

### Matrix form

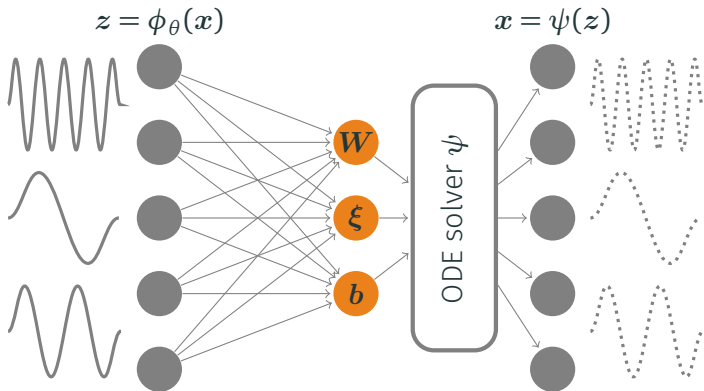
$$\begin{bmatrix} \dot{\xi} \\ \xi \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\omega^2 & 0 \end{bmatrix} \begin{bmatrix} \xi \\ \dot{\xi} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$



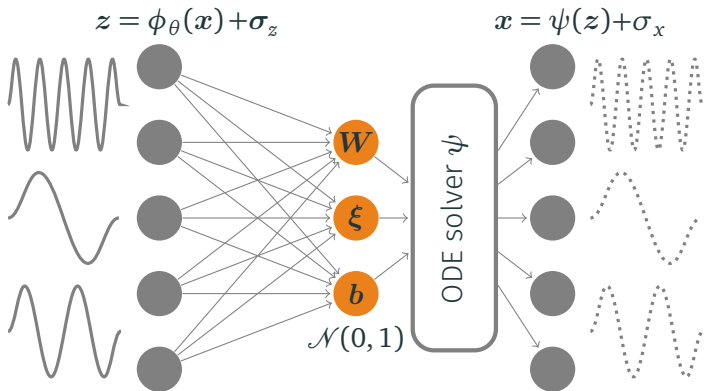
# Odent - VAE + ODE solver



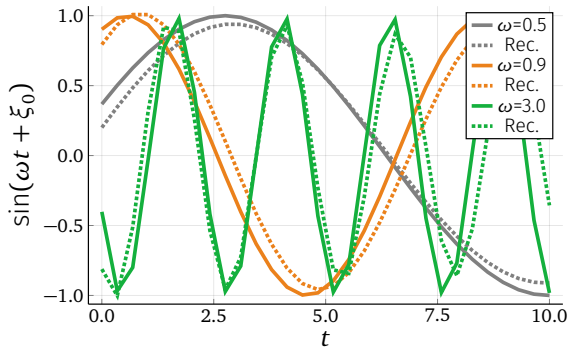
# Odent - VAE + ODE solver



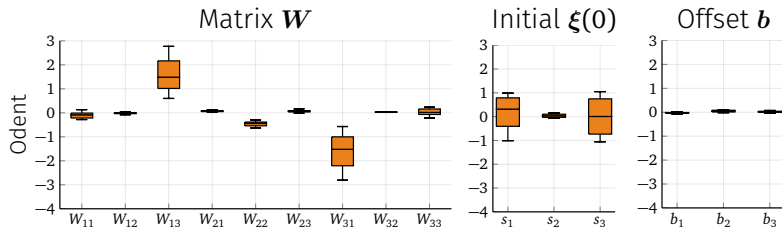
# Odent - VAE + ODE solver



## Results - Reconstructions



## Results - Latent space

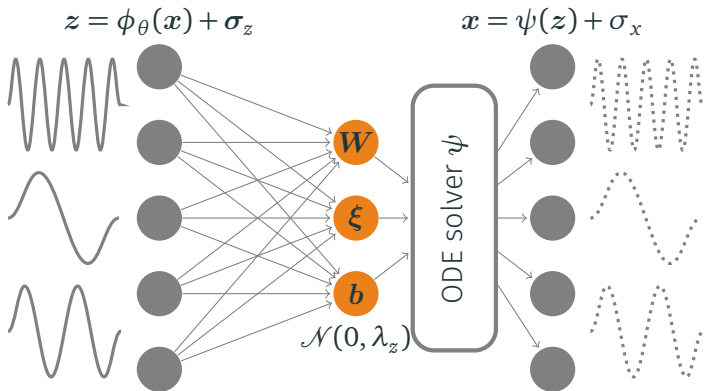


$$\begin{bmatrix} \ddot{\xi} \\ \dot{\xi} \\ \xi \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -\omega^2 & 0 & 0 \end{bmatrix} \begin{bmatrix} \xi \\ \dot{\xi} \\ \ddot{\xi} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

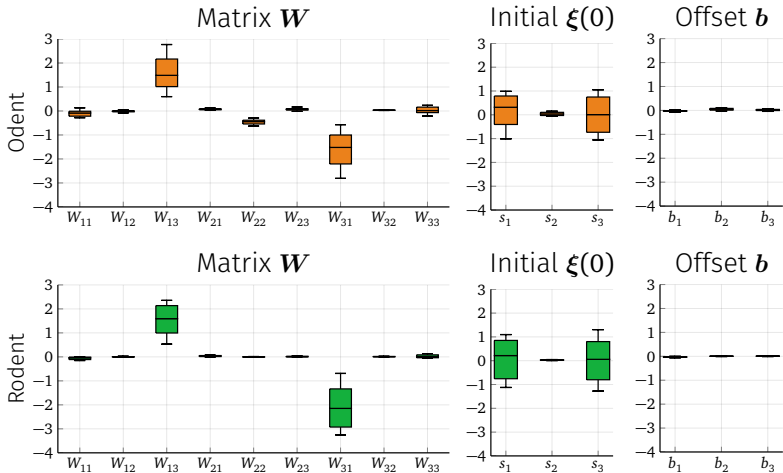
Successful model identification

But: 1-3 irrelevant parameters remain in  $W$

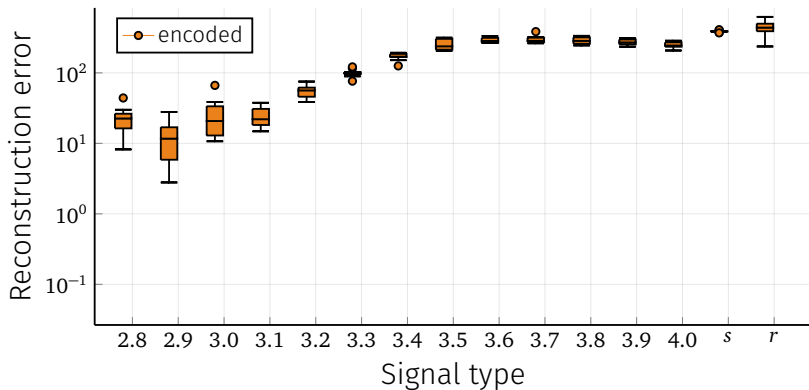
# Rodent - VAE + ODE solver + ARD



# Results



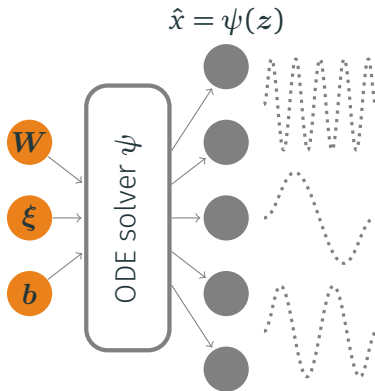
# Results



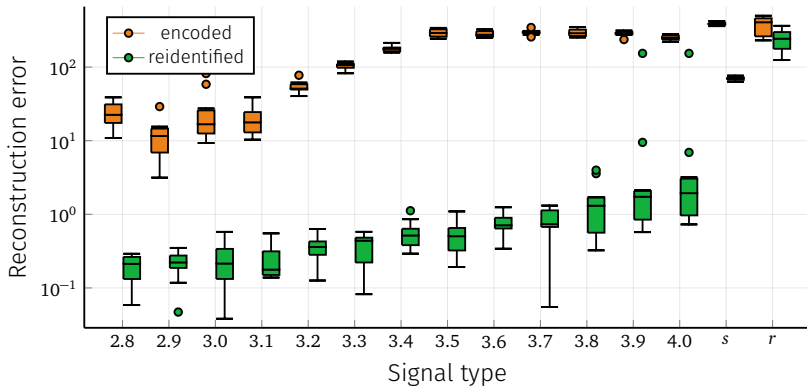


# Reidentification

- Starting point:  $z = \phi(x)$
- Fix irrelevant parameters
- Continue optimizing  $|\psi(z) - x|^2$



# Results



Reidentification enables far extrapolation

## Conclusion

Identification of partially observed system

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Identification of partially observed system  
Sparse, explainable model

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Identification of partially observed system

Sparse, explainable model

Good extrapolation

## Conclusion

Do you have data for us?