

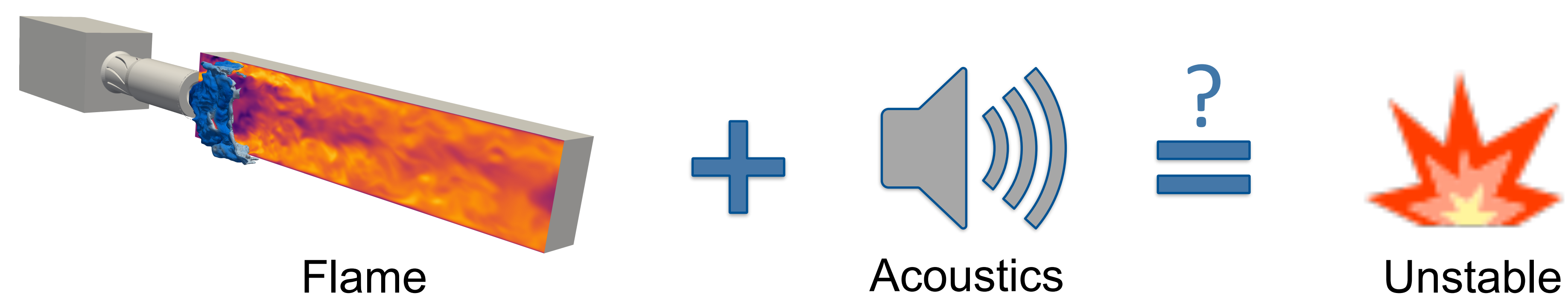
# Probabilistic Thermoacoustic Modeling

Axel Zimmermann, Wolfgang Polifke; Thermo-Fluid Dynamics Group

MDSI General Assembly,  
November 20, 2025

## Our Problems:

### Thermoacoustic Instabilities



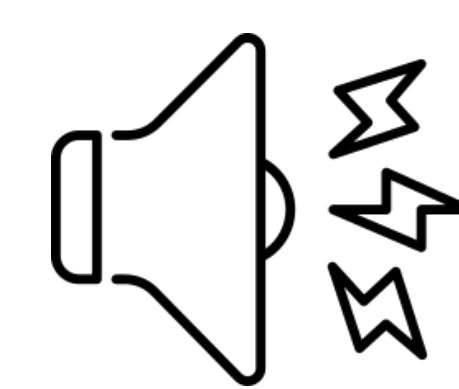
- Highly nonlinear dynamics
- Spatial & temporal scale separation ( $\sim 10^5$ )
- Strongly coupled system
- Sensitive to modeling errors

### Little Data



- Simulations can take months on a super computer
- Experimental information are sparse

### Noisy Data

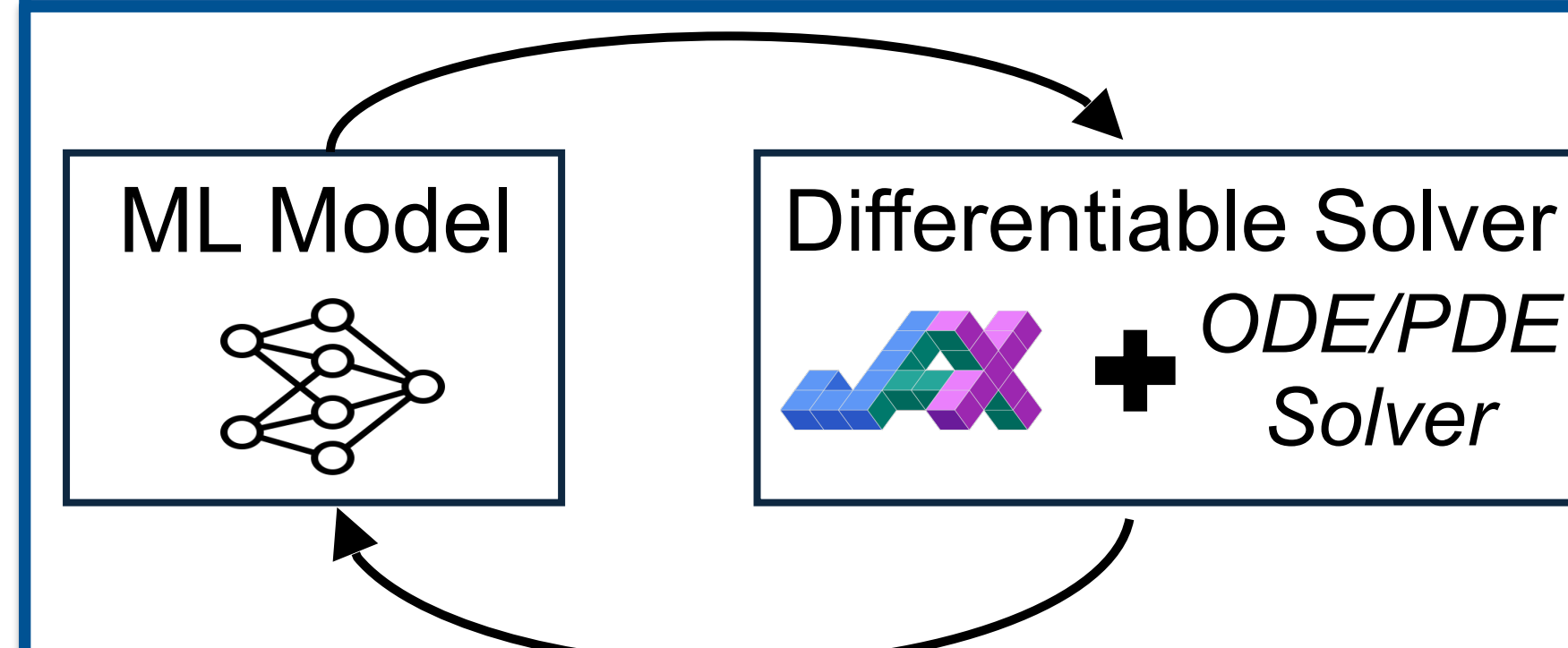


- Flames produce colored noise
- Additional measurement noise

→ ML models often unreliable

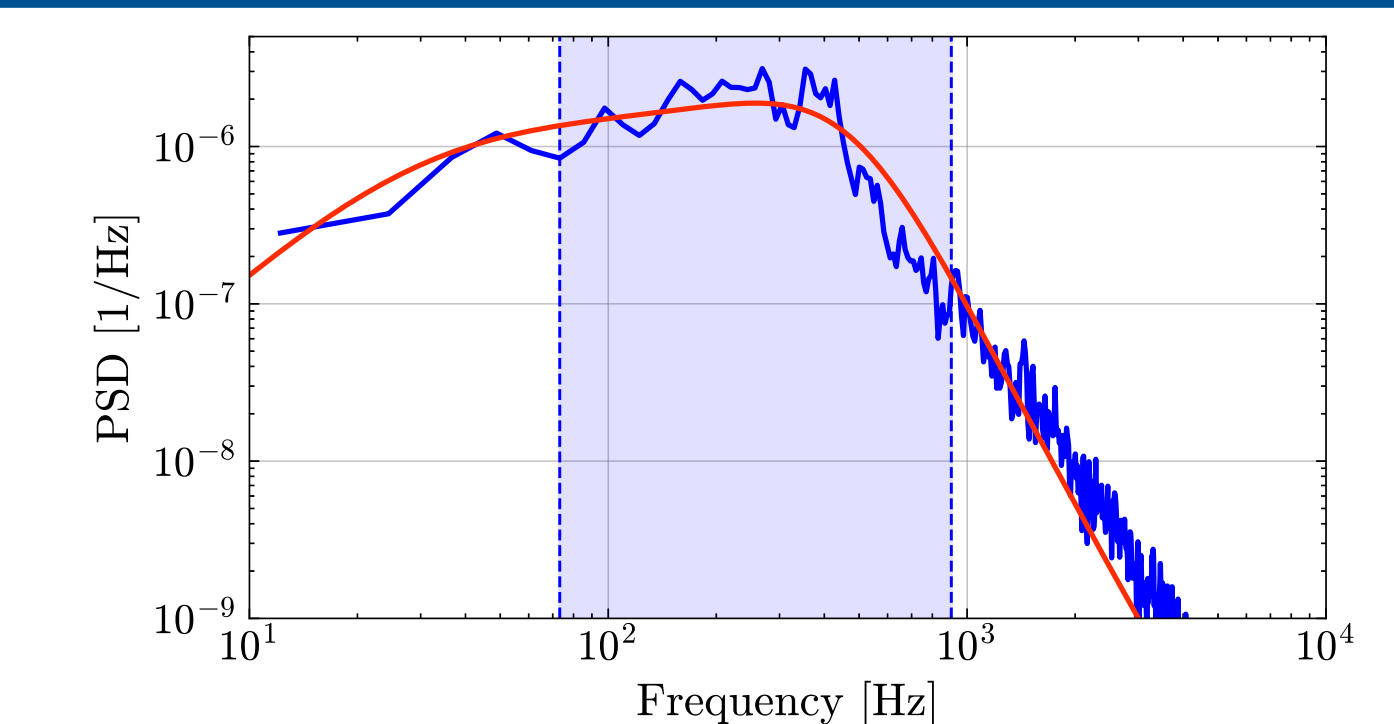
## Our Solutions:

### Differentiale PDE Solvers



- Train ML model inside PDE solver
- Propagate measurement noise to ML model

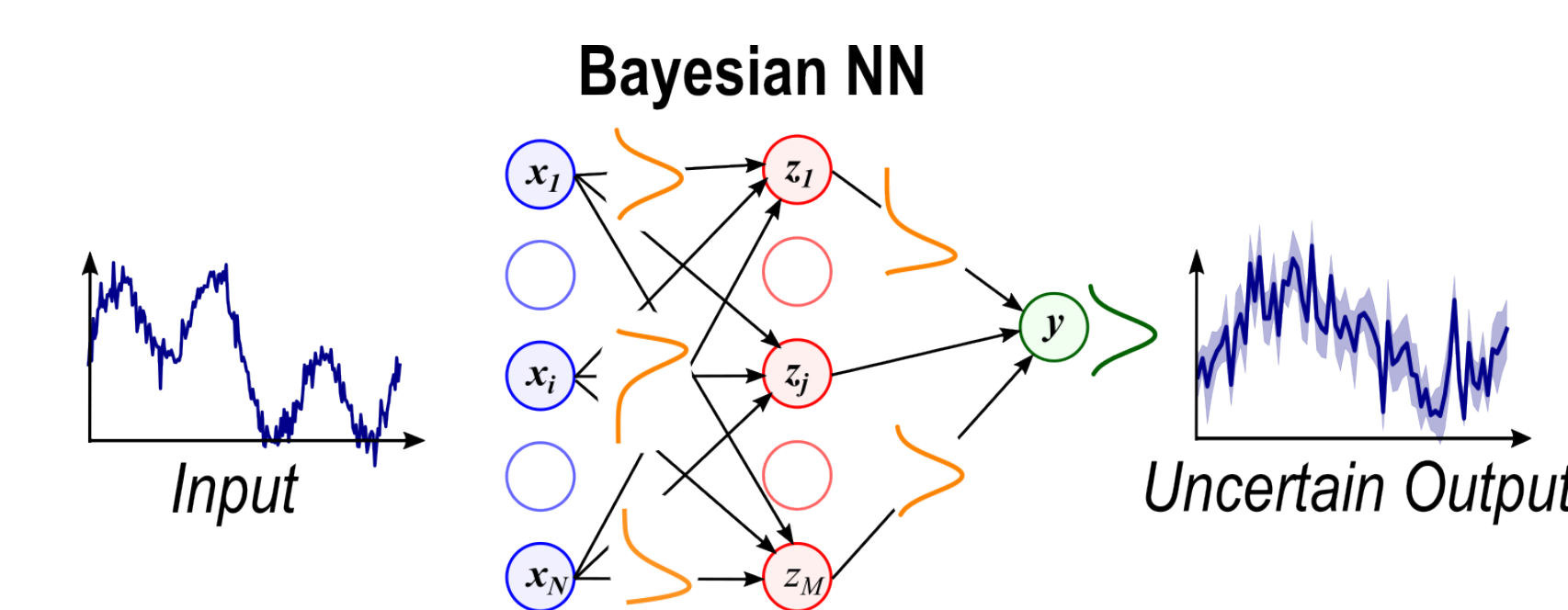
### Colored Noise Modeling



Physics augm. colored noise model improves uncertainty quantification

→ reliable uncertainties

### Bayesian Neural Nets



BNN quantify uncertainties from lack of data / information

→ reliable predictions

### Evidence Based Modeling

$$P(\theta | D, M) = \frac{P(D | \theta, M) P(\theta | M)}{P(D | M)}$$

- Evidence balances complexity vs model fit
- Higher evidence = higher support for model

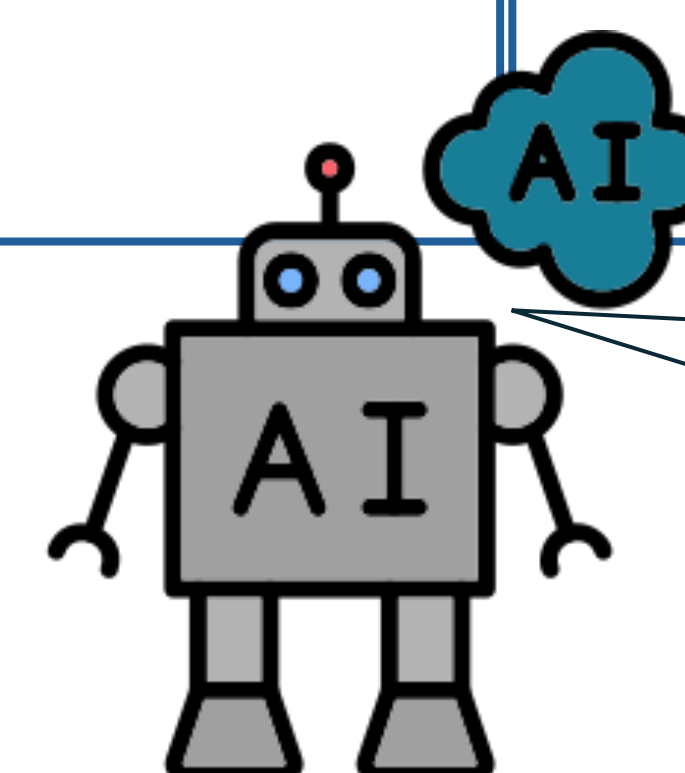
→ reliable model selection



M.Sc. Axel Zimmermann  
TUM; School of Engineering & Design  
Thermo-Fluid Dynamics Group  
axel.zimmermann@tum.de



Prof. Wolfgang Polifke  
TUM; School of Engineering & Design  
Thermo-Fluid Dynamics Group  
polifke@tum.de



*This rocket is all right*

