Accelerated Bayesian inference of multimessenger astronomy with `jax` and machine learning

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Nuclear Multi-Messenger Astrophysics

- `NMMA`: Nuclear Multi-Messenger Astrophysics (Peter T.H. Pang)
- A Pythonic library for probing nuclear physics and cosmology with multimessenger analysis
- Used for overview of EOS constraints, with "precomputed" EOS set (arXiv:2402.04172)
  - Metamodel
  - Speed-of-sound extension scheme

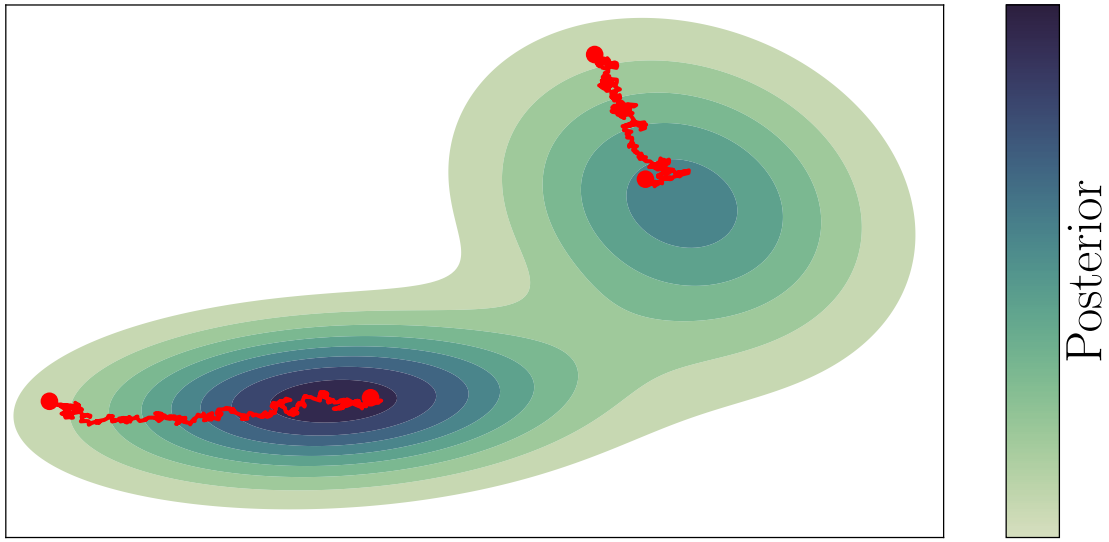
Next step: Infer EOS parameters directly from multimessenger data

Bayesian inference

Bayesian inference: get posterior of parameters θ from data d

$$p(\theta|d) = \frac{p(d|\theta)p(\theta)}{p(d)} = \frac{\text{likelihood} \times \text{prior}}{\text{evidence}}$$

Problem: Prohibitively expensive with multimessenger data



JAX

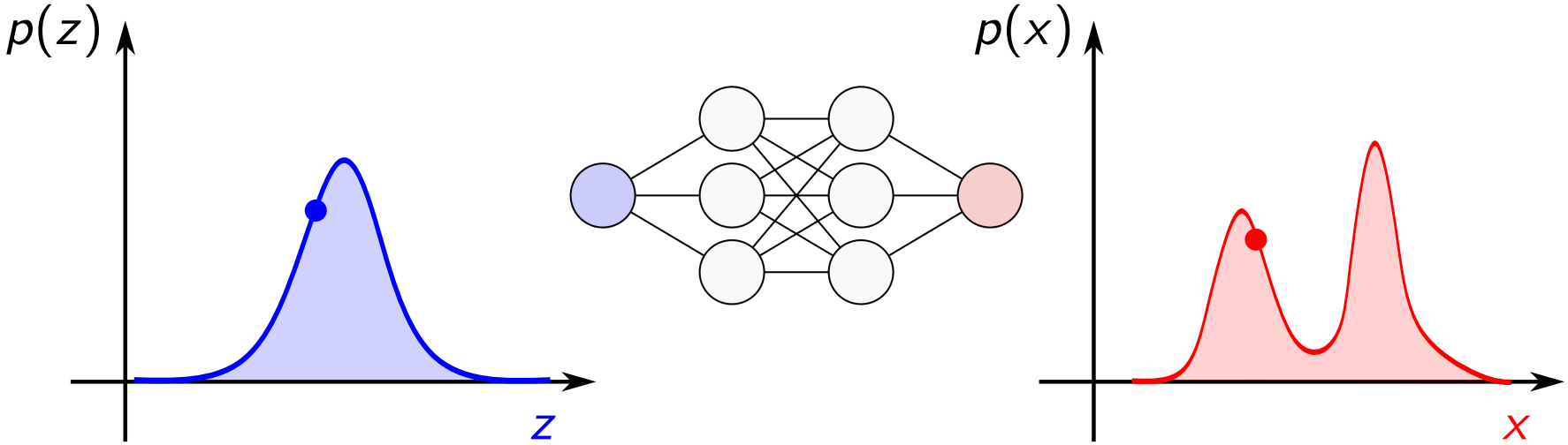
JAX = NUMPY + composable transformations:

1. Automatic differentiation
2. Just-in-time (JIT) compilation
3. GPU acceleration
4. Parallelization

Potential for acceleration in various science areas!

Normalizing flows

- Generative machine learning model
- Learn mapping between latent and parameter space
- Enable approximate sampling from complicated distributions
- Training data: MCMC samples



Accelerating Bayesian inference for MMA: progress

- Gravitational waves:
  - Analyze binary neutron stars in 15 – 30 minutes rather than $\mathcal{O}(\text{hours})$ (arXiv:2404.11397)
  - `kazewong/jim`
- TOV solver:
  - $10 - 100\times$ faster
  - `tsunhopang/jose`
- Kilonovae, GRBs: `ThibeauWouters/fiesta`
- Ongoing:
  - Next-generation gravitational wave detectors
  - Combine into one multimessenger analysis pipeline