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

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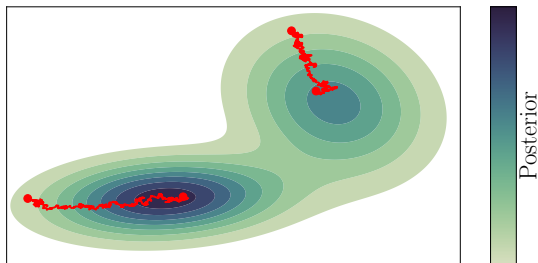23 – 27 September 2024

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Bayesian inference

Bayesian inference: get posterior of parameters θ from data d

$$p(\theta|d) = \frac{p(d|\theta)p(\theta)}{p(d)}$$

Problem: Computationally expensive for multimessenger data $+$ EOS

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  - Metamodel
  - Speed-of-sound extension scheme
  - 100 000 EOS

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Next step: Infer EOS parameters directly from multimessenger data, upgrade software for future detectors

JAX = NUMPY + composable transformations:

1. Automatic differentiation

2. Just-in-time (JIT) compilation

3. GPU acceleration

4. Parallelization

Potential for accelerating science, without resorting to machine learning!

Normalizing flows

- Generative machine learning model

- Learn mapping between latent and parameter space

- Enable approximate sampling from complicated distributions
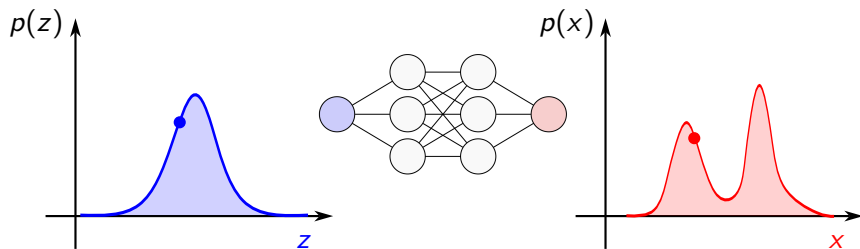
- Gravitational waves (arXiv:2404.11397)

    - Waveforms: $\mathcal{O}(10^3)$ faster

    - Analyze binary neutron stars in 15 – 30 minutes rather than $\mathcal{O}(\text{hours})$

Accelerating Bayesian inference for MMA: progress

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- Future work:

  - Next-generation gravitational wave detectors

  - Combine into one multimessenger analysis pipeline

Thanks for listening!

Our JAX ecosystem:

- Normalizing flow-enhanced MCMC sampler: ⍥ kazewong/flowMC

- Gravitational waveforms: ⍥ tedwards2412/ripple

- Gravitational waves inference toolkit: ⍥ kazewong/jim

- EOS code and TOV solver: ⍥ tsunhopang/jose (*work in progress*)

- Kilonovae and GRB: ⍥ ThibeauWouters/fiesta (*work in progress*)