Flexible Gravitational-Wave Parameter Estimation with Transformers

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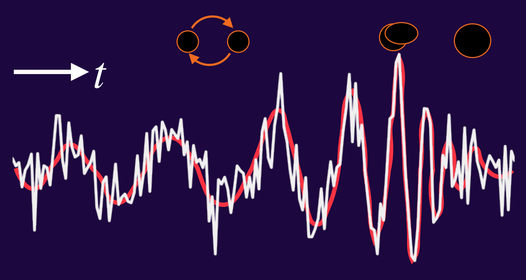
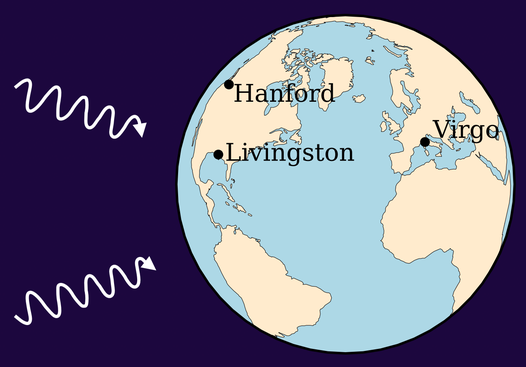
Gravitational waves





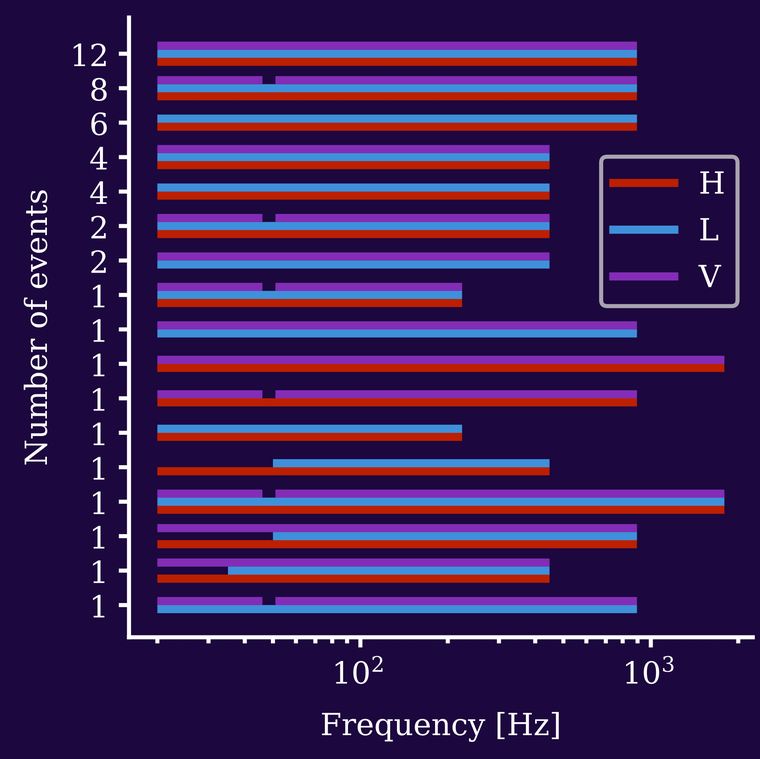
Goal: Analyze signals → posterior distribution of black hole mergers

Problem: Real data is messy

→ Re-train model to adapt to different data analysis settings

Solution: Flexible transformer architecture and masking procedure during training

Real data is messy: 48 events with 17 different data analysis settings

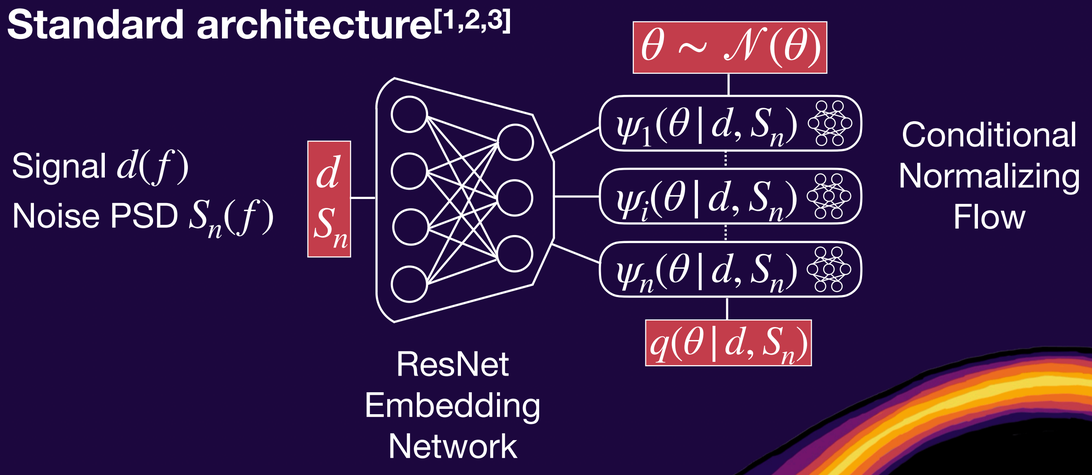


- Missing detectors
- Changes in f_{min} & f_{max}
- Remove small range $[f_{\text{low}}, f_{\text{high}}]$

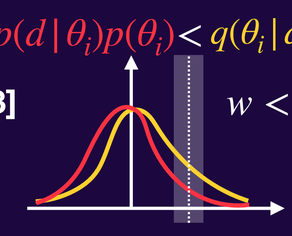
→ We would need to train 17 different DINGO models!

DINGO (Deep INference for Gravitational wave Observations)

Standard architecture[1,2,3]



Validation with importance sampling[3]



Compare learned NPE density and likelihood

$$\frac{p(\theta \mid d)}{q(\theta \mid d)} \propto w_i = \frac{p(d \mid \theta_i)p(\theta_i)}{q(\theta_i \mid d)}$$

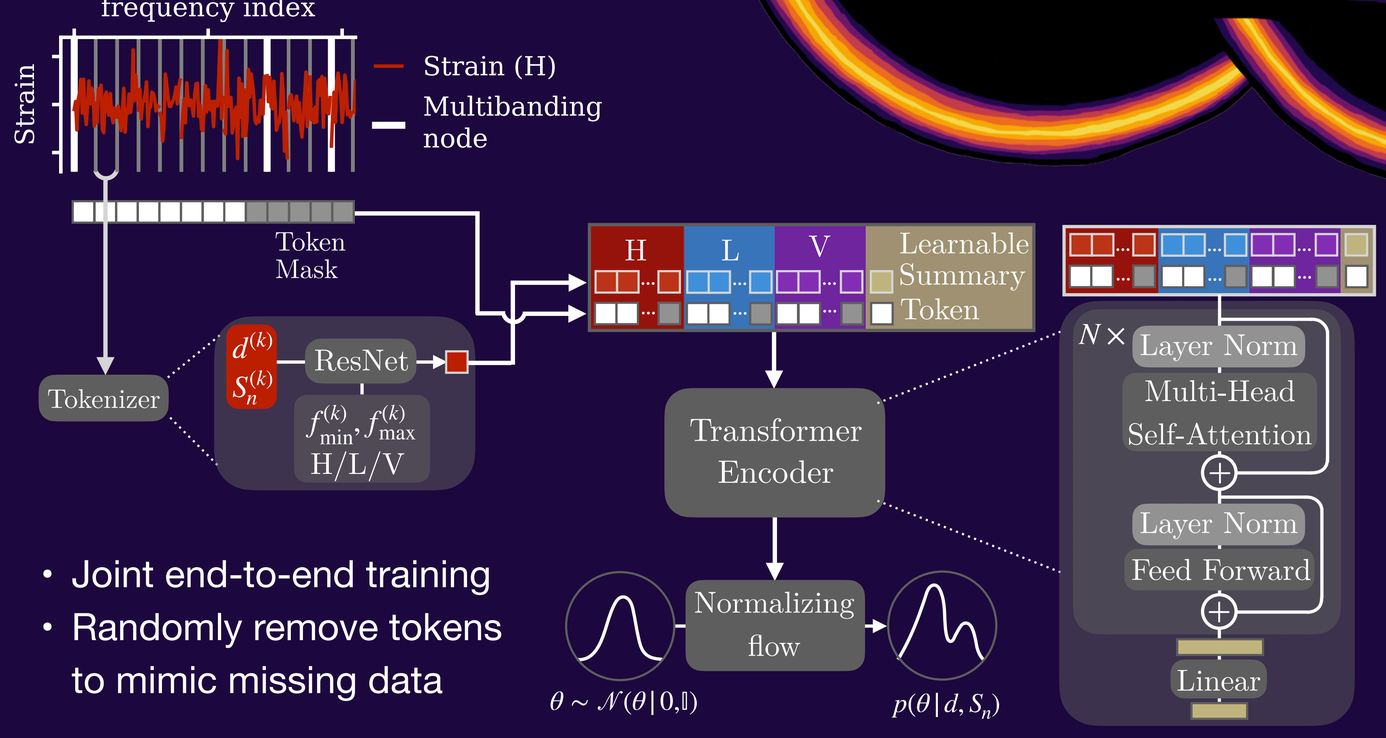
Likelihood · Prior

Proposal (NPE)

Performance criterion: Sample efficiency

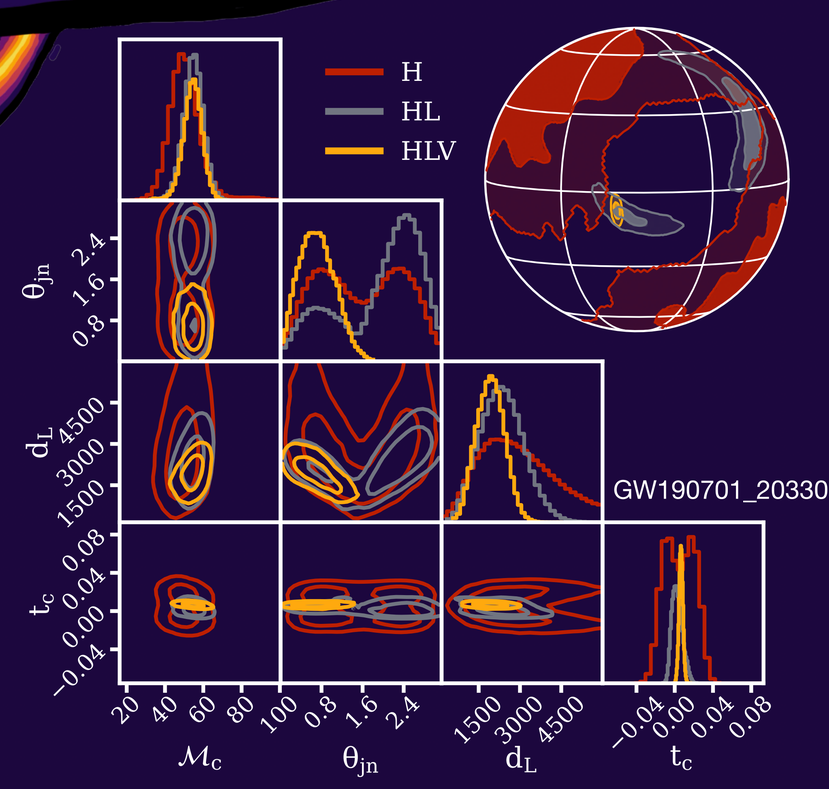
$$\epsilon = \frac{1}{N} \frac{\left(\sum_i w_i\right)^2}{\sum_i w_i^2}$$

DINGO-T1: Architecture

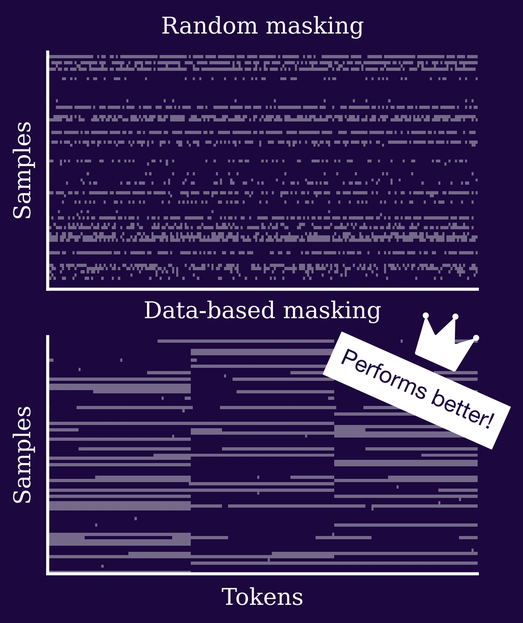


- Joint end-to-end training
- Randomly remove tokens to mimic missing data

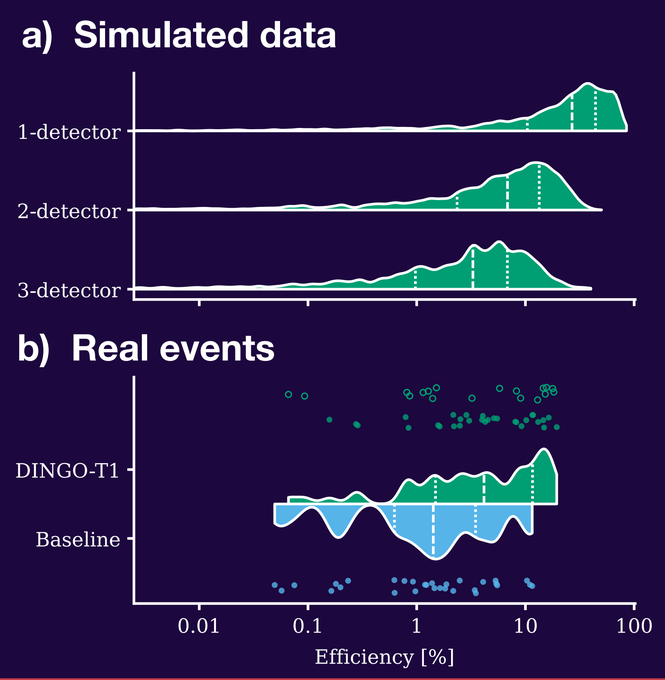
Flexible analysis



Masking strategies

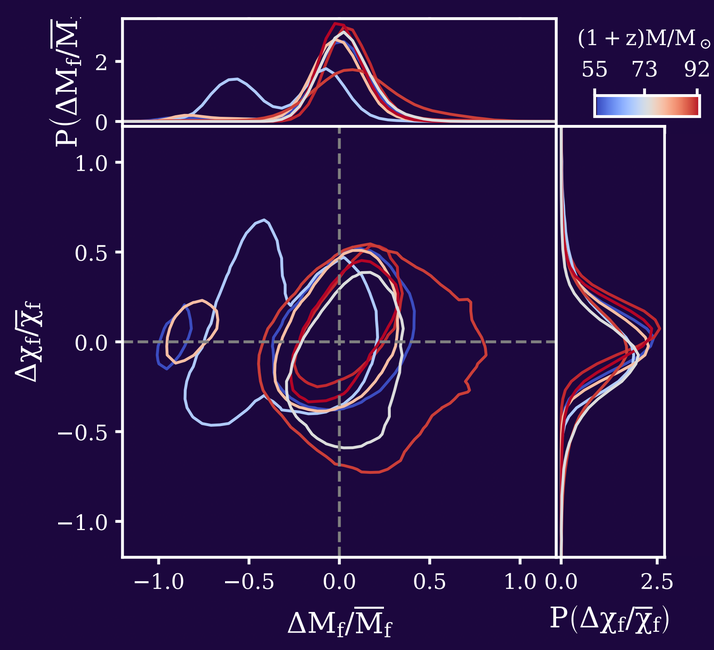


Performance



Tests of general relativity

- Analyze inspiral and postinspiral part of signal separately
- Check whether parameters agree



References
[1] Dax+, Real-Time GW Science with NPE, PRL 2021
[2] Dax+, Group Equivariant NPE, ICLR 2021
[3] Dax+, Neural IS for Rapid and Reliable GW Inference, PRL 2023

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