FACULTY OF SCIENCES

A NOVEL APPROACH TO DISCOVER UNMODELLED FEATURES IN GRAVITATIONAL WAVE SIGNALS

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Gravitational signals from CBC

Parameter estimations

Residual analyses

Machine learning

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GRAVITATIONAL WAVE SIGNALS

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Different sources: focus on CBC

Goal: find parameters of the objects

For example: masses, spin, position in the sky

Start with simulated signals

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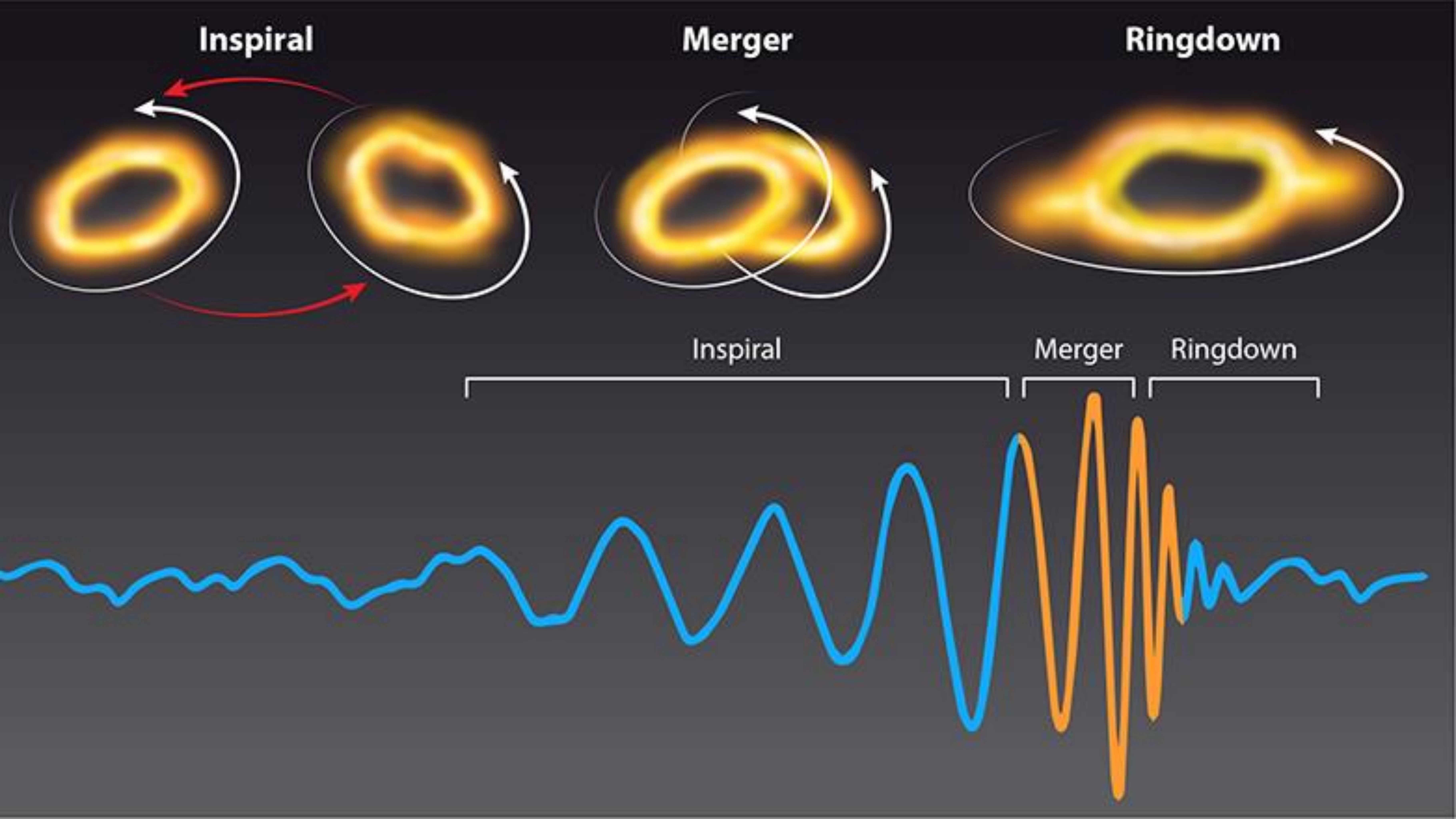
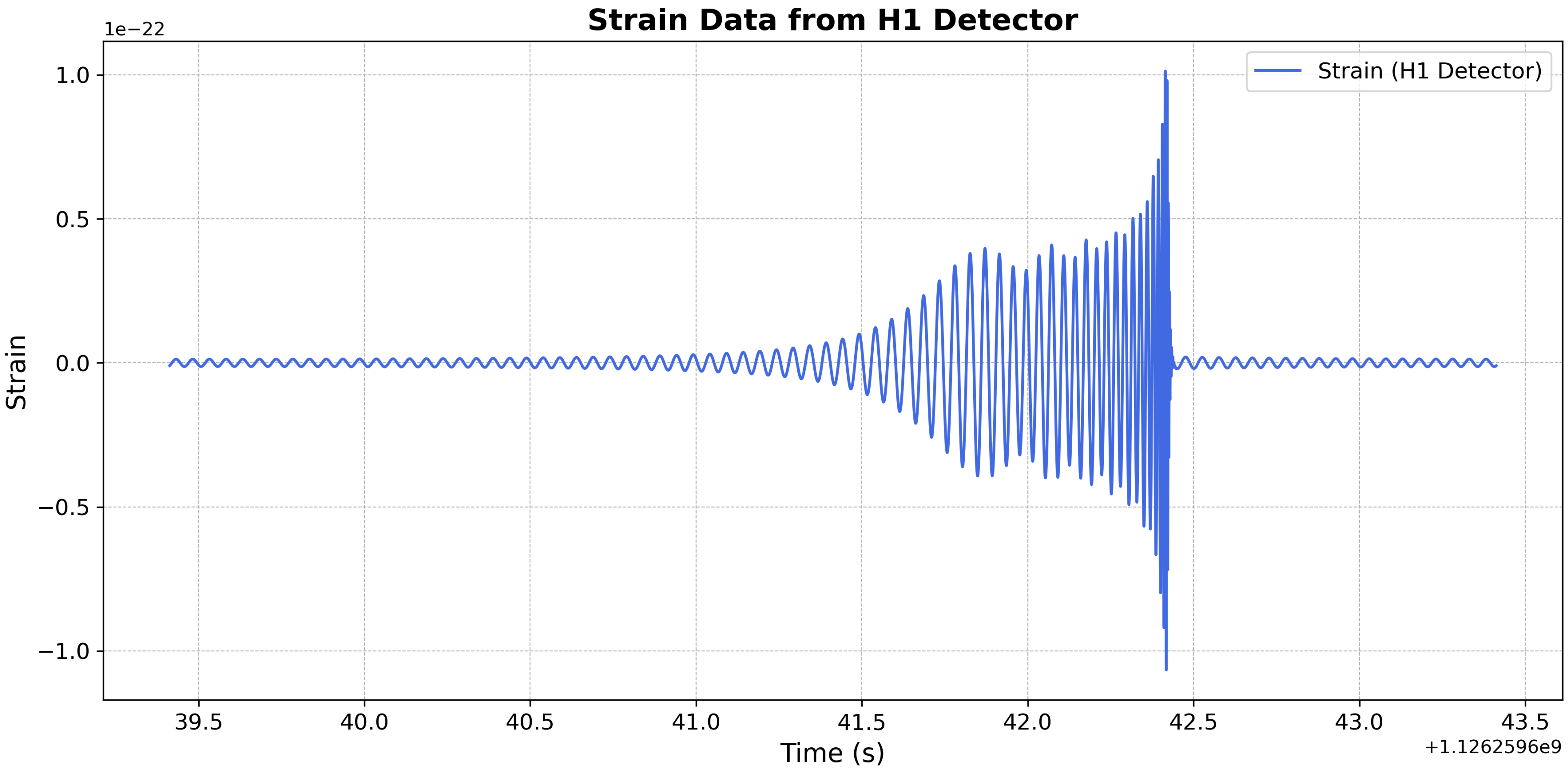

Inspiral
Merger
Ringdown
Inspiral
Merger
Ringdown

SIMULATED SIGNAL



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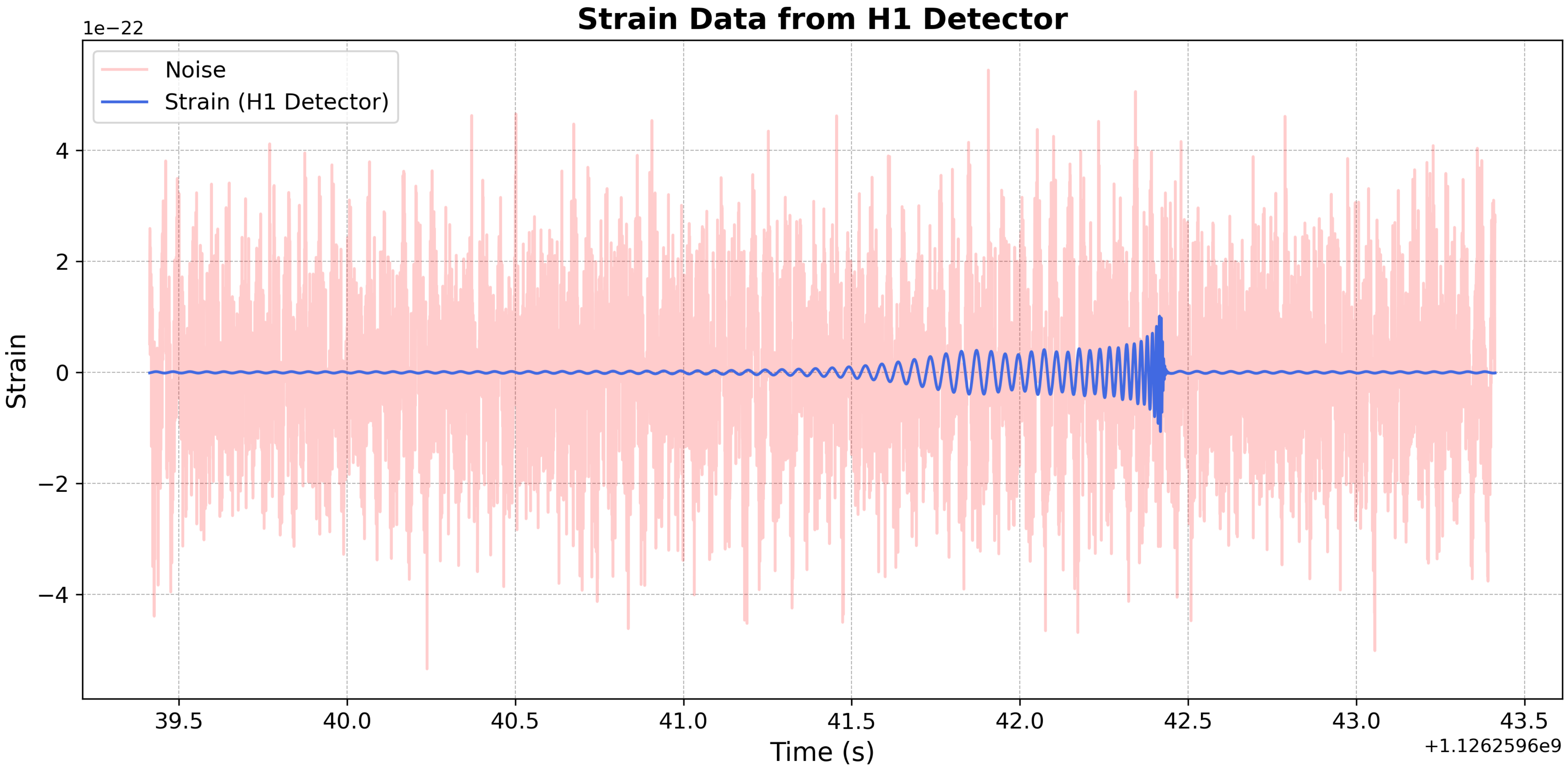
ADDING THE NOISE



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PARAMETER ESTIMATION

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BAYESIAN PARAMETER ESTIMATION

Bilby

↓

Result: posterior distribution

$$P(A \mid B) = \frac{P(B \mid A)\, P(A)}{P(B)}$$

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BILBY WORKFLOW

- Inference: figuring out the model parameters θ given some model M

Injecting signal and noise into bilby

Choose model with parameters

Monte Carlo Markov chain

Returns Posterior distribution

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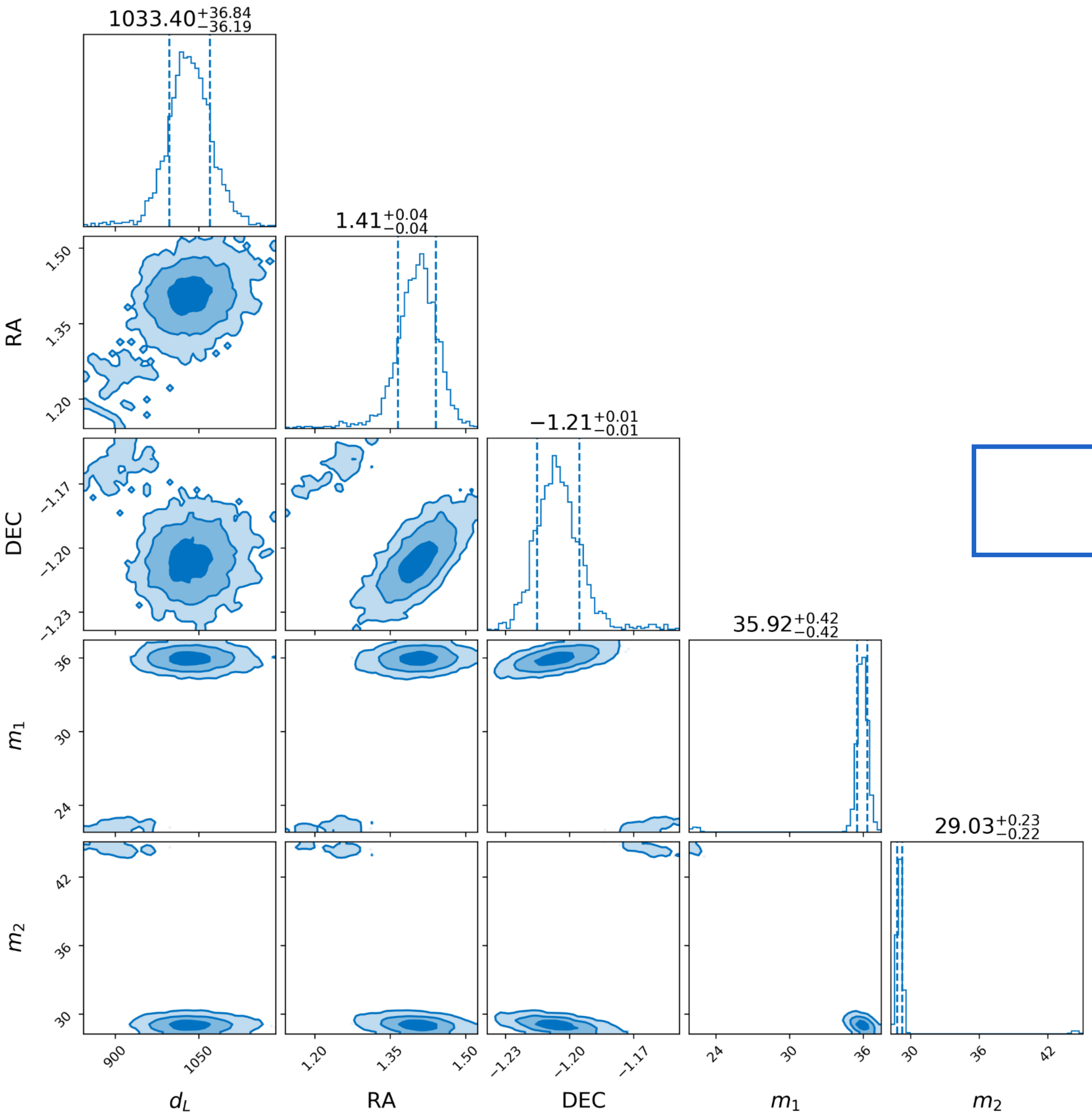
POSTERIOR DISTRIBUTION



$$m_1 = \cdots$$
$$m_2 = \cdots$$
$$DEC = \cdots$$
$$RA = \cdots$$

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PROBLEMS WITH PARAMETER ESTIMATIONS

- Advancing detectors ➔ More data
- Curse of dimensionality ➔ long runtimes
- Less advanced waveforms ➔ less parameters
- Sounds nice but is it still good enough?
- To check this, create ML algorithm

RESIDUAL ANALYSES

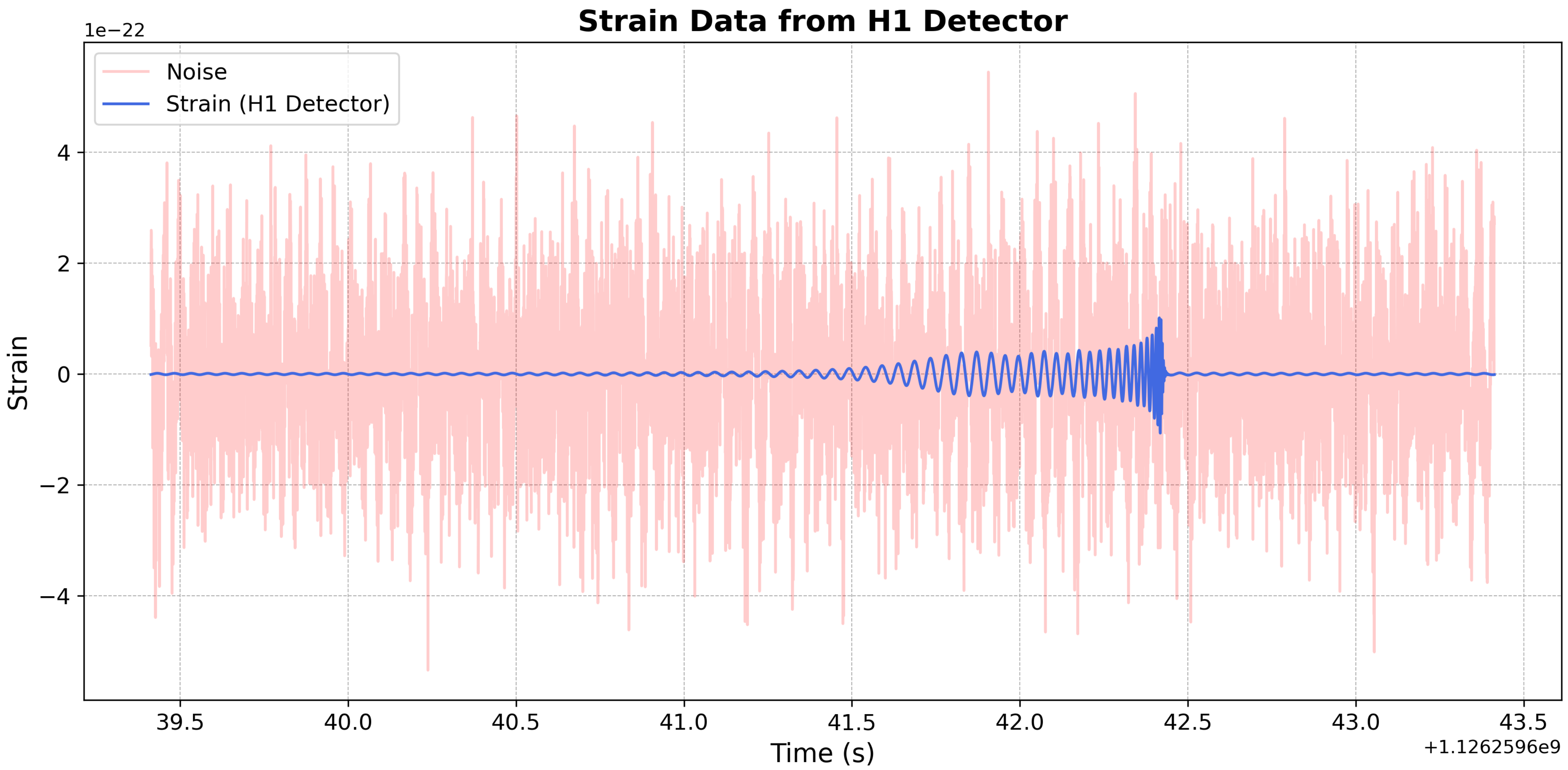
GOING TO THE RESIDUAL

Extract best parameters

Residual = Observed Data−Best-fit Signal

Depends on waveform

ORIGINAL SIGNAL



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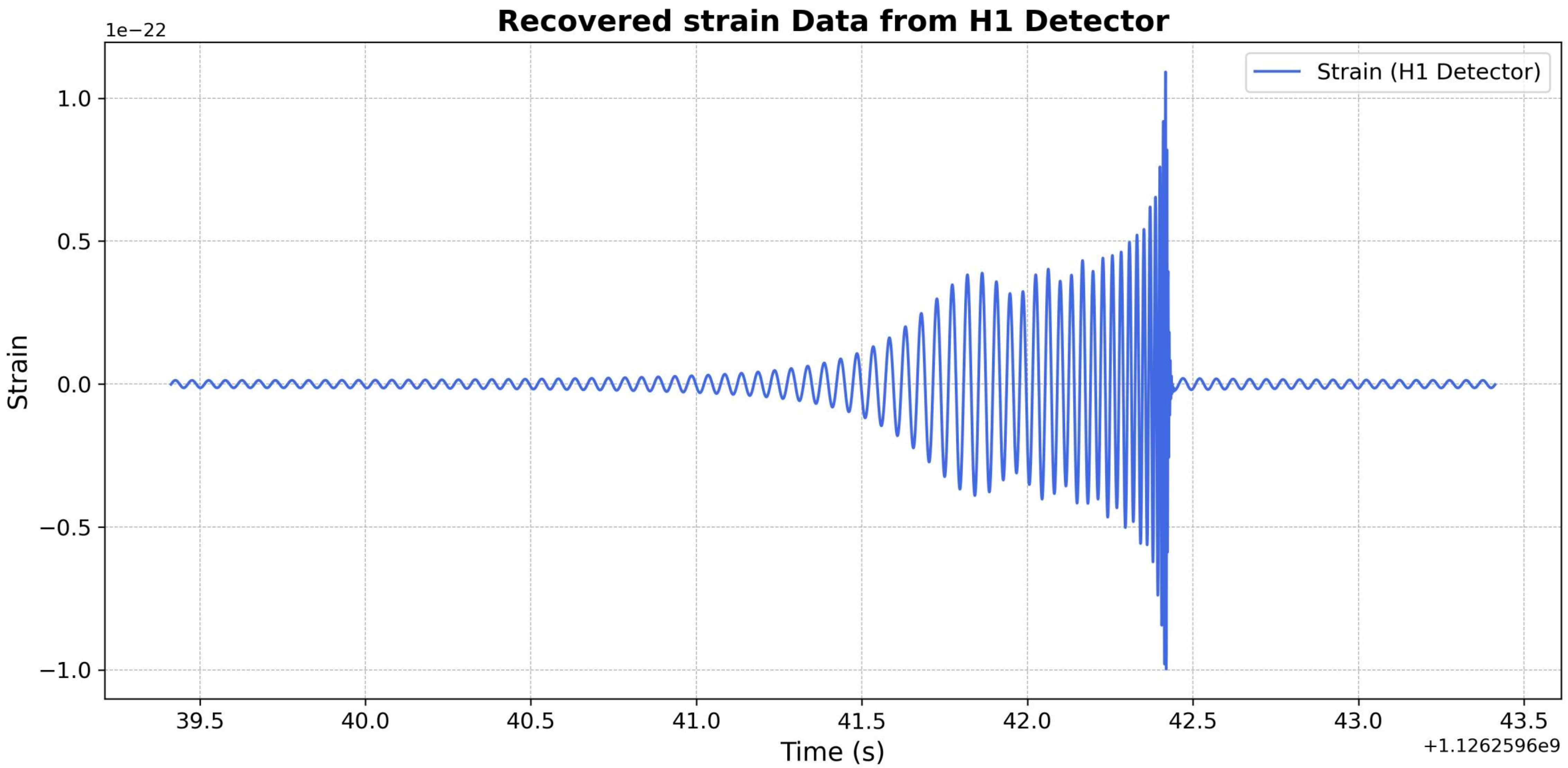
RECOVERED SIGNAL



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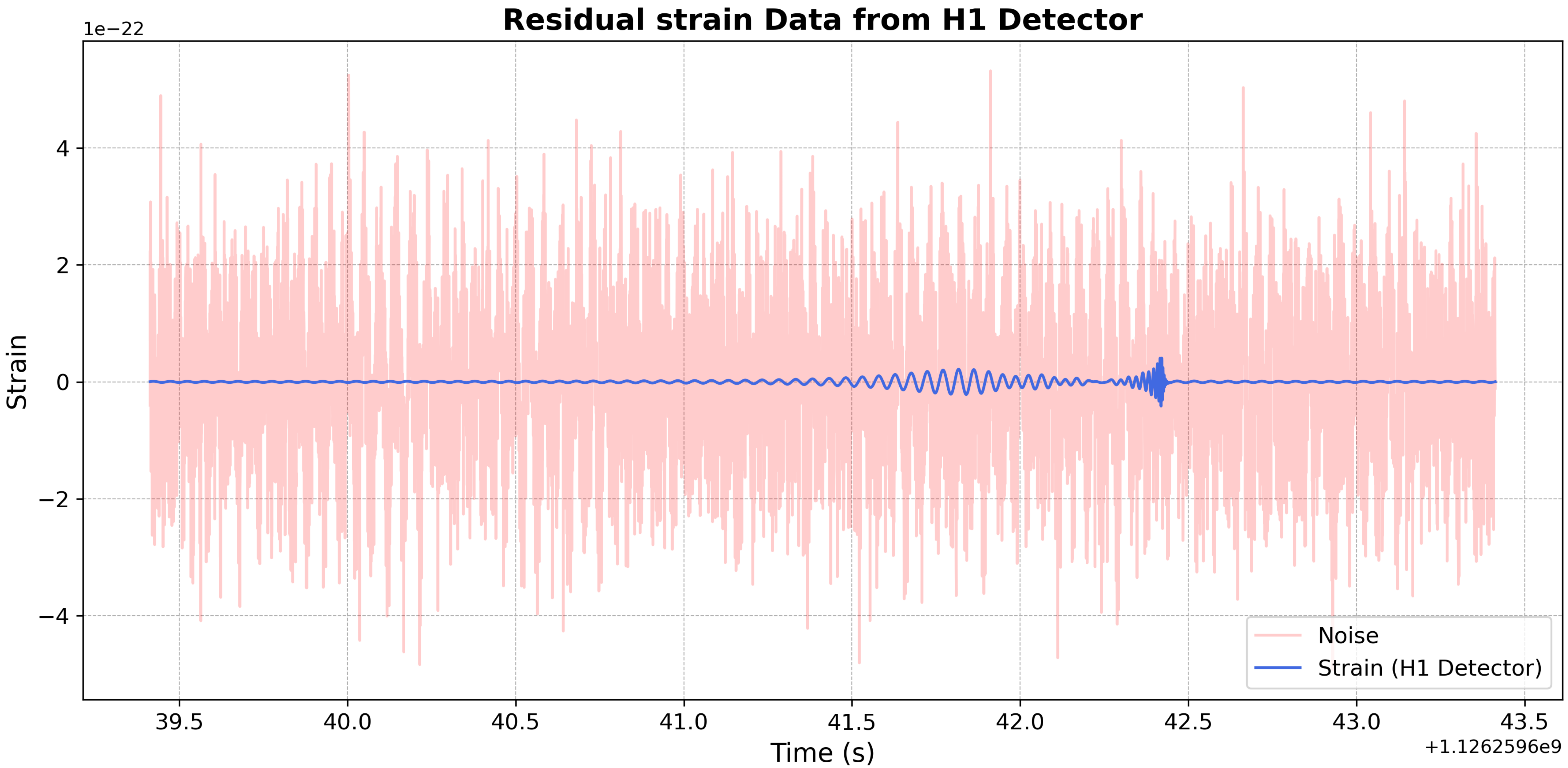
RESIDUAL



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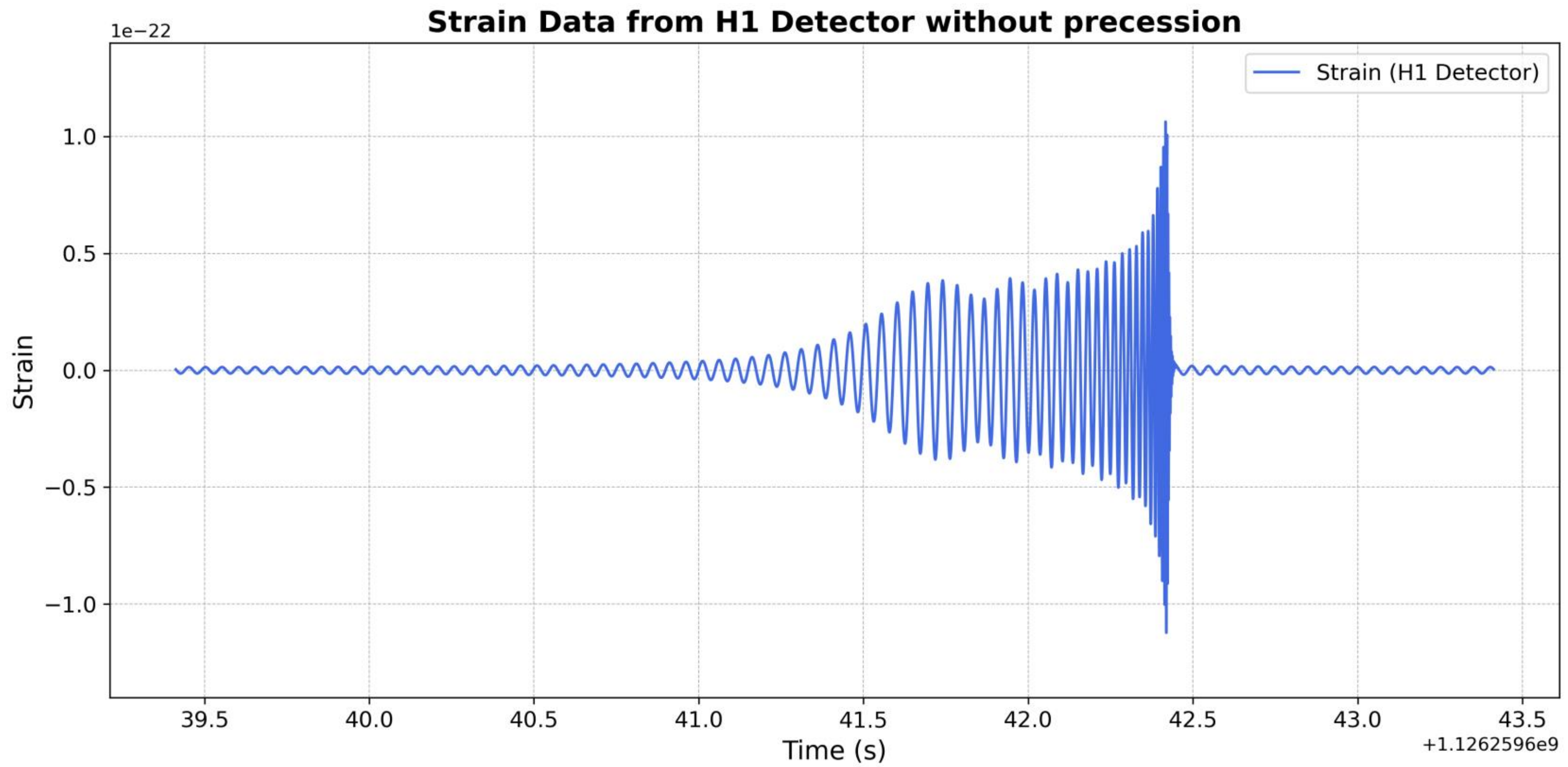
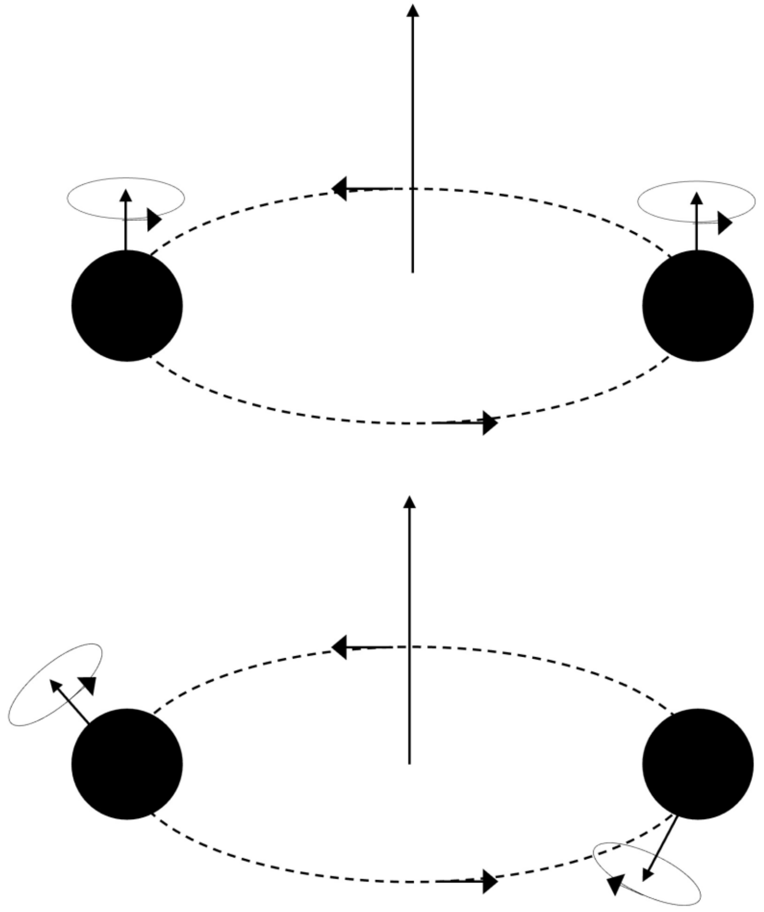
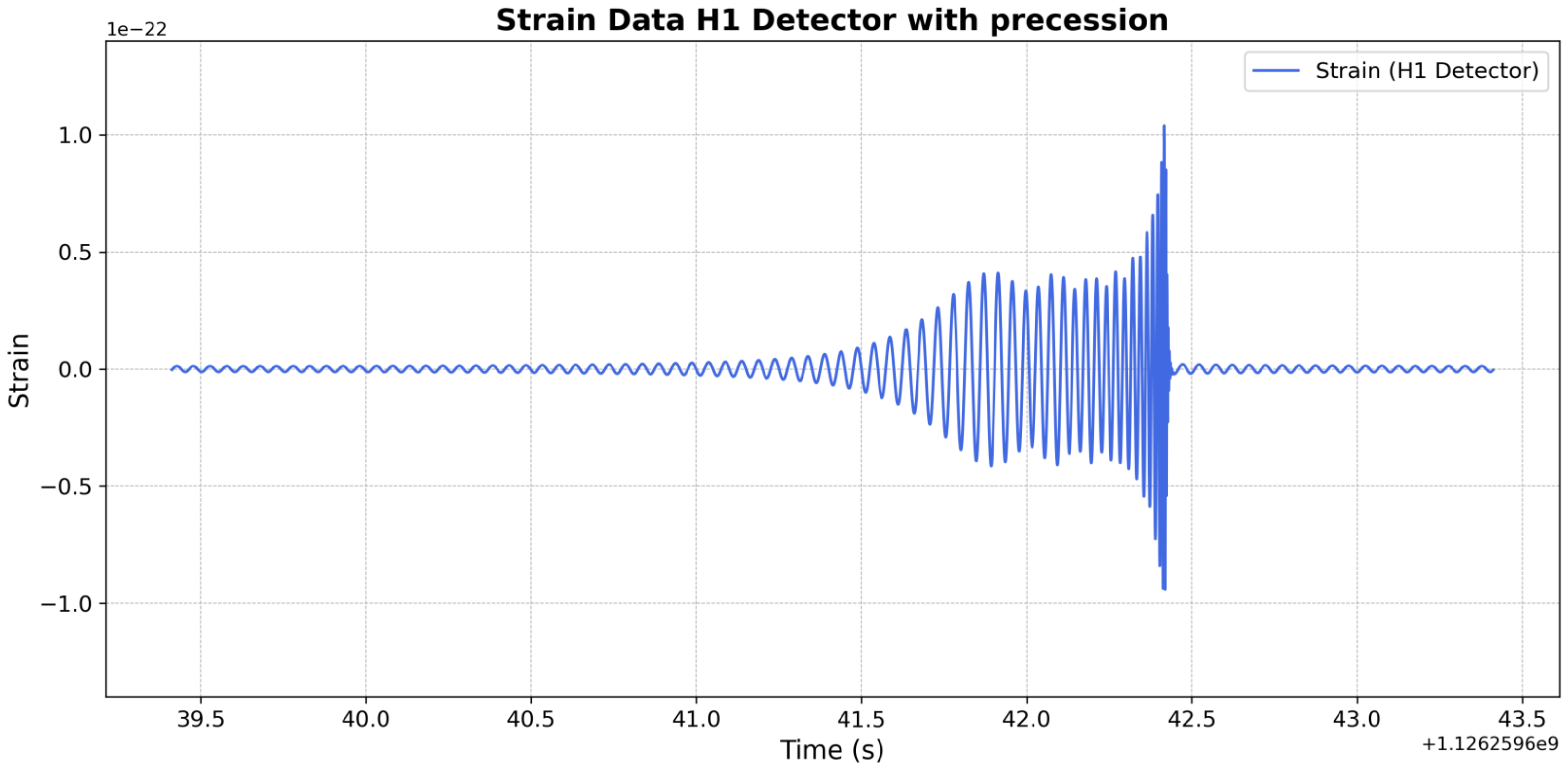
DIFFERENT WAVEFORMS

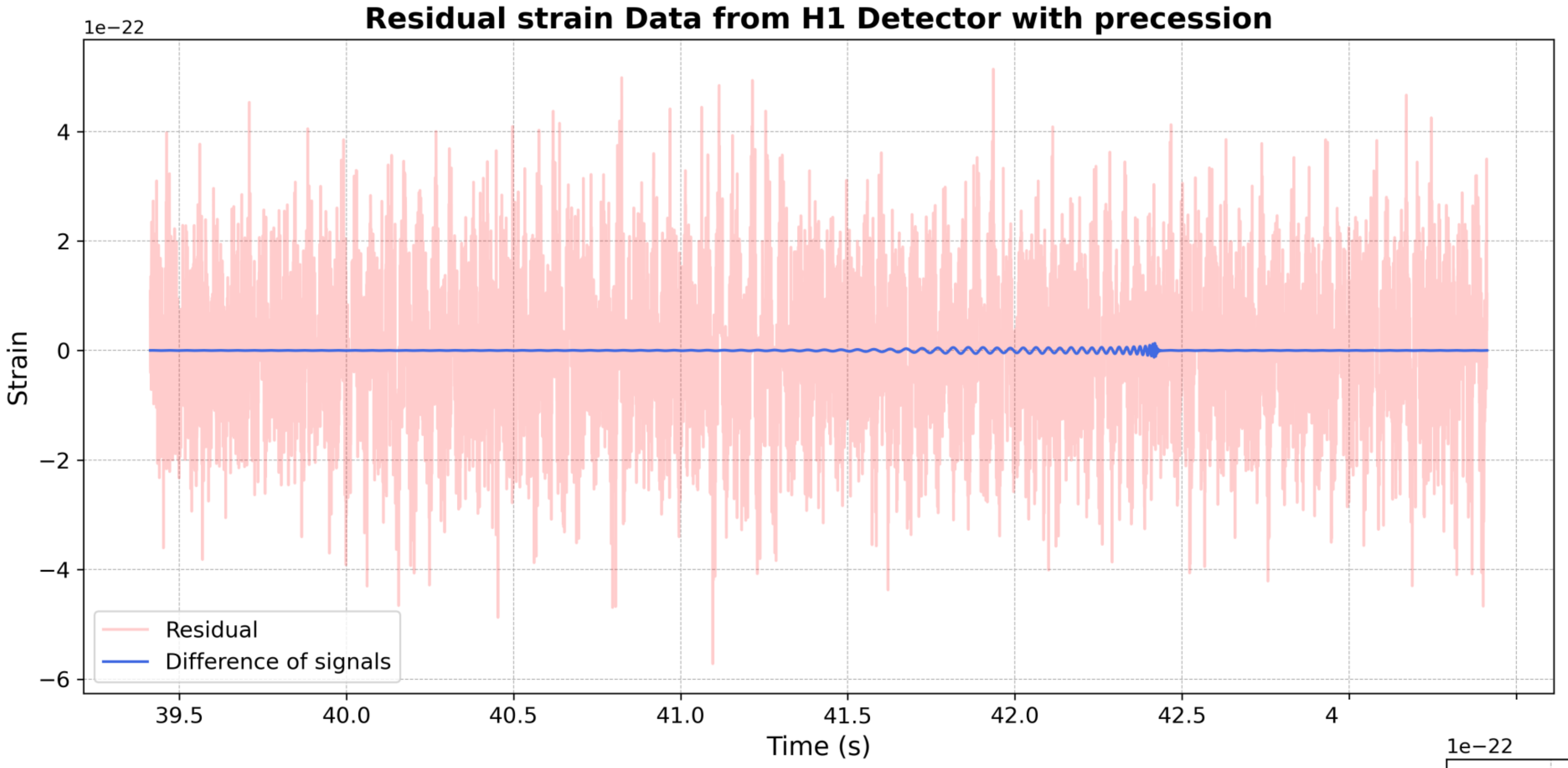
- Gravitational wave features:
  - Precession
  - Higher-Order Modes
  - Other exotic features

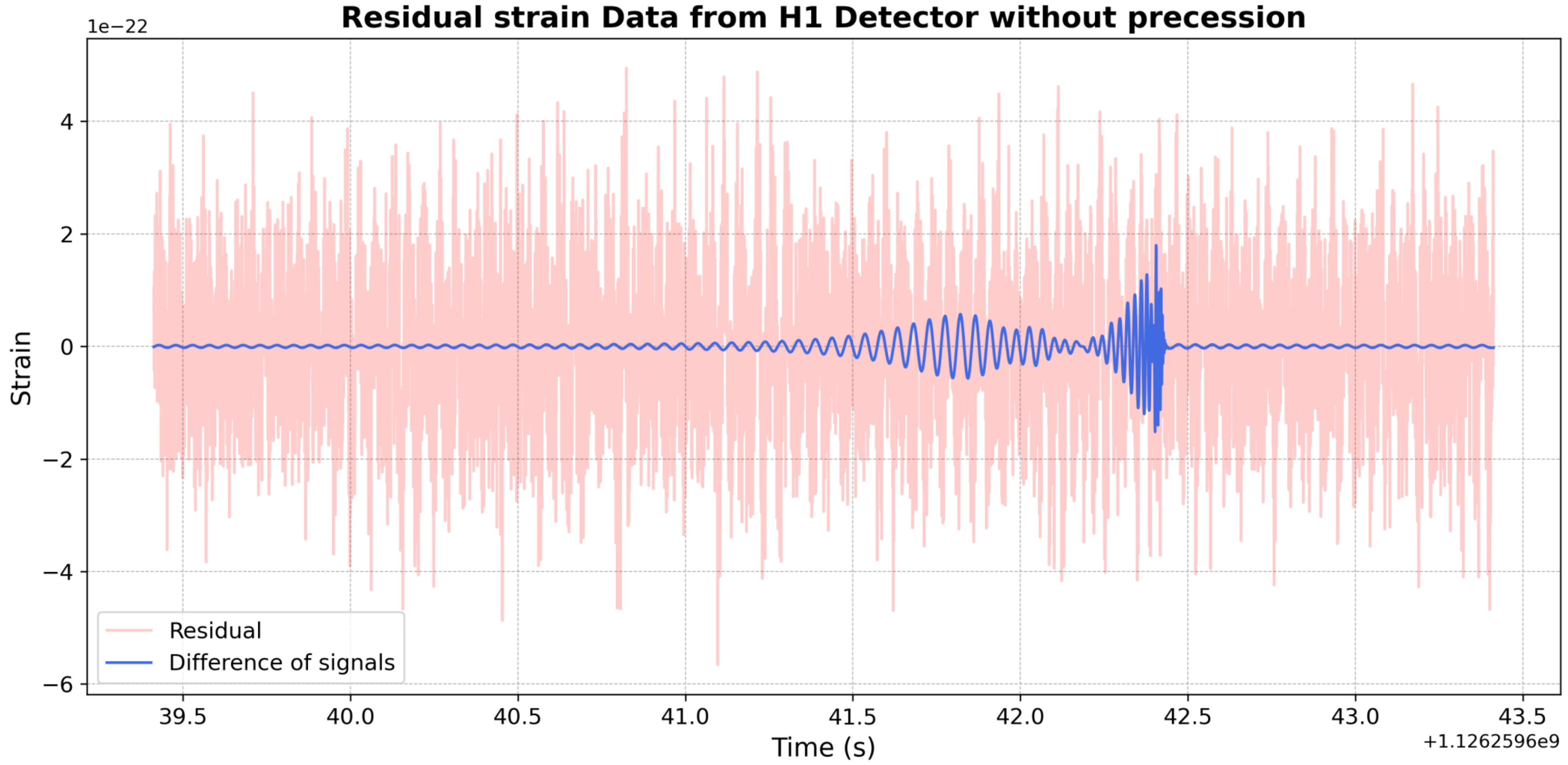






DIFFERENCE IN RESIDUAL





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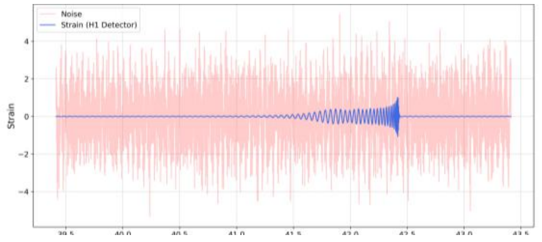
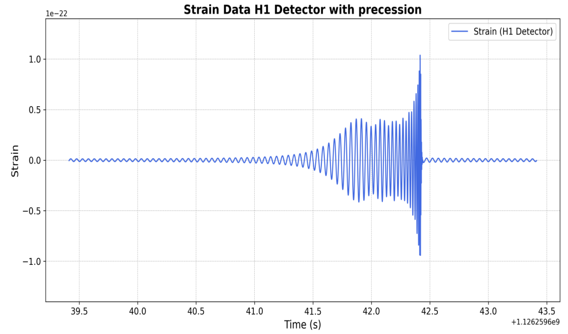
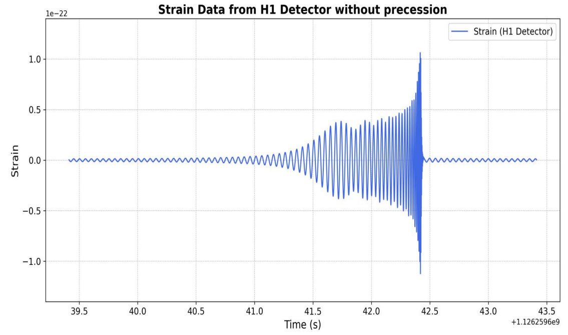
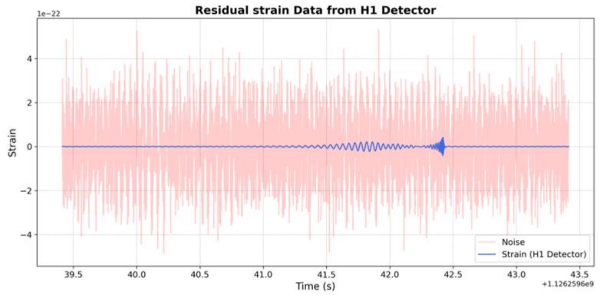
FIRST STEP

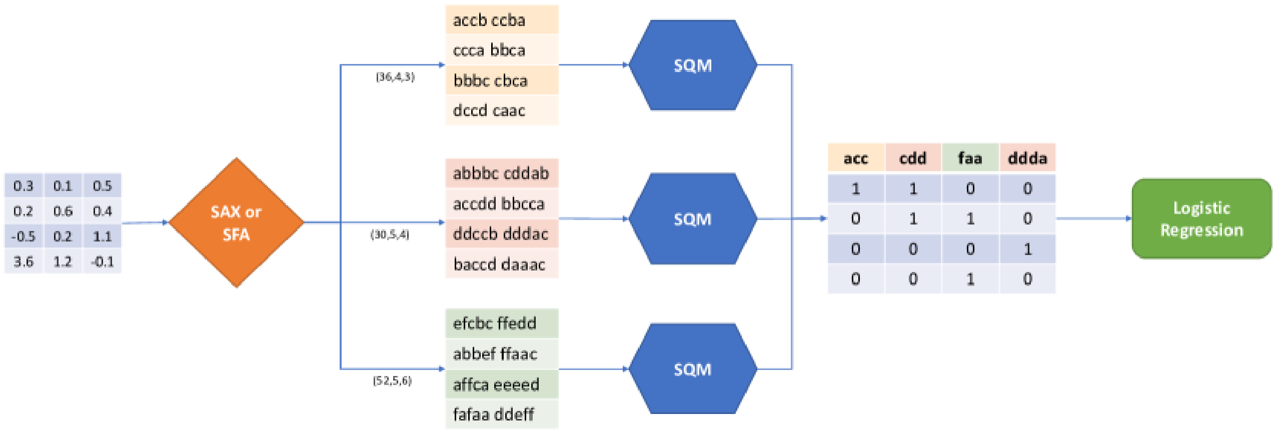
Parameter estimation on simulated GW → Chose waveform for reconstruction → Create residual → Train ML model → Test classifier with simulated signals not in the training set











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NEXT STEPS

Experimenting with different ML algorithms

Extending to more features

Unmodelled features