Correcting biases from overlapping signals in the third generation era: parameter estimation methods

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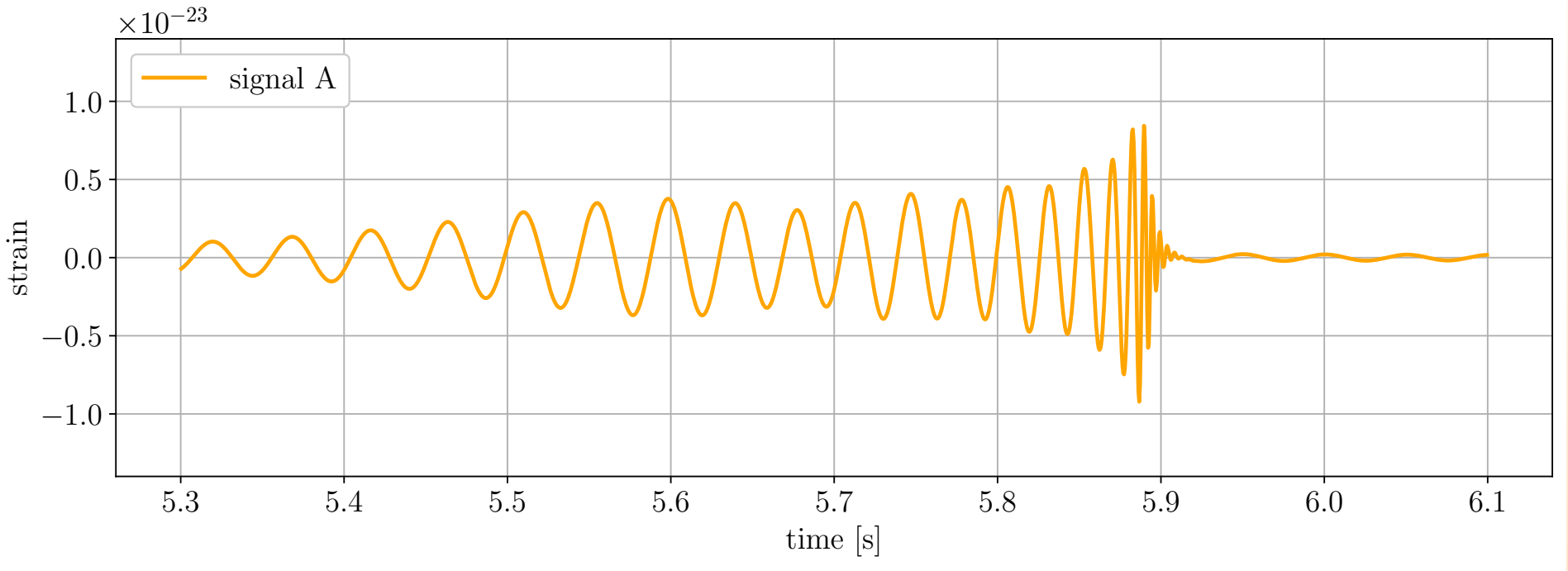
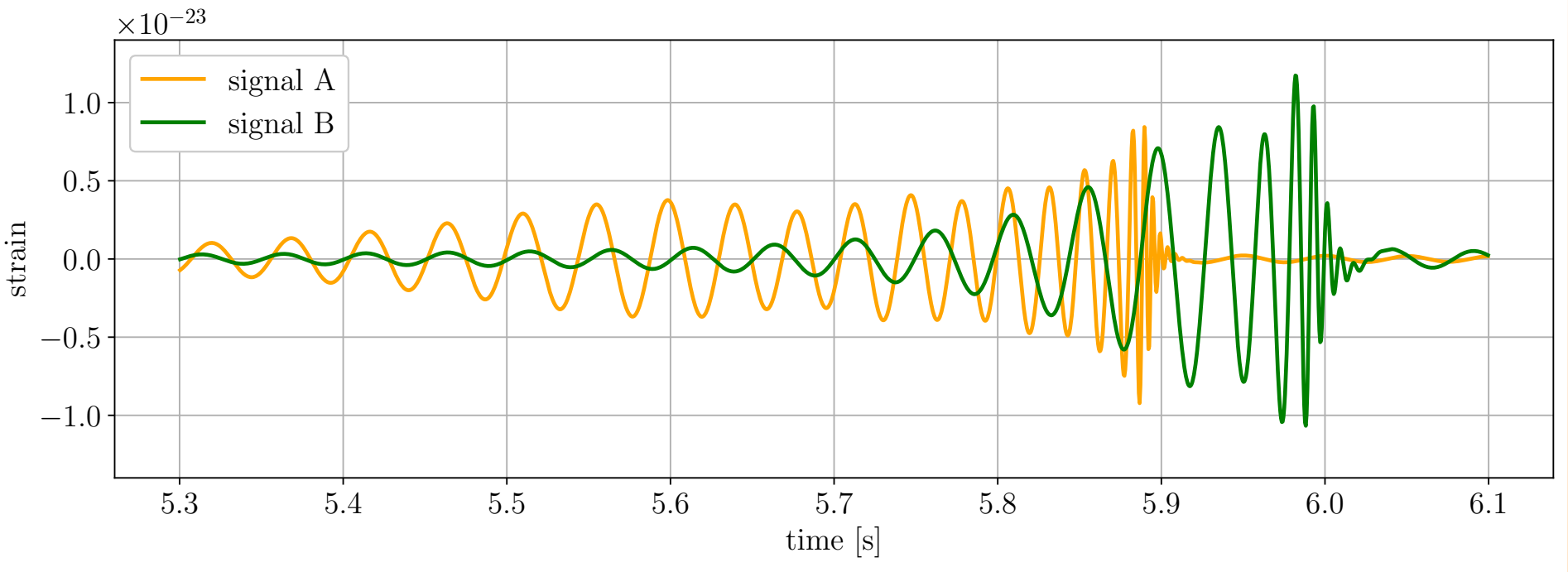
Overlapping signals



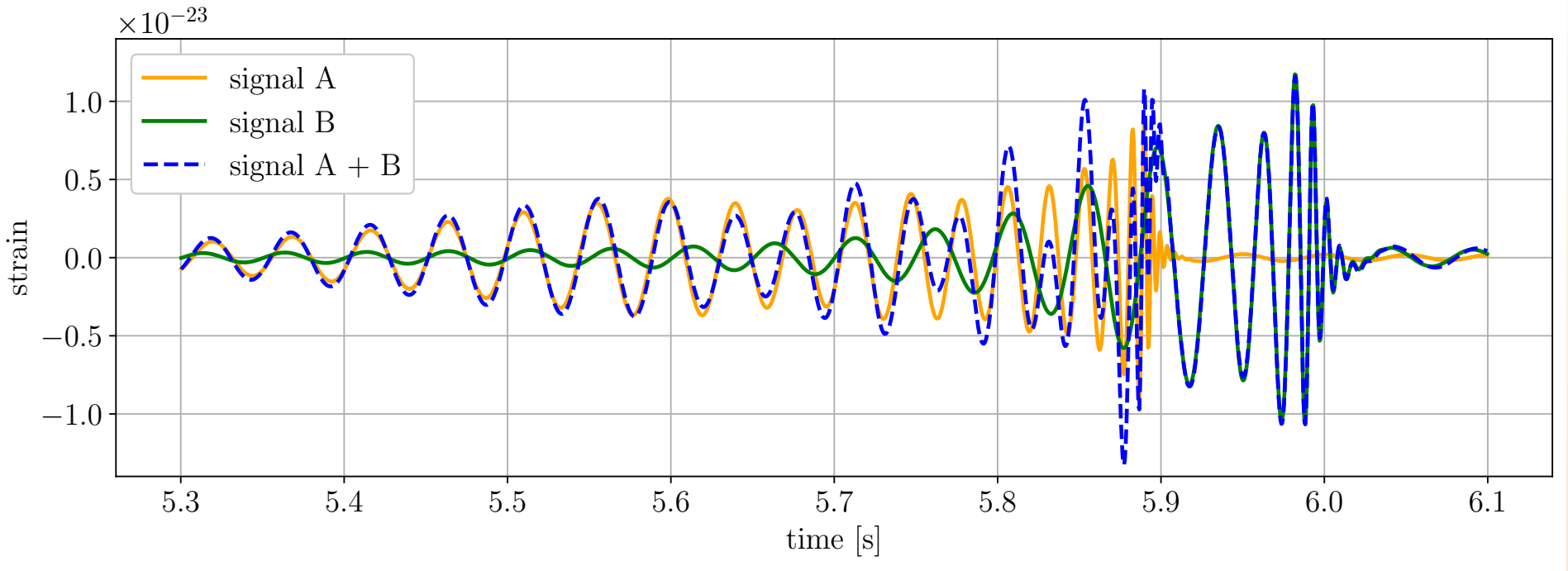
Signal A

Overlapping signals



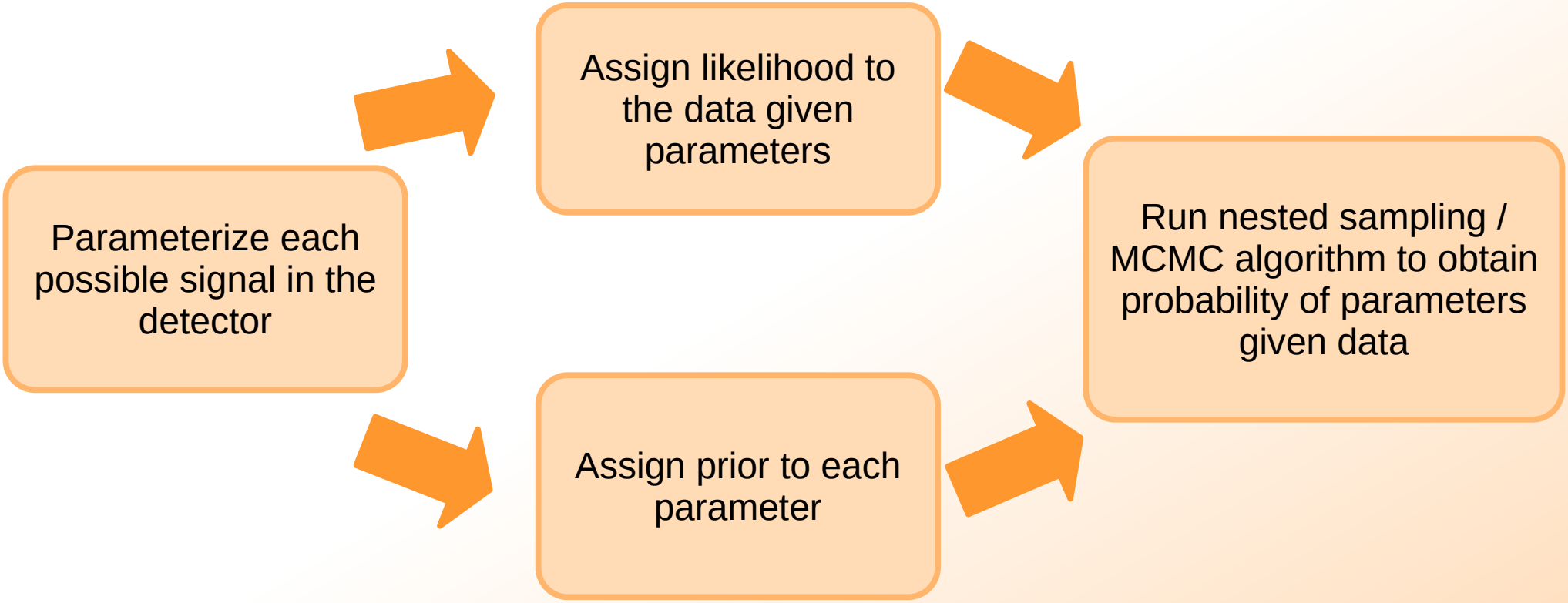
Signal A + Signal B

Overlapping signals



Signal A + Signal B = Overlapping signal

How parameter estimation works?



How joint parameter estimation works?

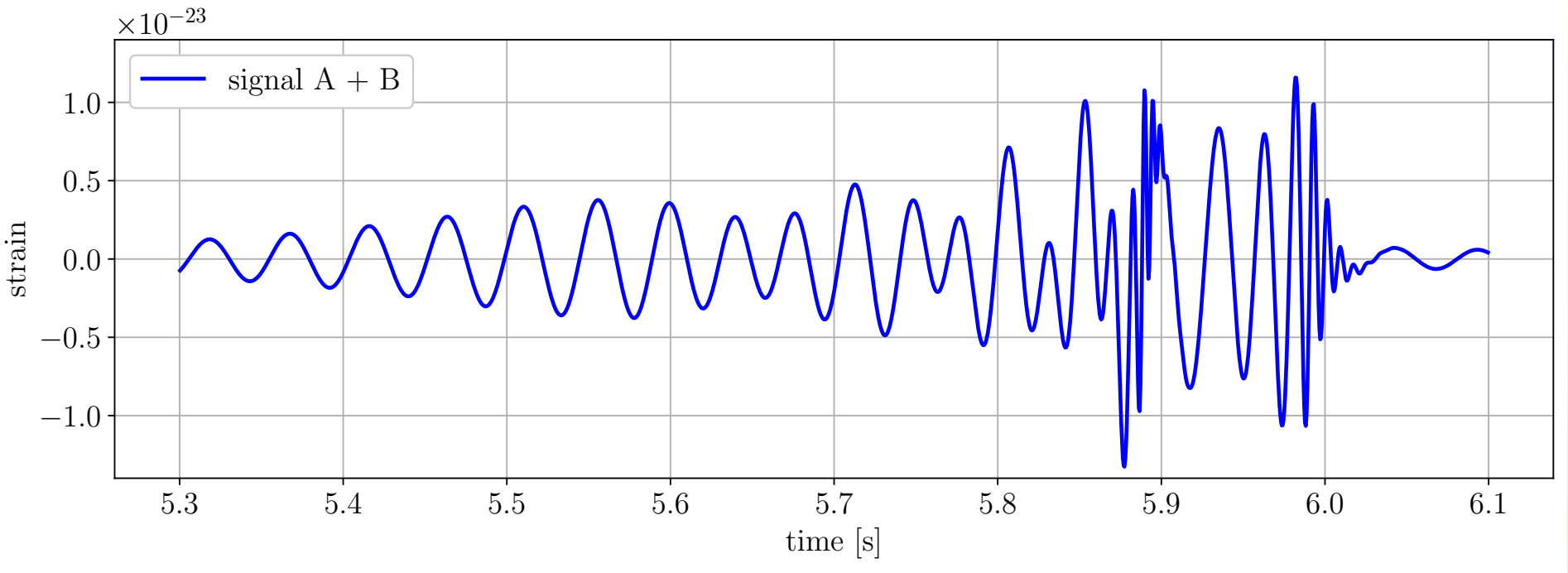
Double the parameter space so that it covers both signals

Modify likelihood to model both signals

Run the sampling algorithm

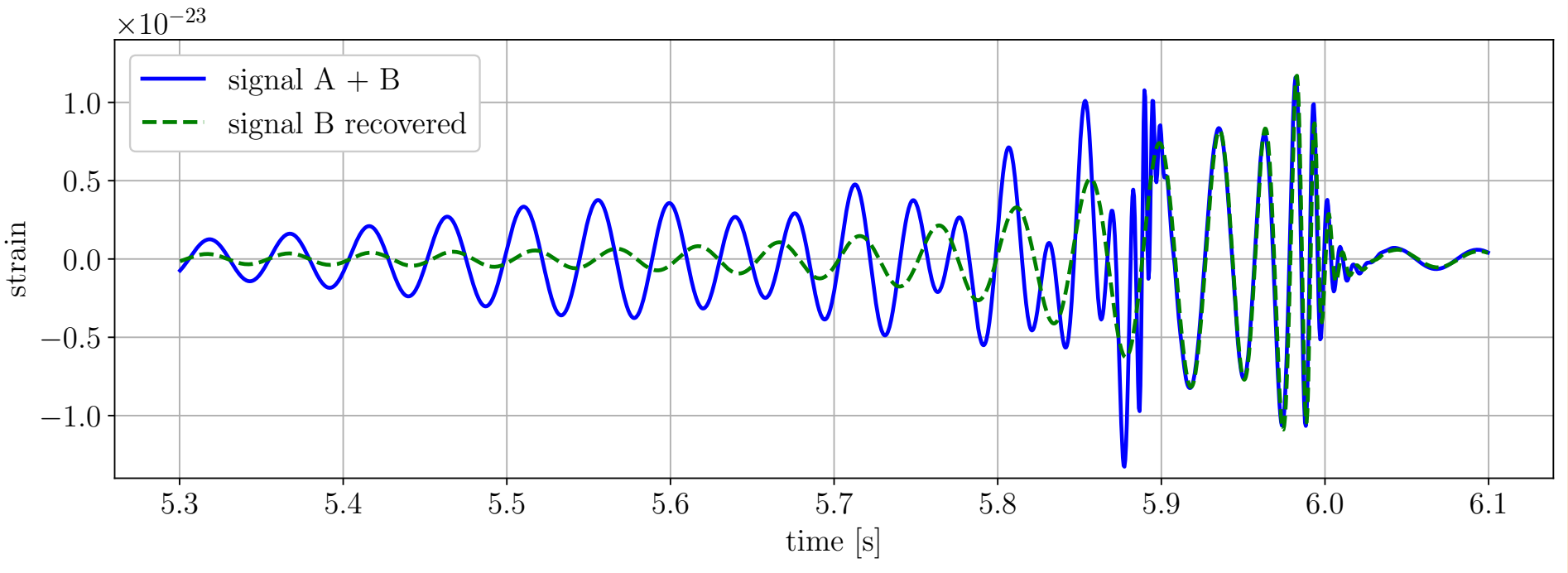
Time-order the signals in post-processing

How hierarchical subtraction works



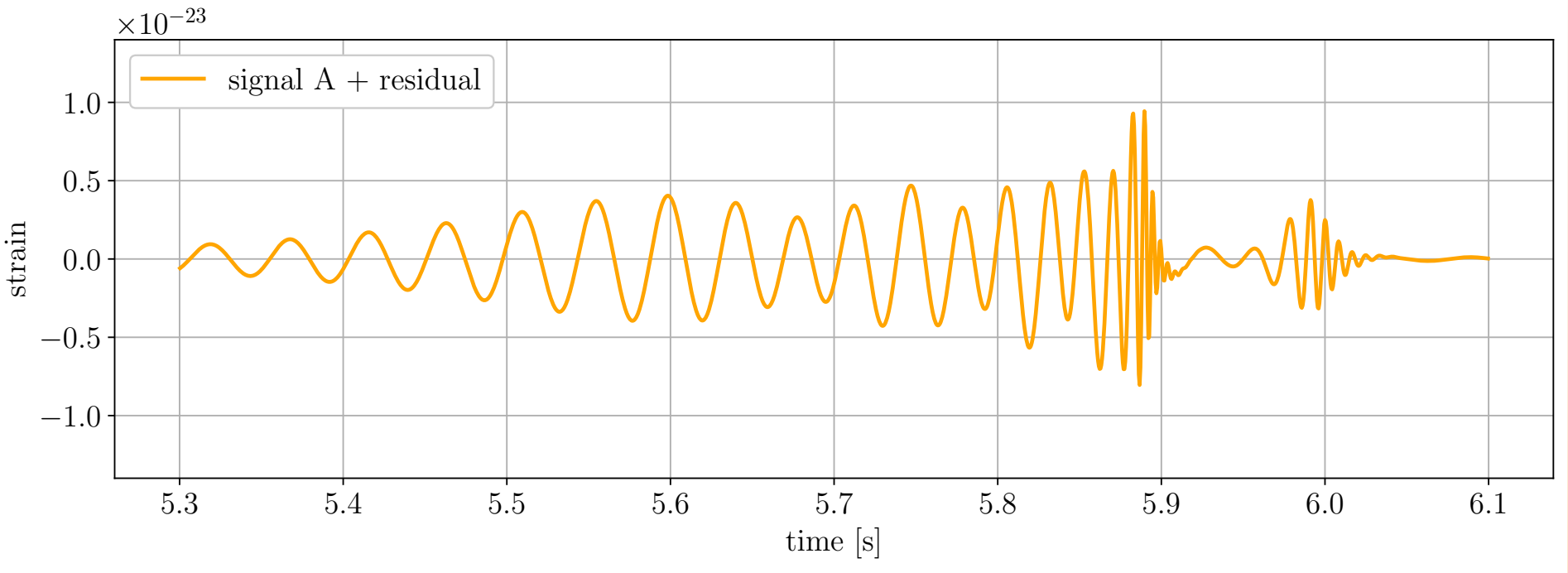
Overlapping signal on which 1st parameter estimation is performed

How hierarchical subtraction works



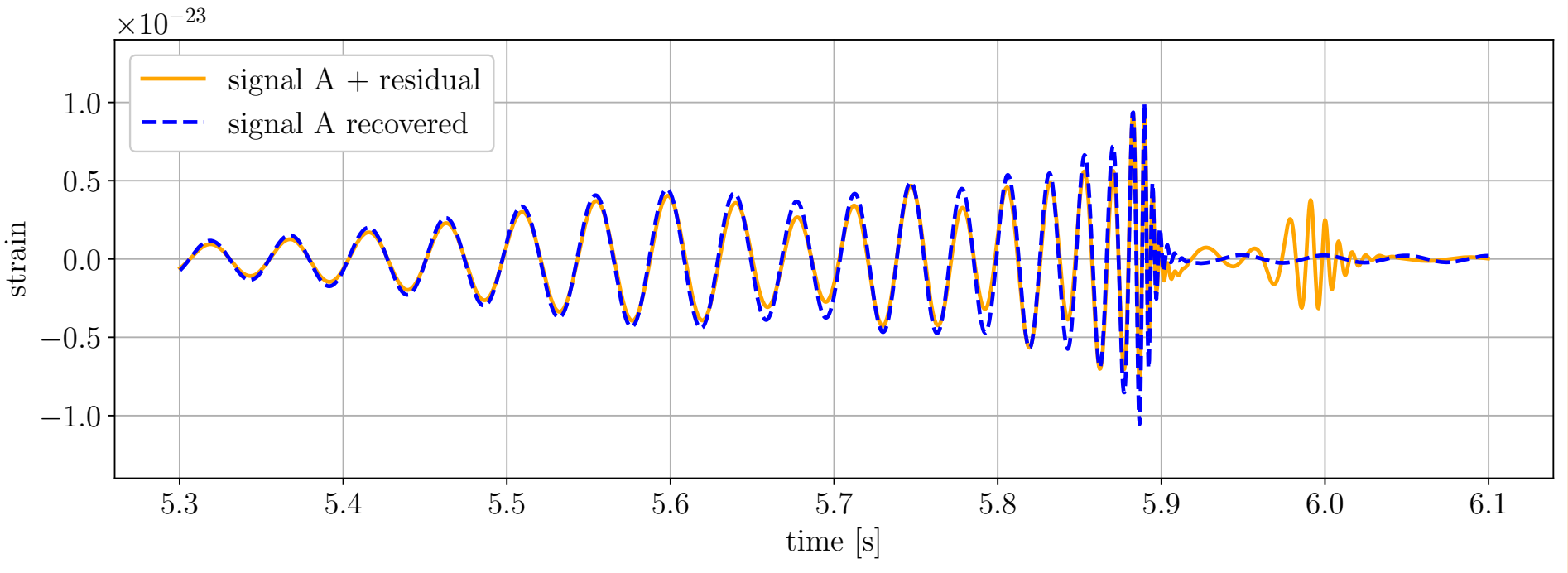
Overlapping signal and the waveform recovered from the 1st parameter estimation

How hierarchical subtraction works



The signal on which the 2nd parameter estimation is performed

How hierarchical subtraction works



The signal and the 2nd recovered waveform

Setup

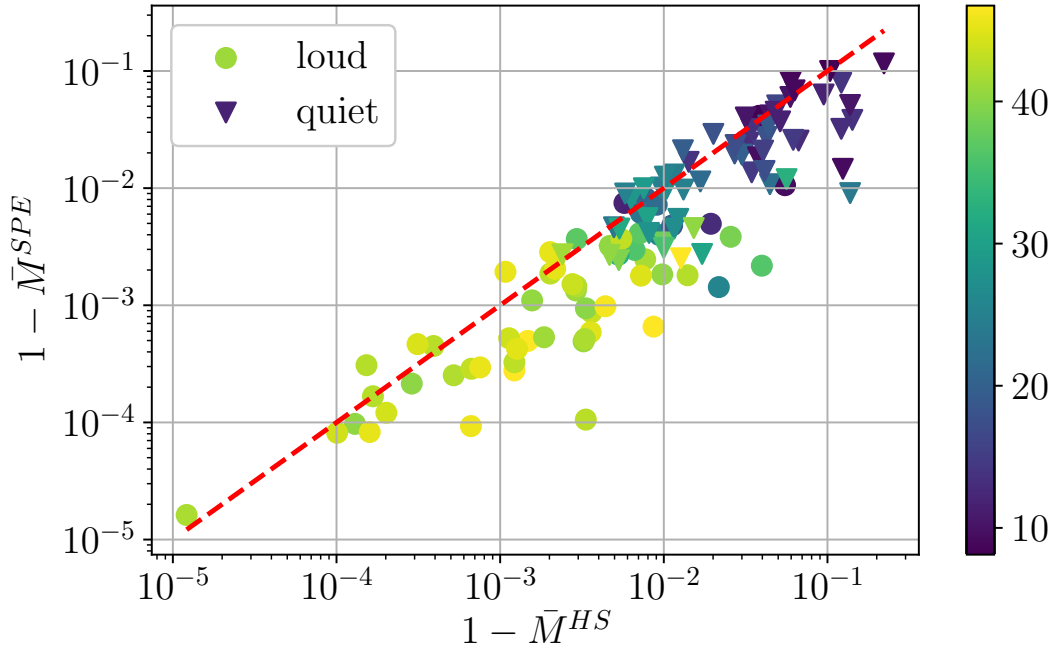
Number of simulated signals	55
Separation of signals	0.1s
Detector Network	Einstein Telescope + Cosmic Explorer
Detector noise	Stationary Gaussian; zero noise
Data segment duration	8s
Sampling rate	2048 Hz
Minimum frequency	20 Hz
Sampler	Dynesty
Injected masses distribution	Power law + Peak, restricted to 30-60 solar masses
Signal to Noise Ratio	8-50

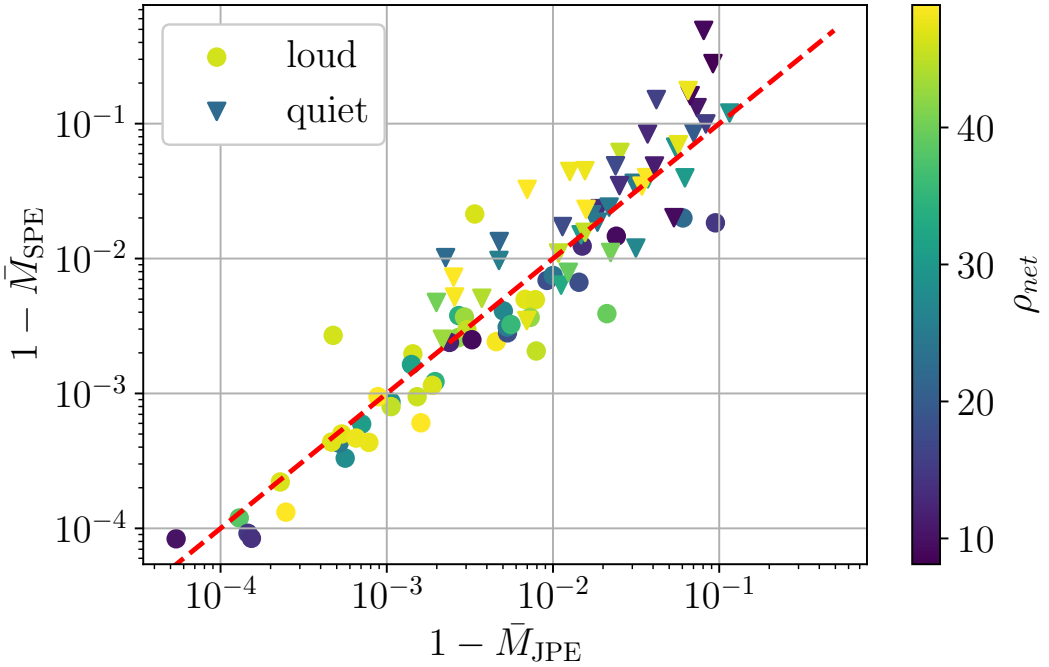
Waveform recovery

- define match between 2 signals as:

$$\bar{M} = \frac{\langle h_1 | h_2 \rangle}{\sqrt{\langle h_1 | h_1 \rangle \langle h_2 | h_2 \rangle}}$$

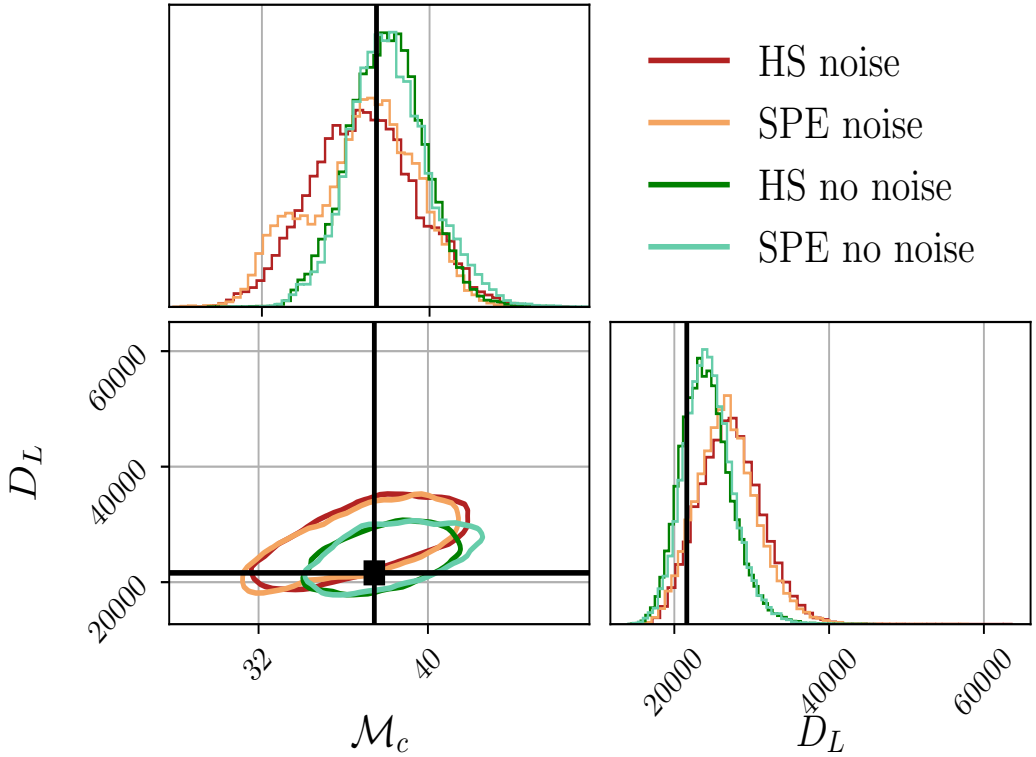
- HS – hierarchical subtraction
- JPE – joint parameter estimation
- SPE – single signal parameter estimation



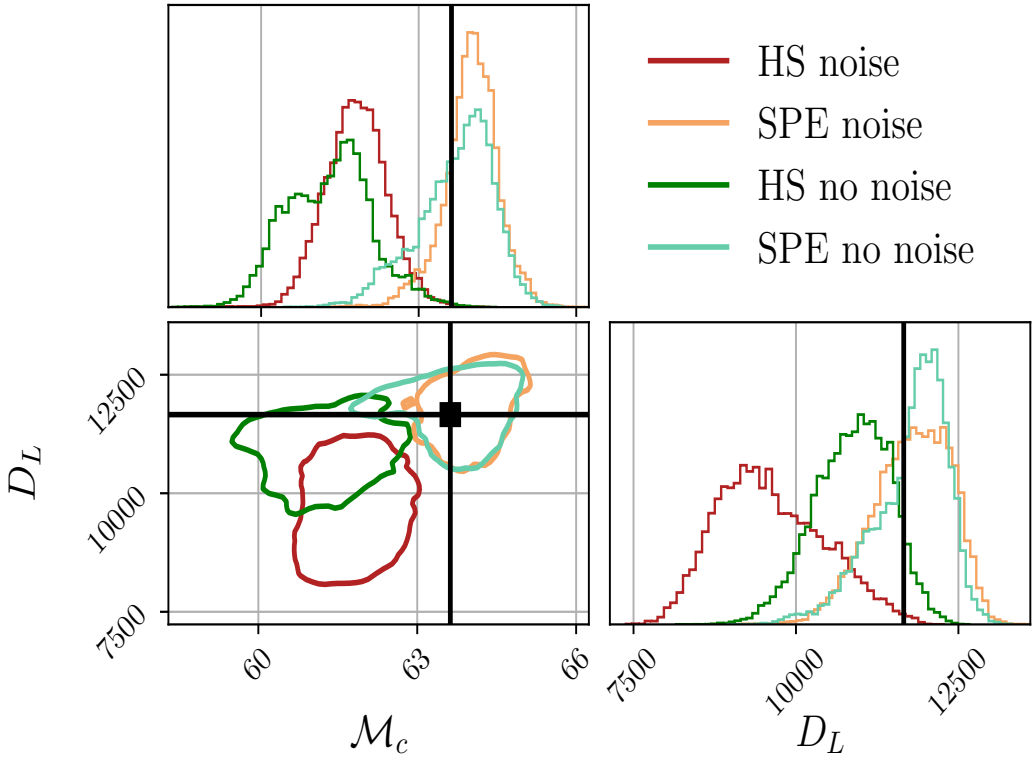


Posteriors

Example of well recovered HS posterior

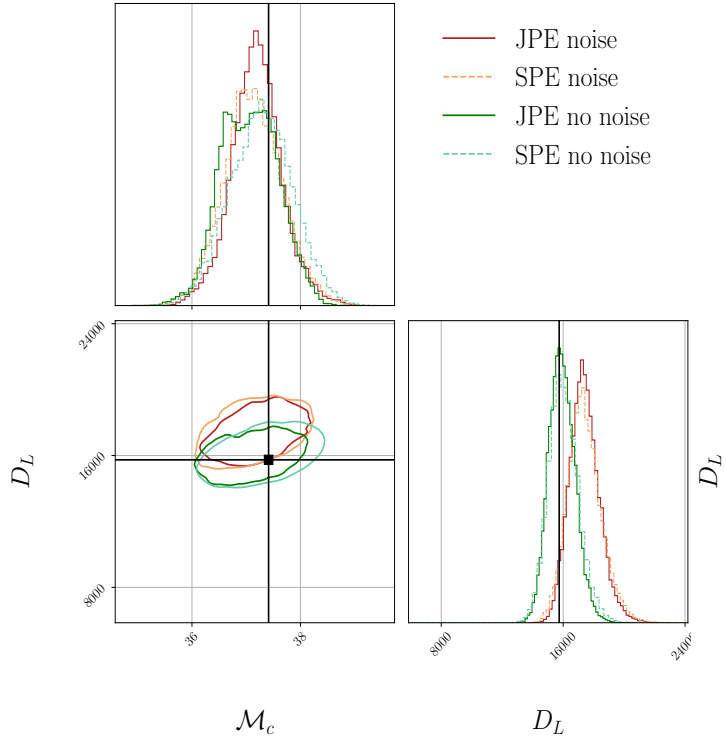


Example of a badly recovered HS posterior

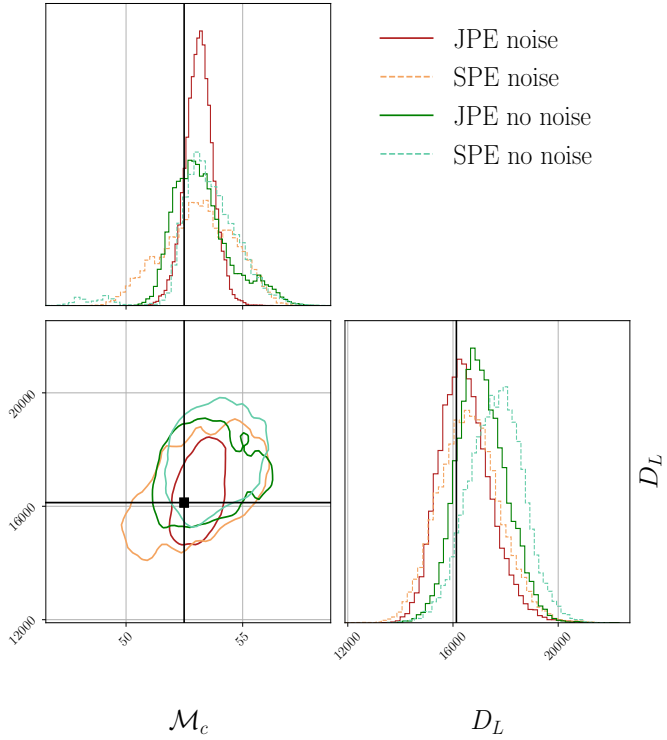


Posteriors

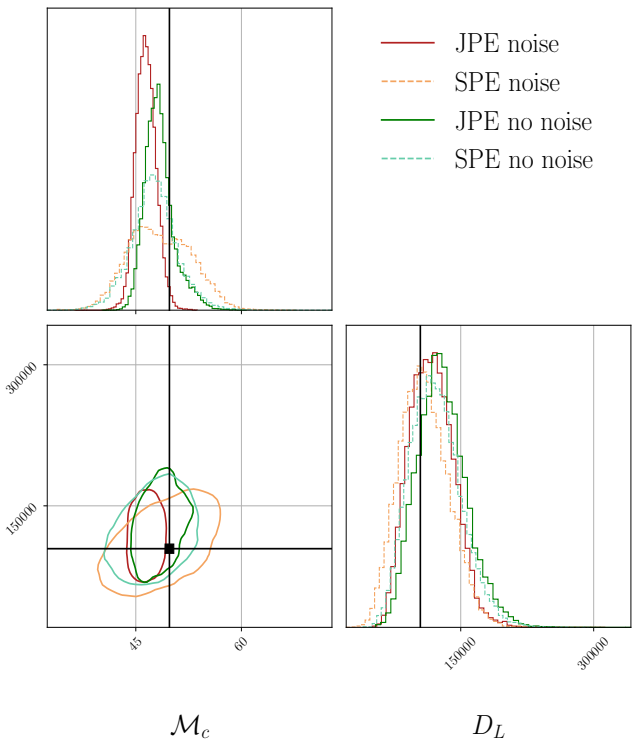
JPE posterior closely matching SPE posterior



JPE posterior narrower than SPE posterior

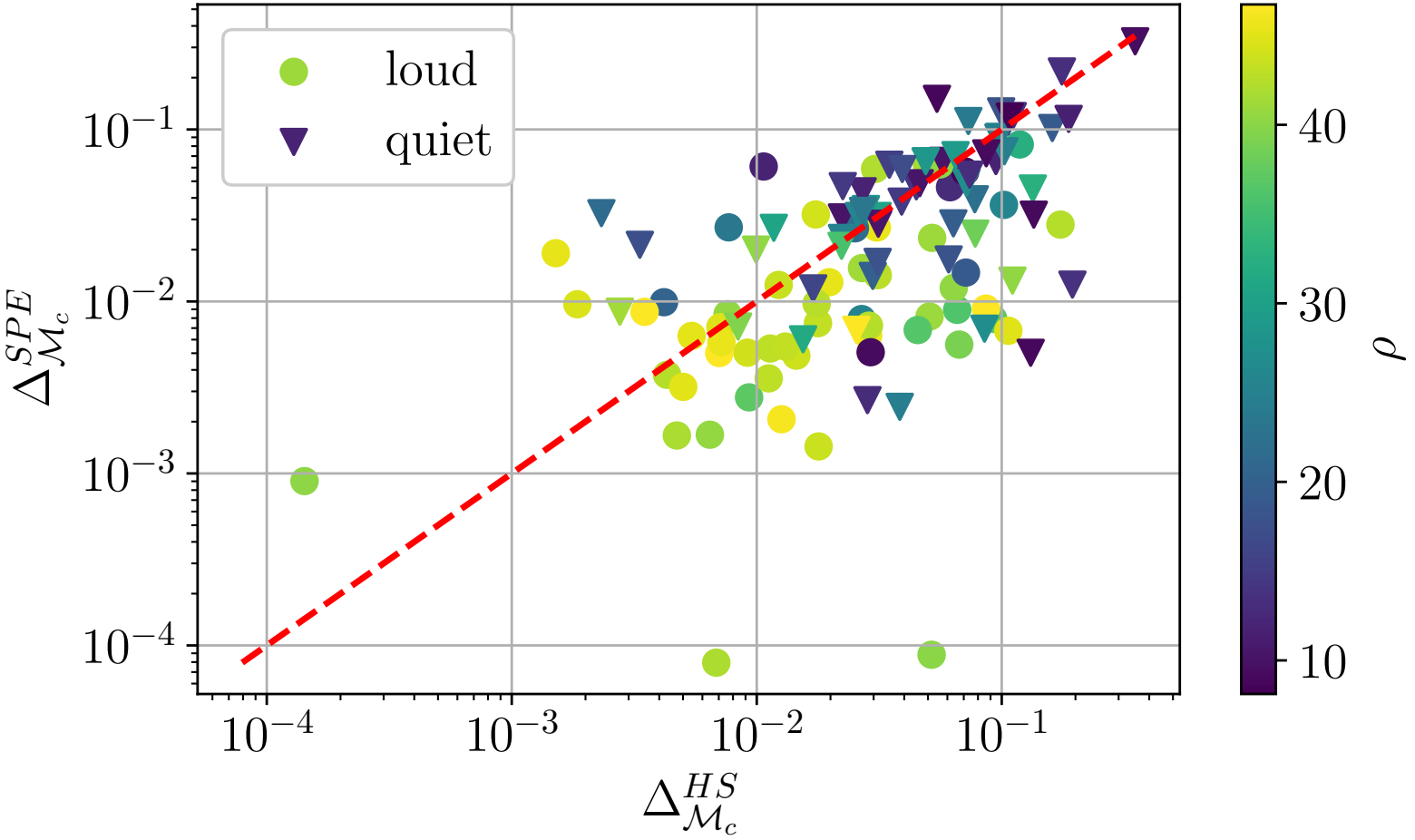


JPE posterior narrower than SPE posterior, but concentrated away from the injection



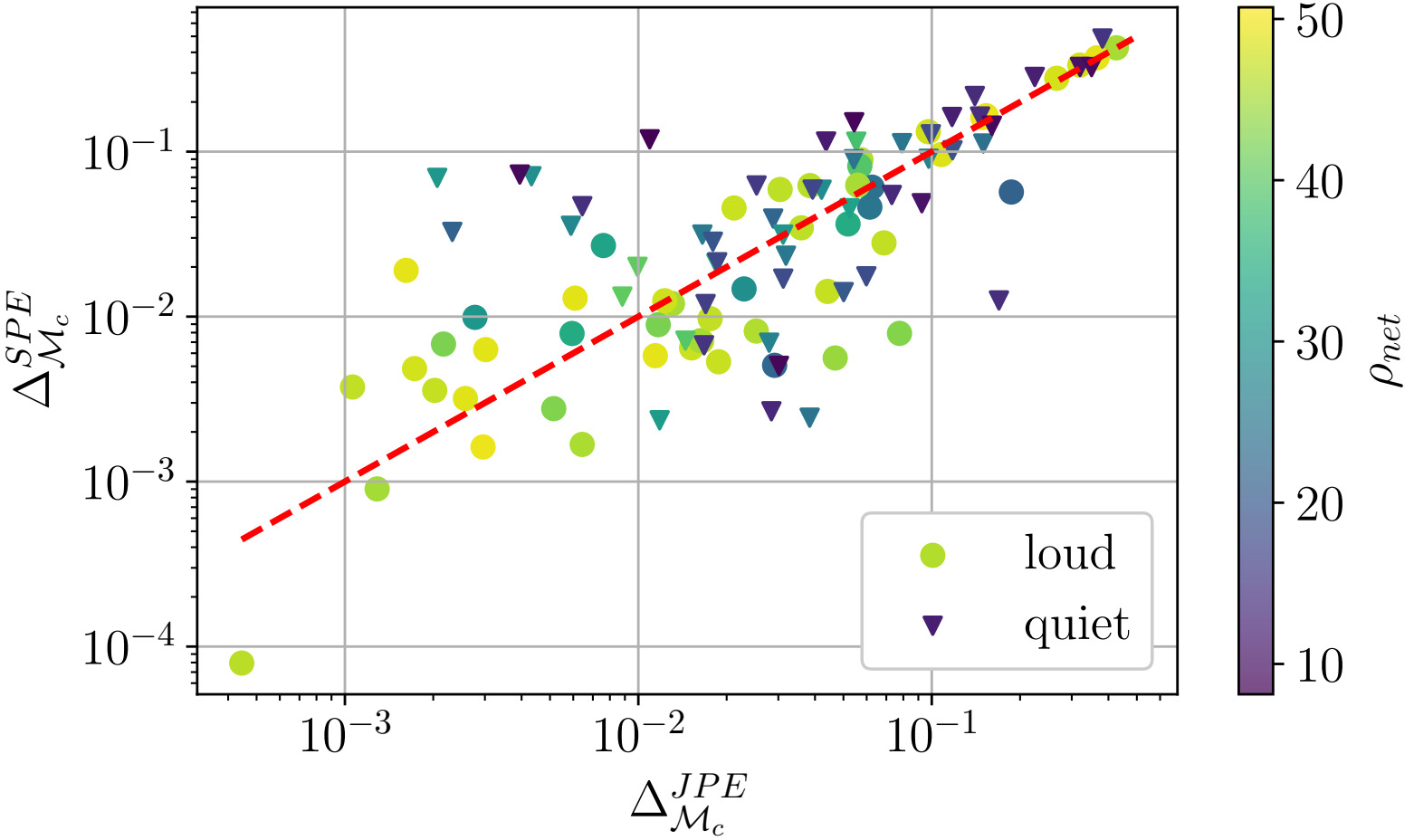
Bias in recovered parameters

- Bias = | median – injection | / injection
- HS shows higher bias in **71%** of loud events and **51%** of quiet ones compared to SPE



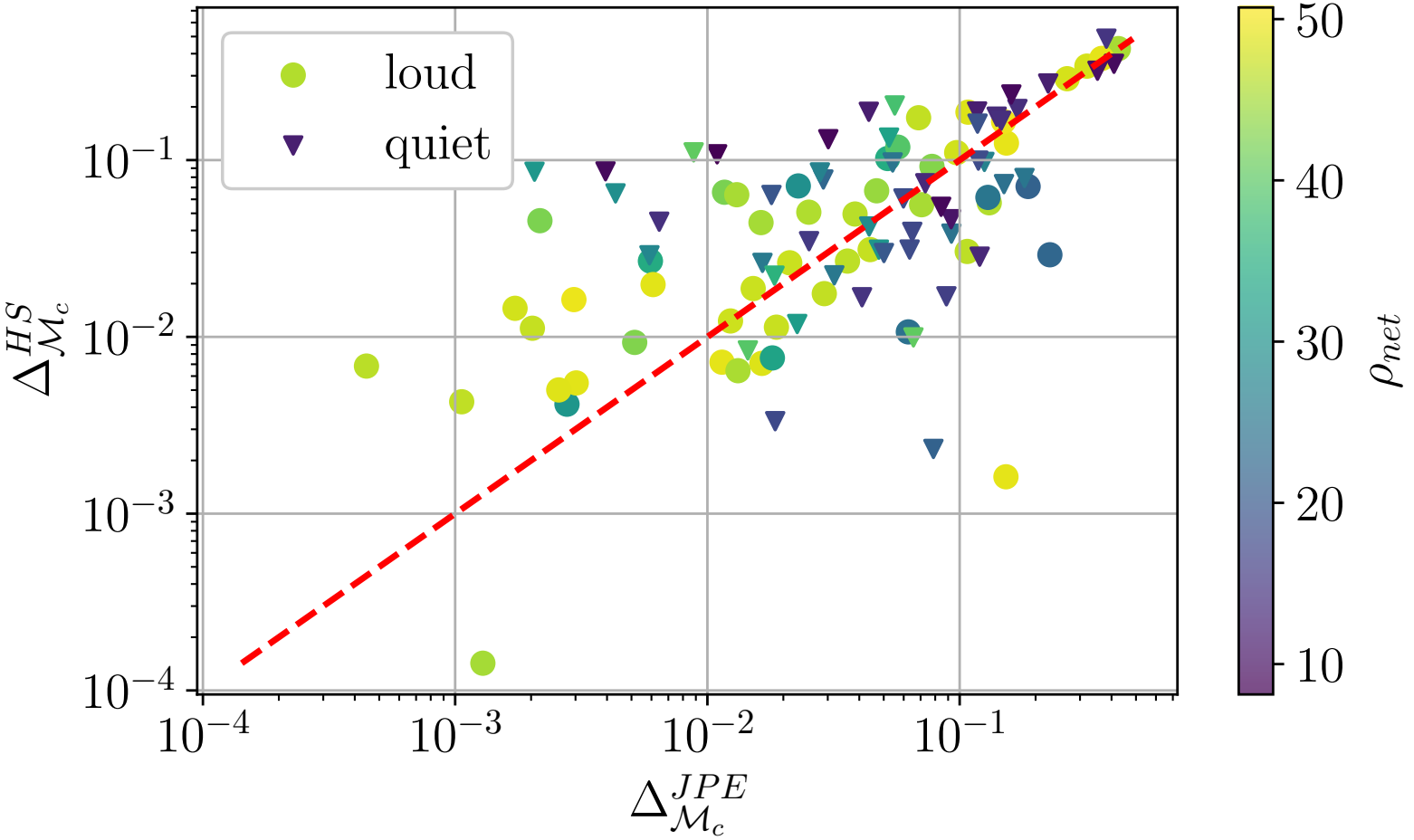
Bias in recovered parameters

- JPE shows higher bias in **55%** of events compared to SPE



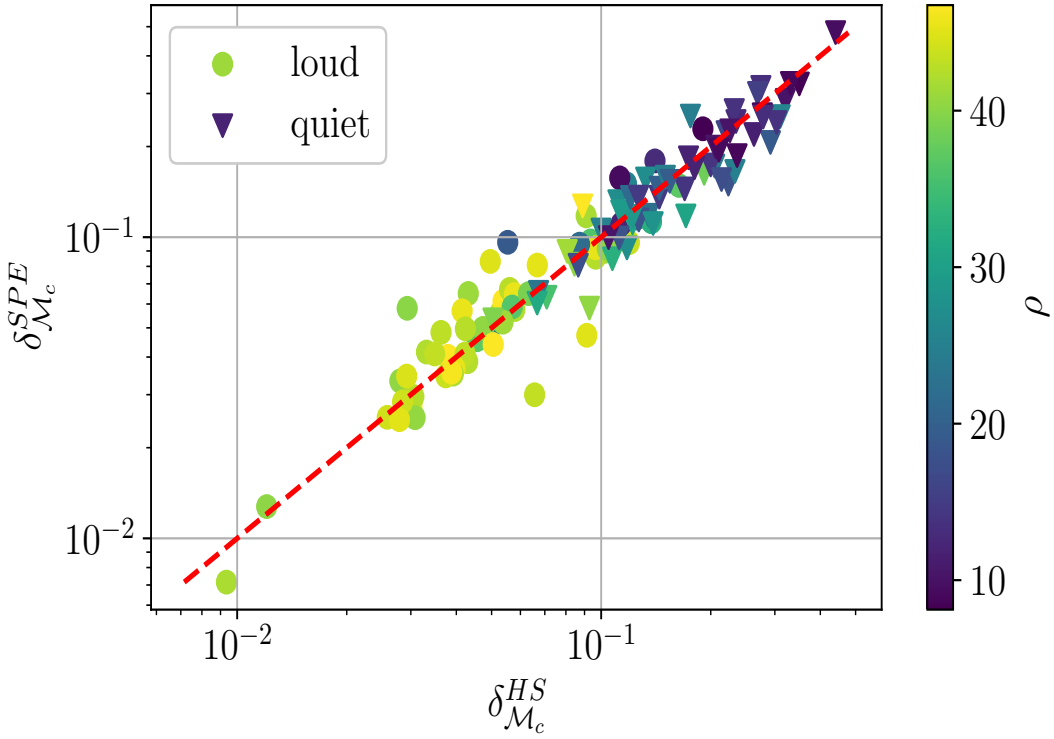
Bias in recovered parameters

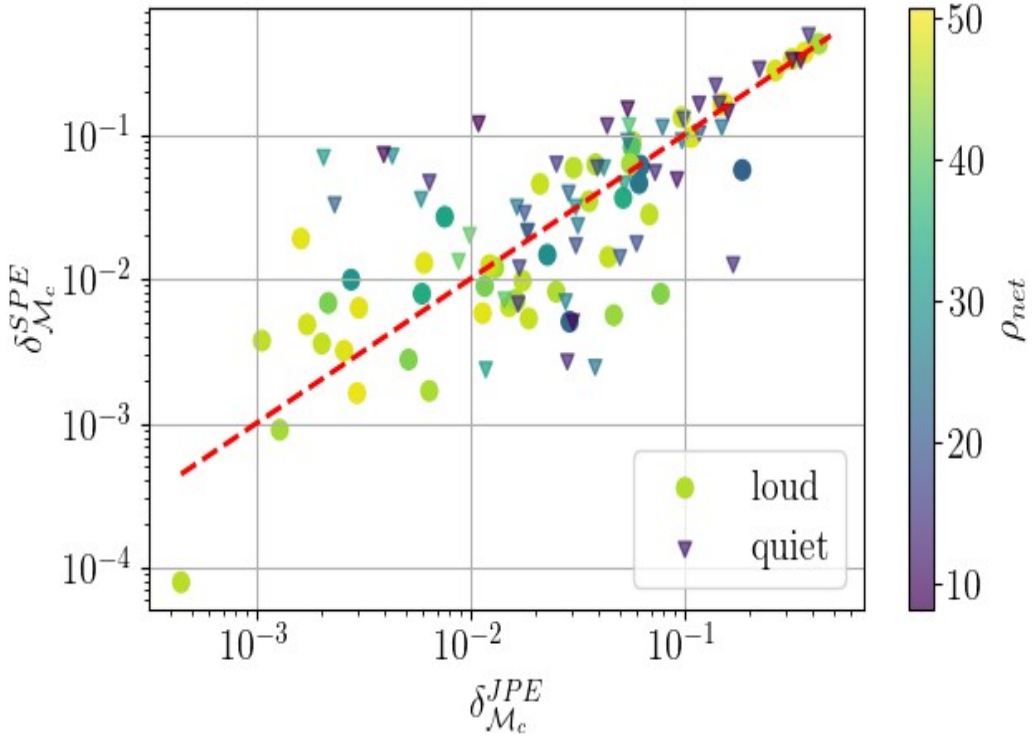
- HS shows higher bias in **65%** of events compared to JPE



Spread of recovered parameters

- 90% confidence interval normalized by injected value





Conclusions

- JPE produces largely unbiased posteriors
- Width of this posterior varies compared with SPE
- JPE is very slow – speed-ups nessercary to aply it in practice
- HS leads to bias, but the recovery of the quieter signal is still possible