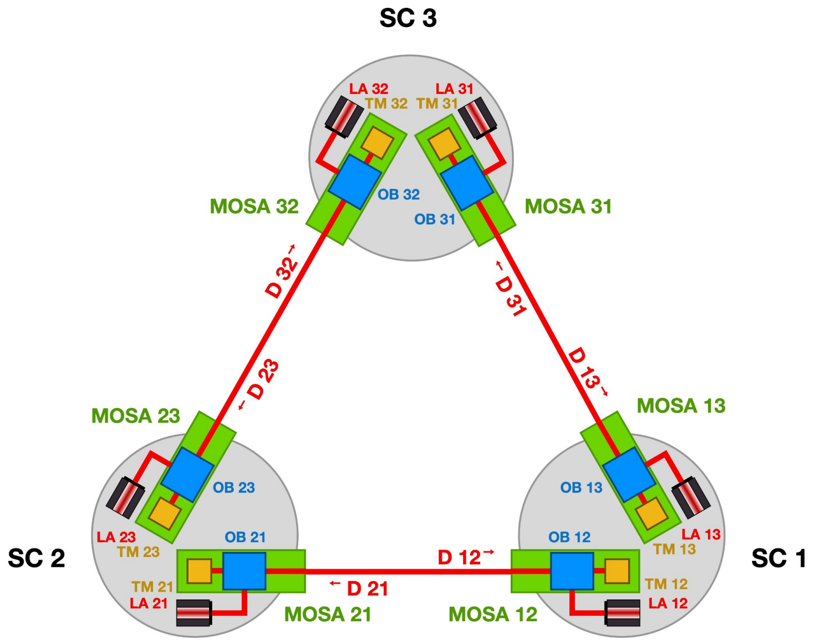
Parameter estimation effort

LISA team @ IRFU, CEA-Saclay

LISA mission

Instrument

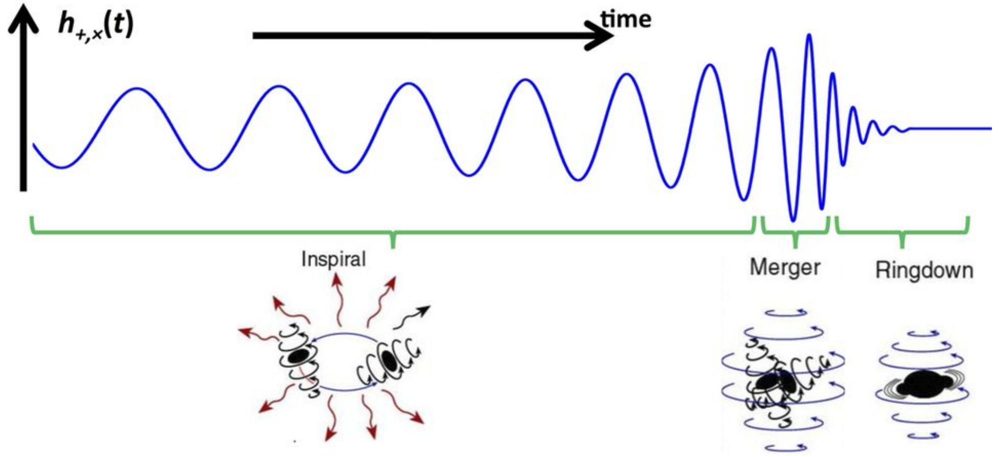
- ➢ 3 satellites constellation in heliocentric orbit and 2.5 millions km apart each others
- ➢ **Test masses isolated from any other force than gravitation.**
- ➢ Communication with 6 laser links
- ➢ Interferometric Detection



Detection domain

- ➢ **Larger bandwidth than ground based instruments**
  - ○ Several sources will be detected before they merge :
    - ■ **Massive Black Hole Binaries (MBHB)**

      → [10^4 - 10^7] solar masses
    - ■ Galactic Binaries
    - ■ Extreme Mass Ratio Inspirals (EMRI)



Example of an MBHB waveform shape

Definition of the Simulator

Observational model: $$\mathbf{y}_{0:n} = F_{\mathrm{obs}}\underbrace{\left(R_{\mathrm{LISA}}\left(W_{0:n}(\theta)\right)\right)}_{h(\theta)} + \mathbf{n}_{0:n}$$

$h(\theta)$: LISA response to the GW signal

$$\text{with } \mathbf{y}_{0:n} = [\mathbf{y}_{t_0}, \mathbf{y}_{t_1}, \ldots, \mathbf{y}_{t_n}]$$

F_{obs} : Observing conditions, gaps, glitches, etc..

R_{LISA} : LISA instrument response

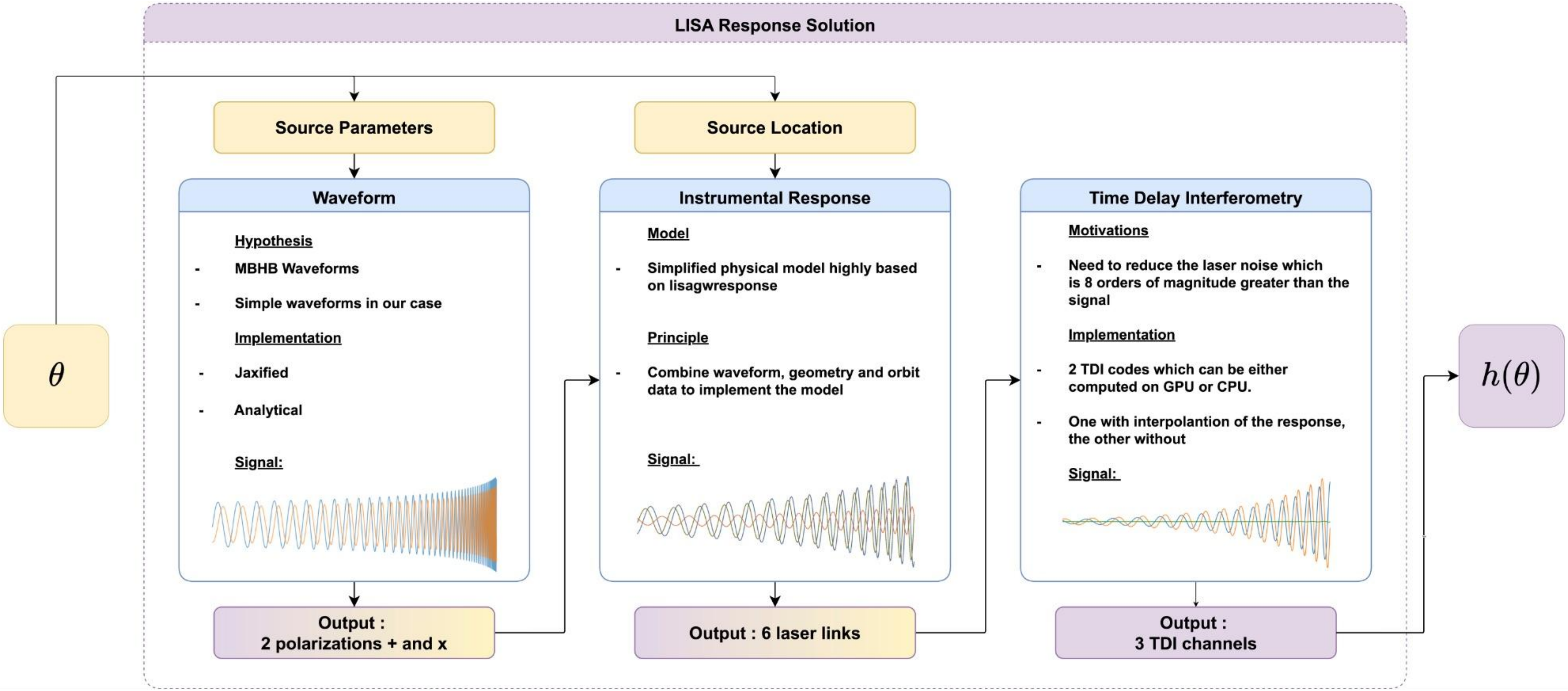
$W_{0:n}(\theta)$: Waveform model

$\mathbf{n}_{0:n}$: Noise (Gaussian and stationary) with a known covariance

Our **objective** is to estimate the pair: $\hat{\theta}, \quad SS(P(\theta \mid \mathbf{y}_{0:n}))$ where SS() is some summary statistic encoding the uncertainty of the estimation.

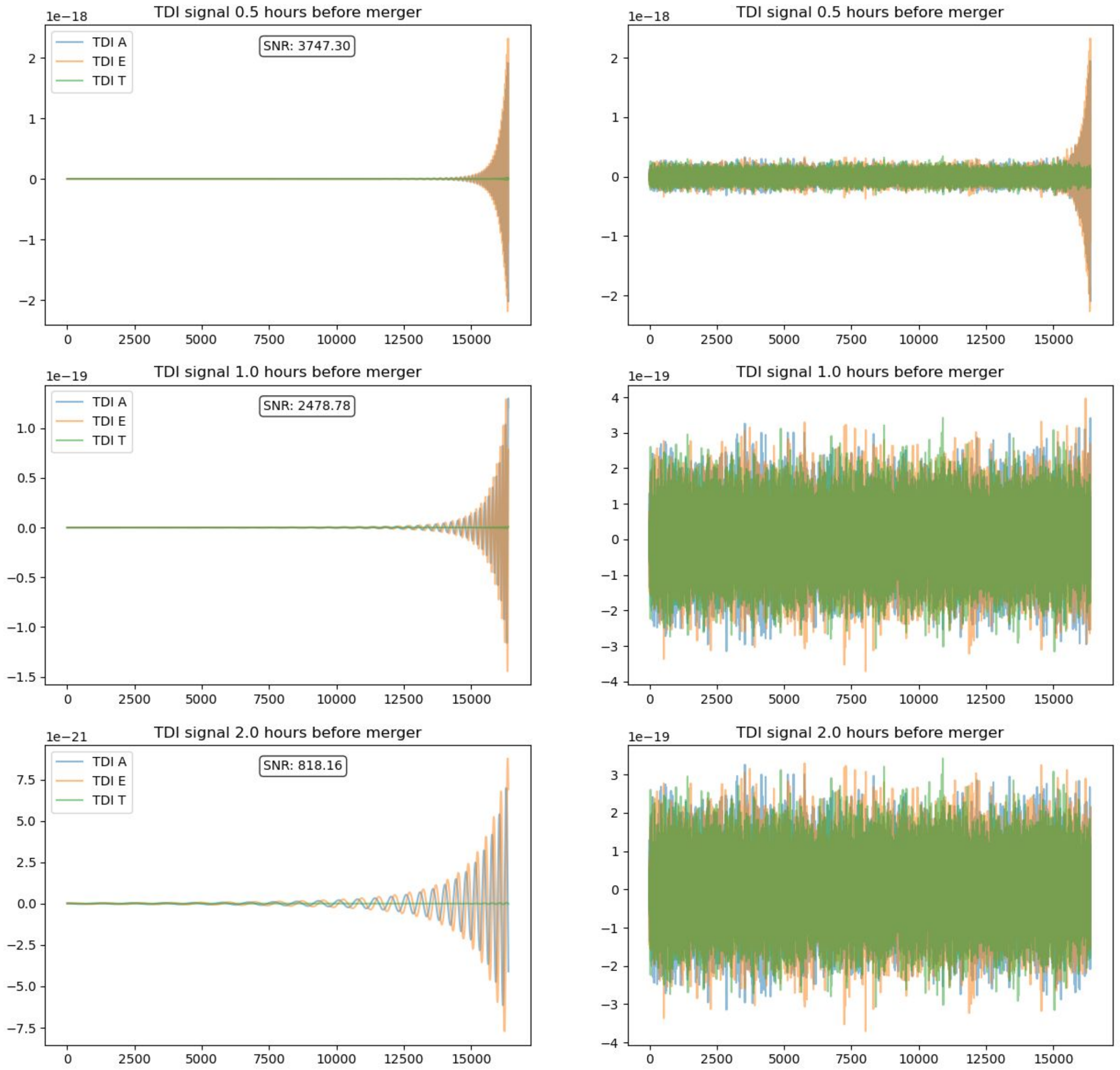
For example: $\hat{\theta} = \mathbb{E}(\theta \mid \mathbf{y}_{0:n}), \quad SS(P((\theta \mid \mathbf{y}_{0:n}))) = \mathrm{Var}(\theta \mid \mathbf{y}_{0:n})$

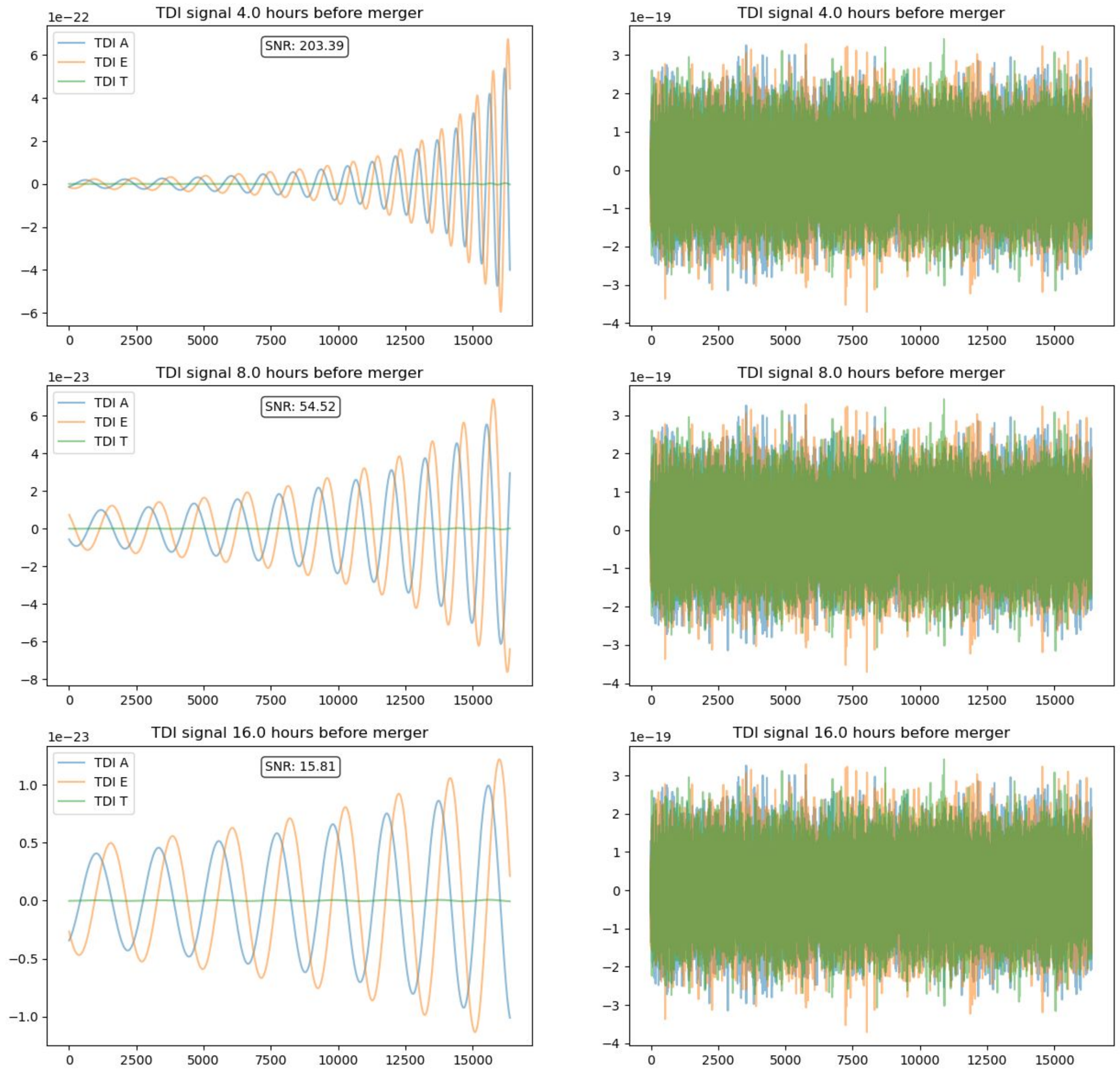
LISA time-domain response function



Data examples

Same time segments, but we get further away to the coalescence time and thus the SNR decreases





Thank you for your attention.

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Extra slide: Simplified waveform

$$h_+ = h_{\theta\theta} = -2\left(1 + \cos^2\theta\right)\frac{\mu}{R}(M\omega)^{2/3}\cos\left[2\omega(t-R) - \phi_0\right]$$

$$h_\times = h_{\theta\phi} = -4\cos\theta\,\frac{\mu}{R}(M\omega)^{2/3}\sin\left[2\omega(t-R) - \phi_0\right].$$

Ref: Babak (2020), “Gravitational Waves from Coalescing Binaries”