

Dixième Assemblée Générale du GdR Ondes Gravitationnelles, Oct 2026

Data analysis challenges with LIGO-Virgo-KAGRA and XG detectors

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Current methods and challenges

Modelled

Unmodelled

Transient

CBC: matched filtering & Bayesian inference

- Large template banks ($\sim 10^6$ templates)
- Glitches & non-stationary noise
- Calibration and waveform systematics
- Fast localisation and Parameter estimation

Bursts coherent unmodelled searches

- No reliable waveform model
- Glitches & non-stationary noise
- Signal/noise discrimination (time sliding)
- Increasing use of ML

Persistent

CW coherent / semi-coherent searches

- Weak signals
- Large parameter space
- Long observation times
- Correlated noise

SGWB cross-correlation

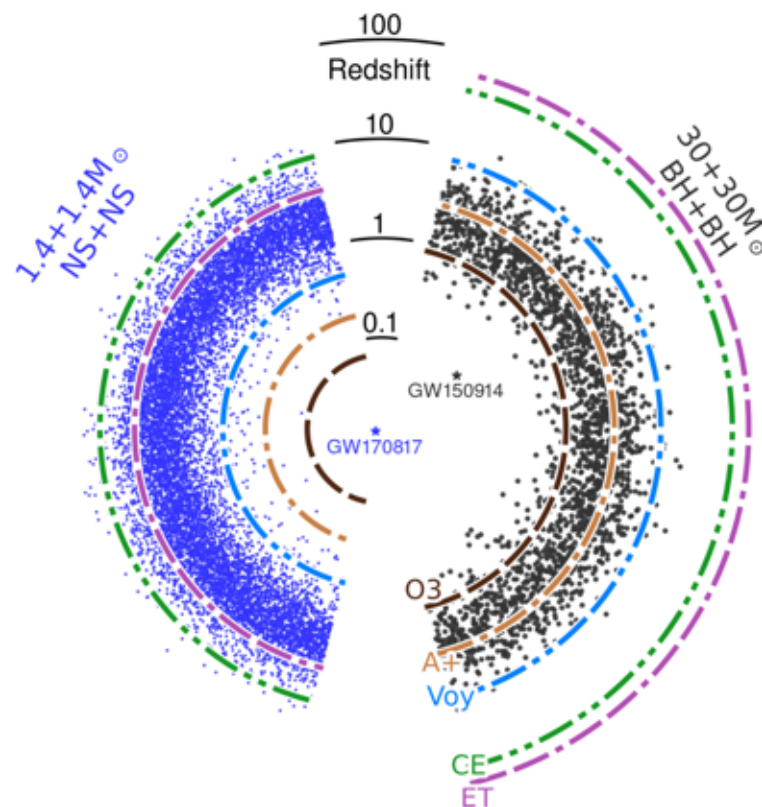
- Weak signal approximation
- Correlated noise
- Astrophysical/cosmological separation

From a noise-dominated to a source-dominated regime

LVK detectors

~1 CBC signal/day
 ≈ 1 min/signal

Noise-dominated regime:
the main challenge is to
extract **faint signals** from
non-ideal noise, and
characterize their
properties.



Credit: Cosmic Explorer

XG detectors

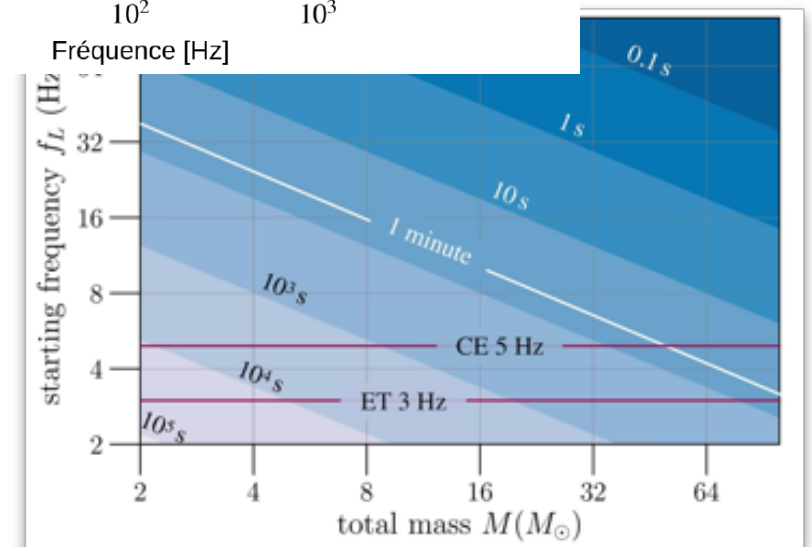
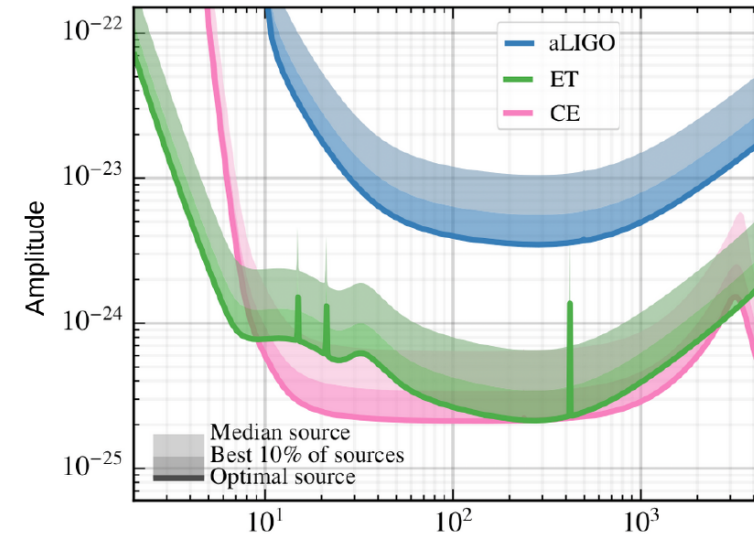
Quasi-signal-dominated
regime:

- **Massive rate** of CBC detections (~10/hour)
- **Long** CBC waveforms (≈ 1 hour/signal)
- **Overlapping** waveforms
- Much **higher SNRs**
- Need **more accurate models**
- New sources?

New Data Analysis Challenges with XG detectors

With a better sensitivity and a lower frequency bound, new problems will appear:

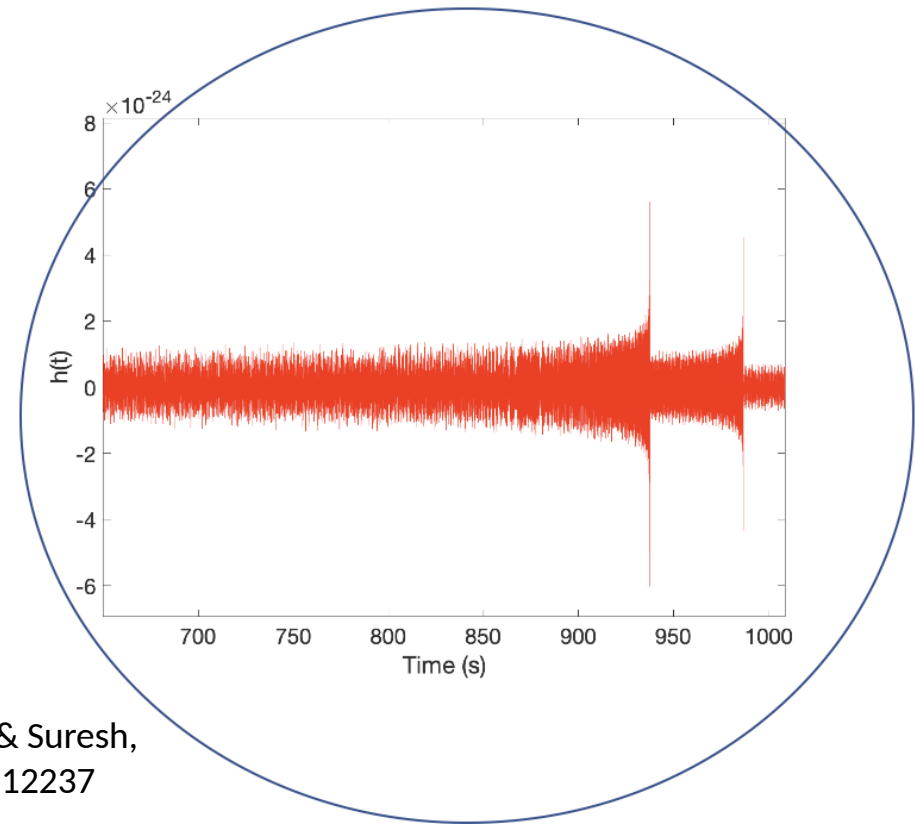
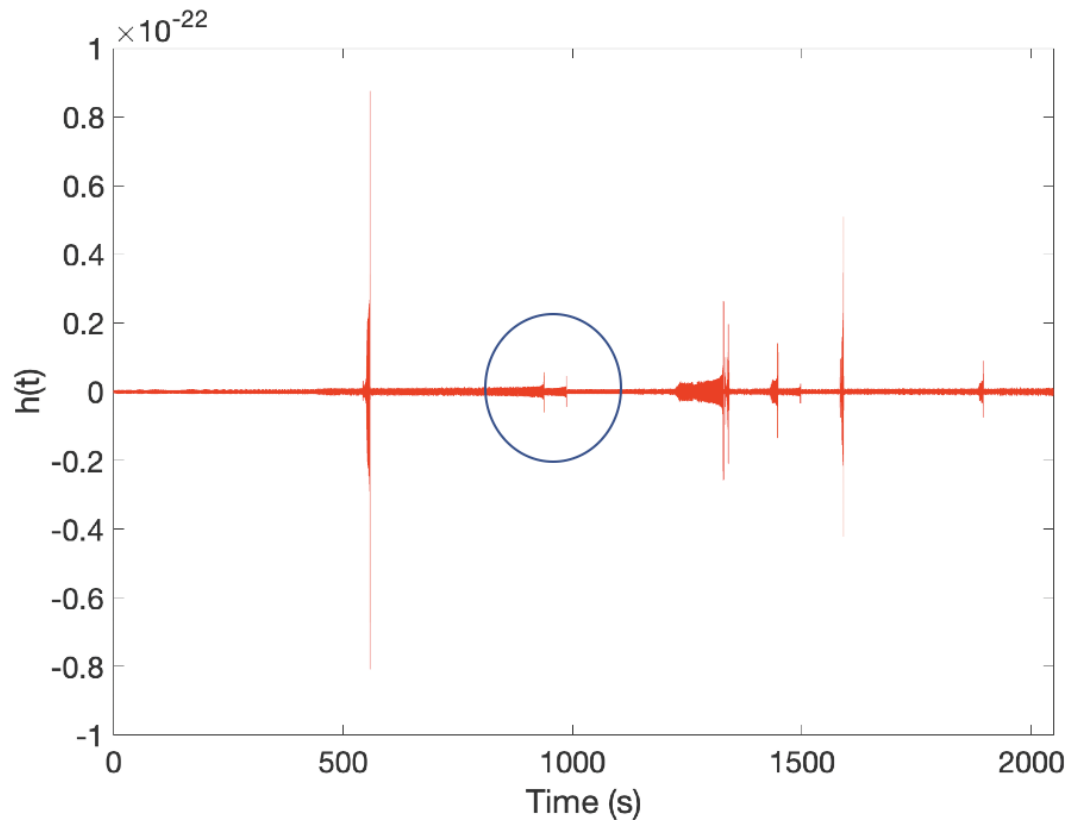
- How do we deal with long duration CBC signals?
- How do we separate overlapping signals?
- How do we estimate the noise background in the continuous presence of sources?
- How do we subtract the astrophysical background or separate astrophysical/cosmological background?



Example of CBC signals overlapping in time

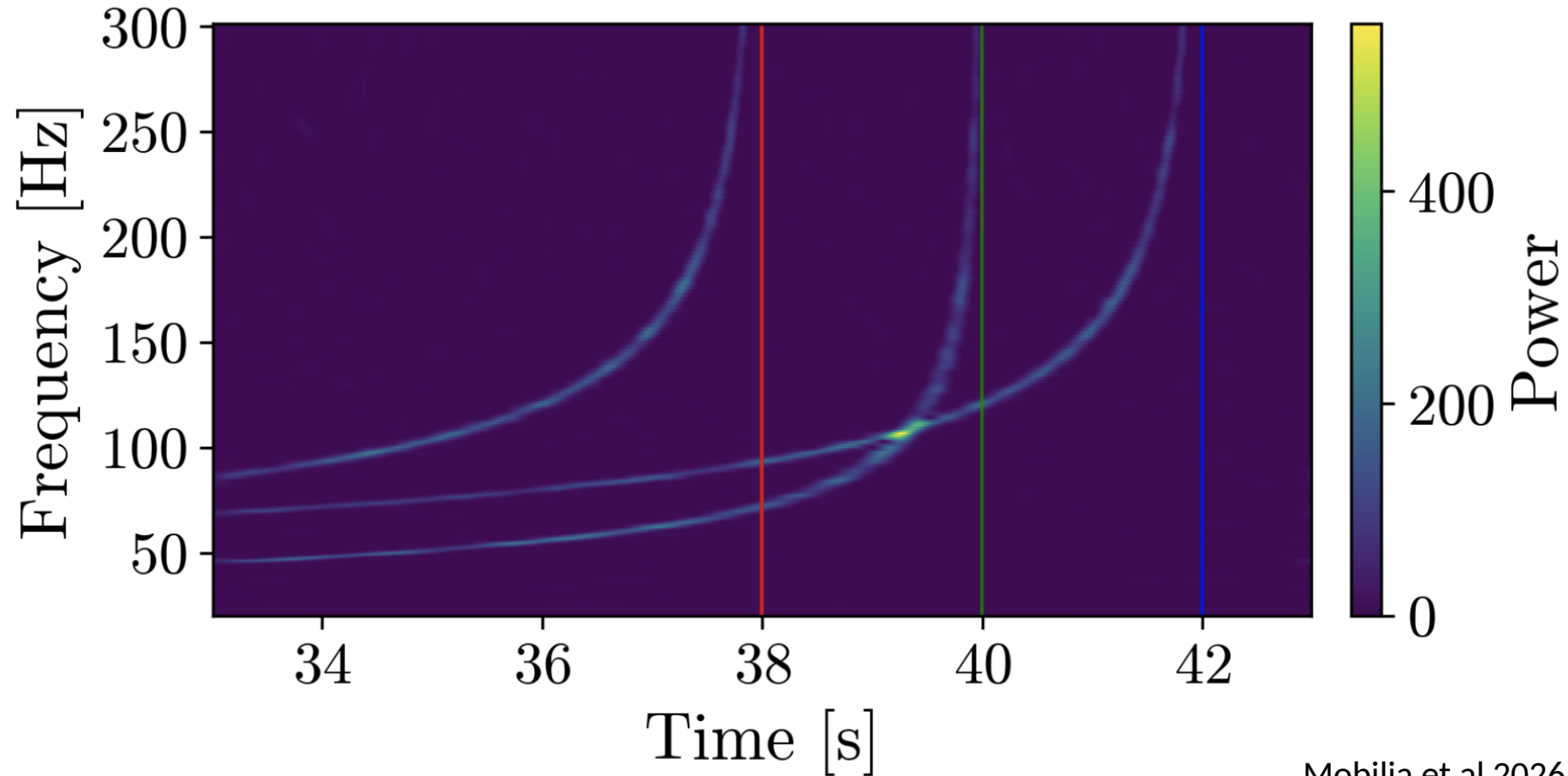
28 signals with SNR>6, largest at SNR=85

BNSs merging at 937s and 986s, that are both long duration and overlapping



ET MDC 1,
Regimbau & Suresh,
arxiv:2506.12237

Example of CBC signals overlapping in time

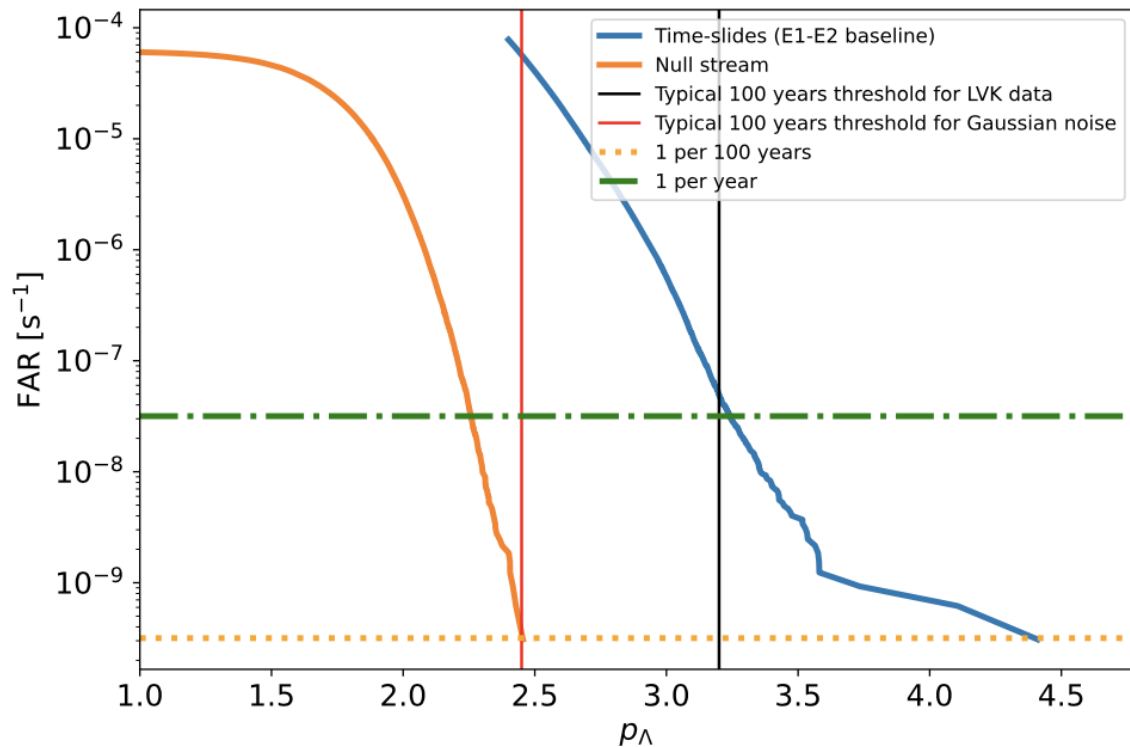


Mobilia et al 2026

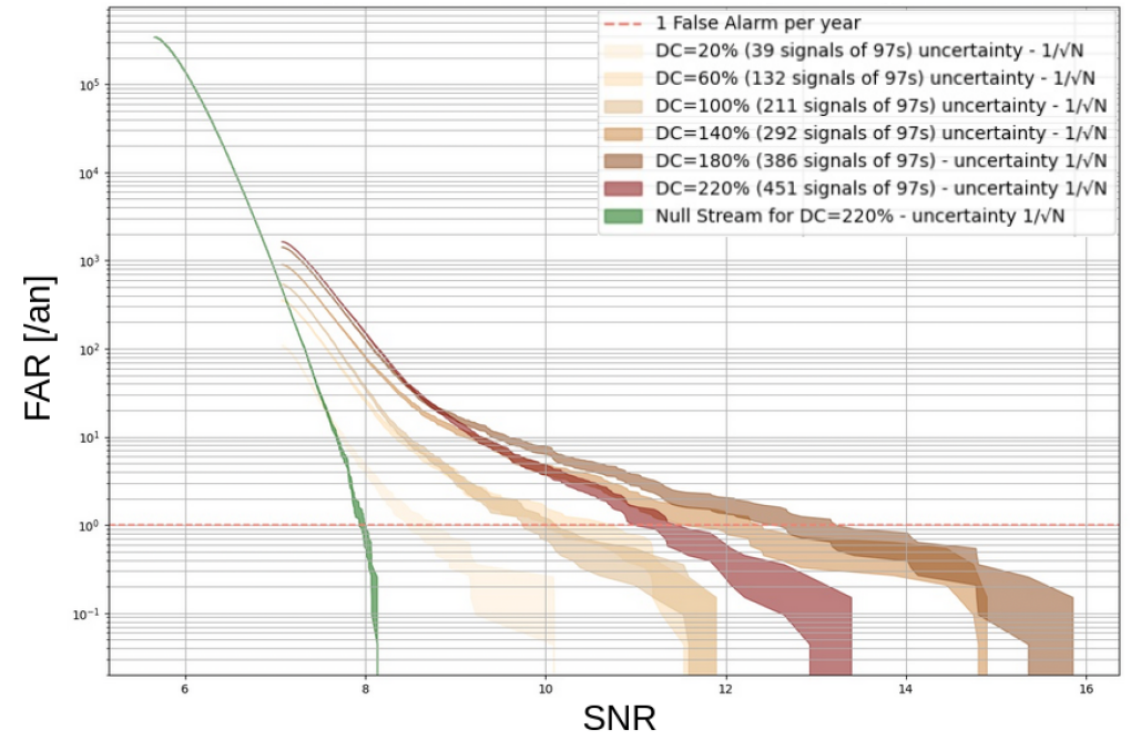
Background estimation and False Alarm Rate

In most current search algorithms, the background rate of false-alarms is estimated using time slides (e.g. Wąs et al 2010).

With a large number of sources, **accidental coincidences** between unrelated signals become frequent, **biasing** the estimated rate of false alarms.



Macquet et al 2025



From P. Larue, master student

Parameter Estimation with XG detectors

Bayesian parameter estimation needs to become feasible in **~1 min** to keep up.

Another challenge is to deal with the superposition of sources (multiple-signal likelihood).

New routes are being explored:

- Hierarchical subtraction (error residual)
- Accelerated waveform calculation: reduced-order-methods, likelihood-free inference, relative binning.
- Machine learning: Neural posterior estimation, truncated marginal neural ratio estimator, nested sampling with AI, normalizing flows, MCMC, deep neural network driven hamiltonian MC.