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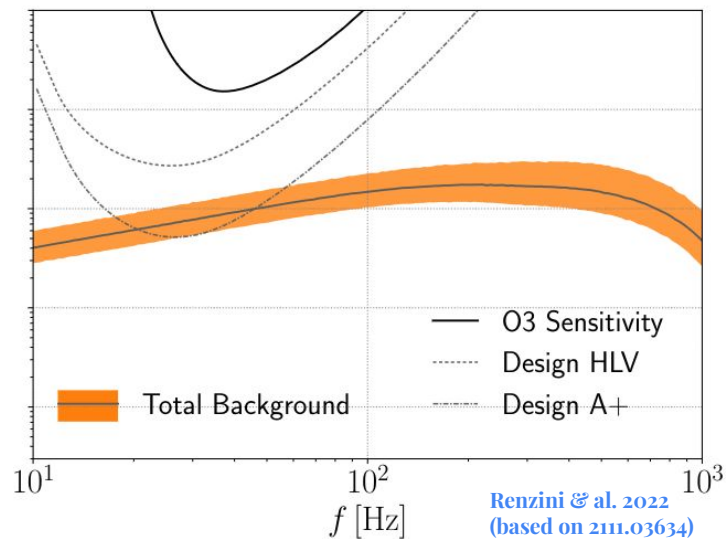
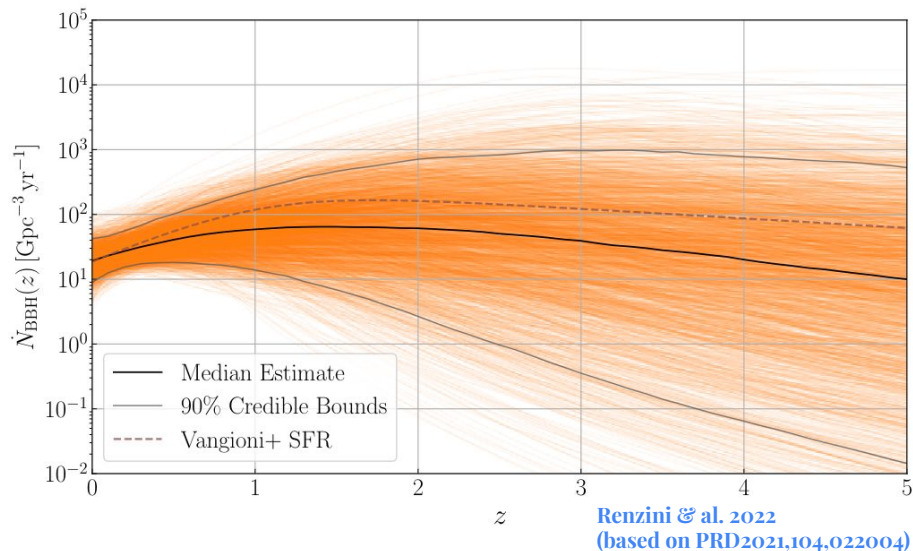


**Non-gaussian gravitational wave backgrounds
across the spectrum**



Astrophysical foregrounds

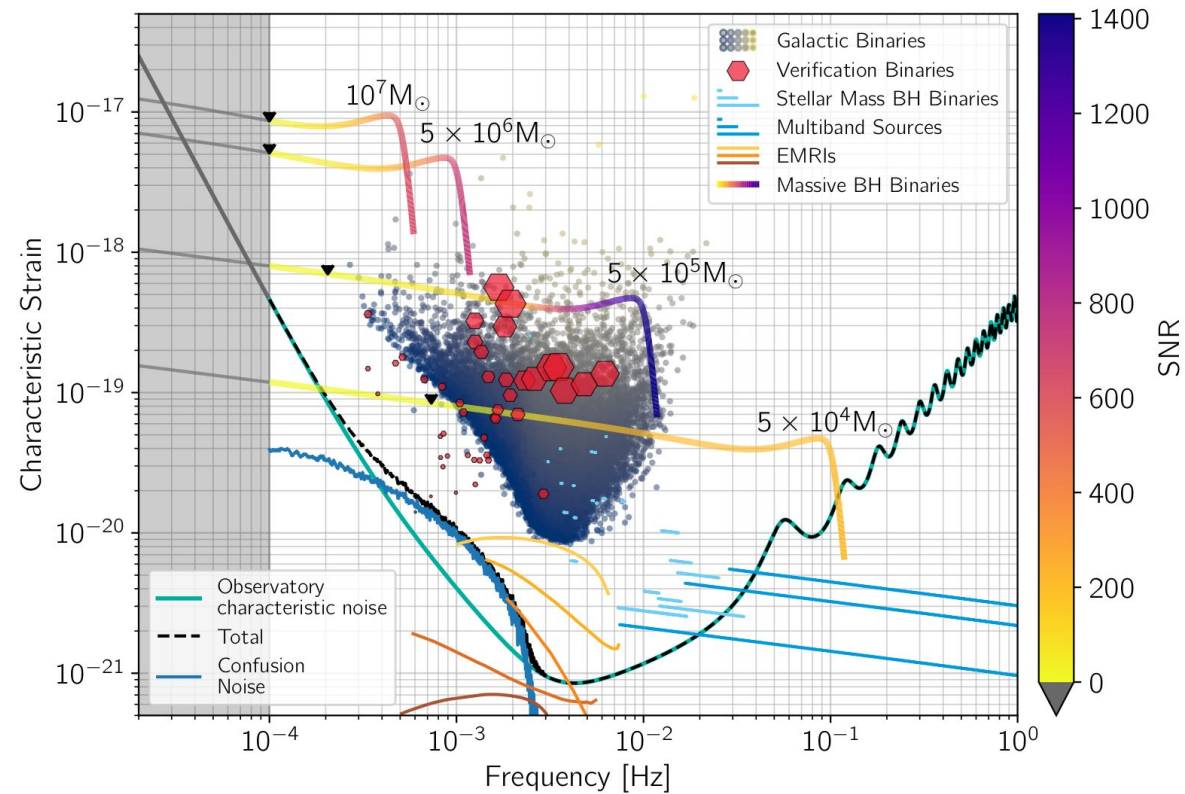
LIGO & Virgo



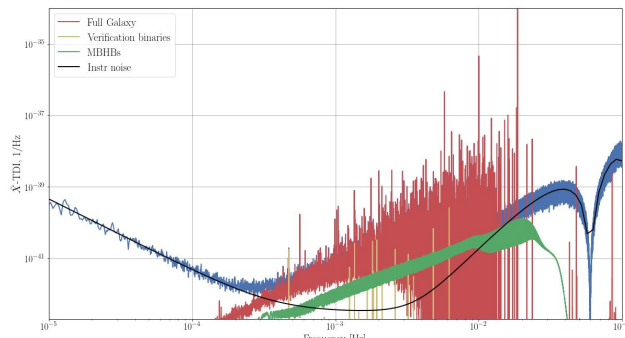
$$\Omega_{\text{GW}}(f) = \frac{1}{\rho_{\text{c}}} \int_0^{\infty} dz \frac{N(z)}{1+z} \left[f_{\text{r}} \frac{dE_{\text{GW}}}{df_{\text{r}}} \right]_{f_{\text{r}}=f(1+z)}$$

Astrophysical foregrounds

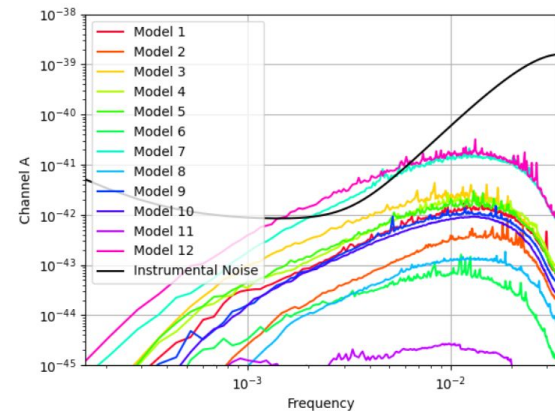
LISA



LISA Definition Study Report (in prep.)



LISA Data Challenge



Pozzoli & al. 2023

Data

Where to draw the line?



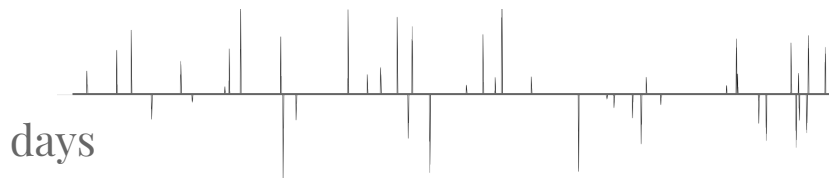
Is it stochastic?

Individual event searches



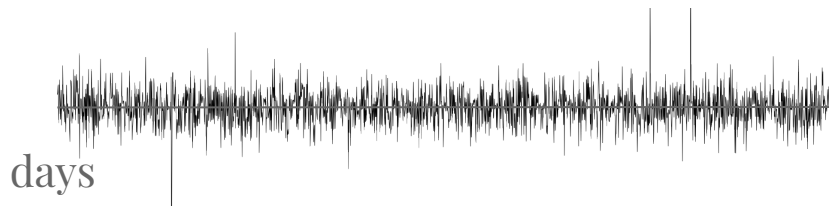
Is it stochastic?

Overlapping event searches



Is it deterministic?

Non-Gaussian SGWB searches

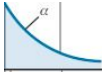
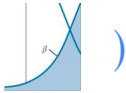



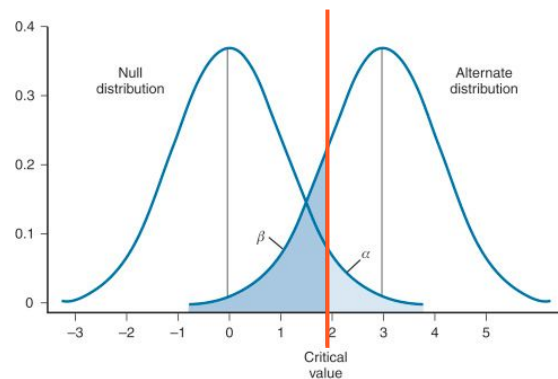
Is it deterministic?

Gaussian SGWB searches

Detection statistics

How to construct a frequentist detector

- Model the data under both hypotheses (noise, noise+signal).
- Fix the probability of false alarm P_{FA} : i.e. 
- Maximize the probability of detection P_D at fixed P_{FA} : i.e. $(1 - \beta)$ 
- Isolate the dependence on data in sufficient statistics $\mathbf{Y}(s)$ (SNR is just an example)
- Obtain a threshold as a function of P_{FA} : i.e. 
- **Bonus:** the likelihood is $P(s|H_1)$

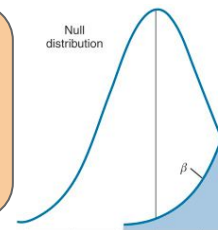


Detection statistics

How to construct a frequentist detector

Key fact:

Expectation values under null hypothesis are not enough under control.
We don't know the noise budget to the same precision of the target SGWB:
you can't switch off SGWB.



- A known fact in Gaussian searches \Rightarrow cross-correlation statistics
 - Non-Gaussian signal: “scrambled” statistics
 - Null-channels (LISA & ET)

Detection statistics

Frequentist approach

Buscicchio & al. 2023 - PRD.107.063027

- A very general detection statistics for non-Gaussian backgrounds

$$Y(\mathbf{s}) = \underbrace{\frac{1}{2}\mathcal{G}(\mathbf{s}, \mathbf{s})}_{\substack{\text{Gaussian search} \\ \text{"Free field"}}} + \underbrace{\log \left\langle e^{-\frac{1}{2}\mathcal{W}_{n+g}(h,h)} e^{\mathcal{W}_{n+g}(\mathbf{s},h)} \right\rangle}_{\substack{\text{New stuff (population informed)} \\ \text{"Interaction term"}}$$

Improved statistics

A careful subtraction

Ballelli, Buscicchio & al. 2023 - PRD.107.124044

Task: remove noise dominated non-zero terms under null-hypothesis

Most general solution:

$$\hat{y}_s = \hat{y} \left[\left(\sum_{\mathcal{A}} u^{\mathcal{A}} \right)^2 \right] - \frac{1}{2^{N_D}} \underbrace{\sum_{\varepsilon_1=-1,1} \cdots \sum_{\varepsilon_{N_D}=-1,1}}_{\text{Combinatorics}} \hat{y} \left[\left(\sum_{\mathcal{A}} \varepsilon_{\mathcal{A}} u^{\mathcal{A}} \right)^2 \right]$$

Exact, single-data statistics

Detector index

Noise-whitened data

Exact, single-data statistics

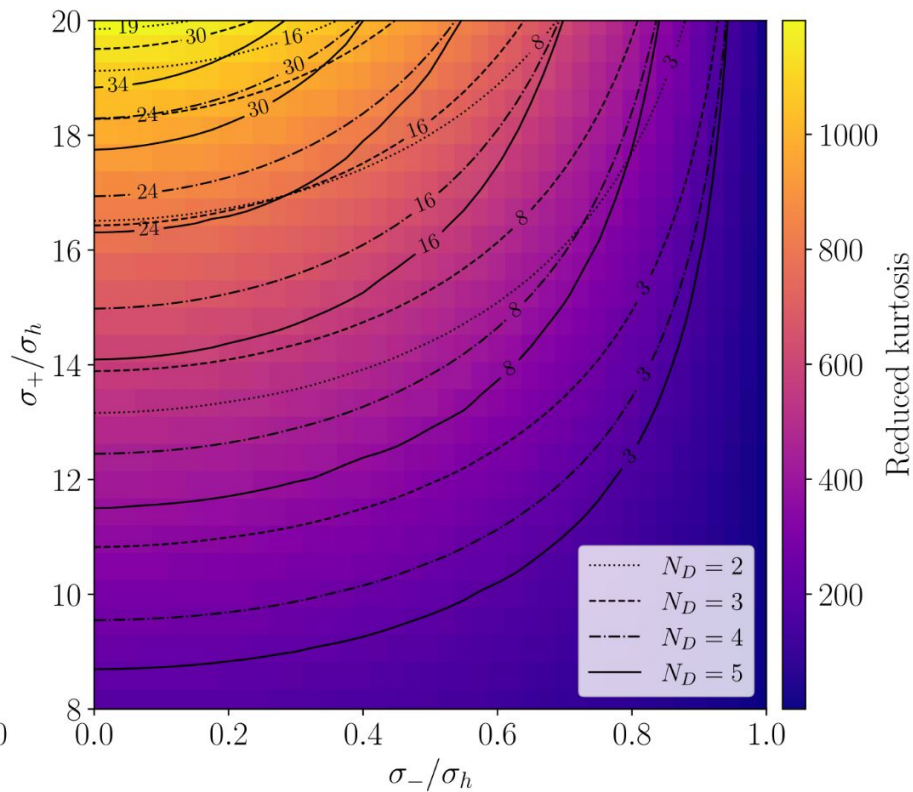
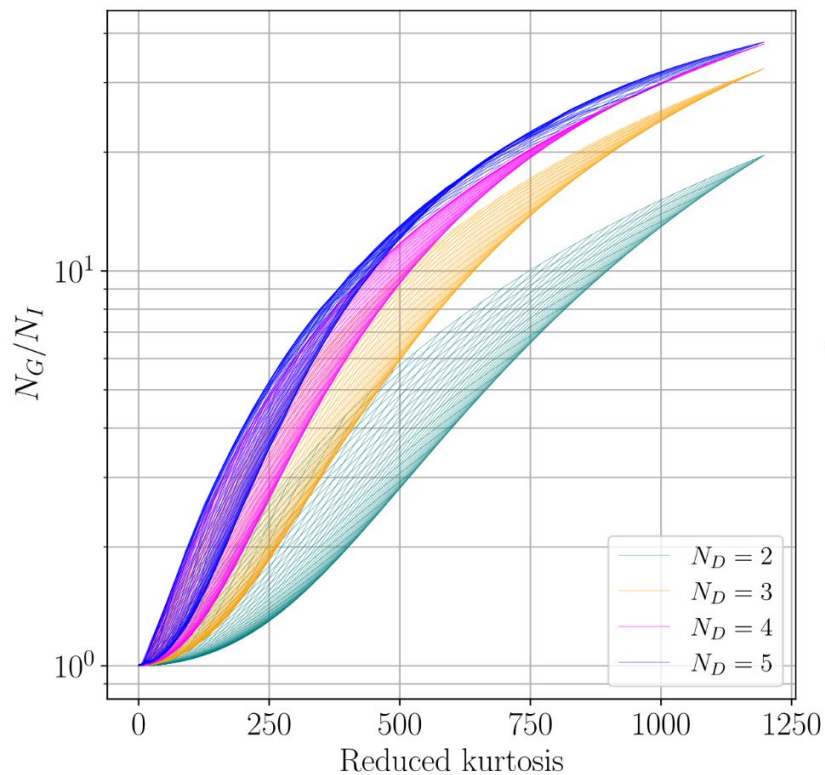
Remark 1: result does not depend on the specific choice of statistics.

Remark 2: result does not depend on GW model. It lives in “detector” indices.

Remark 3: result is **neither** perturbative in non-Gaussianity, **nor** in # of overlapping events (i.e. **neither** Regimbau, Mandic, **nor** Smith&Thrane)

A sneak peek

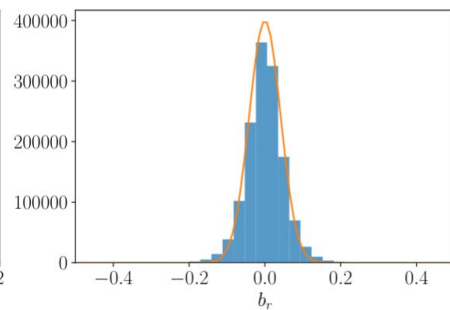
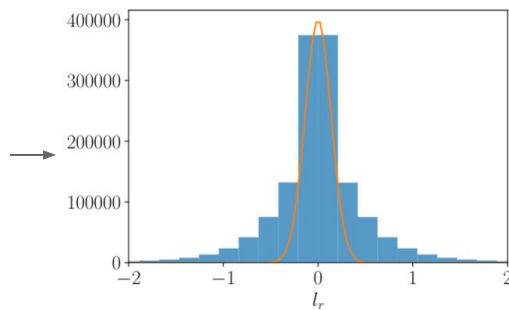
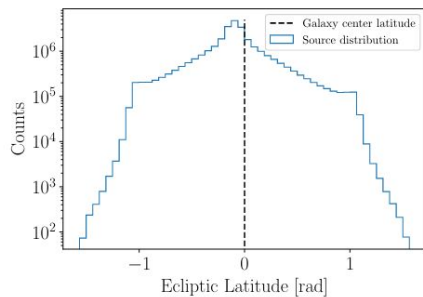
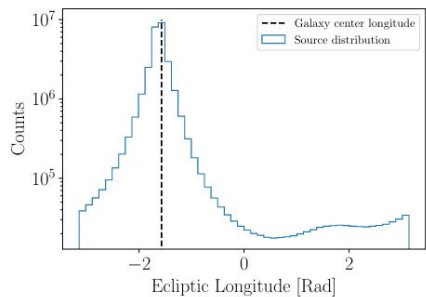
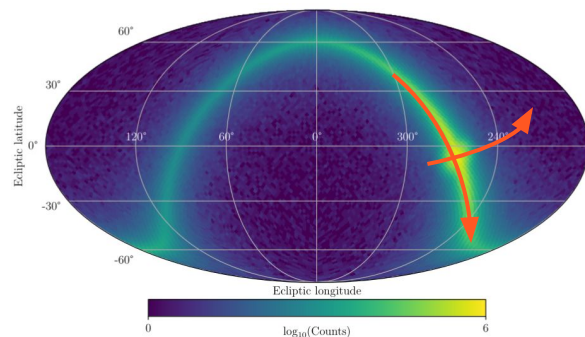
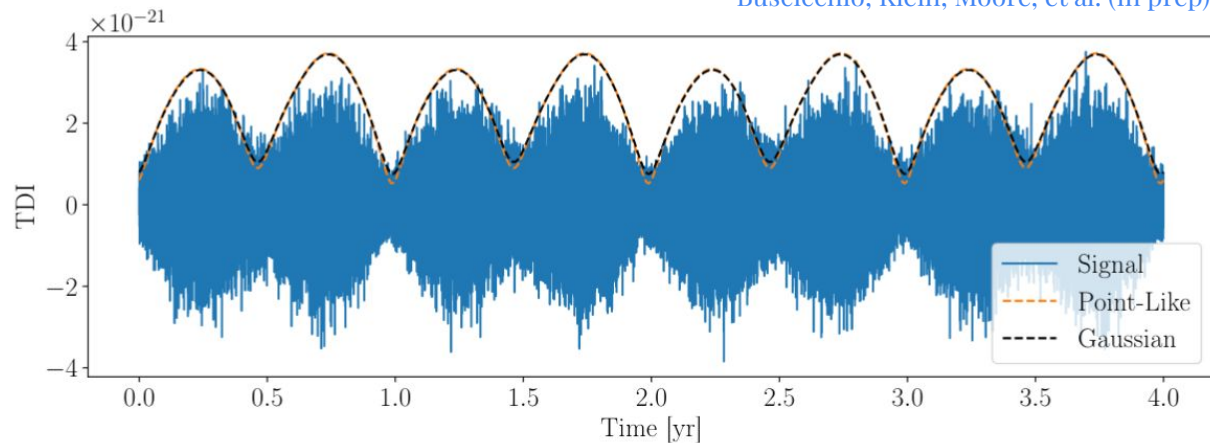
A population informed stochastic background search



Non-gaussianity (Double White Dwarfs)

Do we care?

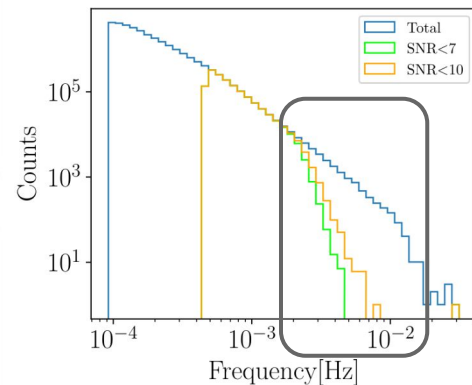
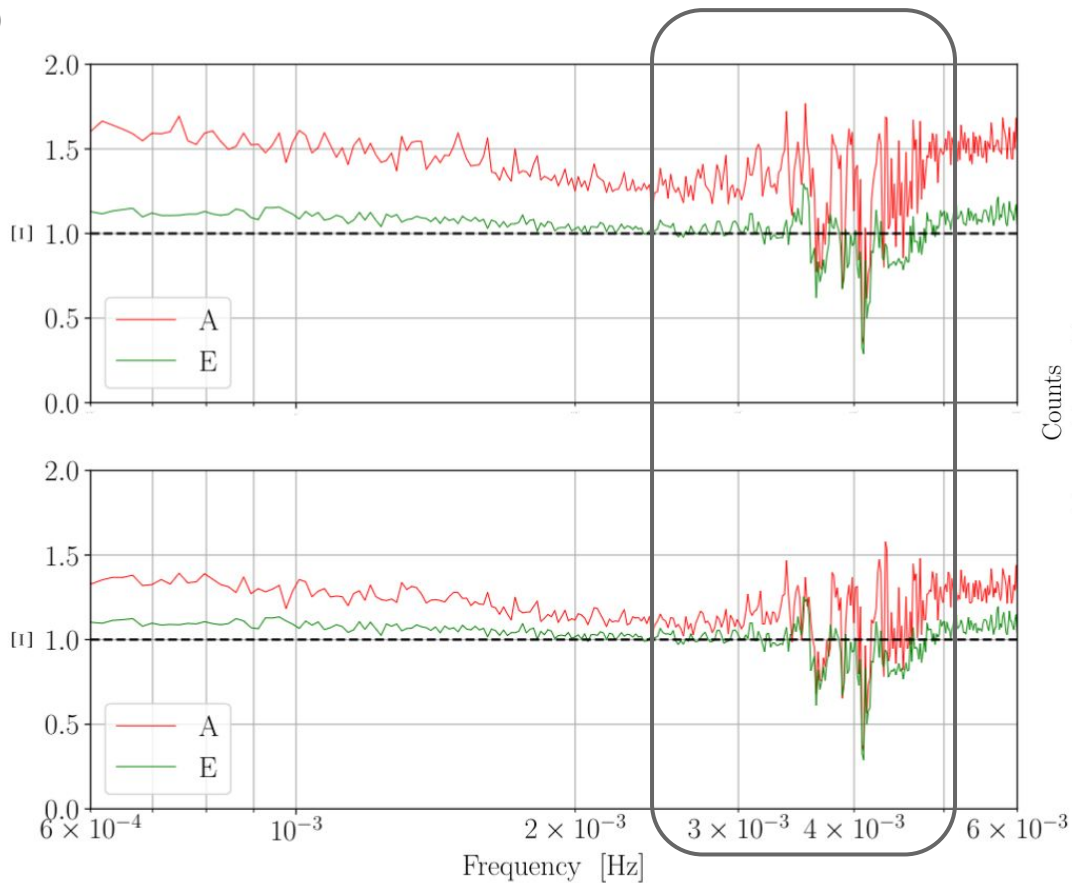
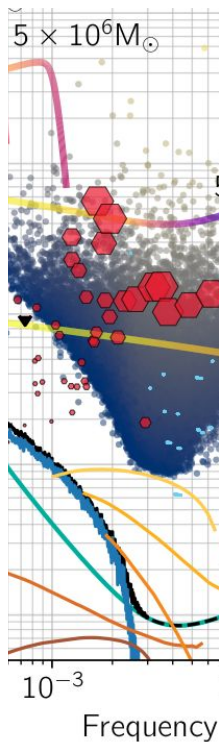
Busicchio, Klein, Moore, et al. (in prep)



Non-gaussianity (Double White Dwarfs)

I think we should

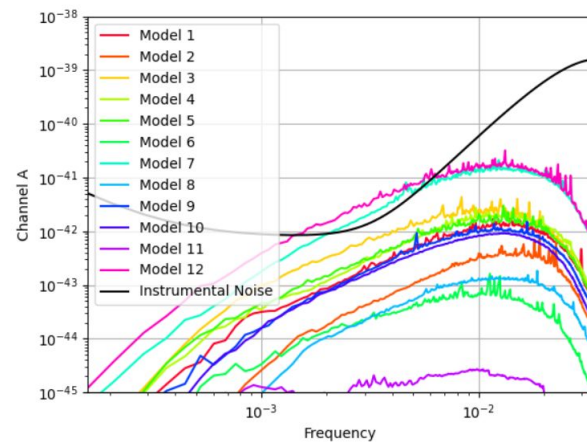
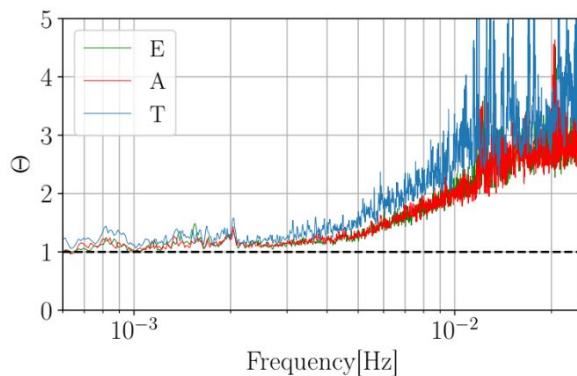
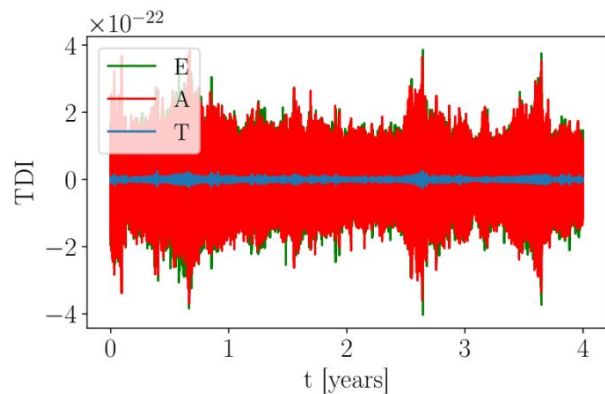
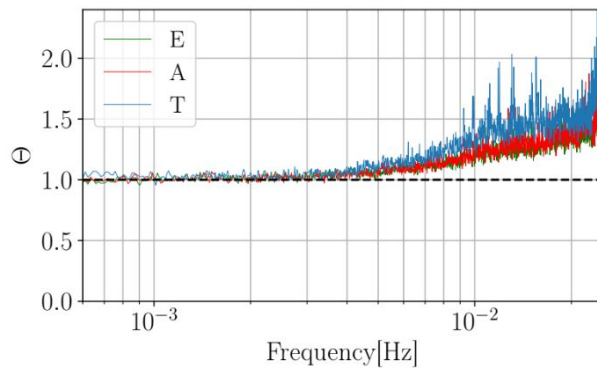
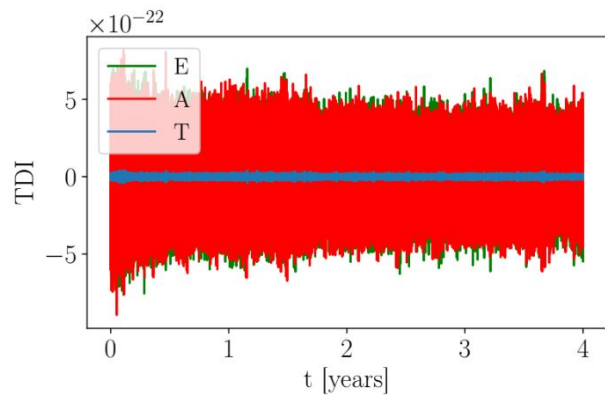
Buscicchio & al. (in prep)



Non-gaussianity (EMRIs)

I think we should

Piarulli, Busicchio & al. (in prep)



Conclusion

- We improved the **detection statistics for non-Gaussian stochastic backgrounds** (any duty-cycle, any number of detectors)
 - it naturally extends the cross-correlation statistics, systematically outperforms it
 - under heavy development in LIGO-Virgo Kagra Collaboration
- LISA needs it in the “bucket”:
 - DWD foreground is non-Gaussian
 - EMRI fore-/back-ground is non-Gaussian
- It is relevant:
 - Foregrounds contaminate the Global Fit:
Gaussian searches would have biased posterior and lower SNR
 - Makes astrophysical backgrounds distinguishable wrt (some) cosmological ones.



Thanks! Questions?