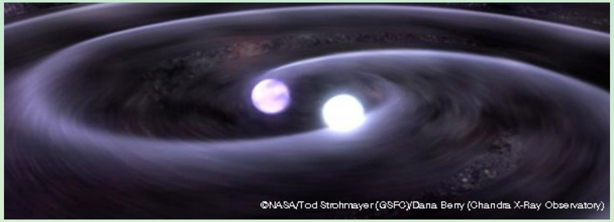
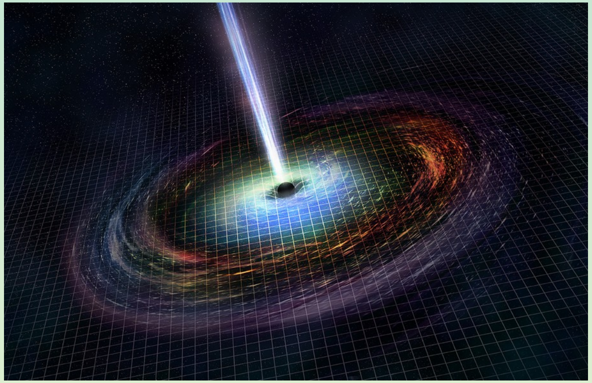
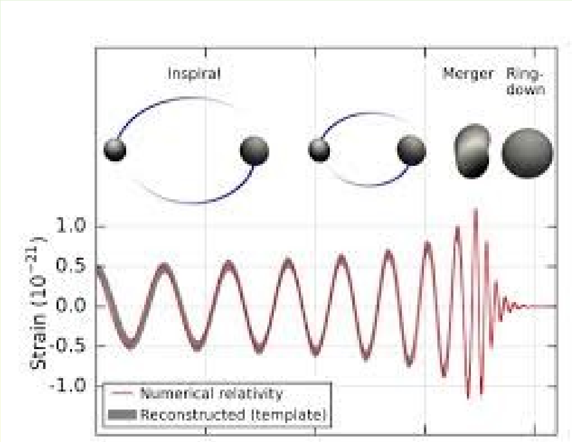
Fermi-GBM follow-up of subthreshold GW triggers

Cosmin, Nelson and others

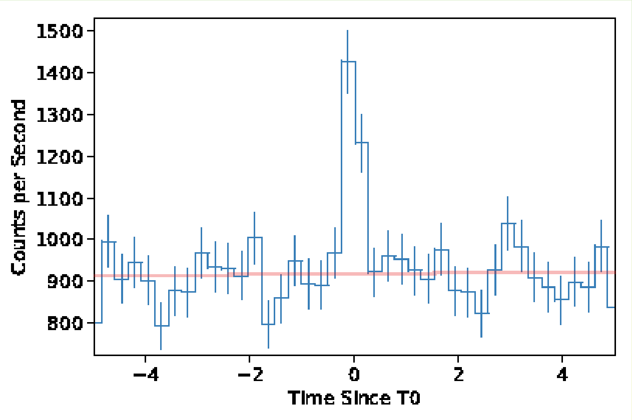
Remind the story



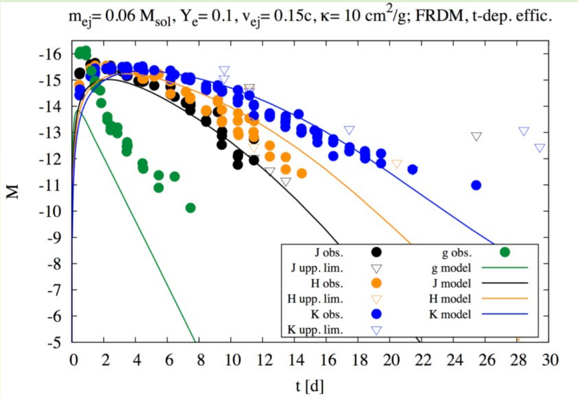




GW 170817

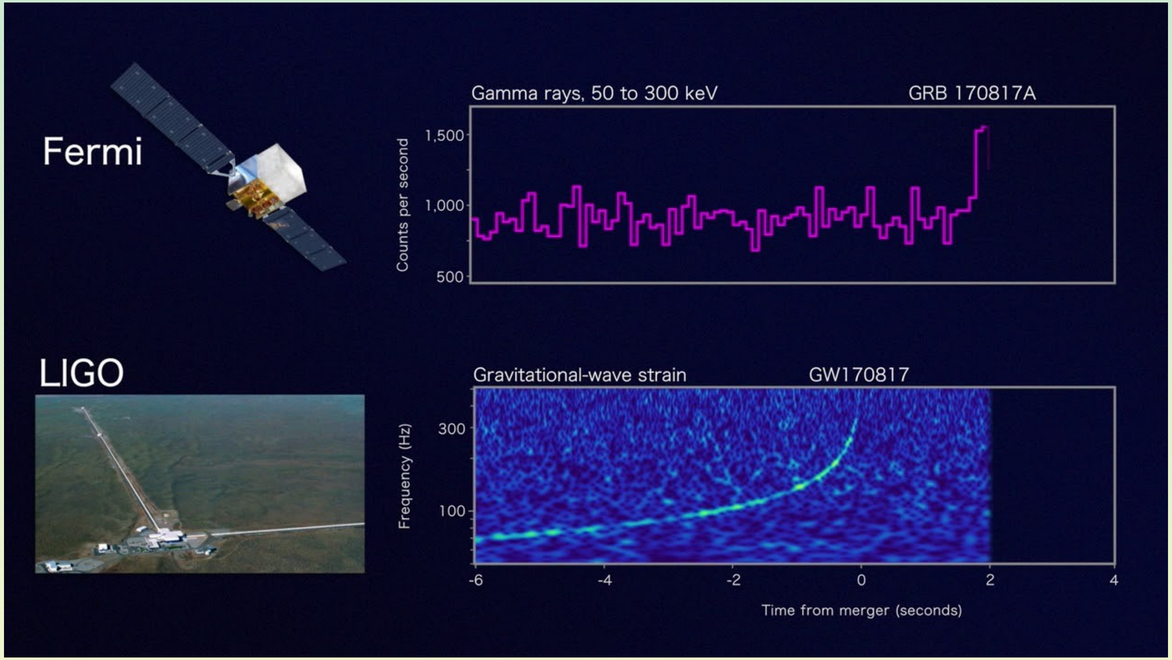


GRB 170817A



AT 2017gfo

Characteristics of GRB 170817A :
→ delay : 1.7s after GW170817
→ duration : 64ms
→ energy : ≈200 keV



The input :
→ list of subthreshold (not confirmed) GW candidates
→ from offline pipelines : ***PyCBC***, GstLAL
→ order of magnitude : ≈1000 triggers for O2

Offline analysis

Analysis of Fermi-GBM data:
→ the *targeted-search* (**arxiv :1806.02378**)
→ it takes as input a GPS time t_0
→ analysis of [t_0 - 30s, t_0 + 30s] GBM data
→ it generates GBM triggers
→ GBM trigger = (t_{GBM}, duration, spectrum, skymap, others)

Desirable conclusion :
→ conclude if there is any astrophysical association between a GW candidate and a GBM trigger

- for a pair (GW trigger, GBM trigger), we want to evaluate how likely is that :
  - the GW trigger is a real astrophysical signal
  - the GBM trigger is a real astrophysical signal
  - the GW signal and the GBM signal have a common astrophysical origin

(GW trigger, GBM trigger)

- t_{GW}
- SNR
- skymap ($\mathbf{\Omega}_{GW}$)

- t_{GBM}
- LLR
- skymap ($\mathbf{\Omega}_{GBM}$)

- solution : define a statistical quantity based on t_{GW}, t_{GBM}, SNR, LLR, $\mathbf{\Omega}_{GW}$, $\mathbf{\Omega}_{GBM}$

Bayes factor

$$\Lambda = \frac{P\left(D_L, D_G | H^C\right)}{P\left(D_L, D_G | H^{NN} \vee H^{SN} \vee H^{NS} \vee H^{SS}\right)}$$

- D_L : the LIGO data, i.e. **t_{GW}, SNR, Ω_{GW}**
- D_G : the GBM data, i.e. **t_{GBM}, LLR, Ω_{GBM}**
- H^C : the hypothesis of two astrophysical signals having the same origin
- H^{NN} : the hypothesis of two backgrounds / noises
- H^{NS} : the hypothesis of a GBM noise and a LIGO astrophysical signal
- H^{SN} : the hypothesis of a GBM astrophysical signal and a LIGO background
- H^{SS} : the hypothesis of two **non-related** astrophysical signals

$$\Lambda = \frac{P\left(D_L, D_G \middle| H^C\right)}{P\left(D_L, D_G \middle| H^{NN} \vee H^{SN} \vee H^{NS} \vee H^{SS}\right)}$$

under some assumptions (**arxiv : 1712.05392**)

$$\Lambda = \frac{I_{\Omega} I_{\Delta t}}{1 + Q_L + Q_G + Q_L Q_G}$$

New quantities :

- $I_{\boldsymbol{\Omega}} = \boldsymbol{\Omega}_{GW} \cap \boldsymbol{\Omega}_{GW}$, the skymap overlap
- $I_{\Delta t}$, the time offset term with $\Delta t = |t_{GW} - t_{GBM}|$
- $Q_L = P(SNR \mid H^N) / P(SNR \mid H^S)$, the LIGO Bayes factor
- $Q_G = P(LLR \mid H^N) / P(LLR \mid H^S)$, the GBM Bayes factor

- H^N : the hypothesis of a noise
- H^S : the hypothesis of an astrophysical signal

- let’s suppose we have two pairs ({t^1_{GW}, $\mathbf{\Omega}^1_{GW}$, SNR^1}, {t^1_{GBM}, $\mathbf{\Omega}^1_{GBM}$, LLR^1}), and ({t^2_{GW}, $\mathbf{\Omega}^2_{GW}$, SNR^2}, {t^2_{GBM}, $\mathbf{\Omega}^2_{GBM}$, LLR^2})
- for each pair we calculate the joint statistics, so we have Λ^1, Λ^2
- let’s suppose $\Lambda^1 = 12.5$ and $\Lambda^2 = 11.8$
- because $\Lambda^1 > \Lambda^2$, the first pair is more likely to be a true astrophysical association than the second pair
- the fact that $\Lambda^1 = 12.5$ doesn‘t tell us how much likely the first pair is to be a true astrophysical association

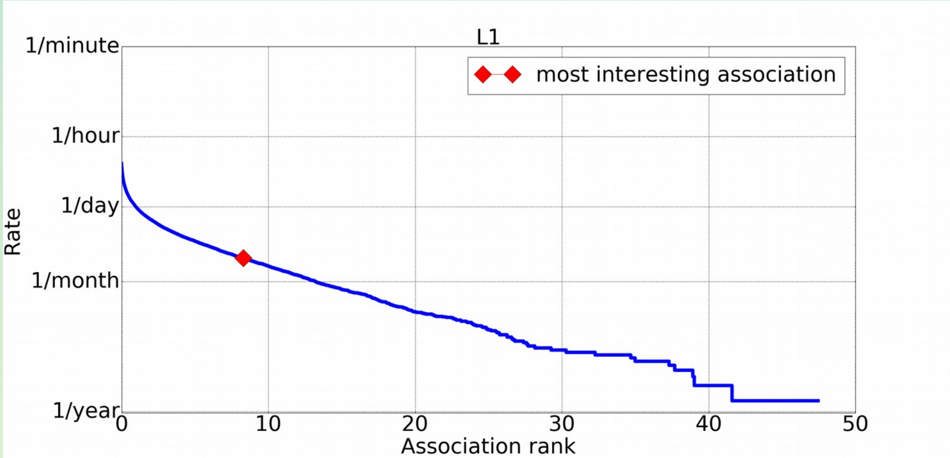
- Λ is a good quantity to compare pairs
- Λ is not a meaningful quantity

- we need to create virtual background pairs
- we proceed like in LIGO world

Convert Λ to FAR

- L_{GW} the list of O2 PyCBC GW trigger
- L_{GBM} the list of GBM triggers over O2
- we time shift by a sufficient amount of time L_{GW} with respect to L_{GBM}
- two new list $L^{new}{}_{GW}$ and L_{GBM}
- we calculate Λ for the new pairs, which is Λ of backgrounds
- we iterate this process lots of times

- we get a distribution of Λ for the backgrounds
- so we have a FAR distribution



- FAR distribution for the O2 follow up of single interferometer GW triggers
- **arxiv : 2001.01462**

- we can see from the distribution of the FAR that there is no hope to have a pair with a good false alarm rate
- one way to remedy this problem is to look for coincidences between BNS triggers only (not all type of CBC) and sGRB-like GRB signals only (not all GBM signals)

Conclusion

- we look for Fermi-GBM counterparts to offline PyCBC triggers
- statistical framework
    - joint statistic, Λ
    - false alarm rate, FAR
- we found no interesting association