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CATCHING THE NEXT WAVE

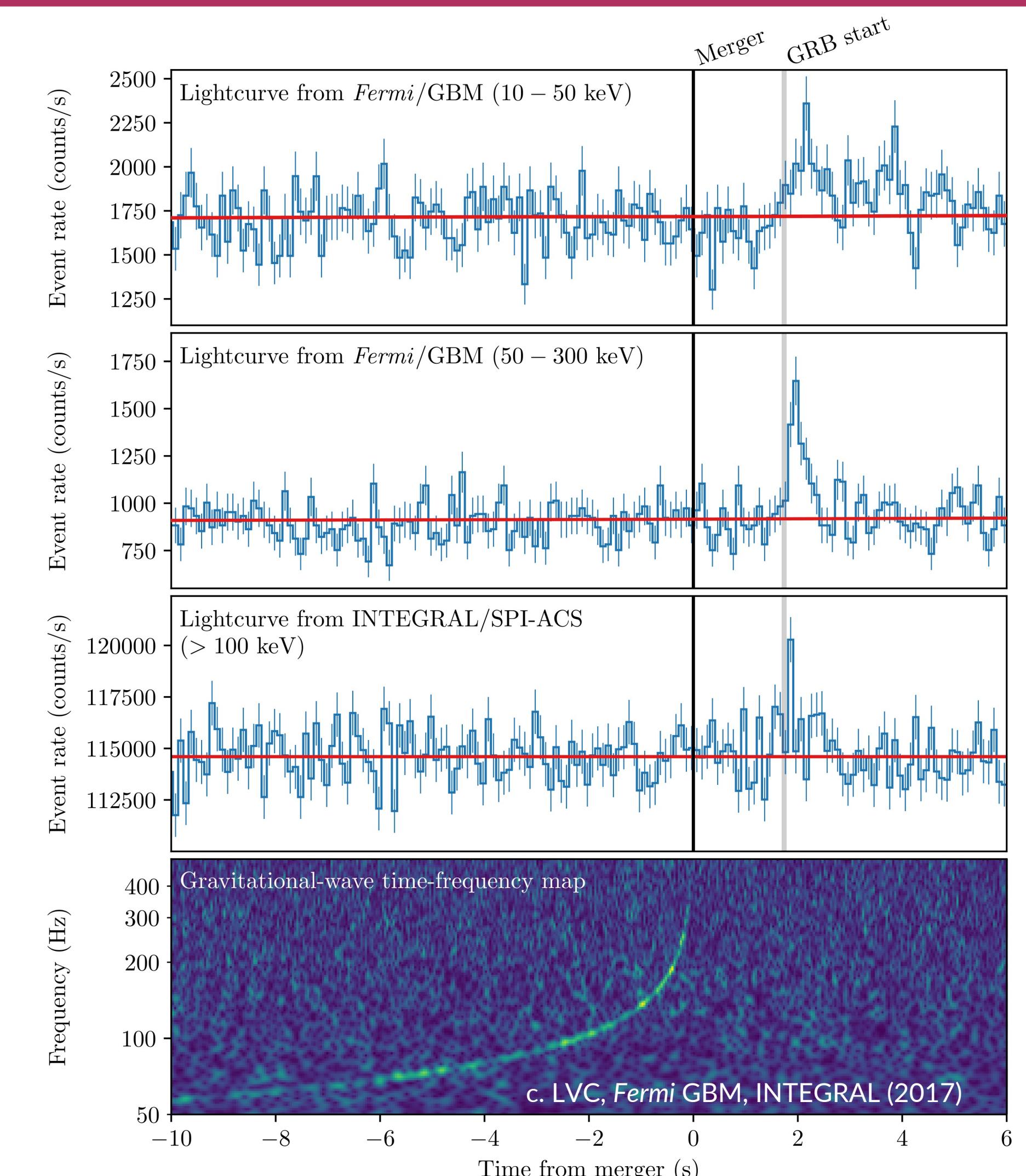
GWTC-3 follow-ups with GBM & BAT

MOTIVATION

- Since the coincident detection of gravitational waves (GWs) from a binary neutron-star (BNS) merger, (GW170817), and the corresponding short gamma-ray burst (GRB170817A), **detecting an analogous event has been a critical research topic in the multimessenger community**
- Recently, the Third Gravitational Wave Transient Catalog (GWTC-3) provided an 8-fold increase in the number of confirmed GW events

GOALS

- Identify potential electromagnetic (EM) counterparts to GW triggers in GWTC-3 using data from the *Fermi* Gamma-ray Burst Monitor (GBM) and the *Swift* Burst Alert Telescope (BAT)
- Constrain theoretical models for γ -ray emission from GW events



γ -ray searches with *Fermi* GBM

Why Fermi GBM?
 + ~full-sky field of view
 + energy coverage spanning the peak of GRB emission

γ -ray searches

- Using Fermi GBM triggers and two sub-threshold searches;
 - Targeted: scans -1 to 30 sec around a trigger time
 - Untargeted: a blind search of GBM data
- Determine if there is any excess γ -ray excess emission coincident with GWTC-3 events

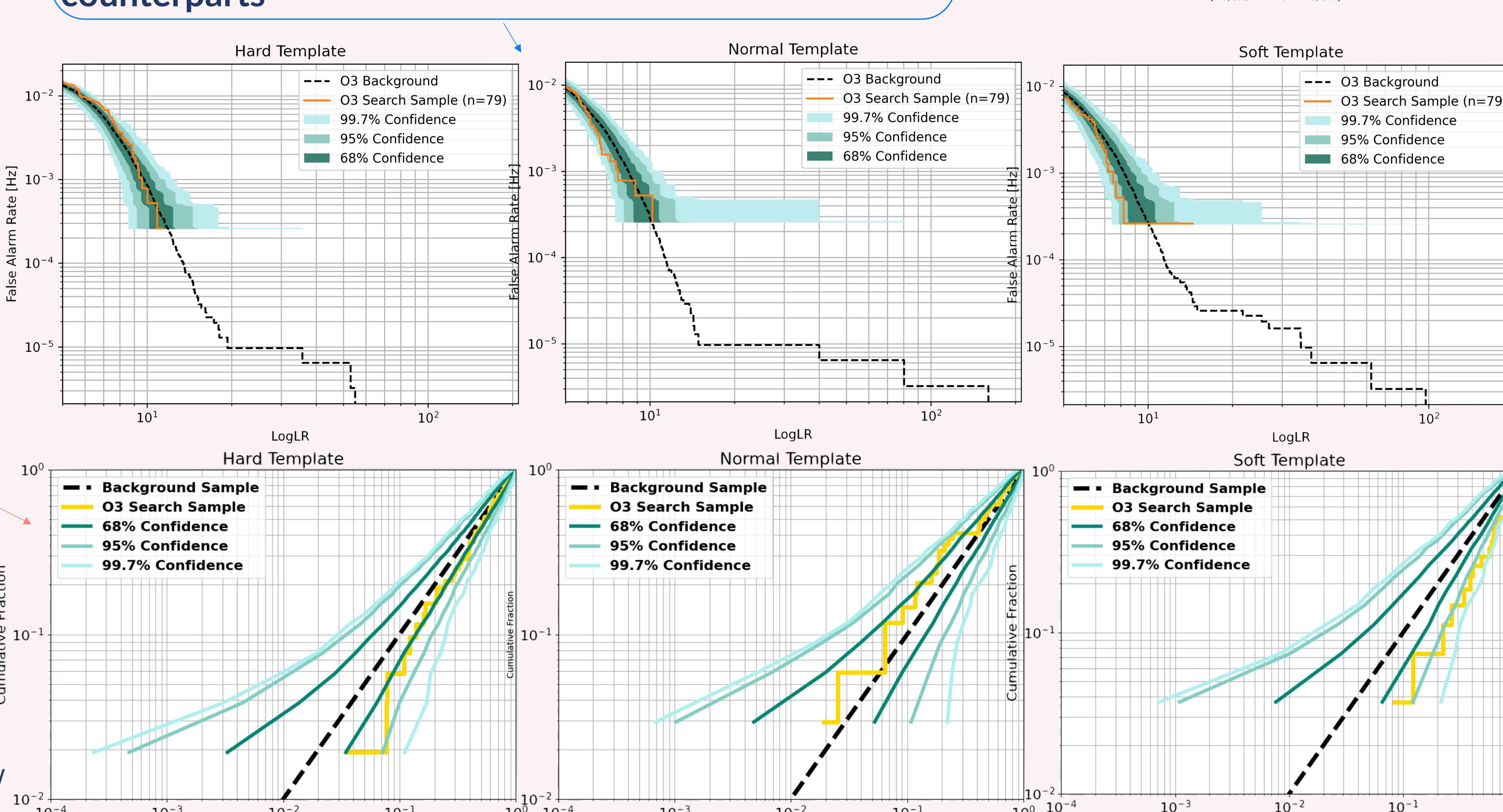
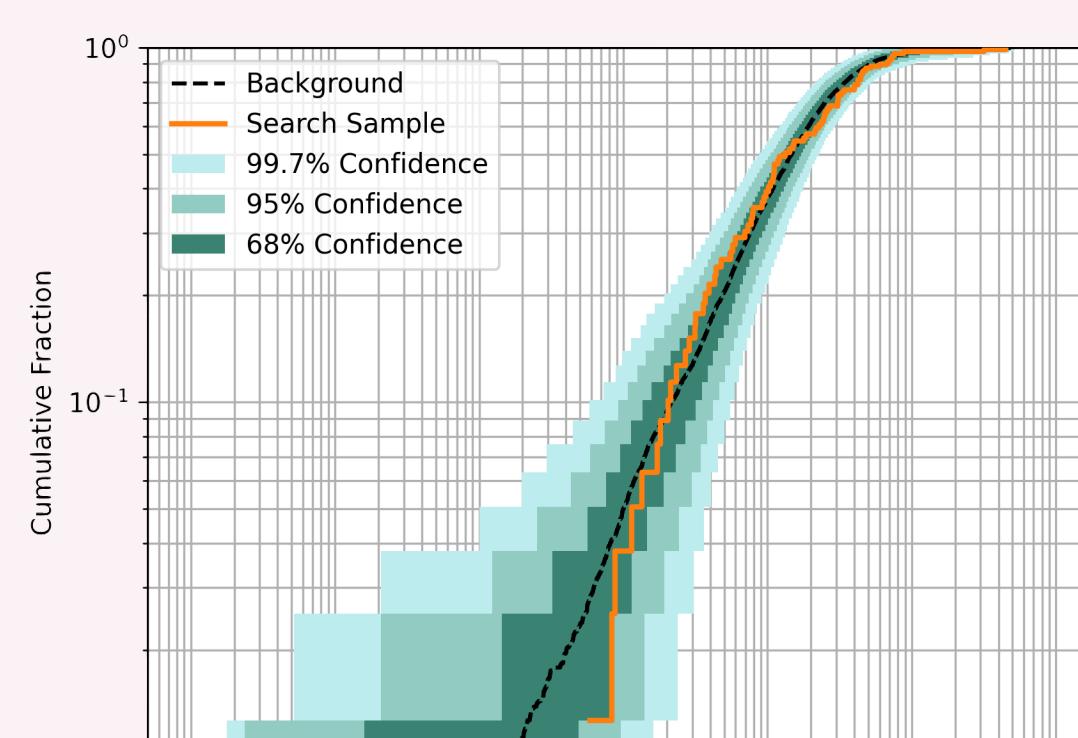
ranking statistic (R)

- R is mapped to a p-value and compared to the cumulative fraction
 → no statistically significant counterparts

$$R = \frac{p_{\text{astro}} \times p_{\text{vis}} \times p_{\text{assoc}}}{|\Delta t - D| \times \text{FAR}_{\text{GBM}}}$$

Equation: the probability the GW event is astronomical (p_{astro}), visible by GBM (p_{vis}), and that GW and GBM event are spatially associated (p_{assoc}), the GW-GBM time offset (Δt), GBM event duration (D), and the GBM False Alarm Rate (FAR_{GBM})

- comparing the time offset from the GBM triggered and untargeted search events and the GW events → no statistically significant counterparts
- ↓ comparing the events found with the GBM targeted search around the GW event times with three spectral templates → no statistically significant counterparts



Equation: the probability the GW event is astronomical (p_{astro}), visible by GBM (p_{vis}), and that GW and GBM event are spatially associated (p_{assoc}), the GW-GBM time offset (Δt), GBM event duration (D), and the GBM False Alarm Rate (FAR_{GBM})

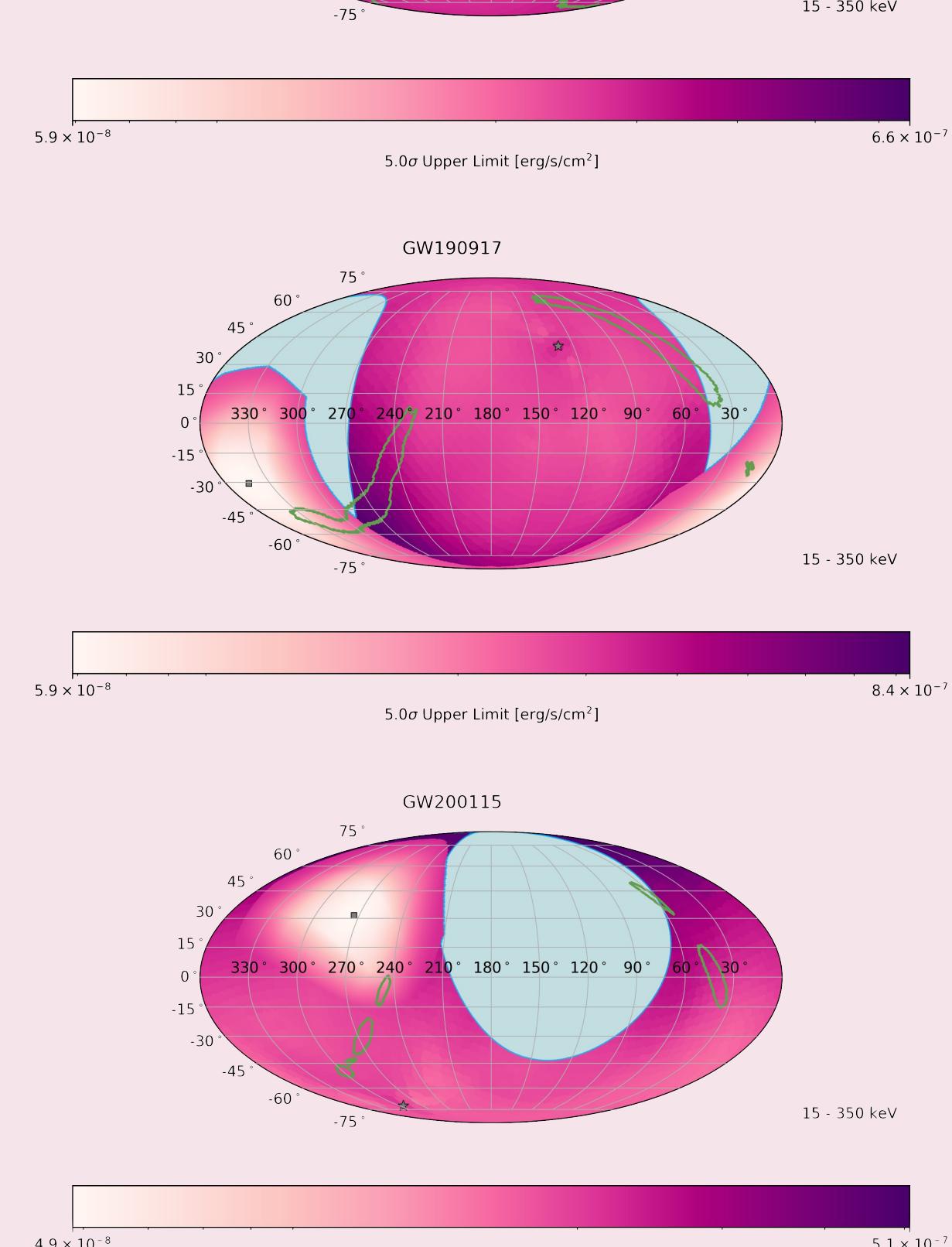
Joint upper-limit skymaps

E.g.: GW190425, GW190918, and GW200115

- all have a chirp mass below $4.0 M_{\odot}$
- at least one NS

Legend:

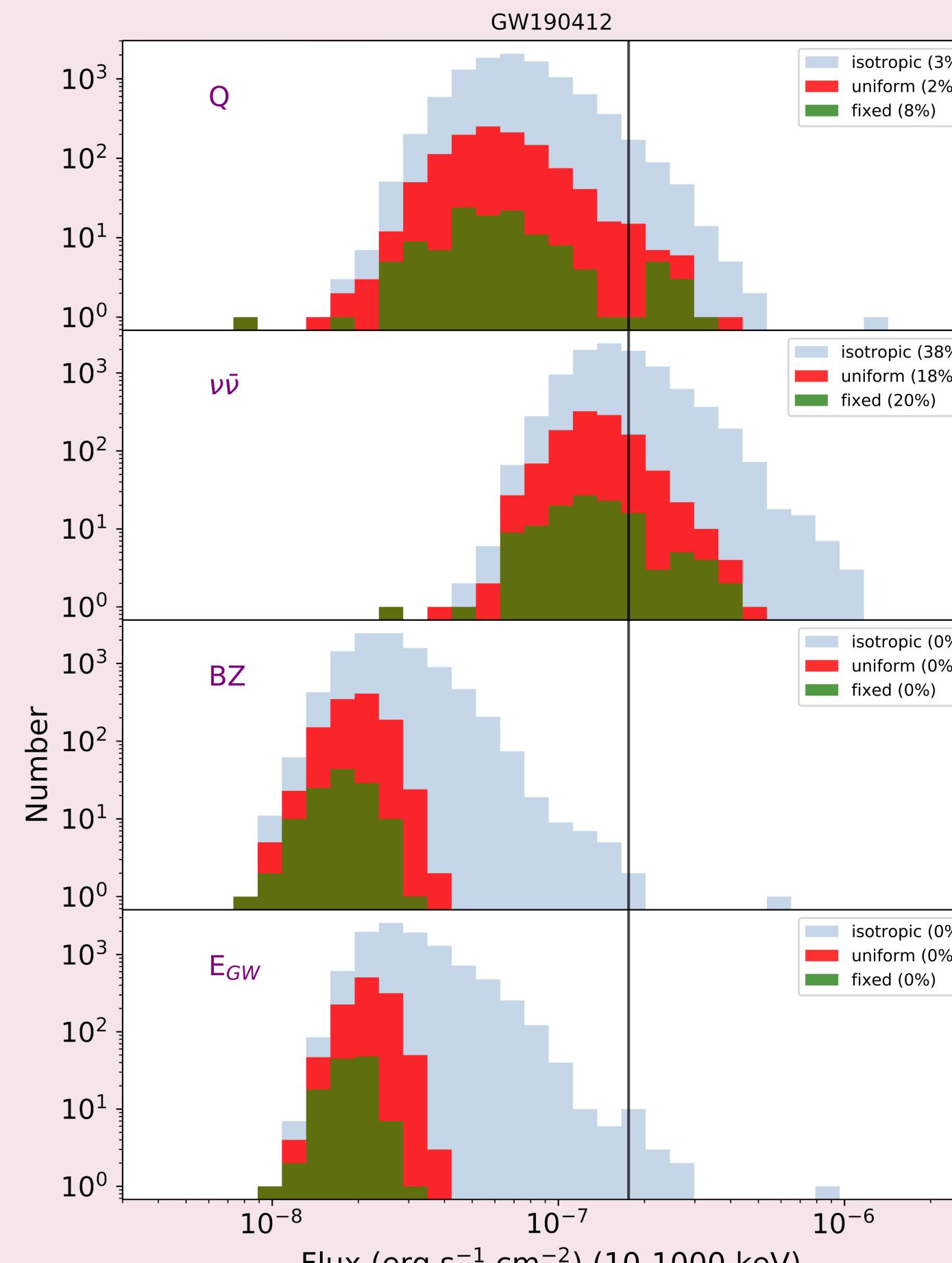
- Purple gradient: 5 σ flux upper limits for GBM and BAT, determined using Band function with $E_{\text{peak}} = 230$ keV, $\alpha = -1.0$, $\beta = -2.3$ and an energy range of 15 - 350 keV assuming a 0.5-s duration
- is the center of BAT FoV
- Green contour: 90% confidence interval of the GW localization
- Blue circle: region occulted by the Earth
- ★ is the zenith of GBM



Joint flux upper limit skymaps for three GWTC-3 events

BBH modeling

EM radiation from binary-black-hole mergers?



- Assuming association between BBH GW150914 & GW150914-GBM, we can use the BBH parameters to derive a distribution of γ -ray fluxes to compare with the GBM 3- σ flux upper limits (10 - 1000 keV)
- Four different models shown; vertical line represents the 3- σ flux upper limit, with the fraction of cases above that limit shown in the legend

Conclusions

- Using Fermi GBM triggers and sub-threshold searches, and Swift BAT's data to search for coincident γ -ray emission with the GWTC-3 events, we found no statistically significant EM counterparts
- We calculated the flux upper limits for both GBM and BAT and present joint upper-limit skymaps
- Comparing the upper limits expectations from various BBH merger theoretical models we find that we can likely rule out the neutrino model for producing EM emission

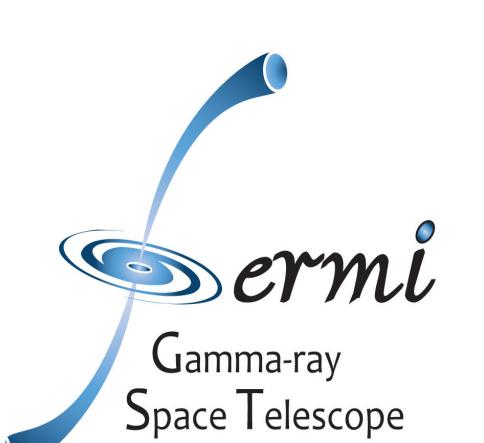
Stay tuned for the paper [Fletcher et al. 2022]! (<month!)

References

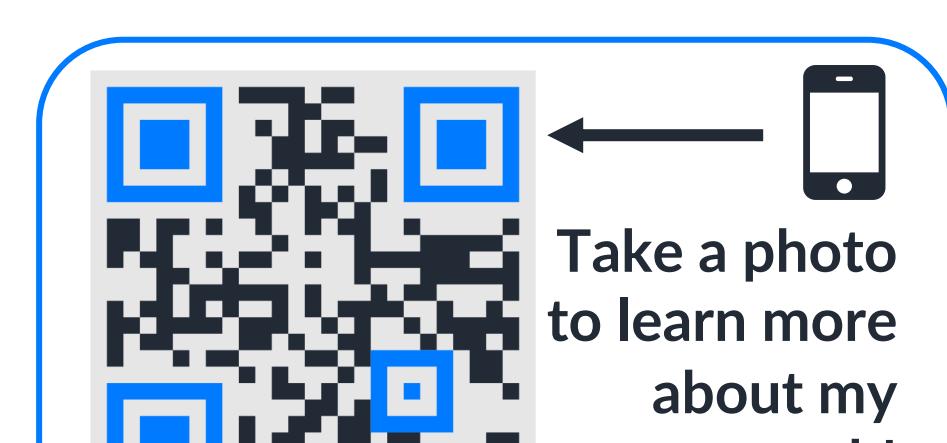
- [1] Meegan et al. 2009;
- [2] Goldstein et al. 2019 ;
- [3] Barthelmy et al. 2005;
- [4] DeLaunay & Tohuvavohu 2021;
- [5] Connaughton 2016.

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