The MBTA pipeline for the 4th observing run of the gravitational waves detector network

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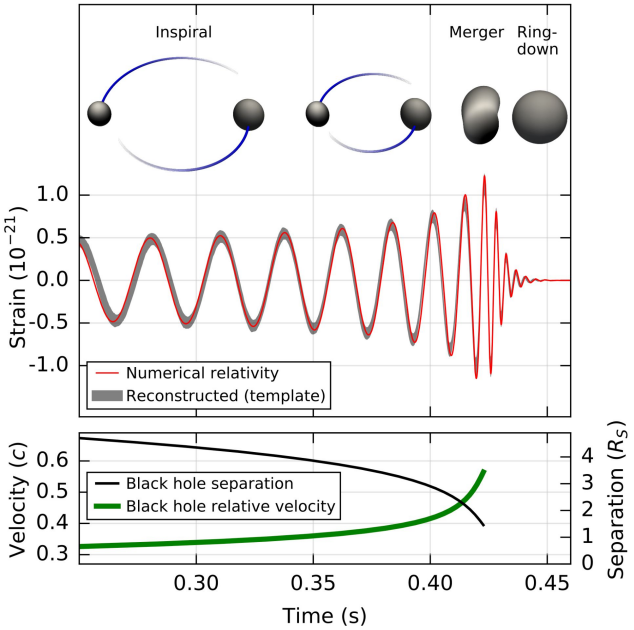
Gravitational waves from compact binary mergers

Two compact object rotating around each other
→ eventually collide

Compact Binary Coalescence (**CBC**):
- Binary Neutron Star (**BNS**)
- Binary Black Hole (**BBH**)
- Neutron Star + Black Hole (**NSBH**)
- others ?



MBTA pipeline: searching for CBC

CBC search pipeline

Uses matched filtering:

→ generate bank of waveforms (templates)

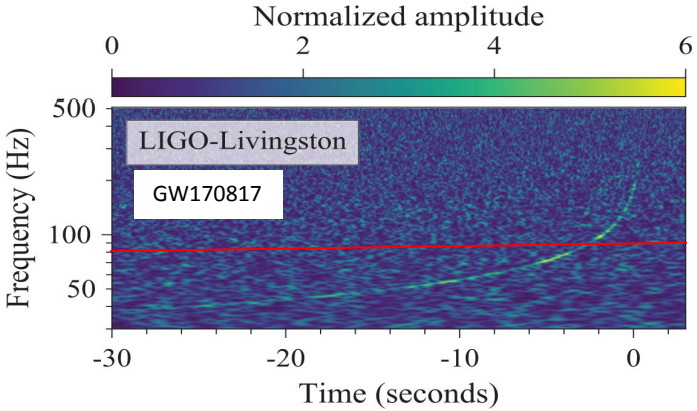
→ compute correlation of data with templates

MBTA = Multi-Band Template Analysis

Matched filtering in 2 frequency bands

→ [24,80]Hz and [80,2048]Hz

→ computationally efficient



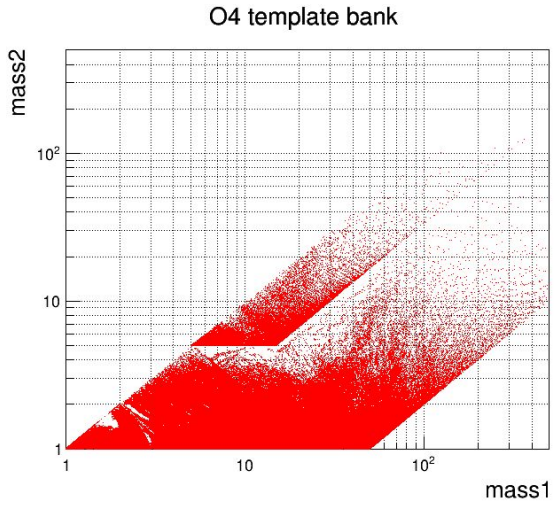
MBTA main search: BNS, BBH, NSBH

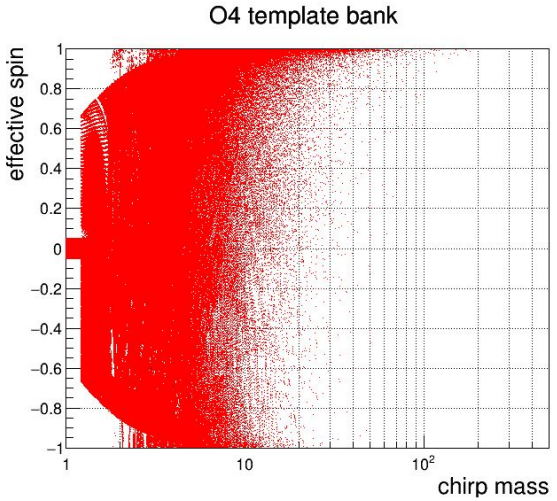
Primarily searches for **HL coincidences**

New template bank for O4, masses : [1, 500] $M_{\odot}$

higher template density for BNS and BBH

New for O4: single detector triggers alerts





New early warning search for O4

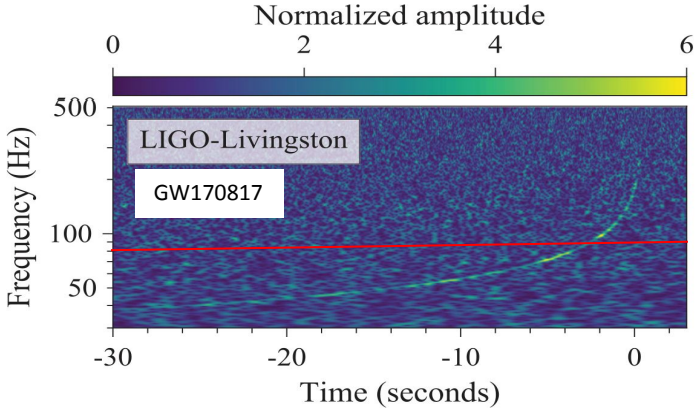
Early warning search

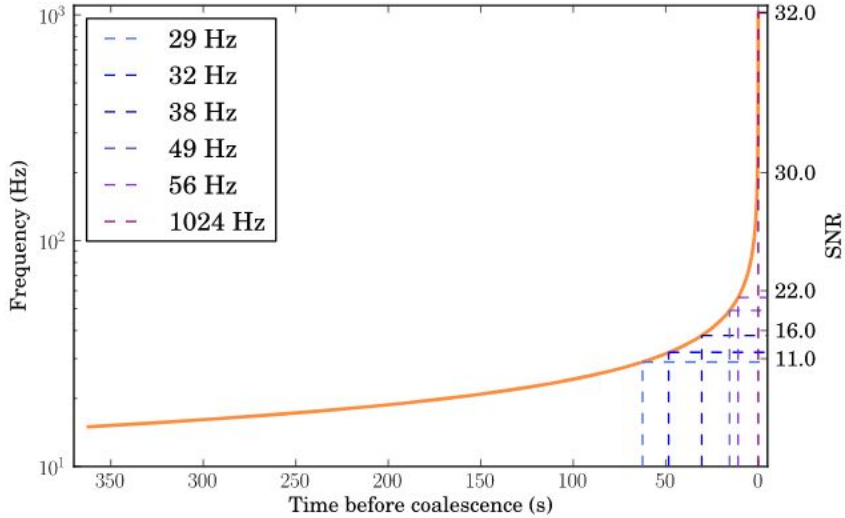
→ identify loud **BNS before merger**

Multiple cutoff frequencies

→ 34Hz, 42Hz, 50Hz, 58Hz

masses: [1, 2.5] $M_{\odot}$, spins<0.05





New sub-solar mass search for O4

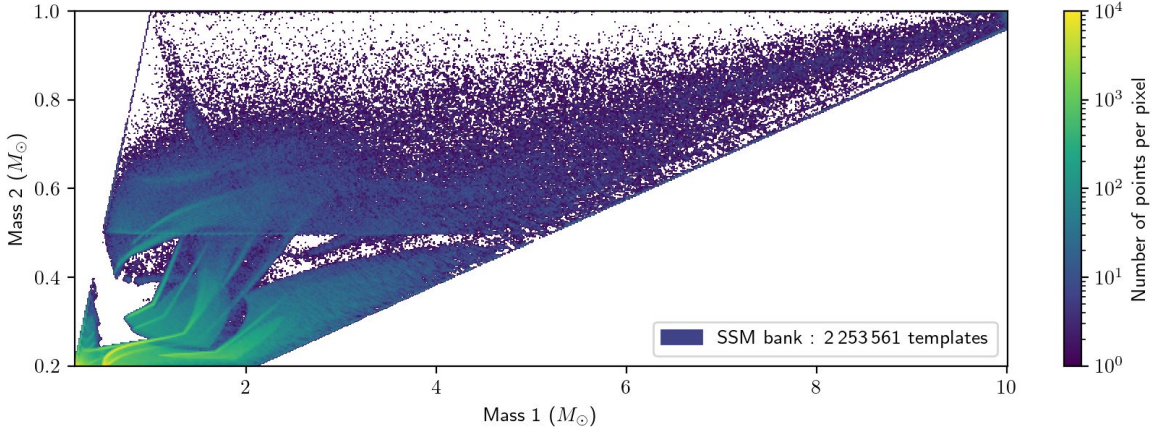
Sub-Solar Mass (SSM) search

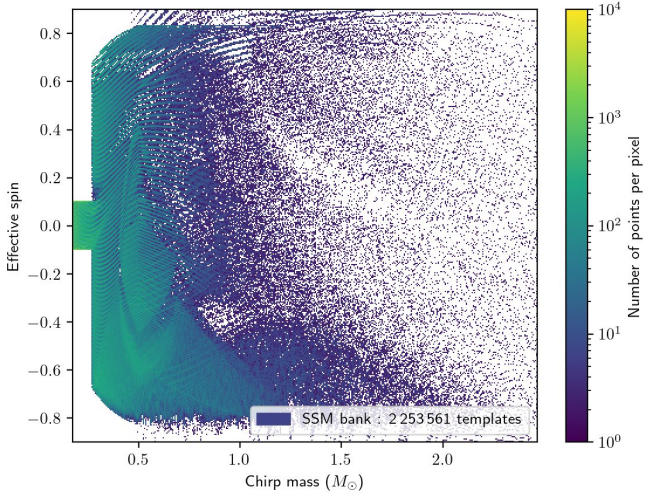
→ search for CBC with at least one component below $1M_{\odot}$

→ developed and ran on O3 offline

→ Run online for O4

→ waiting for green light to send alerts





Probability of astrophysical origin and source classification

New for O4: pipeline specific information
- developed for O3 catalogs

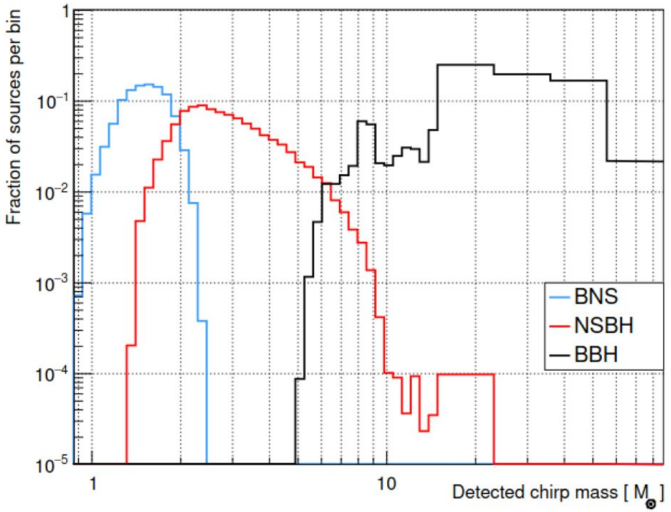
help astronomer in their choice of events

$$p_{\mathrm{astro}} = \frac{\text{astrophysical rate}}{\text{astrophysical rate} + \text{background rate}}$$

astrophysical rate = BNS + BBH + NSBH rate

$$p_{\mathrm{BNS}} + p_{\mathrm{BBH}} + p_{\mathrm{NSBH}} = p_{\mathrm{astro}}$$

Depends on regions of the parameter space
→ divide it in bins of chirp mass and mass ratio
→ each bin has its own foreground and background
→ uses O3 observation



Astrophysical properties

probability of having at least 1 neutron star: $\mathrm{hasNS} = \frac{p_{\mathrm{BNS}} + p_{\mathrm{NSBH}}}{p_{\mathrm{astro}}}$

probability of remaining mass after merger: $\mathrm{hasRemnant} = \frac{p_{\mathrm{BNS}} + p_{\mathrm{NSBH\text{-}bright}}}{p_{\mathrm{astro}}}$

→ relies on parametrization of remnant mass from Foucart et al.

→ bright NSBH if remnant mass > 1.e-3

False alarm rate

new false alarm rate (FAR) computation for O4

During O3: FAR doesn't account for astro. populations and rates
→ gave the same weight to different regions of parameter space

For O4: include the knowledge of rates and populations in FAR computation

→ **FAR(pAstro)**

→ for given pAstro, FAR = expected rate of background event with higher pAstro

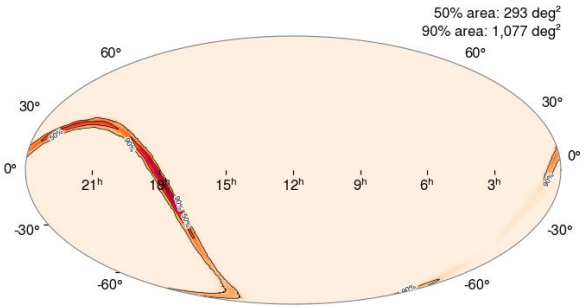
→ ensures more consistency between FAR and pAstro

Conclusion

MBTA is currently running on O4 data

- new template bank
- new searches
- proba of astro origin + source classification
- new FAR(pAstro)

O4: 5 MBTA significant alerts out of 6
2 as preferred event



S230605o: uploaded by MBTA
FAR = 1 per 7.0 years
pBBH > 99%