~~PhD Day~~ RJP

DETECTING SKIBIDI BLACK HOLES

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Under the supervision of
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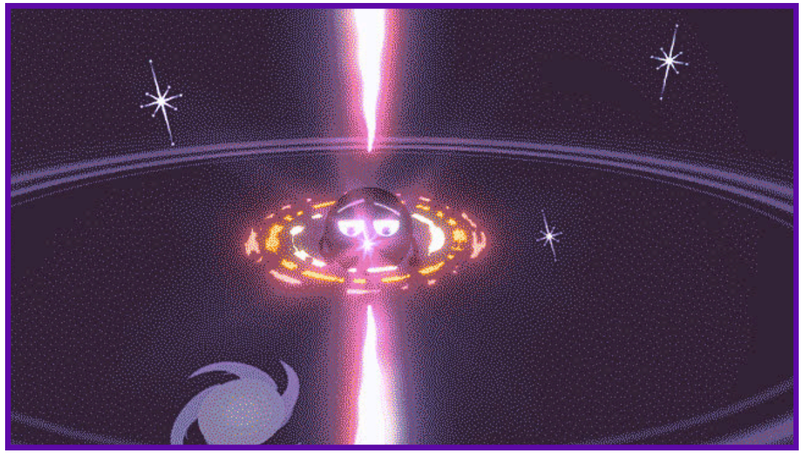
Outline

1. Intro
2. Multimessenger astronomy
3. SSM studies

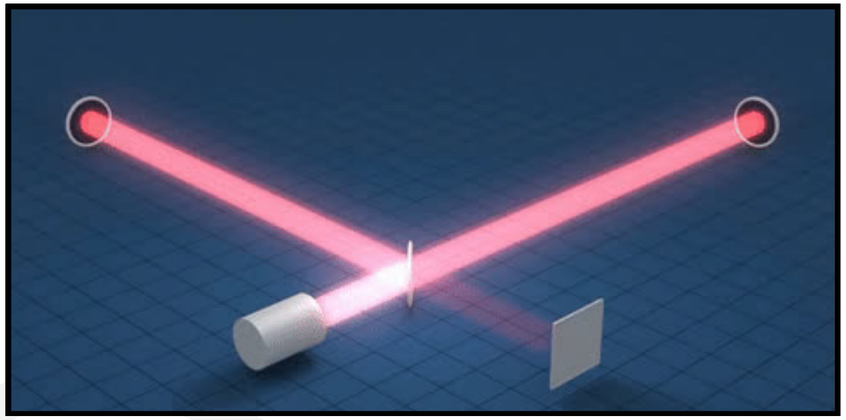
From the presentation before



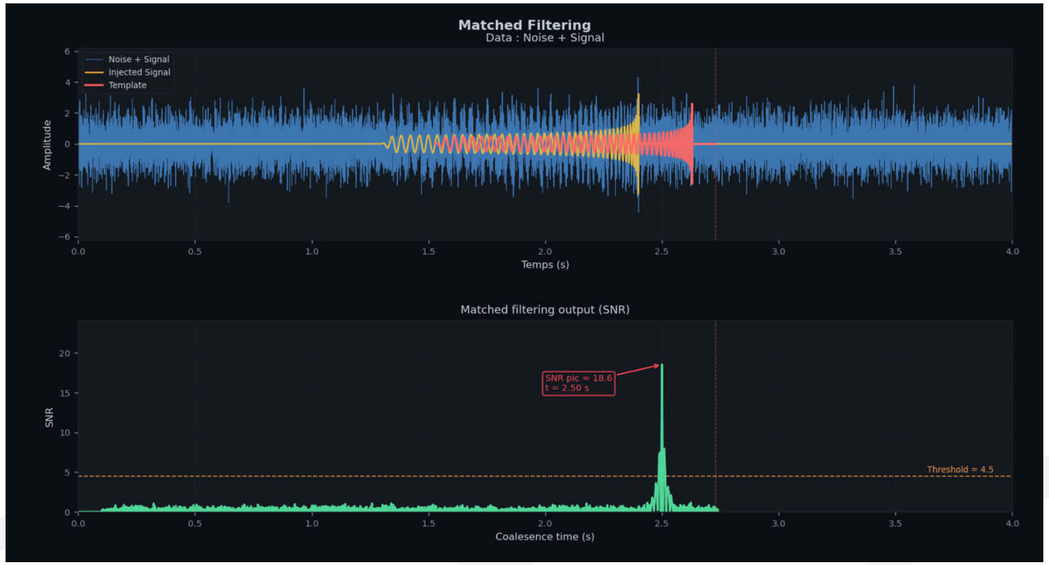
Nice gif of a BNS merger

Gravitational waves

- Predicted by Einstein in 1916
- Most powerful generated by compact accelerating objects :
  - Neutrons stars merger
  - Black Holes merger
  - Yours mom moving
- Detected using big ass interferometers (Giga chad of measurement)
- Extract from noise using matched filtering



Nice gif of an interferometer principle



All-sky and SSM search

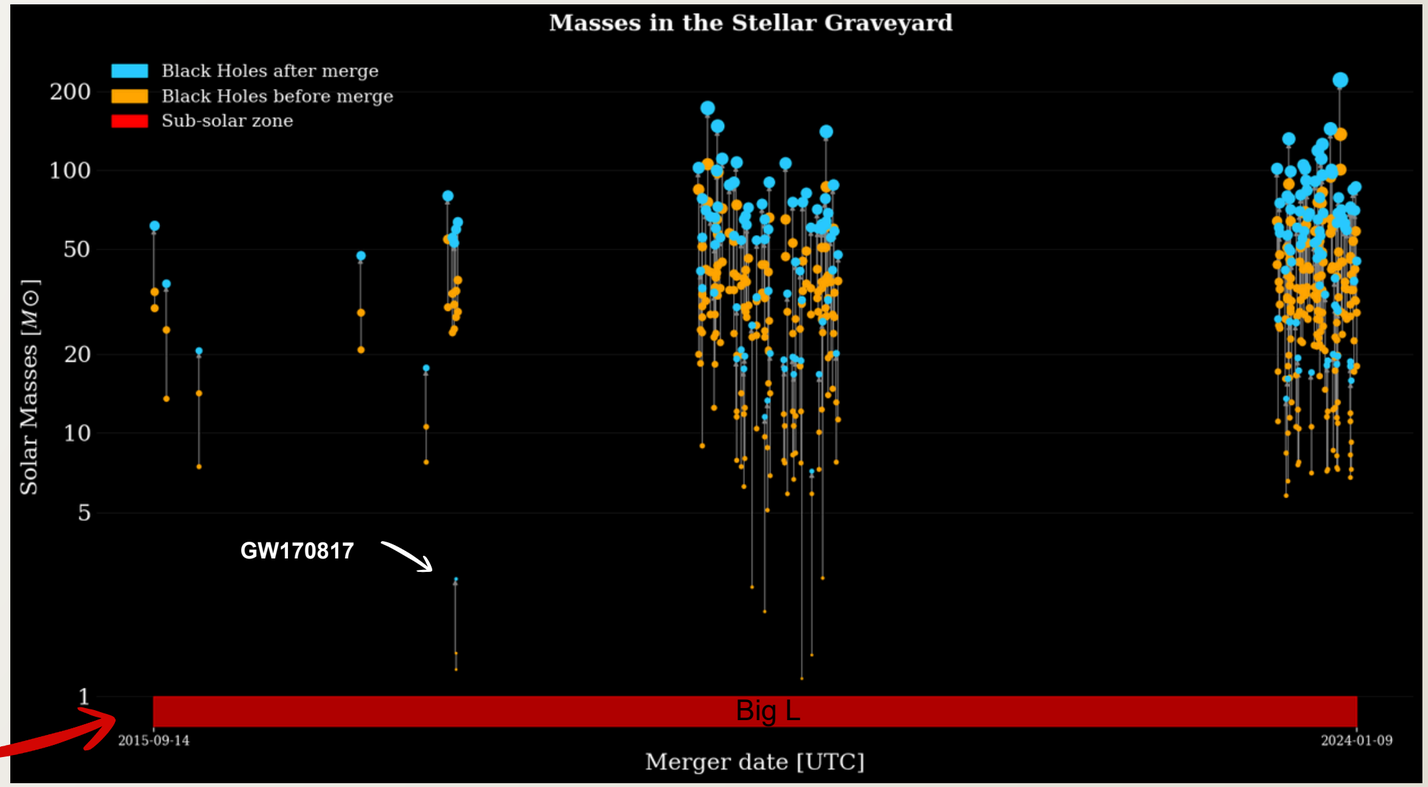
- 2 types of search : All-sky and sub-solar mass black holes (SSM)

Primordial black holes (PBH) are candidates to part of the dark matter

- Indicate formation mechanism alternative to usual stellar evolution
- PBH cover a larger mass range but SSM detection would be unambiguous

SSM : At least one object is bellow 1 M⊙, no detection yet :(

WWIII and GTAVI before ssm detection ?



GWTC-4.0 catalog of detected merger

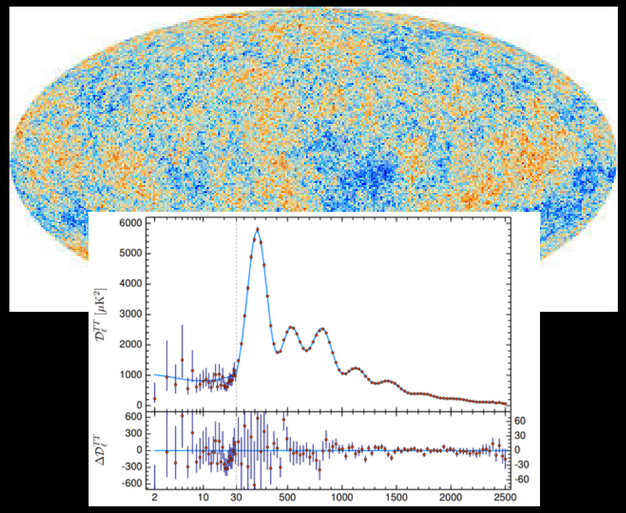
But what do we do with it ?

Multimessenger astronomy

Hubble tension

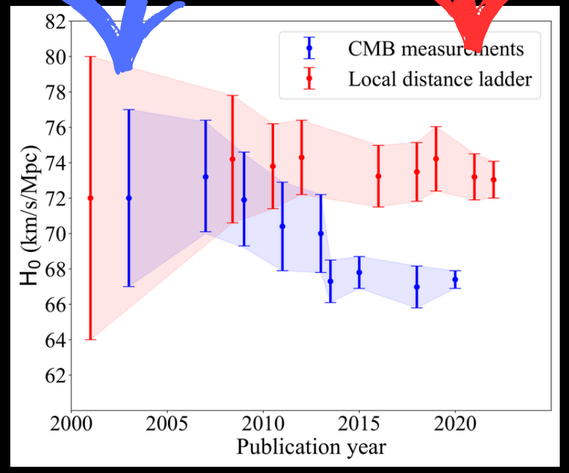
Hubble constant : Mesure the rate at witch the universe expend, high key important

Value using the cosmic microwave background (CMB)

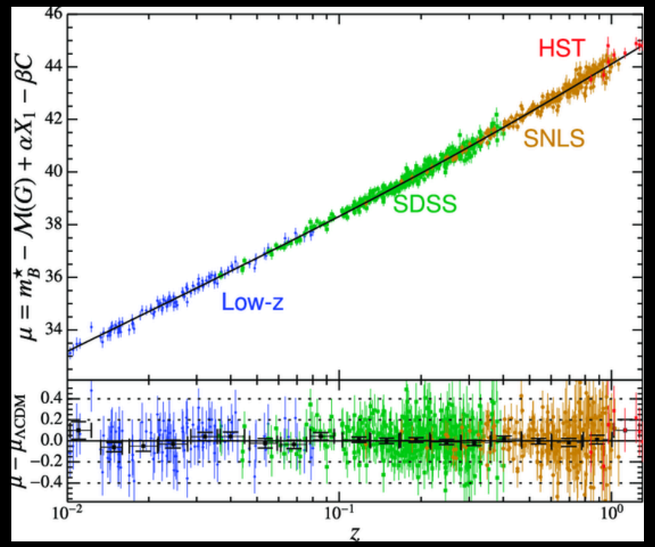


H0 = 67.4 ± 0.5 km·s-1·Mpc-1

*assume a cosmological model



Value using supernovae

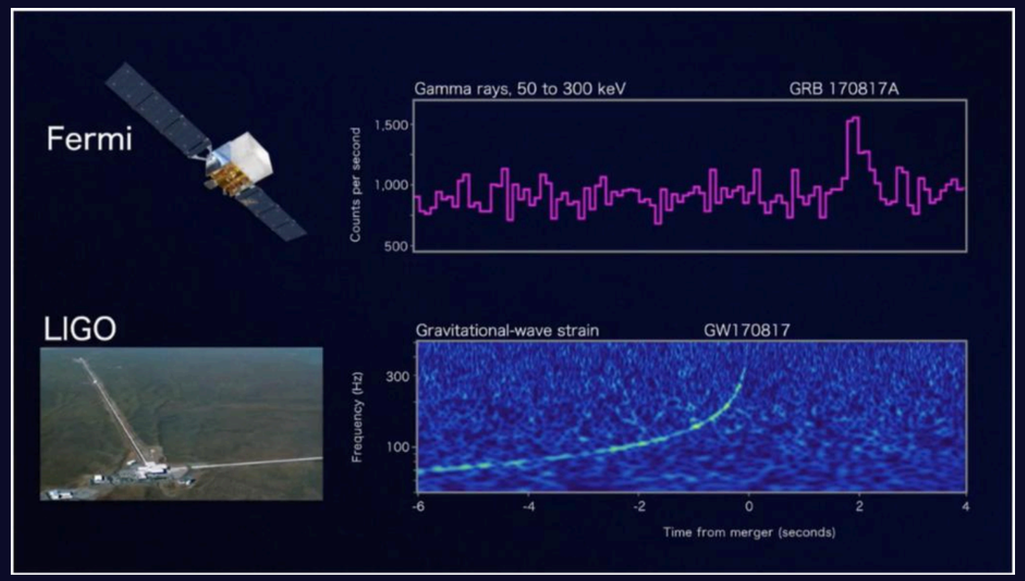


H0 = 73.04 ± 1.04 km·s-1·Mpc-1

Multimessenger astronomy with GW170817

- Electromagnetic counterpart: kilonova + short GRB
- Redshift (z) obtained from host galaxy spectroscopy

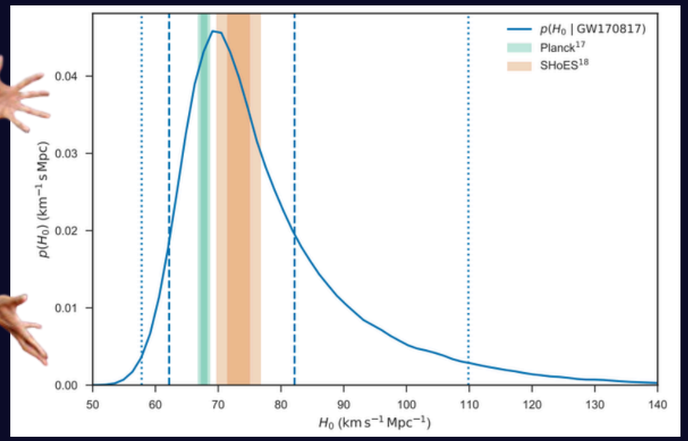
- First binary neutron star merger detected in gravitational waves
- Gravitational waves provide the luminosity distance (dl) directly

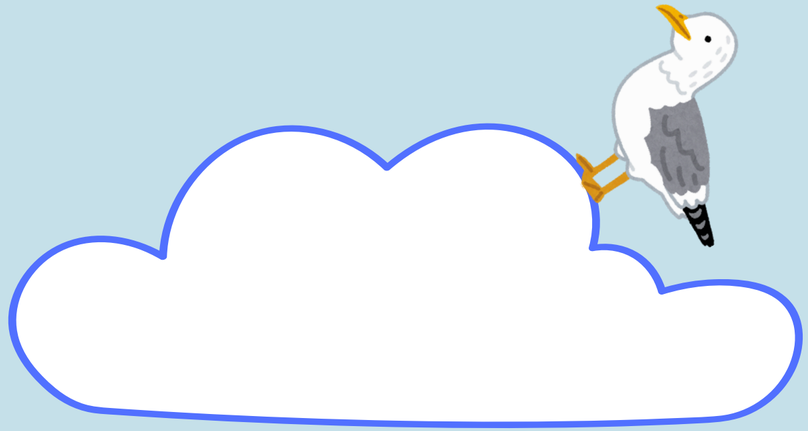


- Combine dl (GW) + z (EM) ⇒ estimate of Hubble constant

$$H_0 = 70^{+12}_{-8} km \cdot s^{-1} \cdot Mpc^{-1}$$

- Single event → large statistical uncertainty but in 20-30 years...





Sub-solar study

SSM search

No detection, is it even working ?

Me waiting for a SSM event

Search Sensitivity

How much volume of the Universe is effectively probed ⟶ Hyperspace volume <VT>

How to quantifies the <VT> :

- We take the maximum distance we can reach with our detectors
- We generate theorical signal using population models inside the associated volume
- We inject these simulated signals into the data strain
- We look at how many signal we recover

The sensitive hyper-volume or <VT> quantifies the sensitivity of a detector over a given observation period

$$\langle VT \rangle = V_c \frac{N_{rec}}{N_{inj}} \cdot T$$

Number of recovered injections

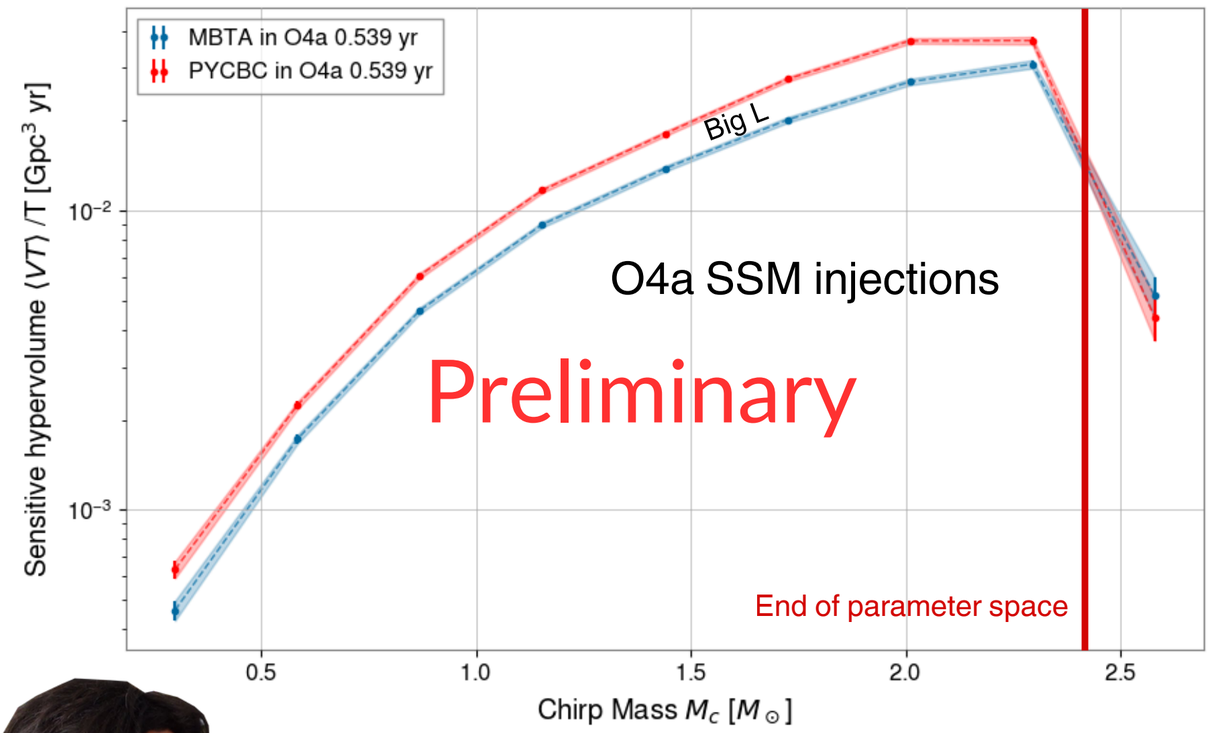
Total observation time

Astrophysical covolume

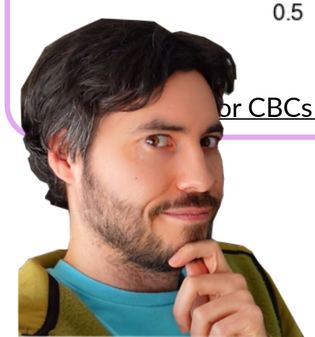
Total number of injections

SSM MBTA efficiency problem

Results from the O4a SSM publication



or CBCs with SSM Components in Data from The First Part of LVK Fourth Observing Run



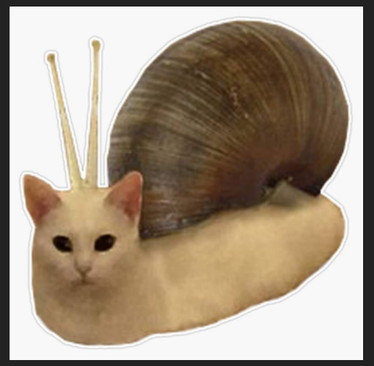
SSM MBTA efficiency problem

- MBTA is less sensitive on injections wrt PyCBC and GstLAL
- From the previous VT formula, every values are the same except for the number of detection.
- We tried to have a better signal reconstruction to increase MBTA sensitivity
- Looking at various hypothesis
- The theorical model (approximant) use to generate our bank
- The frequency bands
-

Algorithm acceleration and tests

My work basically

Tests are very slow



Me

Tests are fast

We do a lot of tests

Configuration chosen for o4b

- Change in approximant for Mtot > 4

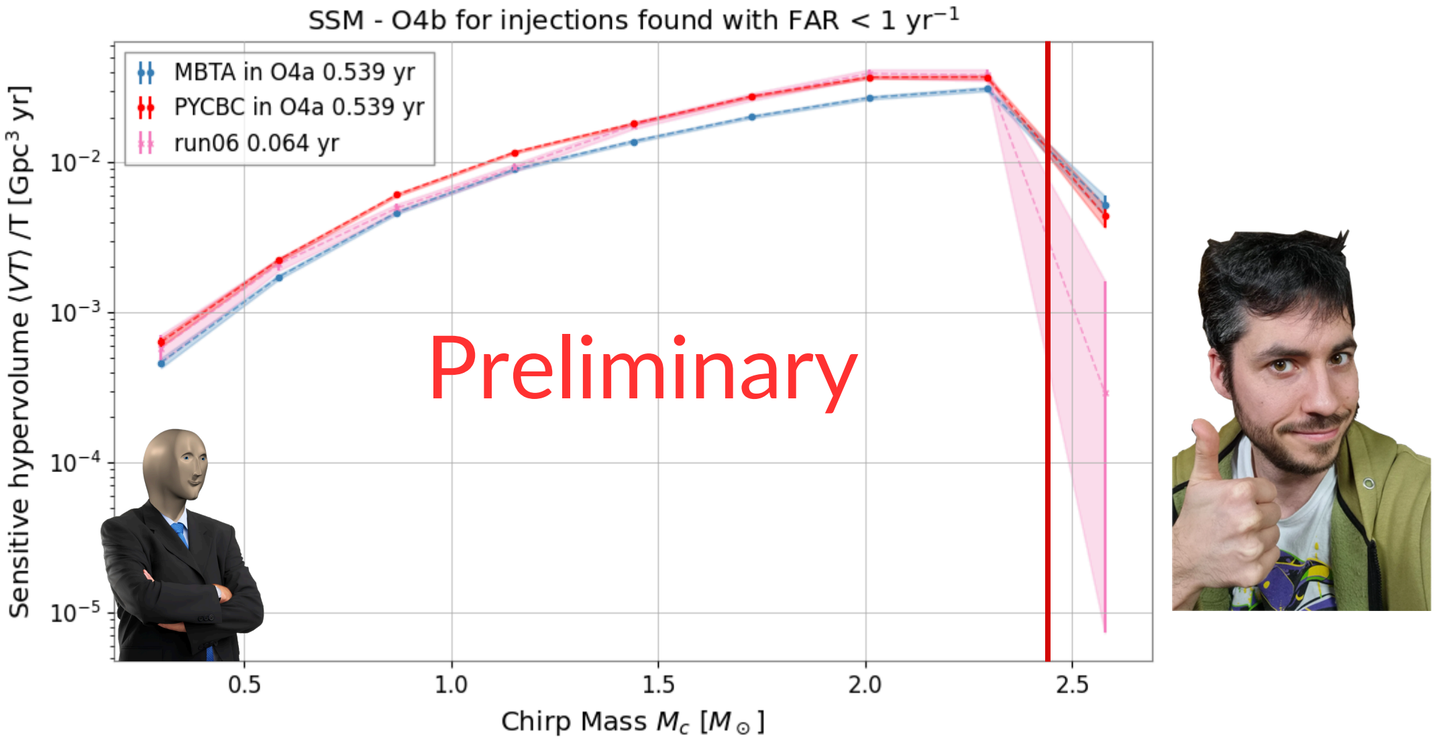
- VT bank generated from 45Hz to 1024Hz

- RTs banks generated from 35Hz to 1024Hz with a cut at 105Hz

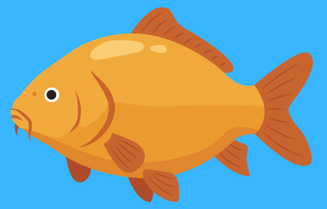
- But we filter from 35Hz to 512Hz

→ Performances similar to PyCBC's

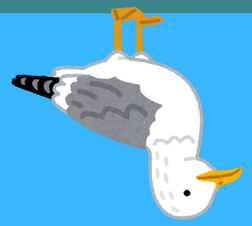
End of parameter space



Volume Time (VT) for BBH for various configurations



Conclusion



hank Yo

y questio

Sensitive Hyper-Volume

The sensitive hyper-volume or <VT> quantifies the sensitivity of a detector over a given observation period
→ How much volume of the Universe is effectively probed.

- How to quantifies the <VT>
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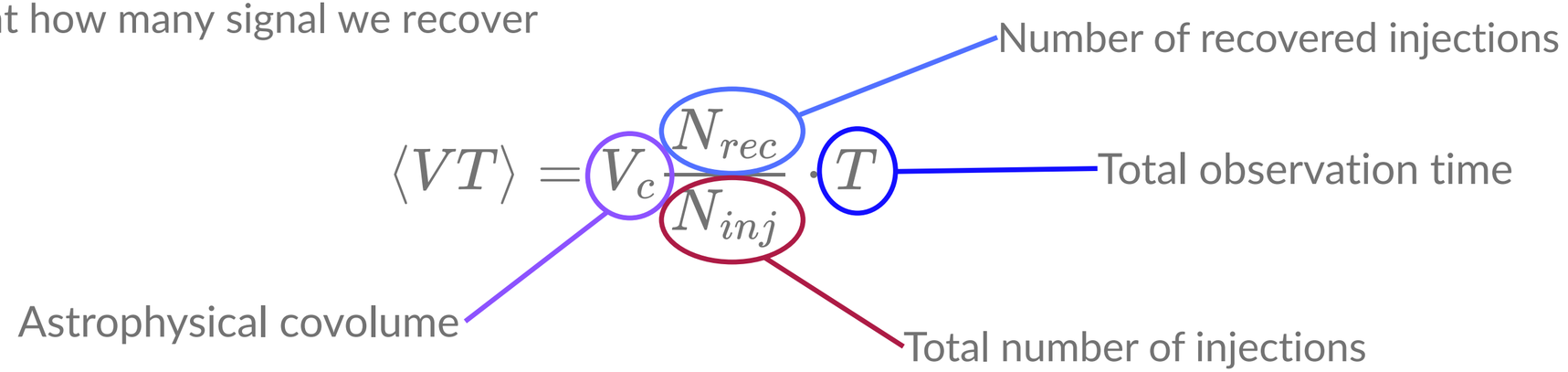


Banks verification

This algorithm can also be used to generate banks

New method to generate RT banks directly from the VT bank :

- Take a point in the VT bank
- Do the match between the template and all the presected ones
- All templates with a matching above threshold is deleted

Advantages :

→ Can work in N bands

→ The matching file is done by construction

Disadvantages :

→ Over estimate the number of template needed

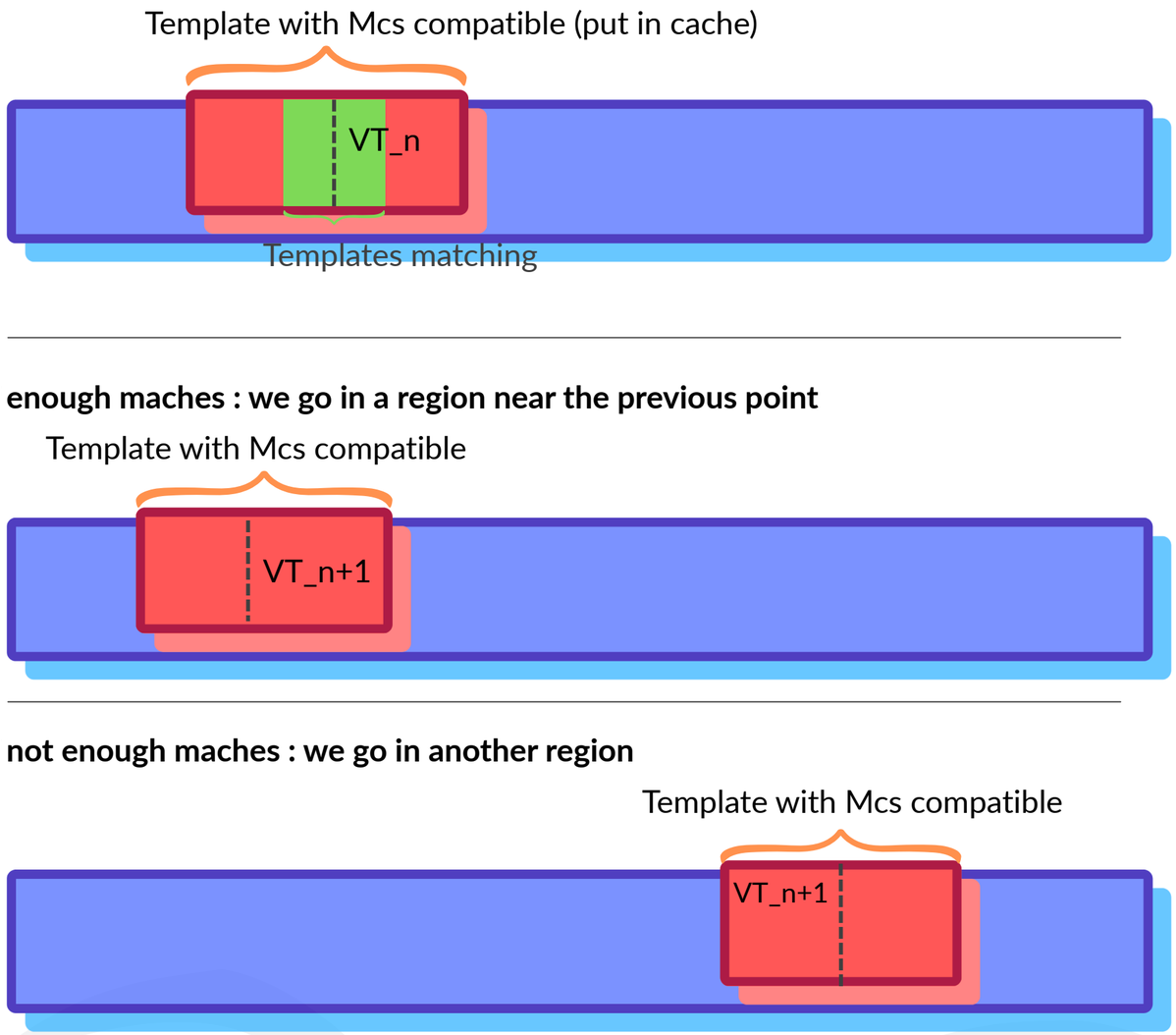


Diagram of the algorithm principle

Algorithm principle

Producing and testing new template banks is computationaly heavy, we developed tools to speed up those stages

Rely on 2 ideas :

- The vectorization of the computation
- The preselection of templates candidates

This algorithm can be used to test banks coverage/miminal match (and determine matching file)
When comparing our algorithm with the reference algorithm on 9000 injections on a ~850000 templates bank :
Banksim ~30 Hours, our algorithm ~1.5 Hours
And consistent results

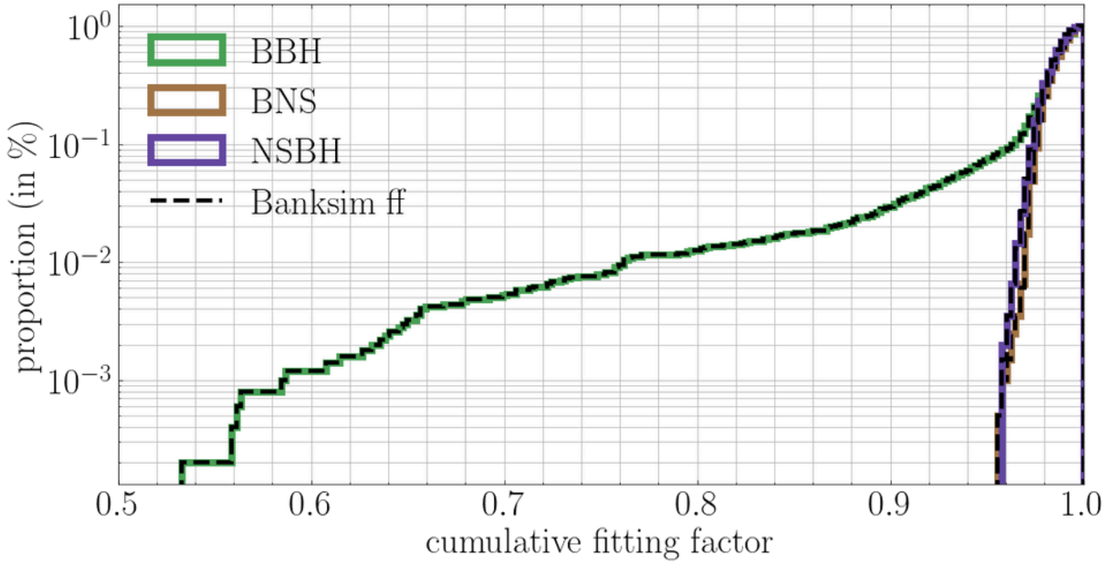


Figure 4. Comparison between our algorithm and Banksim algorithm.

SSM banks generation

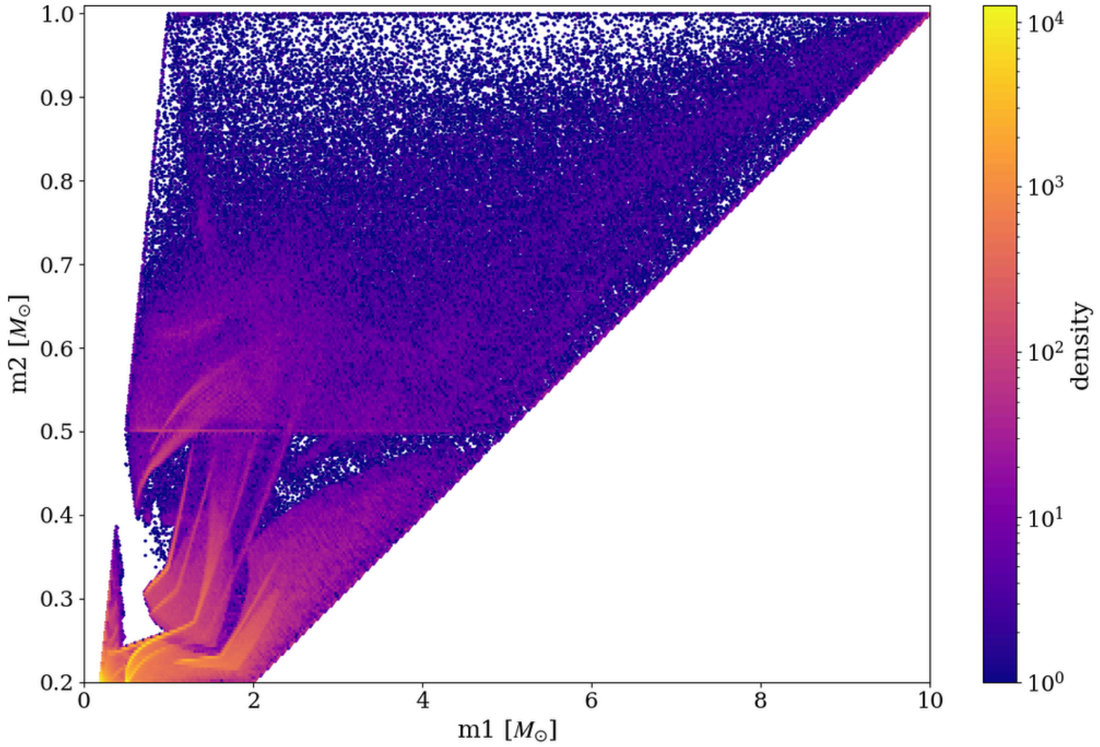
- Template banks are constructed to be able to cover a certain parameter space
- Map the space such that the distance between 2 templates represents the mismatch
- Bank performance metric: Minimal Match (MM) :
  – Computes the fitting factor between injections and bank Templates

$$FF(h_1, h_2) = 2 \int_0^\infty \frac{\tilde{h}_1^*(f)\tilde{h}_2(f) + \tilde{h}_1(f)\tilde{h}_2^*(f)}{S_n(f)}\, df$$

  – Take the best fitting factor found for each injections.
  – Example: MM = 0.97 → recover at least 97% of the SNR

- Millions of template are needed → computationally heavy

SSM Virtual template (VT) bank



SSM VT bank containing 2282654 templates

Back-up

https://canva.link/yjb36a8fljim113