7 new BBHs?

Ian Harry

Introduction

- In a series of recent papers a group at IAS have claimed 7 new BBH mergers on open LIGO data
- This is performed using a new, independently developed search algorithms
- Can we reproduce these results?

arXiv:1904.07214
Phys.Rev. D99 (2019) no.12, 123022
arXiv:1902.10341
arXiv:1902.10331

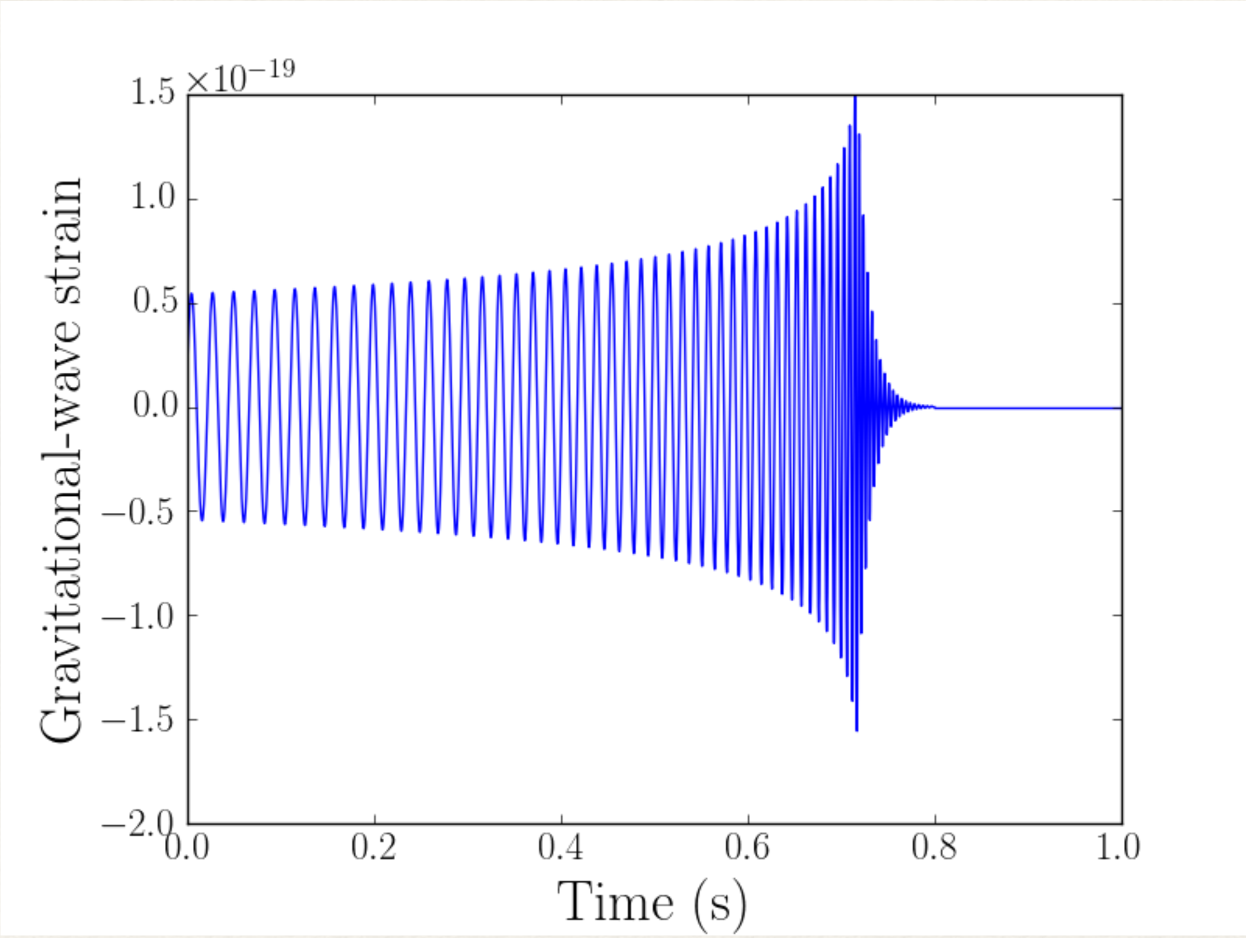
A little bit of a recap

Searching for colliding black holes: What do we know about the signal?

How well do we know the signal?

- Wait for Alessandra's talk tomorrow

How well do we know the signal?



Compact binary parameters

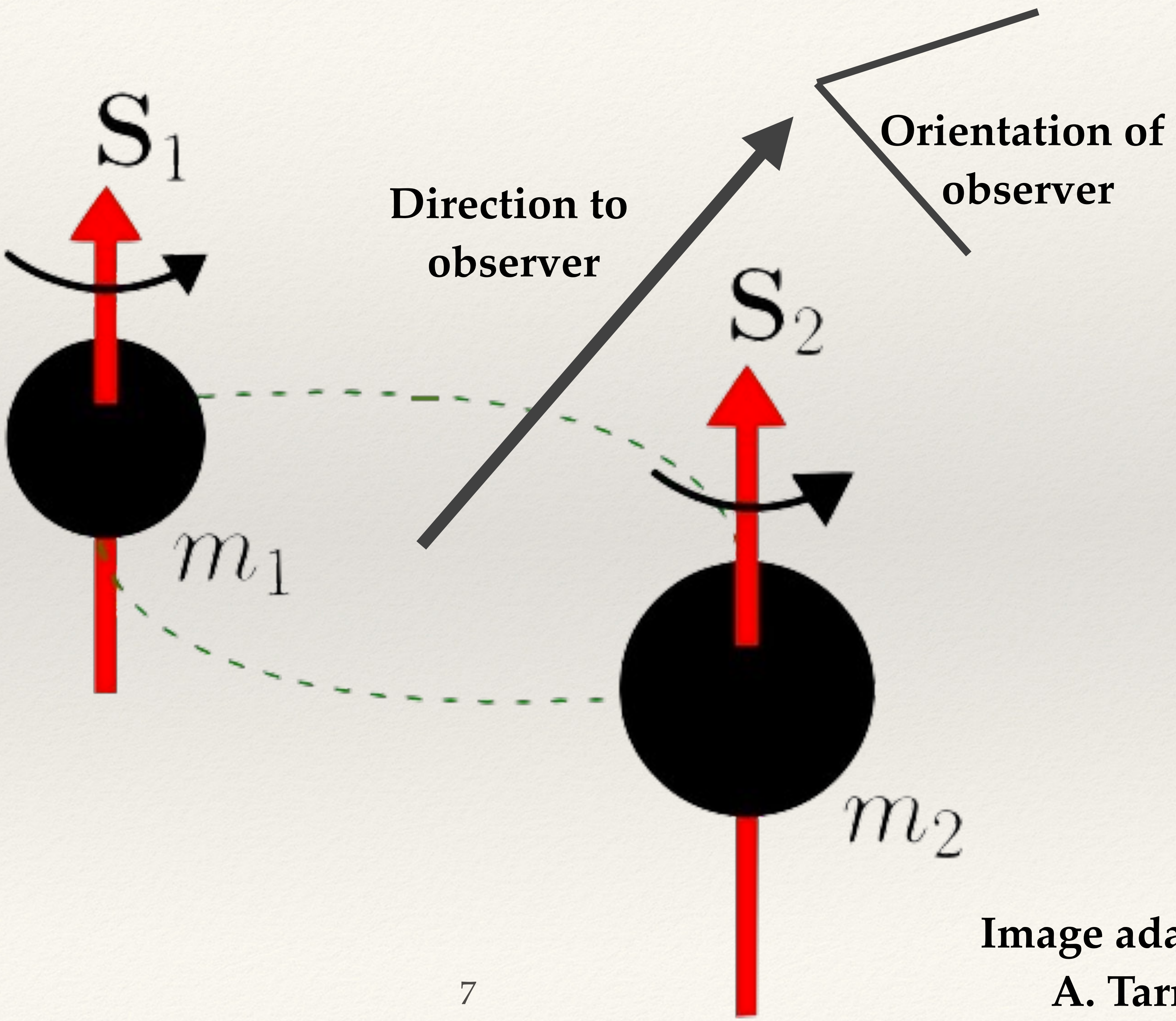
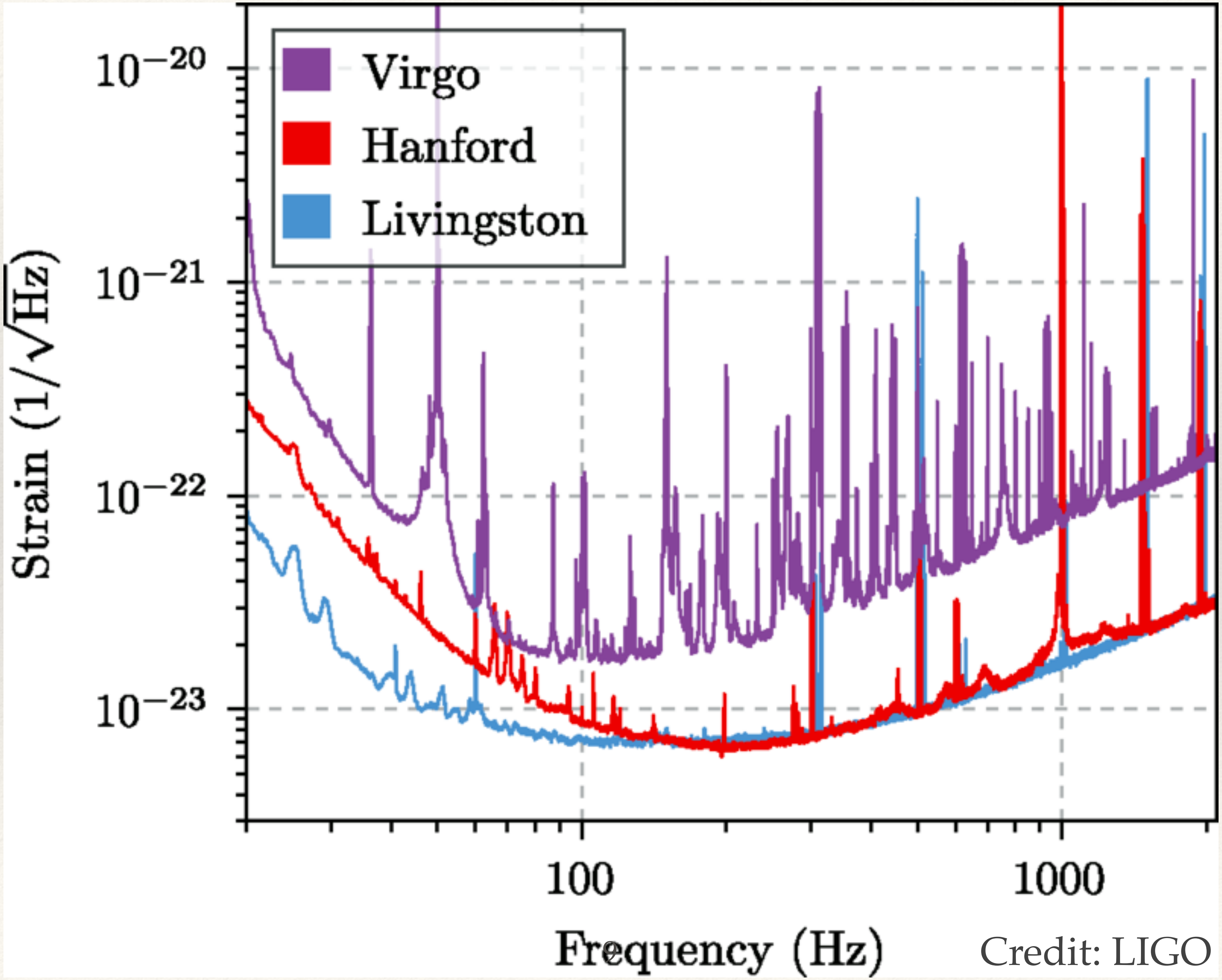


Image adapted from A. Tarrachini

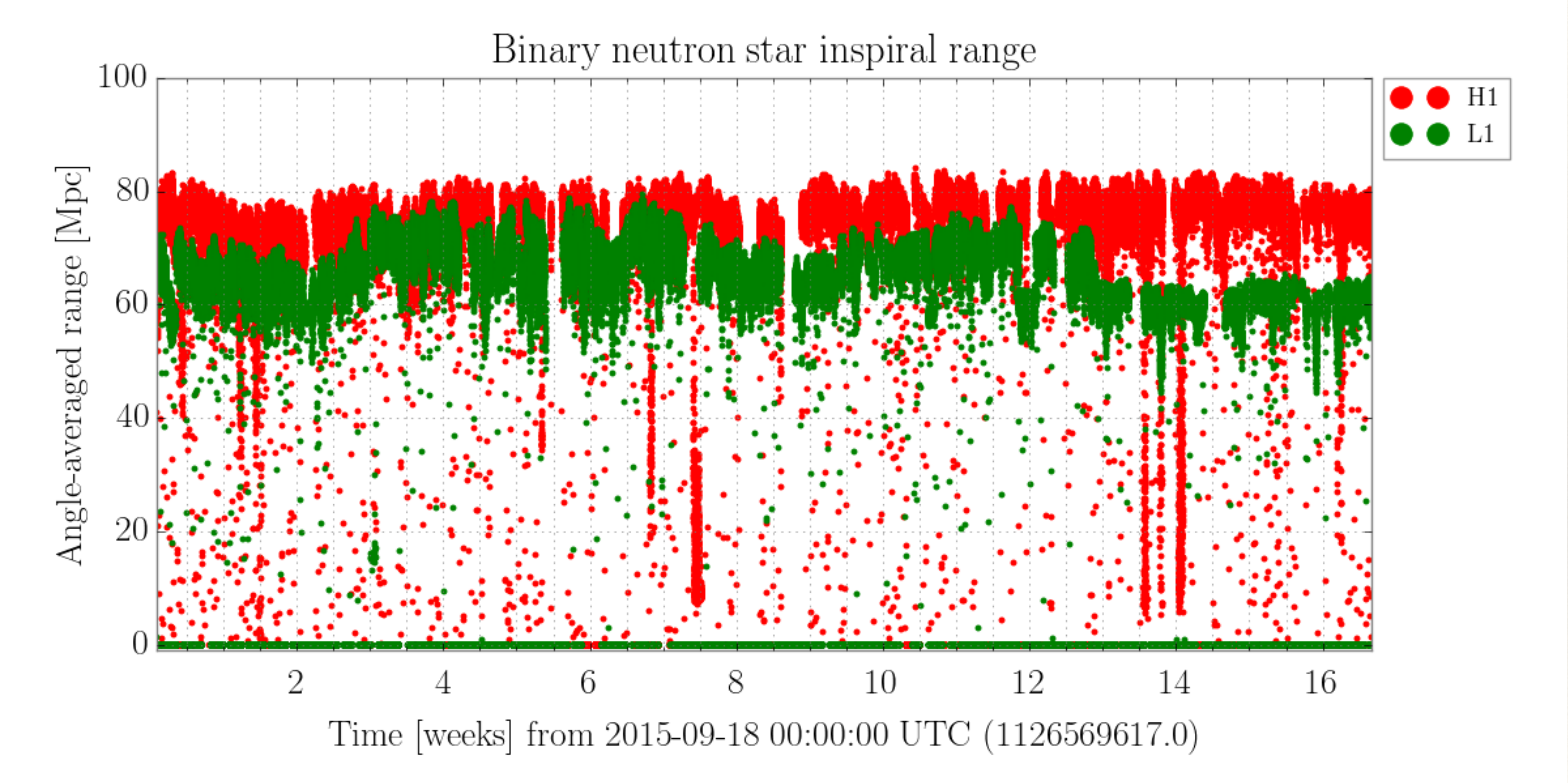
Searching for colliding black holes: What do we know about the noise?

LIGO noise: Complex noise curve



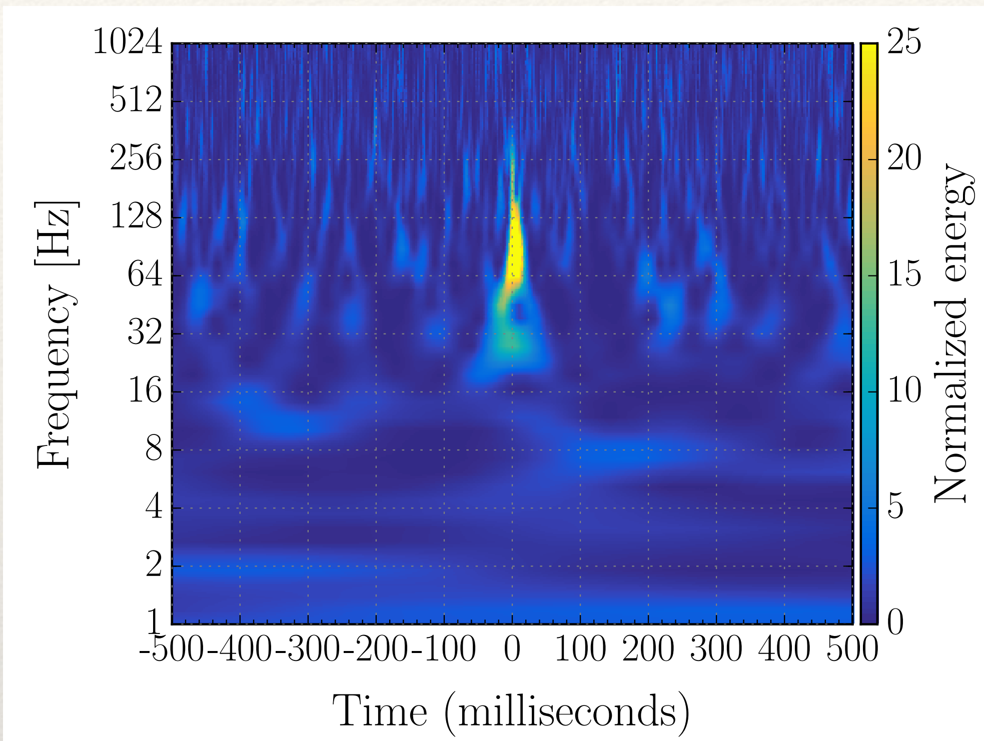
Credit: LIGO

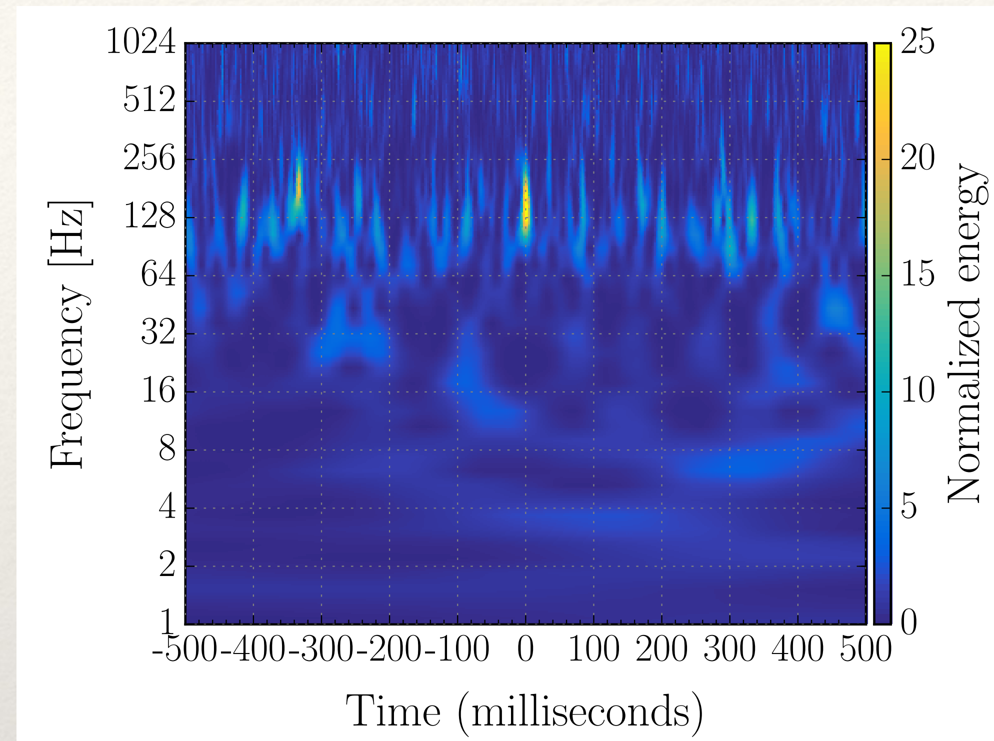
LIGO noise: Non-stationary

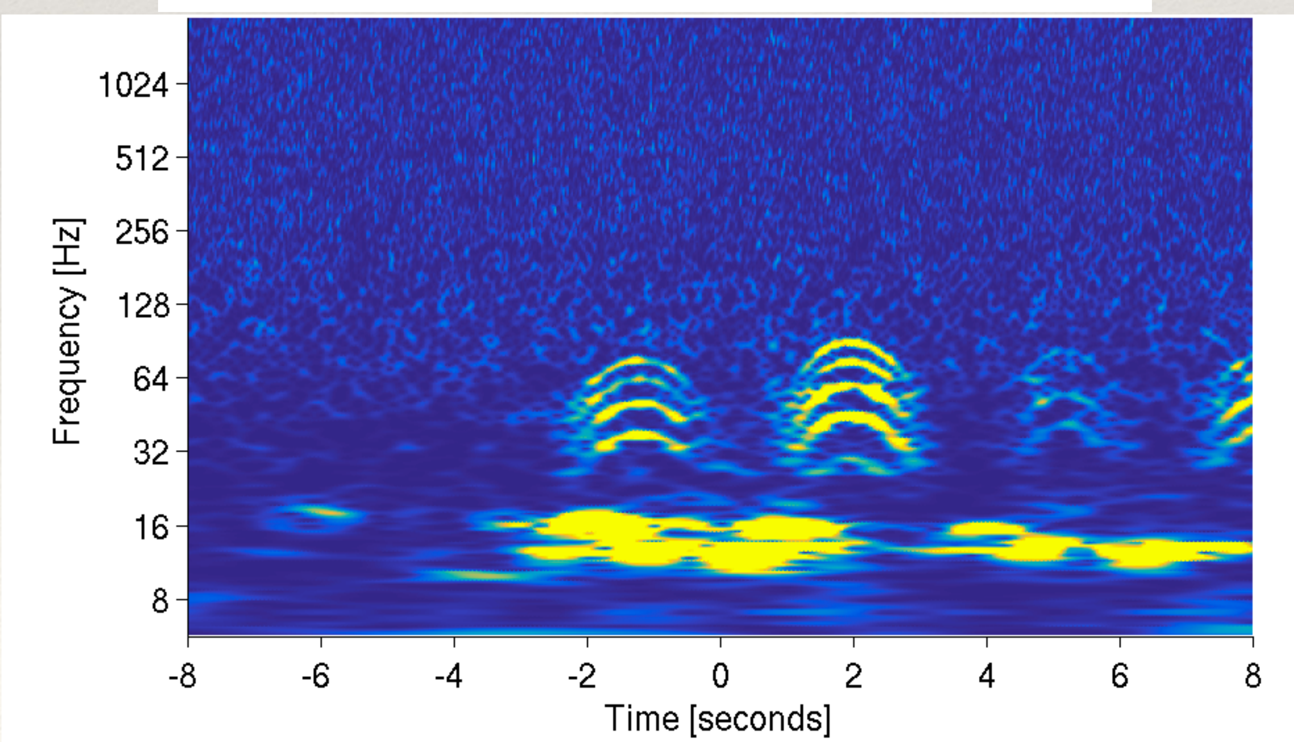


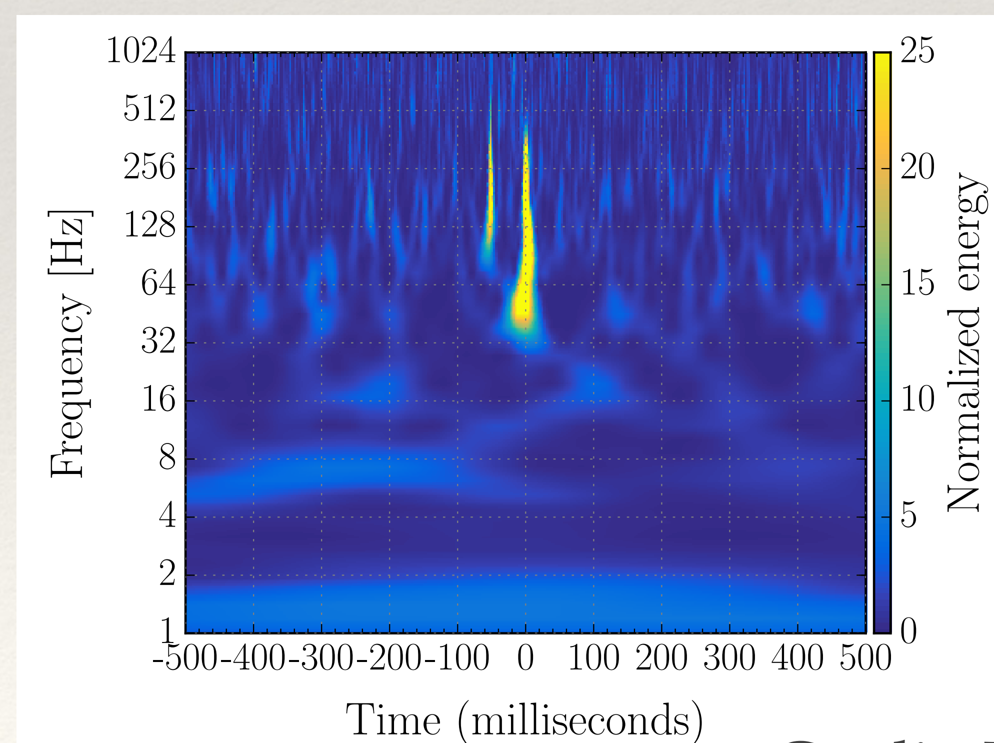
Credit: LIGO

LIGO noise: Non-Gaussian







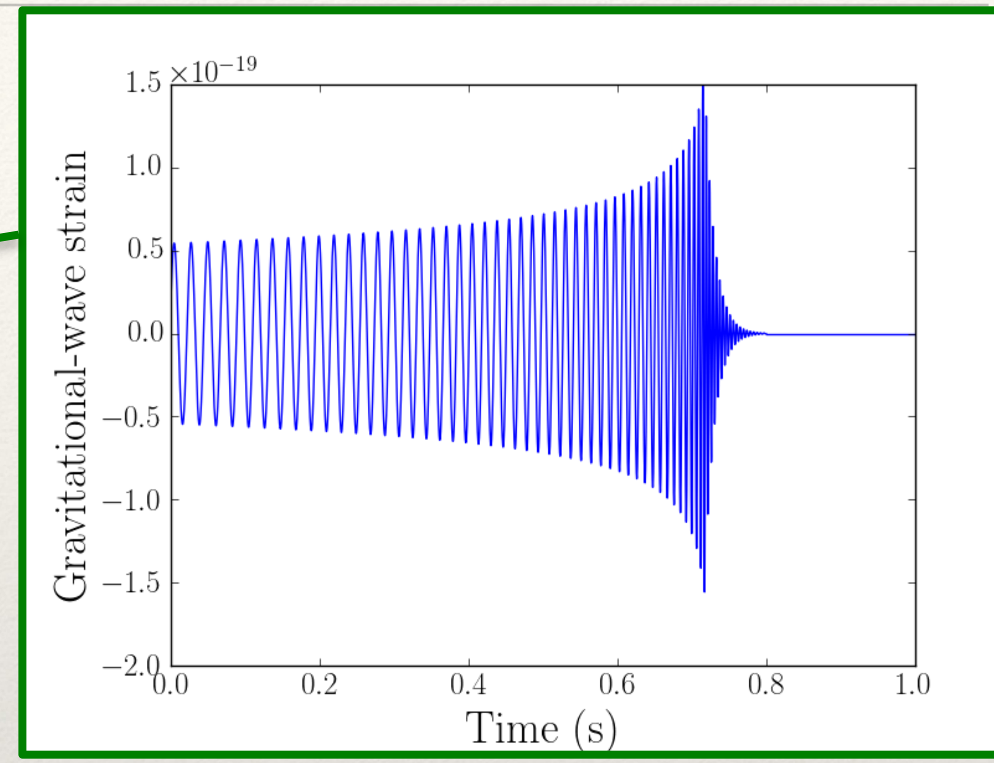


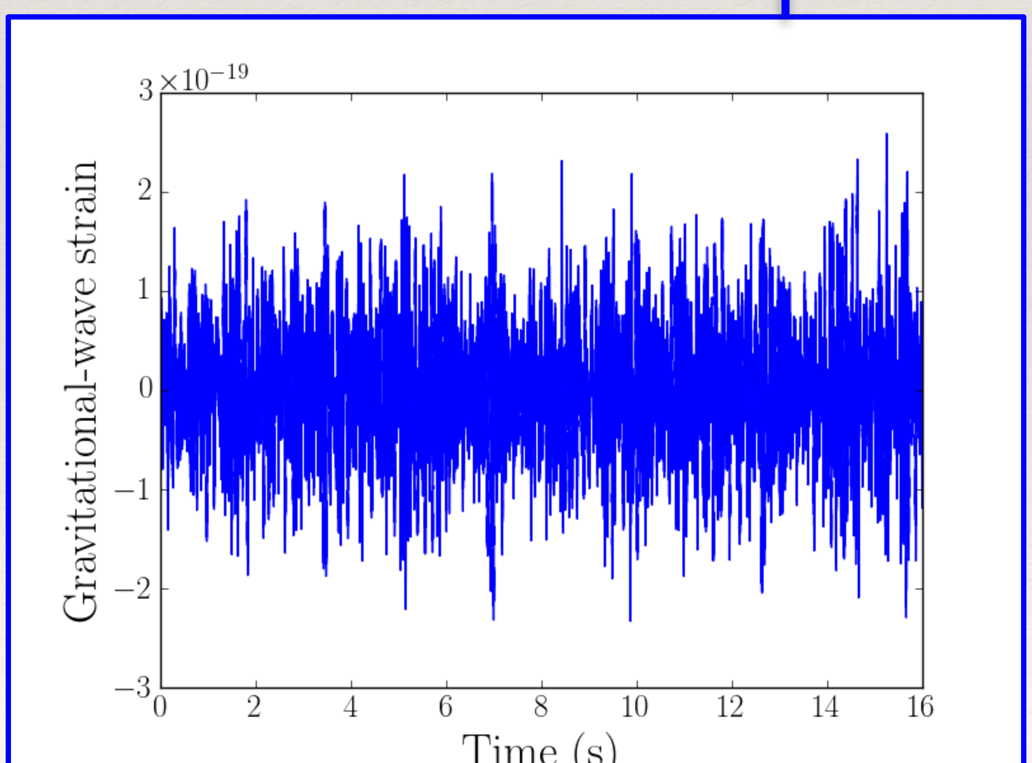
Credit: LIGO

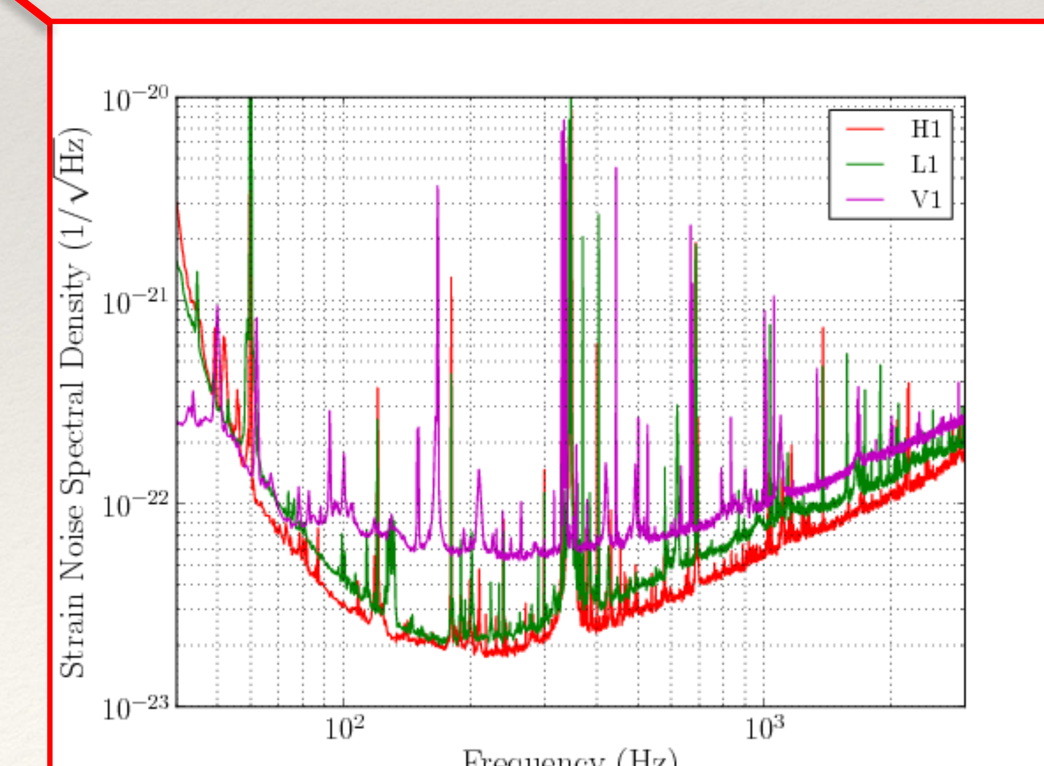
Searching for colliding black holes: How do we actually search for them?

Matched filtering

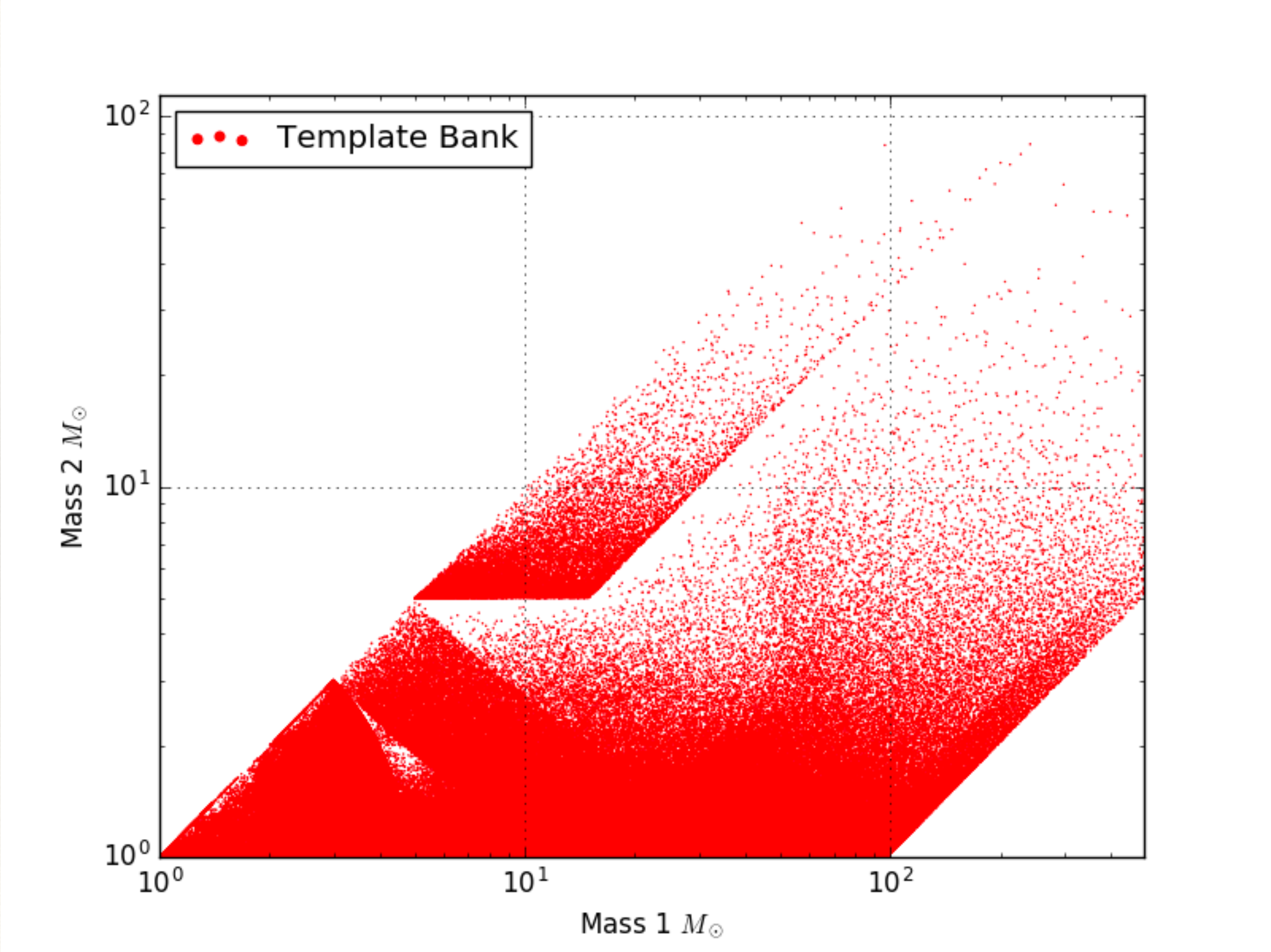
$$(s|h) = 4\Re \int_0^\infty \frac{\boxed{\tilde{s}(f)}\,\boxed{\tilde{h}^\star(f)}}{\boxed{S_h(f)}}\,df$$





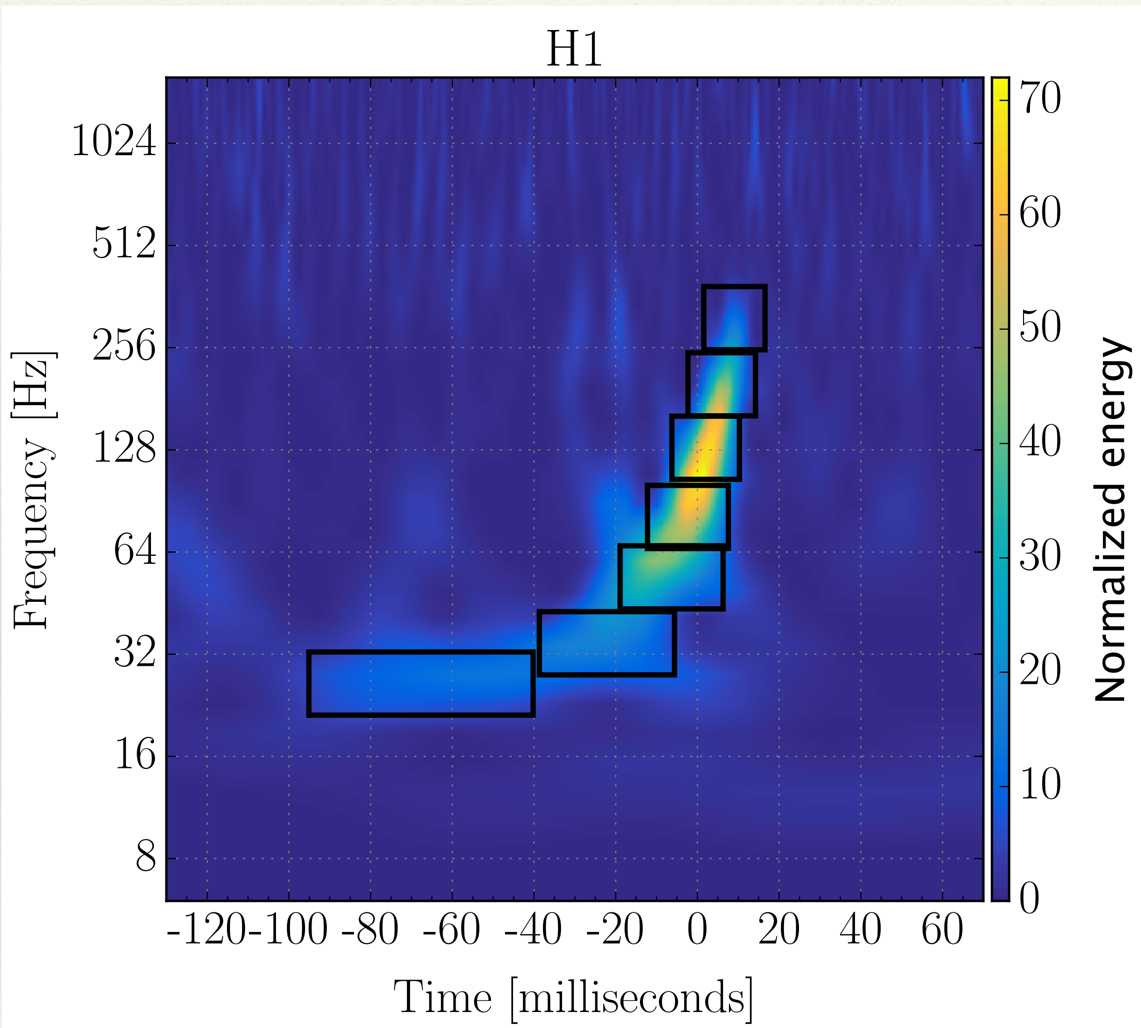


Large parameter space - lots of waveforms

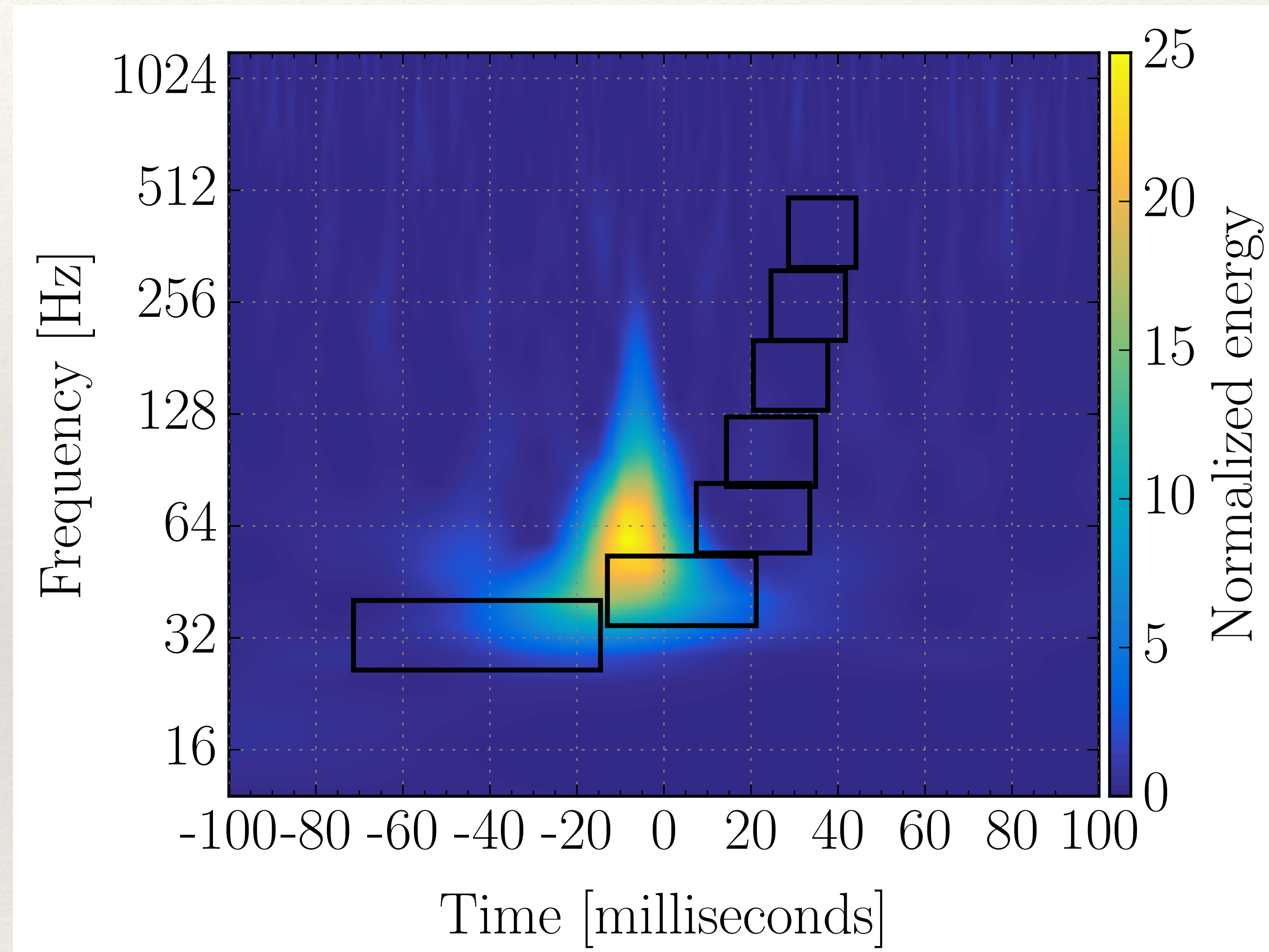


Dal Canton and Harry arXiv:1705.01845

An ad-hoc chi-squared test



Real signal

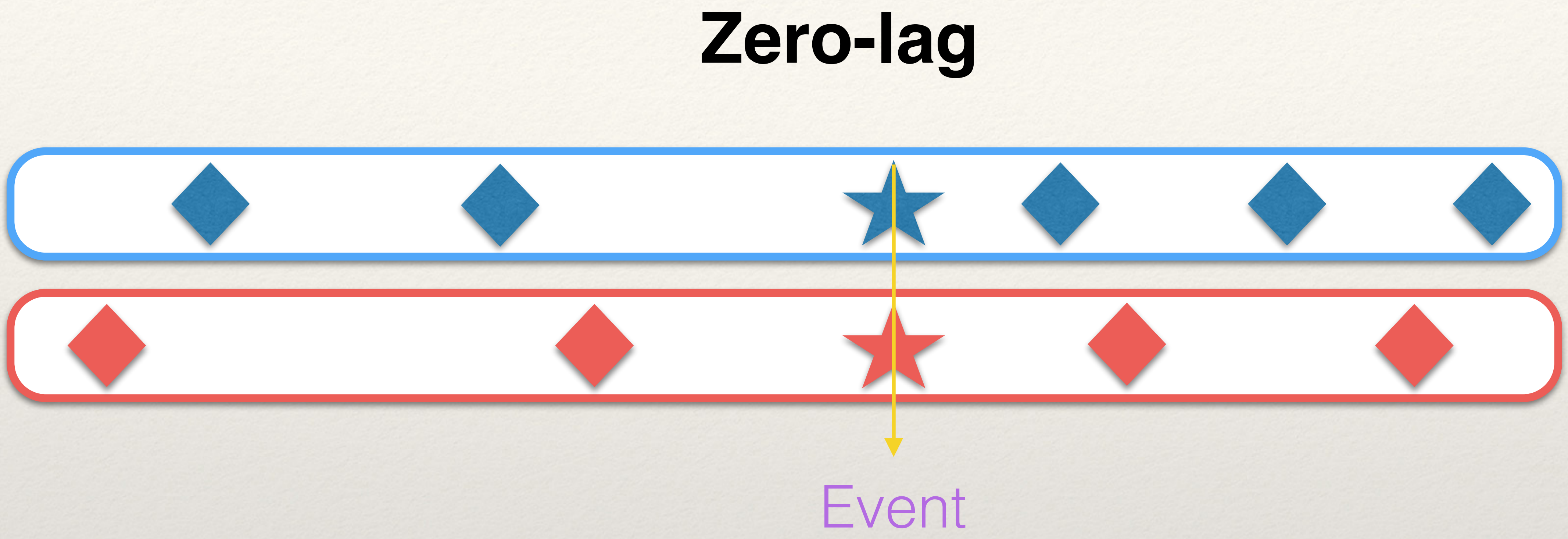


Instrumental artifact

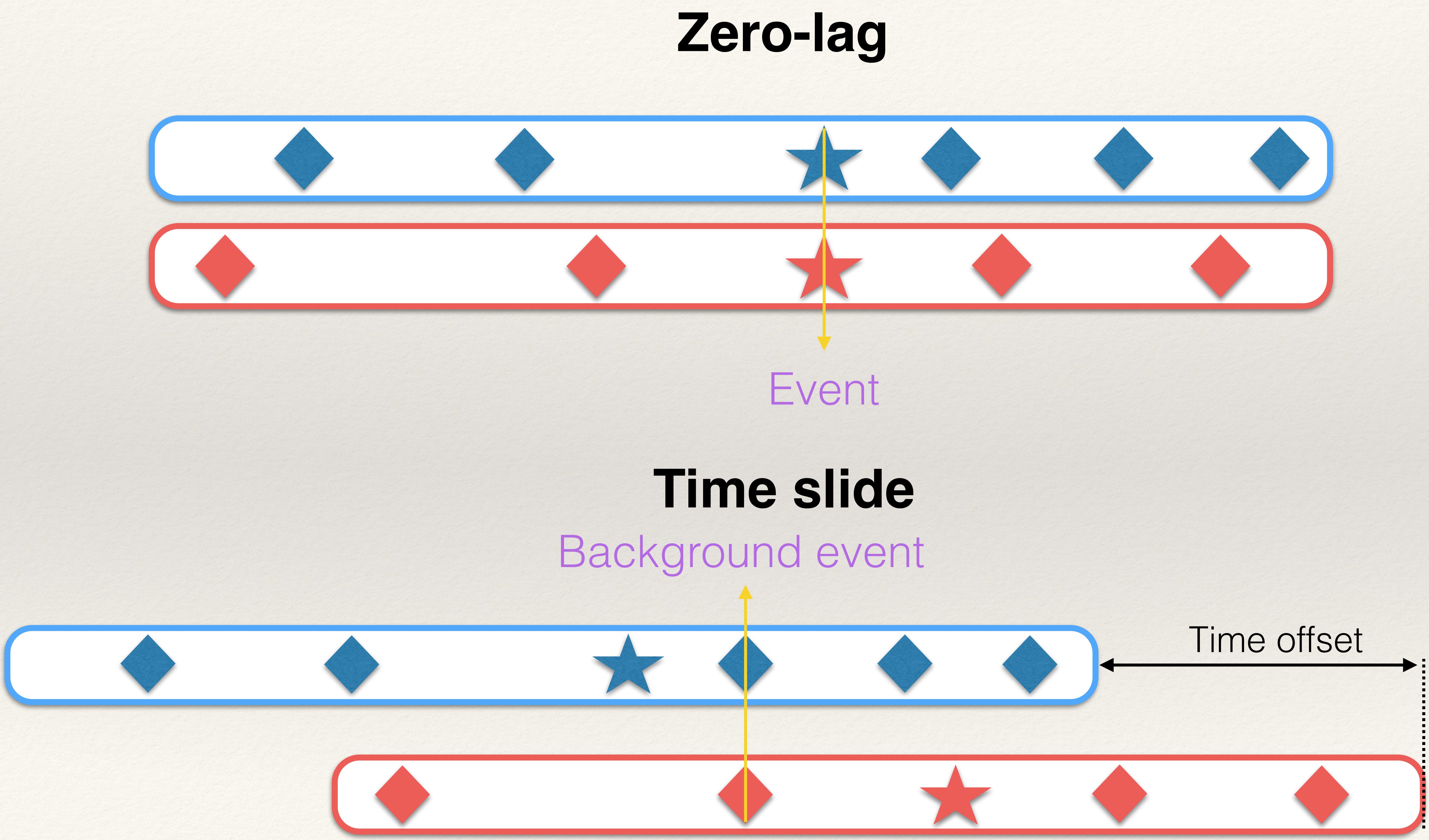
Allen PRD 71 (2005) 062001

SB, …, IH, SP et al. PRD 87 (2013) 024003

Calculating a significance (how many sigmas?)



Calculating a significance (how many sigmas?)



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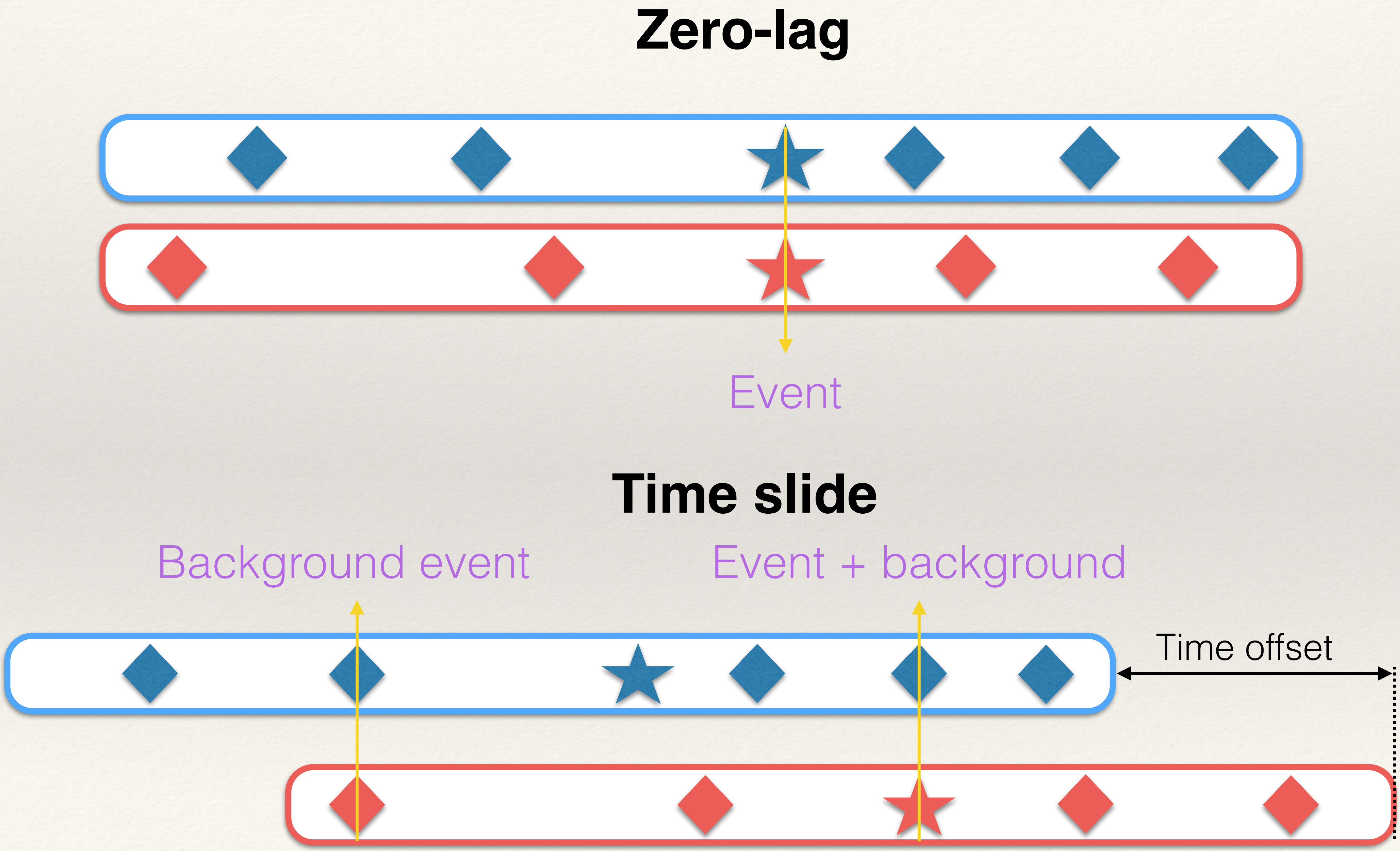
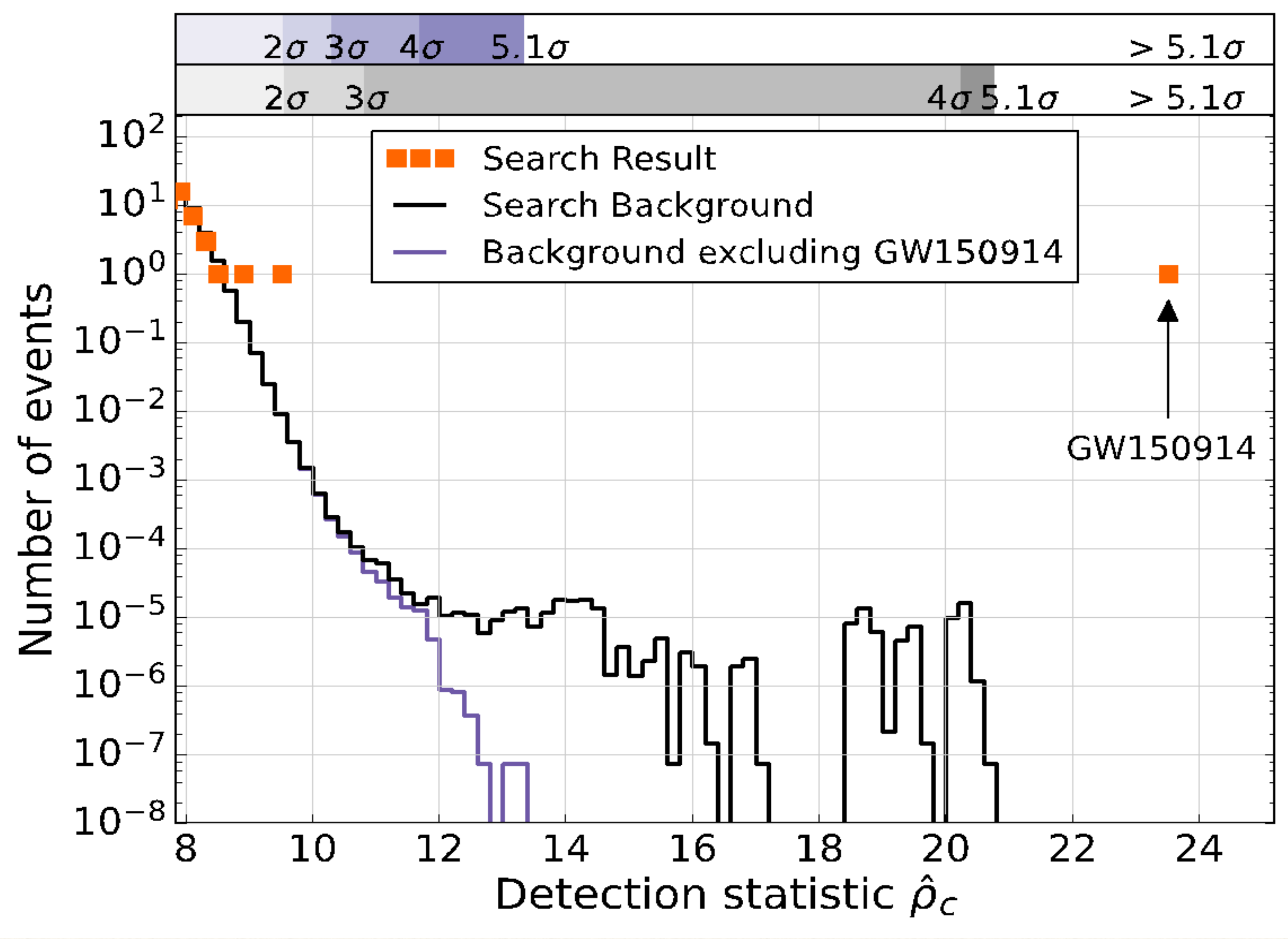


Non-stationarity

- Basic idea to cope with non-stationarity is to keep re-measuring the power-spectral density
- Don't want signals in the data to appear in the measured power-spectral density!
- Use Welch's method every 512s
- If the noise curve changes on timescales less than 512s it will impact sensitivity, but will not affect the validity of a significance measurement.

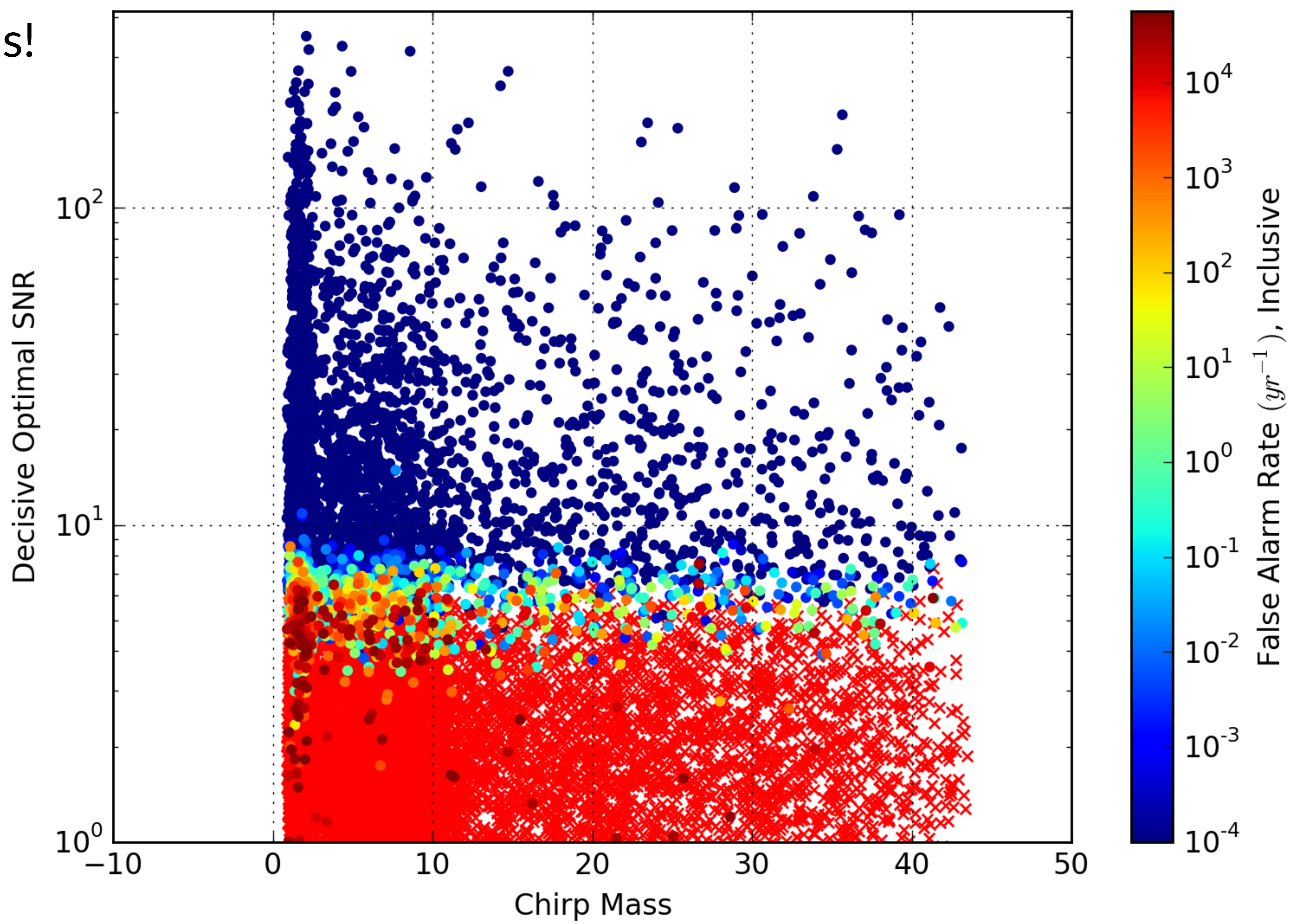
Putting it all together



Phys. Rev. Lett. 116, 061102

How do we validate the analysis?

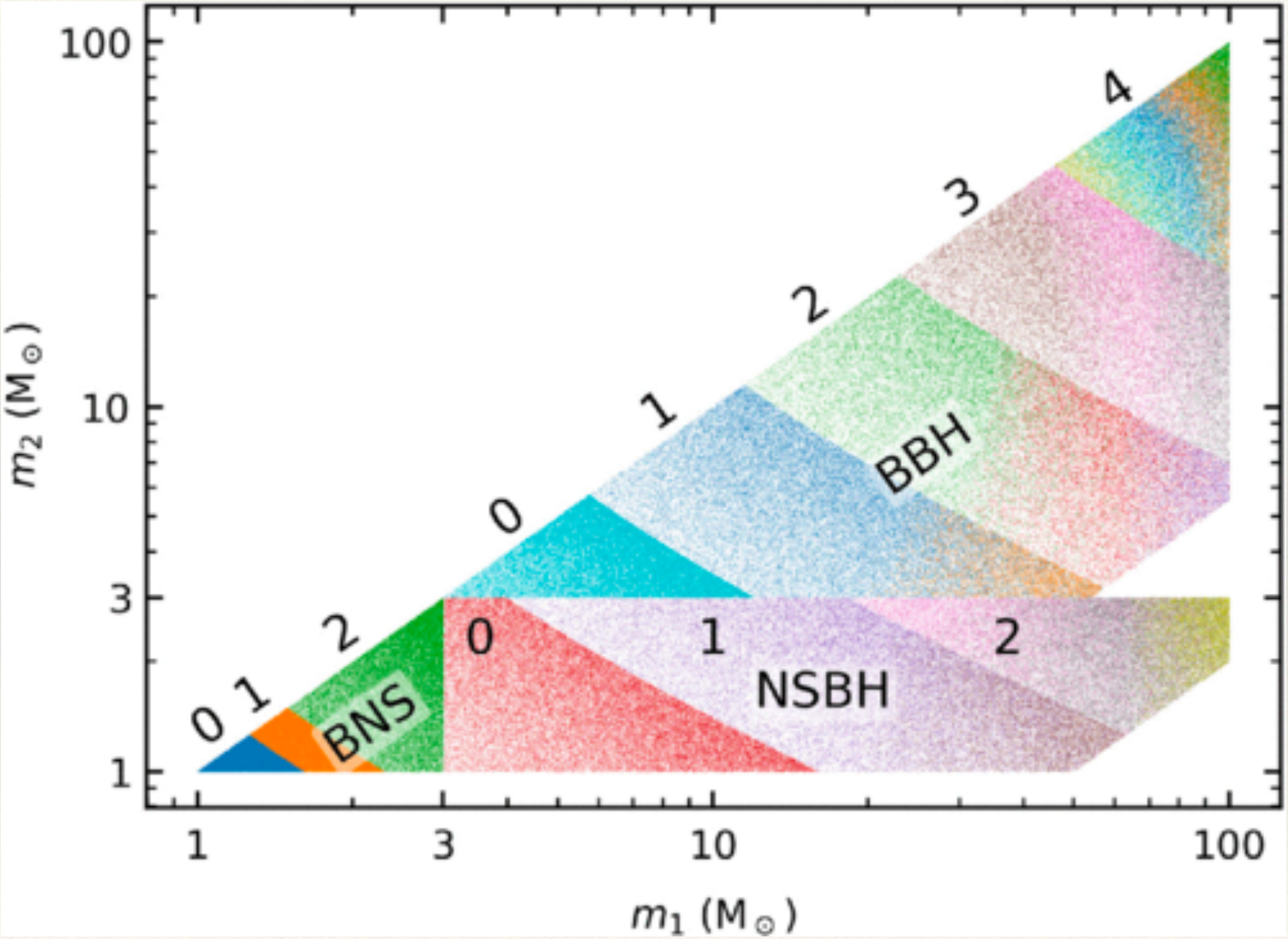
Simulate lots of signals!



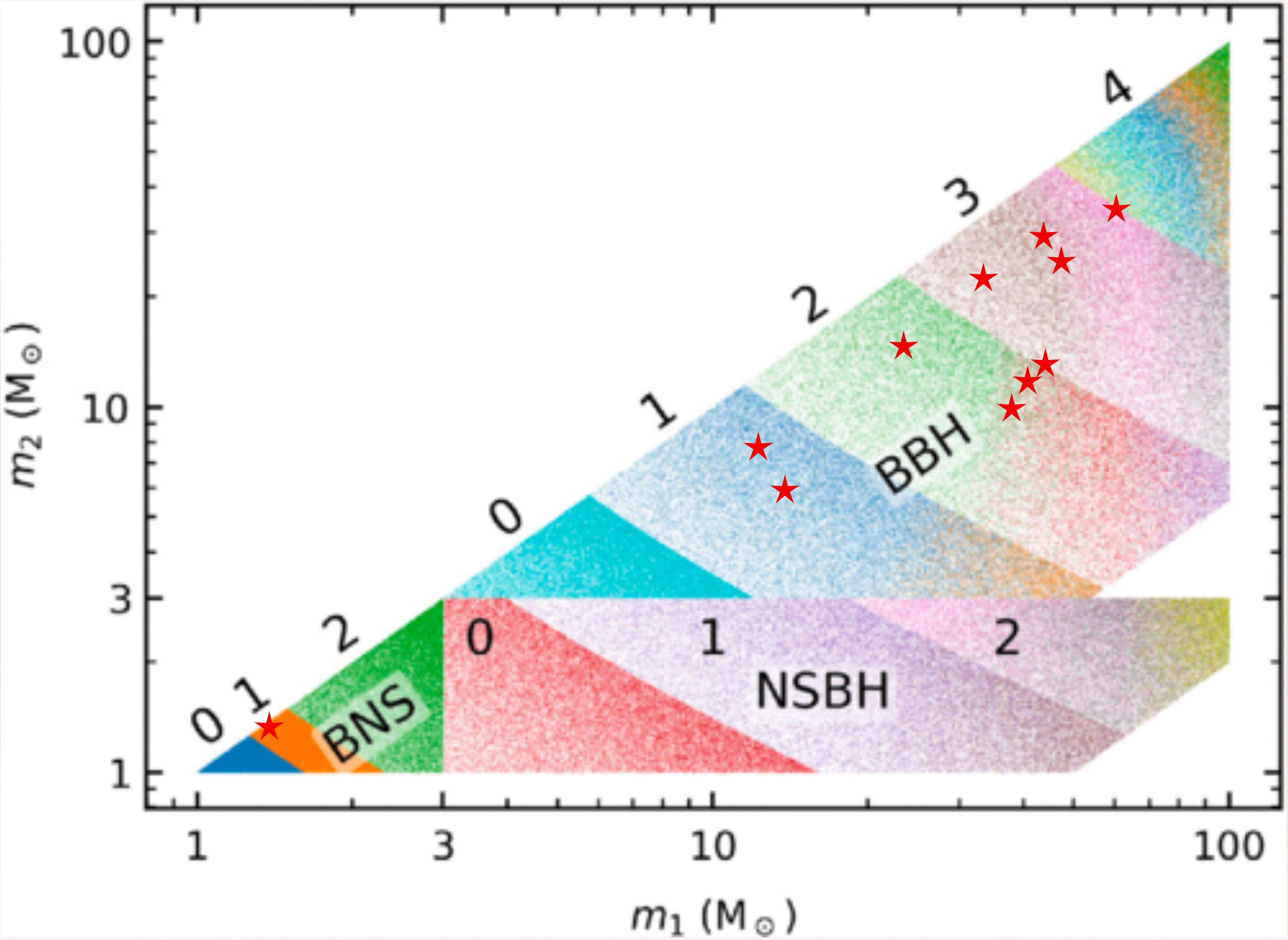
How does the IAS analysis compare

- I could largely have used these slides to describe the IAS methods
- When digging into technical points things differ:
    - Construction of bank is different
    - Methods for distinguishing instrumental artefacts differ
    - A new method is used for identifying times of non-stationarity (and correcting for it)
- The general philosophy is different. LIGO/Virgo probably already saw anything loud, so go after the real quiet things

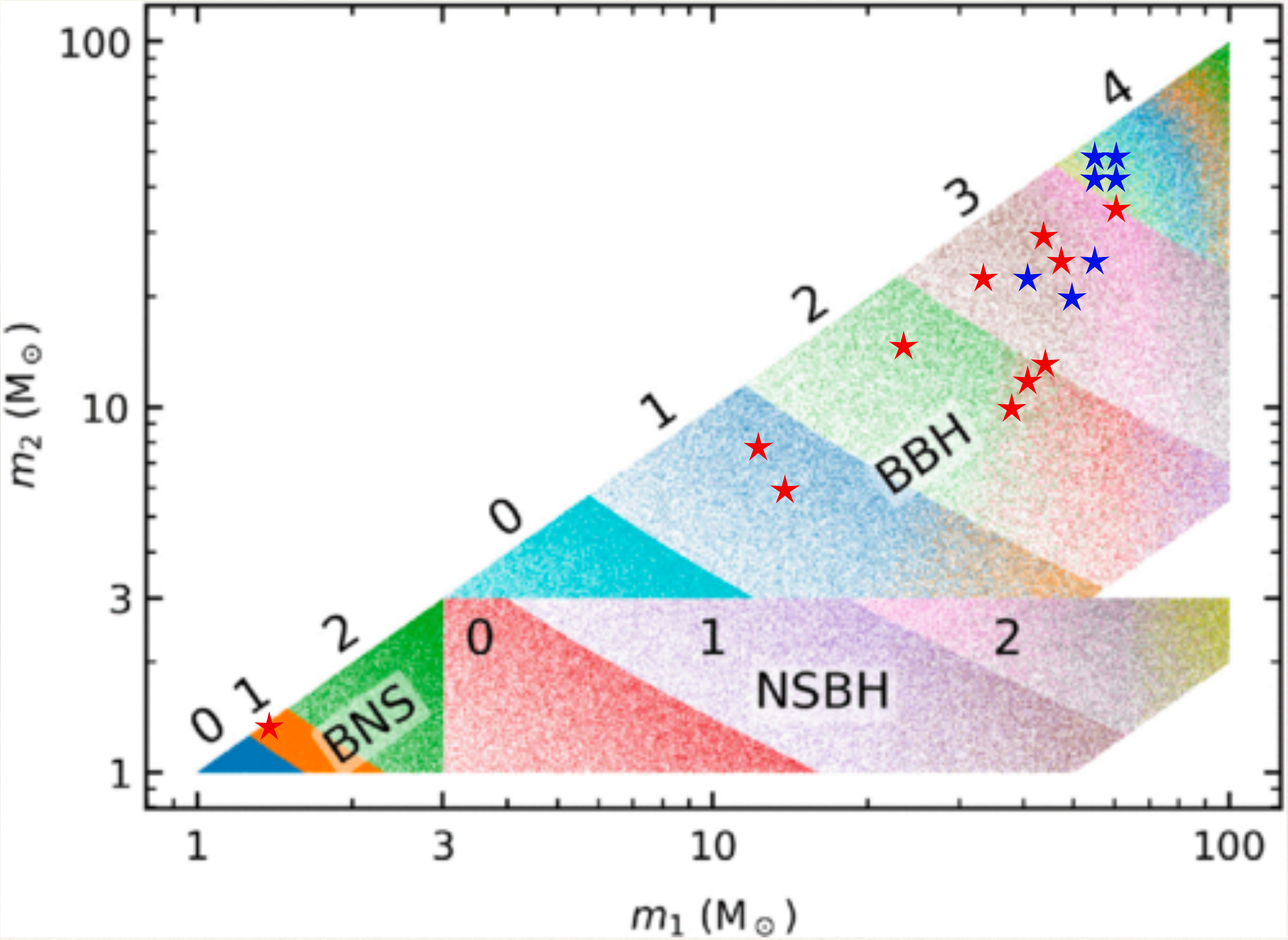
And one IMPORTANT technical difference



And one IMPORTANT technical difference



And one IMPORTANT technical difference



QUESTION:

Can I take the “PyCBC” search pipeline, take the same philosophy and reproduce the results of IAS

Changes to PyCBC Search

- I use the IAS template regions (just 3 and 4), but our template placement codes
- Include single detector events with SNR as low as 4
- I change a number of our cuts to be very aggressive
- I use Laura's (+ Simone's) non-stationarity monitor, and aggressively remove times where this is bad
- No "p-astro"s. The main search result is the rate of false triggers, and that is more easily comparable

Results (so far O2 only)

TRIGGER NAME	IAS False Alarm Rate	New False Alarm Rate
GW170121 (BIN 3)	1 every 1000 years	
GW170304 (BIN 4)	1 every 120 years	
GW170727 (BIN 4)	1 every 120 years	
GW170425 (BIN 4)	1 every 5 years	
GW170202 (BIN 3)	1 every 2 years	
GW170403 (BIN 4)	1 every 1.5 years	

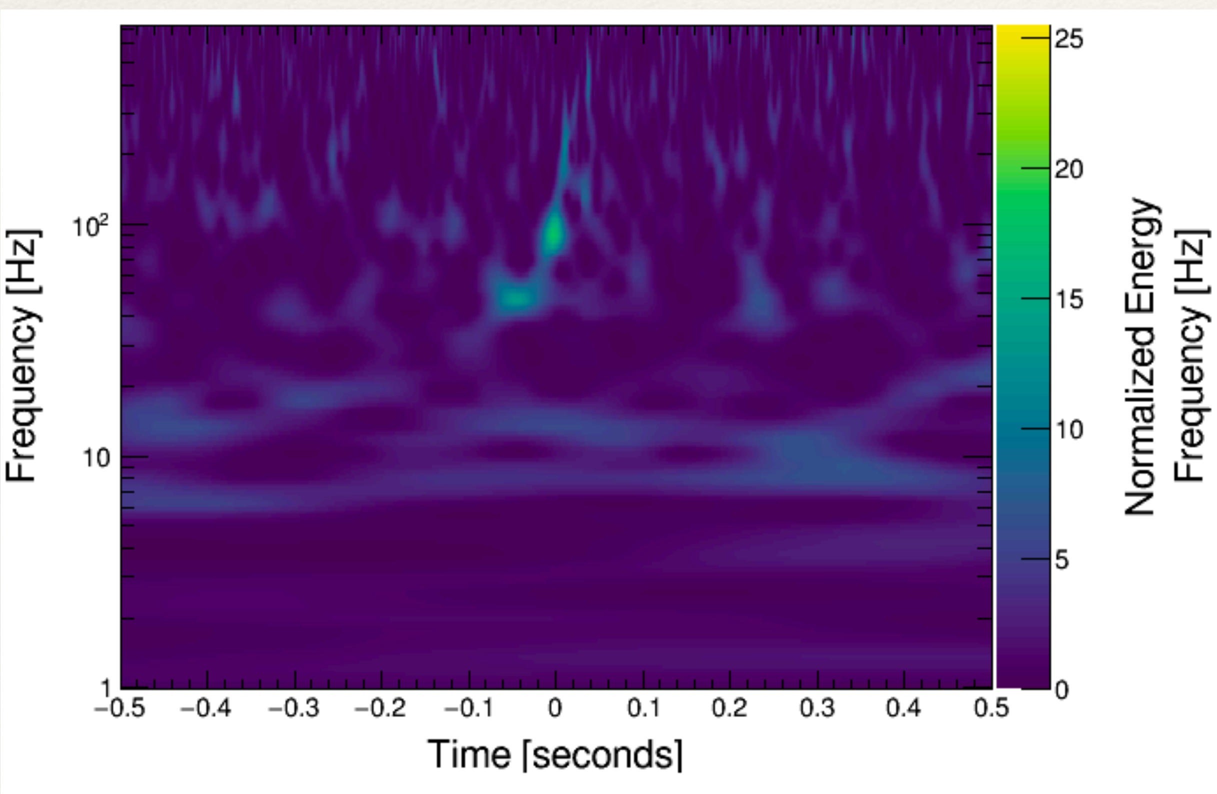
Results (so far O2 only)

TRIGGER NAME	IAS False Alarm Rate	New False Alarm Rate
GW170121 (BIN 3)	1 every 1000 years	1 every 10000 years
GW170304 (BIN 4)	1 every 120 years	1 every 2 years (*1 every 16 years)
GW170727 (BIN 4)	1 every 120 years	1 every 26 years**
GW170425 (BIN 4)	1 every 5 years	1 every 1 year***
GW170202 (BIN 3)	1 every 2 years	1 every 4 years
GW170403 (BIN 4)	1 every 1.5 years	10 every year****

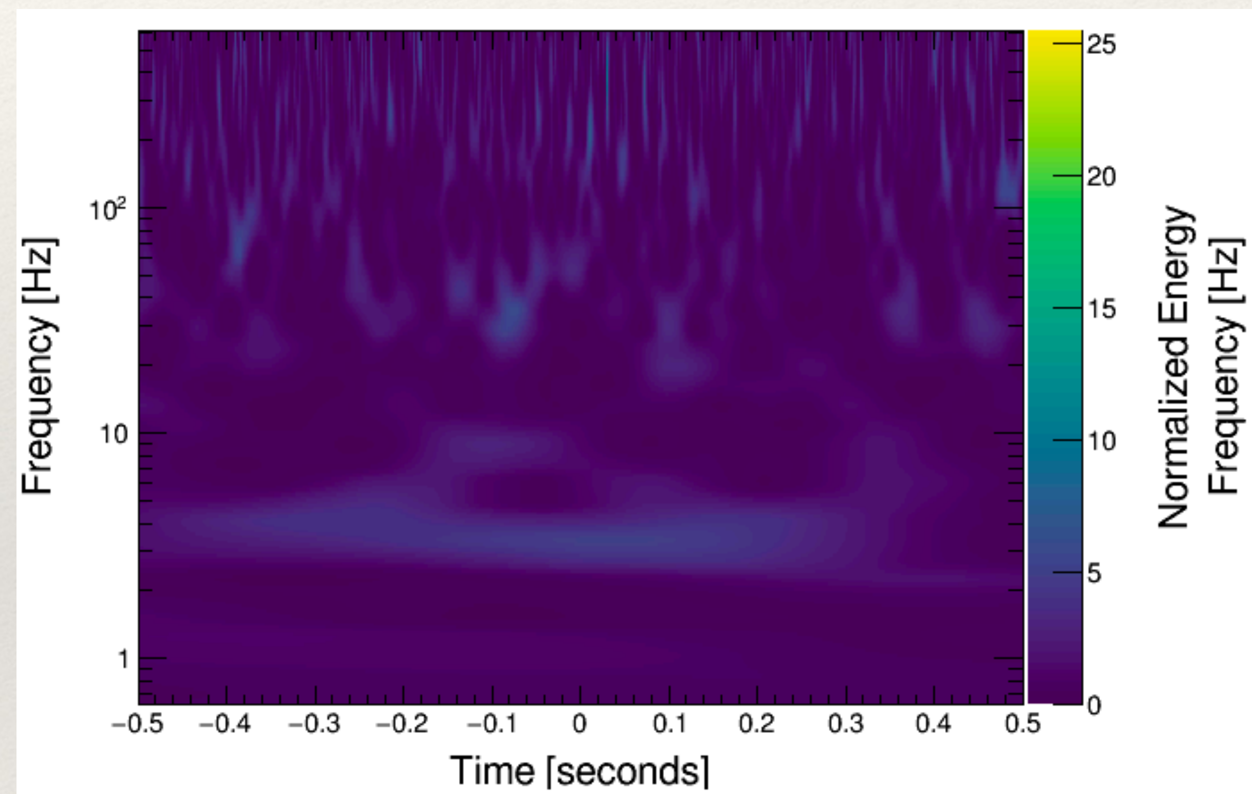
* Number obtained after cutting template bank to a total mass of 100 solar masses
** Background estimate here is polluted by loud L1 single events
*** This event doesn't quite seem consistent in the two detectors
**** This looks like a quiet "blip glitch" in H1

GW170121

L1

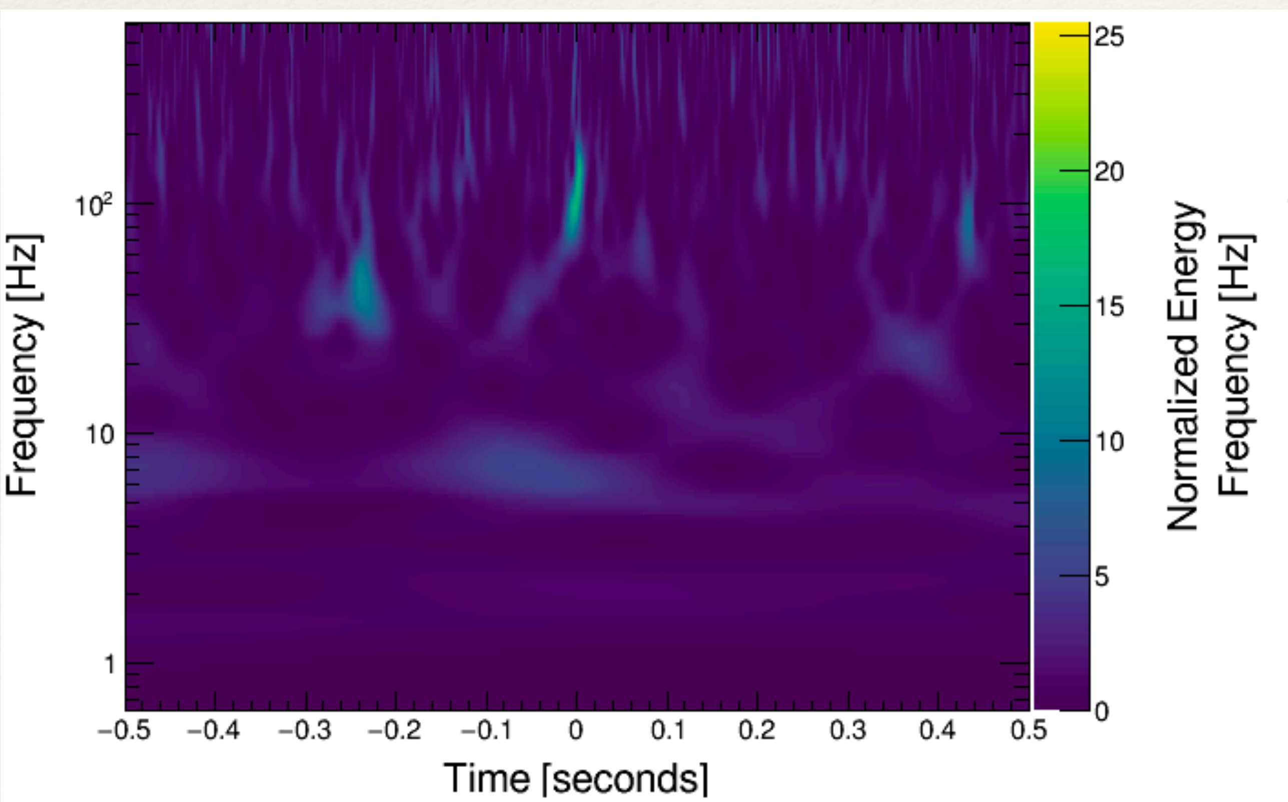


H1

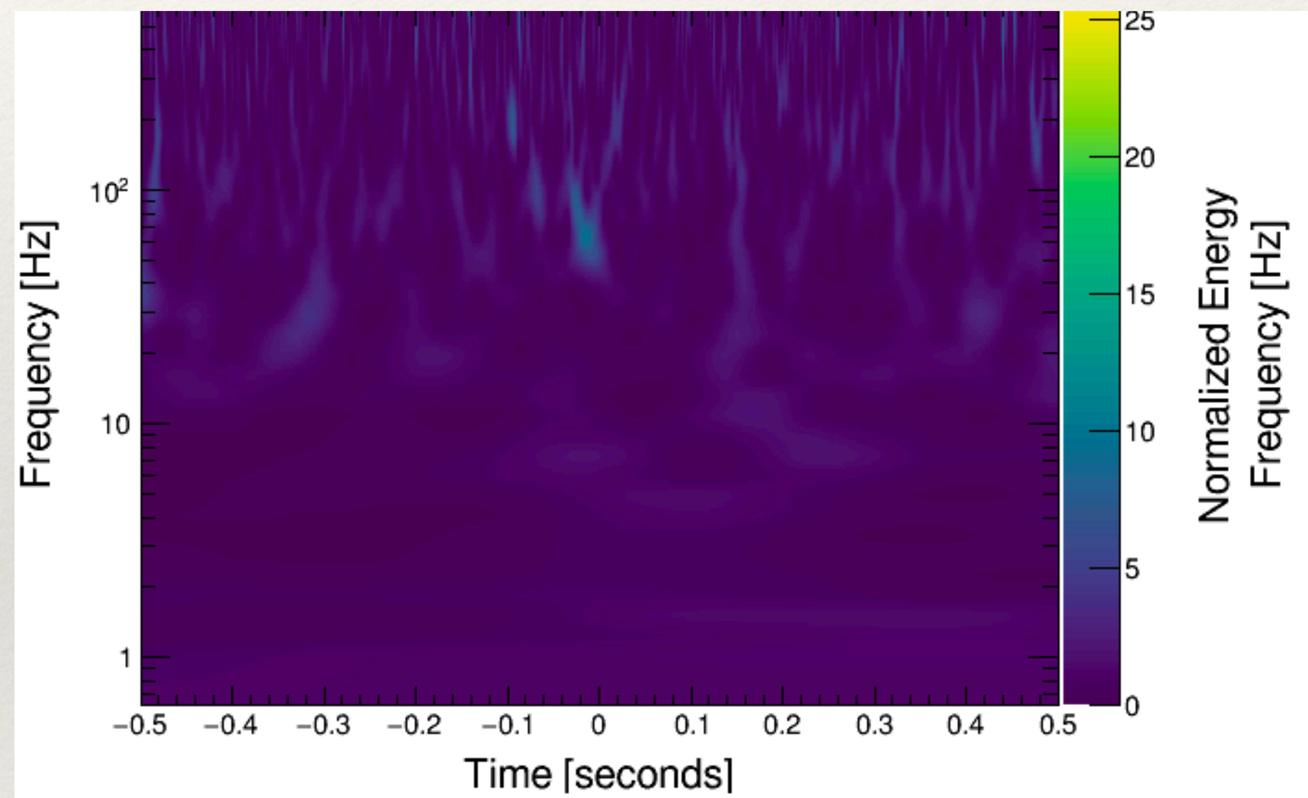


GW170304

L1

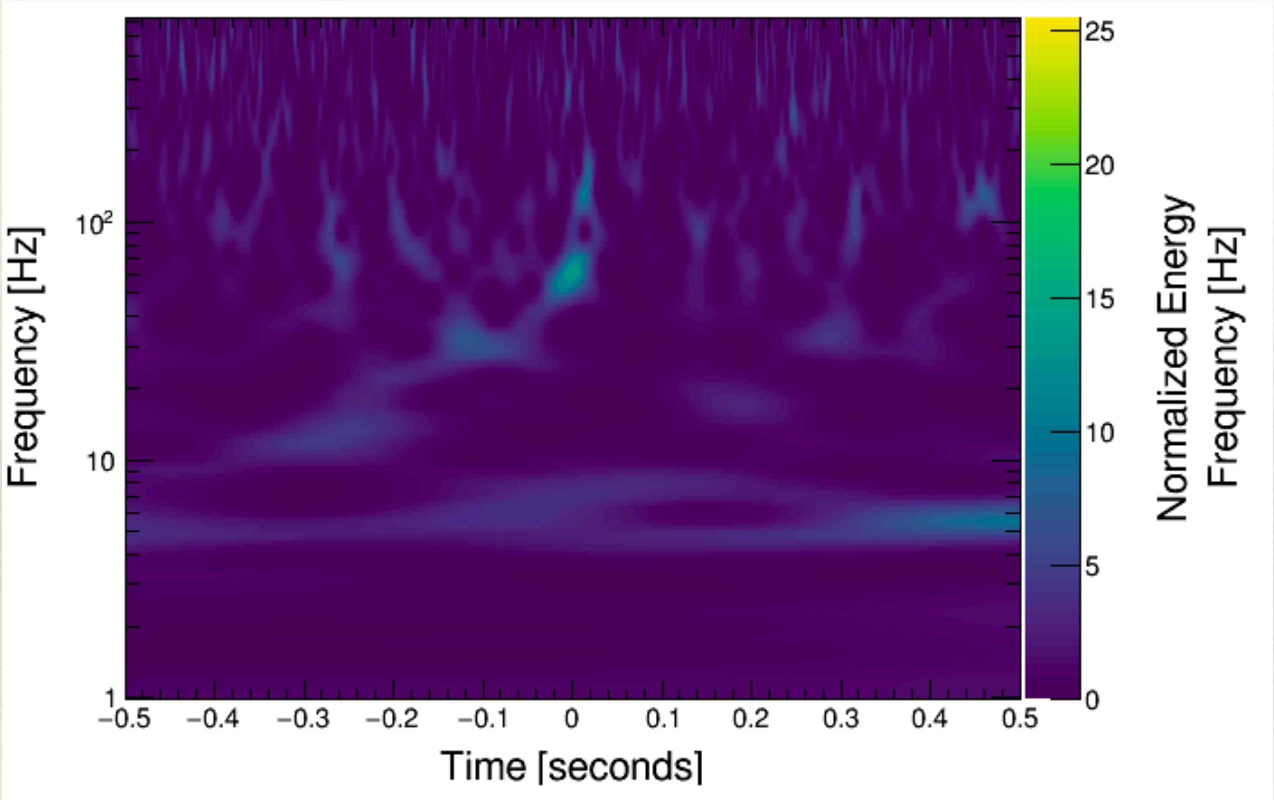


H1

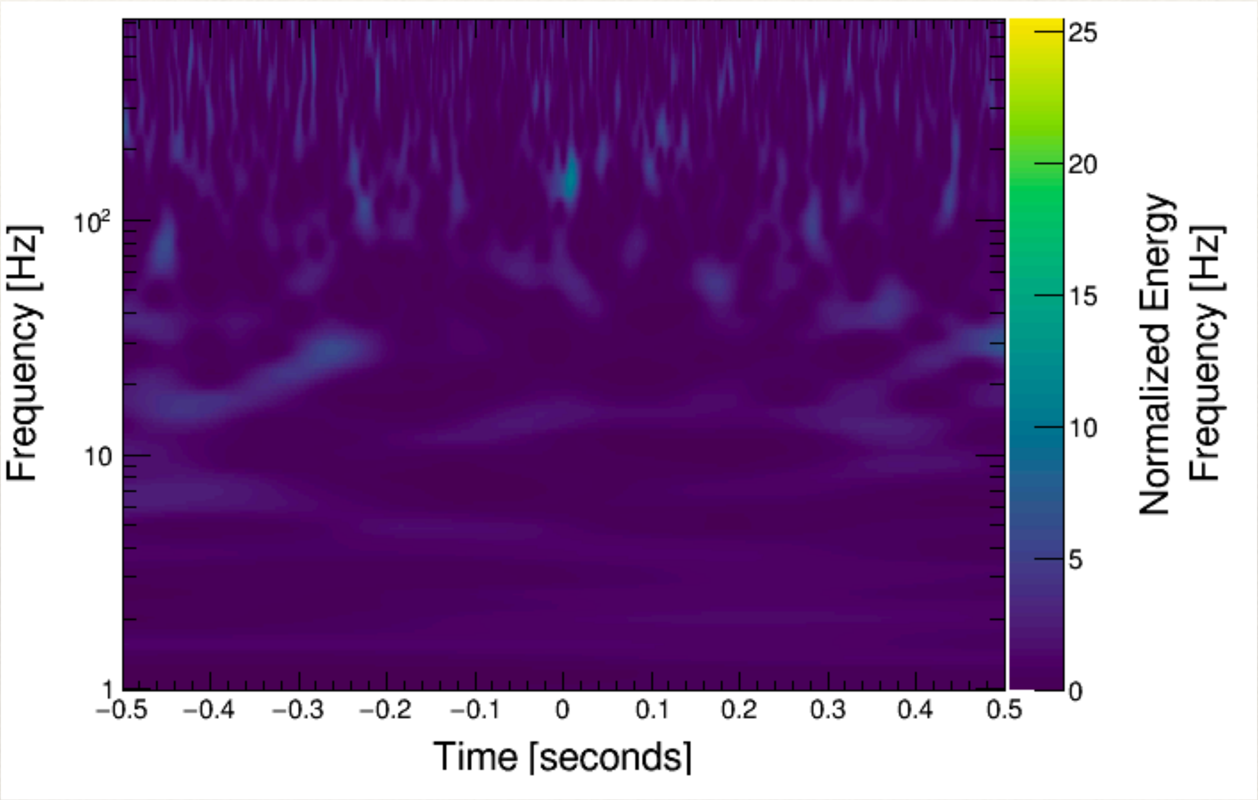


GW170727

L1

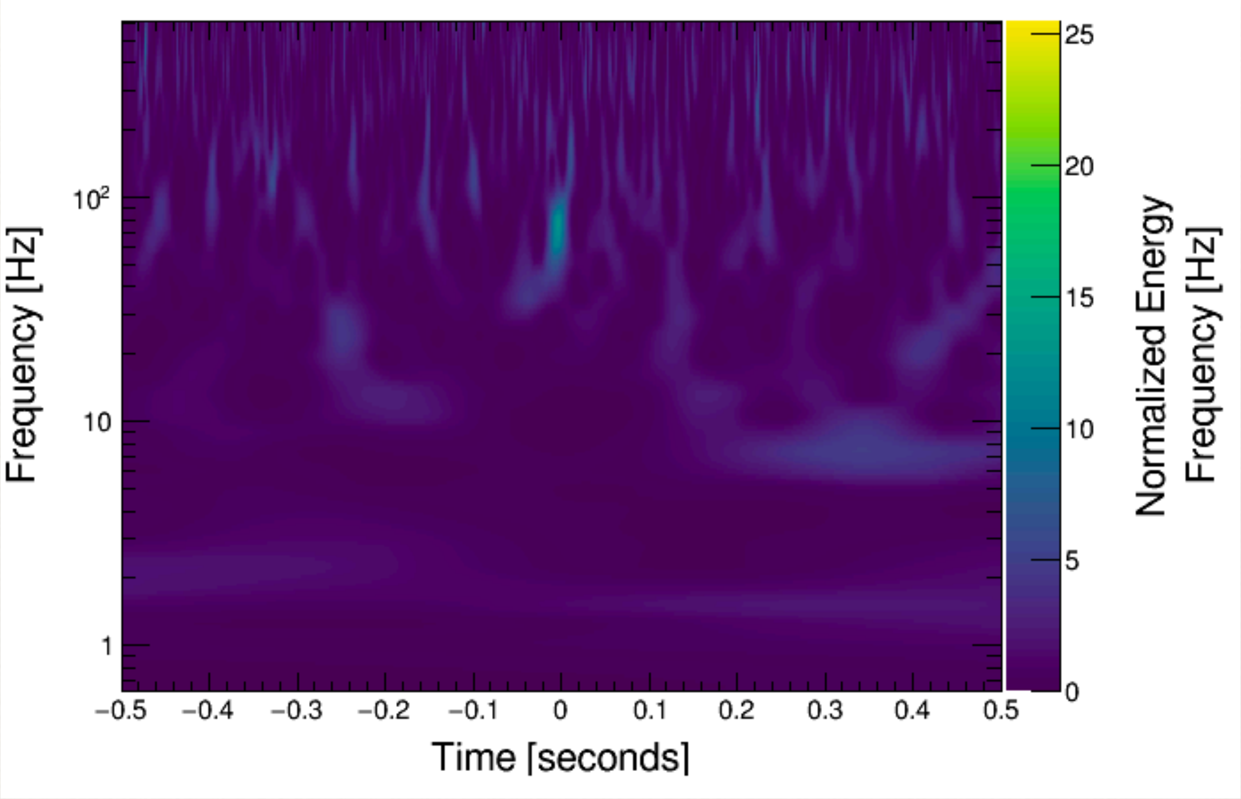


H1

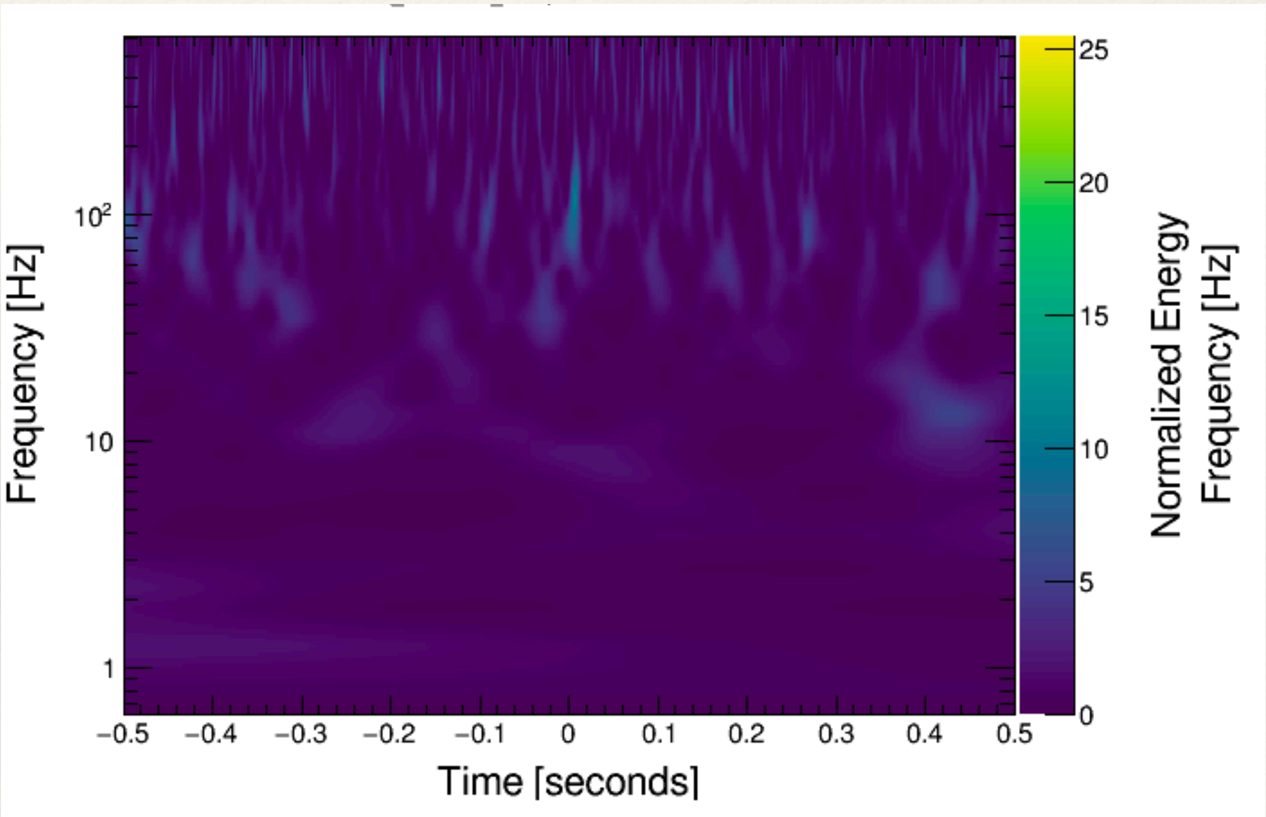


GW170425

L1

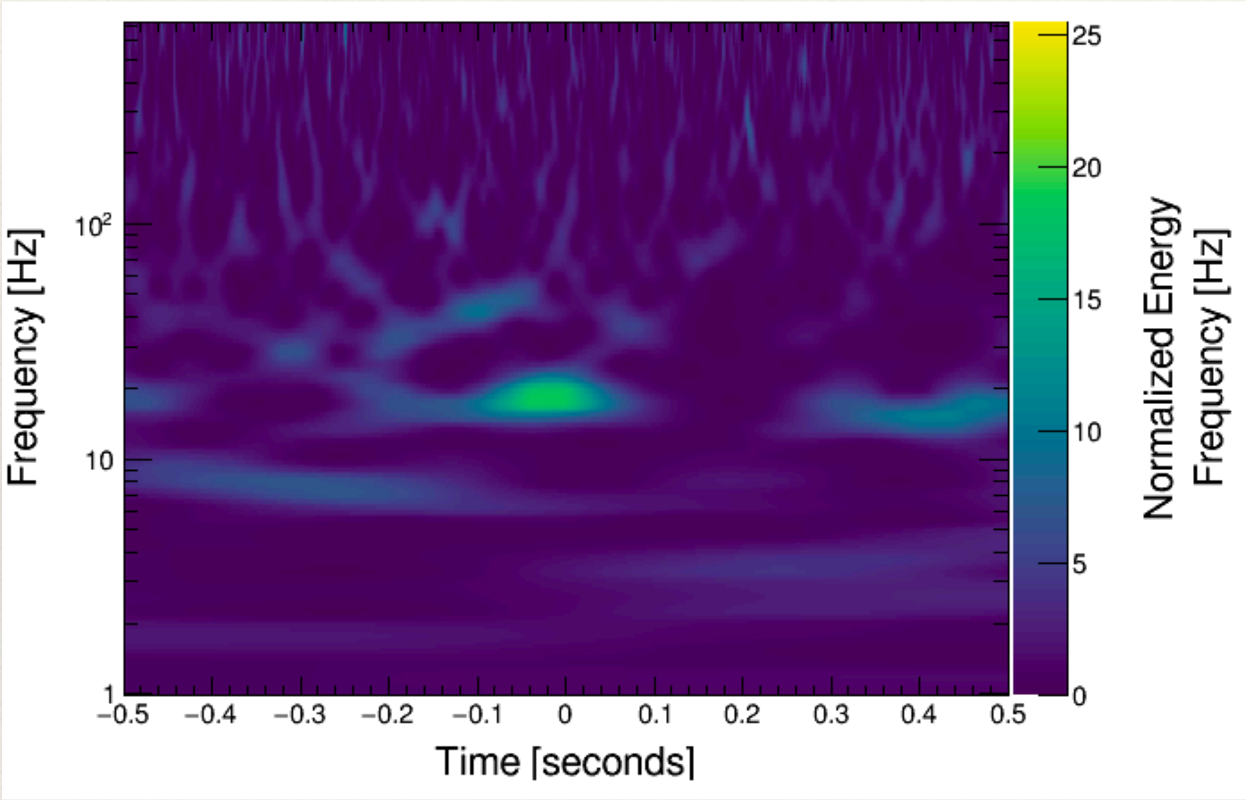


H1

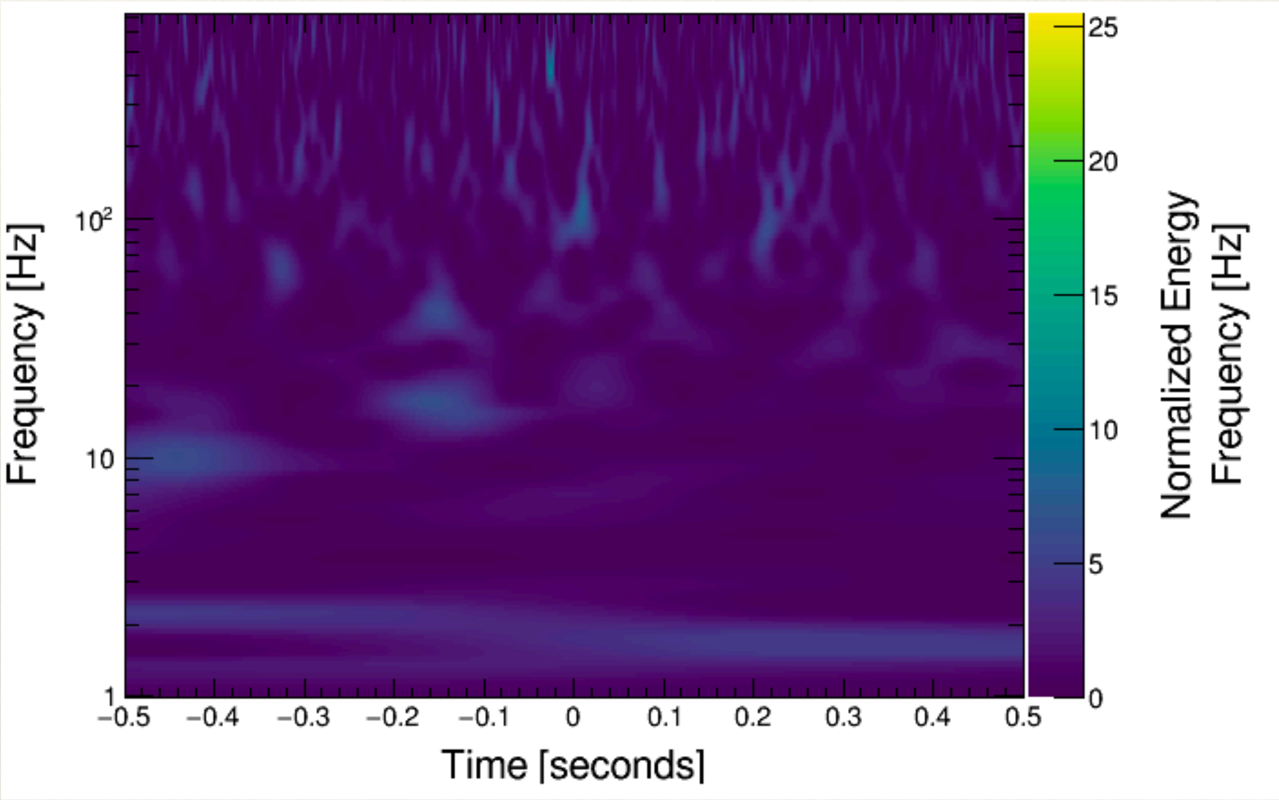


GW170202

L1

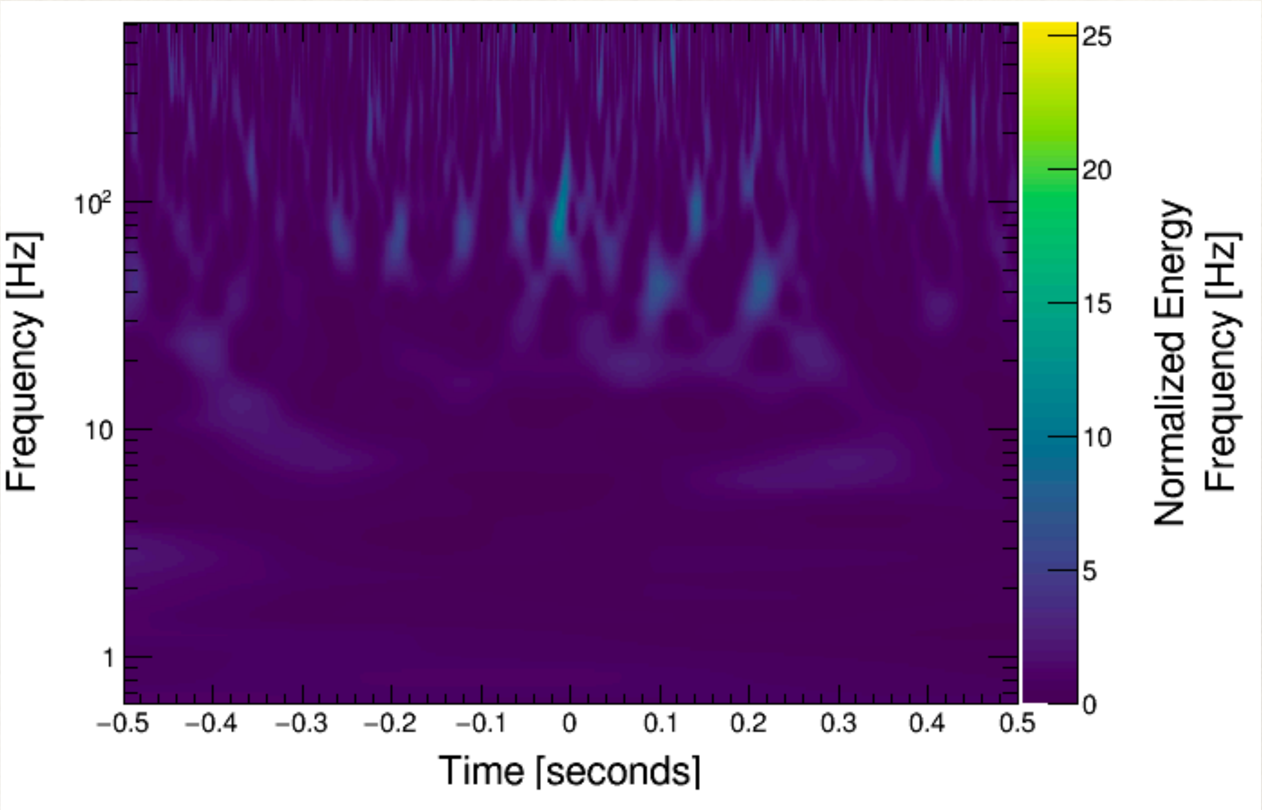


H1

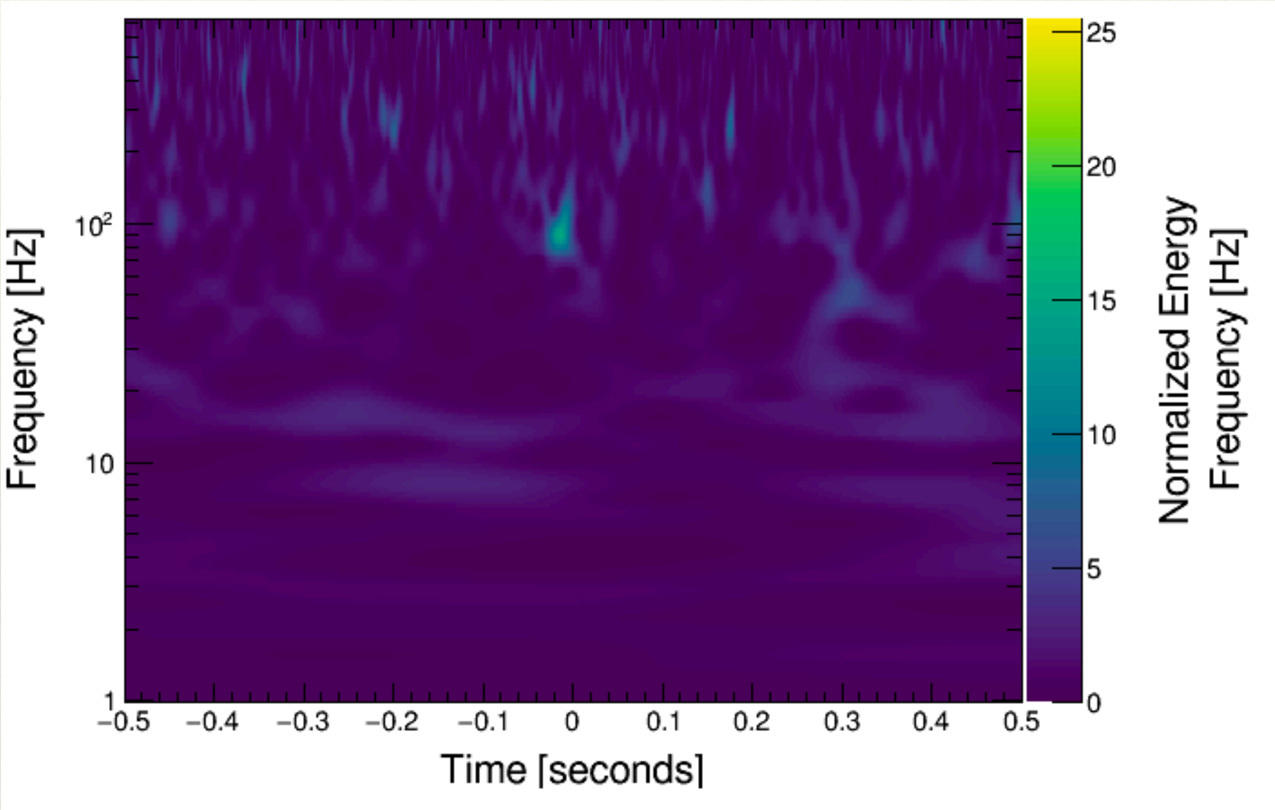


GW170403

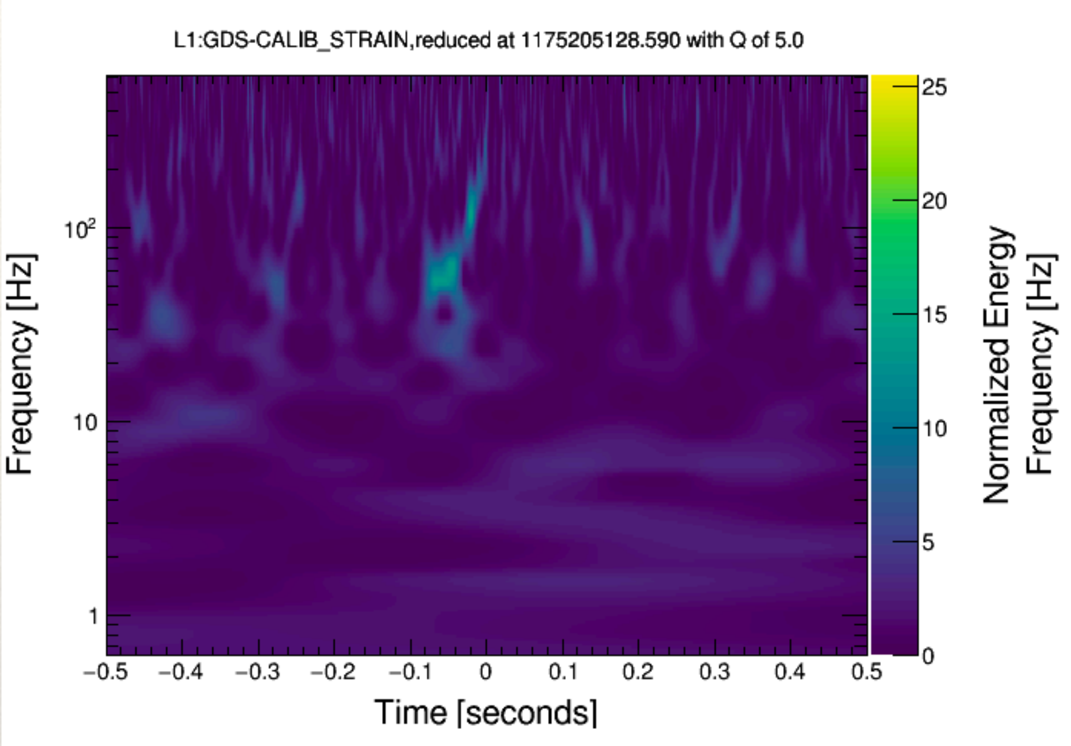
L1

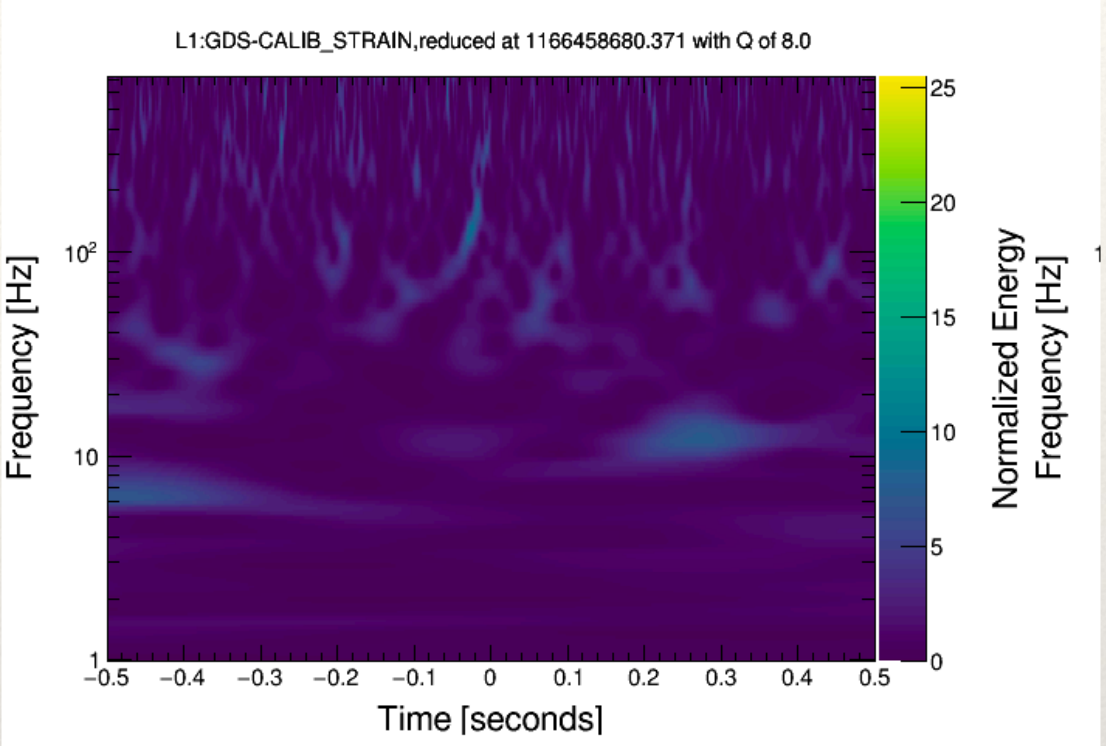


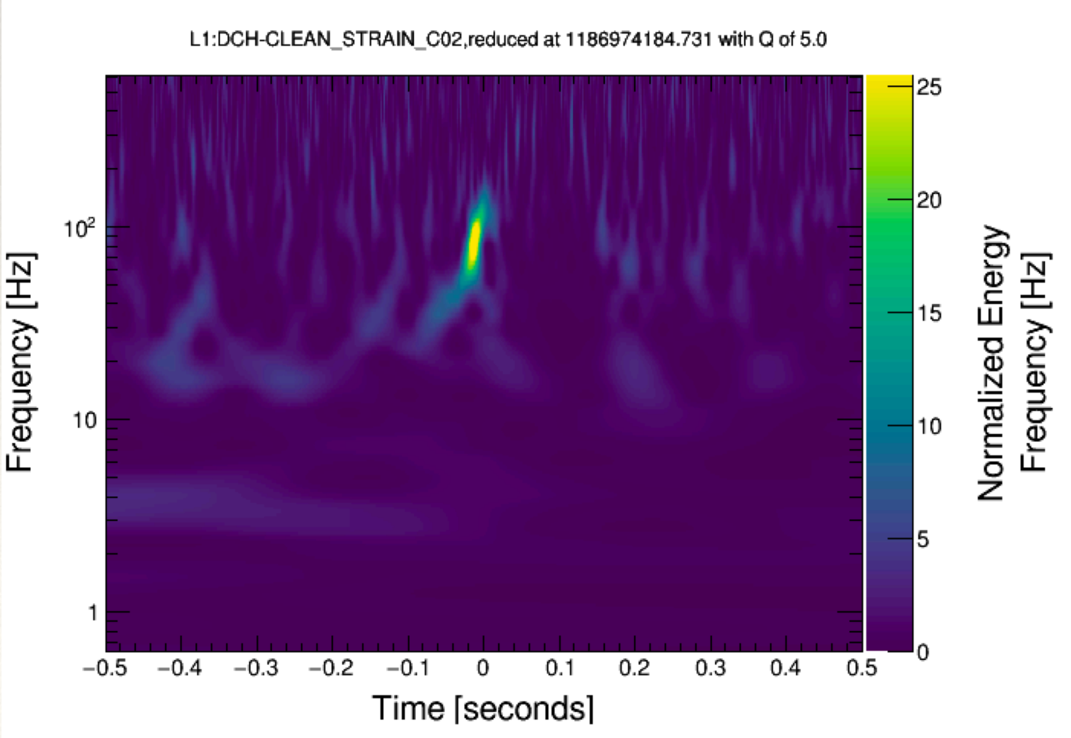
H1

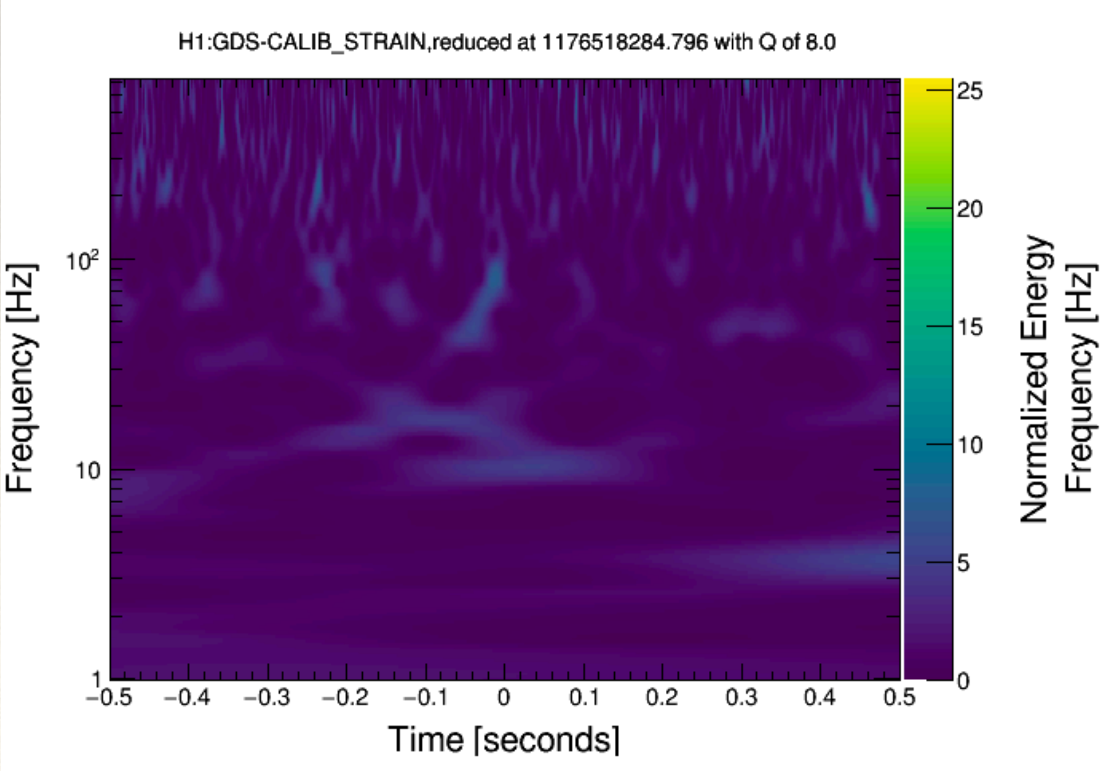


Some NEW interesting one-detector events









What is the sensitivity increase of the new search?

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- The correct answer is “I don’t know yet”

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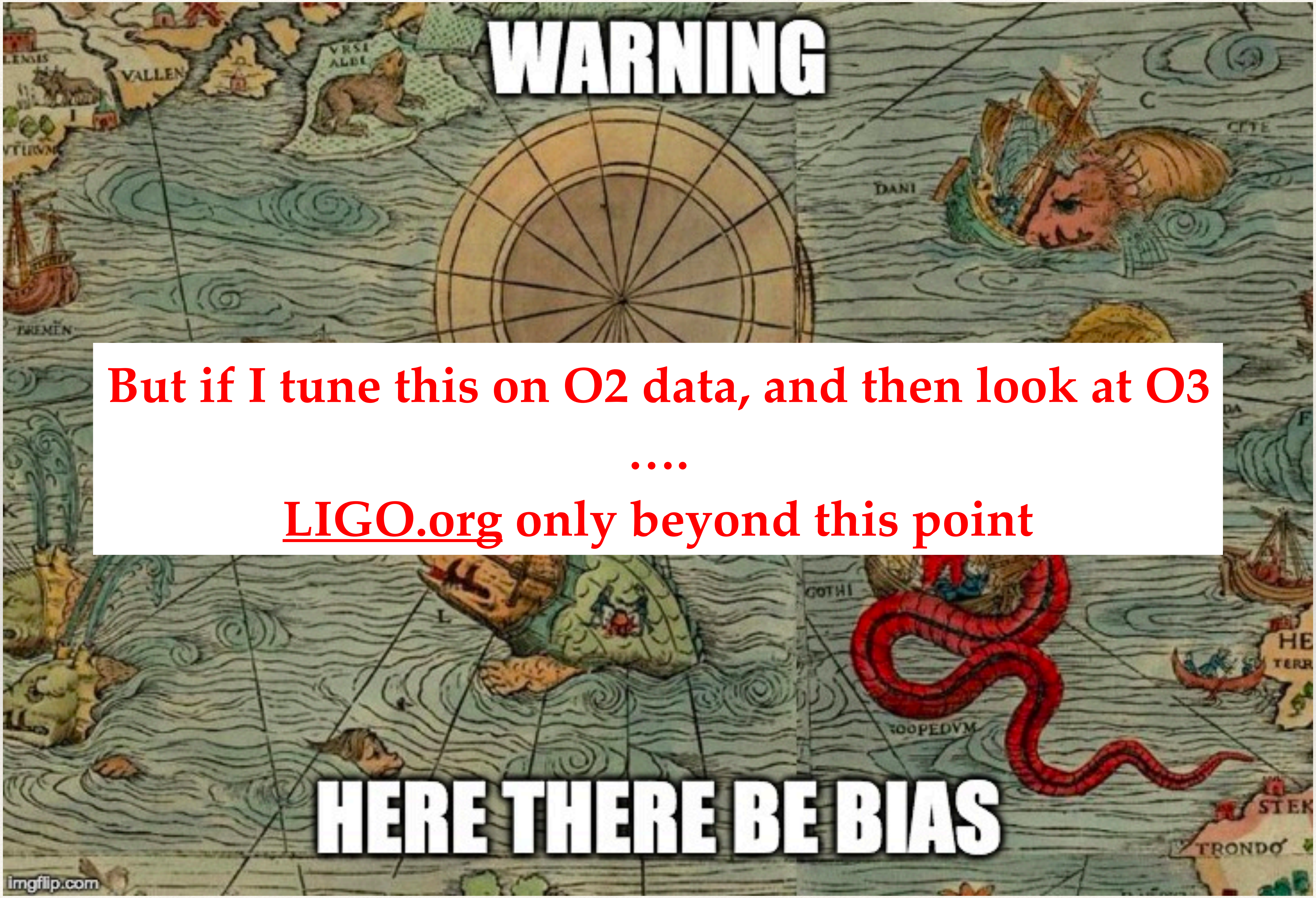
- Richard asked me this
- The correct answer is “I don’t know yet”
- But there’s no LIGO internal review in sight, so let’s get out the envelope:
  - ***ROUGHLY***, the network SNR needed to reach a false alarm rate of 1 every 10 years drops from 9.1 to 8.3 (old to new)
  - (9.1 / 8.3)**3 = 1.32
  - 32% increase in sensitivity
  - I’ve ignored a few things here, but the number seems the same for both regions “3” and “4”

Conclusion (almost)

- I am able to largely reproduce the IAS results
- The improvement in sensitivity largely comes from a significant reduction in search space (IMO) … Also the aggressive cuts help, but would reduce sensitivity to some systems.
- More work to do here on our side!
  - I think IAS is still better at very high masses
  - From inspection of the loudest background events, we are still seeing some events that are clearly not real (and some events that may very well *be* real)
- A targeted low-amplitude BBH/BNS search alongside our existing broad-parameter space search seems like a smart move


WARNING
HERE THERE BE BIAS
imgflip.com



But if I tune this on O2 data, and then look at O3

....

LIGO.org only beyond this point