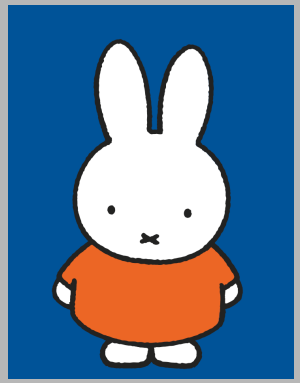
Nijntje: A Null-stream-based glitch mitigation algorithm



Harsh Narola

h.b.narola@uu.nl

In collaboration with Peter T.H. Pang, Thibeau Wouters, Isaac C. F. Wong, Melissa Lopez, Luca Negri, Milan Wills, Francesco Cireddu, Tom Dooney, Sumit Kumar, Justin Janquart, Chris Van Den Broeck, Tjonnie G. F. Li, and Anuradha Samajdar

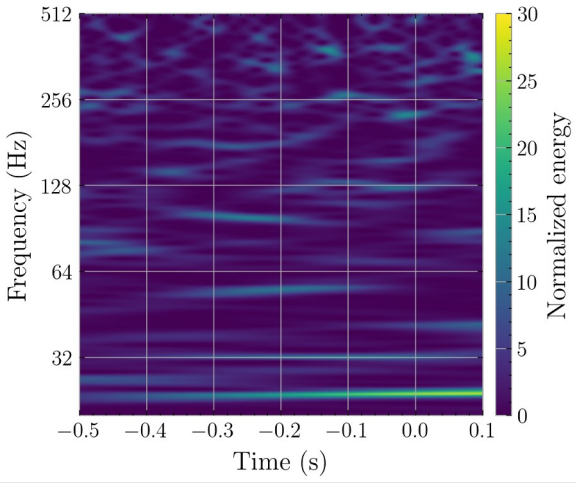
Universiteit Utrecht

Nikhef

KU LEUVEN

UCLouvain

ROYAL OBSERVATORY OF BELGIUM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Time (s)
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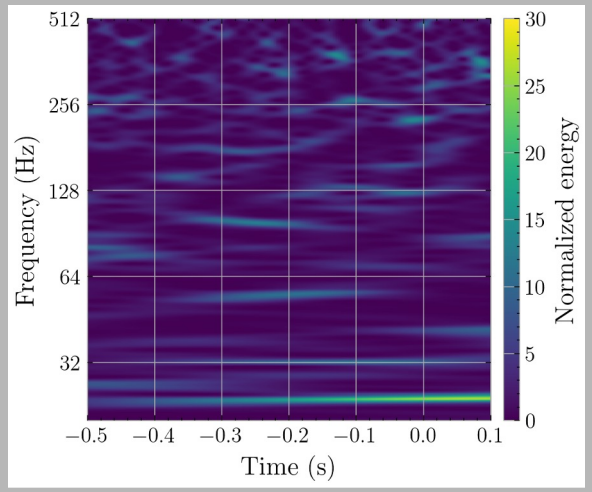
Normalized energy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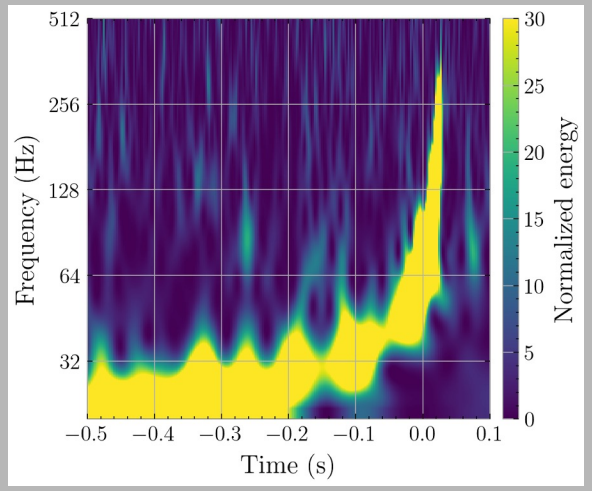
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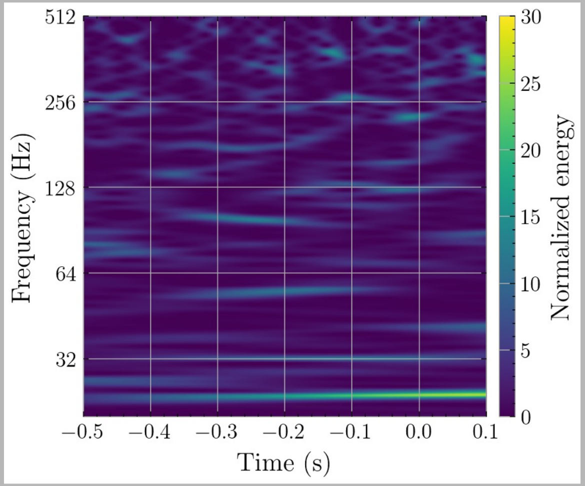
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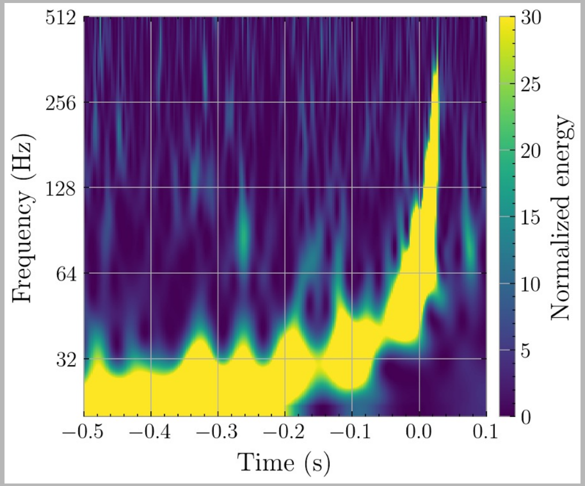
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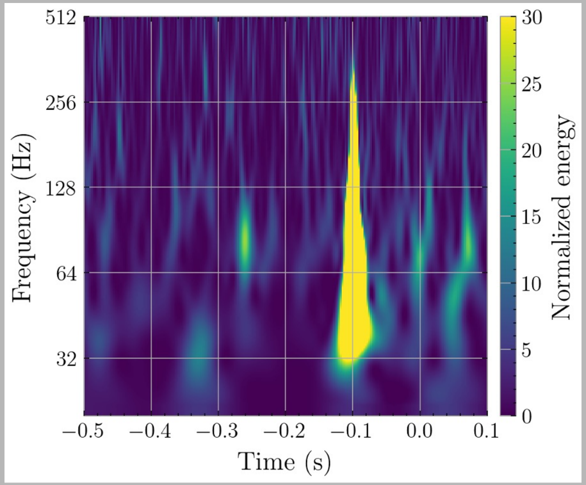
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Time (s)
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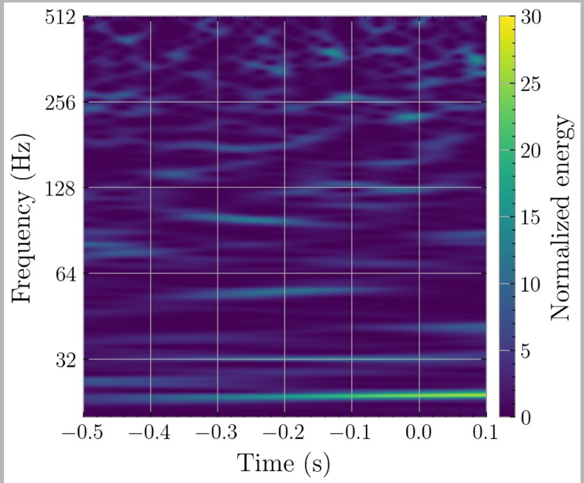
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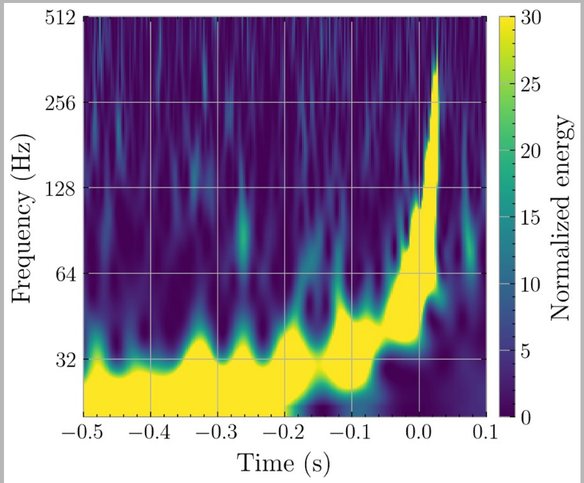
Normalized energy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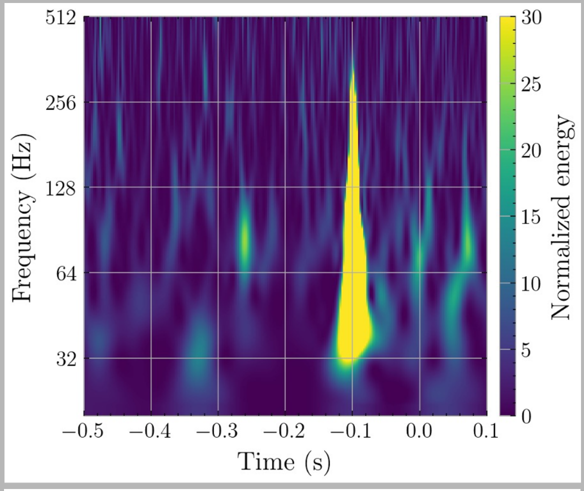
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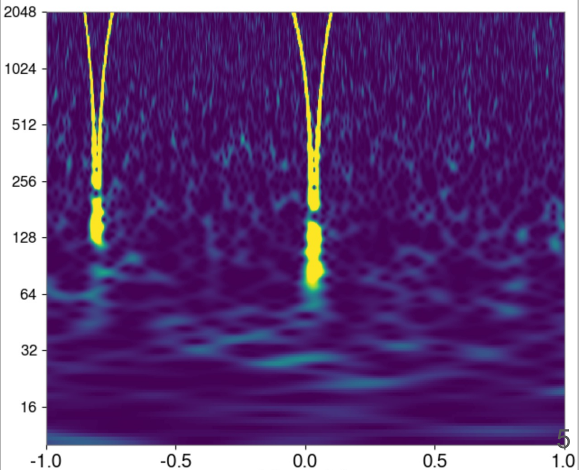
Normalized energy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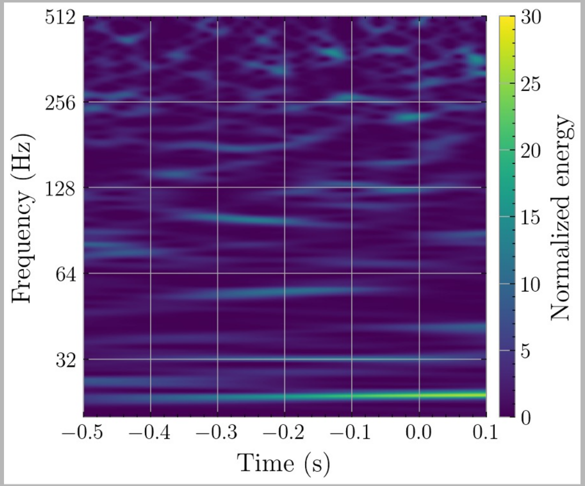
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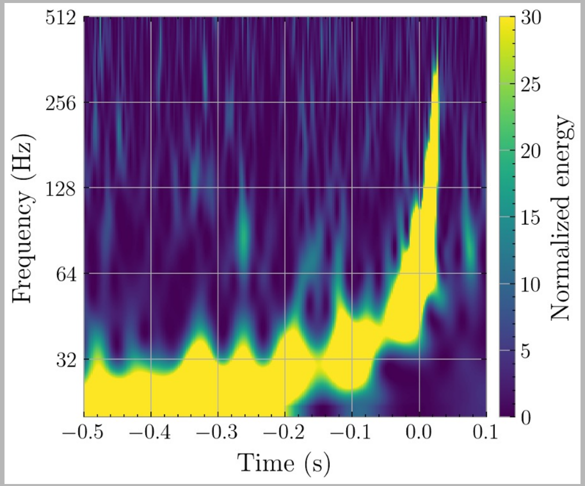
Normalized energy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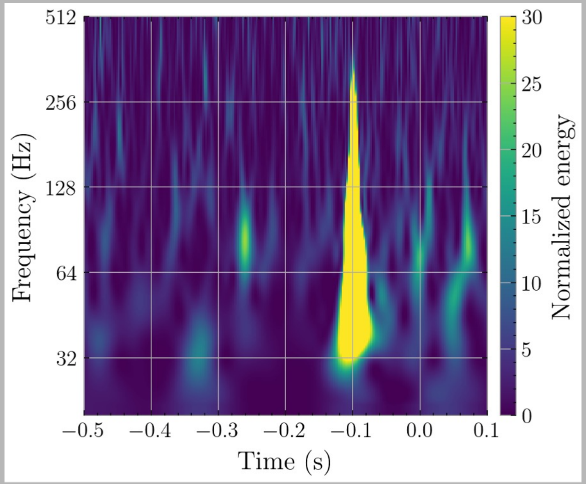
Normalized energy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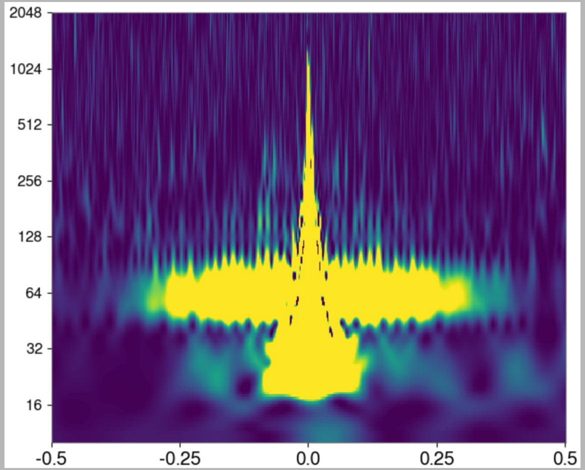
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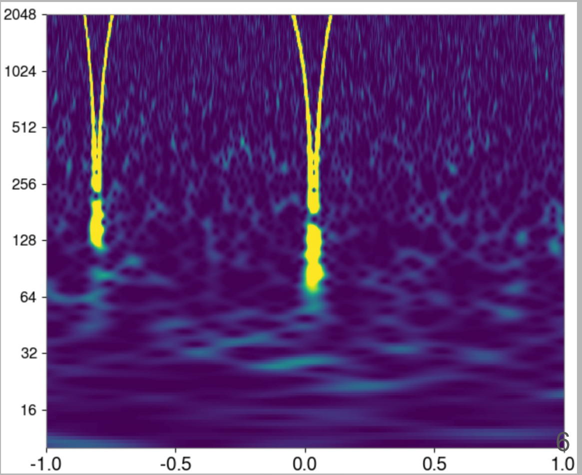
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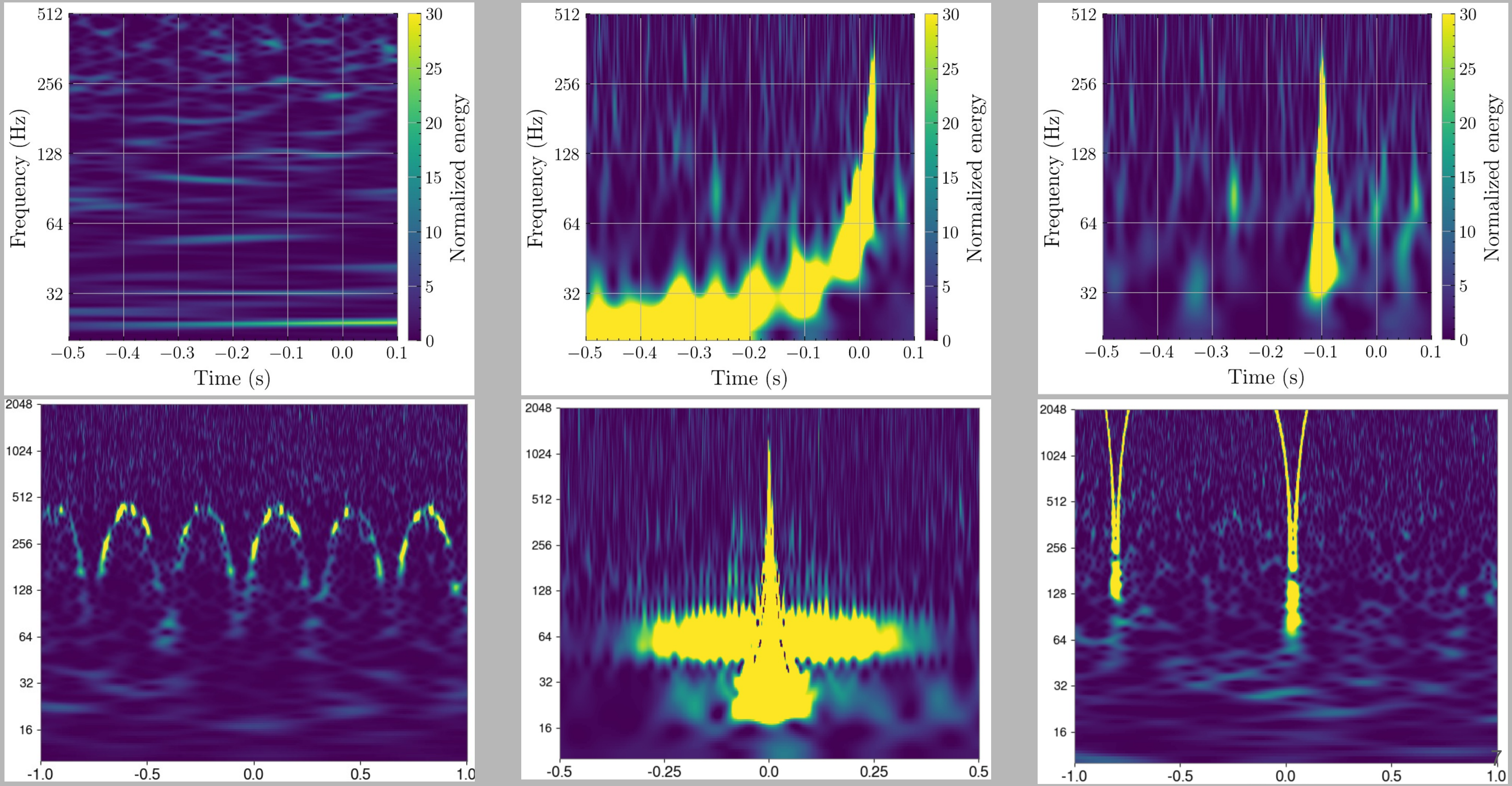
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Time (s)
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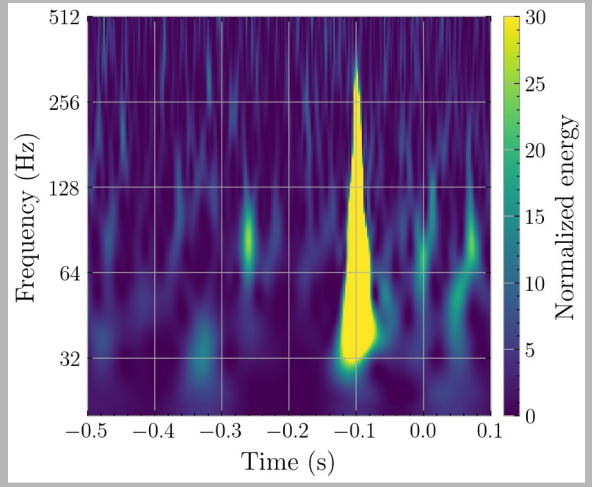
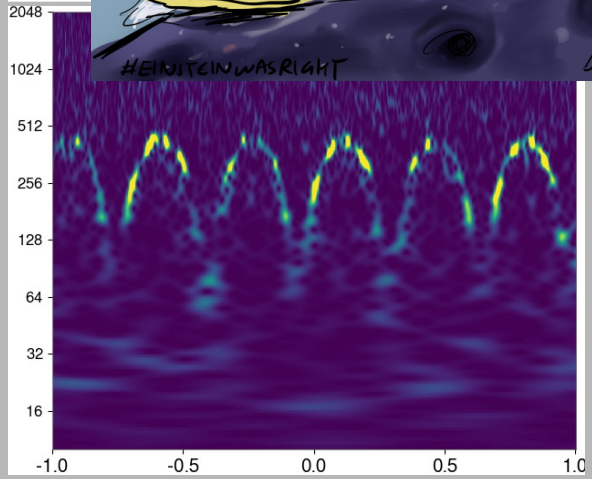
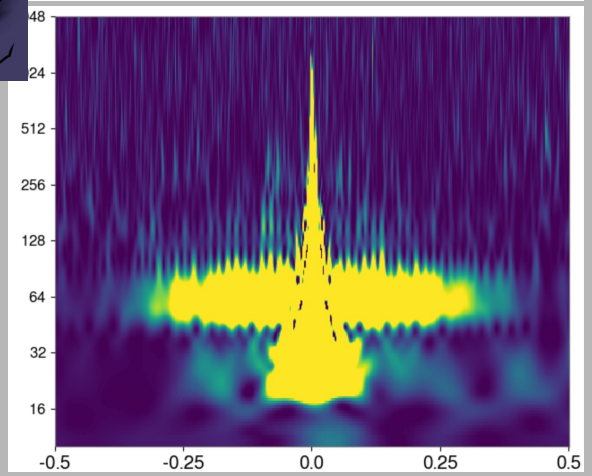
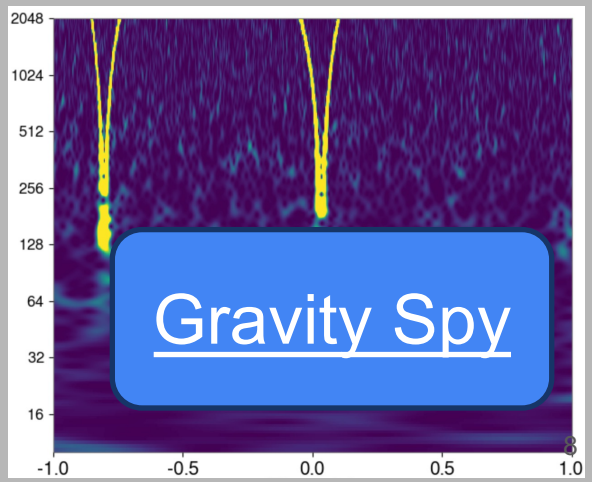
Why are you showing glitches? We are in the business of detecting waves!

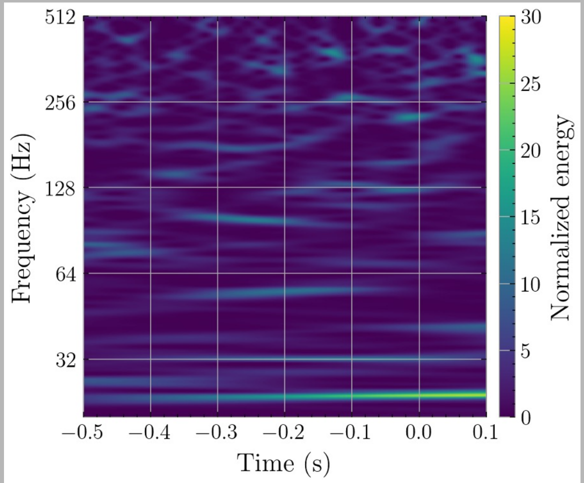


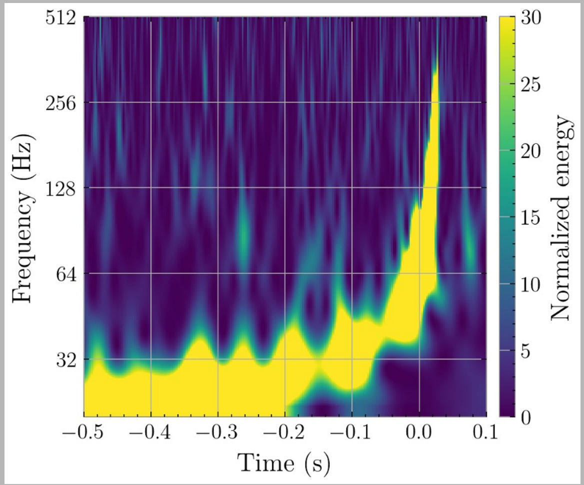


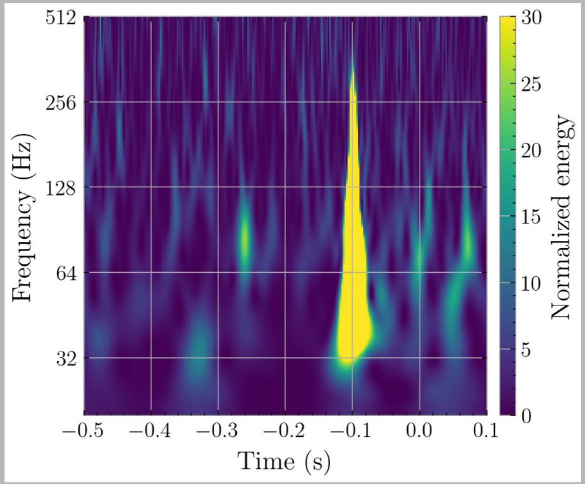


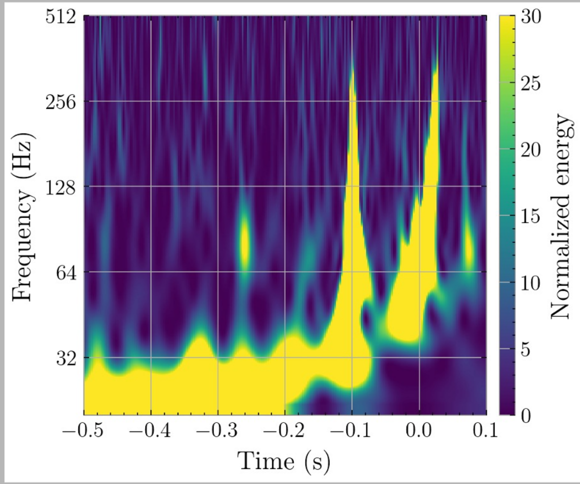


Gravity Spy

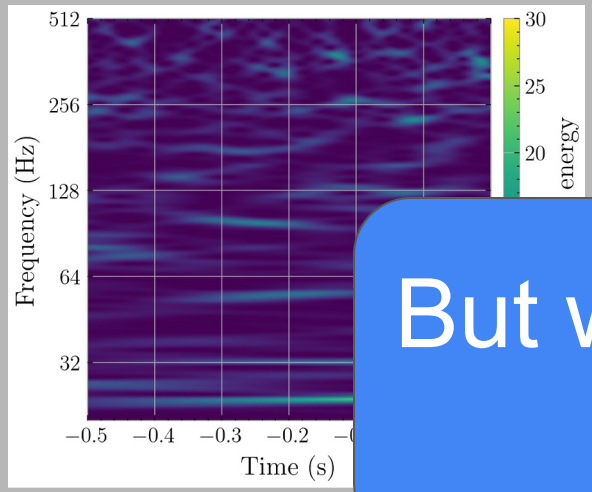


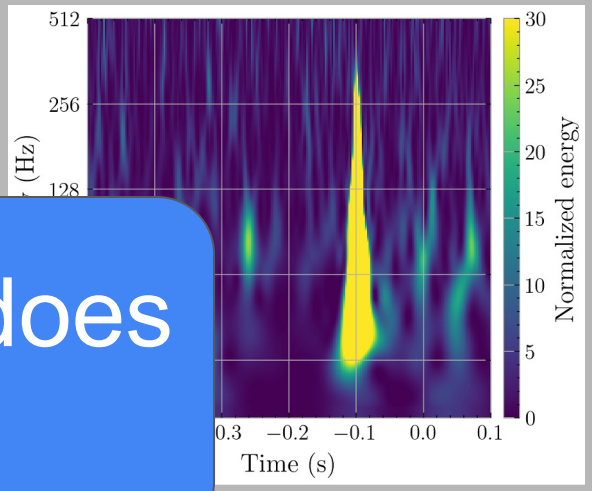




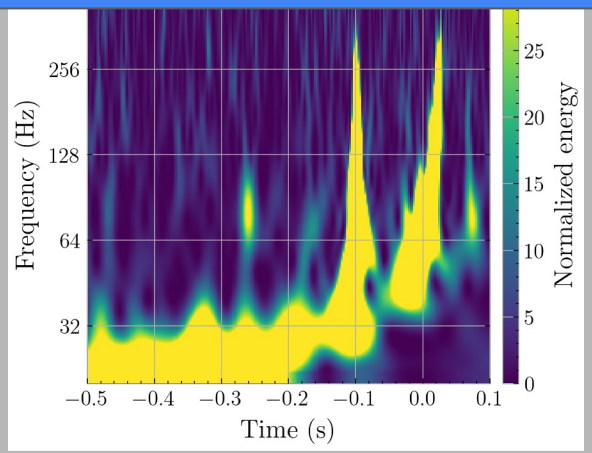


Glitch overlapping with a GW signal

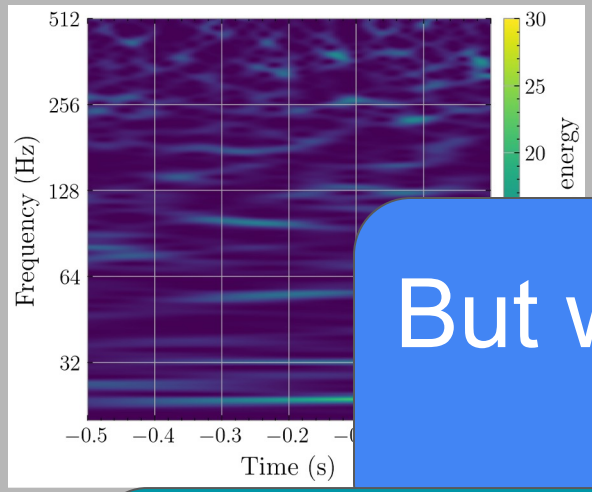


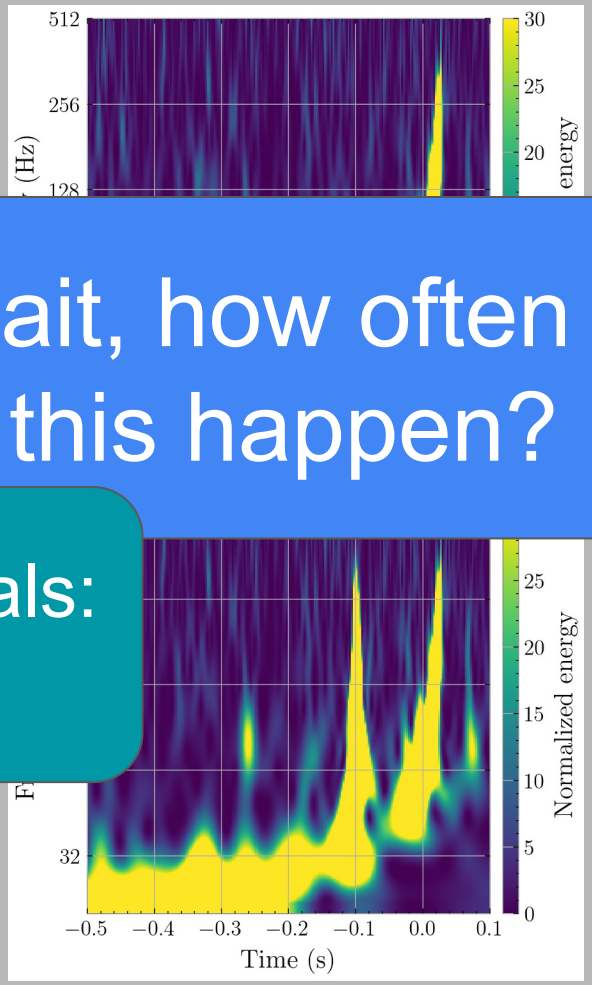


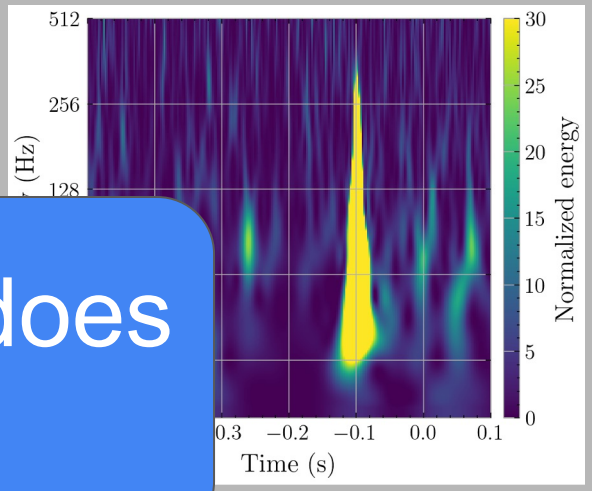
But wait, how often does this happen?



Glitch overlapping with a GW signal



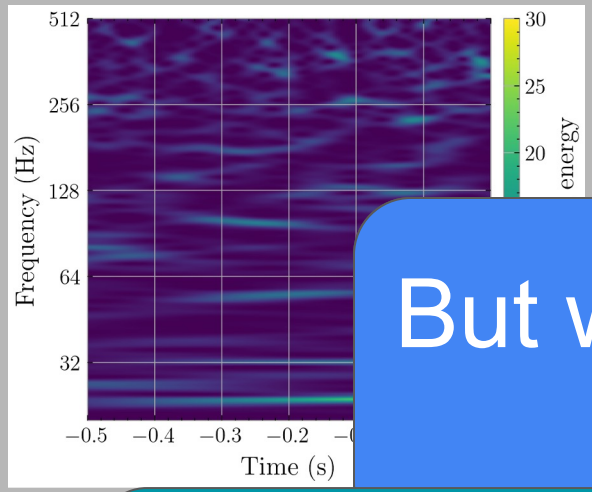


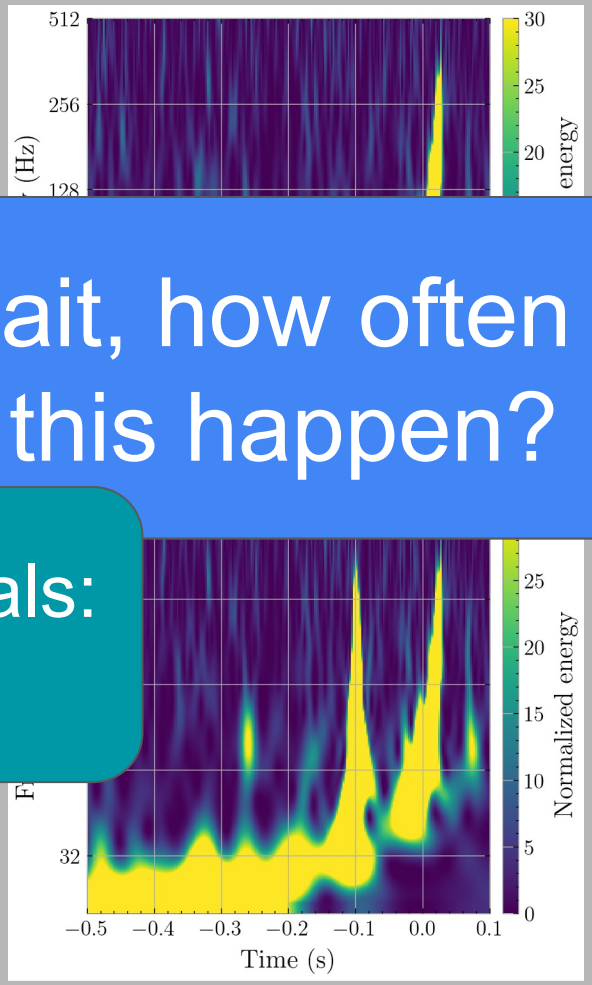


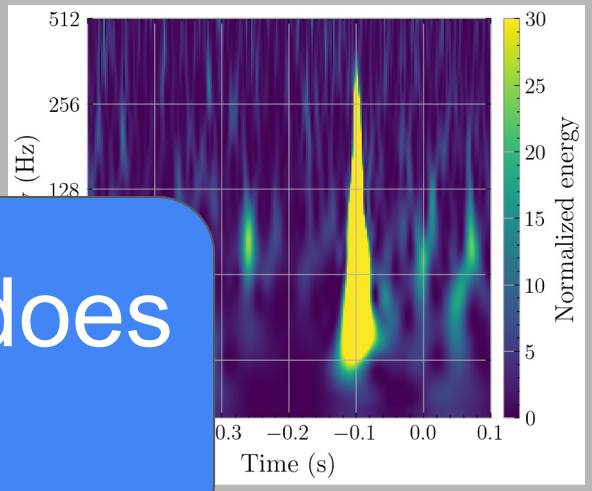
But wait, how often does this happen?

Total GW signals:
[?] / 90

Glitch overlapping with a GW signal



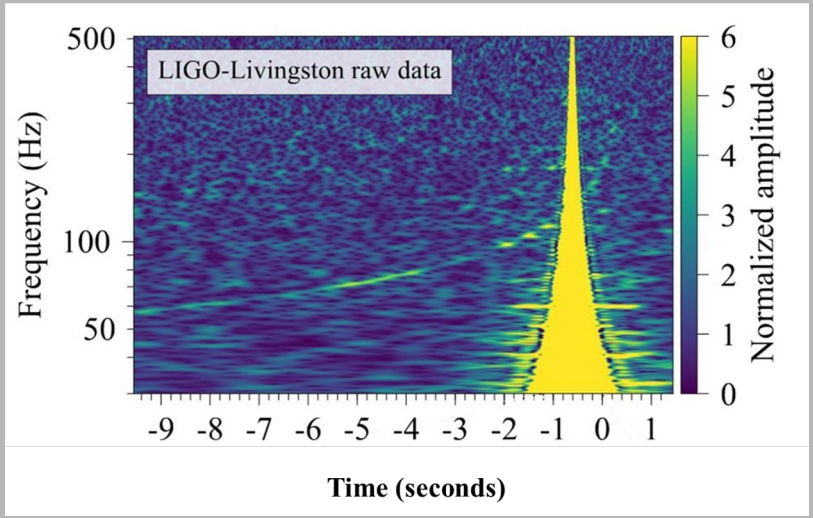




But wait, how often does this happen?

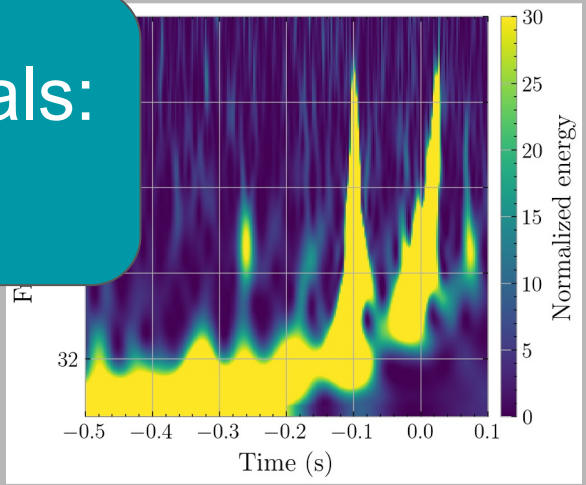
Total GW signals:
25 / 90

Glitch overlapping with a GW signal

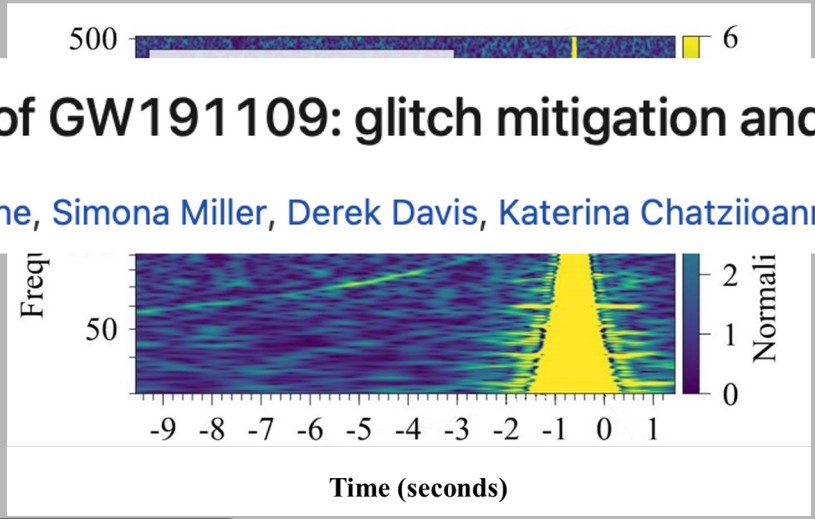


Binary Neutron Star
GW170817

Total GW signals:
25 / 90



Glitch
overlapping with
a GW signal



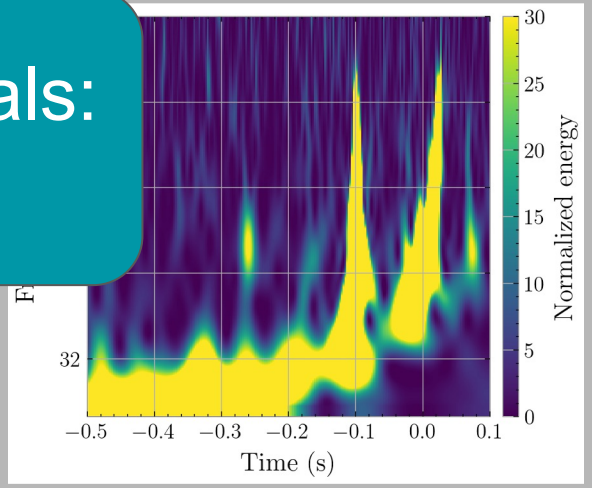
The anti-aligned spin of GW191109: glitch mitigation and its implications

Rhiannon Udall, Sophie Hourihane, Simona Miller, Derek Davis, Katerina Chatziioannou

arXiv: **2409.03912**

Binary Neutron Star GW170817

Total GW signals:
25 / 90



Glitch overlapping with a GW signal

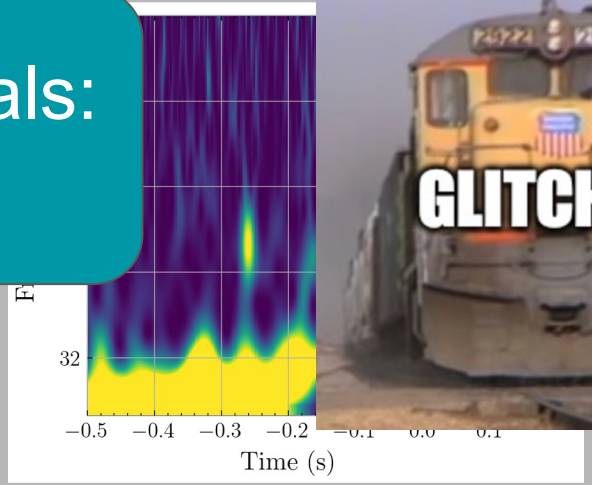
The anti-aligned spin of GW191109: glitc

Rhiannon Udall, Sophie Hourihane, Simona Miller, Derek Dav

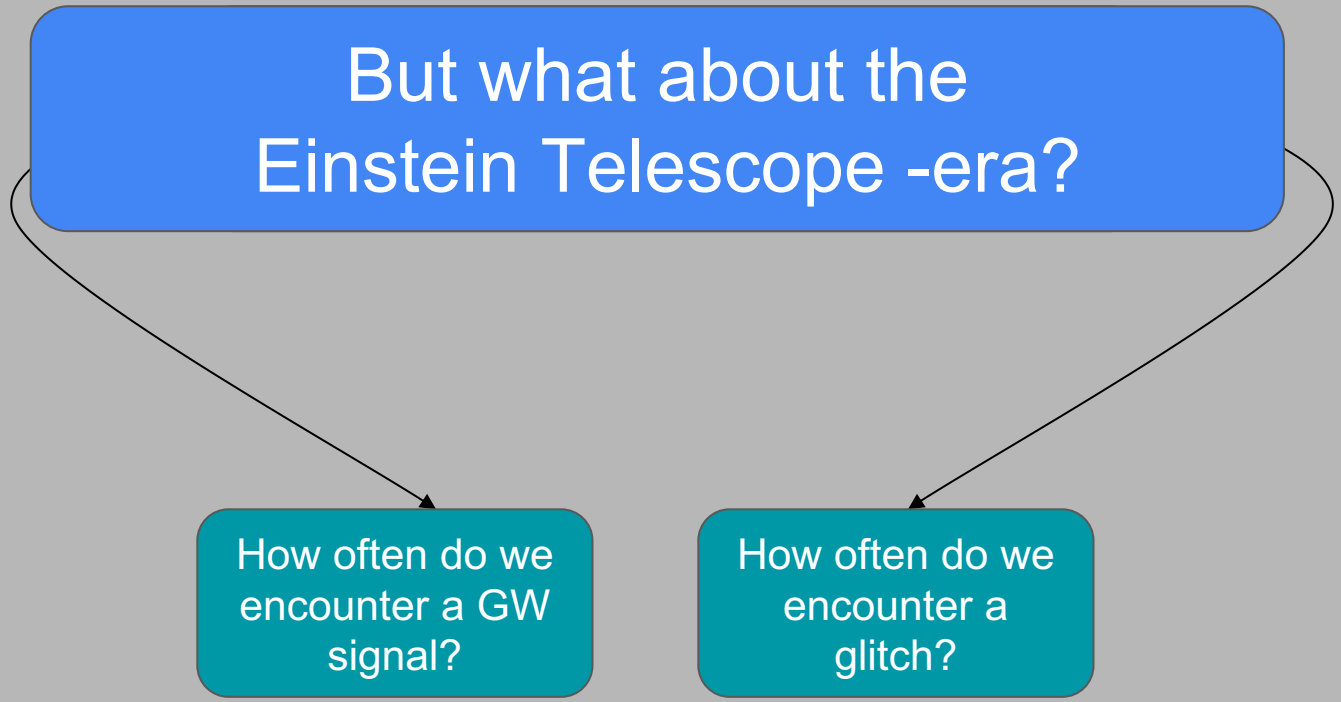
3912

Star

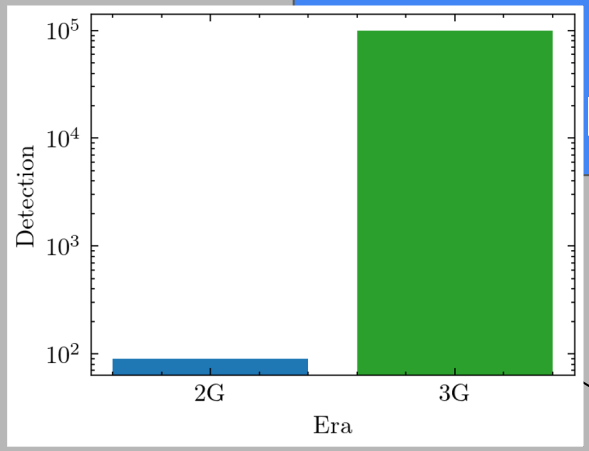
Total GW signals:
25 / 90



But what about the
Einstein Telescope -era?


But what about the
Einstein Telescope -era?
How often do we encounter a GW signal?
How often do we encounter a glitch?

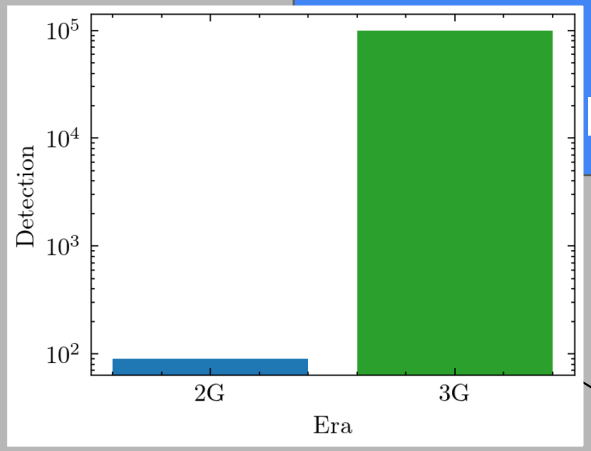
But what about the
nstein Telescope -era?



How often do we encounter a GW signal?

How often do we encounter a glitch?

But what about the nstein Telescope -era?

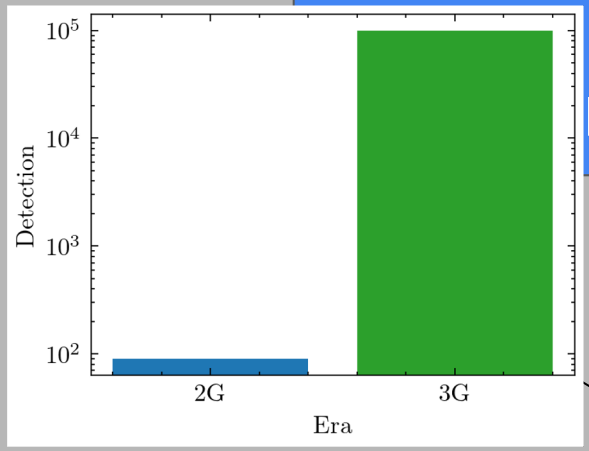


How often do we encounter a GW signal?

~1 every 5 minutes (Branchesi+2023, Samajdar+2021)

How often do we encounter a glitch?

But what about the nstein Telescope -era?



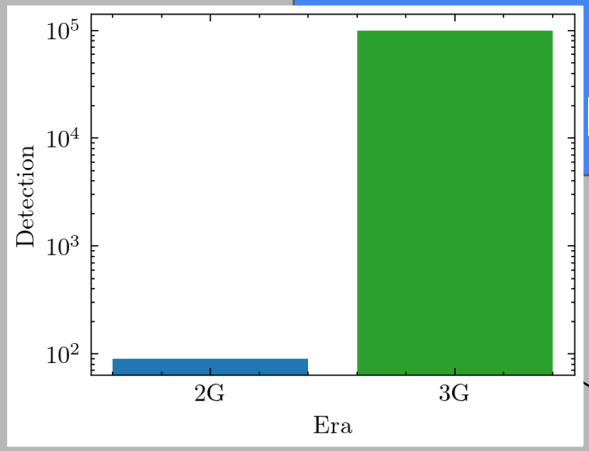
How often do we encounter a GW signal?

~1 every 5 minutes (Branchesi+2023, Samajdar+2021)

How often do we encounter a glitch?

~1 per minute (Hourihane+2022)

But what about the nstein Telescope -era?



How often do we encounter a GW signal?

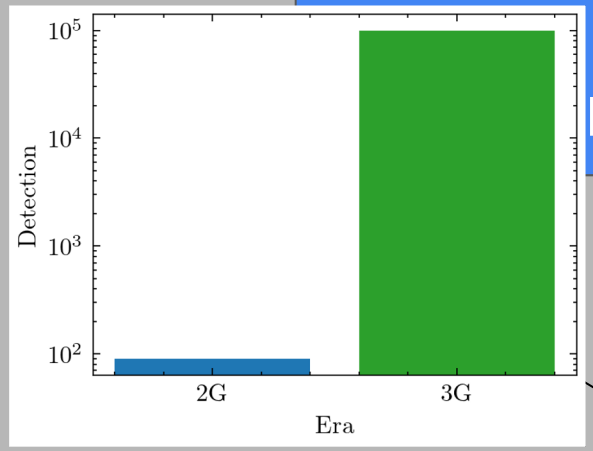
~1 every 5 minutes (Branchesi+2023, Samajdar+2021)

How often do we encounter a glitch?

~1 per minute (Hourihane+2022)

Overlap ~1 per day

But what about
nstein Telescope -era?



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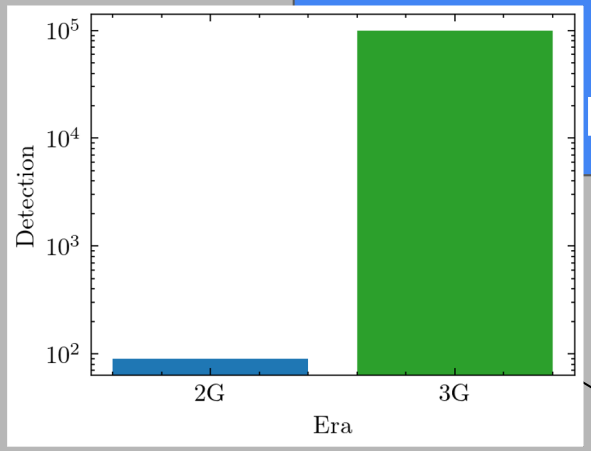
~1 per minute (Hourihane+2022)

Overlap ~1 per day



But what about nstein Telescope -era?

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How often do we encounter a glitch?

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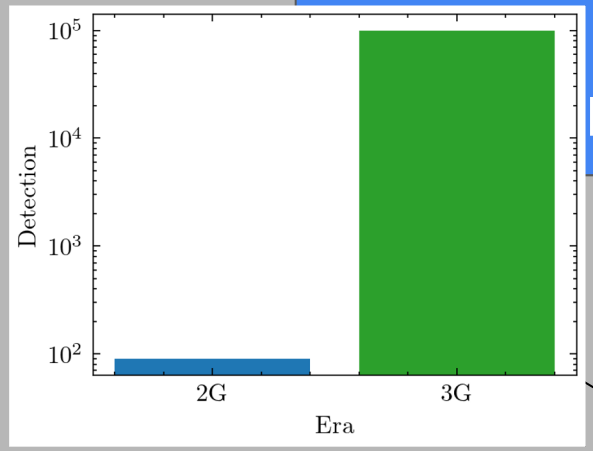
Overlap ~1 per day



But w
nstein -era ?

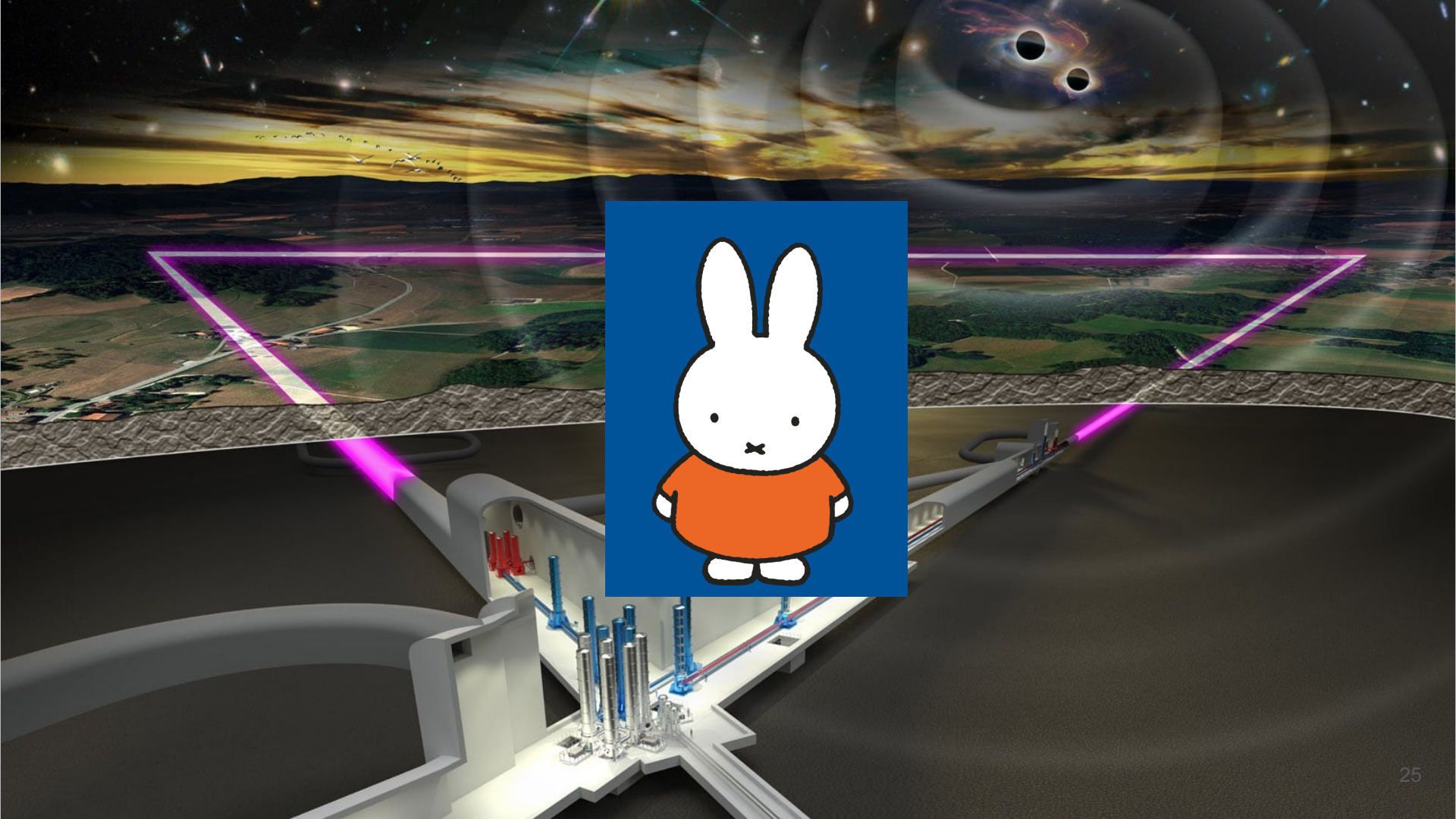
How often do we encounter a GW signal?

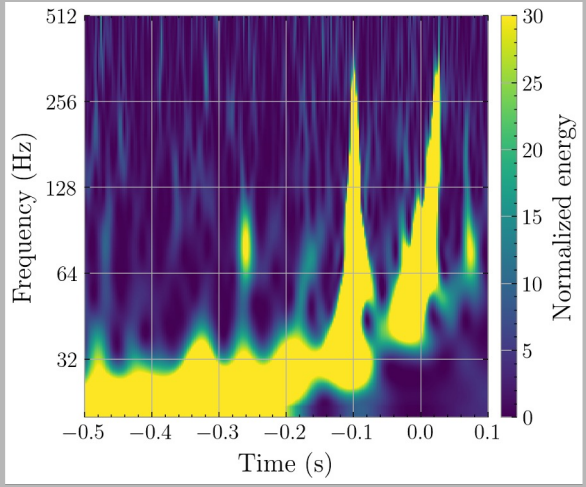
~1 every 5 minutes (Branchesi+2023, Samajdar+2021)

How often do we encounter a glitch?

~1 per minute (Hourihane+2022)

Overlap ~1 per day

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Time (s)
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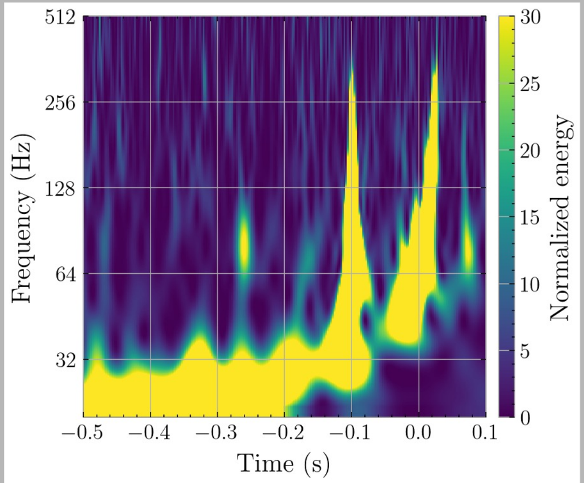
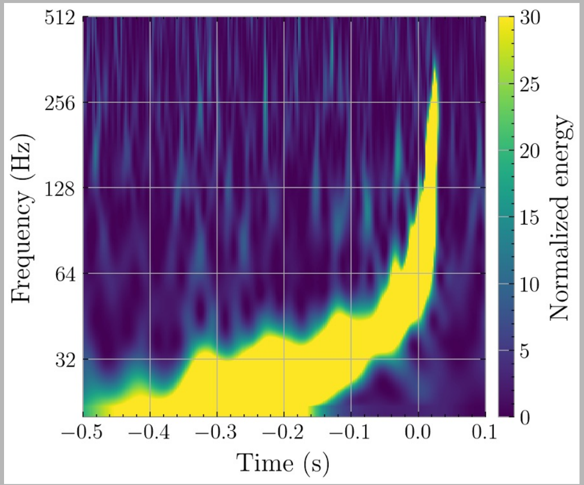
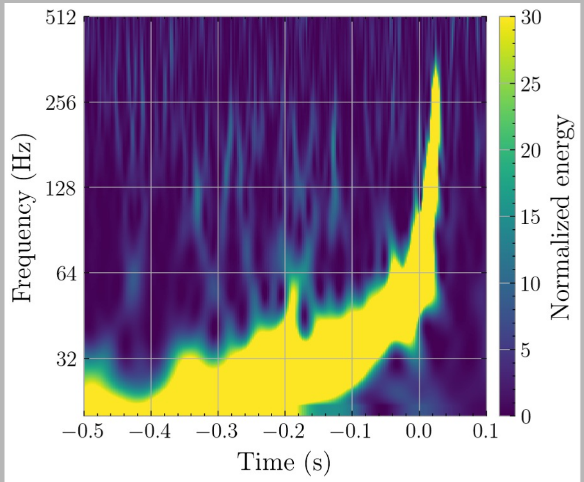
5
0
Normalized energy



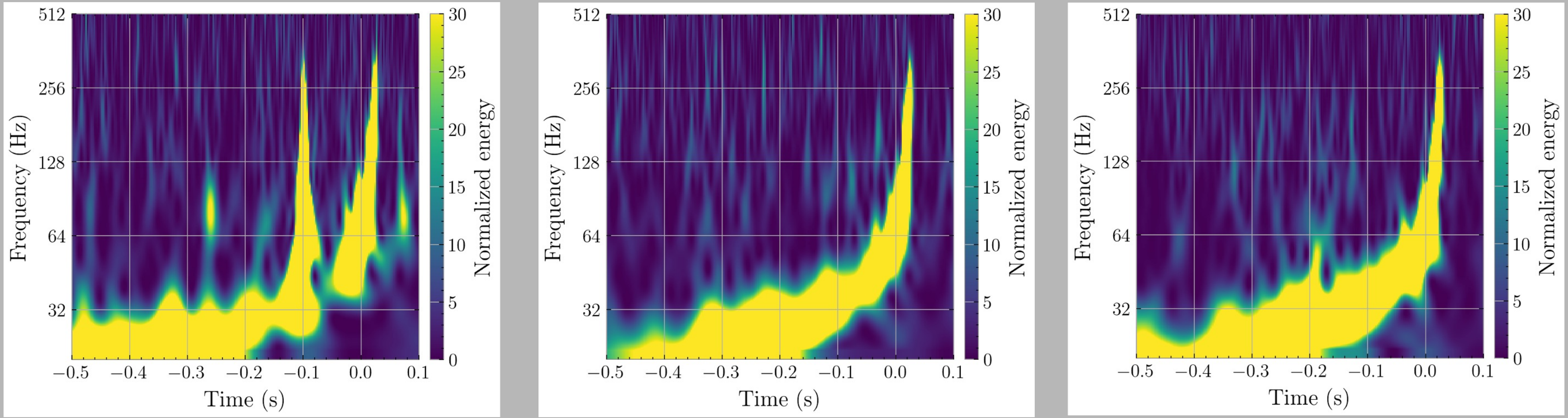
Frequency (Hz)
512
256
128
64
32
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy



Frequency (Hz)
512
256
128
64
32
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

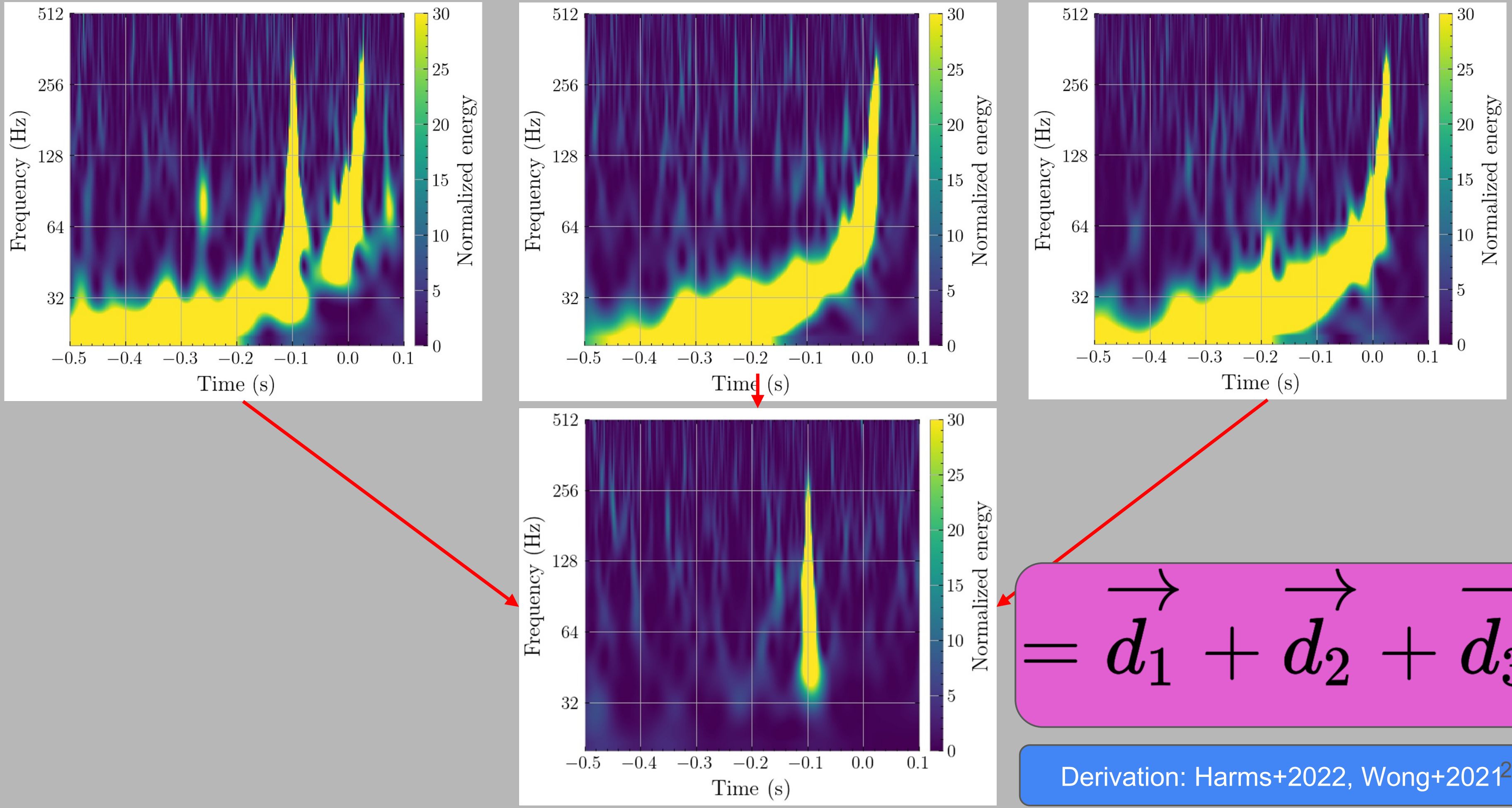


Frequency (Hz)
512
256
128
64
32
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy



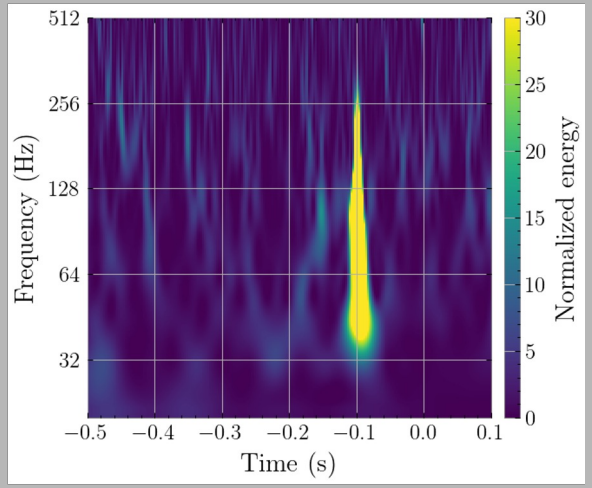
$$= \overrightarrow{d_1} + \overrightarrow{d_2} + \overrightarrow{d_3}$$

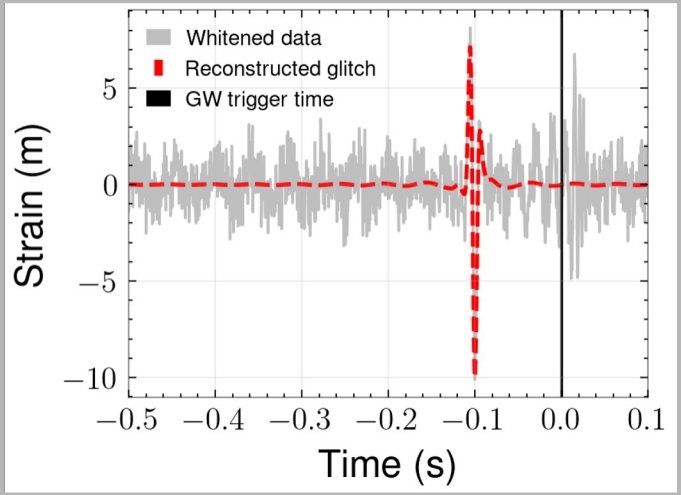
Derivation: Harms+2022, Wong+2021

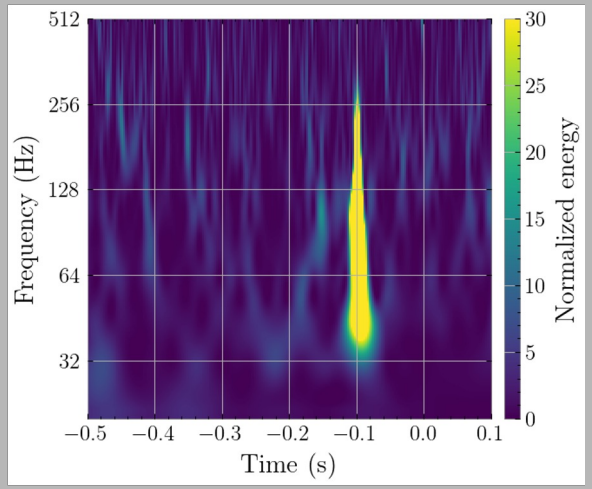


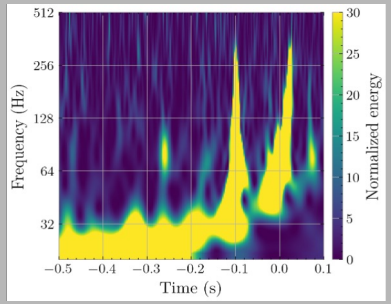
$$= \overrightarrow{d_1} + \overrightarrow{d_2} + \overrightarrow{d_3}$$

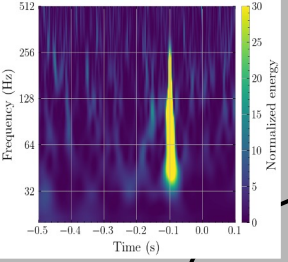
Derivation: Harms+2022, Wong+2021


512
256
128
64
32
Frequency (Hz)
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

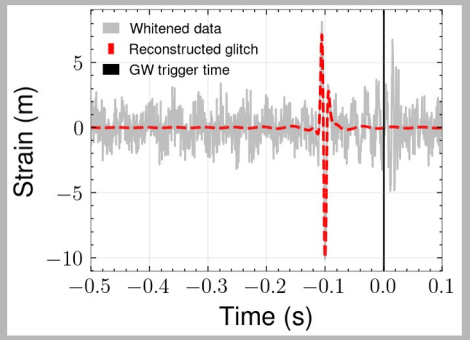

Whitened data
Reconstructed glitch
GW trigger time
Strain (m)
5
0
−5
−10
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)

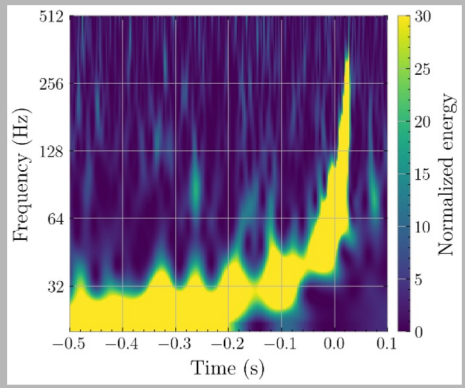

512
256
128
64
32
Frequency (Hz)
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

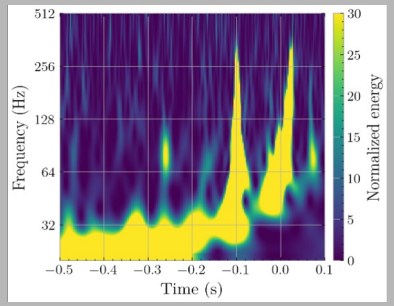

512
256
128
64
32
Frequency (Hz)
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

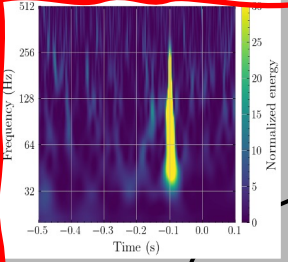


With the null stream

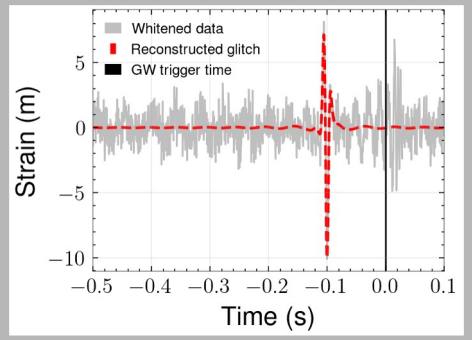


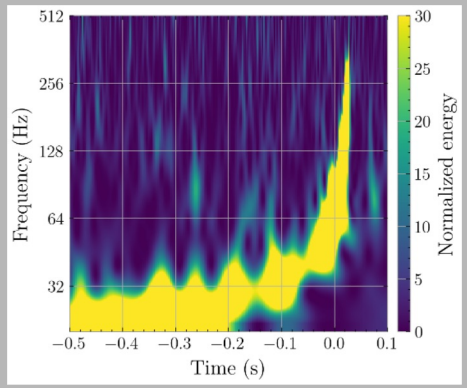


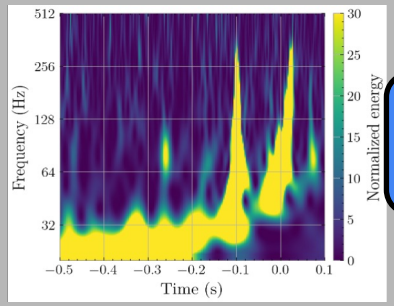




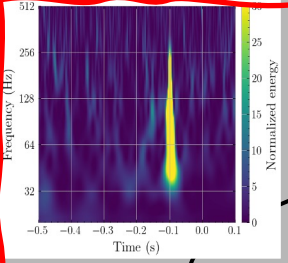
With the null stream



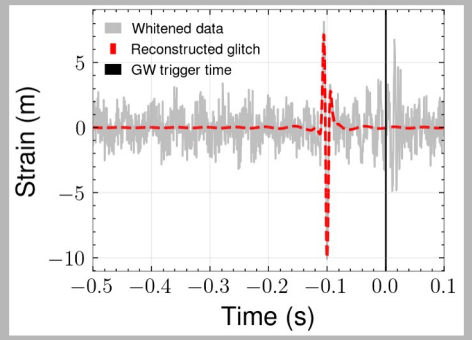


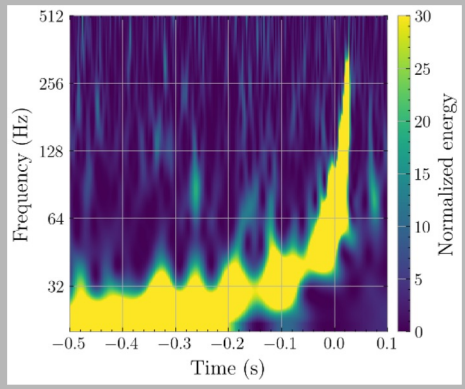


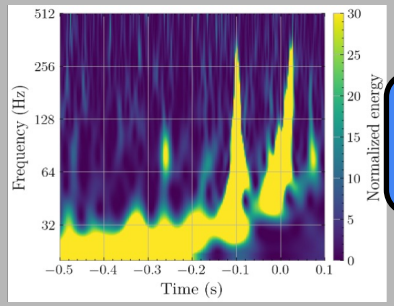
Nullstream Inspired Noise Transient Elimination - Nijntje



With the null stream

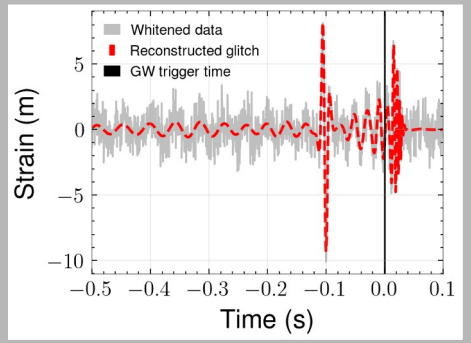


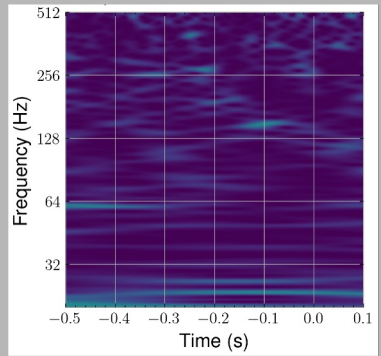




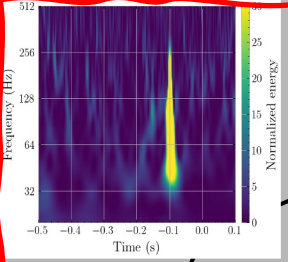
Nullstream Inspired Noise Transient Elimination - Nijntje

Without null stream

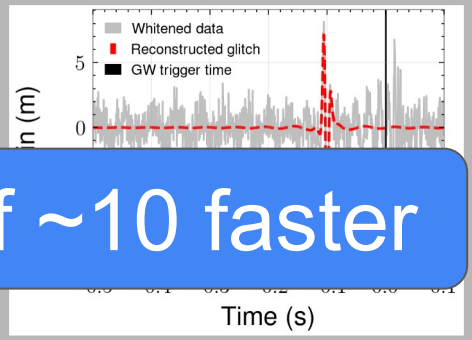


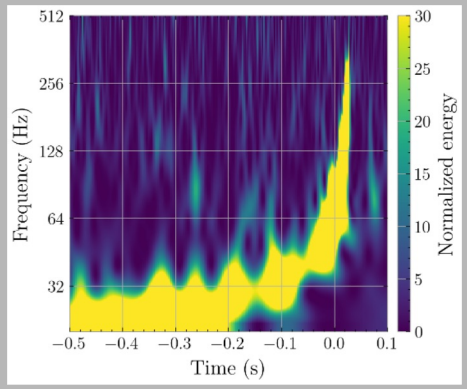


Results

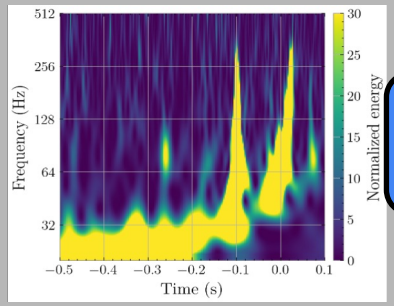


With the null stream



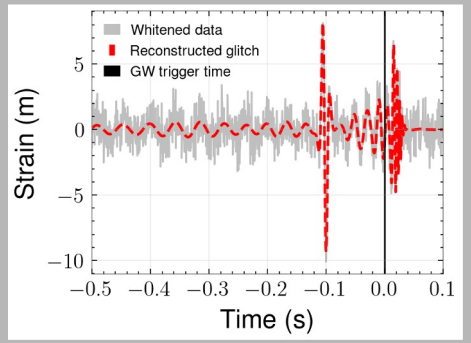


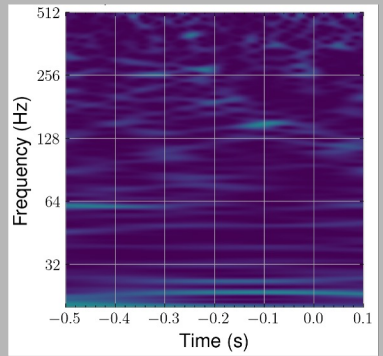
Factor of ~10 faster

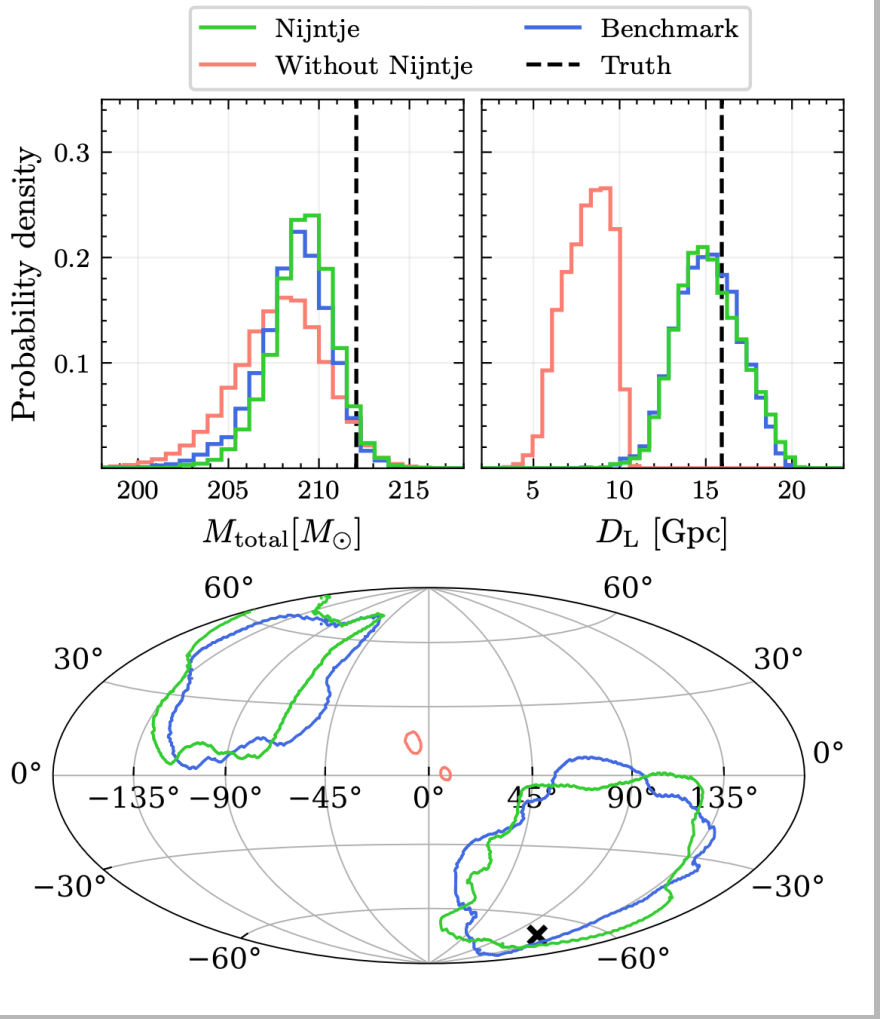


Nullstream Inspired Noise Transient Elimination - Nijntje

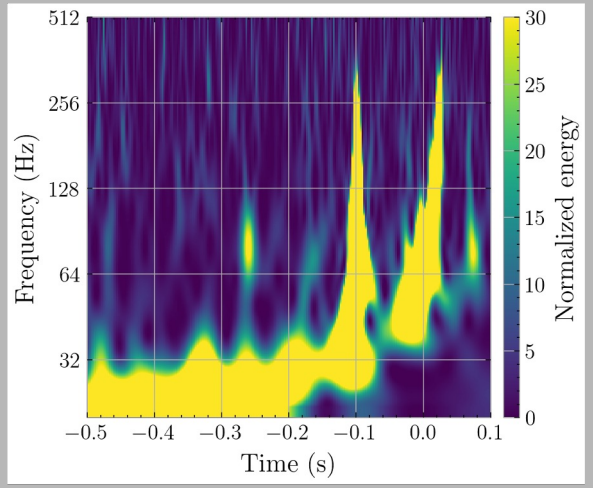
Without null stream

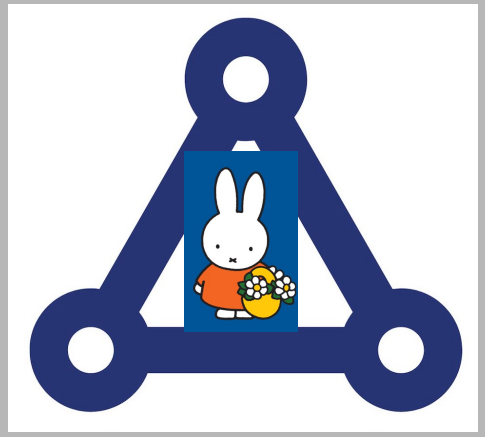


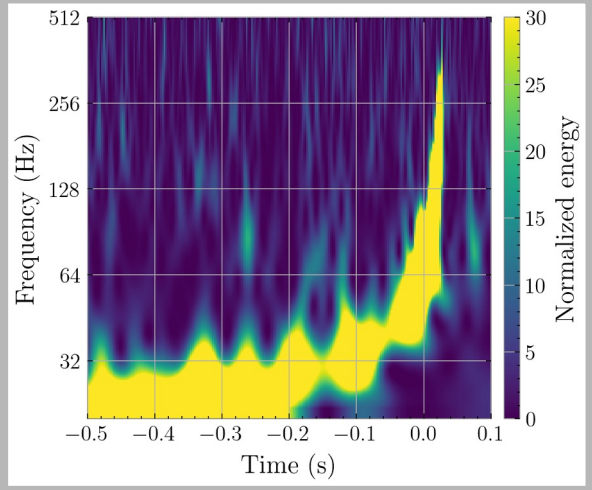



Nijntje
Without Nijntje
Benchmark
Truth
Probability density
0.3
0.2
0.1
200
205
210
215
$M_{\text{total}}[M_\odot]$
5
10
15
20
D_{L} [Gpc]
60°
30°
0°
−30°
−60°
−135°
−90°
−45°
0°
45°
90°
135°

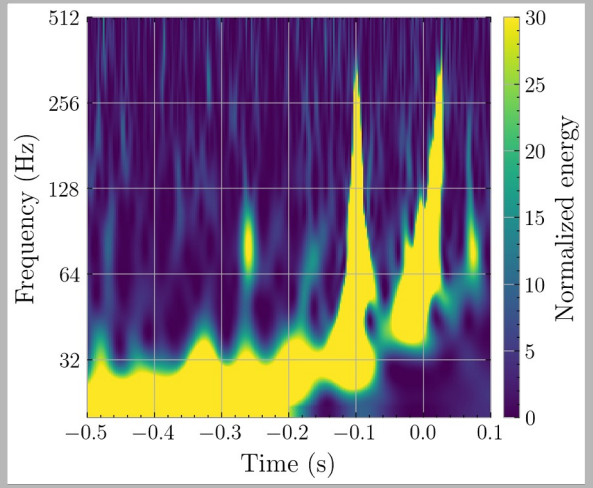
Summary

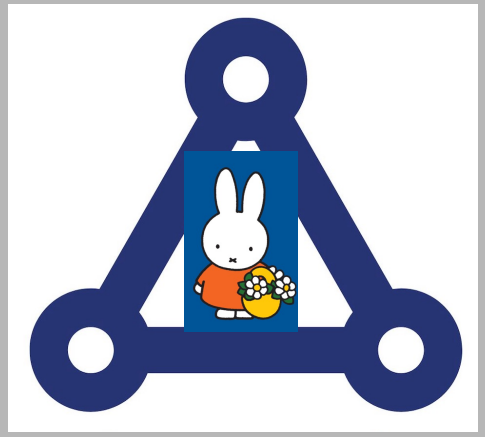

512
256
128
64
32
Frequency (Hz)
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

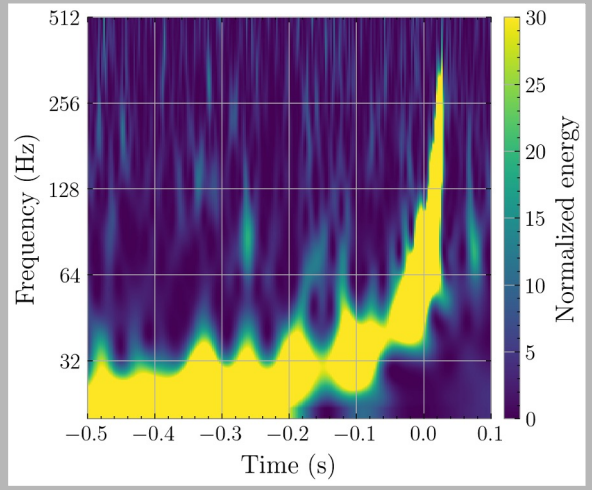



512
256
128
64
32
Frequency (Hz)
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
Time (s)
30
25
20
15
10
5
0
Normalized energy

Summary







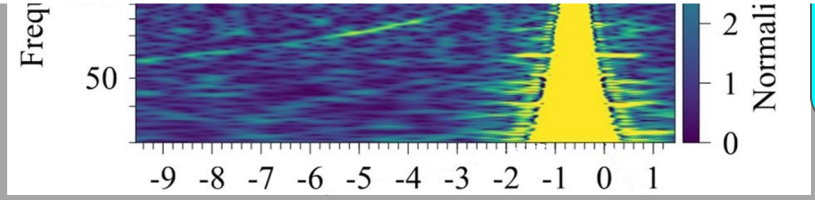
Paper out soon. Thank you!

Back up slides

The anti-aligned spin of GW191109: glitch mitigation and its implications

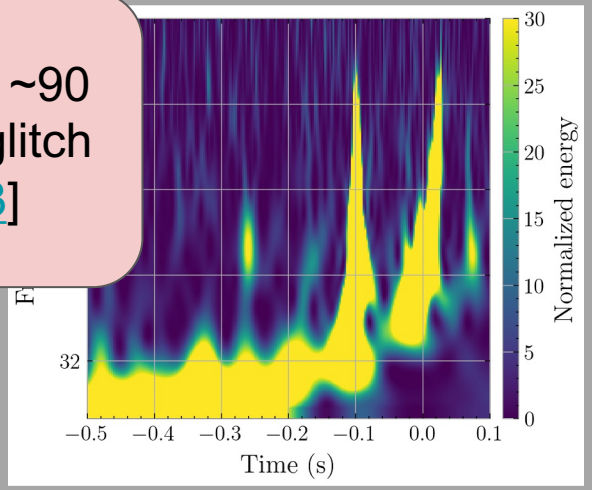
Rhiannon Udall, Sophie Hourihane, Simona Miller, Derek Davis, Katerina Chatziioannou

arXiv: **2409.03912**

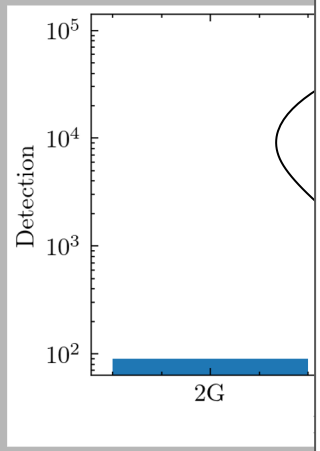


GW170817
(Image: ligo.caltech.edu)

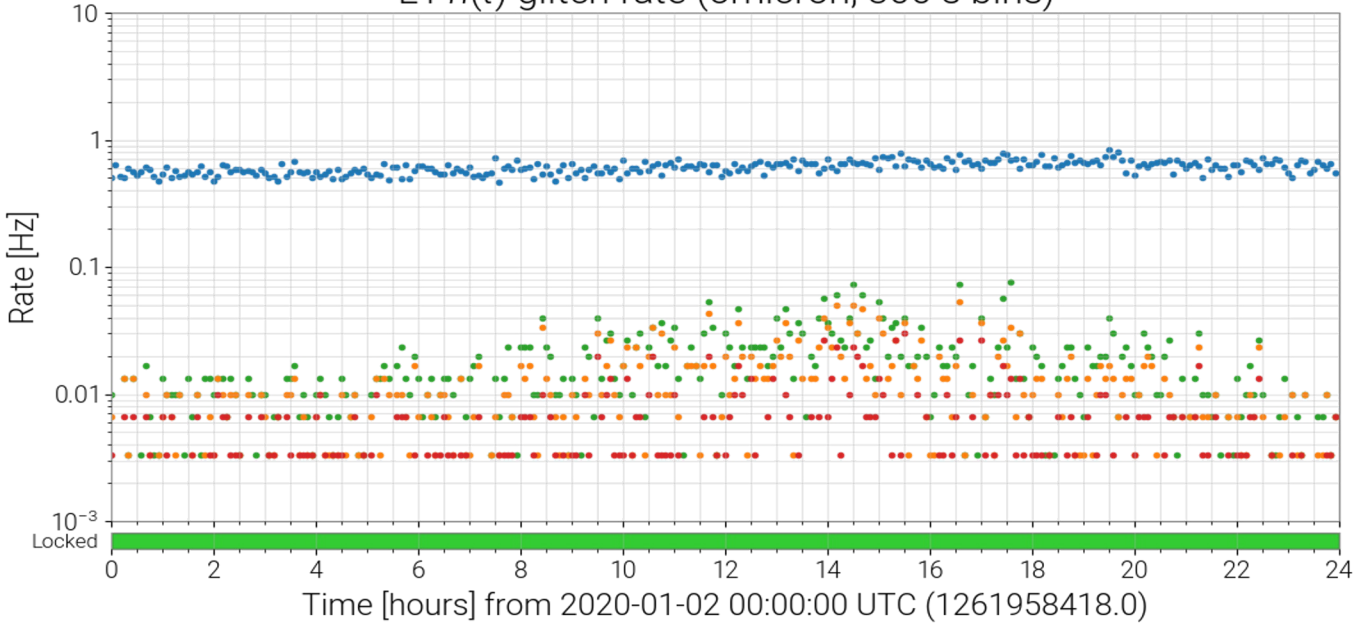
About 25 events out of ~90 needed some form of glitch mitigation [GWTC-3]



Glitch overlapping with a GW signal



Source: https://ldas-jobs.ligo-la.caltech.edu/~detchar/summary/day/20200102/



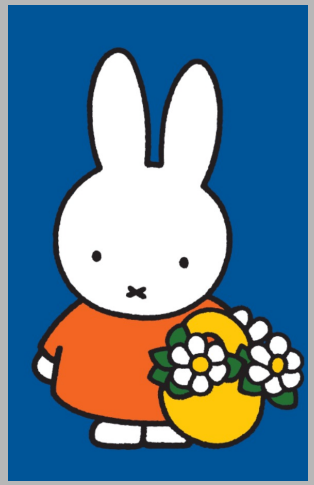
How often do we encounter a GW signal?

~1 every 5 minutes (Branchesi+2023, Samajdar+2021)

How often do we encounter a glitch?

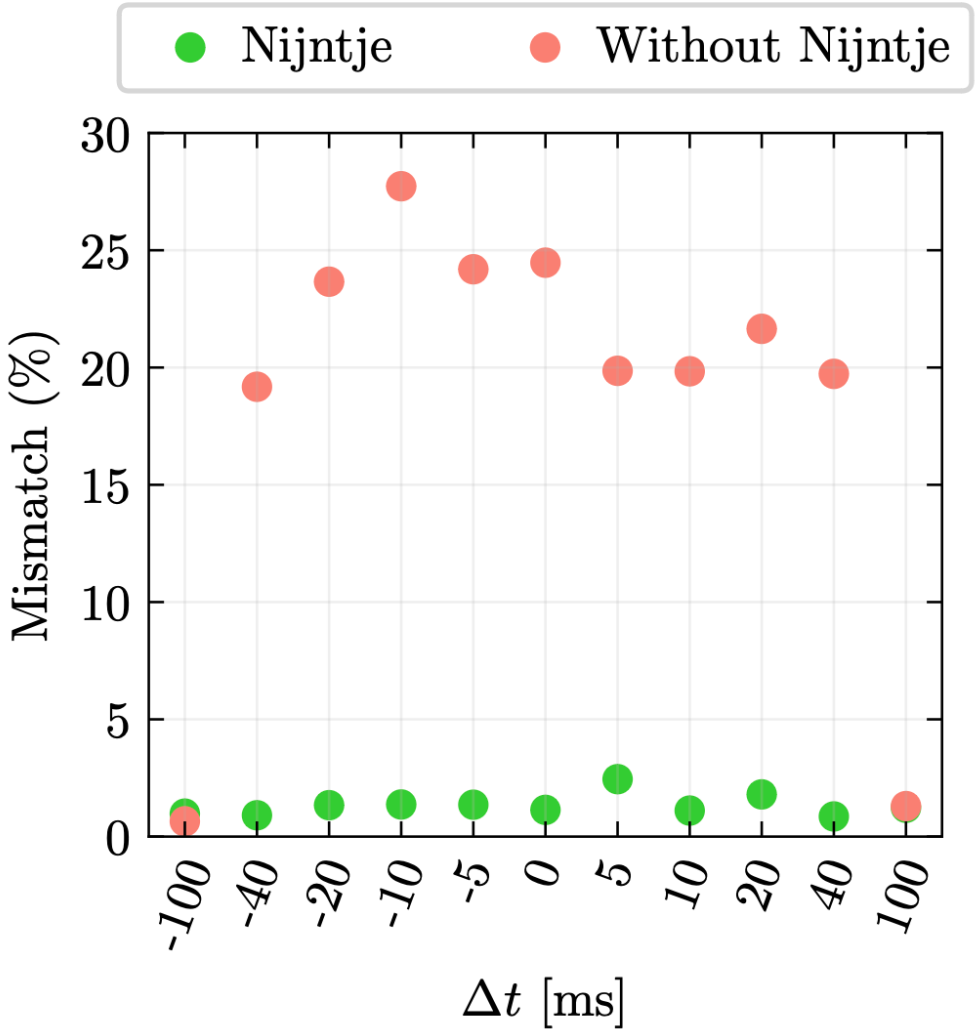
Summary

- The null stream of the ET allows us to use Nijntje algorithm that is
    1. Reducing complexity and increasing the the speed by a factor of >10.
    2. Able to remove glitches arbitrarily close to signal
    3. Robust against changing signal and glitch shapes
    4. Robust against long, loud, and overlapping signals



Work in progress…multiple detectors glitch simultaneously and glitches overlapping scenarios.

Paper out soon. Stay Tuned. Thank you.


Nijntje
Without Nijntje
Mismatch (%)
30
25
20
15
10
5
0
-100
-40
-20
-10
-5
0
5
10
20
40
100
Δt [ms]