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Detection confidence tests for Gravitational Wave Inspiral Candidate Events

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on behalf of

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Motivation

LIGO inspiral search pipeline looks for transient gravitational wave signals from the coalescence of compact binary systems.

- **Uses matched filtering**
- **Outputs list of candidates**

The search is sensitive to non-stationary noise ("glitches") in the detectors.

- **Produces accidental "background" (false alarms).**

We require coincidence in two or more detectors.

- **Still need to discriminate GWs from false alarm**

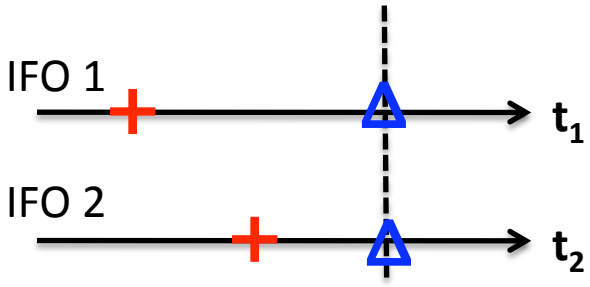
We review interesting candidates* with a detection checklist.

John Rowe, CSIRO

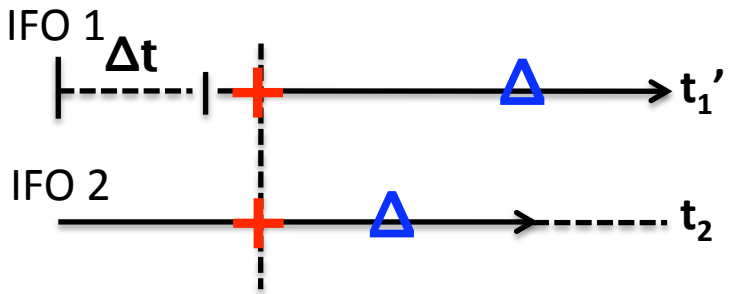
****An "interesting candidate" is a coincident trigger emerging from the analysis pipeline. It is statistically significant when compared to the estimated accidental background.***

Statistical significance of the candidate

The statistical significance of the inspiral candidates is estimated from the time-slide triggers



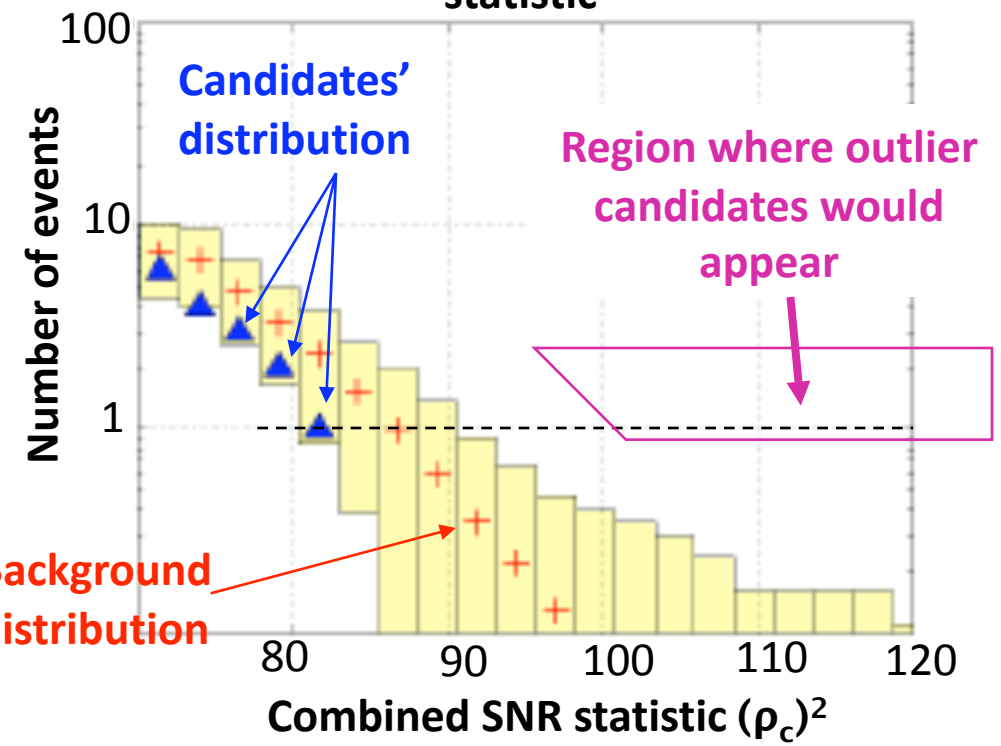
Coincident trigger: *potential gravitational wave*



Time-slide trigger: *not a gravitational wave*

⇒ Count number of time-slide triggers in **100 time slides** in order to estimate background.

Histogram of coincident triggers versus statistic



Ex: S4 Binary Neutron Star search [*arXiv:0704.3368*]

Total analyzed time = 576 hrs; No detection found

Detection Checklist: Two examples

	Simulated Signal (coalescence of two black holes)							**False Alarm** H2L1 (Hanford 2km, Livingston 4km)					
Statistical	**Injection Parameters**		Mass 1 ($M_\odot$)	Mass 2 ($M_\odot$)	Eff Dist (Mpc)	SNR	Eff SNR	**Estimated parameters**	Mass 1 ($M_\odot$)	Mass 2 ($M_\odot$)	Eff Dist (Mpc)	SNR	Eff SNR
	Livingston L1		5.35	5.59	70	11.4	114	**L1**	27.7	2.0	76	6	38
	Hanford	**H1**			64	12.9	106	**H2**	28.1	1.8	2	99	108
		H2				7.5	47						
1.Appearance	✔							✘					
2.Data Quality	✔							✘					
3.Environment	✔							✘					
4.Correlation	✔							-------					
Other tests (20 total)	. . .							. . .					
CONCLUSION	**CANNOT BE RULED OUT**							**NOT A GRAVITATIONAL WAVE**					

✔ = passed detection checklist test ✘ = failed detection checklist test

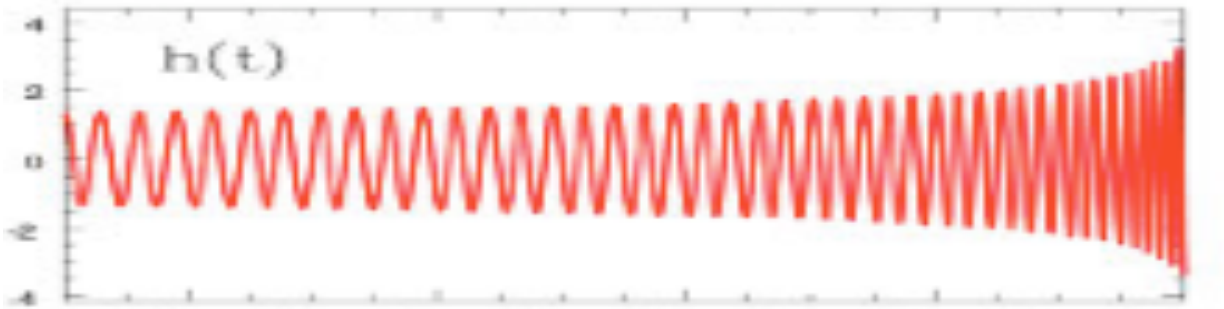
The following slides will show the detection checklist in action on these two candidates…

Candidate appearance

➢ **Check time series, and time-frequency spectrograms of the candidate**

Ex: Simulated inspiral signal

Chirp Signal



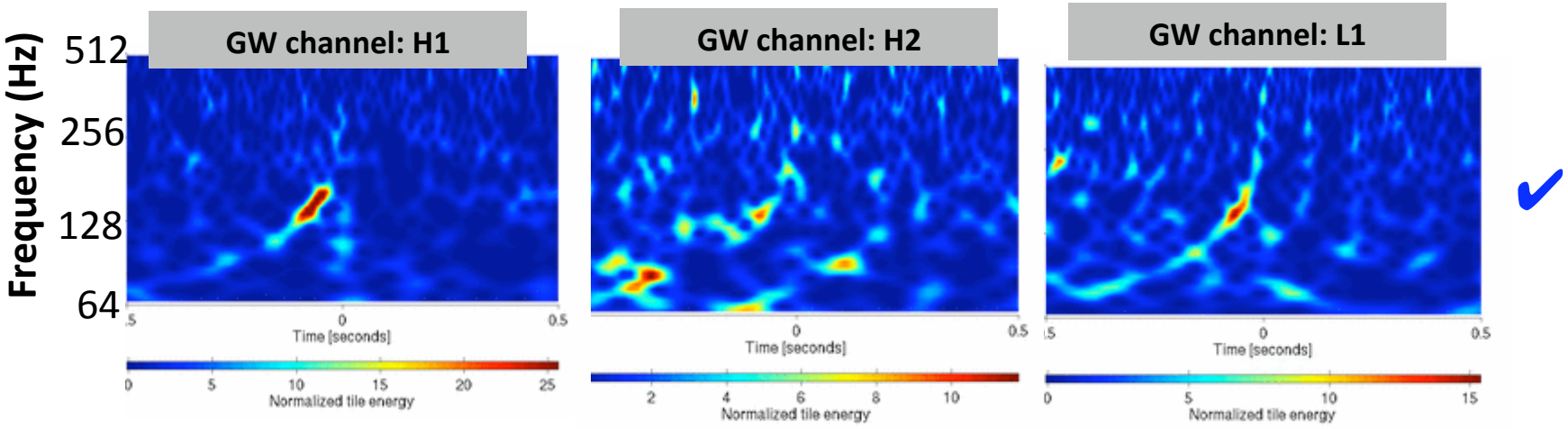
Time

•Characterized by increasing amplitude and frequency

Candidate appearance

➢ Check time series, and time-frequency spectrograms of the candidate

Ex: Simulated inspiral signal → Chirp visible in H1 and L1

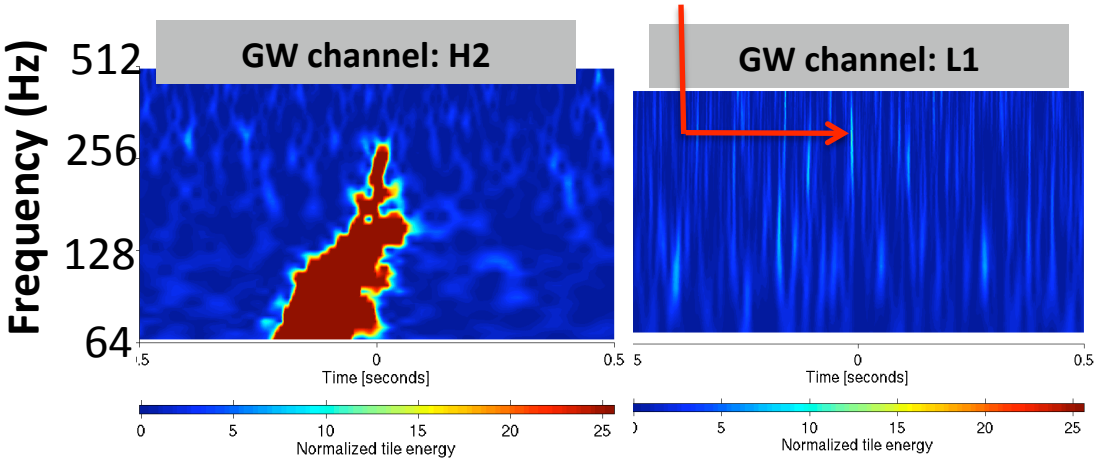


✔

Ex: H2L1 false alarm **loud glitch at Hanford** **weak transient at Livingston**

GW channel: H1

H1 was not operating.



✕

Data Quality Check

Ex: H2L1 false alarm, H2 trigger

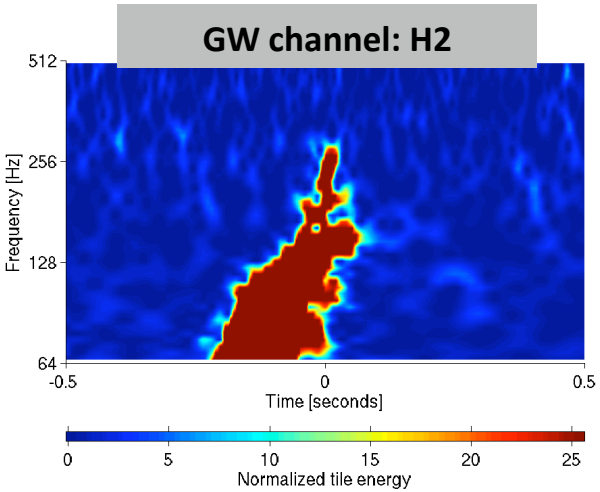
Data Quality Flags

H1 NOT LOCKED

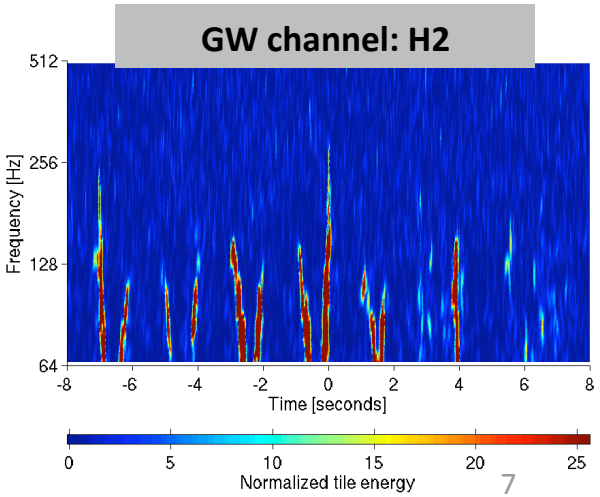
H1 is not locked (not operating).
Does the flag explain the candidate?
Yes!

Evidence:
Candidate appearance in GW CHANNEL…
The H1 mirror is swinging causing light to enter H2.

⇒This candidate is not a gravitational wave. ✕



Repeating pattern due to swinging mirror is visible in 16 sec window. We can see poor data quality here.

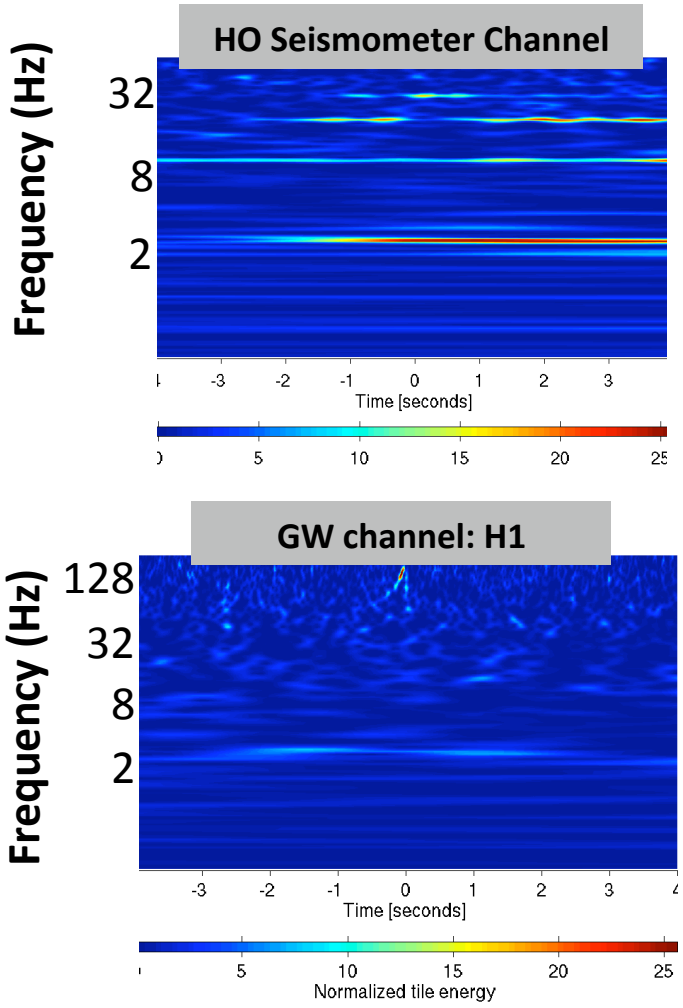


Environmental or instrumental causes

Ex: At time of the simulated signal

Check time-frequency maps of auxiliary channels

Seismic transient at the Hanford Mid X station (close to H2 end test mass)



How relevant is a transient found in an auxiliary channel, given its significance ?

- **Look for coupling to GW channel and nonlinear coupling at candidate's frequency.**

- **Compare amplitude ratio GW channel / auxiliary channel with measured transfer function (if available).**

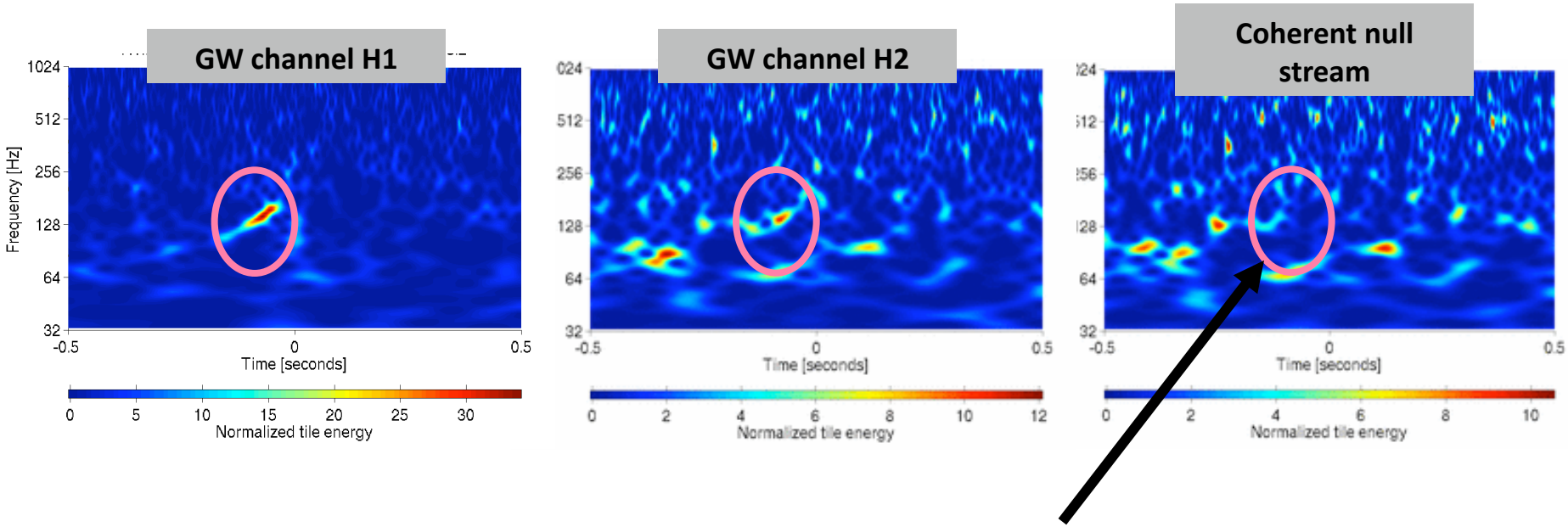
⇒ There is no evidence of nonlinear coupling in GW channel

⇒ We cannot conclude whether the candidate is due to this seismic transient. ✔

H1/H2 correlation

Check for signal correlation between colocated interferometers

Ex: Simulated Signal



The "chirp" pattern is removed in the coherent null stream (the difference of the two GW channels).

⇒ This indicates a correlated signal between the H1 and H2 interferometers. ✔

Conclusions

- Compact Binary Coalescence (CBC) group is developing a list of detection confidence tests
- Automation of the inspiral detection checklist is in progress
- The inclusion of Virgo in those tests will start soon
- We are preparing for detections!