Improving Confidence in Marginal Binary Merger Events

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Outline

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Introduction : Background / Motivation

Some Gravitational Wave Sources (GW)

- Binary Black Holes (BBH)
- Binary Neutron Star (BNS)
- Neutron Star – Black Hole Binary (NSBH)

GW Detected Events

- 11 strong detections from O1 & O2
- 23 significant candidates (as of 08/20/2019)

Scientific Motivation

Increase the number of less significant candidates

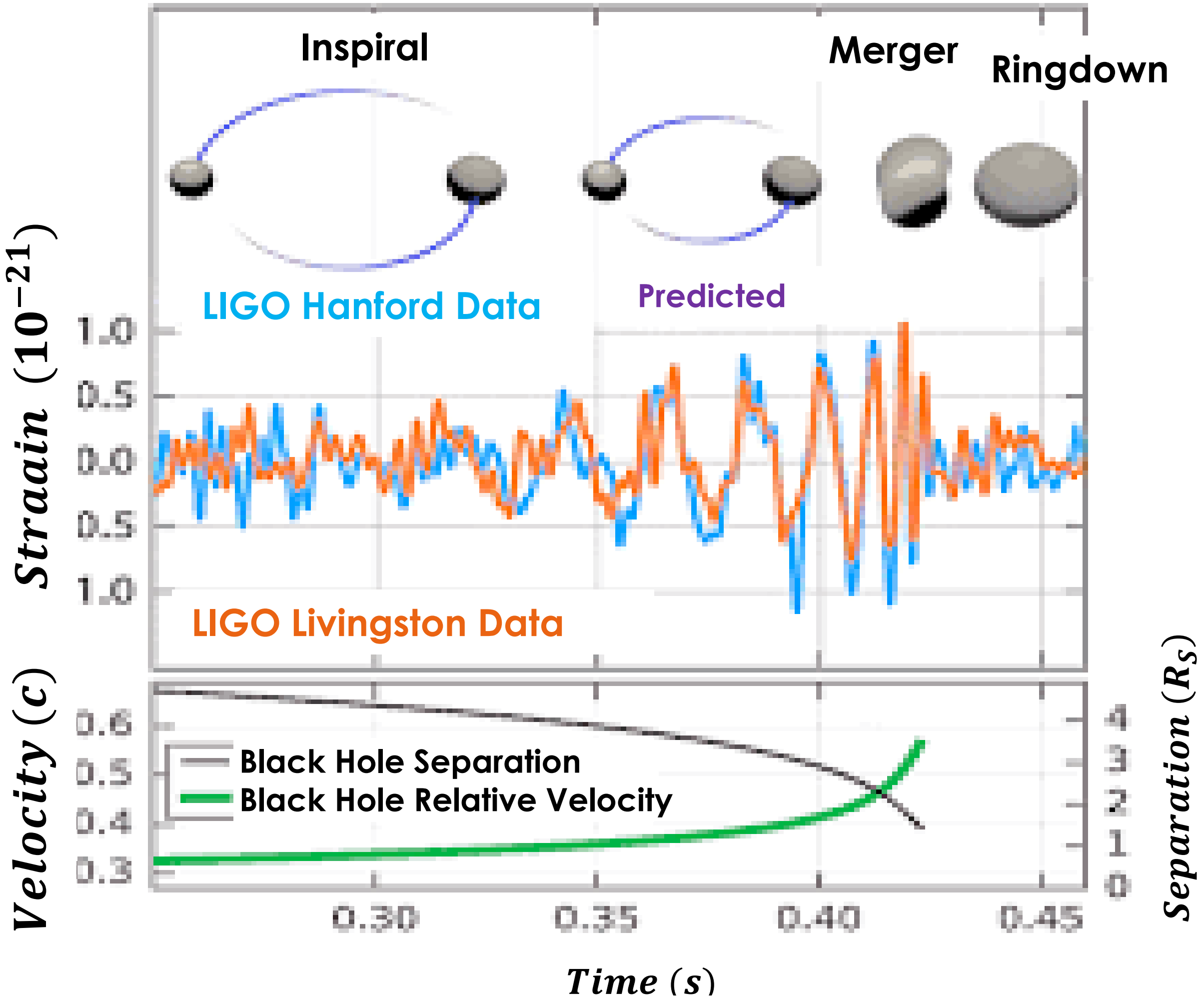


Image from the LSC and Virgo Collaboration

Introduction : Marginal Events

- May be True Signals or Noise Triggers
- Do not have a relatively high Signal to Noise Ratio (SNR)
- Generally have a SNR around 8.5

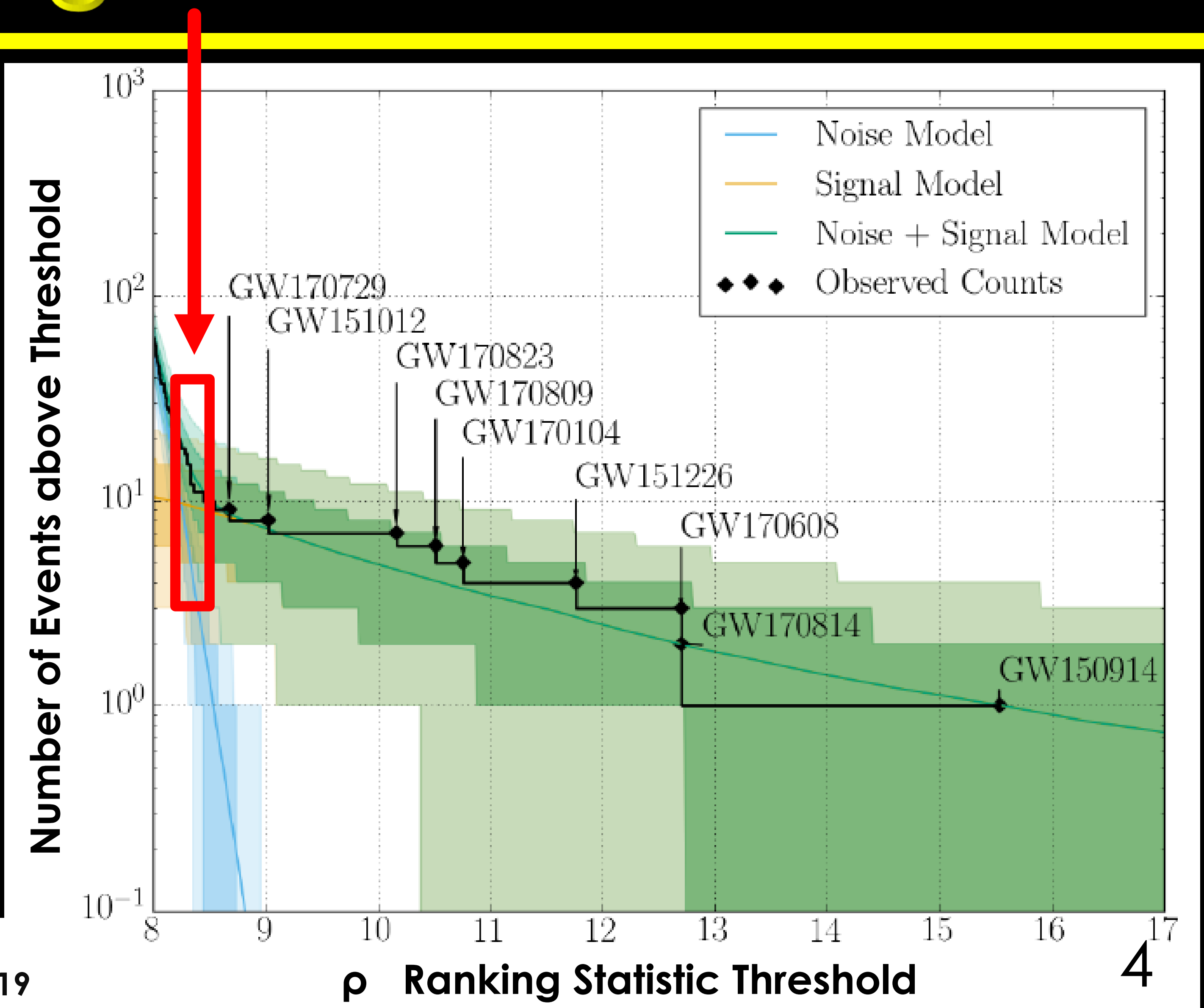
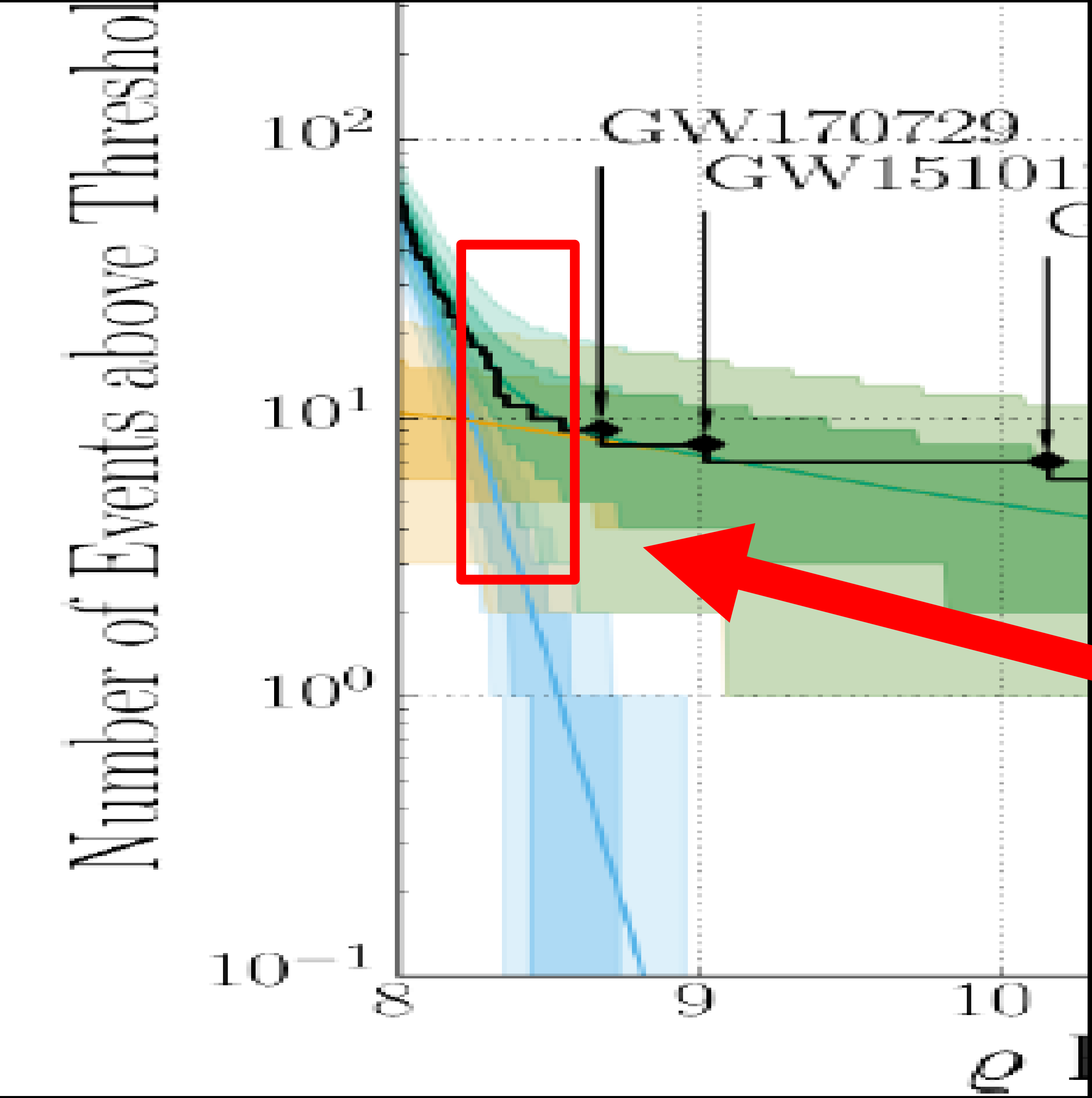


Image from Abbott et al., 2019



Marginal Events

Introduction : Limitation of SNR statistic

- Signal to Noise Ratio (SNR) is a statistic that considers one set of parameters

$$SNR = \frac{Amplitude\ of\ Signal}{Amplitude\ of\ Noise}$$

- Can produce high SNRs for :
  - accidental coincidence of “loud” glitches
  - Other rare noise fluctuations

Introduction : Glitches

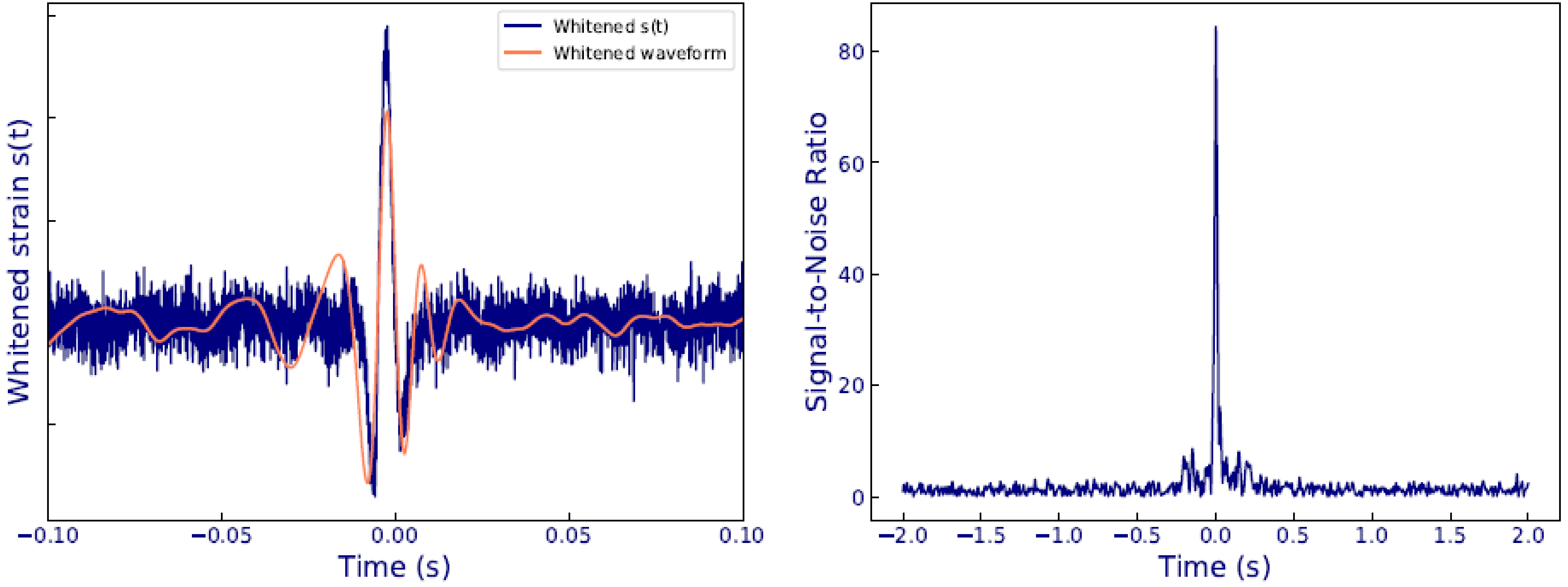


Image from Cabero et al., 2019

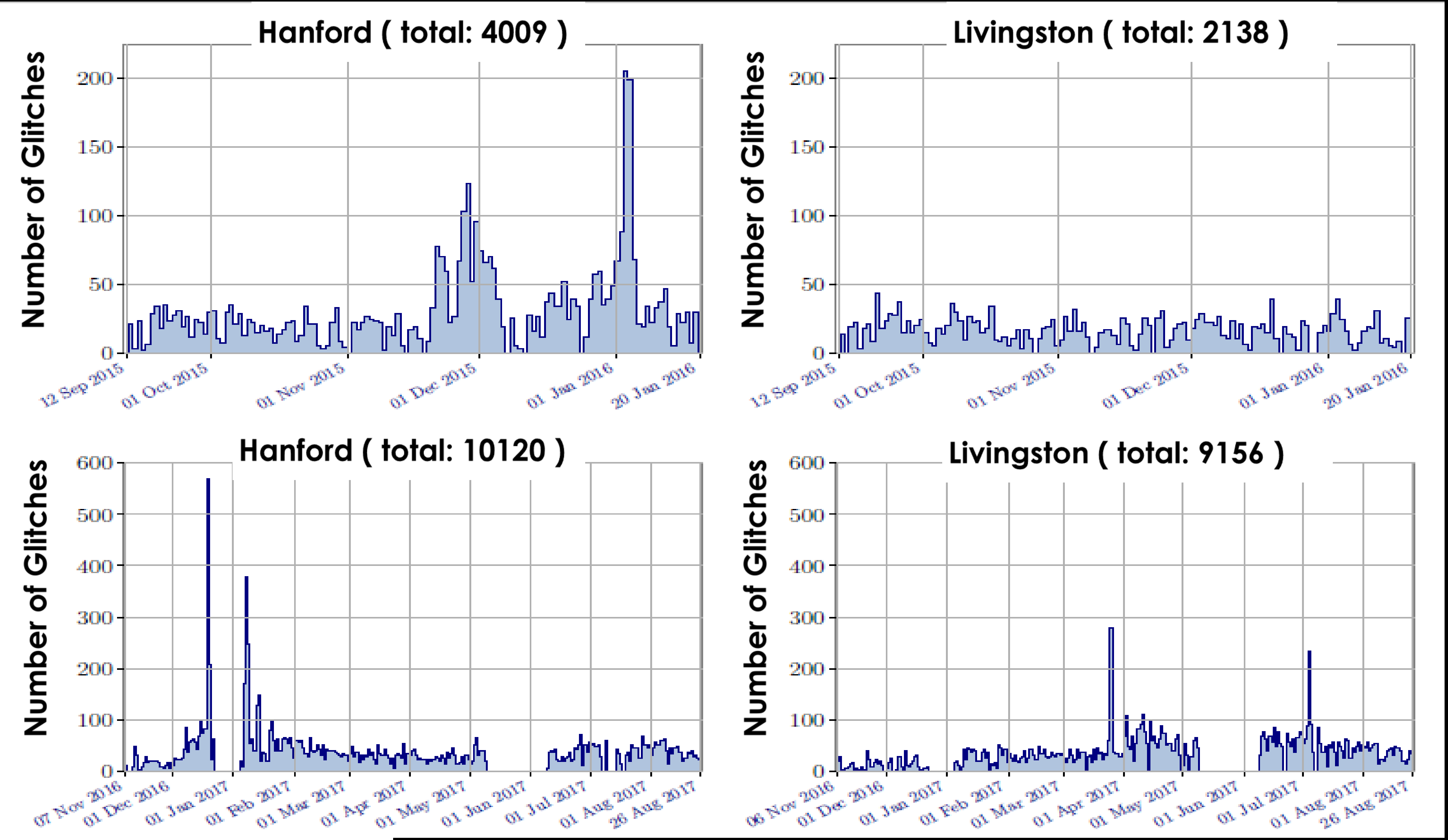


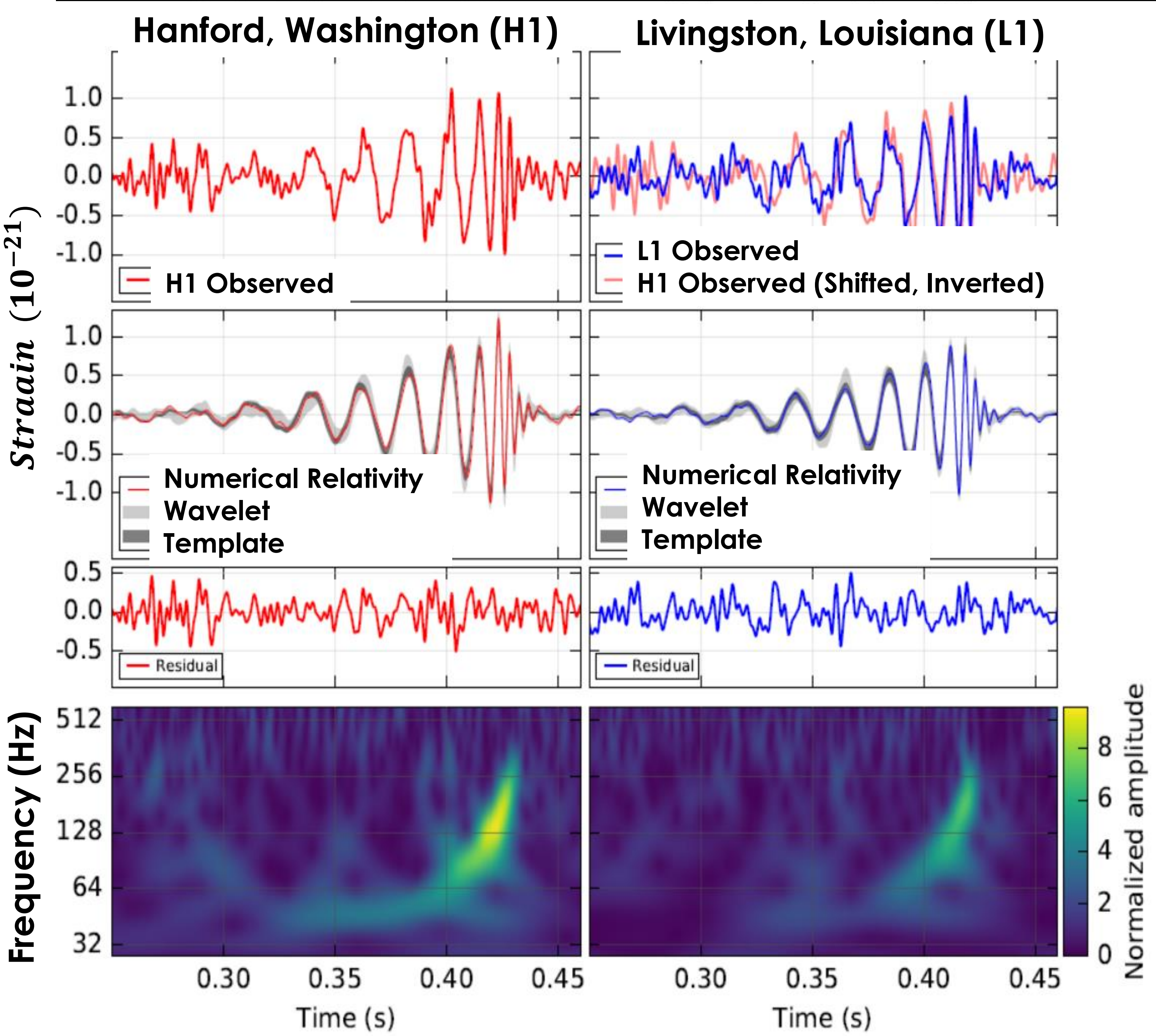
Image from Cabero et al., 2019

Method :

Bayesian Coherence Ratio (BCR)

BCR requires:

1) Strain signals in multiple detectors share a phase evolution of single astrophysical source
2) Represent a CBC waveform
3) Coincident in Time, Phase, and Amplitude



* Compact Binary Coalescence (CBC)

Analysis : CBC Parameters (15)

- Component masses – 1 each (2)
- Component Spin Vectors – 3 each (6)
- Right Ascension – 1
- Declination – 1
- Luminosity Distance – 1
- Orbital Inclination – 1
- Polarization Angle – 1
- Time and Phase of Coalescence – 2

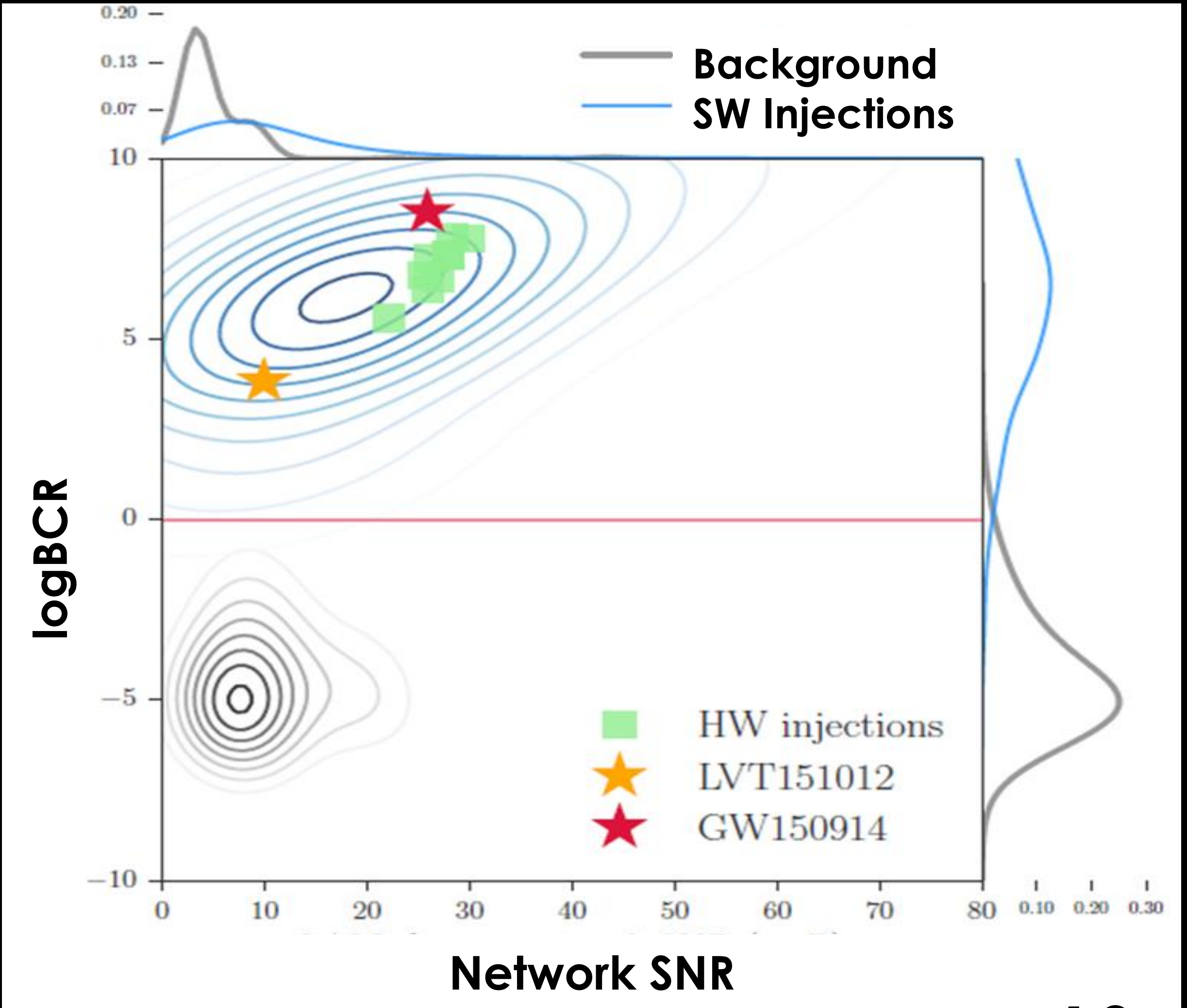


Image from Isi et al., 2018

Method : Bayesian Coherence Ratio

- Bayesian Model Comparison using different models:
  1) GW Signal (S)   2) Gaussian Noise (N)   3) Incoherent Glitch (G)

$$BCR = \frac{P\,(\,H, L\mid GW\ Signal\,)}{P\,(\,H\mid N_H)\,P\,(\,L\mid N_L)}$$

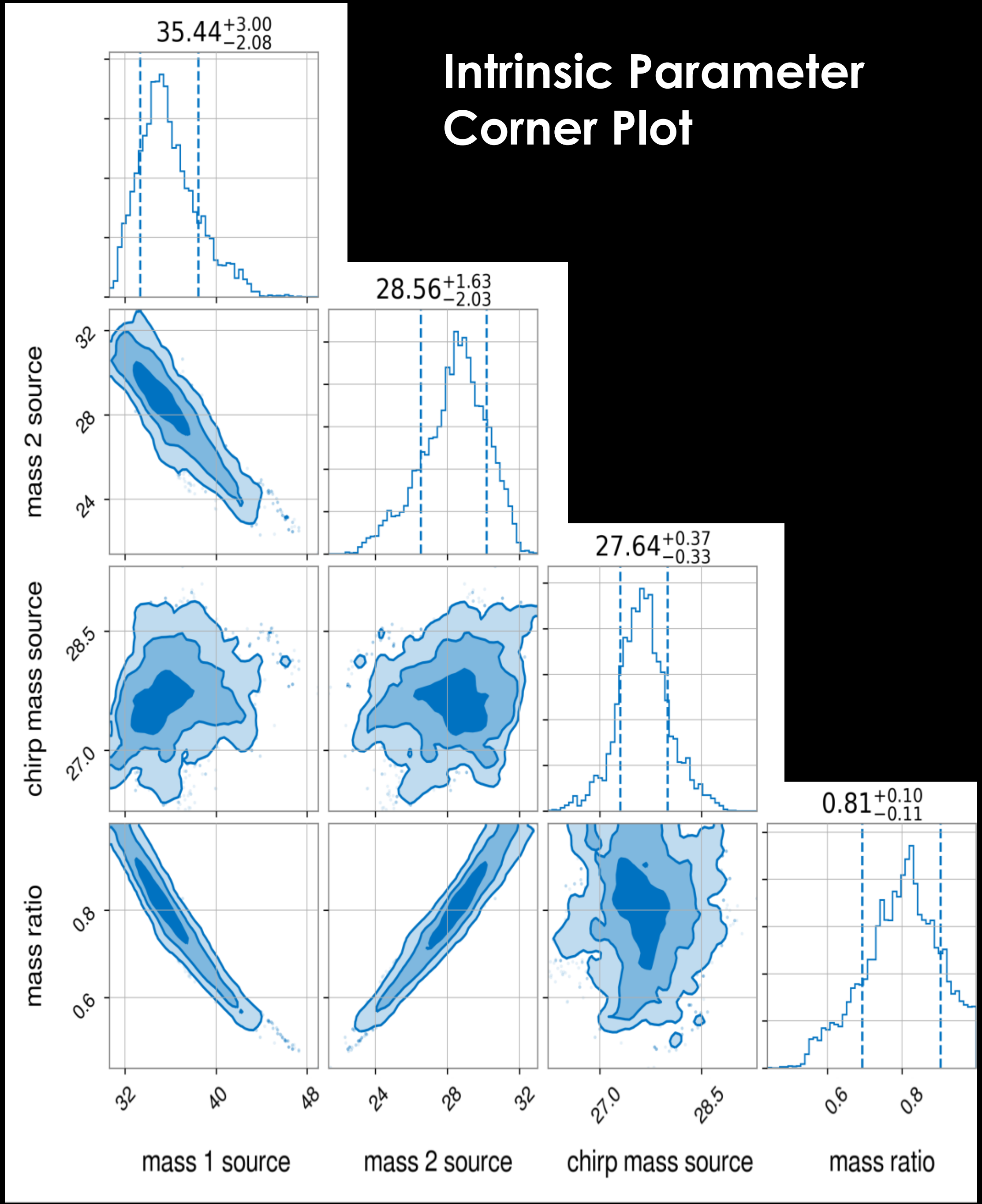
Model Favored	BCR value	lnBCR value
GW Signal	> 1	> 0 (Positive)
Noise / Glitch	< 1	< 0 (Negative)

Analysis : GW150914

- Published SNR value: 24

Trial	UTC Time	Time shift H1 (sec)	Time shift L1 (sec)	lnBCR
1	2015-09-14 09:50:43	0	0	**11.46**
2	2015-09-14 09:59:03 (+ 500 sec)	- 500	+ 500	**-10.66**

Intrinsic Parameter Corner Plot

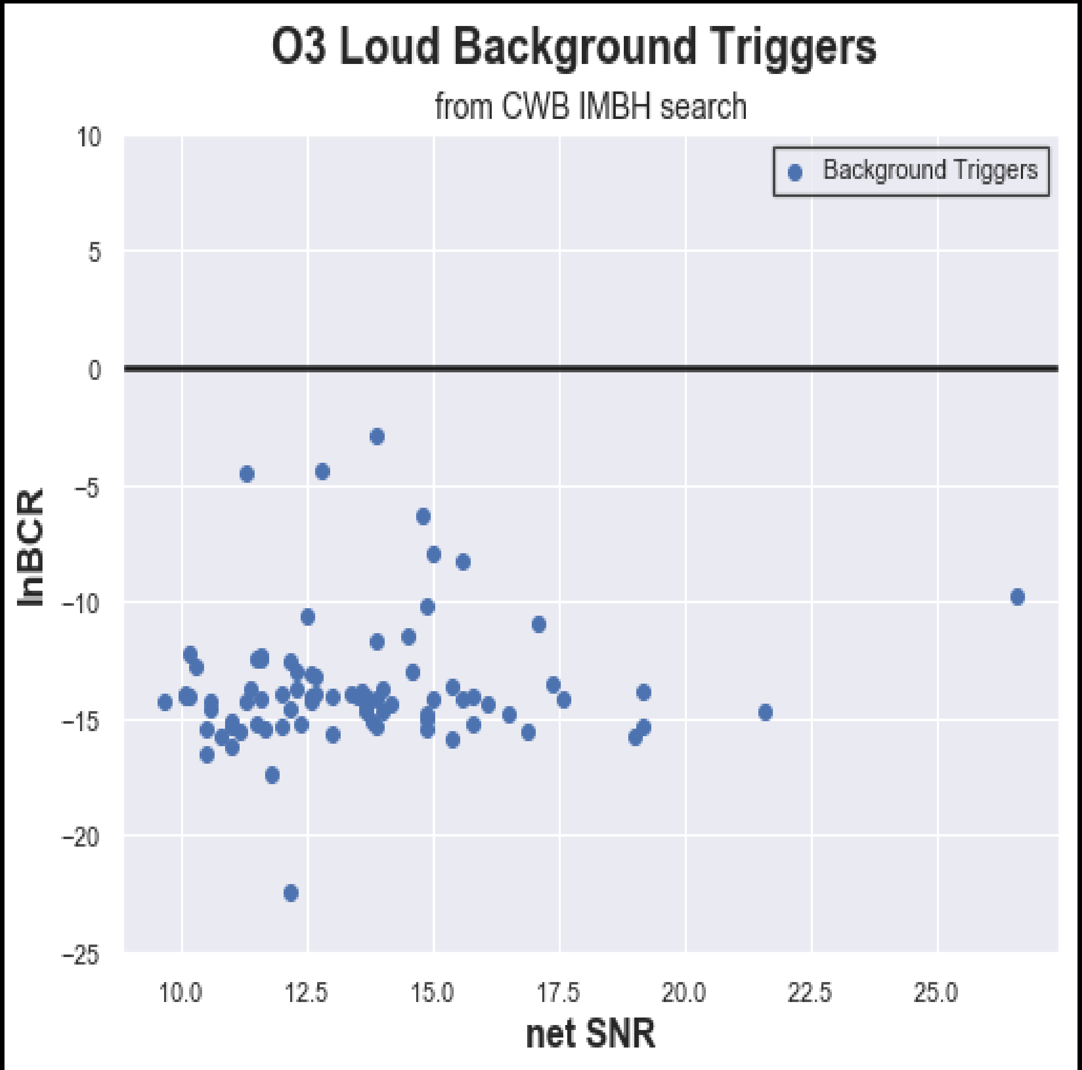


Analysis : Background

- Obtained from CWB IMBH Search of O3 data from April 1 to May 25 (2019)

$$SNR_{NET} = \sqrt{H1_{SNR}^2 + L1_{SNR}^2}$$

* Coherent Wave Burst (CBC)
* Intermediate Mass Black Hole (IMBH)



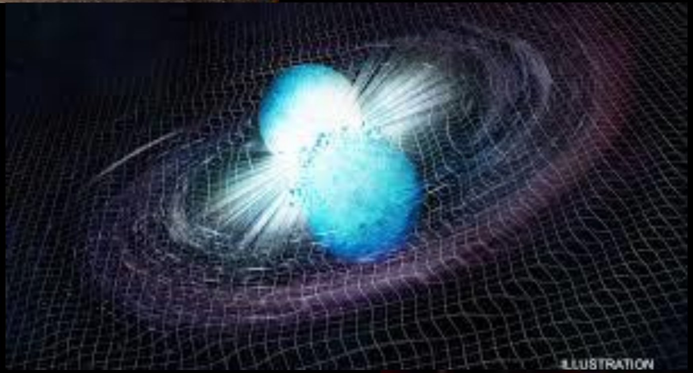
* 83 Background Triggers Plotted

H1 UTC time	L1 UTC time	H1 – L1 (sec)	H1 T-shift (sec)	L1 T-shift (sec)
2019-05-12 04:20:08	2019-05-12 03:05:45	4462.0065	0	4462

Analysis : O3 Event Candidates

- Events and data taken from GraceDB
- 23 Candidate detections as of 08/20/2019

BBH



BNS

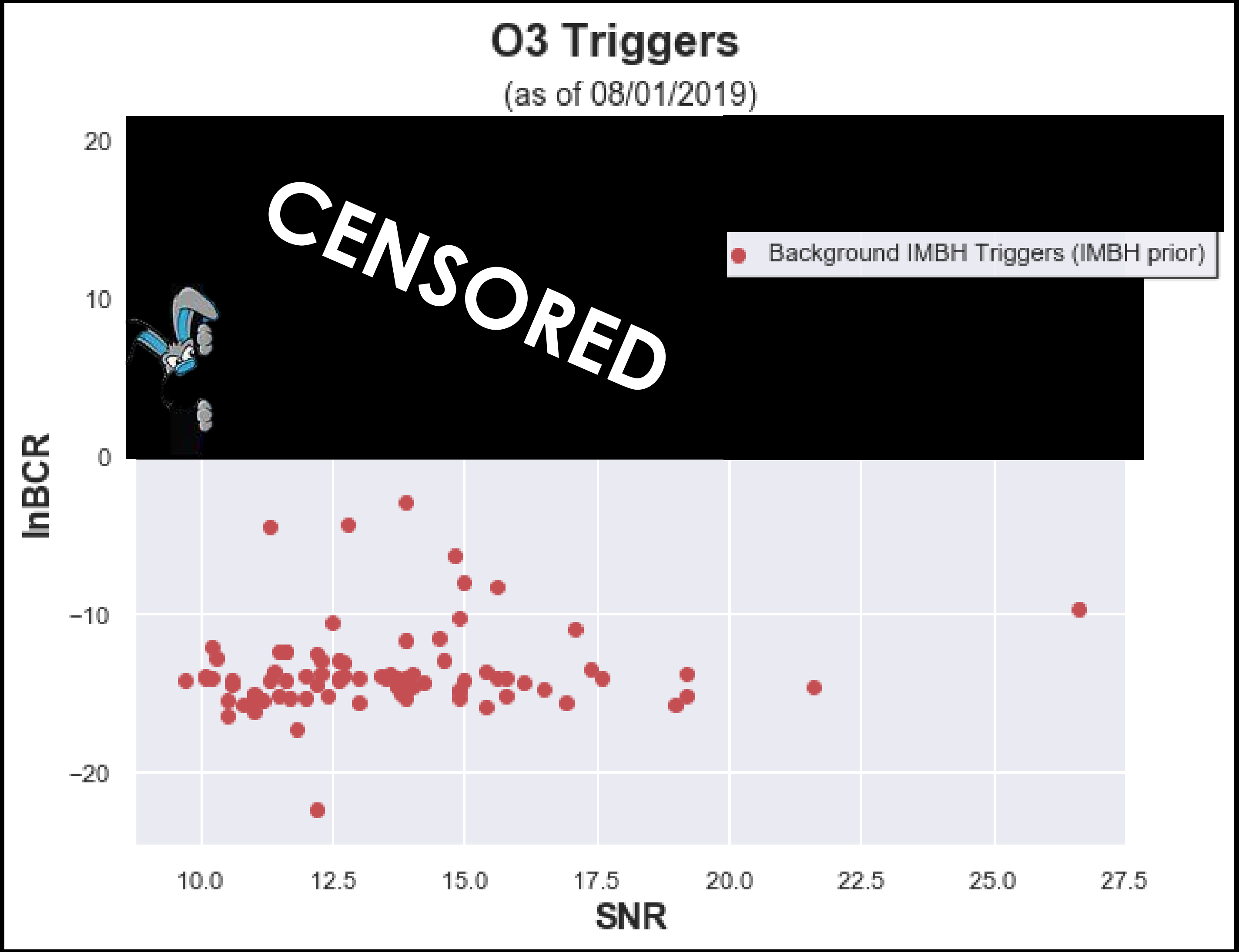
NSBH

Possible Source	# of Candidates
BBH	18
BNS	4
NSBH	1

** Some BNS candidates are likely to be Terrestrial

Results / Future Work

BCR seems to distinguish GW Signals from Incoherent Noise!



Future Work

- Run BCR calculations on a set of O3 injections
- Calculate BCR values for all sub-threshold trigger events from O1 and O2 published catalogs
- Determine if the BCR can be used to improve GW detections

Acknowledgements!

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