# GW4—Data analysis for GW detectors

[See also my colloquium http://indico.ictp.it/event/7900, which is in effect the third lecture in this series.]

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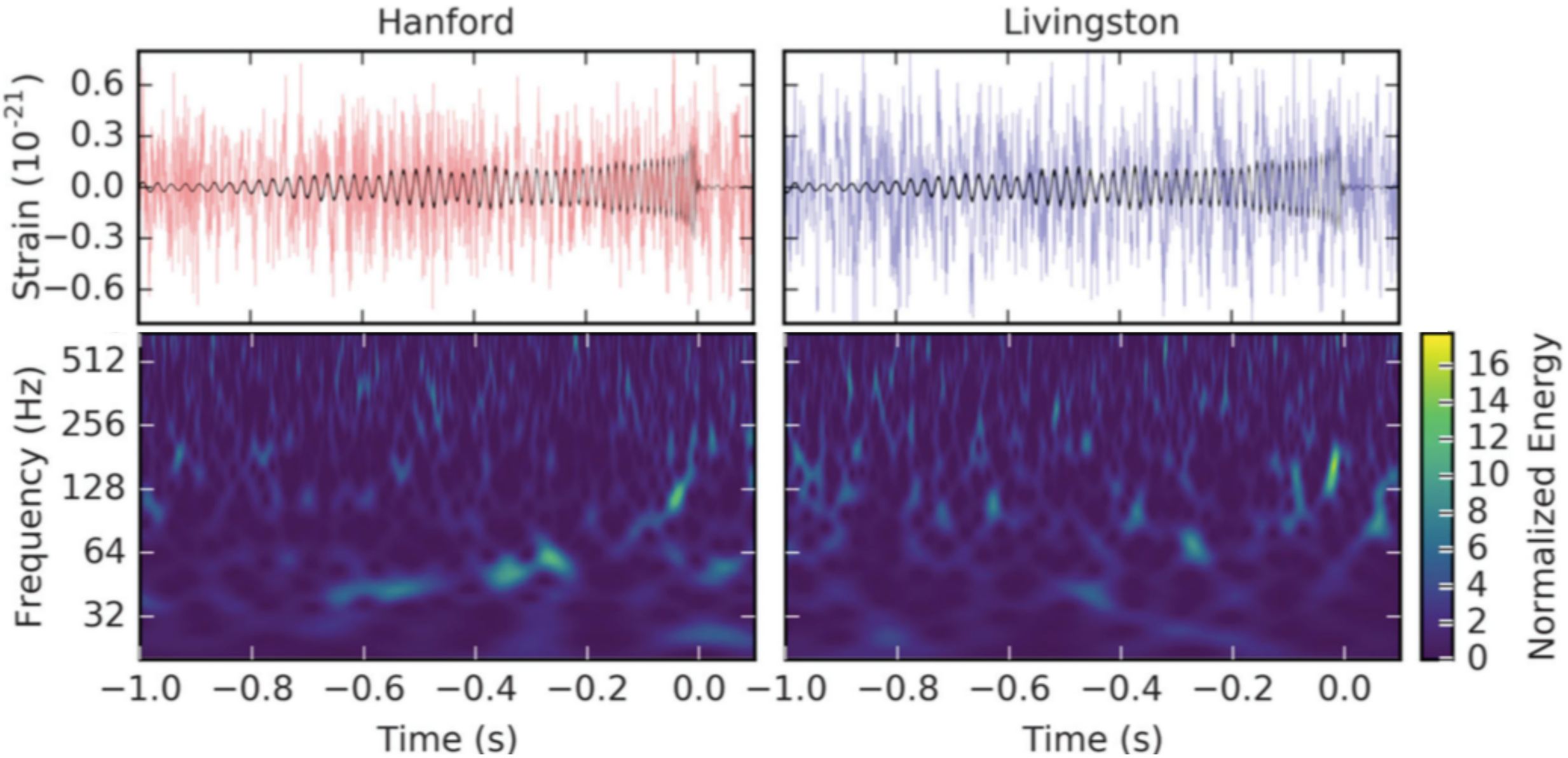
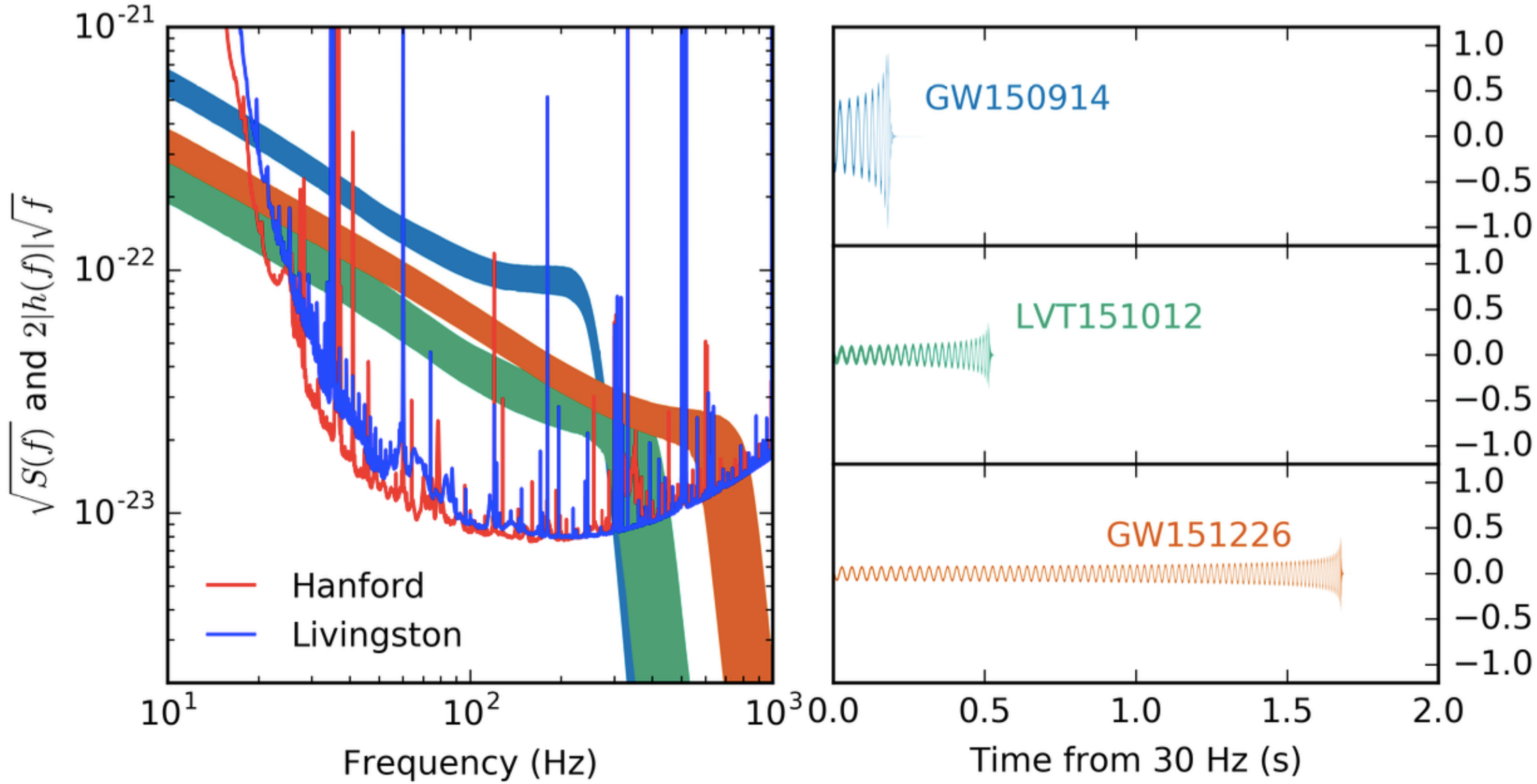
ICTP Summer School on Cosmology 2016

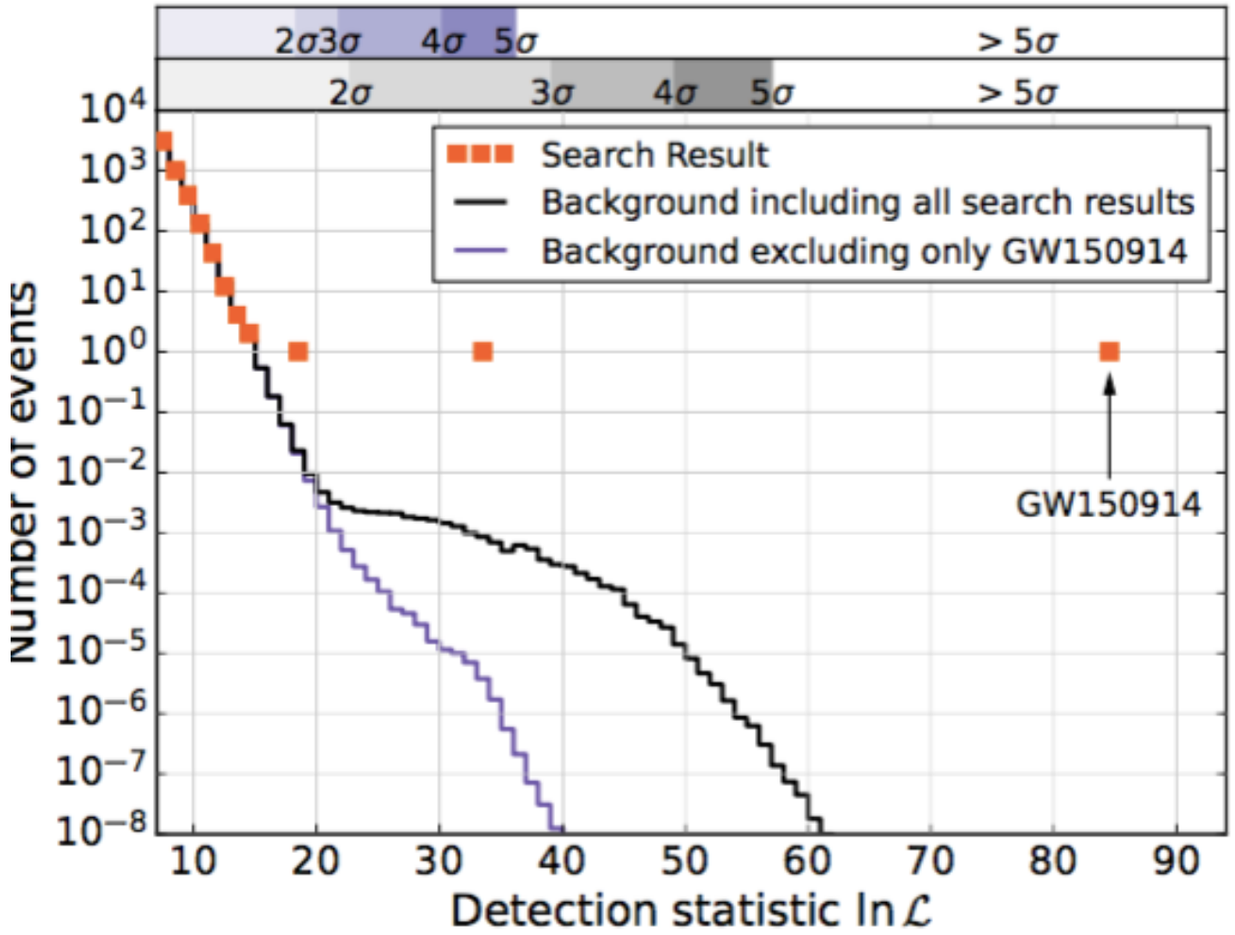
# Introducing GW151226
# (the Boxing Day Event)

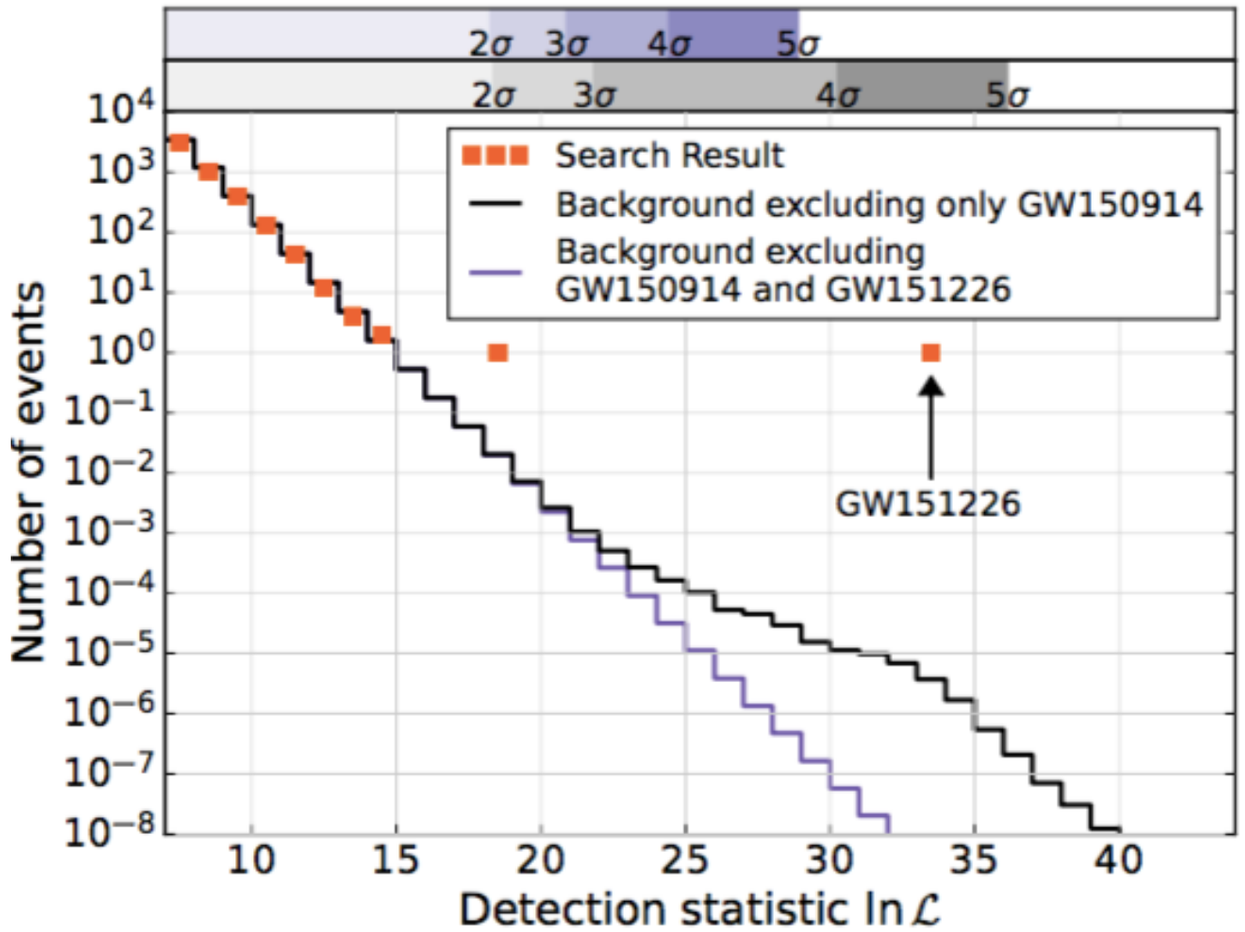


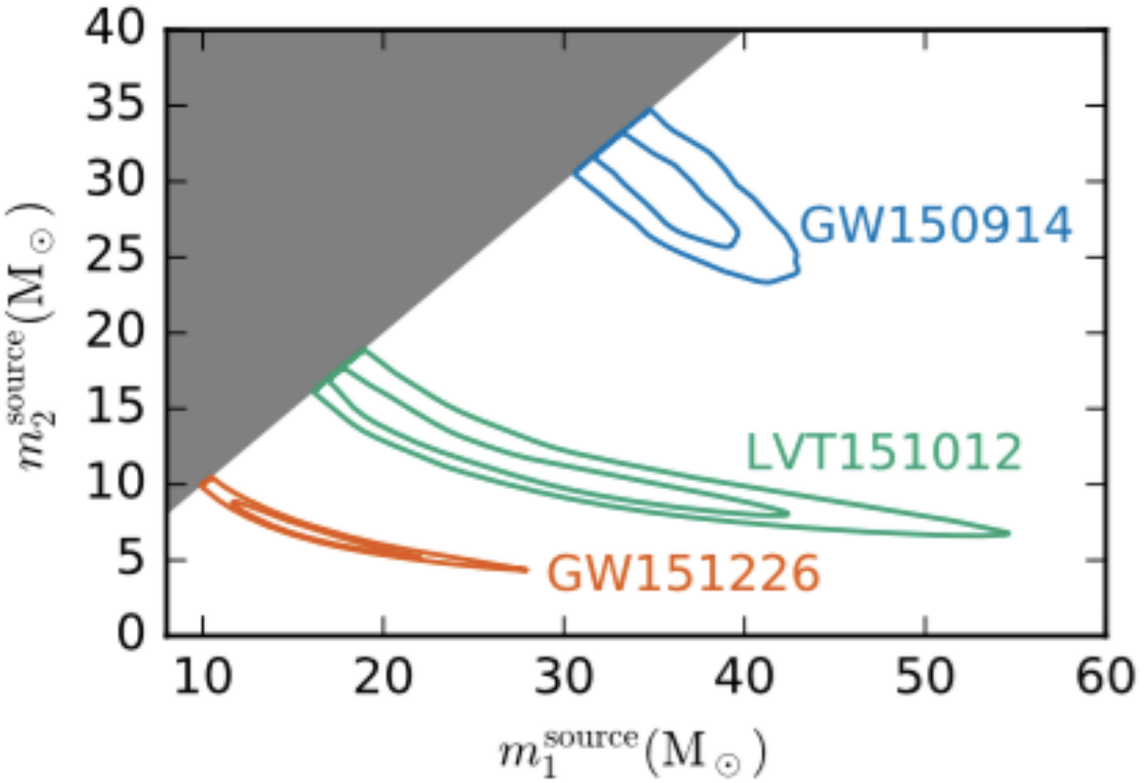

1 s, 55 cycles, 35–450 Hz

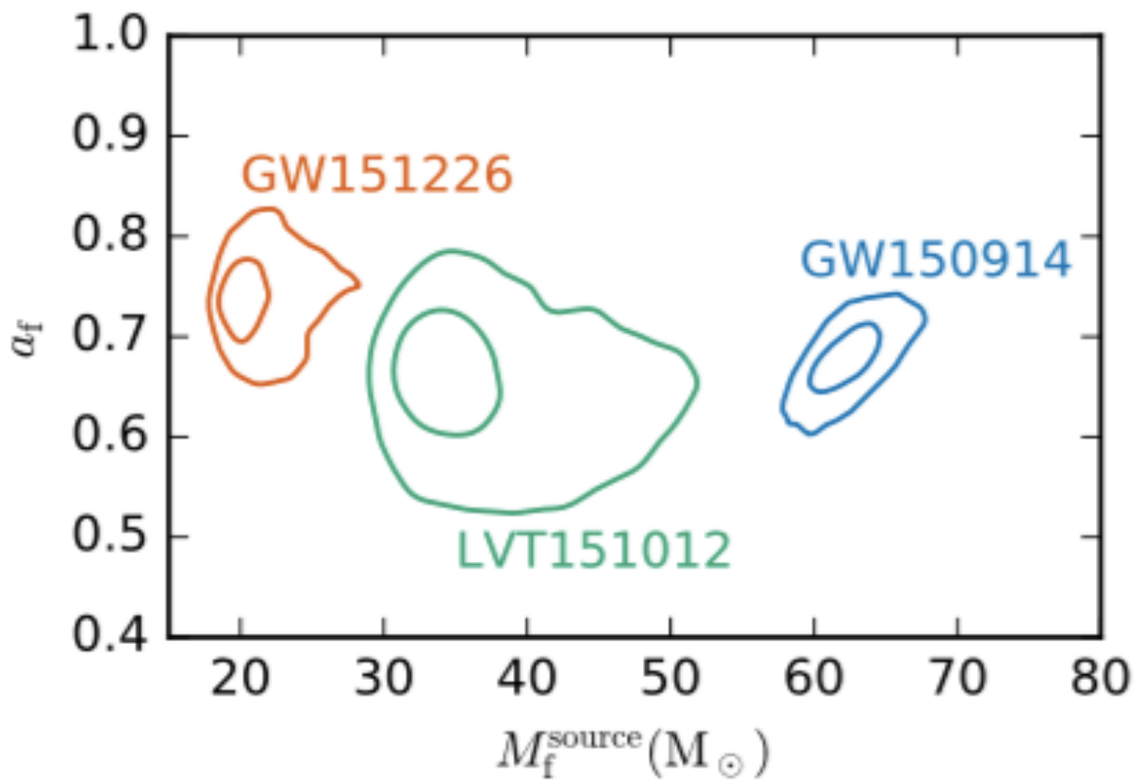


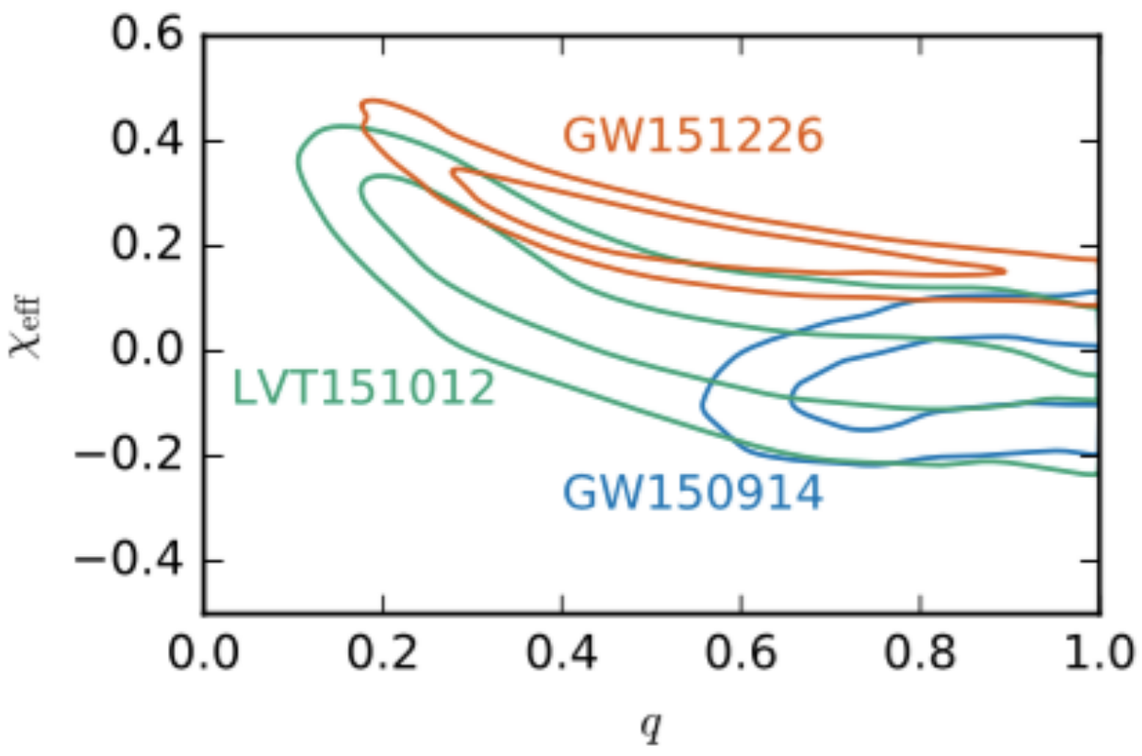

| | SNR | solar masses | effective spin | D/Mpc | z |
|---|---|---|---|---|---|
| GW150914 | 23.7 | 36 + 29 | | 420 | 0.1 |
| LVT151012 | 9.7 | 23 + 13 | | 1000 | 0.2 |
| GW151226 | 13 | 14 + 7.5 | 0.2 | 440 | 0.1 |

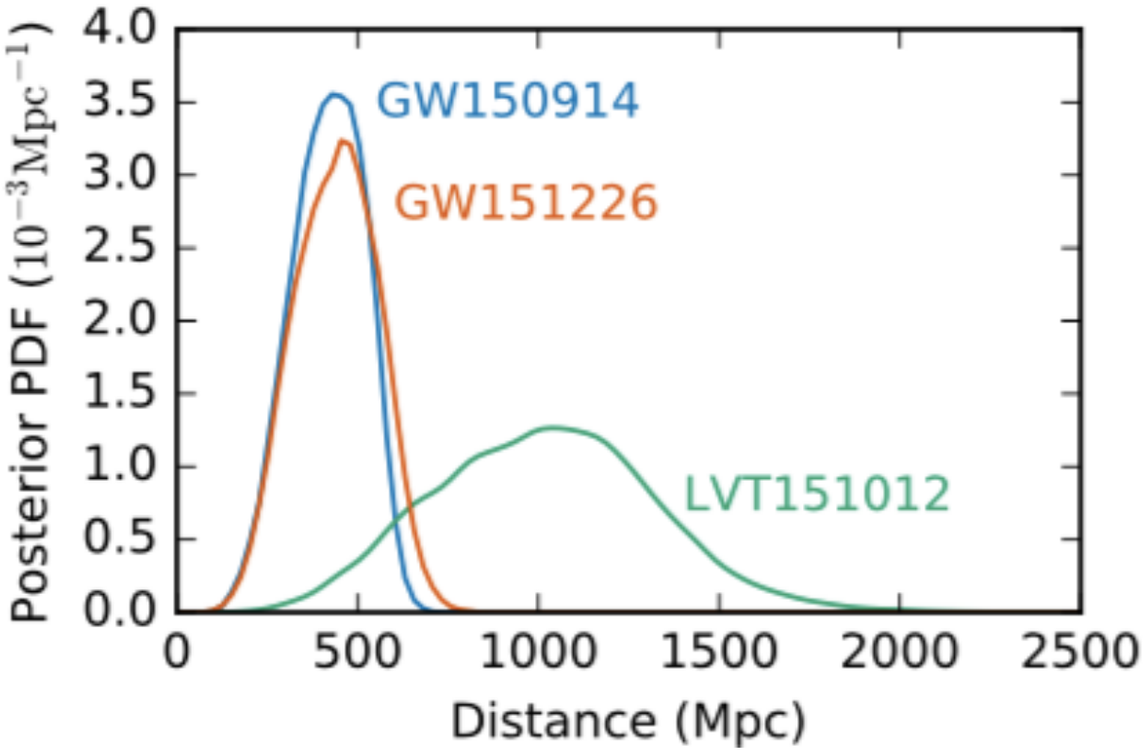

2σ 3σ 4σ 5σ > 5σ
2σ 3σ 4σ 5σ > 5σ
Search Result
Background including all search results
Background excluding only GW150914
GW150914
Number of events
Detection statistic ln $\mathcal{L}$

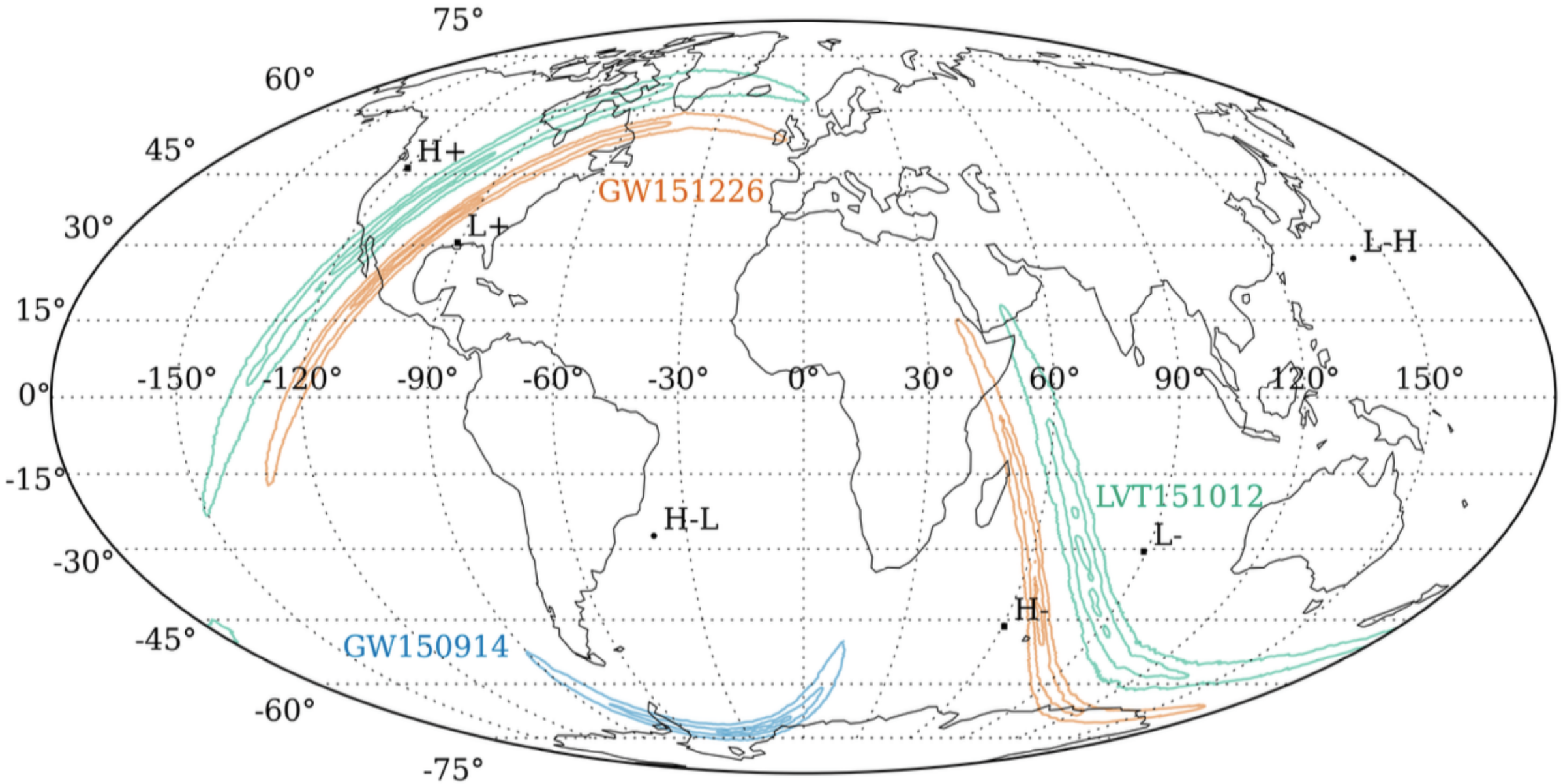

2σ 3σ 4σ 5σ
2σ 3σ 4σ 5σ
Search Result
Background excluding only GW150914
Background excluding
GW150914 and GW151226
GW151226
Number of events
Detection statistic ln $\mathcal{L}$


GW150914
LVT151012
GW151226
$m_2^{\rm source}(\mathrm{M}_\odot)$
$m_1^{\rm source}(\mathrm{M}_\odot)$

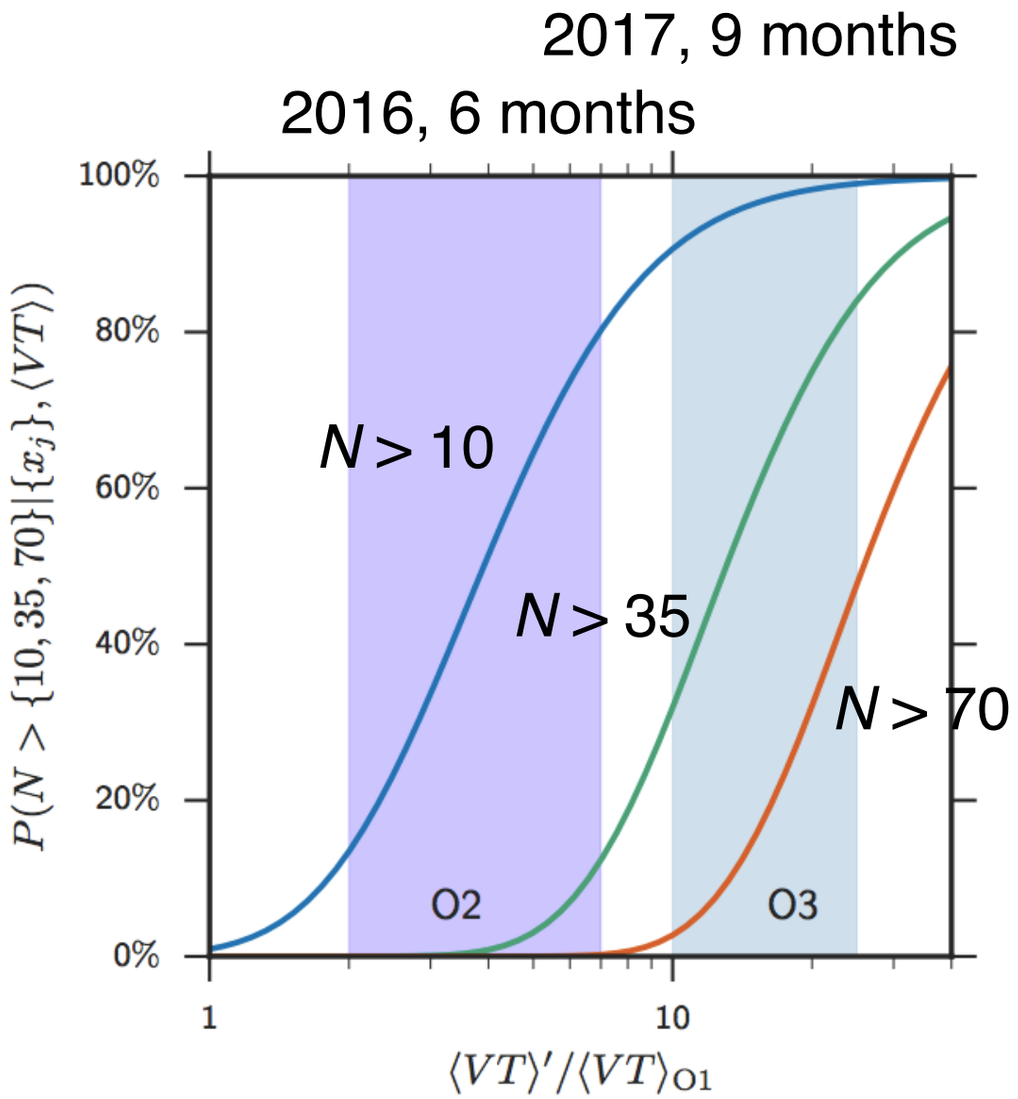

GW151226
GW150914
LVT151012
$a_{\rm f}$
$M_{\rm f}^{\rm source}(\mathrm{M}_\odot)$


GW151226
LVT151012
GW150914
$\chi_{\rm eff}$
$q$


GW150914
GW151226
LVT151012
Posterior PDF ($10^{-3}\mathrm{Mpc}^{-1}$)
Distance (Mpc)


75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°
H+
L+
H-L
H-
L-
L-H
GW151226
LVT151012
GW150914

| Mass distribution | $R/(\mathrm{Gpc}^{-3}\mathrm{yr}^{-1})$ | | |
|---|---|---|---|
| | PyCBC | GstLAL | Combined |
| | Event based | | |
| GW150914 | $3.2^{+8.3}_{-2.7}$ | $3.6^{+9.1}_{-3.0}$ | $3.4^{+8.6}_{-2.8}$ |
| LVT151012 | $9.2^{+30.3}_{-8.5}$ | $9.2^{+31.4}_{-8.5}$ | $9.4^{+30.4}_{-8.7}$ |
| GW151226 | $35^{+92}_{-29}$ | $37^{+94}_{-31}$ | $37^{+92}_{-31}$ |
| All | $53^{+100}_{-40}$ | $56^{+105}_{-42}$ | $55^{+99}_{-41}$ |
| | Astrophysical | | |
| Flat | $31^{+43}_{-21}$ | $30^{+43}_{-21}$ | $30^{+43}_{-21}$ |
| Power Law | $100^{+136}_{-69}$ | $95^{+138}_{-67}$ | $99^{+138}_{-70}$ |



to experiment with the LIGO data releases, see the Python tutorials at http://losc.ligo.org

GW science in a nutshell:
GW detection with addition, subtraction, and multiplication

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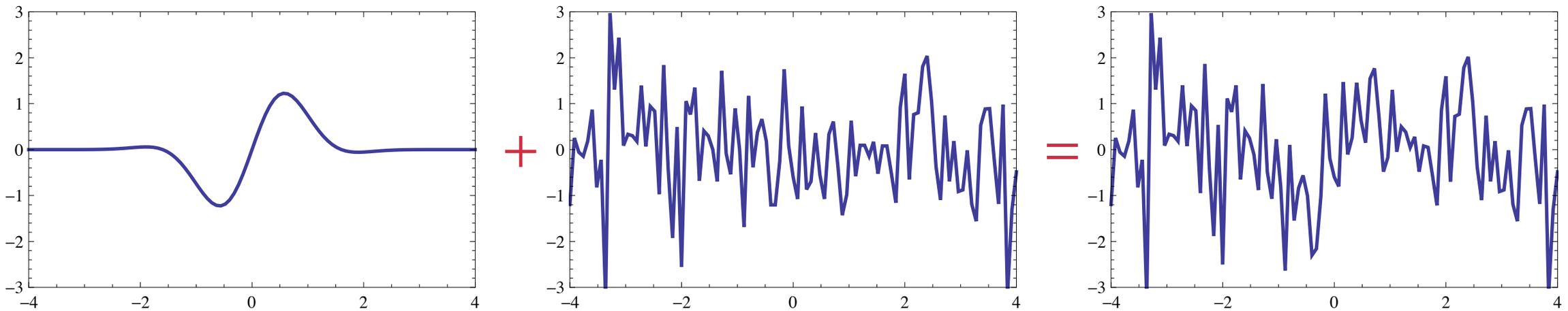
data = signal + noise




(SNR = 5)

therefore: noise = data – signal; to assess detection,
we ask which instance of noise is more probable?

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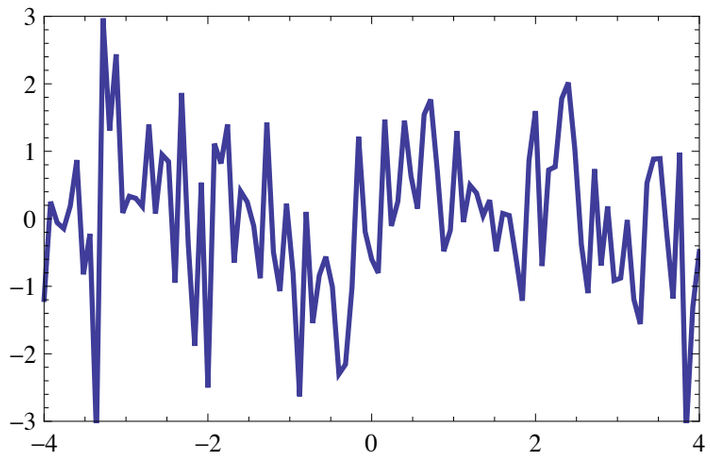
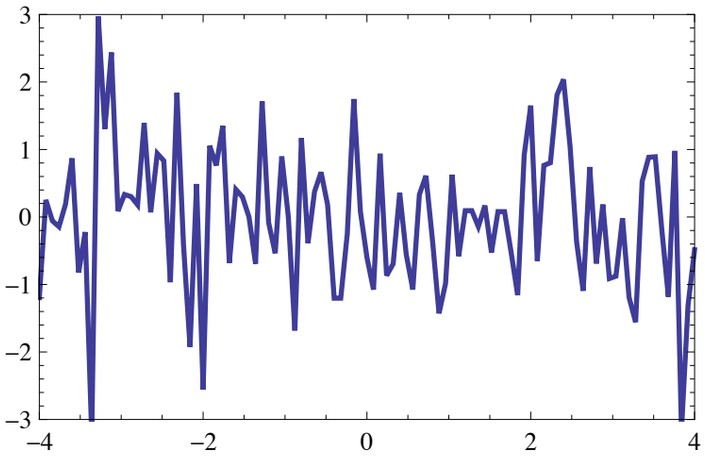


(no signal)

(signal hidden in noise,
so we subtract it out)

or



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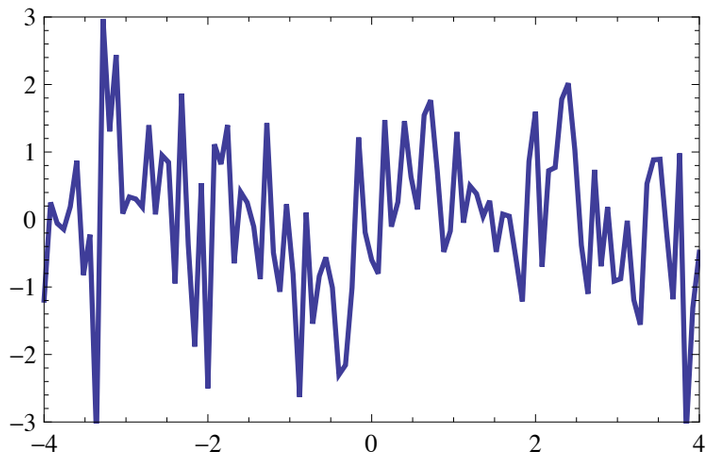

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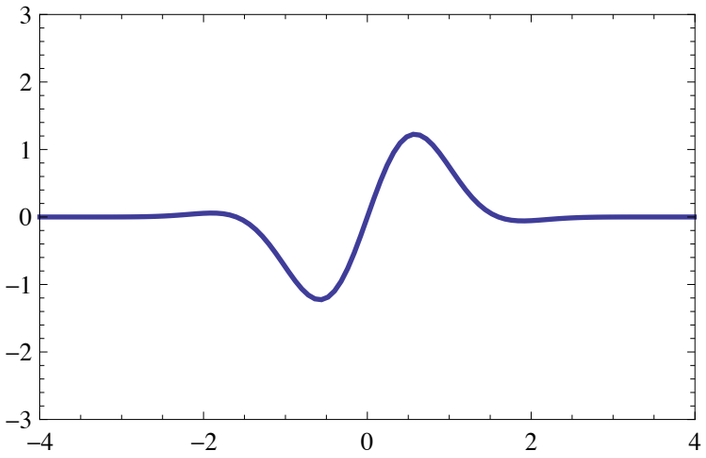
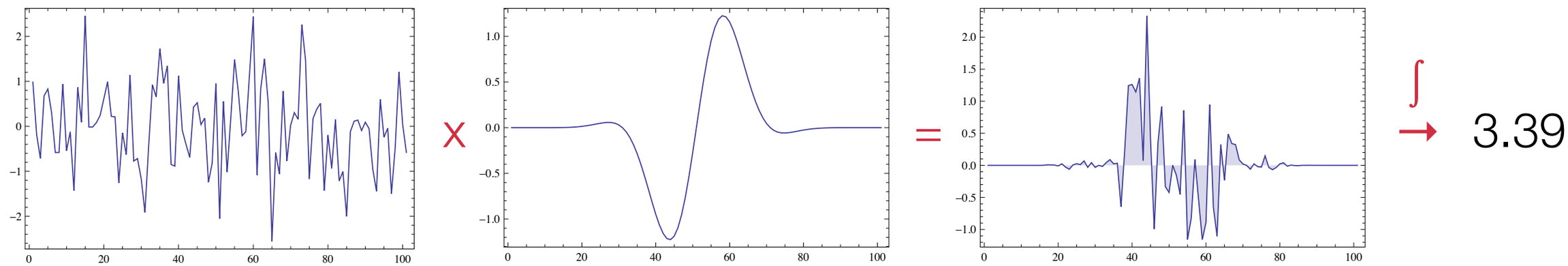
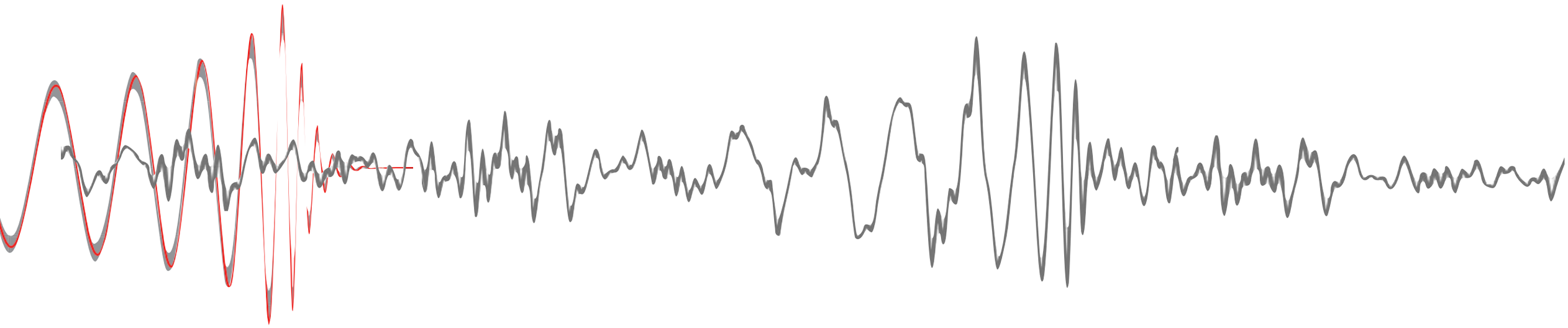


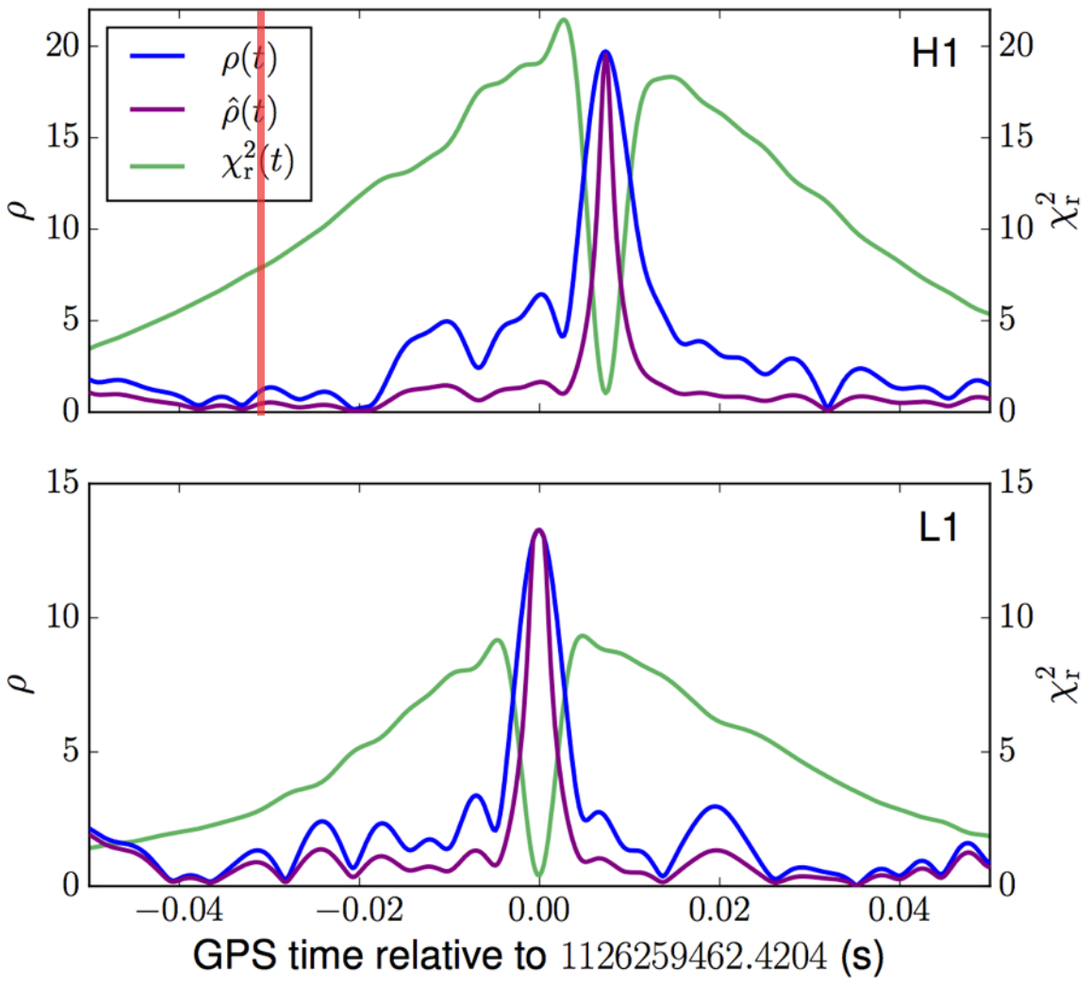
the ratio of probabilities is ~ exp(SNR$^2$/2),
(here ~ 270,000)

# an intuitive interpretation of this process
# is in terms of correlation products/matched filtering





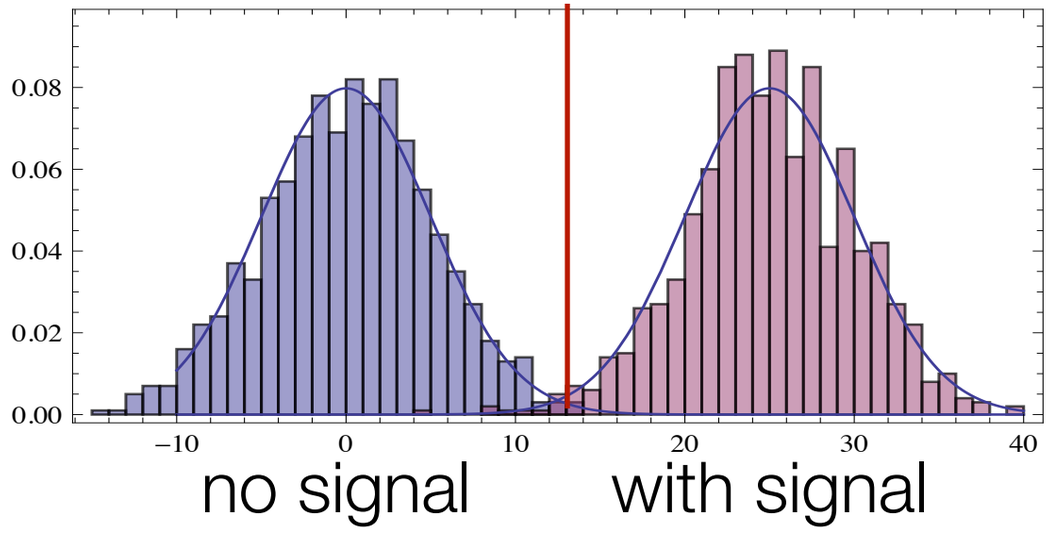



$$\mathrm{SNR}(t_0) = \int_0^{\Delta t} s(t+t_0)h(t)dt$$

detector data

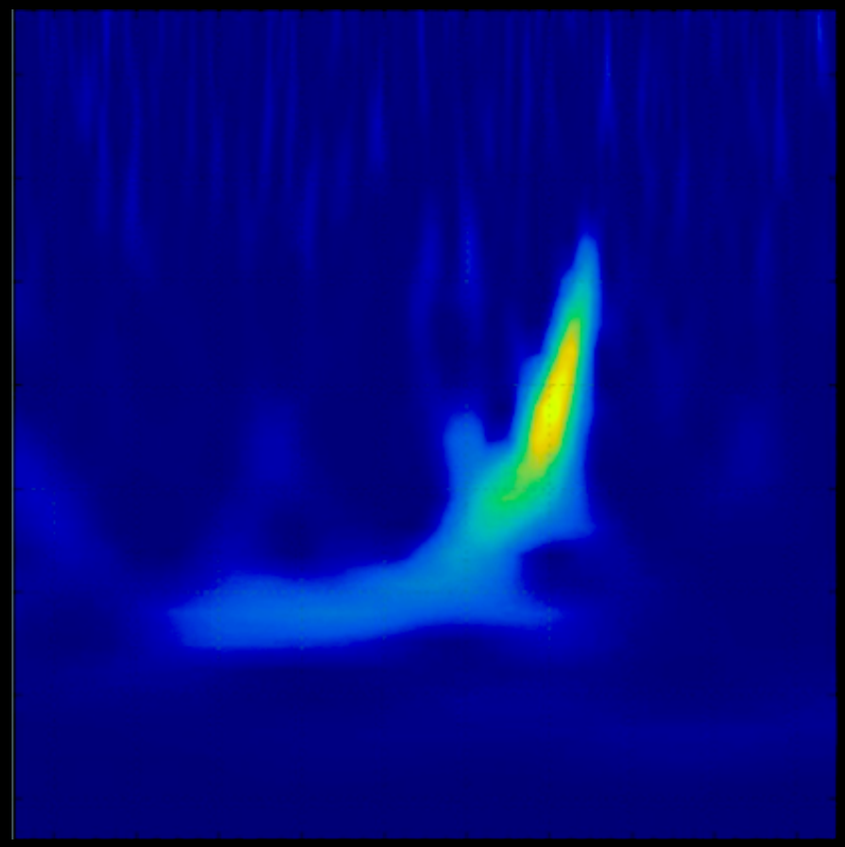
signal “template”

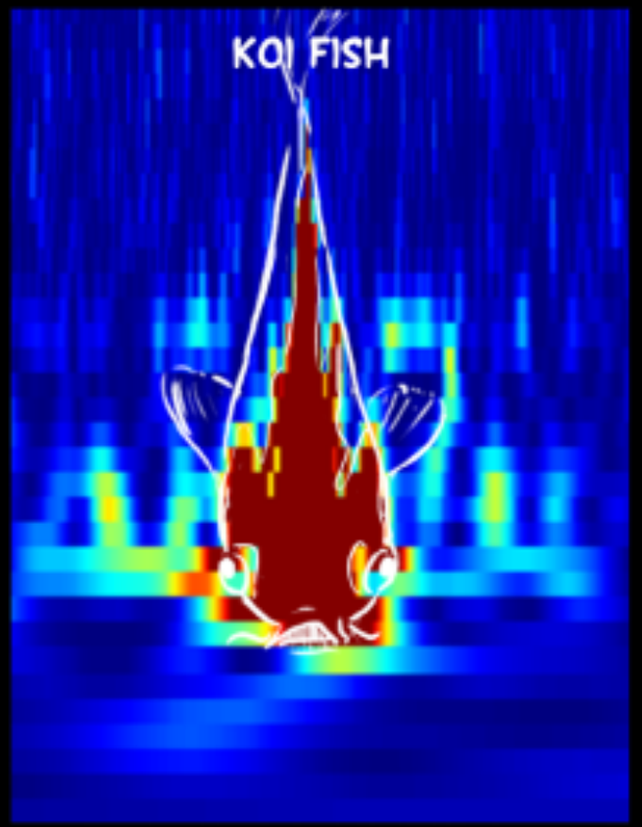
threshold

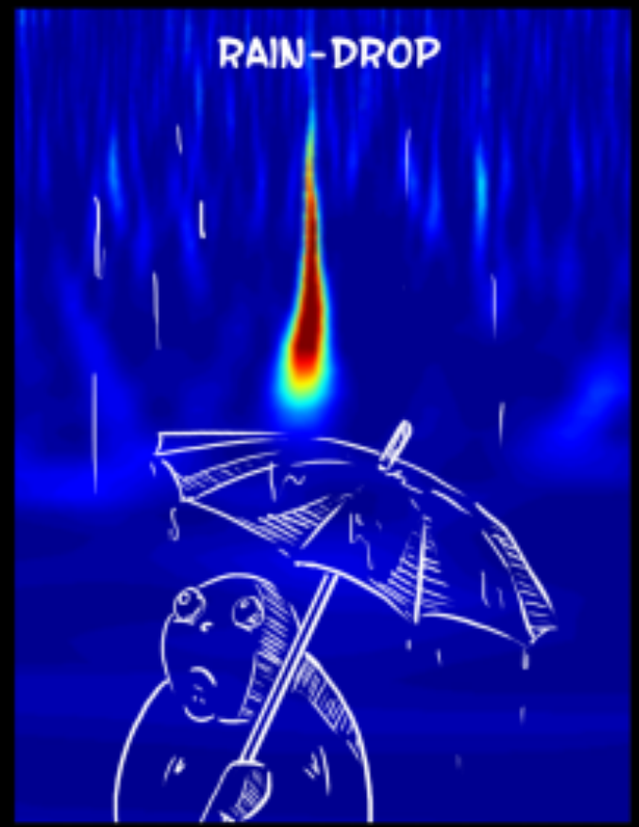


# signal vs glitch

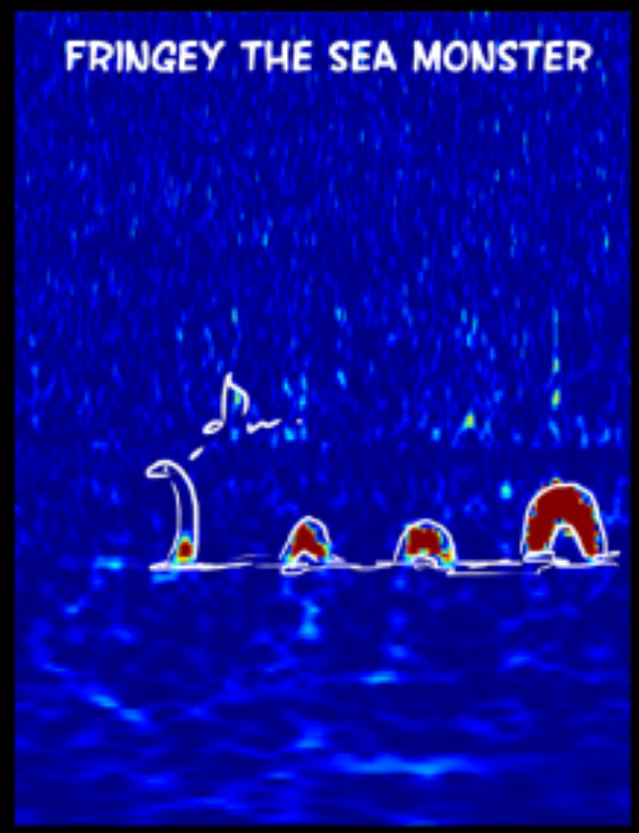
GW150914







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…to be continued…