Objective doubts about the authenticity of the event GW150914

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Abstract. The paper presents the results of processing the registration data of LIGO 14.09.2015. Impulse signals were detected using the theory of optimal detection. Soliton-like signals were highlighted with the help of sub-optimal (two-step) causal filtering of the LIGO data. These signals have a different polarity. It is also found absence of two chirp-signals, which announced February 11, 2016. Doubts about the reliability of the detection of chirp-signals, which announced February 11, 2016, are justified by the results the conducted analysis.

1. Introduction
In 1916 Albert Einstein predicted the existence of gravitational waves [1]. The discovery of the binary pulsar system PSR B1913+16 by Hulse and Taylor [2] and subsequent observations of its energy loss by Taylor and Weisberg [3] demonstrated the existence of gravitational waves.

Experiments to detect gravitational waves began with Weber [4]. It was announced the observation of gravitational waves from black holes merger thanks to the two signals registered according to observatories LIGO Hanford (H1) and Livingston (L1) in [5]. This paper presents the results of processing of registration data posted on the website LIGO (https://losc.ligo.org/events/GW150914) [6].

2. Registration data of two observatories
The time of arrival of gravitational waves:
- \( T_{\text{detect}} = 1126259462.39 = \text{September 14, 2015, 09: 50: 45.39 UTC}, \)
- signals were detected in the frequency band \([35\div350 \, \text{Hz}]\),
- the events have a combined signal-to-noise ratio \( \text{SNR}_{\text{combined}} \approx 24 \) [5-6].

These data were presented in February - May, 2016 on the website [6], later, in July 2016 the time of the gravitational wave arrival was corrected and been removed 0.39 seconds, this is roughening of accuracy the time of arrival.

The detected signals are contained in two strain time series (fragments) \( h_{\text{L}}(t) \), \( h_{\text{N}}(t) \).

Fragments \( h_{\text{L}}(t) \), \( h_{\text{N}}(t) \) have a duration of 32 seconds(Figure 1), strain time series centered at GPS 1126259462=September 14 2015, 09:50:45 UTC.

The corresponding random processes have a bandwidth \([10\div2048 \, \text{Hz}]\). Sampling frequency \( f_s = 4096 \, \text{Hz} \).

Start time of the fragment \( T_{\text{start}} = 1126259446 = \text{September 14 2015,09:50:29 UTC} \), it is...
16 seconds before the time of signal arrival \( T_{\text{detect}} = 16.39 \text{ sec} \).

Further seconds and its share are relative \( T_0 = 09 : 50 : 45 \) or \( T_{\text{start}} = 09 : 50 : 29 \).

Useful signals have an amplitude of \( 10^{-21} \). These signals are under the noise \((\text{SNR} < 10^{-3})\) (Figure 1), therefore it is necessary to apply optimal (suboptimal) detection methods.

On the page “Data release for event GW150914” (https://losc.ligo.org/events/GW150914/) are given:
- results of processing carried out by the members of LIGO Collaboration (Figure 2, top part);
- signals \( s_L(t) \), \( s_H(t) \) (Figure 2, bottom part) according to observation 14.09.2015.

![Figure 1](image)

**Figure 1.** Fragments \( h_L(t) \), \( h_H(t) \). The arrows indicate the time interval of the detected signals.

Times are shown relative to September 14, 2015 at 09:50:45 UTC (Figure 2). For visualization, all time series are filtered with a 35±350 Hz band-pass filter to suppress large fluctuations outside the detectors’ most sensitive frequency band, and band-reject filters to remove the strong instrumental spectral lines [5-6].

Declared time of the entry signal (0.39 s) indicated by blue circles [5-6]. Numbers and frequencies of wave phases (Figure 2, left top part). The true signals arrive into 0.33 s (green circle).

Experimental templates, shown in Figure 2 (bottom part), can be described as a first approximation by the relation:

\[
S(t) = A(t) \cos \left( \phi_0 + 2\pi \left( f_0 t + \frac{\beta t^2}{2} \right) \right),
\]

where \( S(t) \) - the chirp-signal; \( A(t) \) - the chirp-signal amplitude; \( f_0 \) - the carrier frequency; \( \phi_0 \) - the initial phase; \( \beta \) - the speed of change of frequency; \( f_0 = \frac{1}{2} \left( F_{\text{max}} + F_{\text{min}} \right) \); \( \beta = \frac{F_{\text{max}} - F_{\text{min}}}{T_s} \); \( \beta(t) \) - in the general case; \( F_{\text{min}} \), \( F_{\text{max}} \) - minimum and maximum value of the signal frequency; \( T_s \) - signal duration.

If \( \beta \) = constant and \( \beta = \frac{F_{\text{max}} - F_{\text{min}}}{T_s} \), then this signal is called a linearly frequency modulated (LFM) signal = chirp-signal (linear).

**3. Invariants of signals before and after filtering**

1. Chirp-signal stays the chirp-signal after passing through the band filter.
Filtering is defined by the convolution:

\[ Y(t) = X(t) \otimes h_f(t) , \]  

where \( h_f(t) \) - impulse response of a filter; \( X(t) \) - input process; \( Y(t) \) - the filtered process; \( \otimes \) is the sign of the convolution.

\[ f_{\text{H}(f)} = F_s(f) \cdot H(f) . \]

\[ \left| H(f) \right| \approx 1 \Rightarrow \int_{-\tau/2}^{\tau/2} X(\tau)^2 d\tau \approx \int_{-\tau/2}^{\tau/2} |F_s(f)|^2 \cdot 2df \approx \int_{-\tau/2}^{\tau/2} |F_s(f)|^2 \cdot 2df \approx \int_{-\tau/2}^{\tau/2} Y(\tau)^2 d\tau . \]

Where \( H(f) \) - the transfer function of the filter, \( H(f) = F(h_f) \) - the spectrum of the impulse response of the filter, \( \left| H(f) \right| \) - amplitude-frequency characteristic (AFC) of the filter.

2. The integral of the square of the signal remains practically unchanged if the signal in the filter band. This is a consequence of Parseval's theorem.

3. The spectrum of the signal after filtering remains practically unchanged if the signal is filtered in band, where \( |H(f)| \approx 1 \).

4. If the registered signals \( s_h(t) \) and \( s_L(t) \) coincide with the delay and inversion \( s_h(t) = -s_L(t + \tau) \), as stated in [5], their spectra \( \left| F_{s_{\Delta \gamma}}(f) \right| \approx \left| F_s(f) \right| \) are almost equal after filtering:

\[ s_{h_f}(t) = s_L(t) \otimes h_f(t) , \] \[ s_{h_f}(t) = s_h(t) \otimes h_f(t) . \]
4. The procedure of the detection of known signals

Detection of gravitational chirp-signal is based on the selection of one from two alternative hypotheses:

\[ H_0: \quad x_H(t) = n_H(t), \quad x_l(t) = n_l(t) \]
\[ H_1: \quad x_H(t) = n_H(t) + s_H(t), \quad x_l(t) = n_l(t) + s_l(t) \]

\( H_0 \) - hypothesis that chirp-signal is absent (chirp-signal is present) respectively.

From the mathematical theory of statistics follows [7] that the suboptimal receiver represents matched filtering procedure and then comparing to a threshold.

The matched filter has an impulse response equal to the inverted templates (Figure 2, bottom part):

\[ T_L(t) = s_L(T_{\text{template}} - t), \quad T_H(t) = s_H(T_{\text{template}} - t), \]

where \( T_{\text{template}} \) - template duration (duration of impulse response).

The matched filter of input records in the band \([35 \div 350 \text{ Hz}]\) with the signals, represented in Figure 2 (bottom part), is written by the relations:

\[ h_{ij}(t) = h_{ij}(\tau) \odot T_j(t), \quad h_{ij}(t) = h_{ij}(\tau) \odot T_H(t); \]

where \( h_{ij}(t) = h_i(t) \odot h_j(t) \), \( h_{ij}(t) = h_i(t) \odot T_j(t) \) - filtered processes after bandpass filtering in the band \([35 \div 350 \text{ Hz}]\). The procedure for testing the hypothesis of the presence of chirp-signals in the records:

1. Produced filtering \( h_{ij}(t) \), \( h_{ij}(t) \), then find \( h_{ij}(t) \), \( h_{ij}(t) \).

2. The convolution is produced in accordance with (7) and find \( h_{ij}(t) \) and \( h_{ij}(t) \).

3. Modules of \( h_{ij}(t) \) and \( h_{ij}(t) \) are compared with thresholds \((P_1, P_2)\).

\[ |h_{ij}(t)| > P_1 \Rightarrow \text{true } H_1 \text{ else } H_0, \quad |h_{ij}(t)| > P_2 \Rightarrow \text{true } H_1 \text{ else } H_0 \]

The signal/noise ratio is determined by the formula:

\[ \text{SNR} = \frac{A_{\text{max}}}{\sigma_n}. \] (8)

For example, mixtures of signal and noise were formed to demonstrate the matched filtering efficiency

\[ x_L(t) = h_L(t) \odot h_l(t) + s_L(t - \tau_s) \frac{\sigma_s}{\sigma_s} k_{\text{SNR}}, \quad x_H(t) = h_H(t) \odot h_H(t) + s_H(t - \tau_s) \frac{\sigma_H}{\sigma_s} k_{\text{SNR}}, \] (9)

where \( h_L(t) \) - impulse response of a band filter \([35 \div 350 \text{ Hz}]\); \( h_L(t), h_H(t) \) - initial deformation;

\( \sigma_s \) - rms of signal \( s(t) \); \( \sigma_s (\sigma_H) \) - rms of noise \( n_L(t) \); \( n_H(t) \) - \( \sigma = (\text{Disp}(h(t)))^{1/2}, k_{\text{SNR}} \) - factor depending on SNR; \( \tau_s \) - time of signal arrival.

Mixtures of signal and noise \( x_L(t), x_H(t) \) are calculated for the following parameters: time of model signal arrival \( \tau_s = 15 \text{ sec} \), \( k_{\text{SNR}} = 1.0 \).

Matched filtering results \( x_L(t), x_H(t) \) with model signals \( s_H(t) \) and \( s_L(t) \) shown in Figure 3.

The signal/noise ratio at the output \( \text{SNR}_{\text{out}} \) is determined by the \( \text{SNR}_{\text{in}} \) and gain at the expense of processing \((B_{\text{SNR}})\):

\[ \text{SNR}_{\text{out}} = B_{\text{SNR}} \cdot \text{SNR}_{\text{in}}. \] (10)

For formed processes \( x_L(t), x_H(t) \) signal/noise ratio at the input in the simulation near 15th second:

\[ \text{SNR}_{\text{in mod}} \approx 2.323 \]

It is clearly distinguished model signals to the 15th second after matched filtering on Figure 3, \( \text{SNR}_{\text{out}} \approx 8.9 - 10.7 \) when the input signal/noise ratio \( \approx 2.323 \).

Input signal/noise ratio for gravitational signals, if the real signals are in Figure 2:
At such values $SNR_{in}$ by the formula (10)

$$SNR_{out} > \frac{8.9 \cdot 5.25}{2.323} = 20,$$

that is more than twice as many compared with model signals at the 15th second.

![Figure 3](image)

Figure 3. The results of matched filtering the mixture of signals and noises. Signals are at the 15th (test model) and 16th (supposed) seconds.

If hypothesis $H_1$ is true then $SNR_{out}$ should be more than 20.

A small rise seen near 16th second ($SNR_{real} \approx 3$) as a result of matched filtering (Figure 3), which is much smaller than it should be (equation (11)).

Thus, the hypothesis $H_1$ is not confirmed ($SNR_{real} << 20$).

This means: the chirp-signals are absent in the original records (Figures 1, 2).

5. Determination of the signals and their parameters

If the chirp-signals are absent in registration data (Figure 1), it is necessary to determine the type of signals that are in LIGO records 14.09.2015.

Below are the results of processing of registration data for this purpose.

5.1. Evaluation of the times of signal arrivals

For this purpose, the optimum detector is used, which calculates the likelihood ratio:

$$L(h_n | s) = \ln \frac{P(h_n | s)}{P(h_n | n)}, \quad L(h_i | s) = \ln \frac{P(h_i | s)}{P(h_i | n)}.$$  \hspace{1cm} (12)

From equation (12) it follows that the unknown signal detection in a first approximation, based on the calculation of the functional [7-8]:

$$U(t) = \int G_{st} (f) \frac{G_{st}(f)}{G_{st}} df,$$  \hspace{1cm} (13)

where $G_{st}(f)$, $G_{st}(f)$ - energy process spectra before and after the current time $t$, $f_l$, $f_u$ - lower and upper frequency range of the signal.

Looking at Figure 4, you can see:

- confident detection of signals on the observatories L1, H1;
- signal arrived first at L1 and $\leq 10$ ms later at H1;
- $SNR \geq 7$;
arrival time at L1 earlier 16.4 sec. $T_{arrival}=16.395$ sec, $T_{arrival}>16.33$ sec.

Figure 4. The results of the optimal detector Hanford ($H1$) - blue line, Livingston ($L1$) - red line.

5.2. Definition of signal waveforms using filtration

This is done using a two-stage causal filtering:

1st step. Butterworth filter, $35 \div 350$ Hz band, the filter order = 8.

2nd step. Butterworth filter, $60 \div 450$ Hz band, the filter order = 4 (to notch components at frequencies near 32 Hz and 60 Hz).

According to [5-6], the amplitude of the wave phases $\neq 47\ A \approx 4 \cdot 10^{-21}$ (Figure 2), and their frequency is greater than 80 Hz and below 250 Hz, so after a two-step filtration ($AFC \ |H(f)| \approx 1$), these wave phases have not practically change.

However, these wave phases are not observed in the time interval 16.39 seconds -16.45 seconds in Figure 5 and Figure 8, and there are pulse signals (amplitude signals from $1 \cdot 10^{-21}$ to $2.5 \cdot 10^{-21}$).

This is a clear contradiction, and so the property of invariance $\neq 1$ is violated.

Similarly, one can see in violation of their of invariance $\neq 2$.

In more detail the detected signals are represented in Figure 5 (right part, Regime “Magnifier”). Signals (Figure 5, right part) are similar to the wavelets “Mexican hat”.

They have the property of solitons: the higher the frequency the greater the amplitude,

$\max A_L > \max A_H$ , $f_L > f_H$.

Spectra of these signals are shown in Figure 6.

Spectrum of signal $L1$ is a higher frequency than spectrum of signal $H1$ and invariants ($\neq 3,4$) are not performed.

It follows from Figure 6:

$max S_H(t) \approx 165$ Hz, $\max S_L(t) \approx 205$ Hz;

$\Delta F = F_{max L}F_{max H} = 40$ Hz = $205 - 165$ Hz.

This is a clear contradiction to the declared data about detected signals [5,6], and contradicts the invariance properties of the spectra of signals at filtering (Invariants $\neq 3,4$).

It means: $s_H(t) \neq -s_L(t + \tau)$ !
Figure 5. Left part. Recordings of filtered information, the time interval 13.2 sec - 16.8 sec.
Right part. Recordings of filtered information, the time interval 16.425 sec - 16.445 sec.
Regime “Magnifier”. For a visual comparison the \( L_1 \) data are inverted.

6. Discussion of processing results

Different types of filtration are used in detection of signal with a priori unknown form: bandpass, whitening, etc. [7-8].

Physically realizable filter whitening is based on the use of optimal filtering of Wiener-Kolmogorov theory [9-10] and Levinson-Durbin procedure [11-12].

This approbation way of noise whitening was refused in [5-6].

Whitening (rectify) is proposed to conduct in the frequency domain in [5-6], using the equation:

\[
Y(t) = F^{-1} \left( F_X(f) F_h(f) \right),
\]

where \( F_X(f) \) - Fourier transform of \( X(t) \); \( F_h(f) \) - transfer function of the whitening filter; \( F^{-1} \) - inverse Fourier transform.

The transfer function of the whitening filter is in [5]:

\[
H(f) = R_{whitening}(f) + i \text{Im}_{whitening}(f),
\]

\[
R_{whitening}(f) = \frac{1}{G_e(f)^{1/2}}, \quad \text{Im}_{whitening}(f) = 0.
\] (15)

This function has a zero phase.

The transfer function of the filter (equation (15)) is a real even function. The impulse response is the inverse Fourier transform (\( F^{-1} \)) of the function (equation (15)). From the properties of the Fourier transform it follows that the impulse response will also be a real even function.

\[
\text{transfer function } H(f) \quad \text{even, real}
\]

\[
\text{impulse response } h(t) \quad \text{even, real}
\]

\( F^{-1} \)

This function \( h(t) \) is symmetric with respect to \( t = 0 \) and therefore there will be non-zero values of the impulse response in negative time \( t < 0 \) (Figure 7).

If there are non-zero values in the impulse response for \( t < 0 \), the causality principle is violated: the filter response occurs earlier than the input effect.

This is the proof that filter (equations (14), (15)) is a physically unrealizable (not causal).

The application of the corresponding filter leads to false detection of signals, shifts of the time of their arrival and distortion of their forms [13-15].
Figure 6. Signal spectra on observatories L1 (red line) and H1 (blue line).

A clear example of the impulse response of a zero-phase filter is given below (Figure 7, right part). In this figure $h_1(t)$ is the impulse response of the Butterworth filter, 35–350 Hz, the order is 6, the transfer function is:

$$H_1(f) = F(h_1(t)) = H_{batter}(f);$$

the transfer function $H_2(f)$ is equal to the modulus $H_1(f)$:

$$H_2(f) = |H_{batter}(f)|.$$

The function $H_2(f)$ is real and even, the impulse response $h_2(t)$ is also real and even (Figure 7, right part) and non-zero values are clearly visible for $t < 0$.

These two filters have the same amplitude-frequency characteristics ($|H_2(f)| = |H_1(f)|$), and different phase characteristics ($\varphi_2(f)$ is not equal $\varphi_1(f)$), $\varphi_2(f) = 0$).

A visual comparison of the results of two different types of processing of registration data is presented in Figure 8.

Chirp-signals are not visible after causal filtering (Figure 5, 8), therefore the signals (Figure 2) are false, obtained by the not causal filters based on equations (14) and (15).

Figure 7. Left part. Impulse response of the Butterworth filter, 35–350 Hz, order = 6.

Right part. Impulse response $h_2(t)$, transfer function $H_2(f) = |H_{batter}(f)|$. 

In accordance with the LIGO scenario, the input useful signals (perturbations of the metric of the space at the input of the recorders of LIGO) are chirp-signals, which are obtained as solutions to the equations of rotation and merger of two black holes [16-17] along elliptical trajectories. Above, the absence of black hole merger signals was experimentally confirmed by on the same records and signals of a different type are found.

It can be explained as follows:
parabolic or hyperbolic trajectories without the merger are more likely[18-19].
For such trajectories, the most probable signals are signals of several half-periods (example is shown at Figure 5, right part).
In this case, the body makes several turns around the black hole and once again flies off in space.

7. Conclusions
1. Chirp-signals are absent in LIGO data 14.09.2015.
This is established by means a matched filter and two-steps filtration, therefore signals of the merger of black holes are absent in the these data.
2. Signals of type “soliton” were highlighted by means of bandpass filtering (two steps). Two impulse signals of different polarity were found in these records. The corresponding wavelet “Mexican hat”.
3. The spectra of the detected impulse signals have maxima:
max $S_H(t) \approx 165 \text{ Hz}$, $\max S_L(t) \approx 205 \text{ Hz}$;
4. The detected signals at $L1$ и $H1$: $s_H(t) \neq -s_L(t + \tau)$.
Appendix. You can filter data using standard procedures of MATLAB
Filtering program (MATLAB) for LIGO data and its description
(https://cloud.mail.ru/public/74ZC/nQUn6LryQ)
With its help everyone can make sure, that there are no signals from black hole merger in the LIGO records 14.09.2015.

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