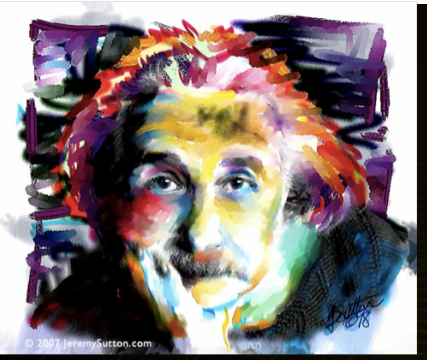
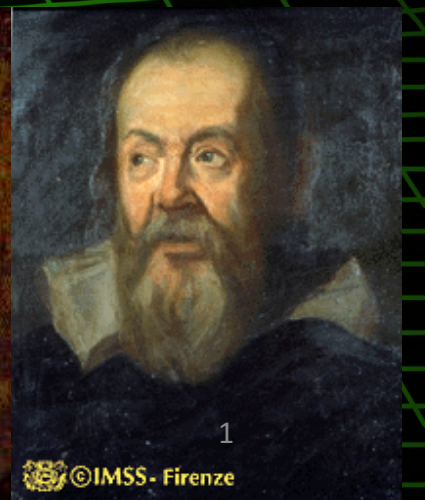
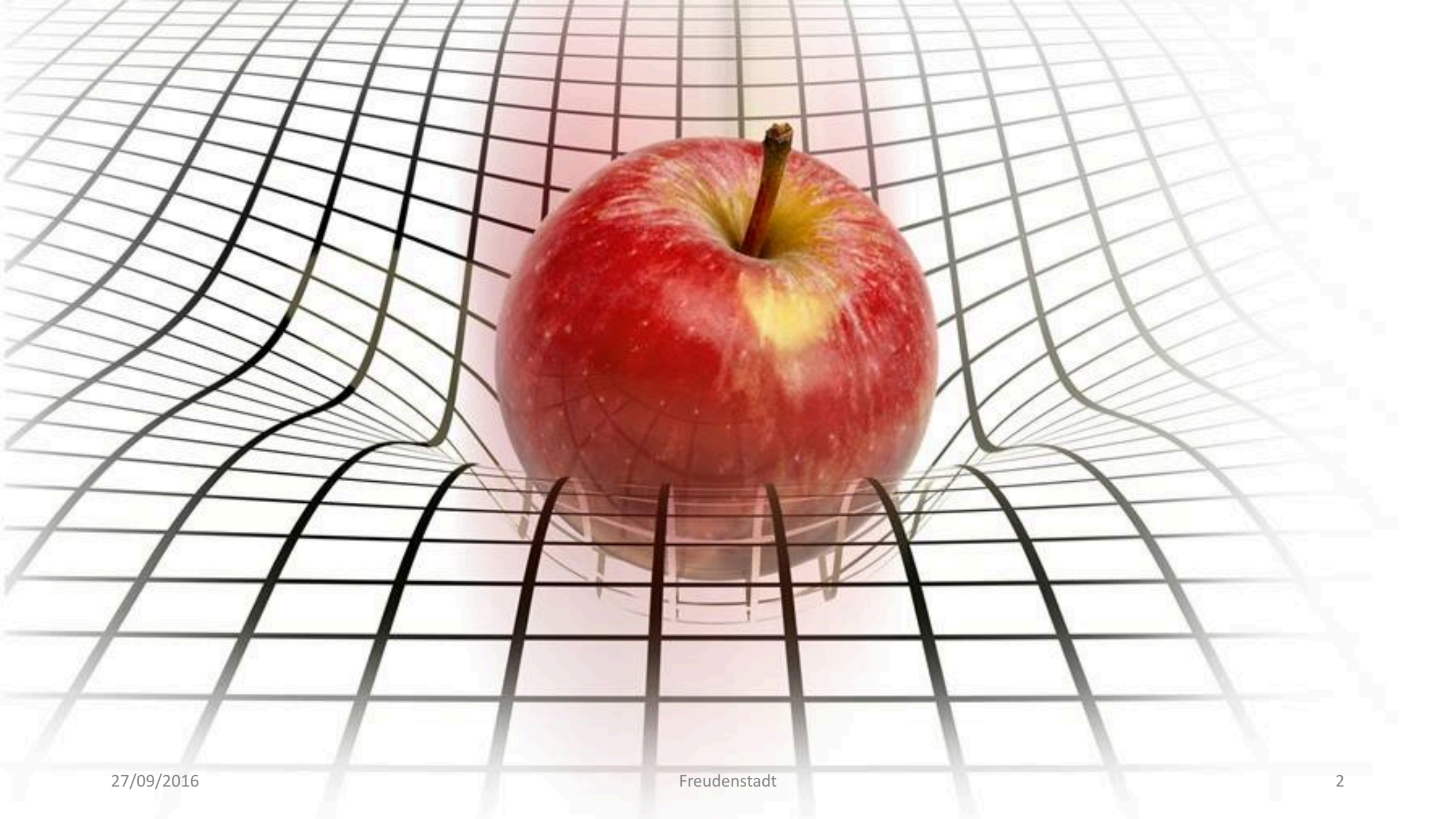


GRAVITATIONAL WAVES

KOSTAS KOKKOTAS

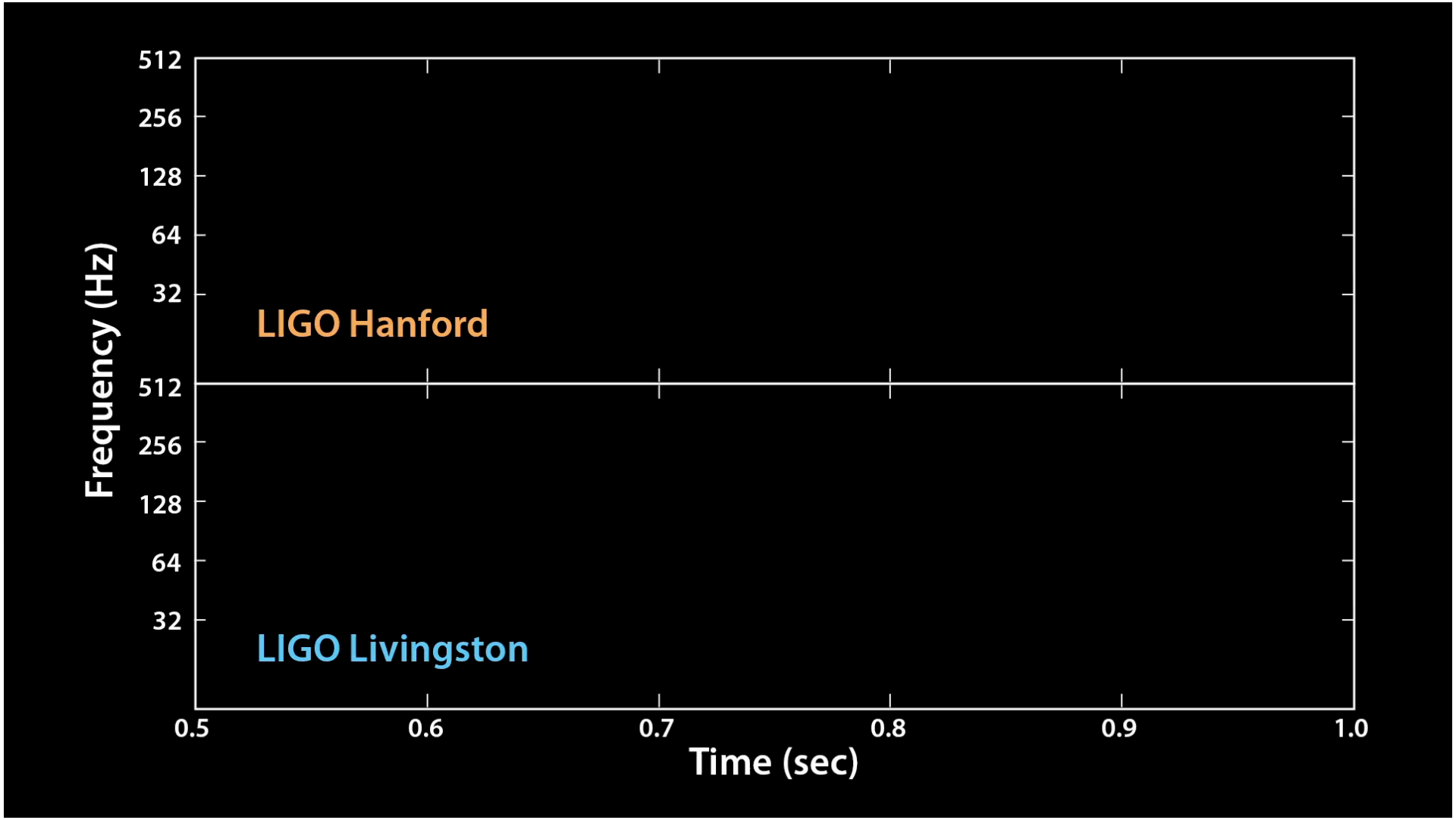




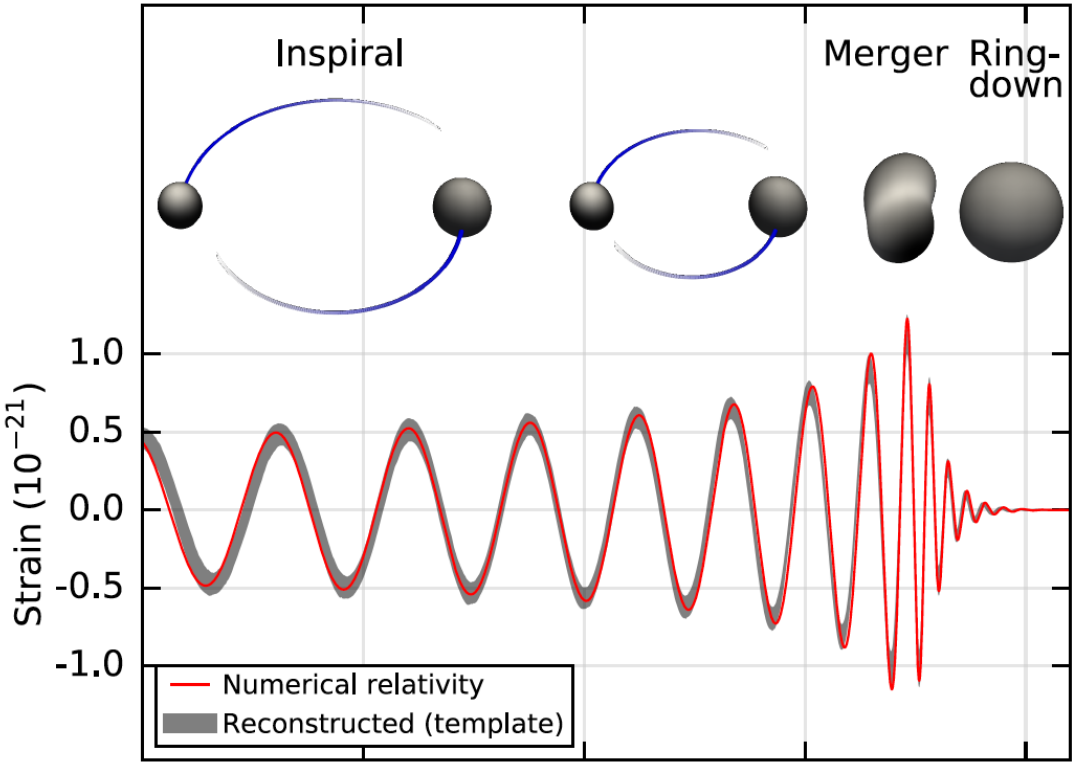
1.300.000.000 years ago!

Credits LIGO

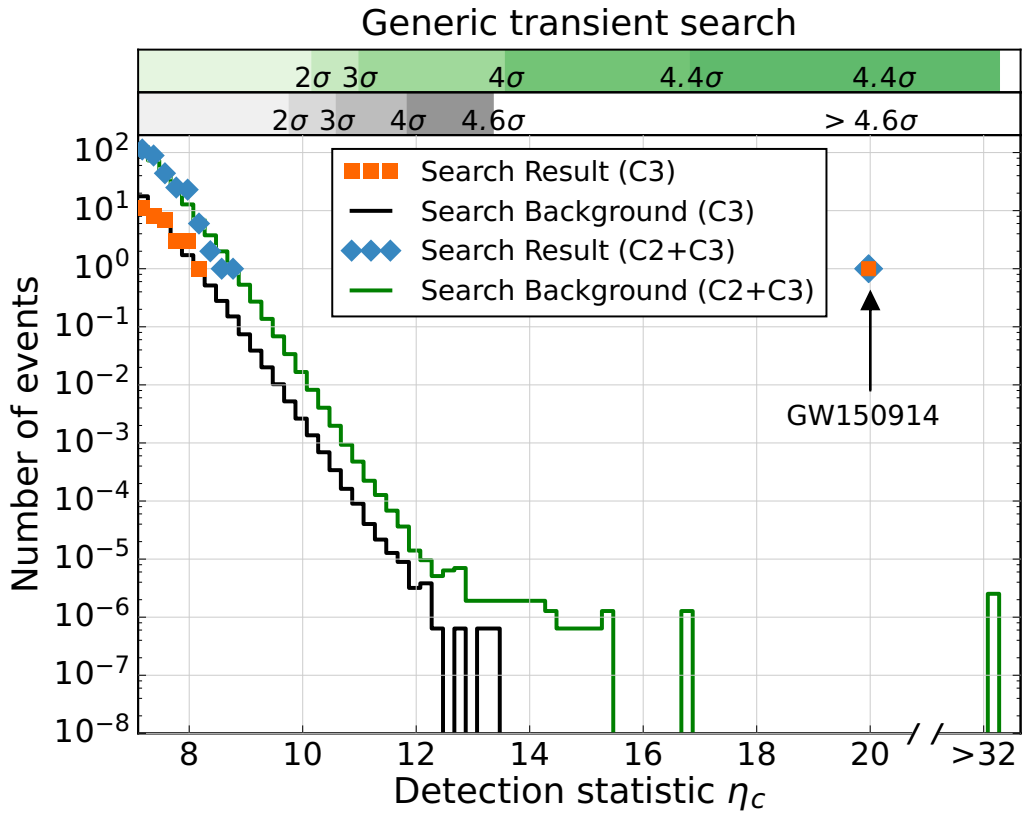
THE «SOUND» OF VACUUM

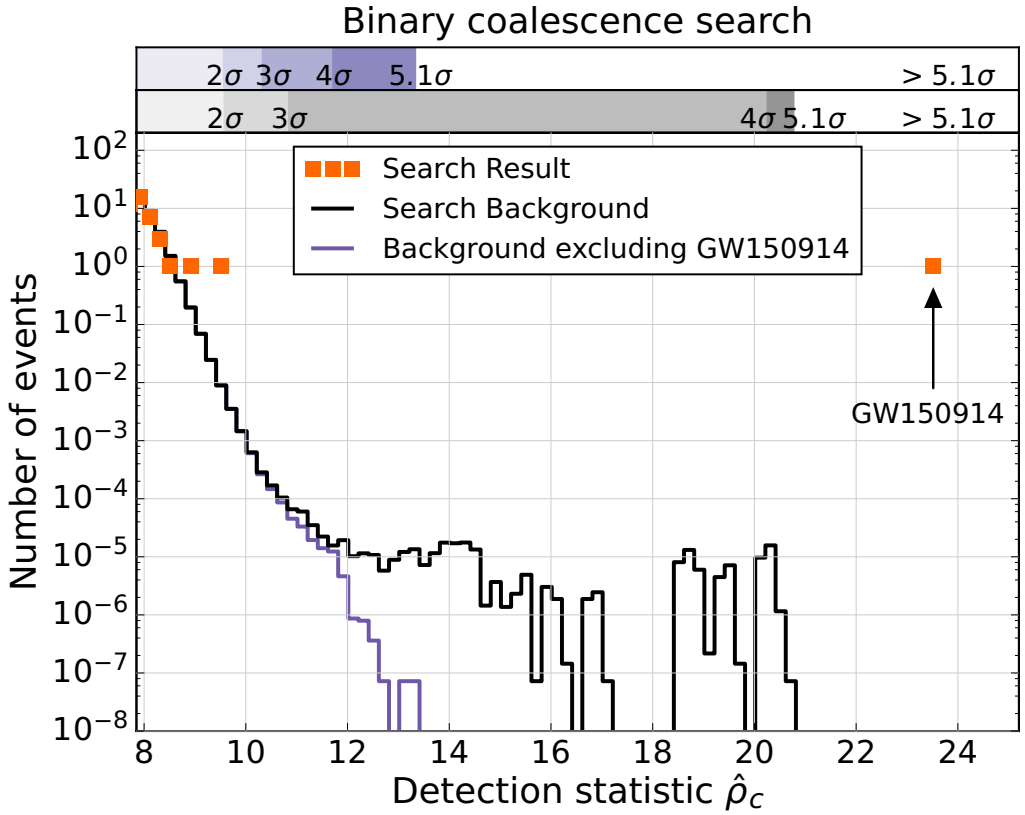


THE EVENT: 14/9/2015 (09:50:45 UT)



Detection Confidence





Event significant in both unmodeled and modeled searches

Abbott et al. 2016a, PRL 116, 061102

WHAT DID THEY OBSERVE?

M_1 : $36^{+5}_{-4}\ M_\odot$

M_2 : $29^{+4}_{-4}\ M_\odot$

S/N : **~24**

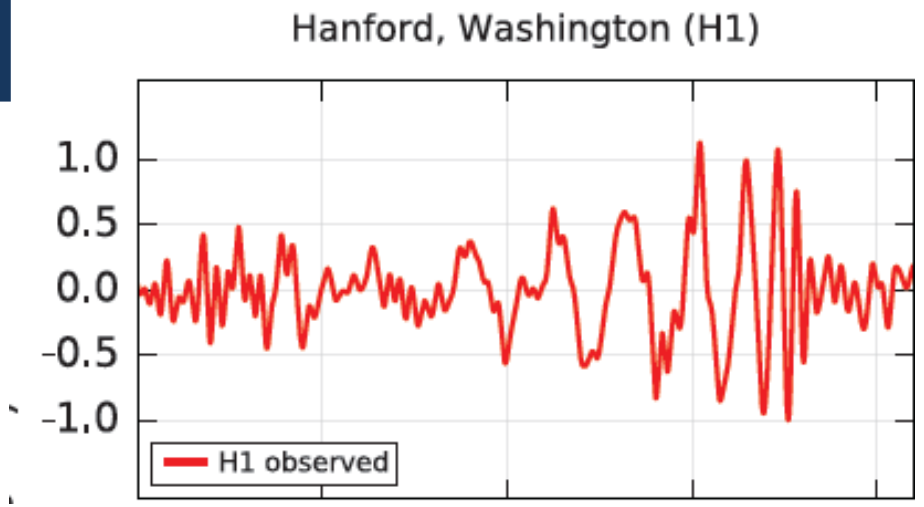
Spin : 0.67

Final Mass : $62^{+4}_{-4}\ M_\odot$

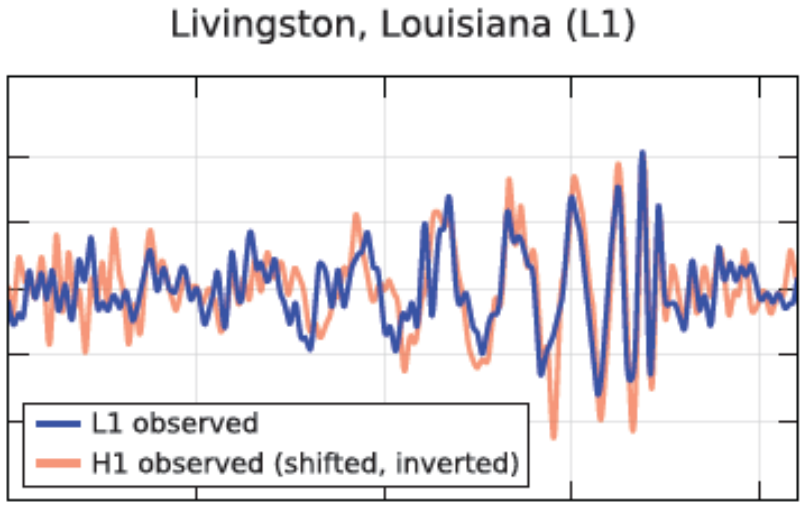
Distance : $410^{+160}_{-180}\ Mpc$

~1.3 x 10^9 light years

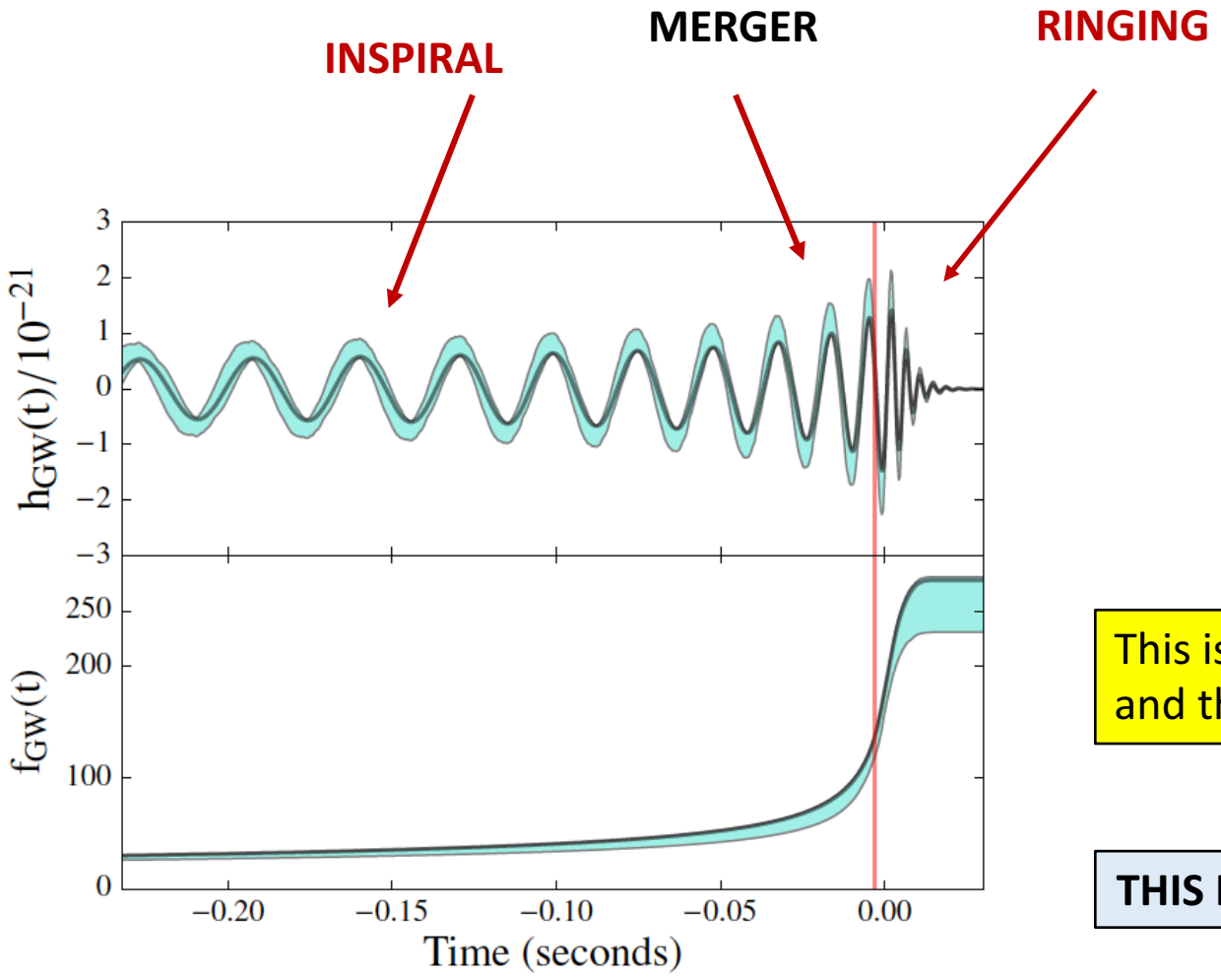
Redshift : **z~**$0.09^{+0.03}_{-0.04}$



GW150914



SIGNAL ANALYSIS



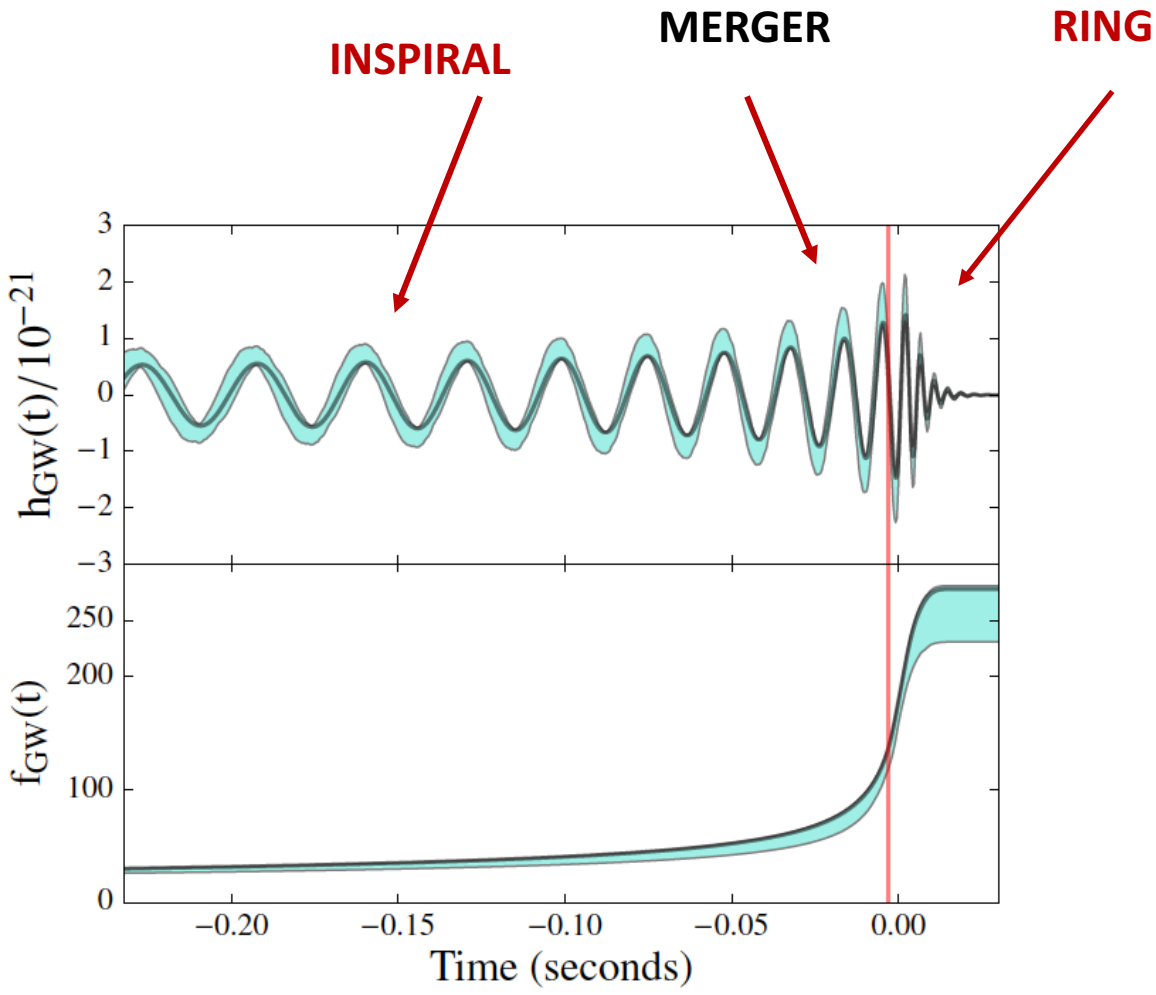
- $f_{GW} \sim 35\ Hz$
- $f_{GW} \sim 150\ Hz$
- 8 περιφορές
- Duration ~0.23-0.25 sec
- $\frac{v}{c} \sim 0.5$

This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

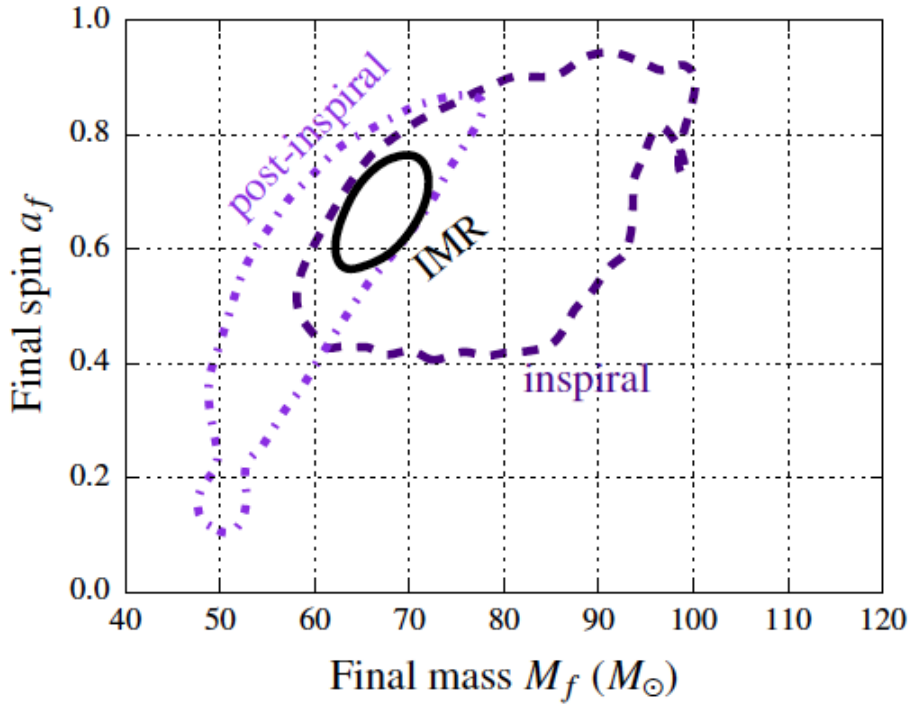
NOT ONLY!

THIS IS THE FIRST DIRECT DISCOVERY OF BLACK HOLES

SIGNAL ANALYSIS



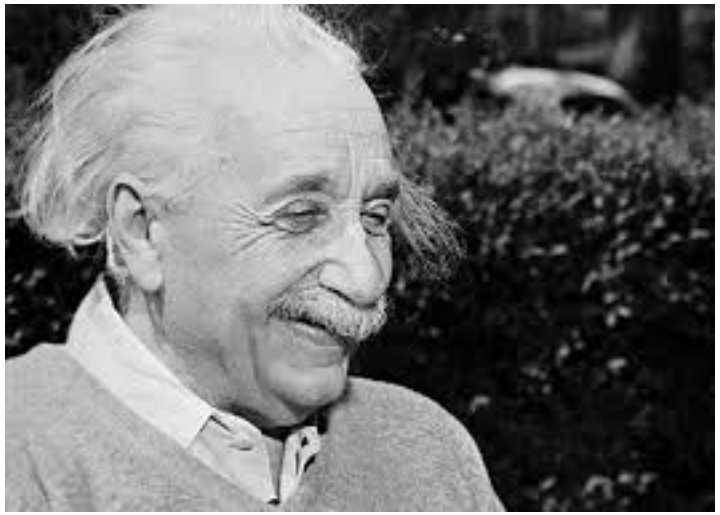
90% confidence regions for the final compact object



FINDINGS

- **Quite good agreement with the event rate**
- **First detection of binary black-hole systems**
- **Larger than expected black-holes !**
- **------**
- Estimation of masses before and after merger
- Total energy emitted **~3 solar masses**
- Peak luminosity **3.6×10^{56} erg/sec**
  - **Equivalent to 200 solar masses/ sec**
  - **50 higher than the luminosity of the whole universe**
  - «Graviton mass» if exists should be smaller than: **$m_g < 1.2 \times 10^{-22}$ eV/c^2**
- The **final "ringing"** (quasi-normal mode) in agreement with the ringing of a Kerr black-hole.

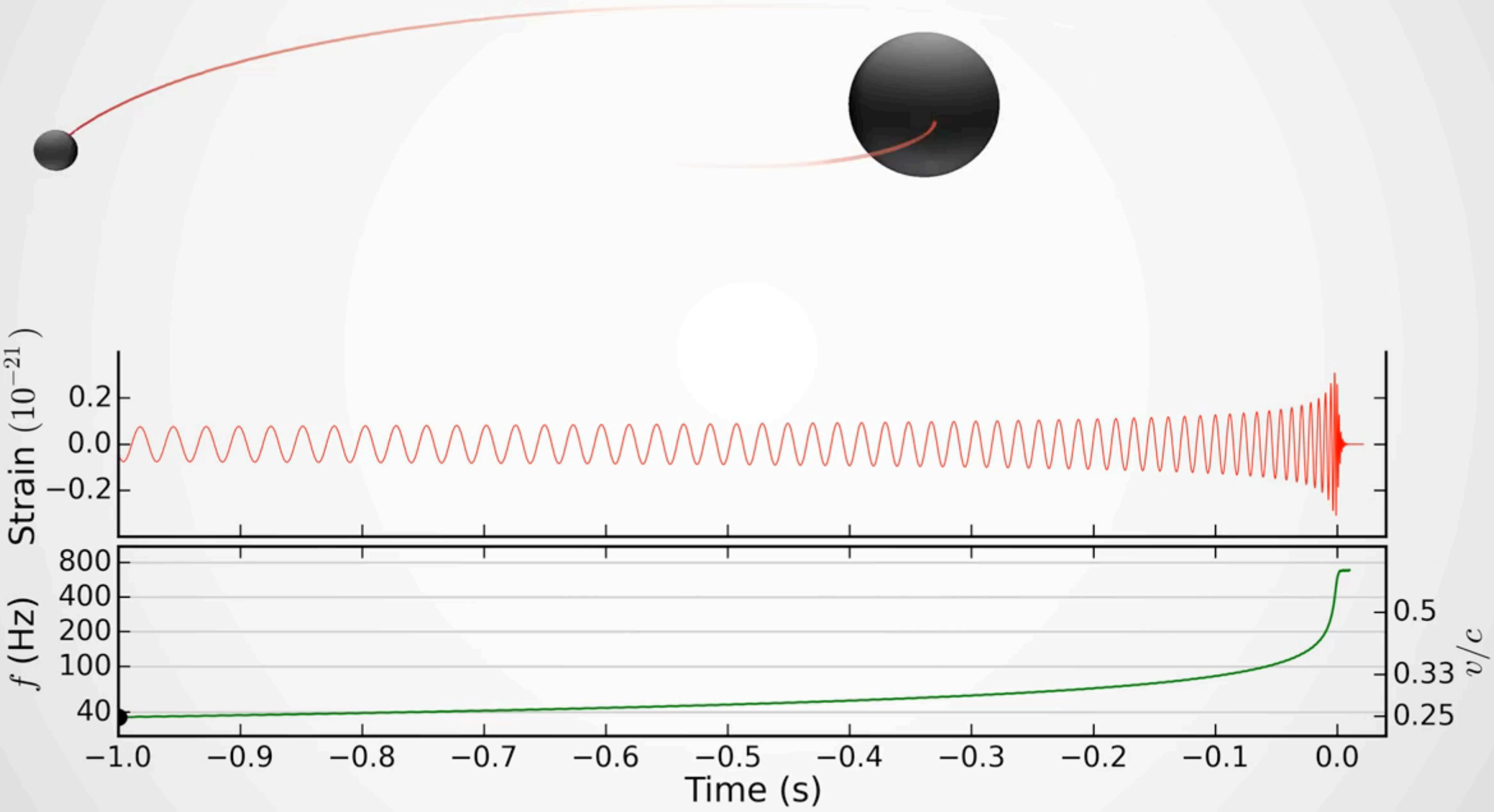
FINDINGS



ALL FINDINGS
IN GOOD AGREEMENT
WITH
GENERAL THEORY OF RELATIVITY

100 days later, it happened again

26.12.2015 – Boxing day


Strain (10^{-21})
0.2
0.0
−0.2
f (Hz)
800
400
200
100
40
0.5
0.33
0.25
v/c
−1.0
−0.9
−0.8
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
Time (s)

WHAT DID THEY OBSERVE?

GW151226

M_1 : $14.2^{+8.3}_{-3.7}\ M_\odot$

M_2 : $7.5^{+2.3}_{-2.3}\ M_\odot$

S/N : ~13

Spin : 0.74

Final Mass : $20.8^{+4}_{-4}\ M_\odot$

Distance : 440^{+180}_{-190} Mpc

~1.4 x 10^9 light years

Redshift : z~$0.09^{+0.03}_{-0.04}$

Radiated GW energy : ~$1.0^{+0.1}_{-0.2}\ M_\odot c^2$