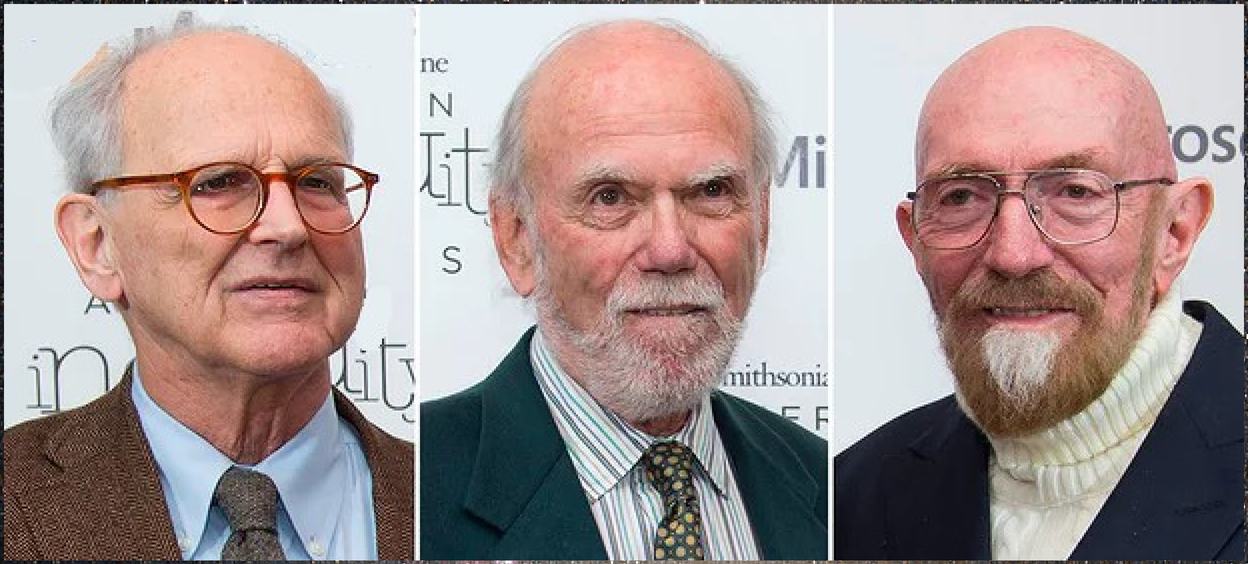
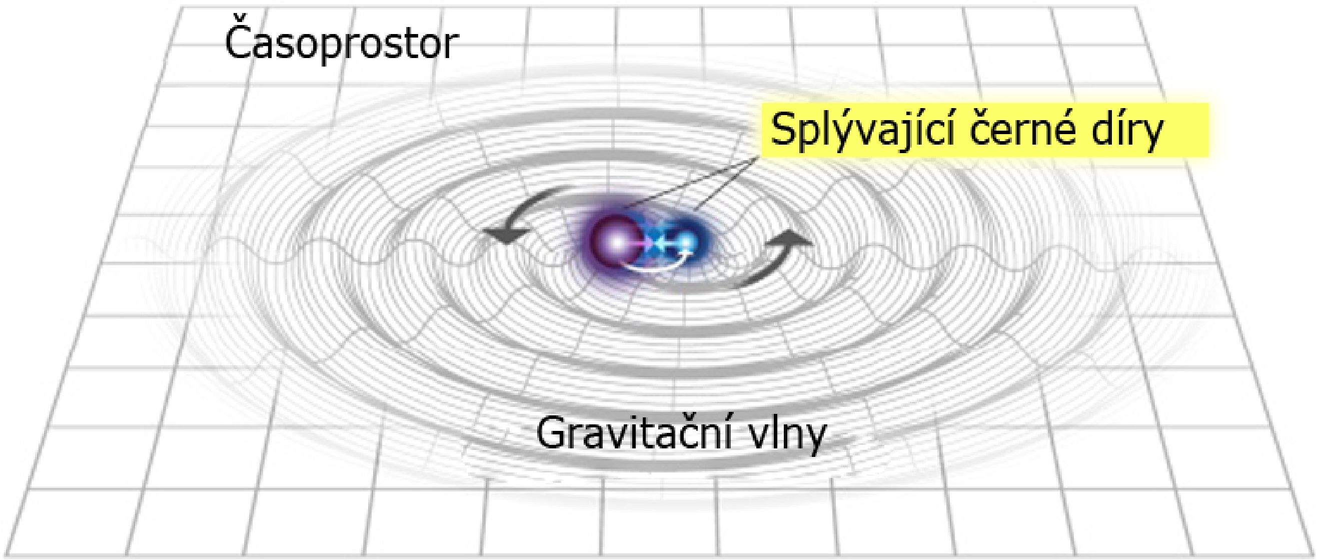
Nobelova cena za fyziku 2017

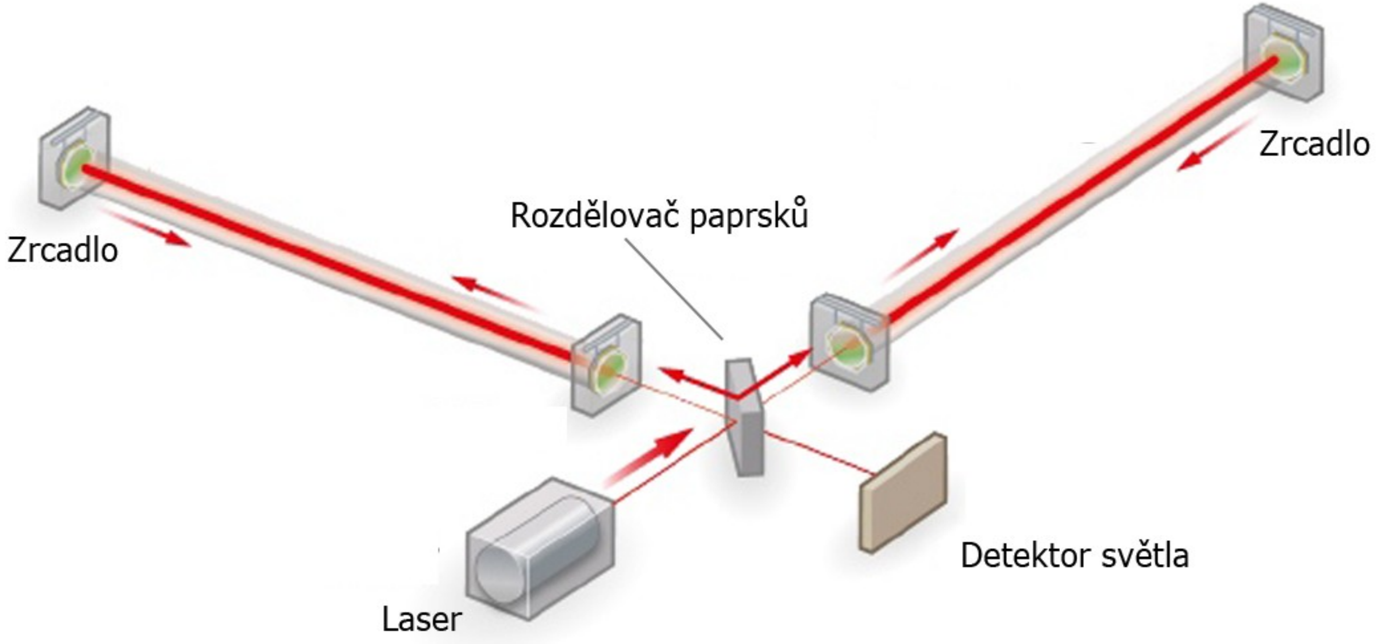


Jak LIGO zachytilo gravitační vlny?

Laser Interferometer Gravitational-Wave Observatory (zkráceně LIGO) zachytilo zvlnění časoprostoru, které předpovídala již Einsteinova Obecná teorie relativity.

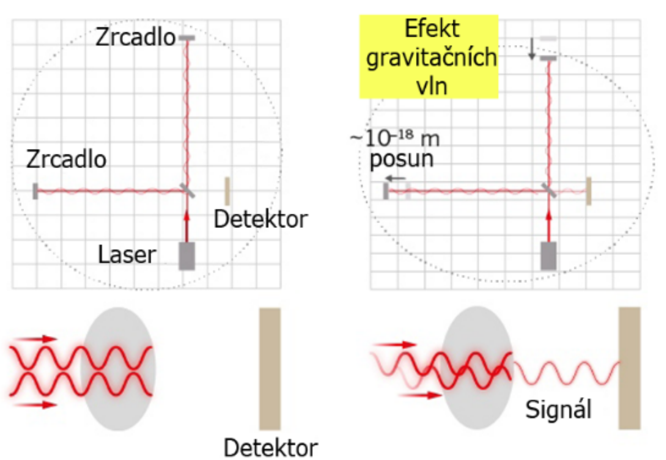


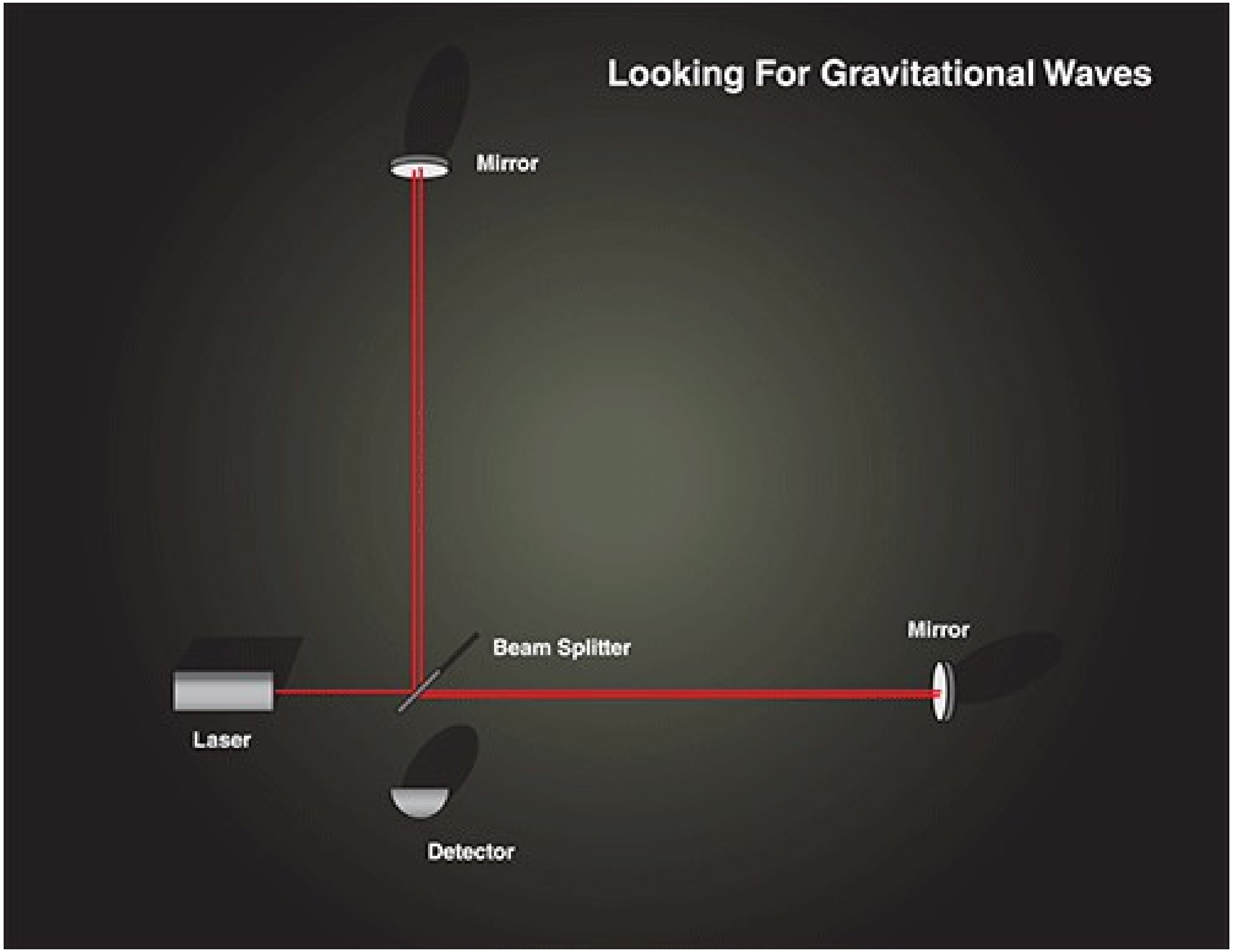
https://youtu.be/zLAmF0H-FTM

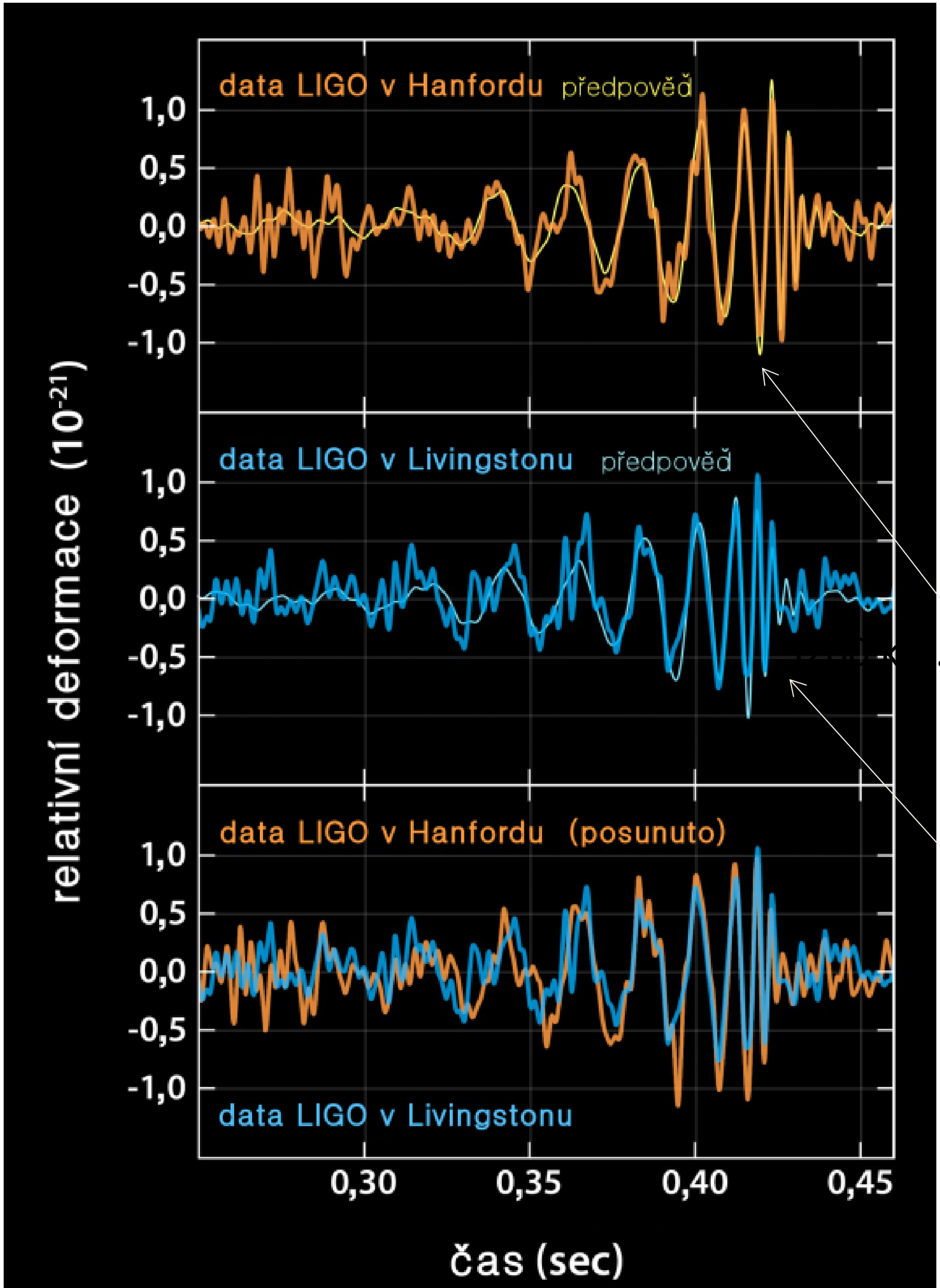


Normálně by se oba světelné signály vyrušily, protože by ulétly stejnou vzdálenost a vlny by byly identické. Detektor by pak nic nezaznamenal.

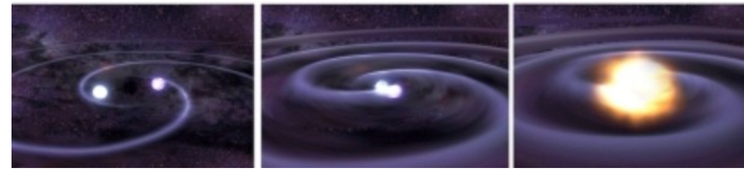
Když observatoří LIGO prochází gravitační vlna, tunely se mírně deformují a oba paprsky urazí odlišnou vzdálenost. Nevyruší se a detektor zachytí světlo.

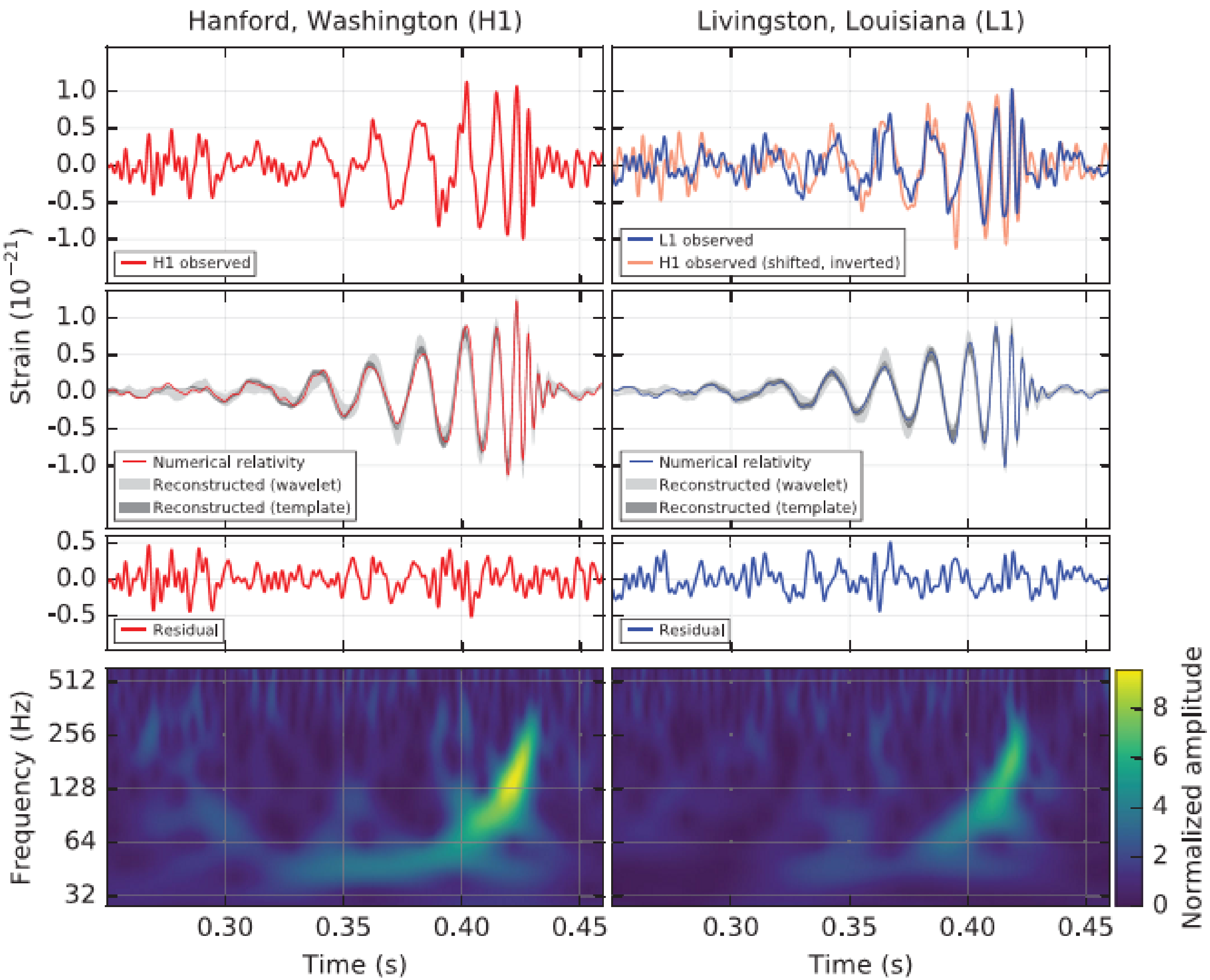



Looking For Gravitational Waves
Mirror
Beam Splitter
Mirror
Laser
Detector



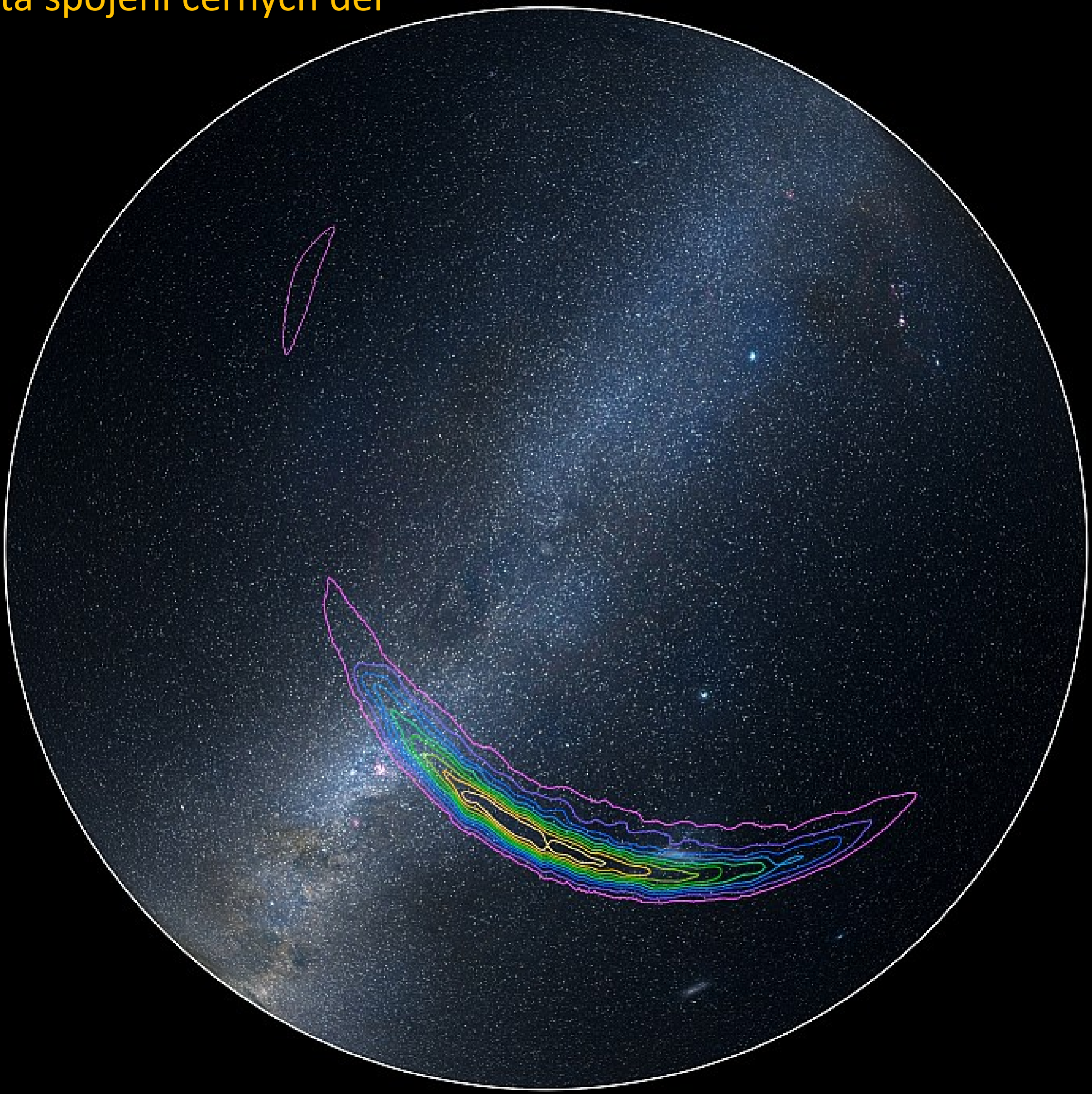
14.9.2015 11. února 2016

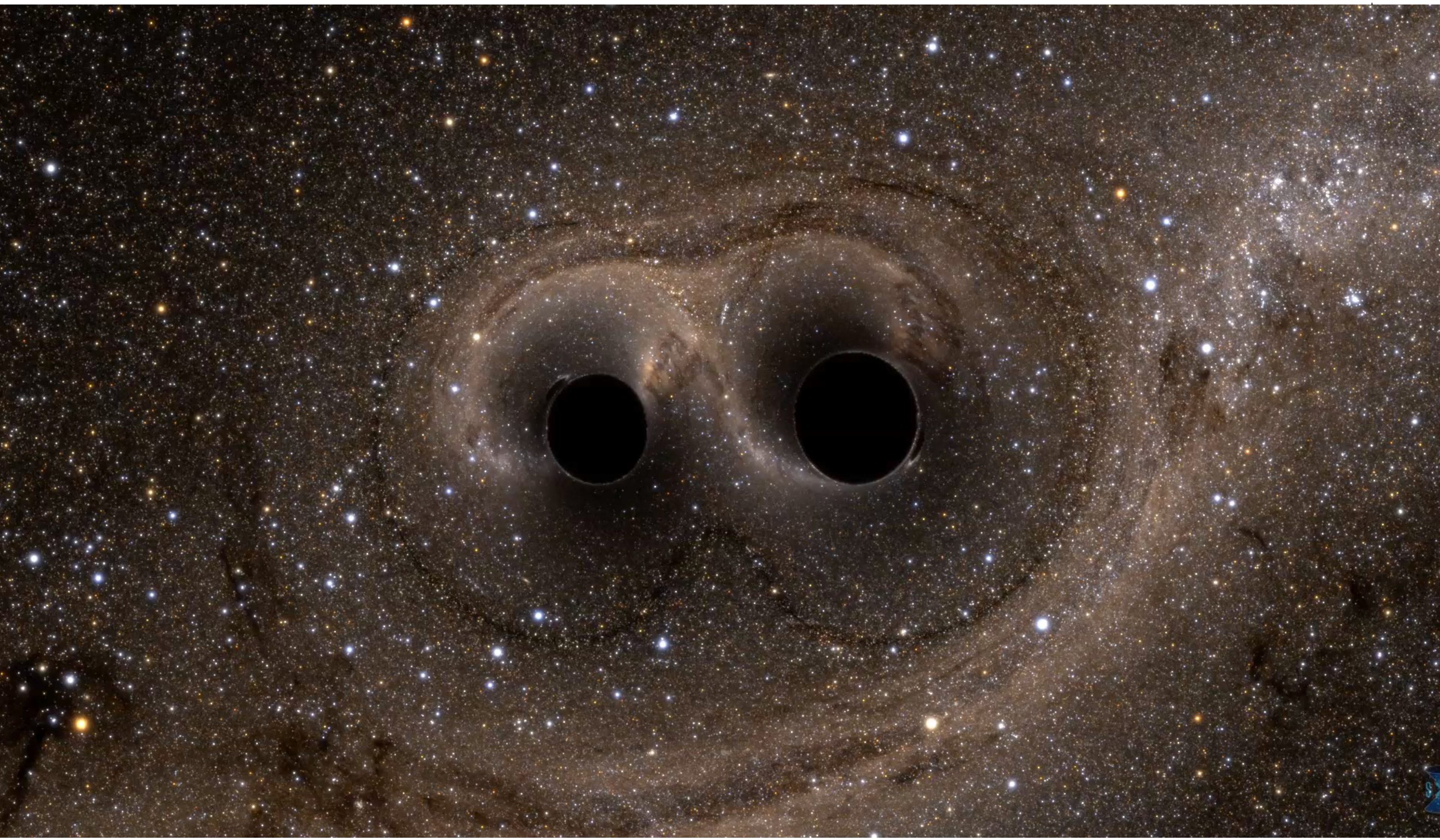




Hanford, Washington (H1)
Livingston, Louisiana (L1)
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
H1 observed
L1 observed
H1 observed (shifted, inverted)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Frequency (Hz)
512
256
128
64
32
Normalized amplitude
0
2
4
6
8
0.30
0.35
0.40
0.45
Time (s)

Odhad místa spojení černých děr

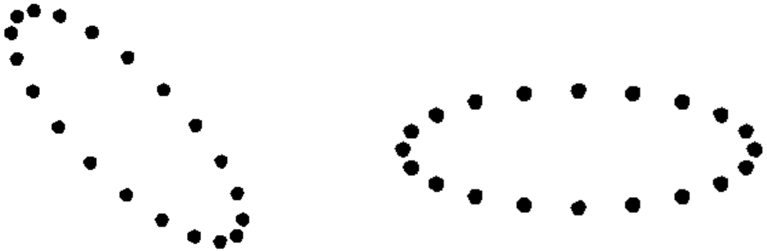


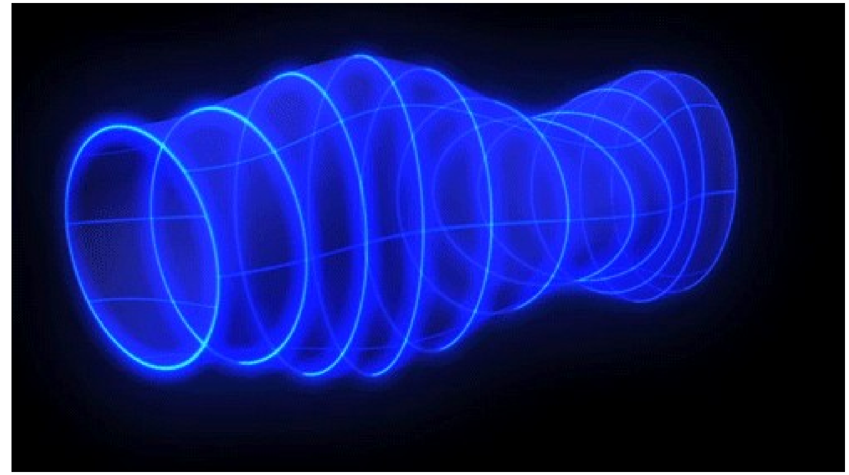


Vizualizace sloučení černých děr. Obíhající černé díry ztrácejí energii vyzařováním gravitačních vln. Ty jsou znázorněny zprohýbanou plochou v okolí černých děr

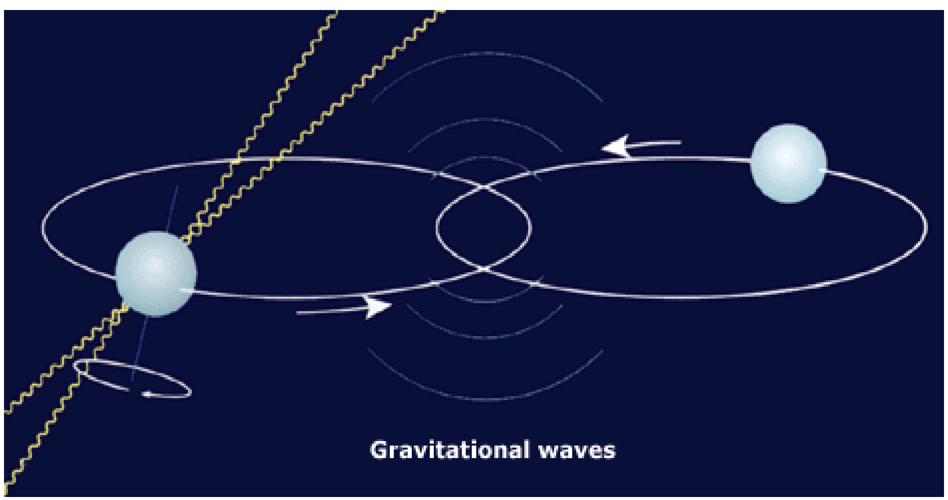
aldebaran

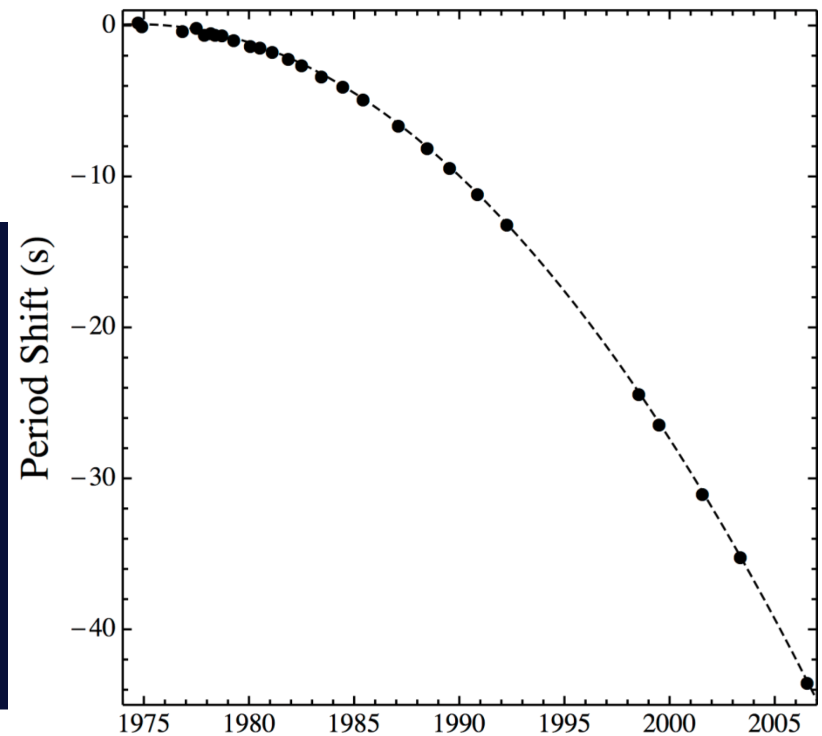

Scale of Effect Vastly Exaggerated





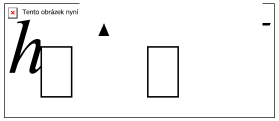
Možné zdroje gravitačních vln

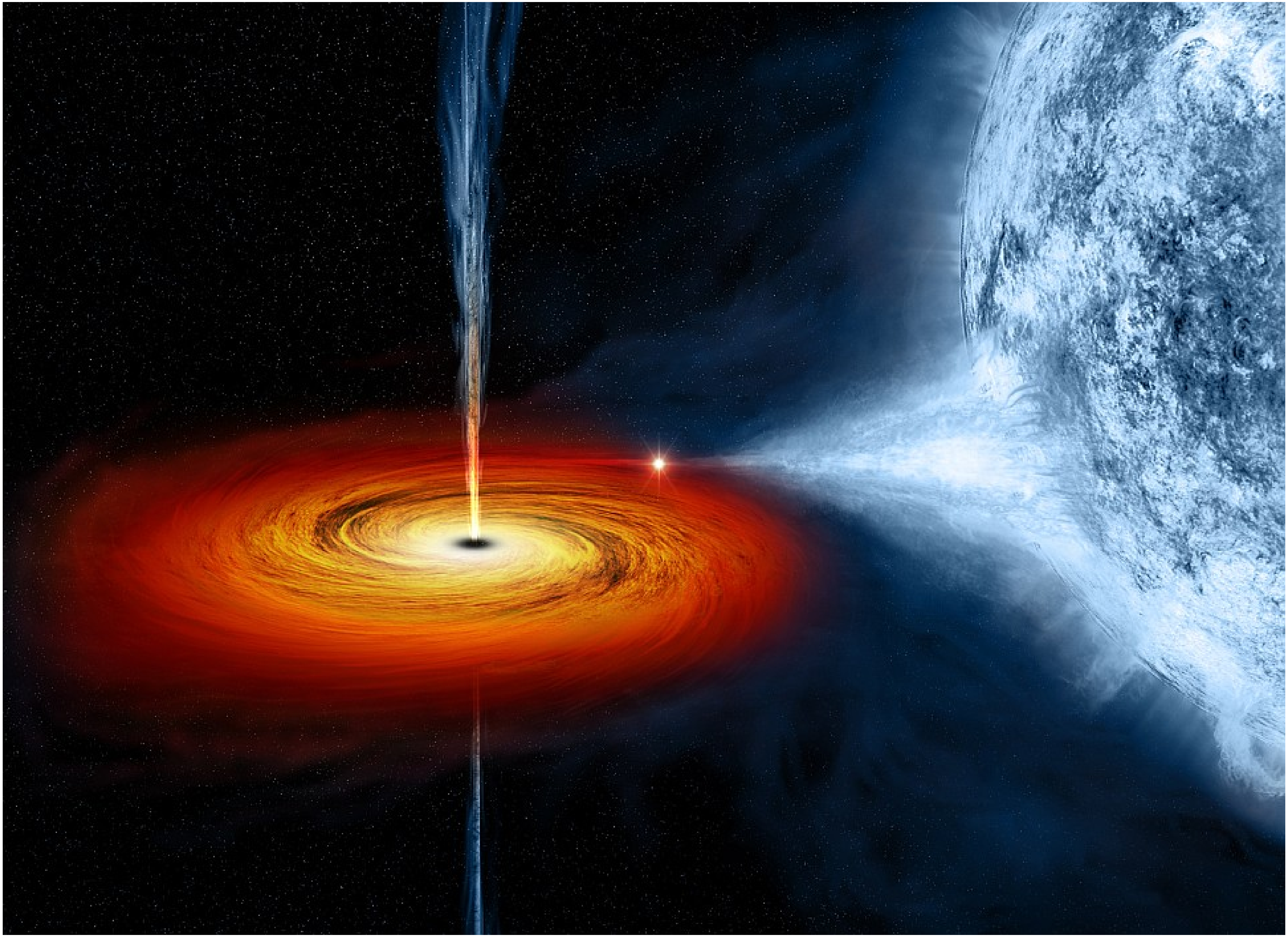




Joseph Weber
kontroverzní pionýr měření gravitačních vln

Zprovozněno v roce 1966 a v roce 1972 byla naměřena jediná koincidence, která se již nikdy nezopakovala. Dnes se soudí, že relativní citlivost byla malá.





For robustness and validation, we also use other generic transient search algorithms [41]. A different search [73] and a parameter estimation follow-up [74] detected GW150914 with consistent significance and signal parameters.

B. Binary coalescence search

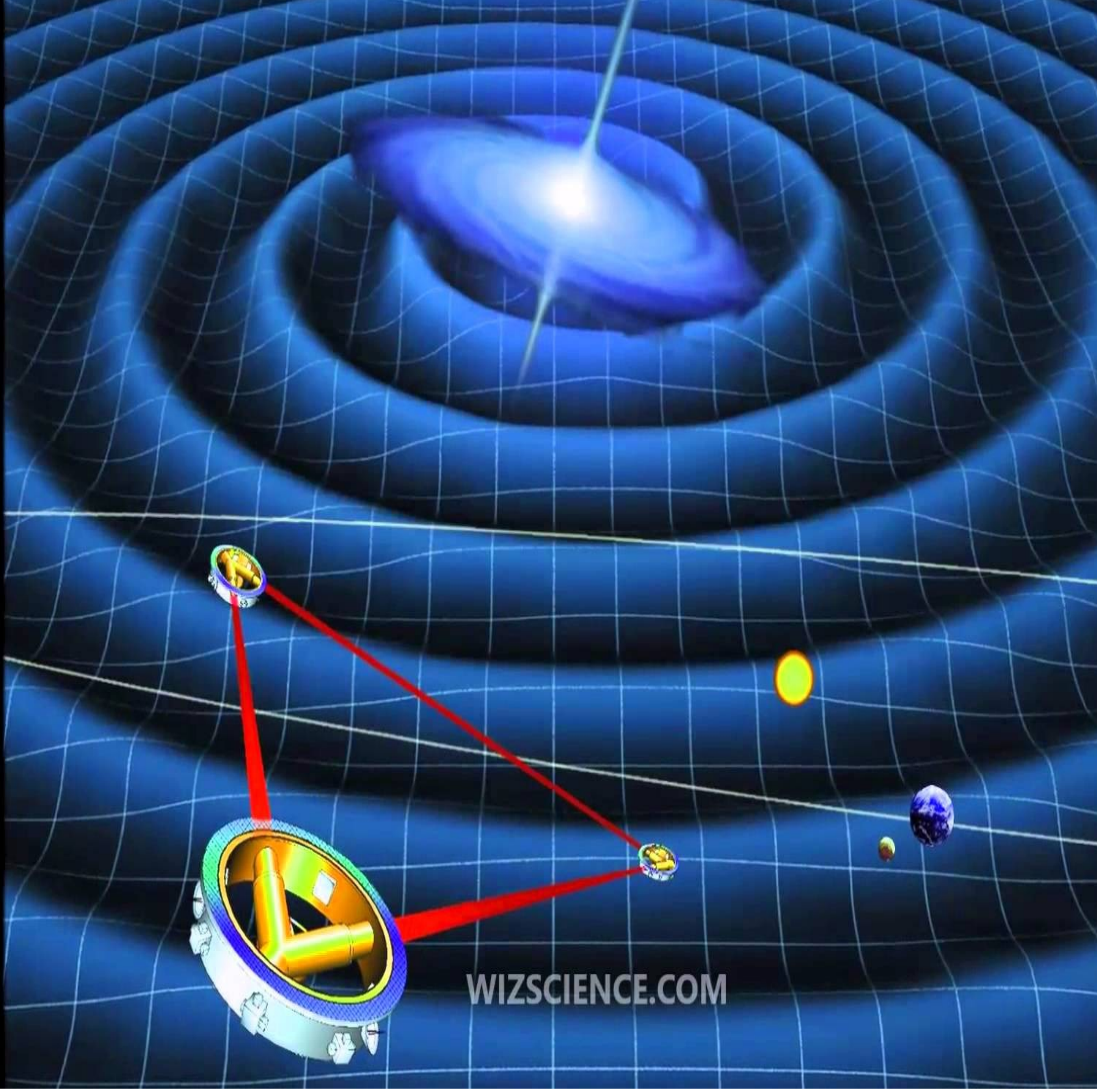
This search targets gravitational-wave emission from binary systems with individual masses from 1 to $99M_\odot$, total mass less than $100M_\odot$, and dimensionless spins up to 0.99 [44]. To model systems with total mass larger than $4M_\odot$, we use the effective-one-body formalism [75], which combines results from the post-Newtonian approach [11,76] with results from black hole perturbation theory and numerical relativity. The waveform model [77,78] assumes that the spins of the merging objects are aligned with the orbital angular momentum, but the resulting templates can, nonetheless, effectively recover systems with misaligned spins in the parameter region of GW150914 [44]. Approximately 250 000 template waveforms are used to cover this parameter space.

The search calculates the matched-filter signal-to-noise ratio $\rho(t)$ for each template in each detector and identifies maxima of $\rho(t)$ with respect to the time of arrival of the signal [79–81]. For each maximum we calculate a chi-squared statistic χ_r^2 to test whether the data in several different frequency bands are consistent with the matching template [82]. Values of χ_r^2 near unity indicate that the signal is

TABLE I. Source parameters for GW150914. We report median values with 90% credible intervals that include statistical errors, and systematic errors from averaging the results of different waveform models. Masses are given in the source frame; to convert to the detector frame multiply by $(1+z)$ [90]. The source redshift assumes standard cosmology [91].

Primary black hole mass	$36^{+5}_{-4}M_\odot$
Secondary black hole mass	$29^{+4}_{-4}M_\odot$
Final black hole mass	$62^{+4}_{-4}M_\odot$
Final black hole spin	$0.67^{+0.05}_{-0.07}$
Luminosity distance	410^{+160}_{-180} Mpc
Source redshift z	$0.09^{+0.03}_{-0.04}$

When an event is confidently identified as a real gravitational-wave signal, as for GW150914, the background used to determine the significance of other events is reestimated without the contribution of this event. This is the background distribution shown as a purple line in the right panel of Fig. 4. Based on this, the second most significant event has a false alarm rate of 1 per 2.3 years and corresponding Poissonian false alarm probability of 0.02. Waveform analysis of this event indicates that if it is astrophysical in origin it is also a binary black hole merger [44].


WIZSCIENCE.COM

Spaghettification!

To Black Hole