Demystifying Gravitational Waves: A Sweet of App Utilities

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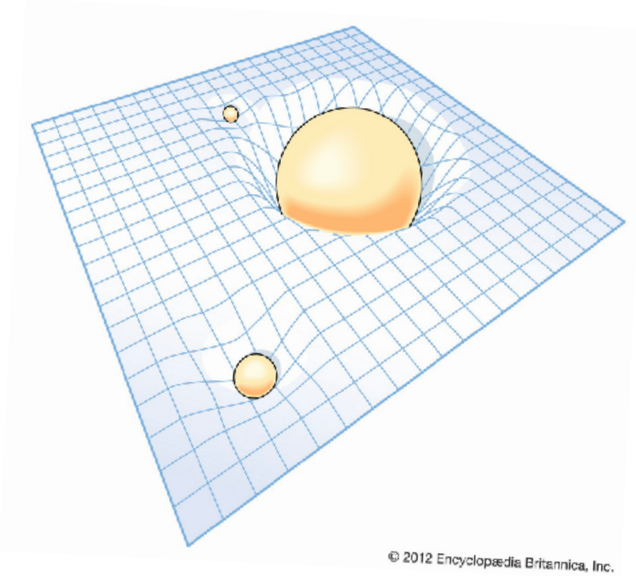
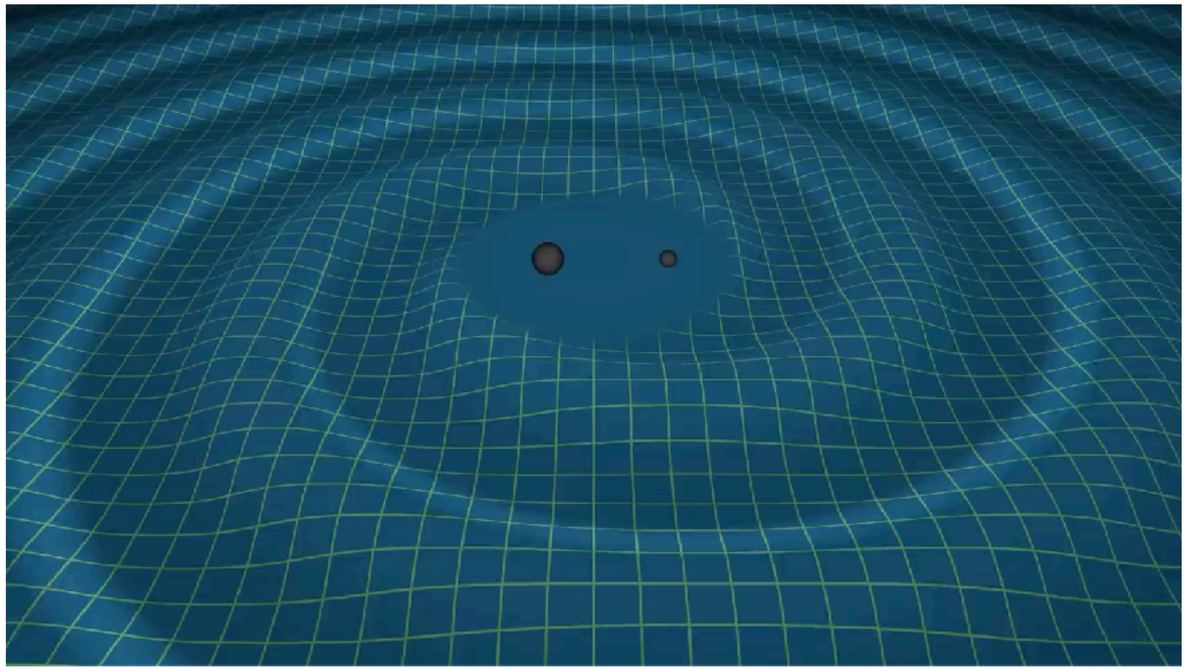
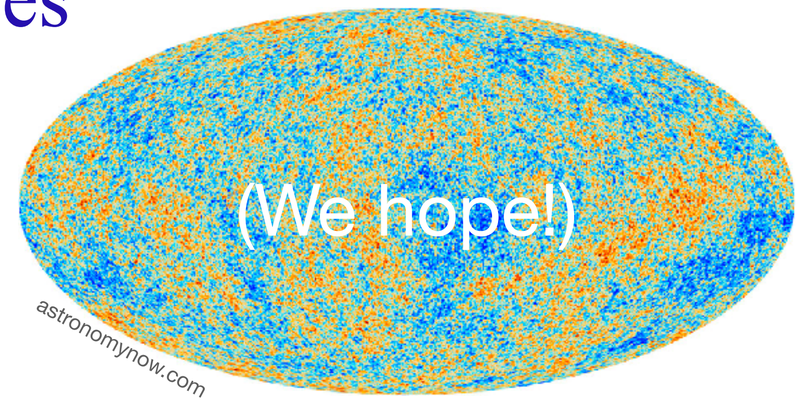
Gravitational waves introduction

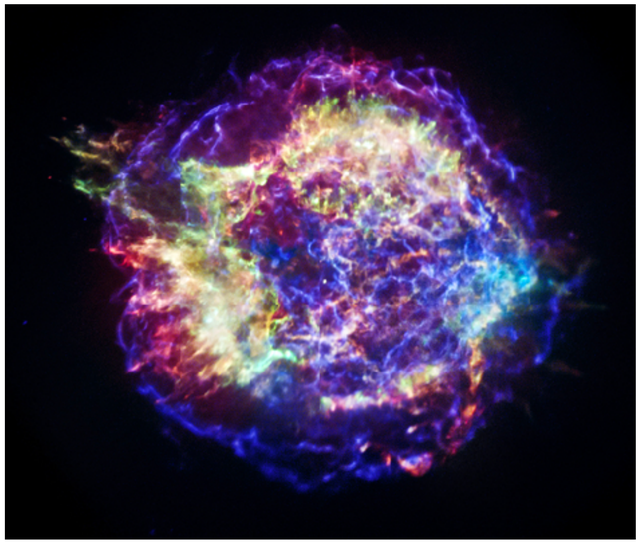


Generally, gravitational waves originate from the acceleration of massive bodies. We now routinely observe gravitational waves from compact binary mergers.

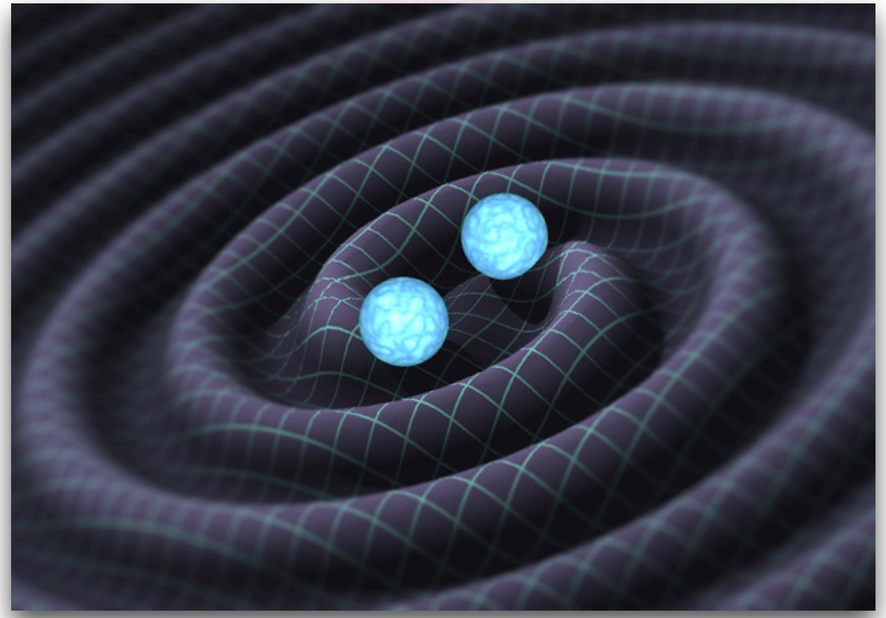


Gravitational waves sources

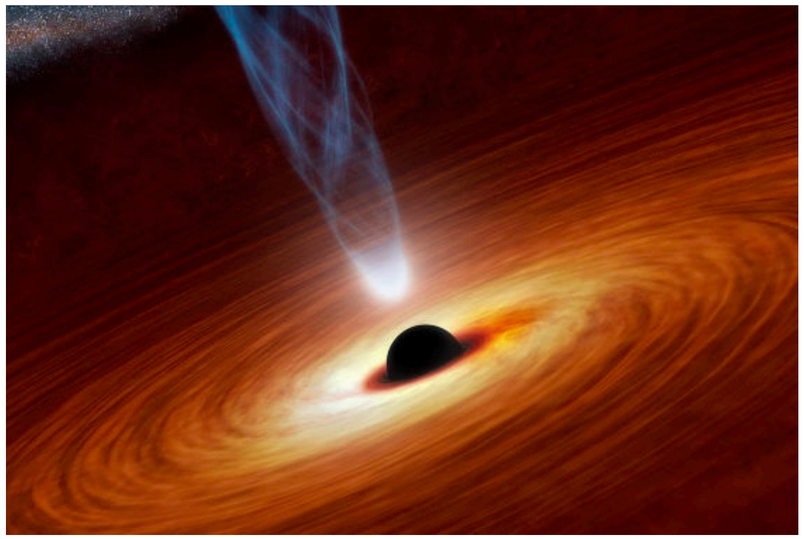




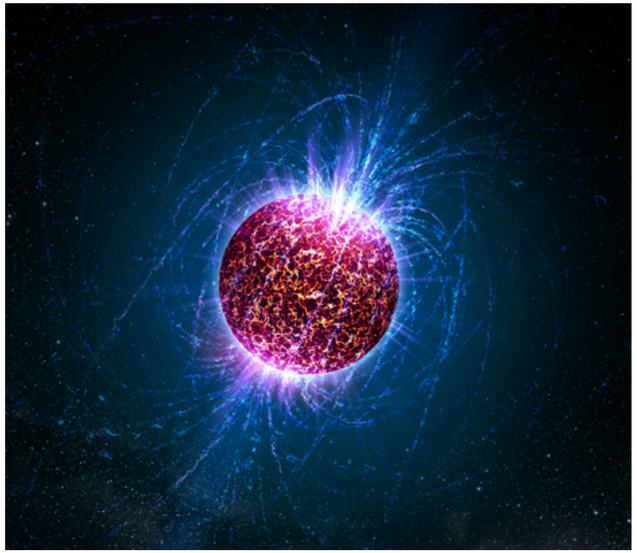
www.scitechdaily.com



www.sciencecircle.org



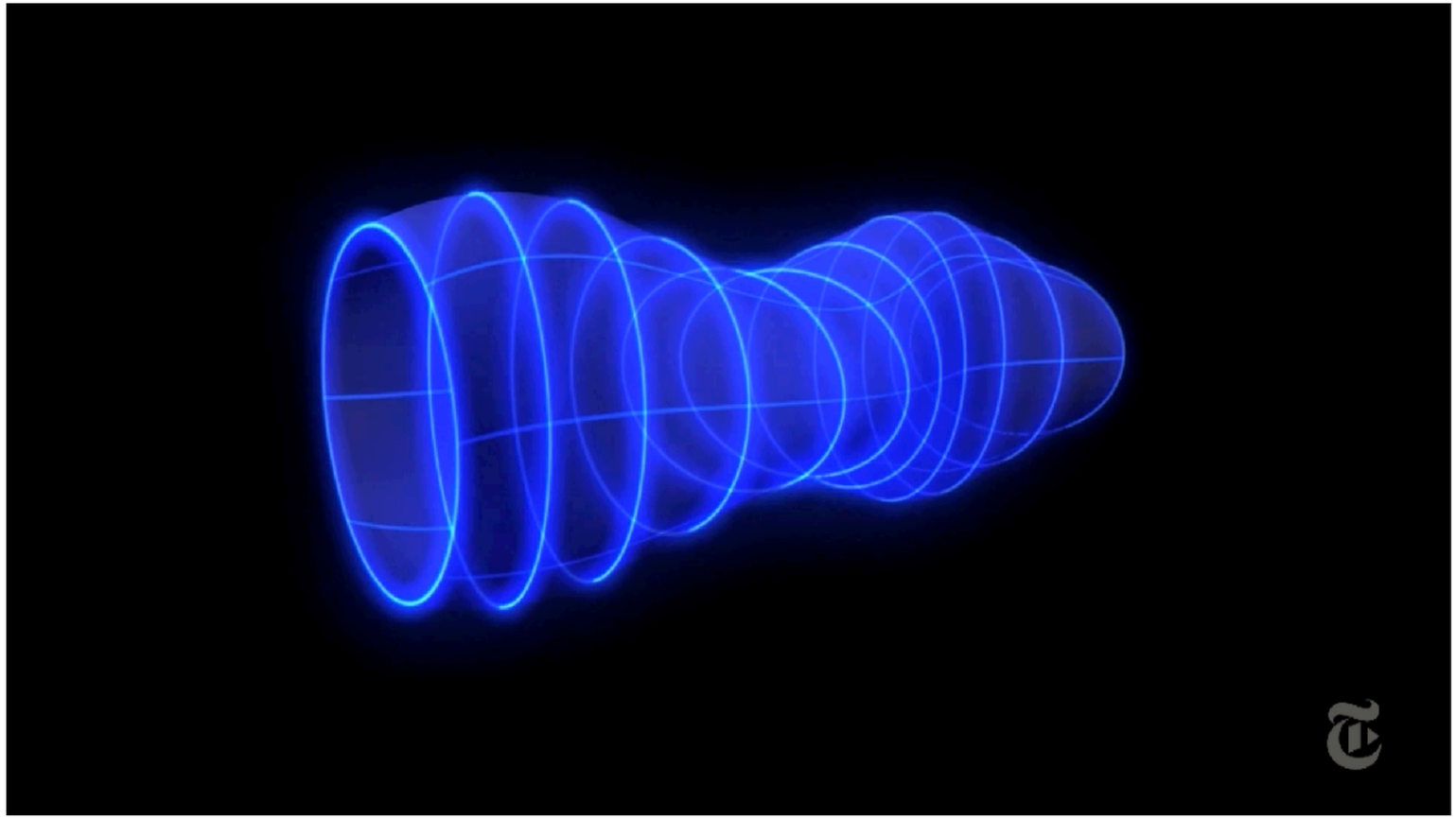
zhuanlan.zhihu.com



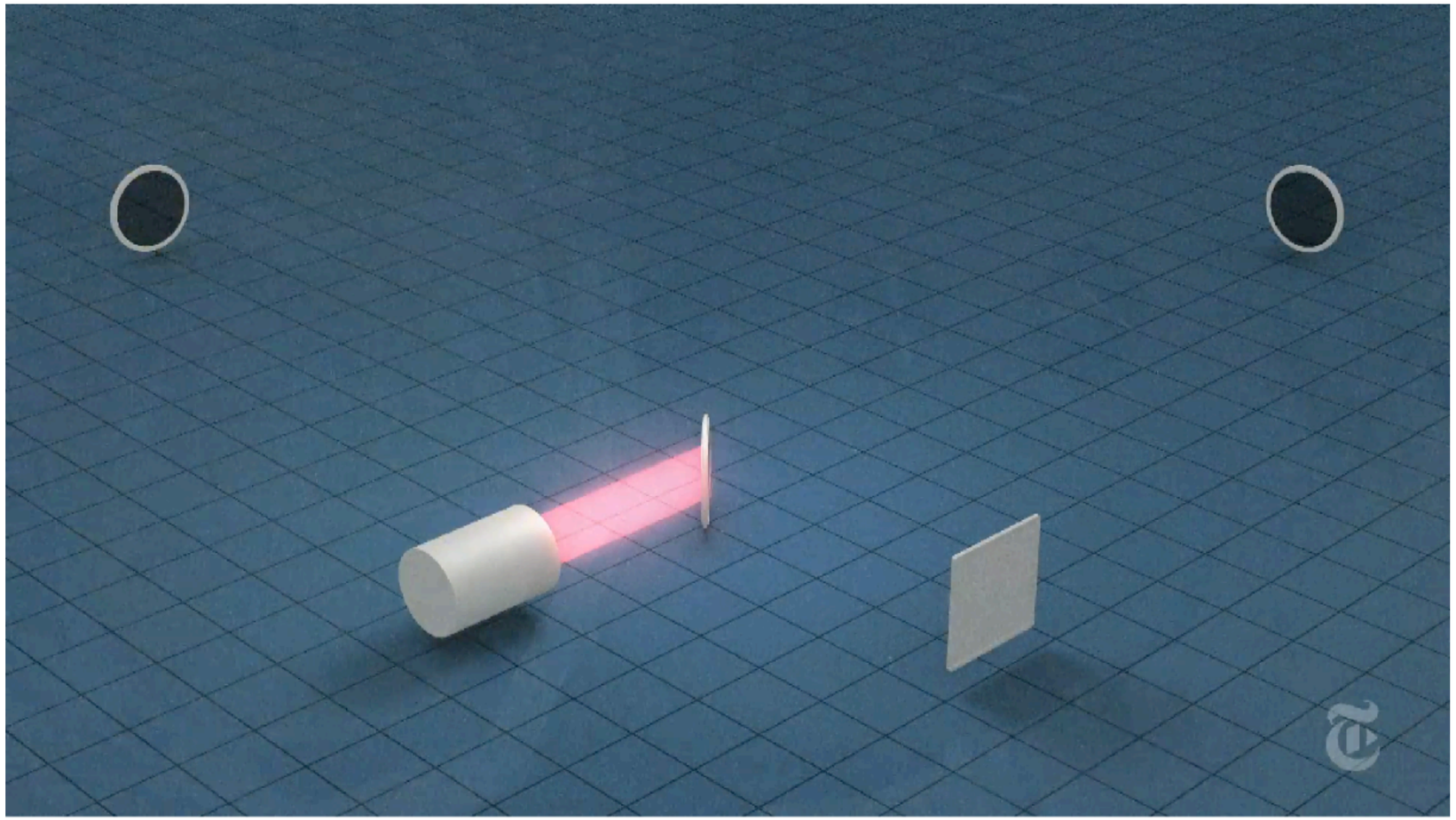
phys.org

How do gravitational waves propagate in the Universe?

GWs stretch space-time in one direction and squeeze it in the other direction, while traveling in a third direction - a transverse wave just like EM but with spin-2.



Laser Interfeometer Gravitational-wave Observatory (LIGO)



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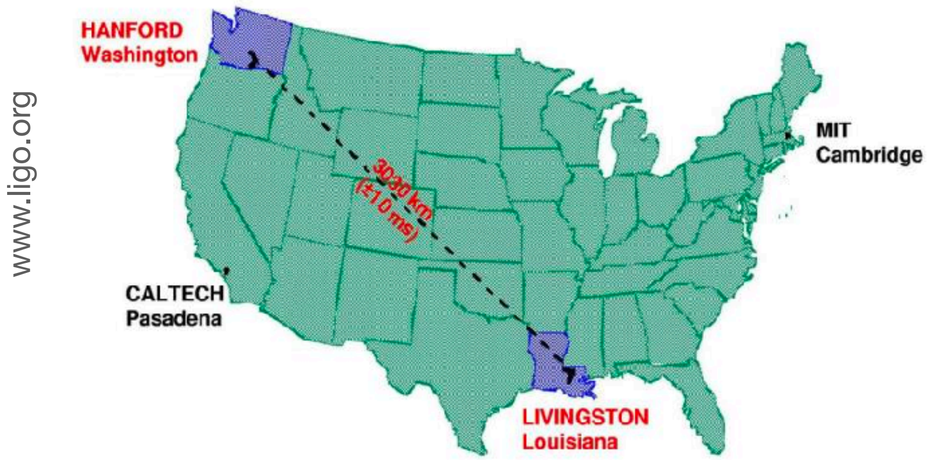
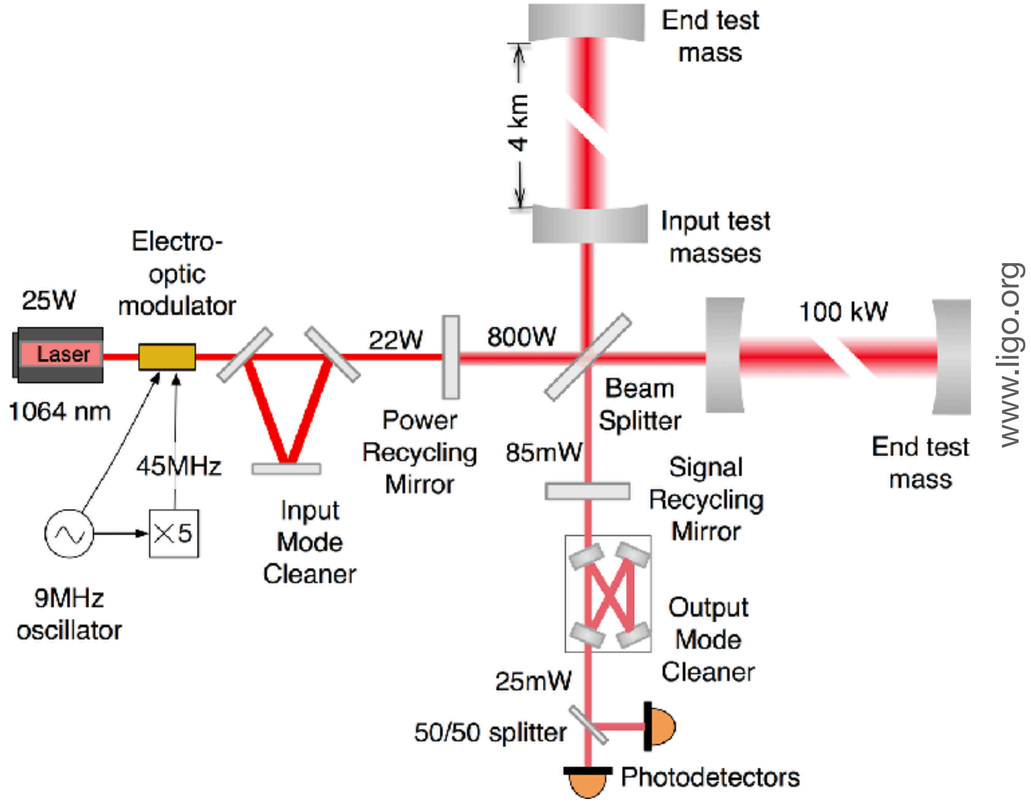
LIGO is configured to detect spin-2 gravitational-waves by interferometry in a km-scale Michelson-Morley type experiment





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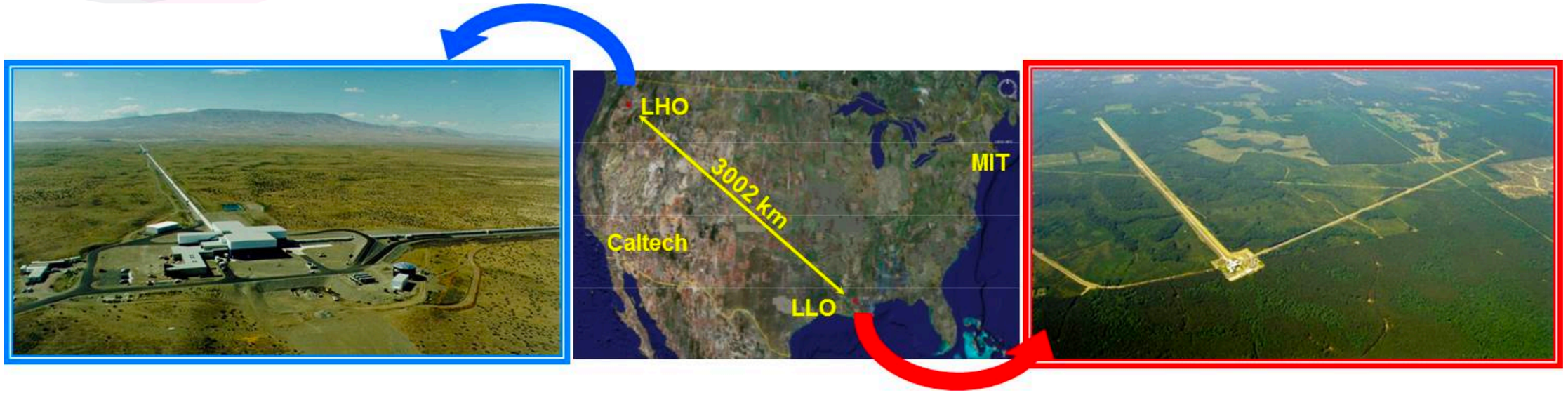
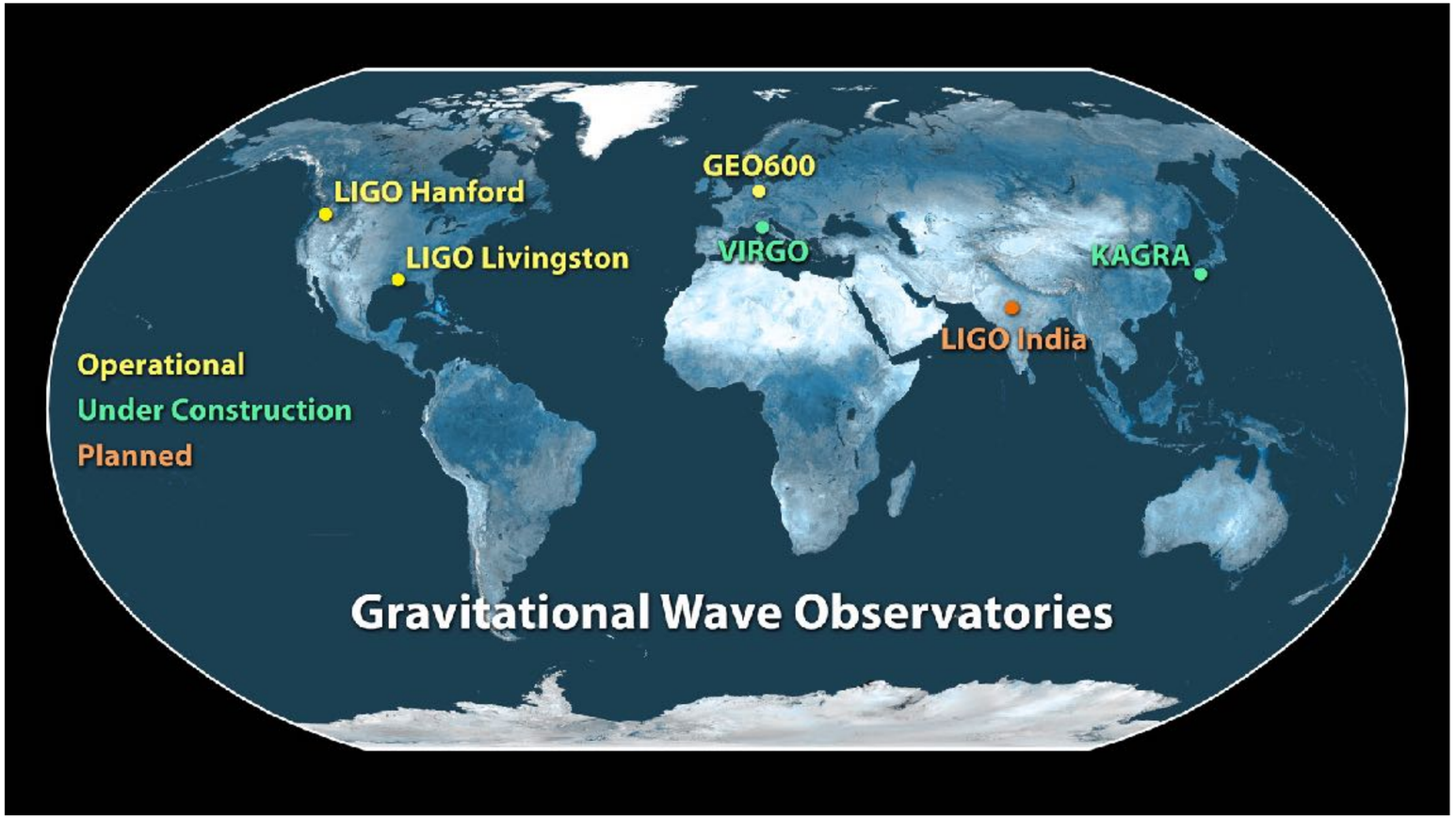


Ground Based Gravitational waves observatories

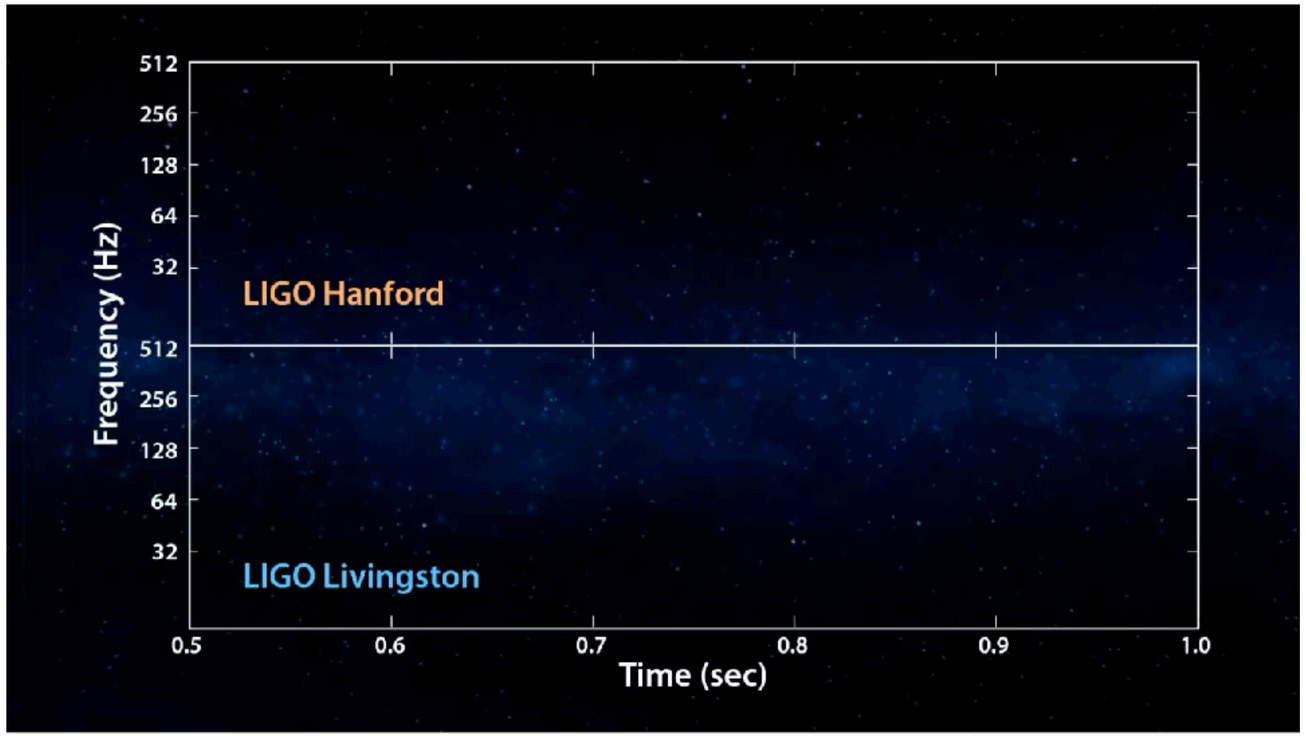
LIGO started its mission in 1995, with six scientific runs and three observational runs up to now.



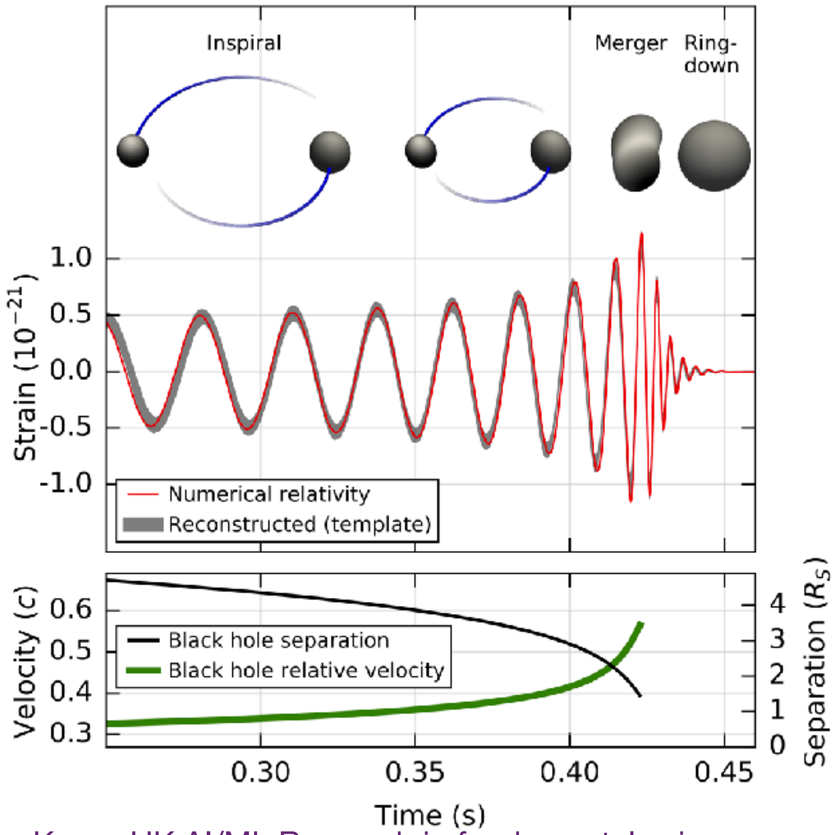
www.ligo.caltech.edu

First detection: GW150914 (O1)

BBH
M1=29 solar mass
M2=36 solar mass
Chirp Mass=30 solar mass
Frequency=250 Hz
Distance=410 Mpc
Remnant mass=62 solar mass



PhysRevLett.116.061102



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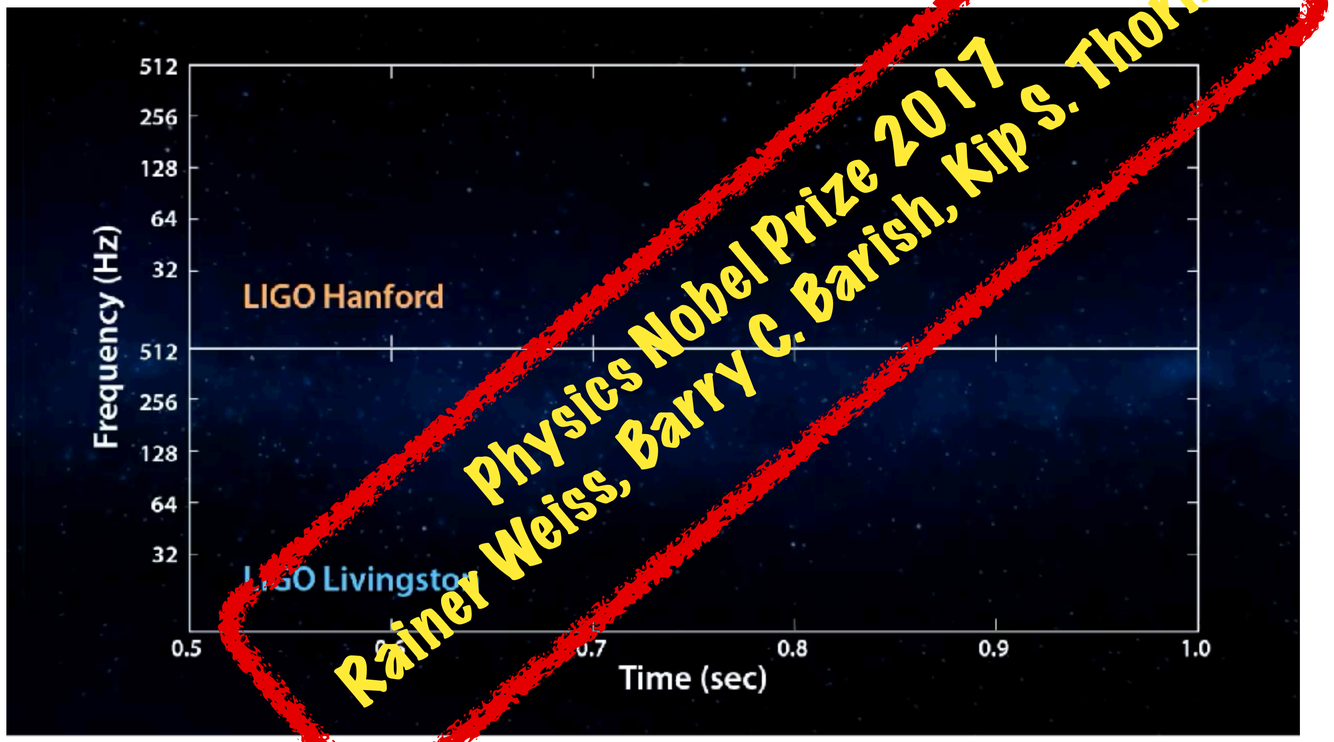
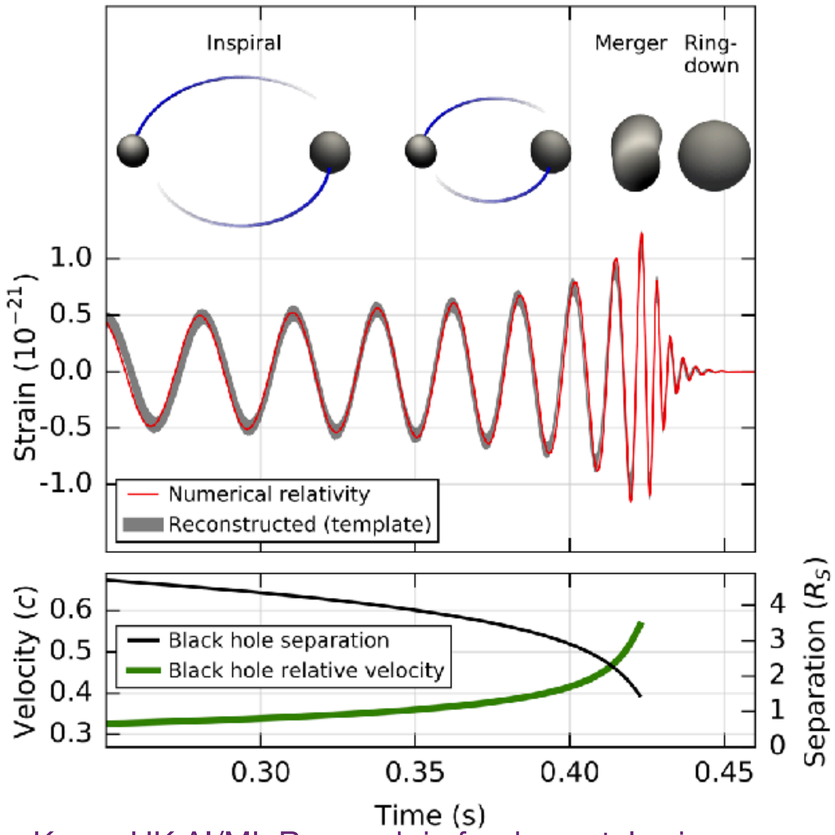


Physics Nobel Prize 2017
Rainer Weiss, Barry C. Barish, Kip S. Thorne

PhysRevLett.116.061102



Beginning of the amazing story: GW170817 (O2)

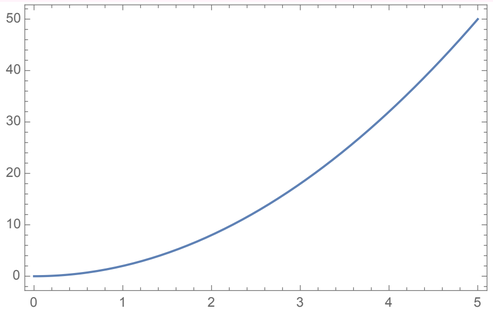
DNS
M1=1.46 solar mass
M2=1.27 solar mass
Total Mass=2.7 solar mass
Frequency=350 Hz
Distance=40 Mpc

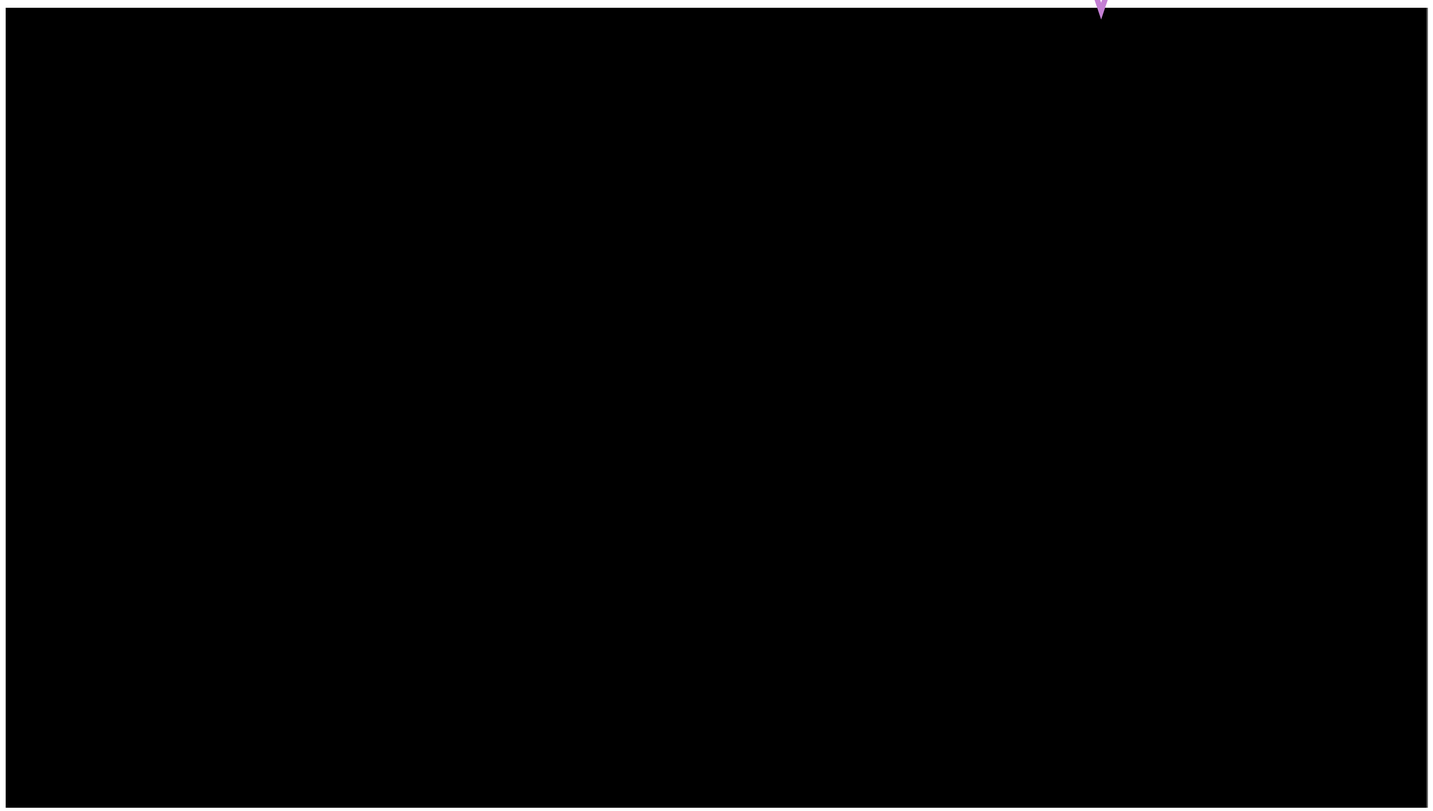
It is not a silent event like 150914,

but a festival of radiations:

GW, GRB, Kilonova, x-ray,

optical, radio, even a post-merger signal.

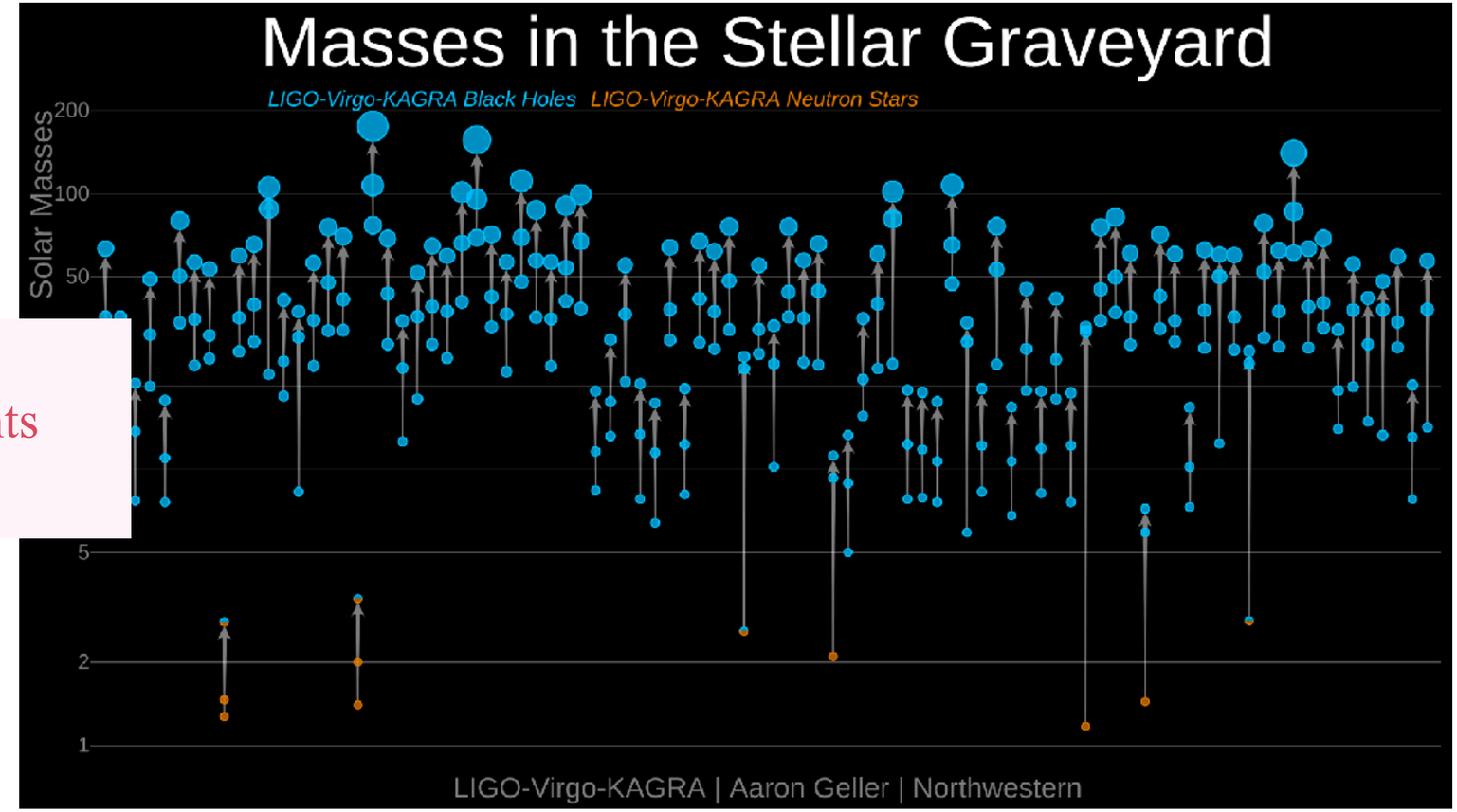




NASA/Goddard Space Flight Center

But it is not the full story…….

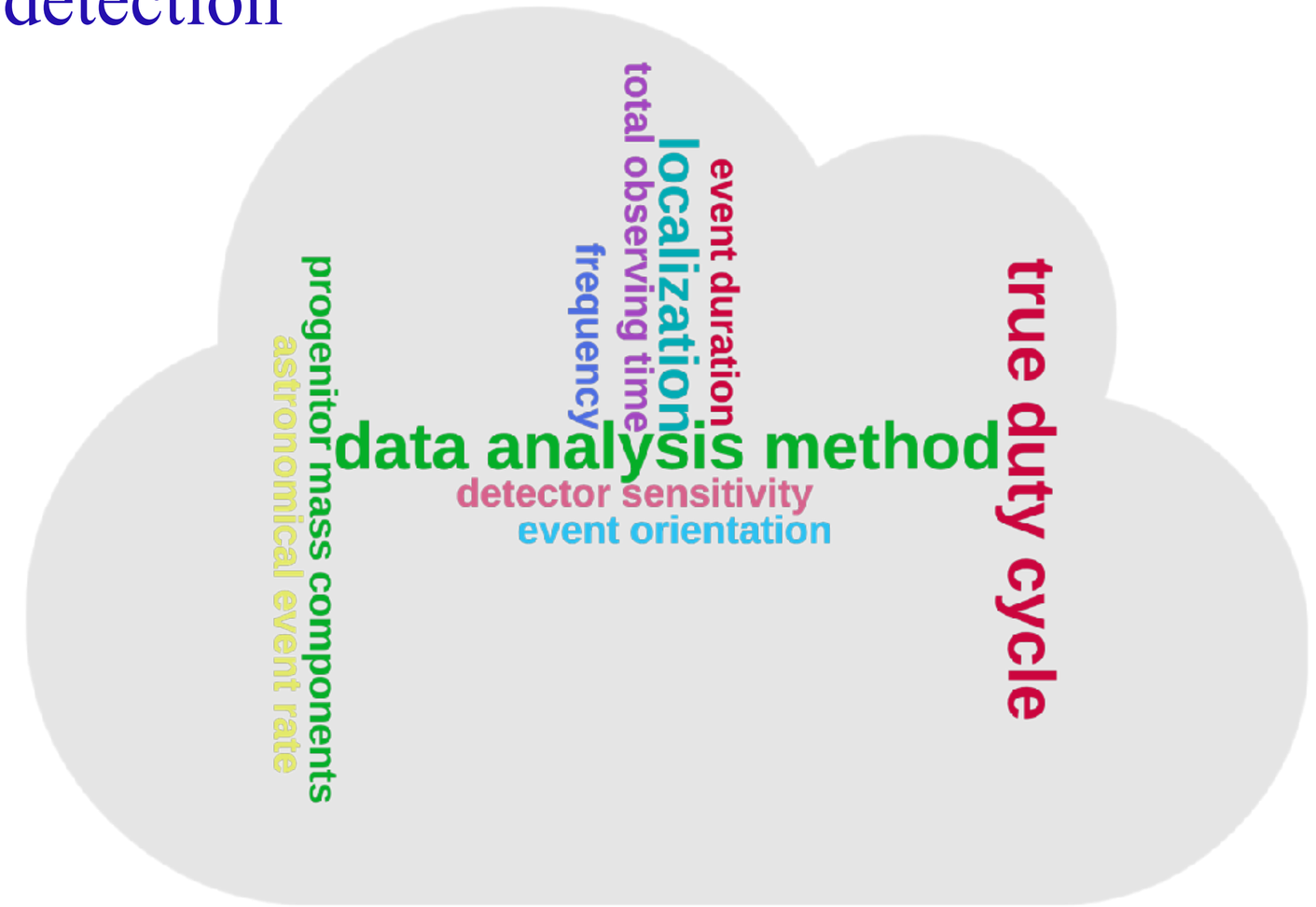
There is room for serious improvements



www.ligo.org

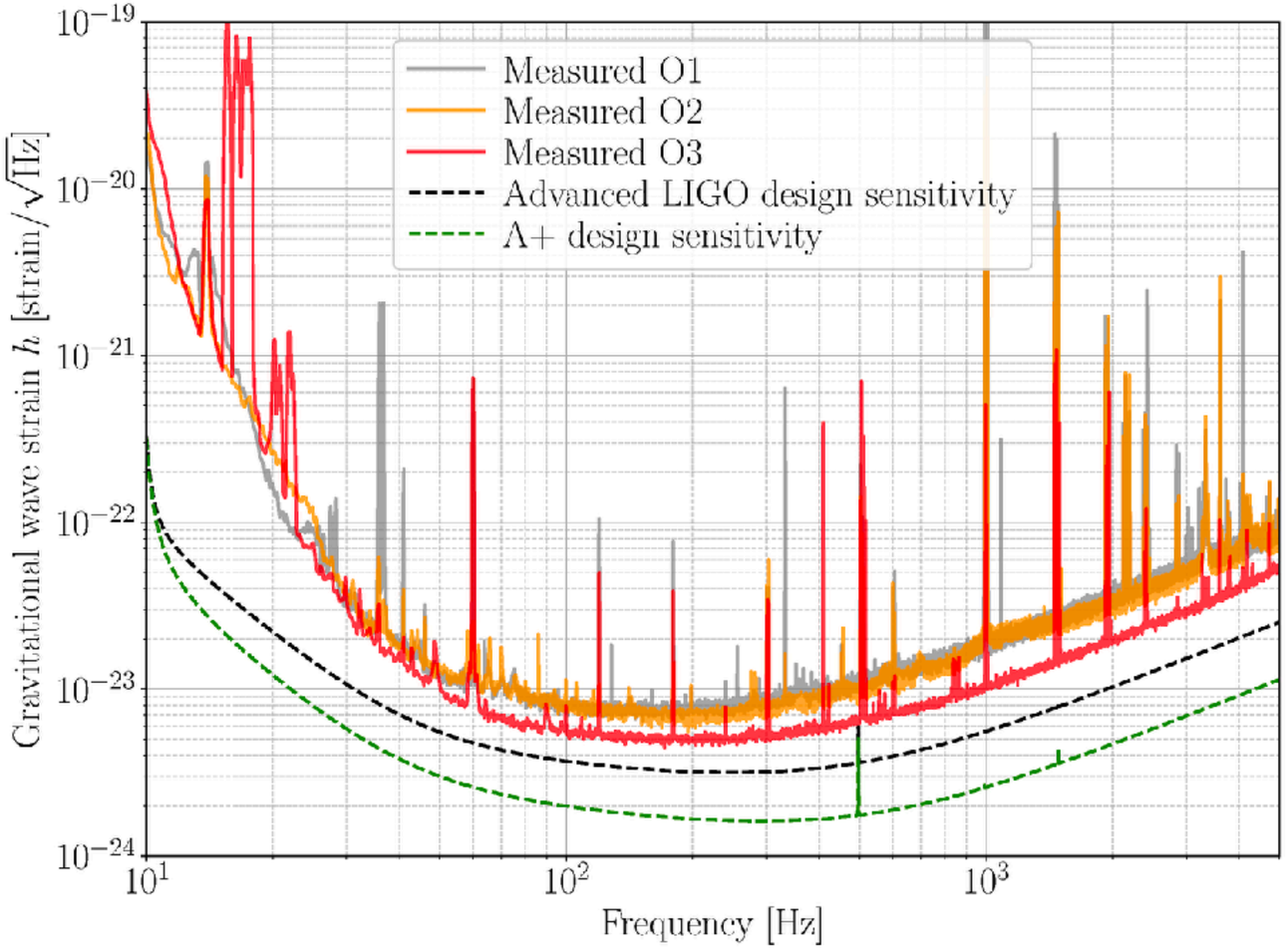
Important factors in event detection

Raw data are provided in the form of frames of 4096 seconds of data in 4KHz frequency. And there are multiple pipelines in LVK collaboration working on different aspects and sources of gravitational waves

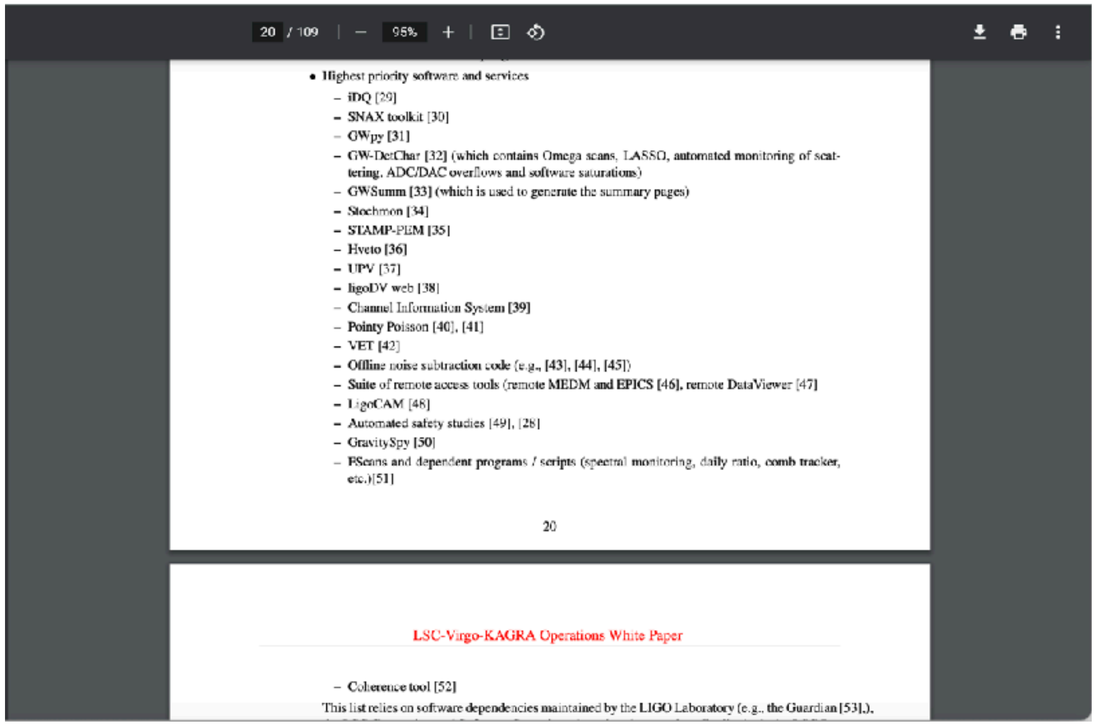


O1-O3ab…..what's next for O4-O5?

Run	S5	S6	O1	O2	O3a	O3b
number of days	697	471	130	269	184	148
duty cycle	~70%	~ 50%	~55%	~65%	75%	75%



LIGO pipelines and software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- Highest priority software and services
  - iDQ [29]
  - SNAX toolkit [30]
  - GWpy [31]
  - GW-DetChar [32] (which contains Omega scans, LASSO, automated monitoring of scattering, ADC/DAC overflows and software saturations)
  - GWSumm [33] (which is used to generate the summary pages)
  - Stochmon [34]
  - STAMP-PEM [35]
  - Hveto [36]
  - UPV [37]
  - ligoDV web [38]
  - Channel Information System [39]
  - Pointy Poisson [40], [41]
  - VET [42]
  - Offline noise subtraction code (e.g., [43], [44], [45])
  - Suite of remote access tools (remote MEDM and EPICS [46], remote DataViewer [47]
  - LigoCAM [48]
  - Automated safety studies [49], [28]
  - GravitySpy [50]
  - FSenns and dependent programs / scripts (spectral monitoring, daily ratio, comb tracker, etc.)[51]

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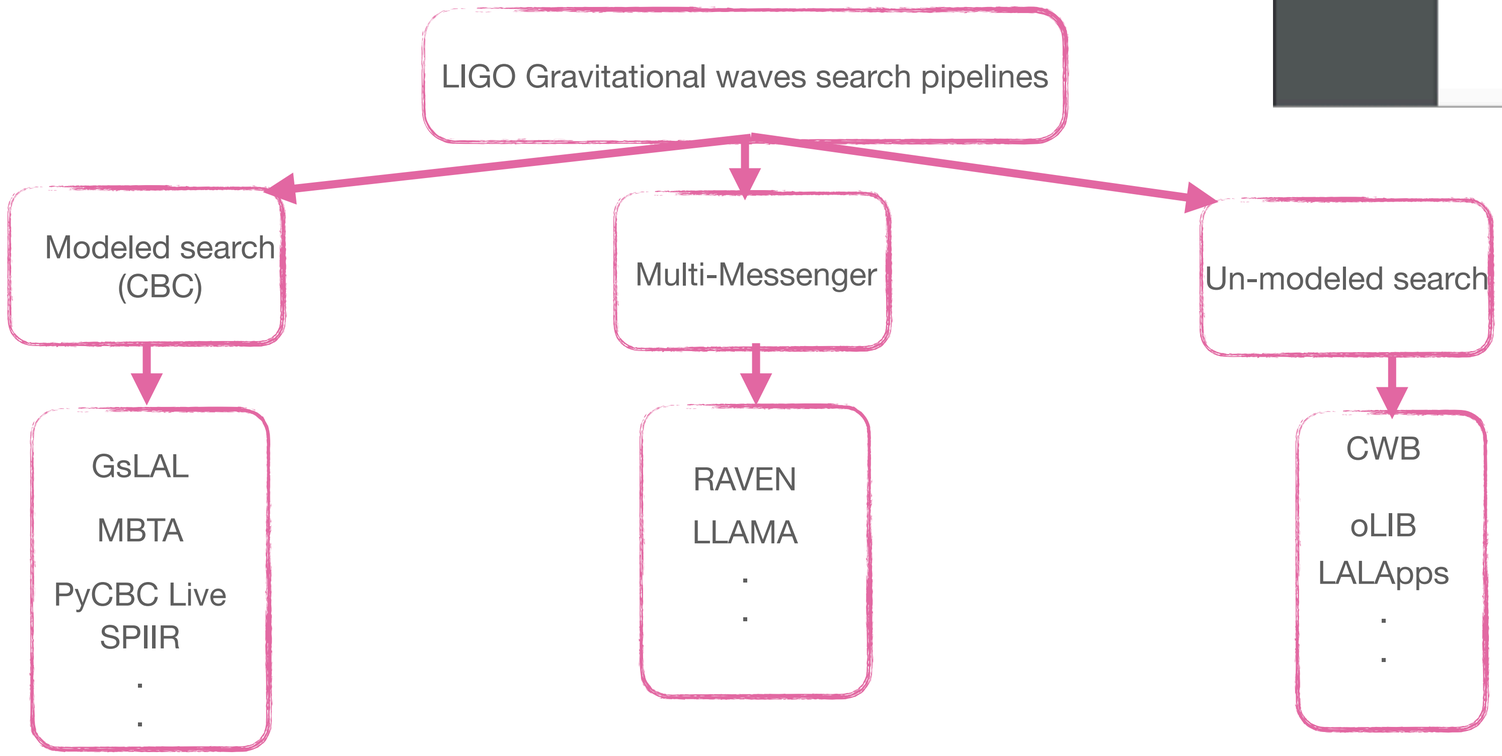
LSC-Virgo-KAGRA Operations White Paper

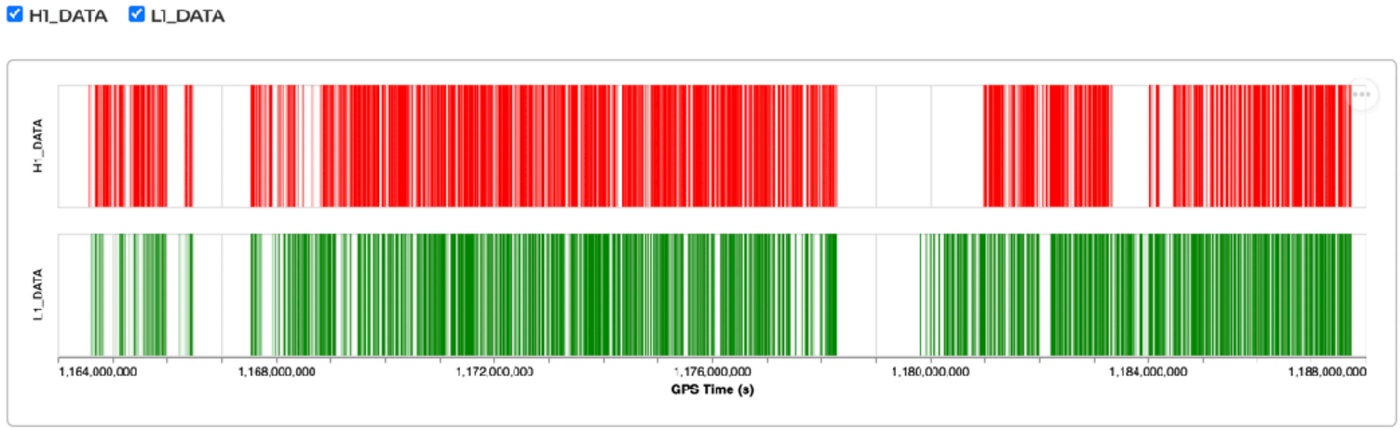
- Coherence tool [52]

This list relies on software dependencies maintained by the LIGO Laboratory (e.g., the Guardian [53],).

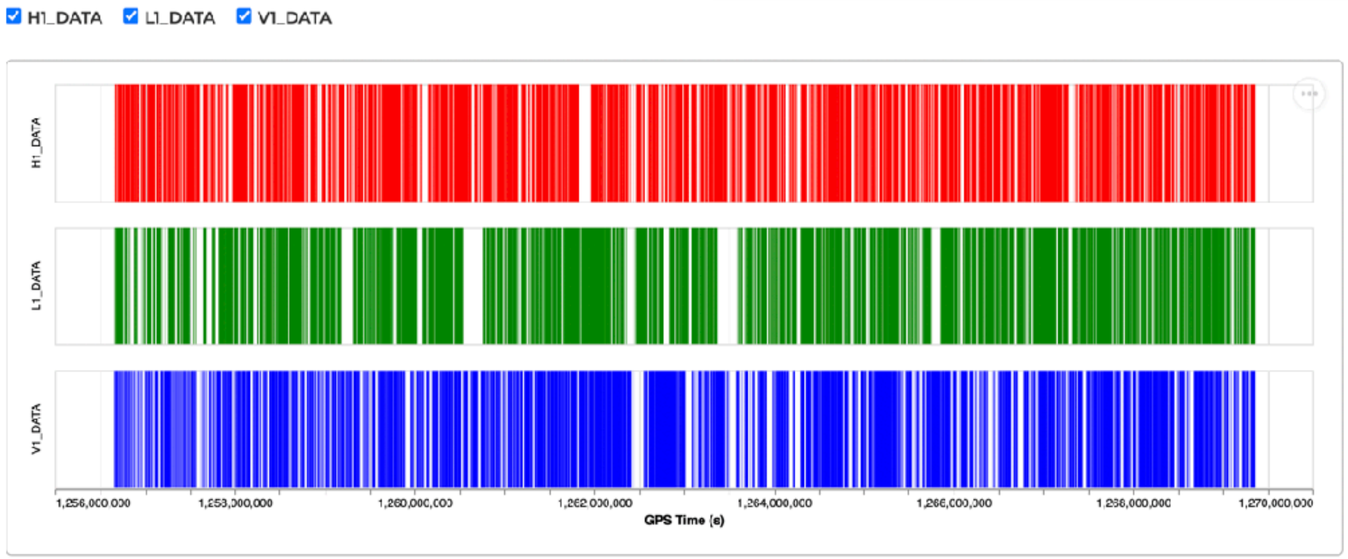


Even the open data itself is not easily accessible

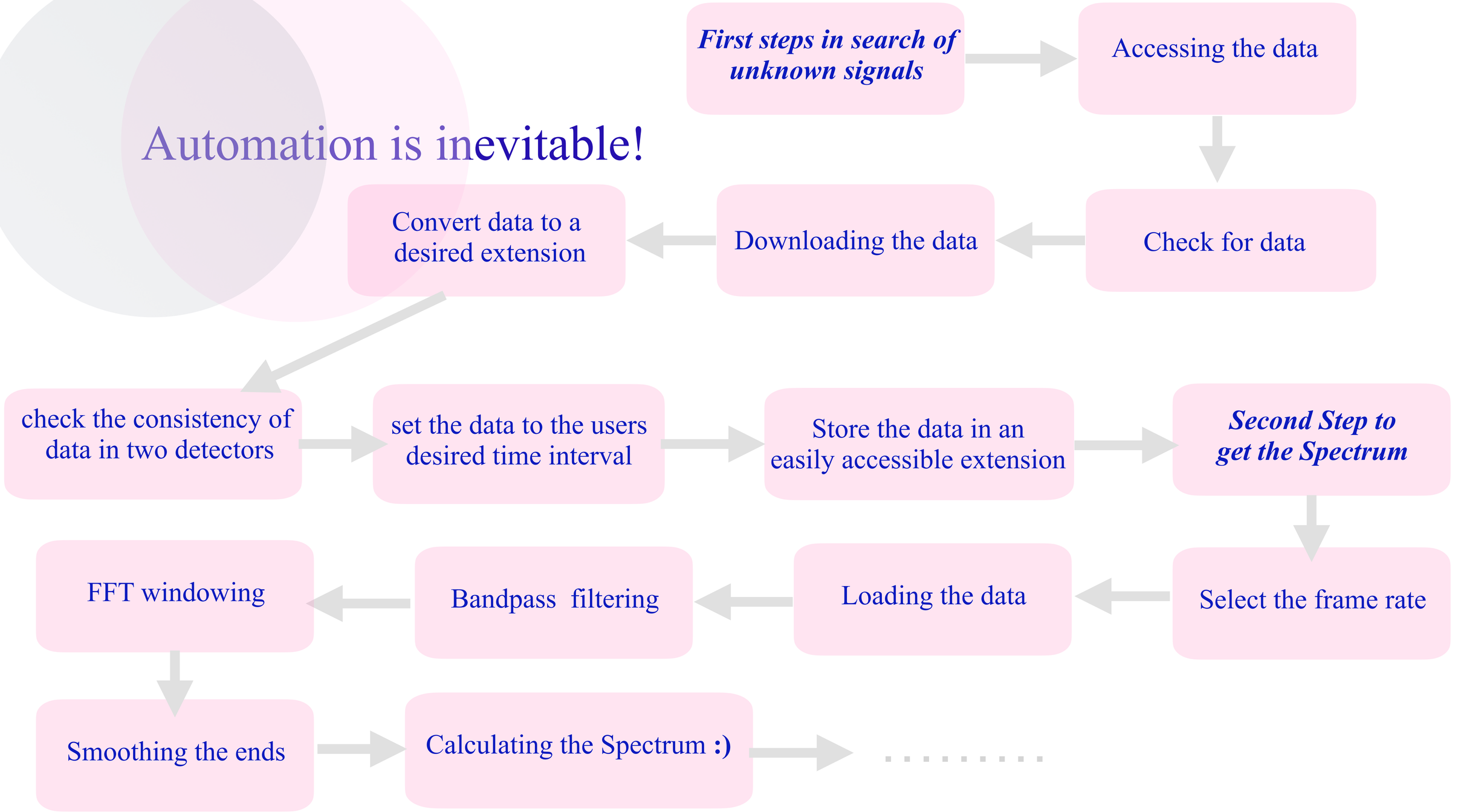
LIGO Open Science Center



www.gw-openscience.org



Automation is inevitable!



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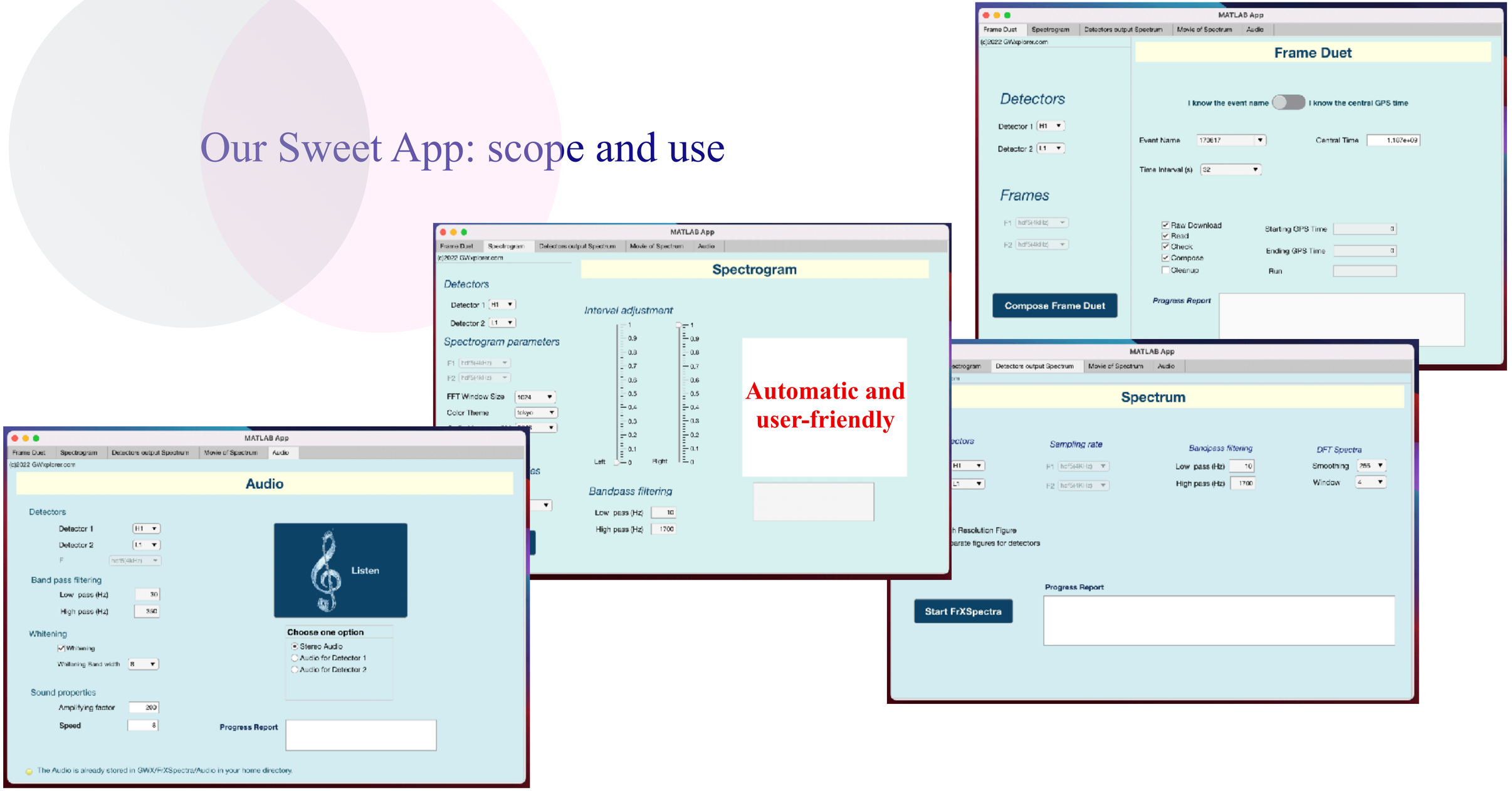
Our Sweet App: scope and use



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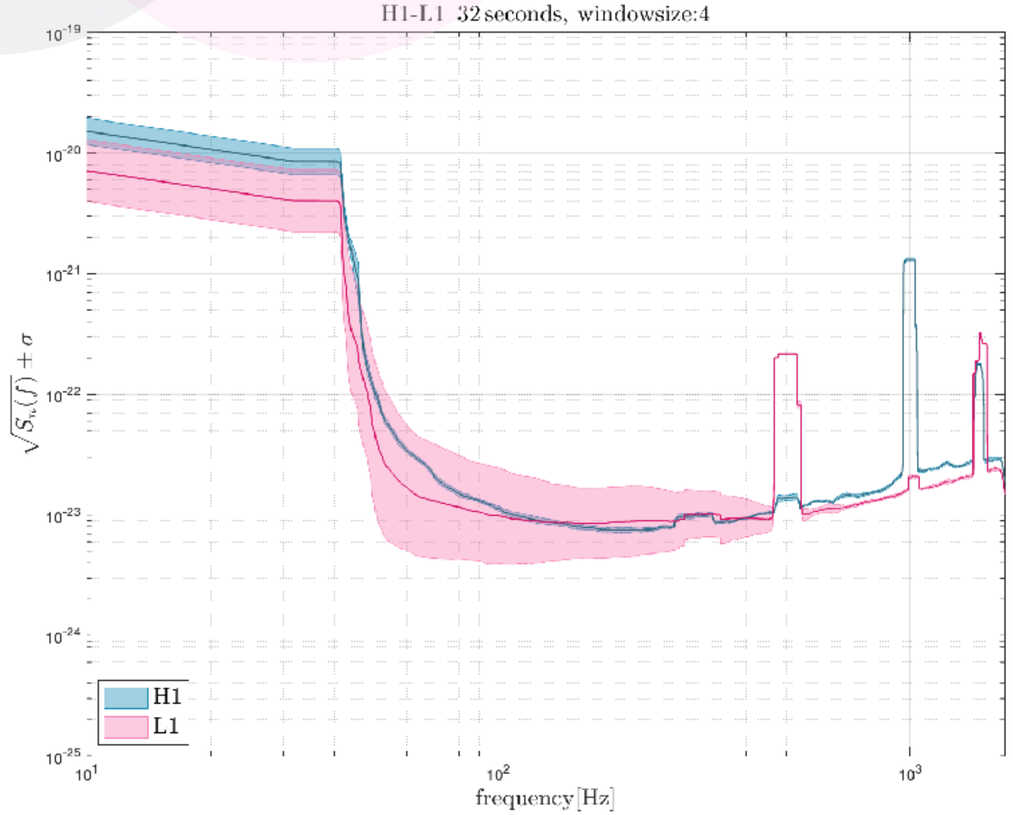

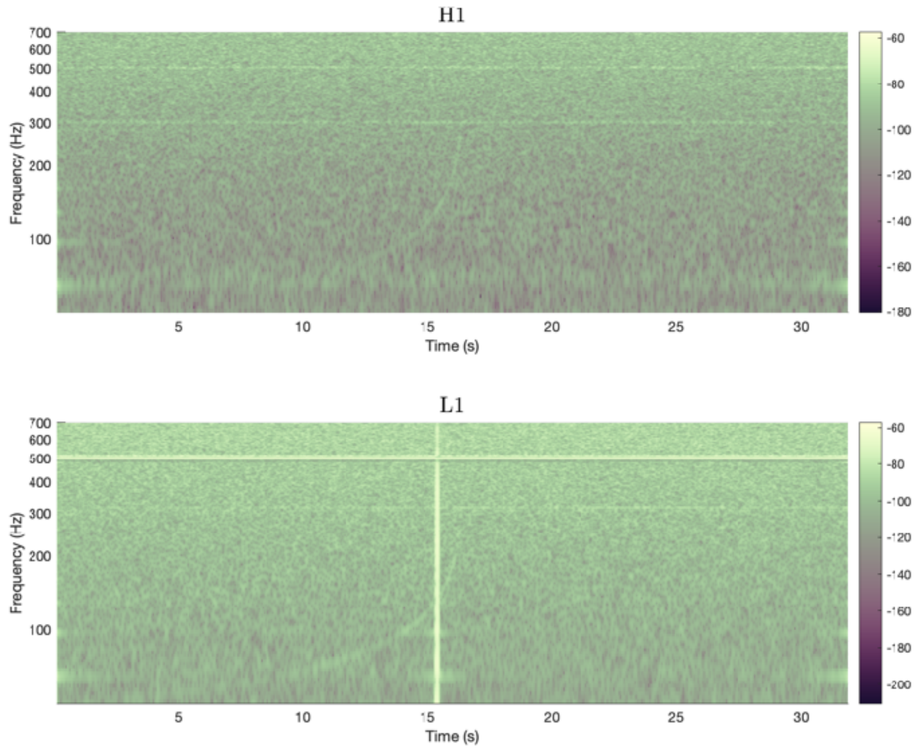

Our Sweet App: scope and use

-In our App, we use FFT as the most common time-symmetric matched-filtering method,

-You need only four clicks to hear the signal (and of course a stable internet connection),

-It stores all the outputs and figures on your machine,

-One important characteristic of this App is its outreach factor….even high school students Installation is easy and straight forward,

-By considering the standard deviation of Spectrum it gives a well defined measure of high quality data, in search of unknown signals,

-No need for MATLAB installation,

-It is open source,

-It will be extended……,


Thank You