Using Fscans to detect combs in LIGO Detector Characterization Channels

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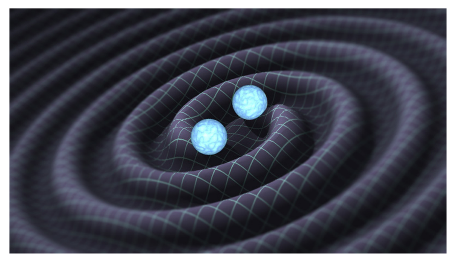
Gravitational Waves: The Basics



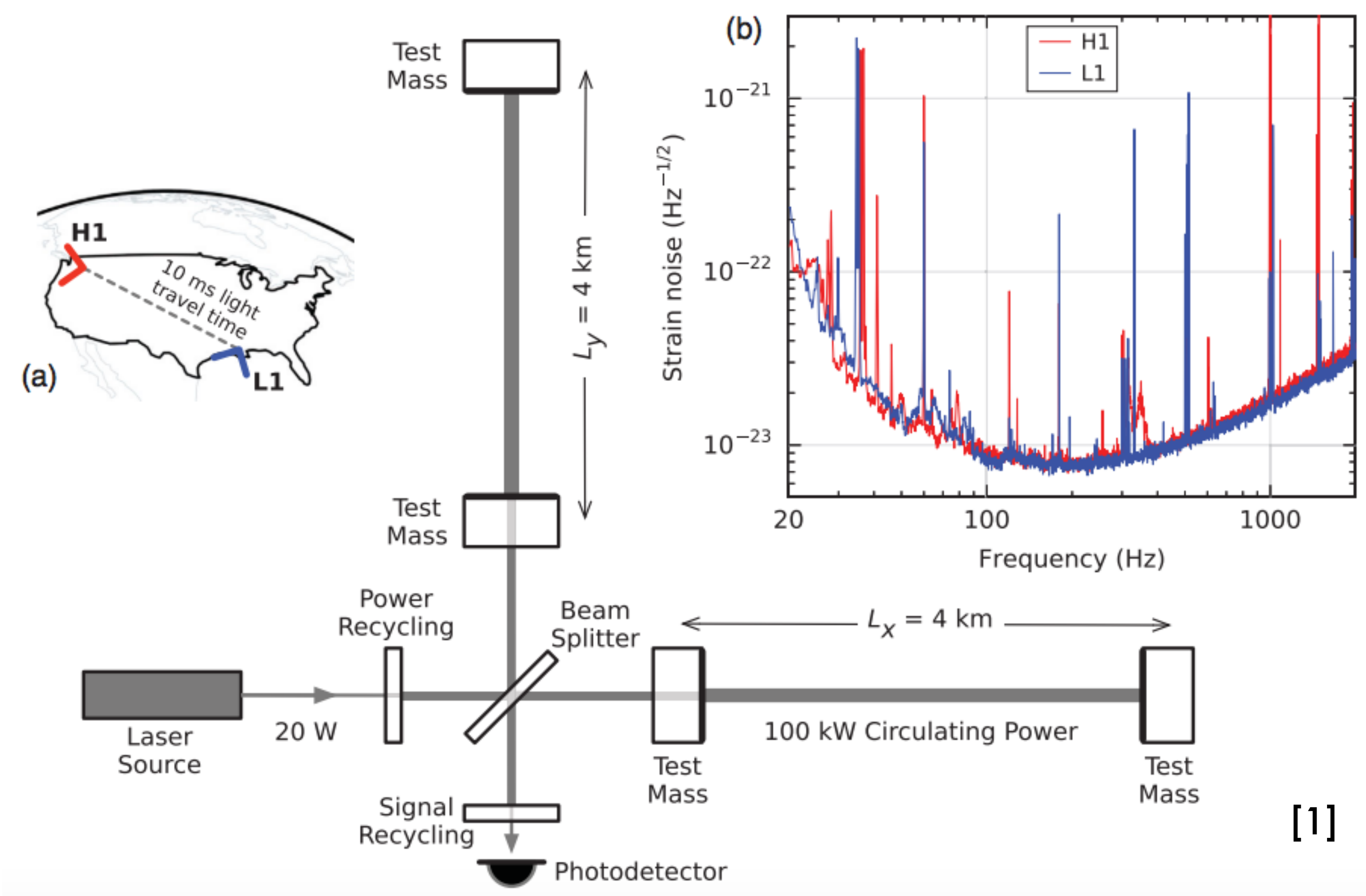
Gravitational Waves are ripples in spacetime due to the accelerated motion of a matter and energy.

Sources of Gravitational Waves include:

- the inspiral of a binary black hole merger
- rotating asymmetric neutron stars
- bursts from unexpected sources (e.g. supernova)

How does LIGO detect Gravitational Waves?

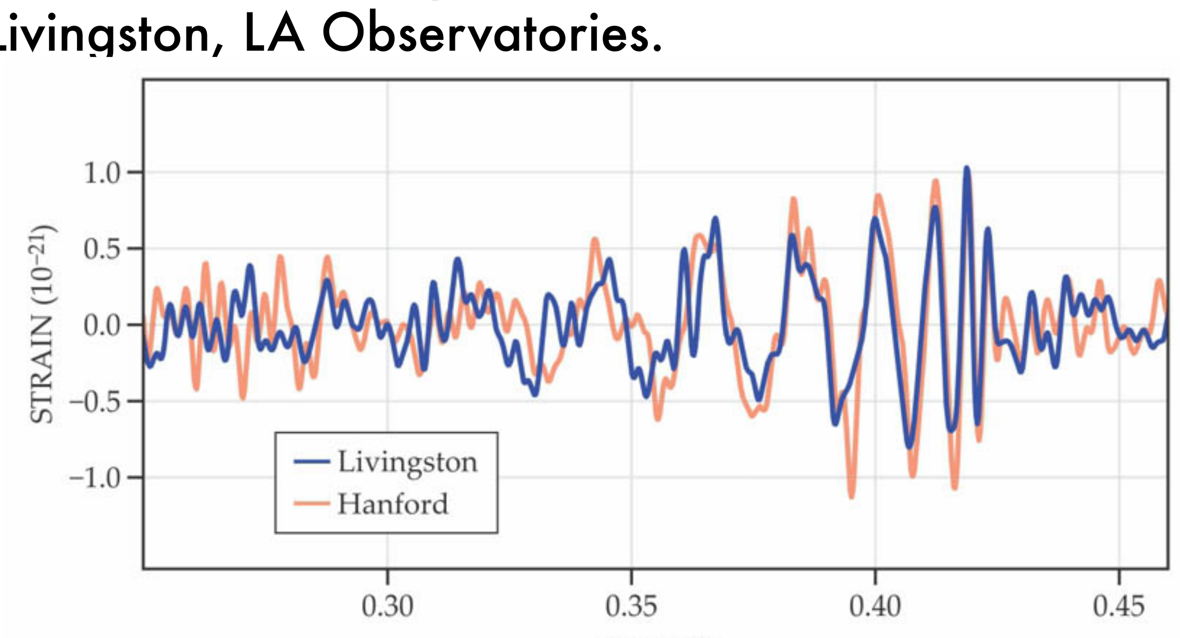
An example of a basic interferometer is shown below. Laser light is sent through a beam splitter, and exits down two perpendicular vacuum tubes. The light hits a mirror at the end of the tube and returns to a detector.



[1]

As a gravitational wave passes through the detector, one arm will be stretched and the other compressed. The detector detects the difference in how long it takes the light to travel down each arm.

The graph on the below shows the signal of the first detection as seen by both the Hanford, WA and Livingston, LA Observatories.



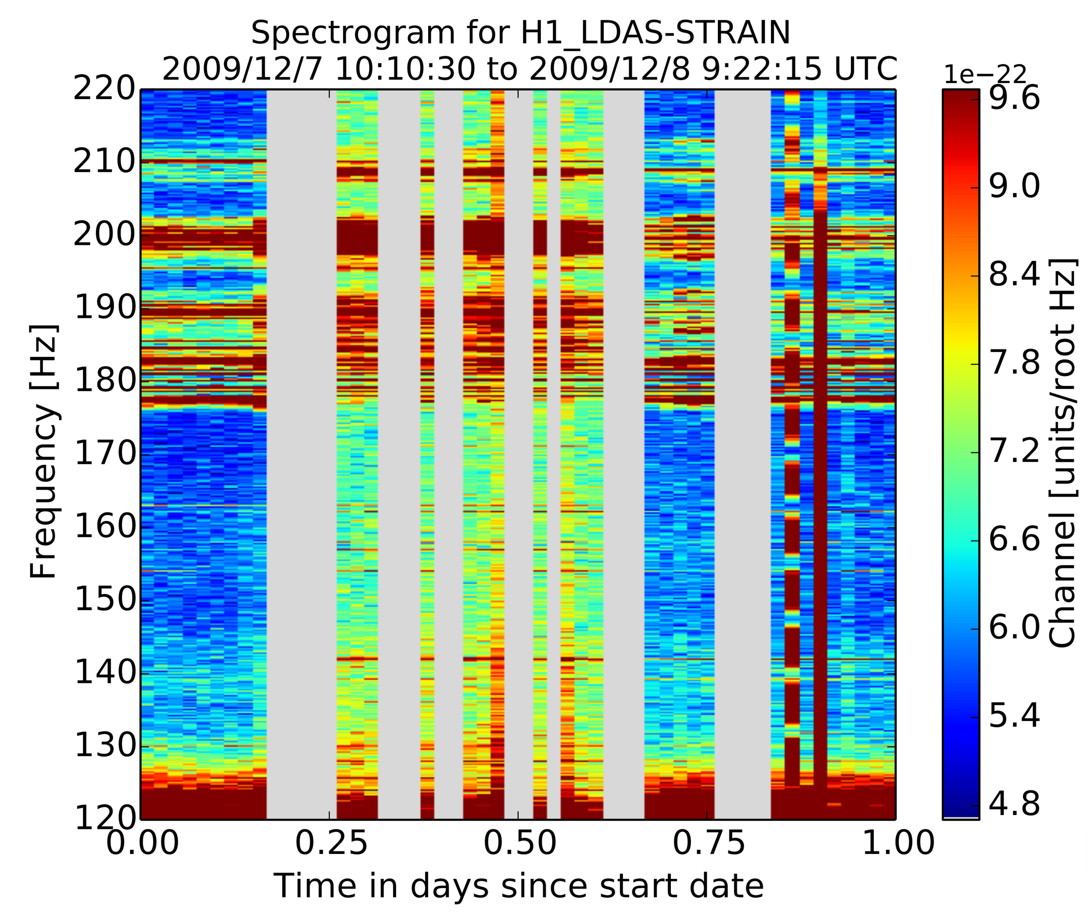
[1]

Fscans produce spectrograms and time-averaged Power Spectra

Some uses of Fscans include:

- aiding in continuous gravitational wave searches
- identifying coincidence lines between environmental sensors and the gravitational wave channel

Specrograms plot a time evolution of the power spectrum of different frequency bins



$$\mathrm{ASD} = \sqrt{\frac{2\left\langle|\tilde{x}|^2\right\rangle\Delta t^2}{T}}$$

- $\tilde{x}$ is FFT of the signal
- Δt is the time between samples
- T is the time duration

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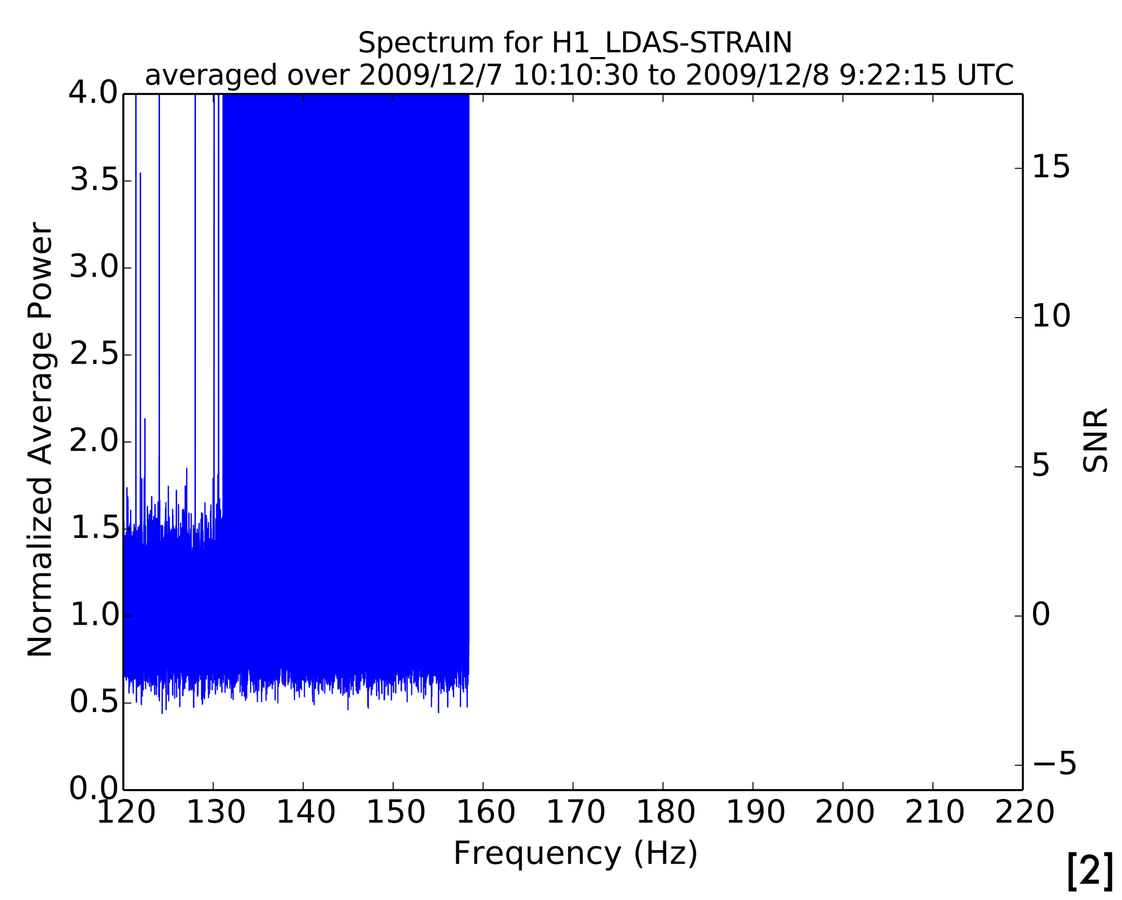
Time-averaged Power Spectra plot the normalized average power over a 24 hour period of each frequency bin



A running median is used to whiten the data, allowing weak noise lines to stand out above the background.

[2]

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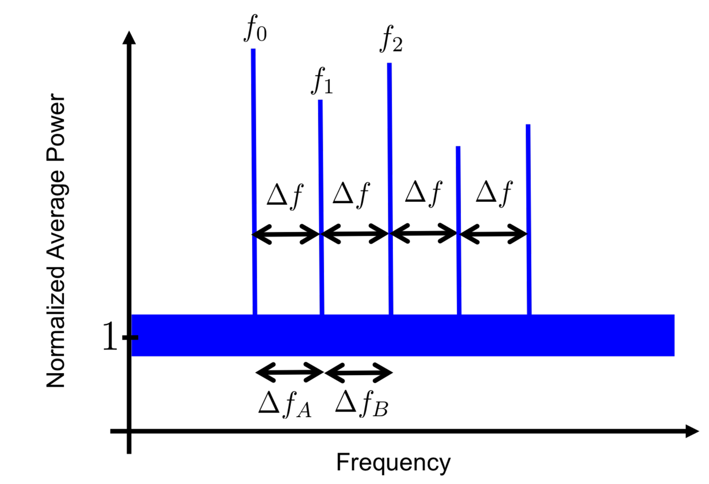
Searching for combs to identify noise sources

A comb is a sequence of strong frequencies repeated at regular frequency intervals Δf, such as shown in the cartoon figure below.

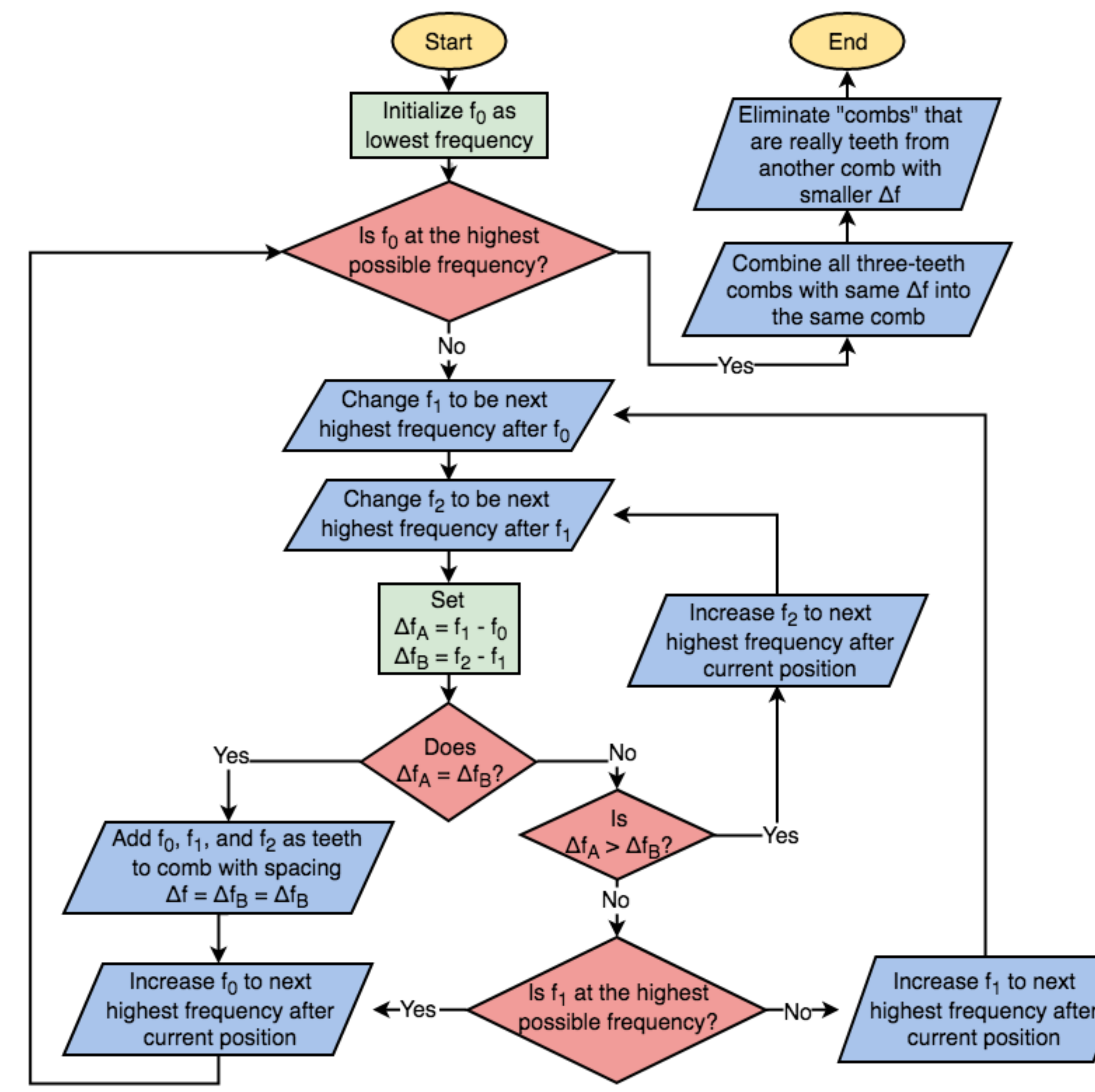
Combs identify noise lines, such as those from an electronic clock turning on and off

For example, the time-averaged Power Spectrum in the previous column has several combs with a spacing of 0.5 Hz



Implementing a Comb Finding algorithm

The Comb Finding algorithm scans through frequencies f_0, f_1, and f_2, computing $\Delta f_A = f_1 - f_0$ and $\Delta f_B = f_2 - f_1$. If $\Delta f_A = \Delta f_B$ within a tolerance of ε = 0.01 Hz, then f_0, f_1 and f_2 make up the teeth to a comb.



[1] "Observation of Gravitational Waves from a Binary Black Hole Merger", B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), Phys. Rev. Lett. 116, 061102.

[2] LIGO Scientific Collaboration, "LIGO Open Science Center release of S6", 2015, DOI 10.7935/K5RN35SD (https://losc.ligo.org

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