Noise characterization for continuous-wave searches

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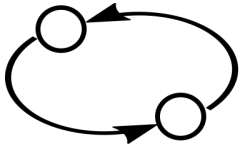
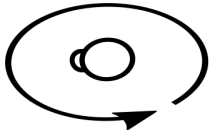
Outline

- Continuous waves - fast overview
- Narrow spectral artifacts - fast overview
- What do we need to know?
- Automation challenges
- Automation status
- Projects and students at UWB
- Where to learn more

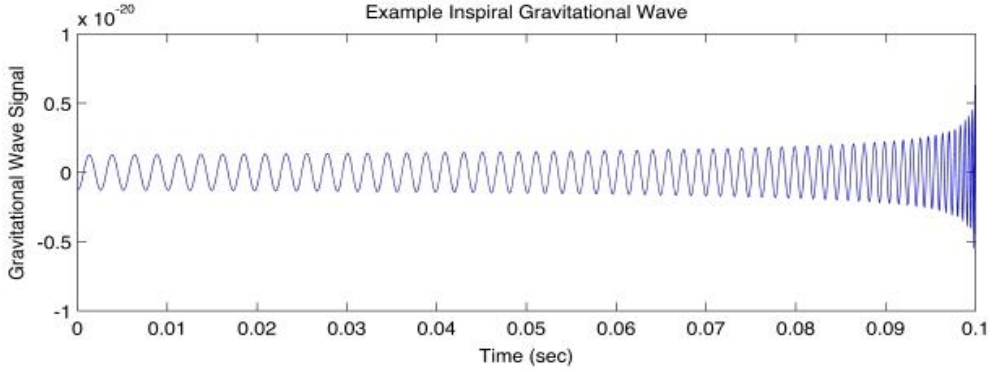
Continuous waves

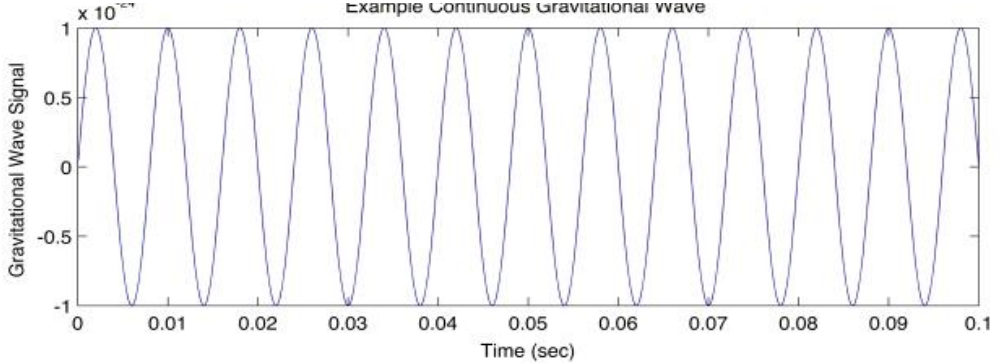


CBC



CW





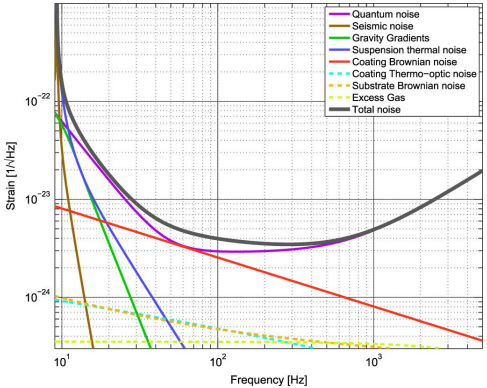
Above figures from: Introduction to LIGO and gravitational waves: sources of gravitational waves. https://www.ligo.org/science/GW-Sources.php

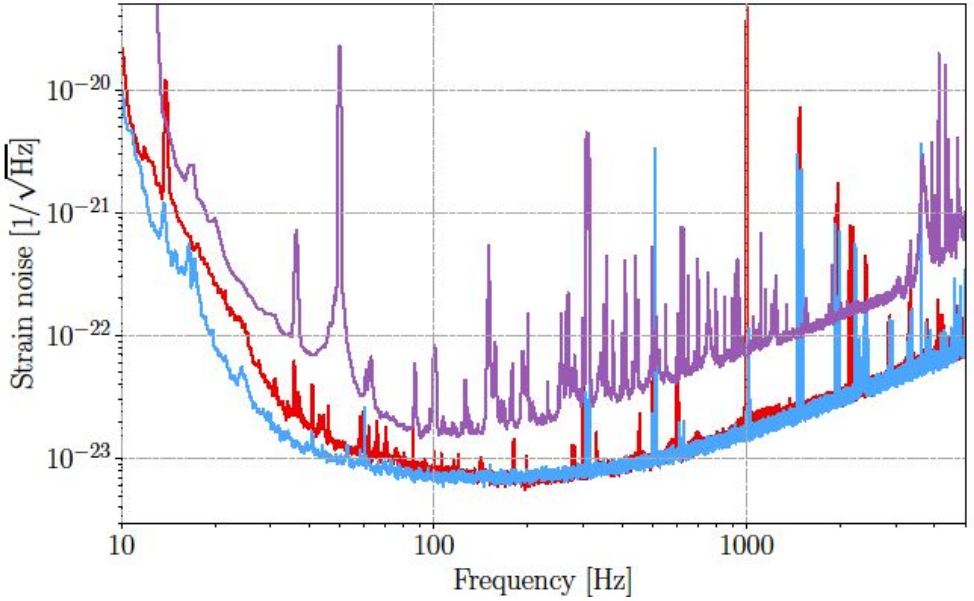
Continuous waves

- Canonical source: isolated spinning neutron star
  - Other sources may exist as well!
- Considerably weaker than CBC sources
- Persistent signals, near single frequency
  - ... aside from spindown, Doppler modulation, glitches, etc.
- Need to integrate data over weeks, months, or years

Narrow spectral artifacts

- Near single frequency ➔ can mimic a CW signal
- Arise from a variety of sources, but particularly electronic noise in the detector.





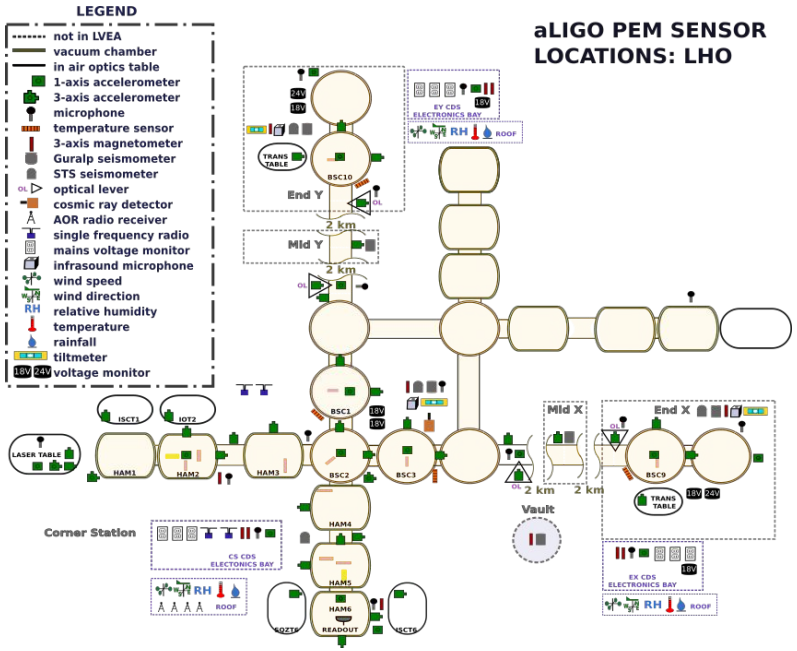
Figures from: (1) GWTC-1: A gravitational-wave transient catalog of compact binary mergers observed by LIGO and Virgo during the first and second observing runs, 2018. (2) LIGO Scientific Collaboration. Advanced LIGO. Classical and Quantum Gravity , 32(7):074001, 2015.

What do we want to do?

- Best case scenario: mitigate a problem before much data is contaminated.
- Second best: document a problem before CW searches need to use the data.
    - Consequences: may need to clean data, or use a subset of the data. Sensitivity may be degraded; may take more time.
- Worst case: discover a problem while CW searches are running.
    - Consequences: spurious outliers, degraded sensitivity. May need clean data and re-run searches, or to re-run on a subset of data. Person hours and computational time wasted.

Why is automation hard?

- Spectra are complicated
  - Line strength, width, shape vary greatly
  - Artifacts may overlap
- Time dependence
  - Lines appear and disappear
  - Background noise spectrum changes
  - Weak lines may only be visible over long stretches of data
  - Detailed time-dependence information requires short stretches of data
- Lots of data
  - Auxiliary channels (e.g. magnetometers)



What do we need to know about lines & combs?

- **Presence in DARM**
- **Priority for investigation**
- **History in DARM**
- **Presence in auxiliary channels**
- **History in auxiliary channels**
- **Theories about origin / coupling mechanism**
- **Steps taken to mitigate**
- **Results of mitigation attempts**

What do we need to know about lines & combs?

- **Presence in DARM** - minimal / unreliable automation; human vetting needed
- **Priority for investigation** - strength & frequency bins contaminated?
- **History in DARM** - automated for some artifacts
- **Presence in auxiliary channels** - automated for some artifacts and channels
- **History in auxiliary channels** - automated for some artifacts and channels
- **Theories about origin / coupling mechanism** - task for humans
- **Steps taken to mitigate** - task for humans
- **Results of mitigation attempts** - task for humans

The big goal: less human time spent on tasks that can be automated; more information available for investigations.

Projects at UWB

- Improve automated line detection [active]
  - Support line list generation
  - Support DQ shift efforts
  - Provide better input for automated comb detection
- Improve automated comb detection [active]
  - Combs are high priority for mitigation
  - Support DQ shift efforts
- Historical studies on line impacts [planning stages]
  - Motivation: better figures of merit for line/comb mitigation priority
- Update interactive spectrum plotting tools [future]
- Update comb tracker [future]

Students working on lines at UWB

- Autumn ‘19: **Sandra Hughey**, **Cody Barschaw** - contributed to O3a lines list
- Winter ‘20: **Sukhjit Kaur** - draft of representative lines list for historical studies
- Summer ‘20: **Ruth Paras**, **Daniel Esterkin**, **Nathan June**, **Carol Miu**
    - Initial focus on improving peak & comb identification; may branch out into additional projects

Where can I learn more?

- Overviews:
  - 2018 line paper: https://arxiv.org/abs/1801.07204
  - Line & combs intro notes: https://wiki.ligo.org/CW/LinesCombsIntroNotes
- Recent things:
  - O3a lines list presentation (Evan Goetz): https://dcc.ligo.org/LIGO-G1902208
  - Comb tracking pages: https://dcc.ligo.org/LIGO-G1900495