Gravitational Wave Discovery

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LIGO Scientific Collaboration (LSC)
Exciting Time for GW Discovery

- 2015: First Detection of GWs from Binary Black Hole Merger
- 2017: Nobel Prize in Physics
- 2017: First Detection of GWs and Light from Binary Neutron Star Merger
- 2019 Apr 1 – : First Open Public Alert

O1/O2 Discoveries:
- 11 confirmed detections: 10 BBHs (4 previously unpublished), 1 BNS
- 14 marginal detections (FAR < 1/30 days, P_astro < 50%)

O3 Discoveries:
- NSBH: 5
- BNS: 3
- Mass Gap: 2
- BBH: 21

GraceDB — Gravitational-Wave Candidate Event Database

LIGO/Virgo Public Alerts

- Event ID
- Possible Source (Probability)
- UTC
- GCN
- Location
- FAR

- S190709
  - BBH (109%, Terrestrial (150), BNS (10))
  - July 18, 2019: 07:35 UTC
  - GCN Circulars
  - Notes: VDE
  - 1.1514 per year

- S190718
  - BBH (99%), Terrestrial (150)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years

- S190721
  - BBH (99%), Terrestrial (150), BNS (10)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years

- S190727
  - BBH (99%), Terrestrial (150), BNS (10)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years

- S190728
  - BBH (99%), Terrestrial (150), BNS (10)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years

- S190729
  - BBH (99%), Terrestrial (150), BNS (10)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years

- S190730
  - BBH (99%), Terrestrial (150), BNS (10)
  - July 18, 2019: 03:53:26 UTC
  - GCN Circulars
  - Notes: VDE
  - 1 per 6016.9 years
UWA Gravitational Wave Astronomy Group

At the Frontier of GW Discoveries

Online Pipelines

A number of search pipelines run in a low latency, online mode. These can be divided into two groups, modeled and unmodeled. The modeled (CBC) searches specifically look for signals from compact binary mergers of neutron stars and black holes (BNS, NSBH, and BBH systems). The unmodeled (Burst) searches on the other hand, are capable of detecting signals from a wide variety of astrophysical sources in addition to compact binary mergers: core-collapse of massive stars, magnetar star-quakes, and more speculative sources such as intersecting cosmic strings or as-yet unknown GW sources.

Modeled Search

GstLAL, MBTAOnline, PyCBC Live and SPIIR are matched-filtering based analysis pipelines that rapidly identify compact binary merger events, with \(< 1\) minute latencies. They use discrete banks of waveform templates to cover the target parameter space of compact binaries, with all pipelines covering the mass ranges corresponding to BNS, NSBH, and BBH systems.

A coincident analysis is performed by all pipelines, where candidate events are extracted separately from each detector via matched-filtering and later combined across detectors. SPIIR extracts candidates from each detector via matched-filtering and looks for coherent responses from the other detectors to provide source localization. Of the four pipelines, GstLAL and MBTAOnline use several banks of matched filters to cover the detectors bandwidth, i.e., the templates are split across multiple frequency bands. All pipelines also implement different kinds of signal-based vetoes to reject instrumental transients that cause large SNR values but can otherwise be easily distinguished from compact binary coalescence signals.

- Authorized by LVC to generate GW open public alerts
  - One of the 5 groups in the world!
  - Based on 2 UWA PhD thesis + 1 MS thesis + several research papers

- Our detections are among the fastest!
  - Send alerts within 18-30 s after binary merger
  - Now aiming at pre-merger detections
  - To facilitate prompt EM follow up observations

- Finalist for 2019 HPC Wire Reader’s Choice Award for “best use of HPC in physical sciences”
UWA GWA Group: MS/PhD Projects

• **Rapid Online Detection and Follow-ups of Gravitational Waves**
  (Projects within the LIGO-Virgo Scientific Collaboration)
  

• **Pre-merger Detection of Gravitational Waves and Electromagnetic Follow-ups**
  (Projects within the LIGO-Virgo Scientific Collaboration, collaborate with ICRAR-Curtin, MWA and ASKAP)
  

• **Machine Learning for GW Discoveries**
  (Projects within the LIGO-Virgo Scientific Collaboration, collaborate with ICRAR-UWA and UWA Computer Science)
  
  (Chatterjee, C. et al 2019 PRD, accepted upon revision)
UWA GWA Group: MS/PhD Projects

- **Coincidence Search for Gravitational Wave and Fast Radio Bursts/Gamma Ray Bursts**
  
  (Project within the LIGO-Virgo Scientific Collaboration, collaborate with ASKAP/MWA/CRAFT)

- **Binary Black Hole Merger Modeling, and Using GW Data to Probe our Universe**
  
  (Collaborate with Caltech and USTC)

- **High-performance Computing, Algorithm Design, Mathematical Optimization, and GPU-Acceleration**
  
  (Collaborate with UWA Computer Science and Tsinghua U in China)