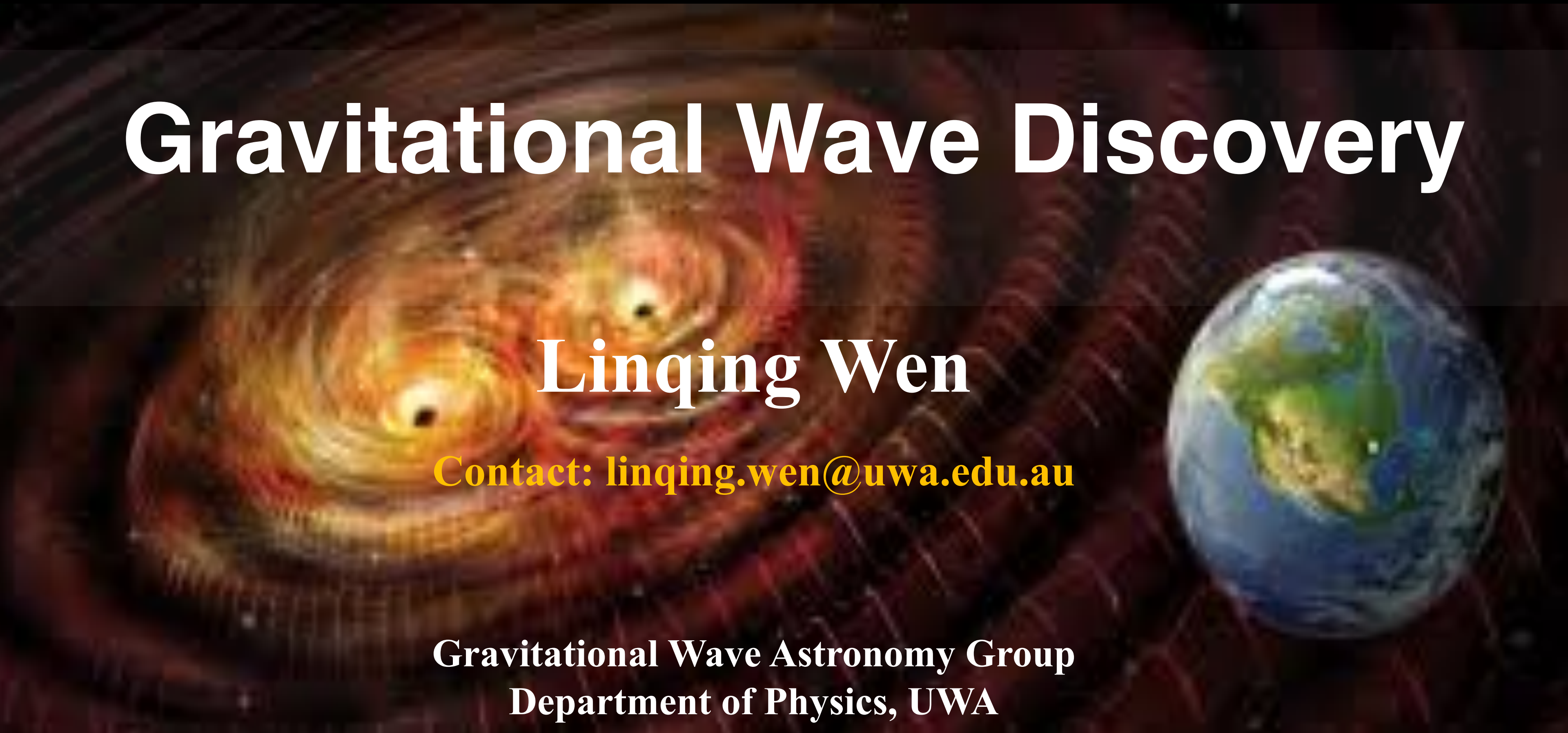

Gravitational Wave Discovery

Linqing Wen

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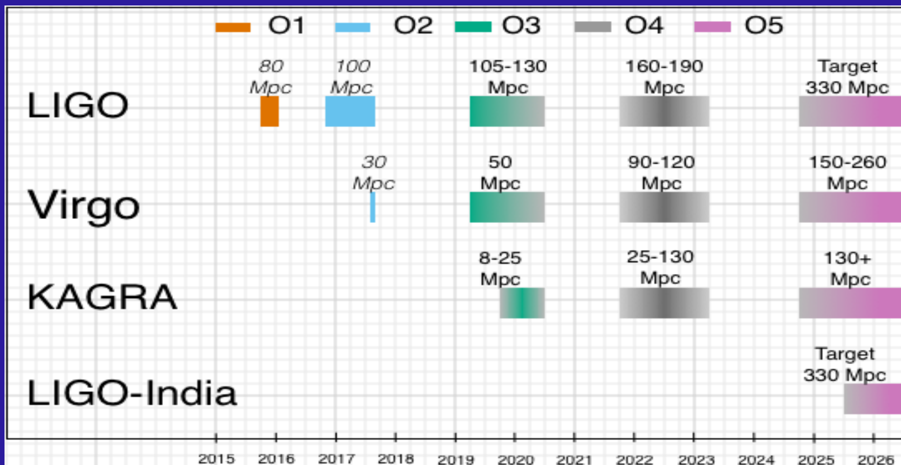
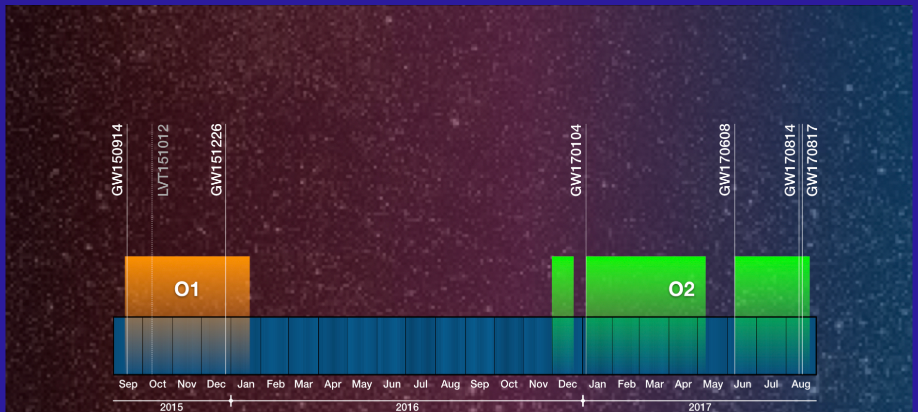
Gravitational Wave Astronomy Group
Department of Physics, UWA
ARC Center of Excellence for Gravitational Wave Discovery (OzGrav)

Gravitational Wave Technology and Education Research Cluster
Machine Learning Application for Physical Sciences Research Cluster

LIGO Scientific Collaboration (LSC)

Exciting Time for GW Discovery

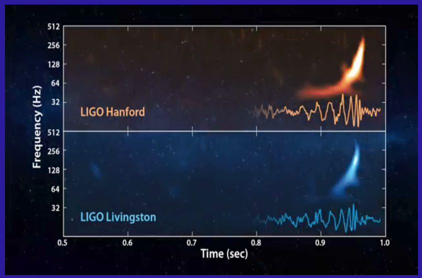




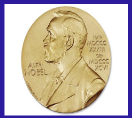
O1/O2 Discoveries:

- 11 confirmed detections: 10 BBHs (4 previously unpublished), 1 BNS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

- 2015: First Detection of GWs from Binary Black Hole Merger

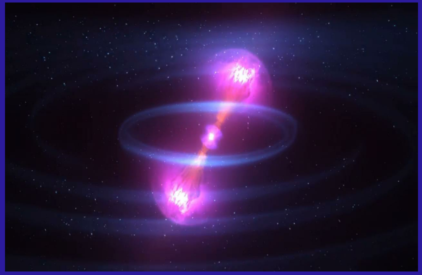


- 2017: Nobel Prize in Physics



Rainer Weiss (MIT) Kip Thorne (Caltech) Barry Barish (Caltech)

- 2017: First Detection of GWs and Light from Binary Neutron Star Merger



- 2019 Apr 1 – : First Open Public Alert

GraceDB — Gravitational-Wave Candidate Event Database

HOME | PUBLIC ALERTS | SEARCH | LATEST | DOCUMENTATION | LOGIN

LIGO/Virgo Public Alerts

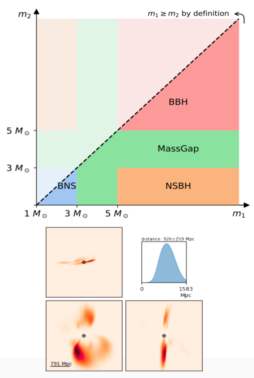
Detection candidates: 22

(O3: https://gracedb.ligo.org)

SORT: EVENT ID (A-Z)

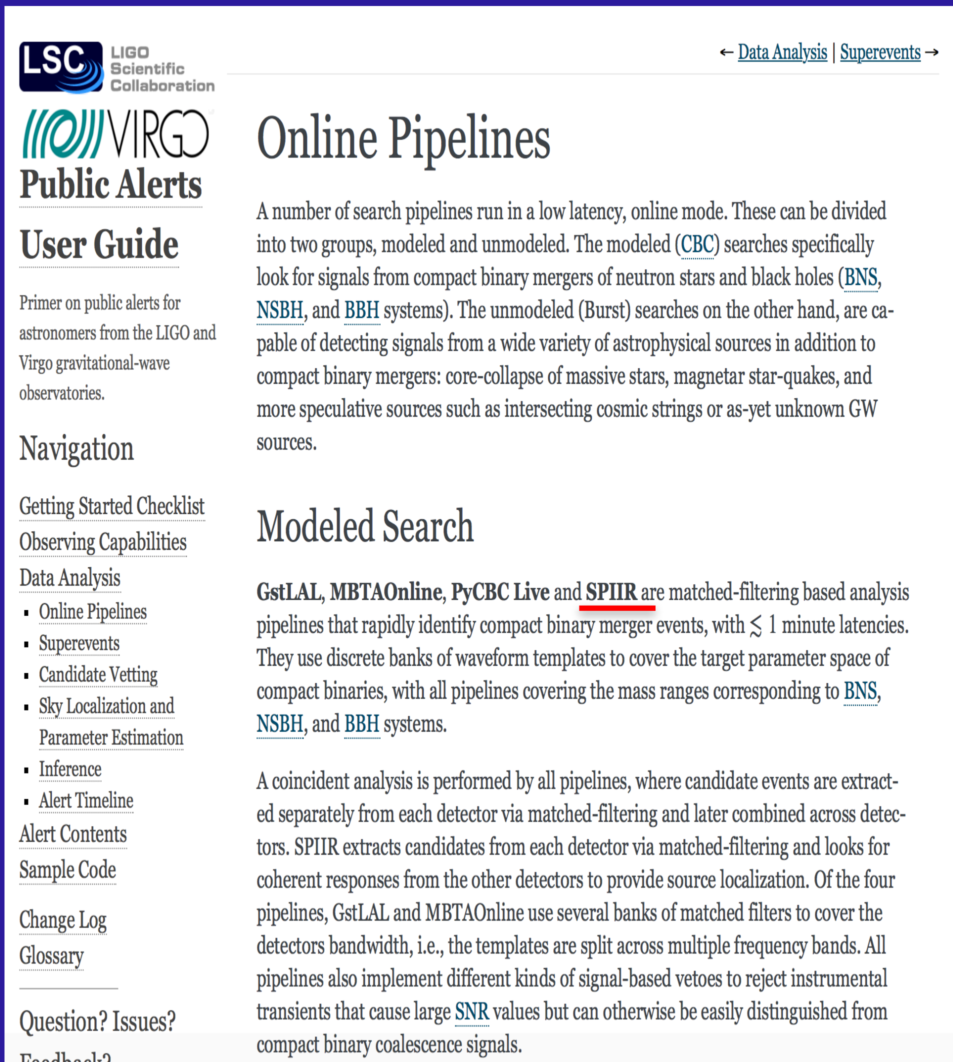
Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	
S190808ae	Terrestrial (57%), BNS (43%)	Aug. 8, 2019 22:21:21 UTC	GCN Circulars Notices | VOE		1.0622 per year	RETRACTED
S190728q	BBH (95%), MassGap (5%)	July 28, 2019 06:45:10 UTC	GCN Circulars Notices | VOE		1 per 1.2541e+15 years	
S190727h	BBH (92%), Terrestrial (5%), MassGap (3%)	July 27, 2019 06:03:33 UTC	GCN Circulars Notices | VOE		1 per 229.92 years	
S190720a	BBH (99%), Terrestrial (1%)	July 20, 2019 00:08:36 UTC	GCN Circulars Notices | VOE		1 per 8.3367 years	
S190718y	Terrestrial (98%), BNS (2%)	July 18, 2019 14:35:12 UTC	GCN Circulars Notices | VOE		1.1514 per year	
S190707q	BBH (>99%)	July 7, 2019 09:33:26 UTC	GCN Circulars Notices | VOE		1 per 6018.9 years	

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



UWA Gravitational Wave Astronomy Group

At the Frontier of GW Discoveries


← Data Analysis | Superevents →

LSC LIGO Scientific Collaboration

VIRGO

Public Alerts User Guide

Primer on public alerts for astronomers from the LIGO and Virgo gravitational-wave observatories.

Navigation

- Getting Started Checklist
- Observing Capabilities
- Data Analysis
  - Online Pipelines
  - Superevents
  - Candidate Vetting
  - Sky Localization and Parameter Estimation
  - Inference
  - Alert Timeline
- Alert Contents
- Sample Code
- Change Log
- Glossary

Question? Issues? Feedback?

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 $\lesssim$ 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*"

THE UNIVERSITY OF WESTERN AUSTRALIA

LIGO Scientific Collaboration

ARC Centre of Excellence for Gravitational Wave Discovery

PPTA

SPIIR Collaboration

GW Technology and Education Cluster

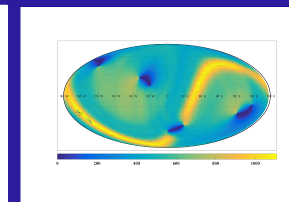
MAPS Cluster

Machine-learning Application for Physical Sciences

UWA GWA Group: MS/PhD Projects

- **Rapid Online Detection and Follow-ups of Gravitational Waves**

  (Projects within the LIGO-Virgo Scientific Collaboration)

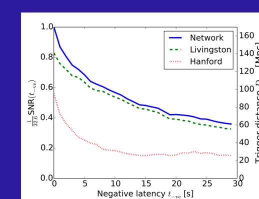


(GCN Notices at gracedb.ligo.org, Chu, Q. 2017 UWA PhD thesis, Hooper, S. 2014 UWA PhD thesis…)

- **Pre-merger Detection of Gravitational Waves and Electromagnetic Follow-ups**

  (Projects within the LIGO-Virgo Scientific Collaboration, collaborate with ICRAR-Curtin, MWA and ASKAP)

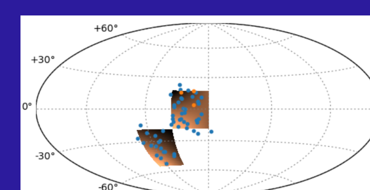
(Clancy, J. et al 2019, MNRAS Letter)



- **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

THE UNIVERSITY OF WESTERN AUSTRALIA

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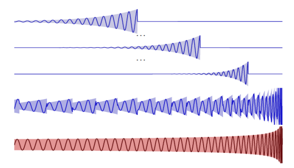
PPTA



SPIIR Collaboration

GW Technology and Education Cluster

MAPS Cluster

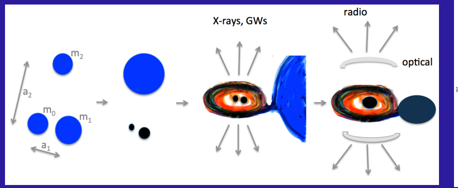
Machine-learning Application for Physical Sciences

- **Coincidence Search for Gravitational Wave and Fast Radio Bursts/Gamma Ray Bursts**

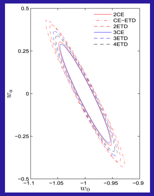
(Project within the LIGO-Virgo Scientific Collaboration, collaborate with ASKAP/MWA/CRAFT)

- **Binary Black Hole Merger Modeling, and Using GW Data to Probe our Universe**

(Collaborate with Caltech and USTC)



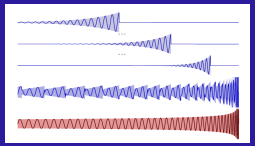
(Wen & Phinney 2018)

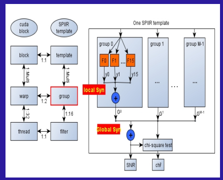


(Zhao & Wen 2018 PRD)

- **High-performance Computing, Algorithm Design, Mathematical Optimization, and GPU-Acceleration**

(Collaborate with UWA Computer Science and Tsinghua U in China)





(Hooper S. et al 2012, Luan et al 2012, Liu et al 2012, Guo et al 2018 , Chu 2017