Multi-messenger Astronomy: Major Goals

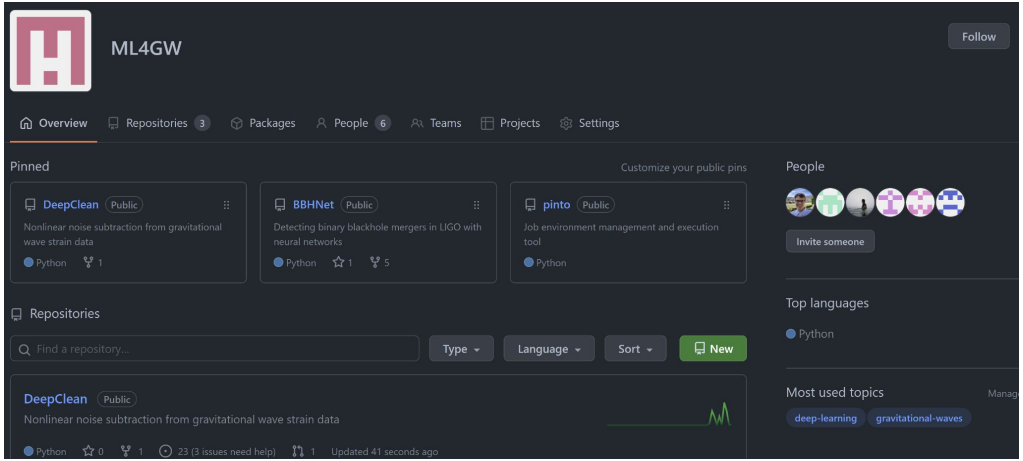
The Multi-Messenger Astronomy (MMA) pillar is currently revolved around preparation for ongoing and forthcoming observing runs by the astronomical facilities. In particular, we are focused on development to contribute to characterize compact binary coalescences detected by gravitational-wave detectors such as Advanced LIGO, Virgo and KAGRA, and the associated follow-up by optical facilities such as the Zwicky Transient Facility of these candidates, beginning February 2023.

An additional direction is development of low-latency triggering and pointing algorithms for supernova burst neutrino direction, in the context of DUNE and the SuperNova Early Warning System.

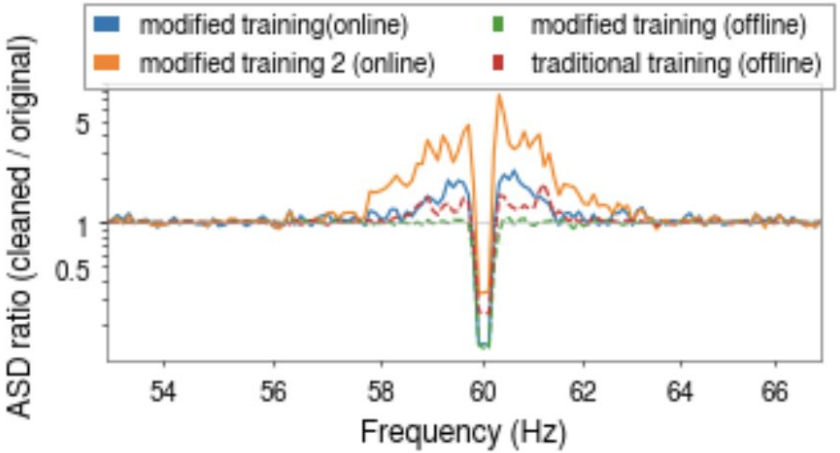
Activities, Objectives, and Results

Gravitational Waves

Zoom Meetings:
Thursdays 08:30-09:30 Central Time,
Fridays 14:00-15:00 Central Time



Public release (with ongoing CI development) of the associated IaaS libraries here: https://github.com/ML4GW/DeepClean

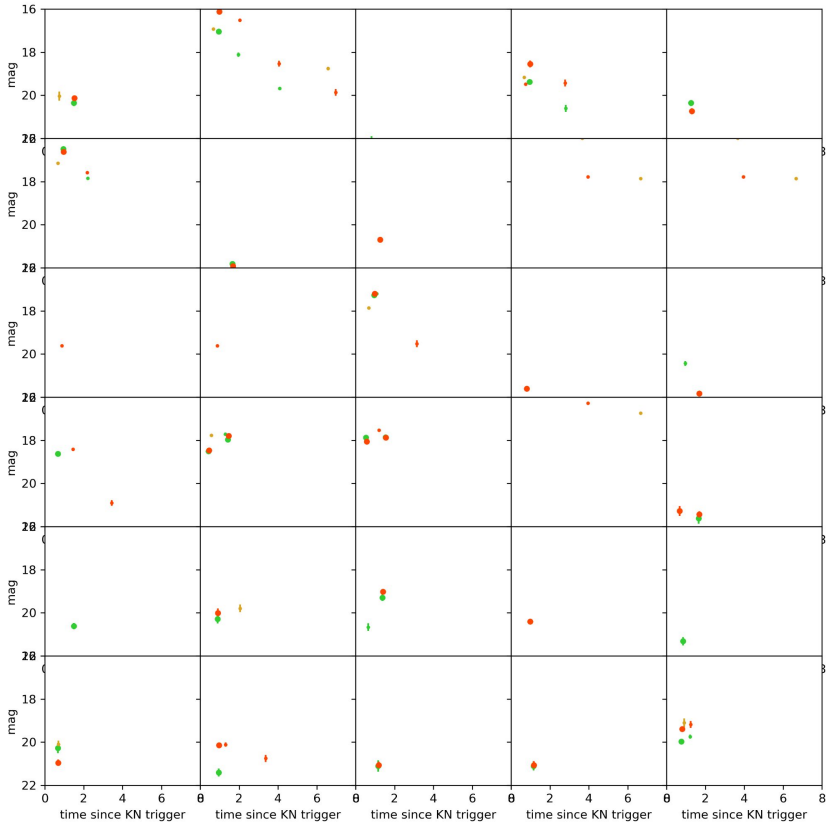


Main focus: Extending the inference-as-a-service prototype and using it to implement a real-time noise subtraction pipeline for use in the upcoming fourth observing run of LIGO-Virgo-KAGRA on dedicated hardware at the detector sites. Work continues on gravitational-wave transient detection.

Optical Astronomy

Meeting:
Tuesday at 10:00 Central

- NMMA software released publicly here: https://github.com/nuclear-multimessenger-astronomy/nmma
- With documentation here: https://nuclear-multimessenger-astronomy.github.io/nmma/
- Goal: Developing and implementing injection pipelines to simulate gravitational-wave counterparts such as kilonovae and gamma-ray burst afterglows, and contaminants such as shock breakout supernovae with realistic observing scenarios.
- Ready: training light curves for kilonovae from BNS and NSBH mergers (10k each) expected from ZTF during LIGO O4.
- Working on adding gamma-ray burst afterglows and contaminants such as shock breakout supernovae.



Samples from training dataset for KNe from simulated BNS as observed by ZTF in g, r and i. Larger datapoints are due to ToO observations.

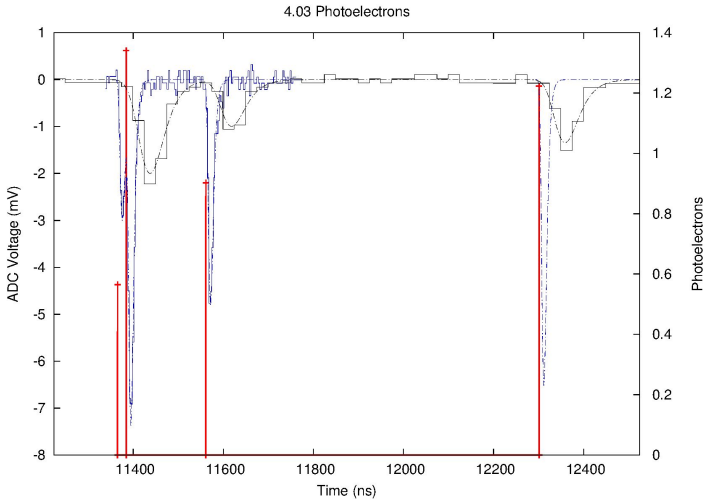
Neutrinos

DUNE/SNEWS/COHERENT

Postdoc search: offer accepted (Janina Hakenmuller) to start 7/1/22)
Pre-matriculation grad student identified for summer (Joshua Queen)
Post-bacc student (Van Tha Bik) offer accepted, to start 7/27/22
Specific projects TBD (supernova burst trigger, pointing)

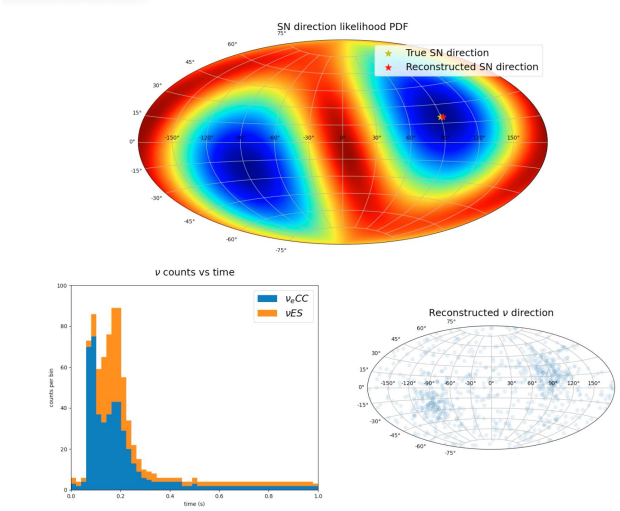
IceCube

- Started collaboration /w/ Pan Li, Atlas Wang, Stanley Chen, and others on ML unfolding of IceCube PMT waveforms.
- Searching for methods to port waveform unfolding to DOMs (embedded: uC/FPGA), currently only have solution for unfolding dark noise waveforms
- Want to accelerate unfolding algorithms on the surface for new ML based reconstruction algorithms



Supernova burst pointing studies @ Duke

- New (pre-matriculation) grad, Josh Queen, getting up to speed on DUNE (FNAL process takes some weeks), joining ML working group
- In meantime, working on toy pointing study to learn the physics & reco issues



Outcomes, Achievements, and Objectives

Gravitational waves

- Bringing in other data analysis pipelines within the IGWN into the inference as a service framework
- Established connections with the AEI, UvA and Cardiff groups
- Goal: Running noise subtraction online on MDC and then O4 data

Optical Astronomy

- Developing telescope triggering and analysis toolkit and distributing to other teams (discussion with Rubin in use for their ToOs, discussion with Australians for O4, etc.)
- Used framework for follow-up of a high energy neutrino
- Goal: First end-to-end Fermi GRB and then gravitational-wave event

Neutrinos

- Developing new fast reconstruction tools for supernova burst pointing in DUNE and waveform unfolding in IceCube
- Goal: ML-based channel-tagging for fast pointing reco for DUNE; accelerated unfolding algorithms on the surface for new ML based reconstruction algorithms for IceCube

Products and Papers

Gravitational Waves

- https://arxiv.org/abs/2108.12430 (Inference as a service; Nature Astronomy)

Optical/NIR Astronomy

- https://arxiv.org/abs/2205.08513 (NMMA; in review at Nature Astronomy)

Impact

- On the development of the principal discipline(s) of the project:

All three pillars are very well integrated into and driving the growth of their respective communities

- On other disciplines

With the gravitational-wave work, we have curated and provided a data set to test novel regression algorithms against, and will be doing something similar for the detection work. On the optical side, we are creating a novel fast transient focused data set with Bayesian inference posteriors provided; we are also enabling the observing scenarios for the next gravitational-wave observing run. All of these provide unique data sets for others to test out algorithms with.

- On the development of human resources

The projects all have significant graduate student and undergraduate involvement in a variety of forms, with post-docs and graduate students the point of contacts for a number of deliverables.

- On the development of educational experiences

The data sets being curated will be used in the ZTF Summer School and in a variety of classes taught by the A3D3 professors.

- Institutional resources that form infrastructure

N/A

Thank you!