GW astronomy at UBC/TRIUMF

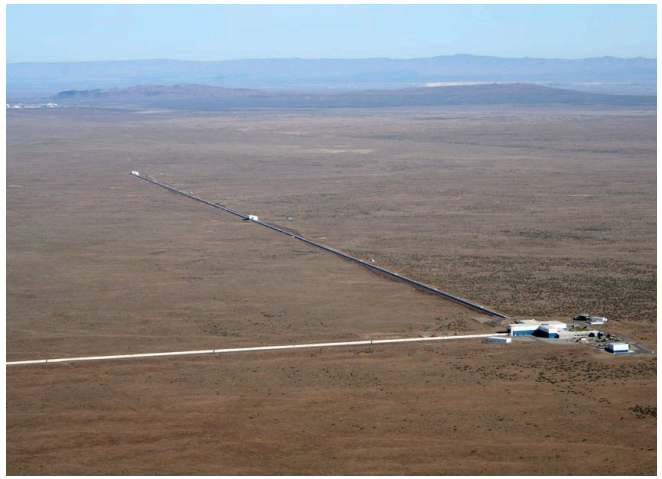
Jess McIver for the UBC/TRIUMF team

June 27, 2023

GWANW 2023

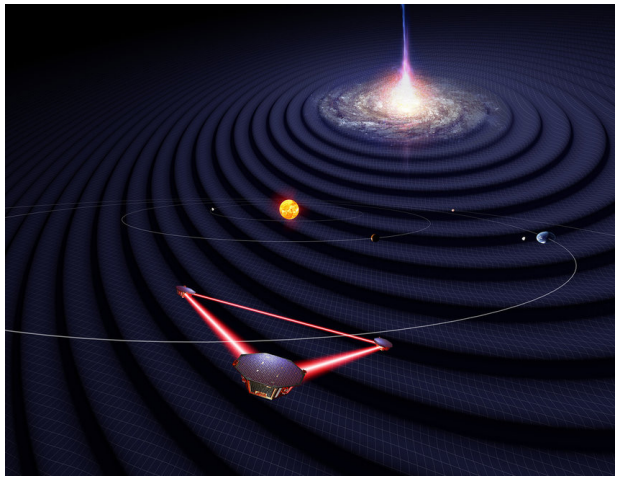
LIGO DCC G2301233

Across the GW spectrum: UBC and TRIUMF



Ground based interferometers

- UBC LIGO group
- Cosmic Explorer/future GW detectors



Space based interferometers

- UBC-TRIUMF LISA group

Pulsar Timing Arrays

- UBC CHIME team

B-mode polarization

- Search for B-mode polarization at UBC

Not pictured: Katja Nell, Franz Herbst, Harshini Paranjape

The UBC LIGO team: astrophysics

In collaboration with Beverly Berger (Stanford LIGO), Connie Hong (Stanford LIGO), Raymond Ng (UBC DSI), Xiaoxaio Li (UBC ECE), Ruichen Yao (UBC ECE) and David Stenning (SFU)

We are hiring (soon)!

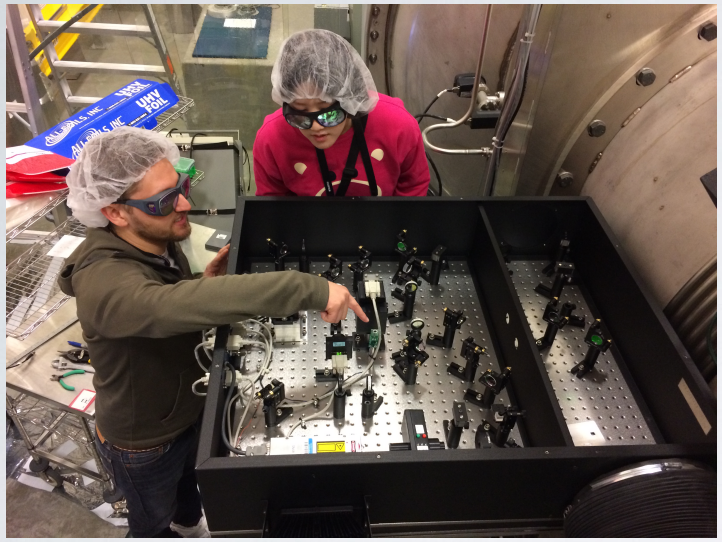
The UBC GW astro team will be looking for a research associate proficient with software development/maintence to contribute to support of git.ligo.org, as well as the collaboration's identity and authentication infrastructure.

Job ad to come soon – please get in touch with Jess if you are interested!

(UBC CHIME is also hiring a software development position soon; get in touch with Ingrid Stairs)

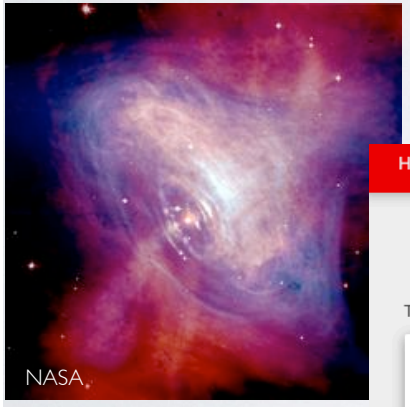
EVAN GOETZ

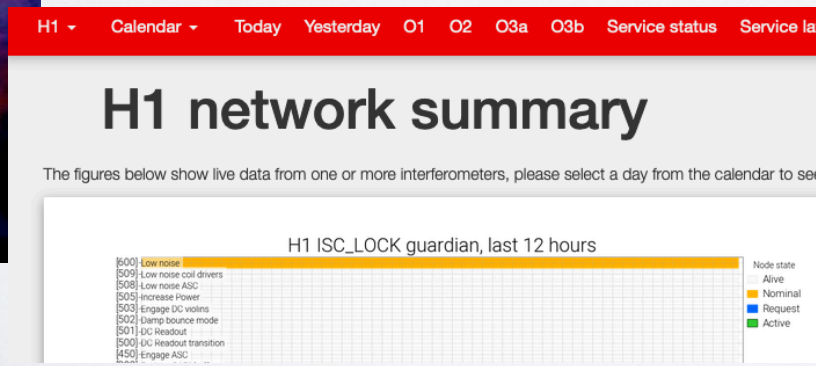
Research associate
UBC Physics and Astronomy

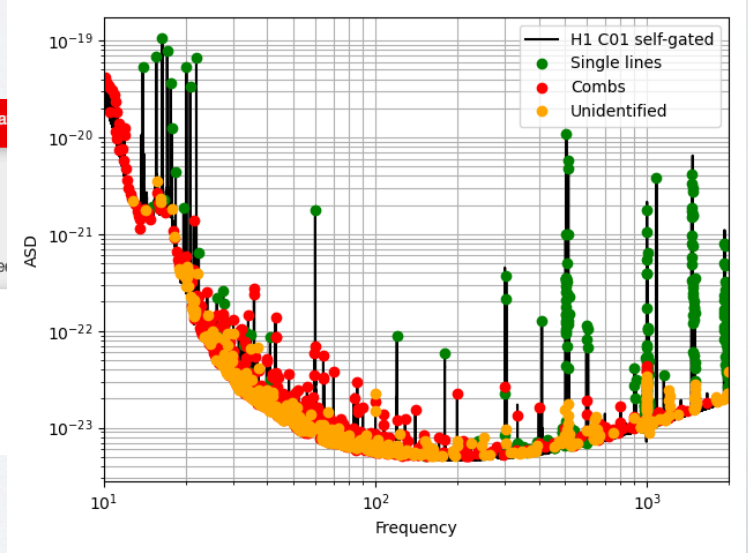


Main research topics:

- Astrophysics with gravitational waves particularly neutron stars
- Gravitational wave detector calibration and characterization
- Precision metrology
- Developing enabling software







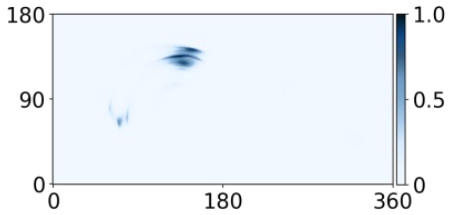
A Machine Learning Driven Low-latency Annotation Pipeline For O4

Man Leong Chan, Jess McIver et al

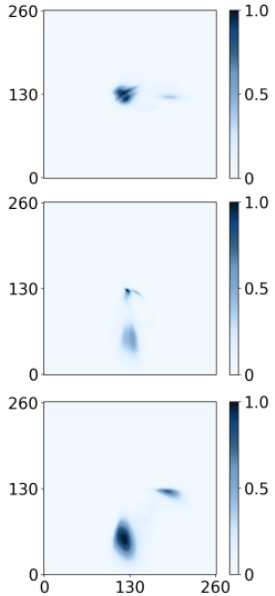
An LVK Gravitational wave alert

an associated FITS file

A 2D sky map



Volume rendering images



Other numerical data

detectors, normalization factors, etc

convolutional neural network

multilayer perceptron

GWSkyNet model

Layers connecting the inputs

Low latency O(10s)

Astronomer community

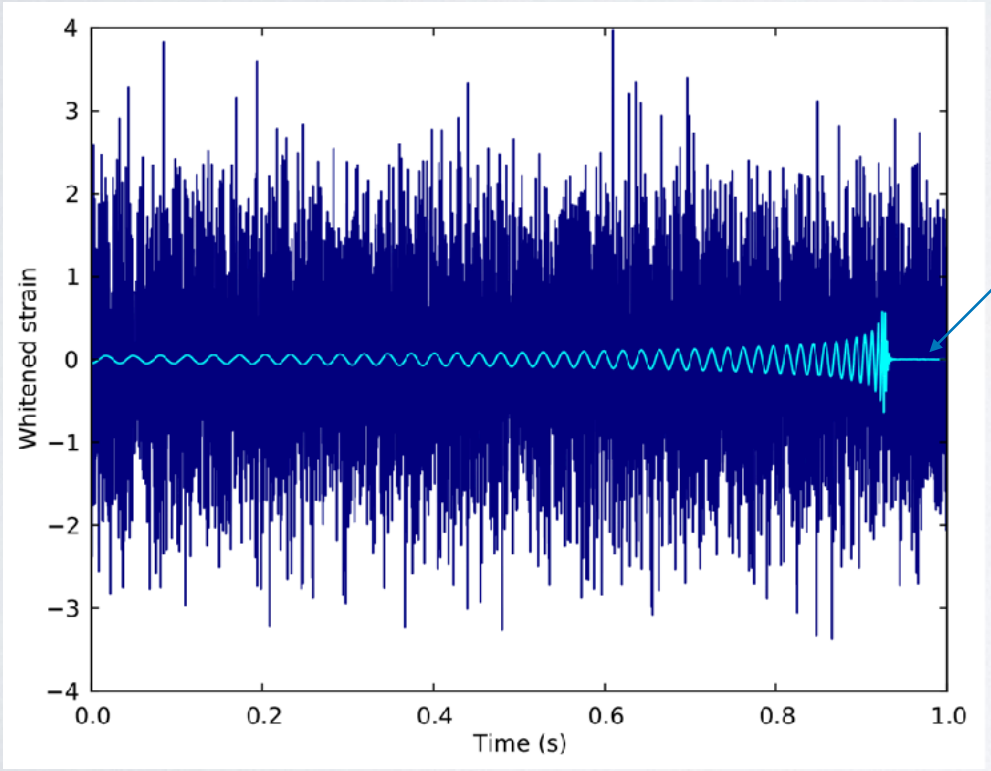
1. GWSkyNet score
2. False alarm probability
3. False negative probability

*The size of the layers is not to scale

https://dcc.ligo.org/LIGO-P2300142

Heather Fong

CITA National Fellow,
University of British Columbia

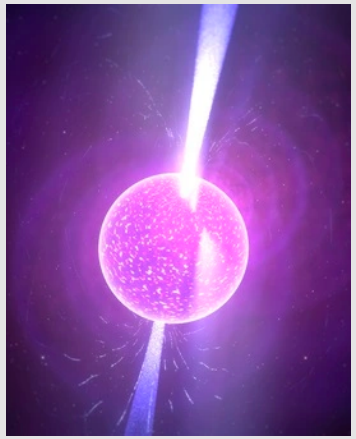


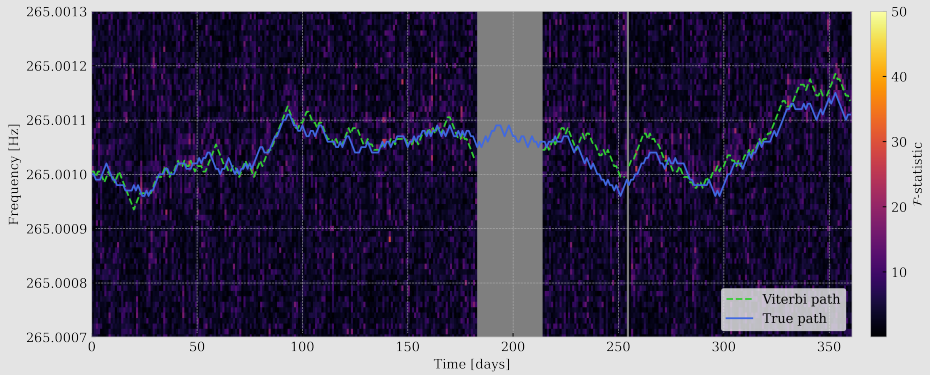
Research:

- Gravitational wave data analysis of compact binaries from LIGO, Virgo, and KAGRA (GstLAL)
- Searching for gravitationally lensed sub-threshold events using GWs
- Improving current techniques of signal vs glitch distinguishers

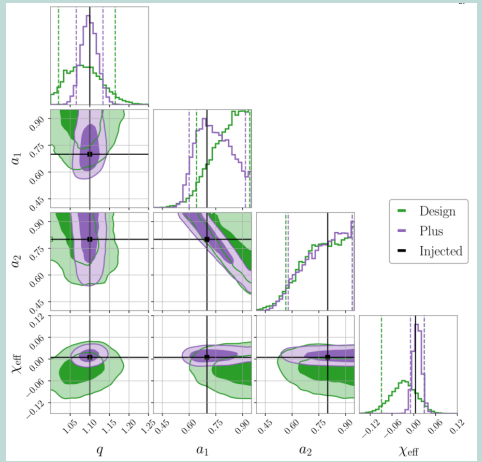
Alan Knee

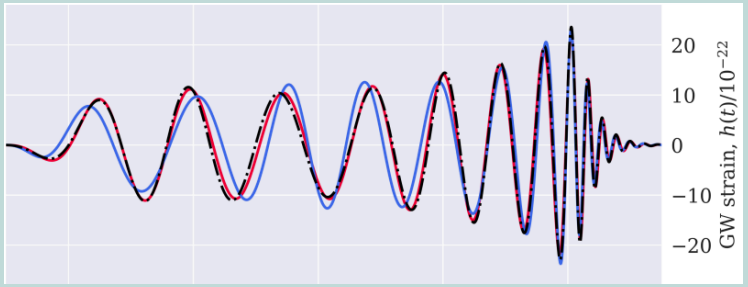
PhD Candidate in Astronomy
Department of Physics & Astronomy
University of British Columbia



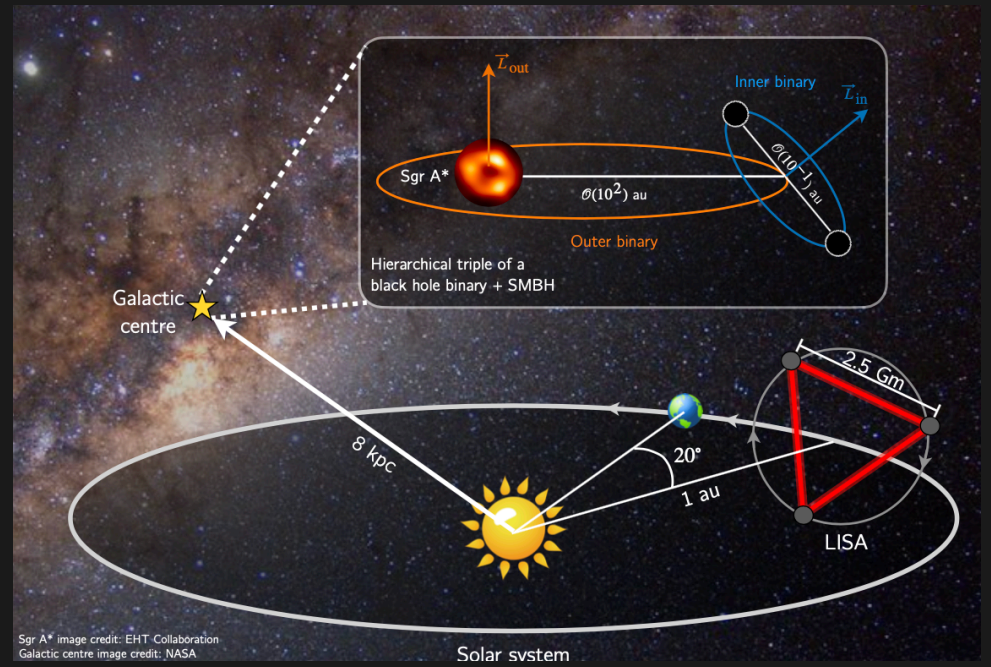


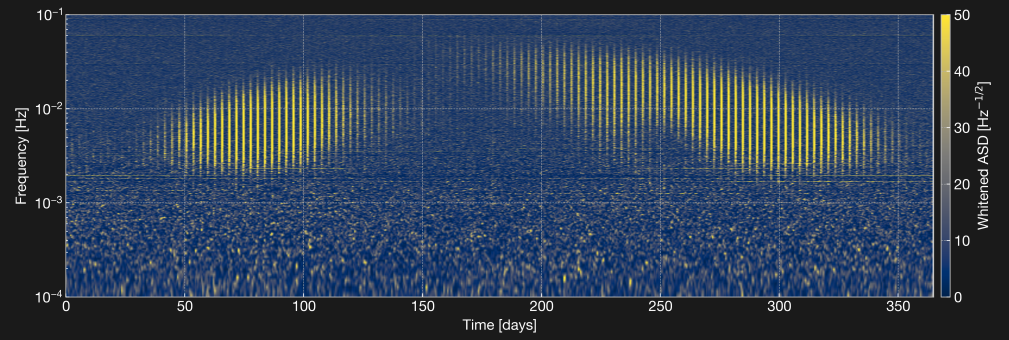
Searches for continuous gravitational waves





Bayesian parameter estimation
for coalescing binary systems



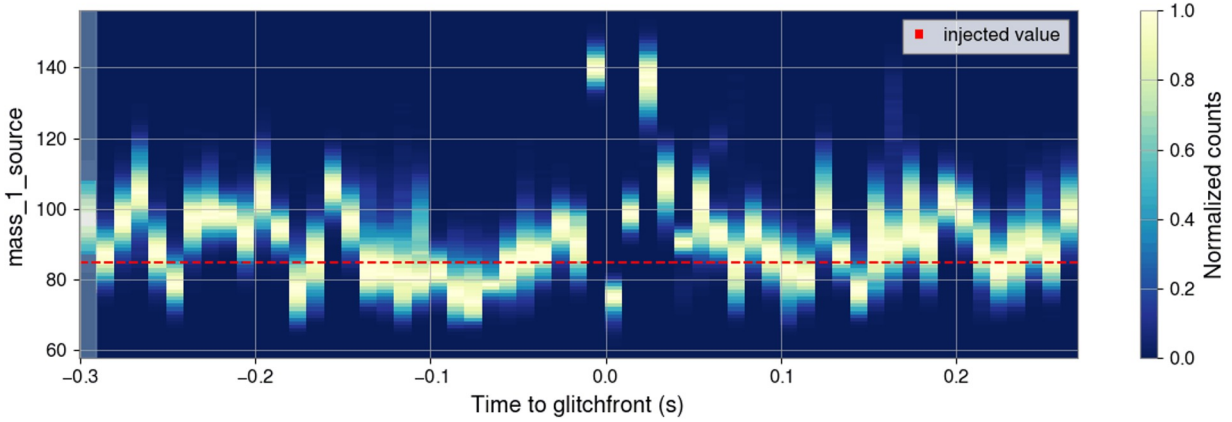


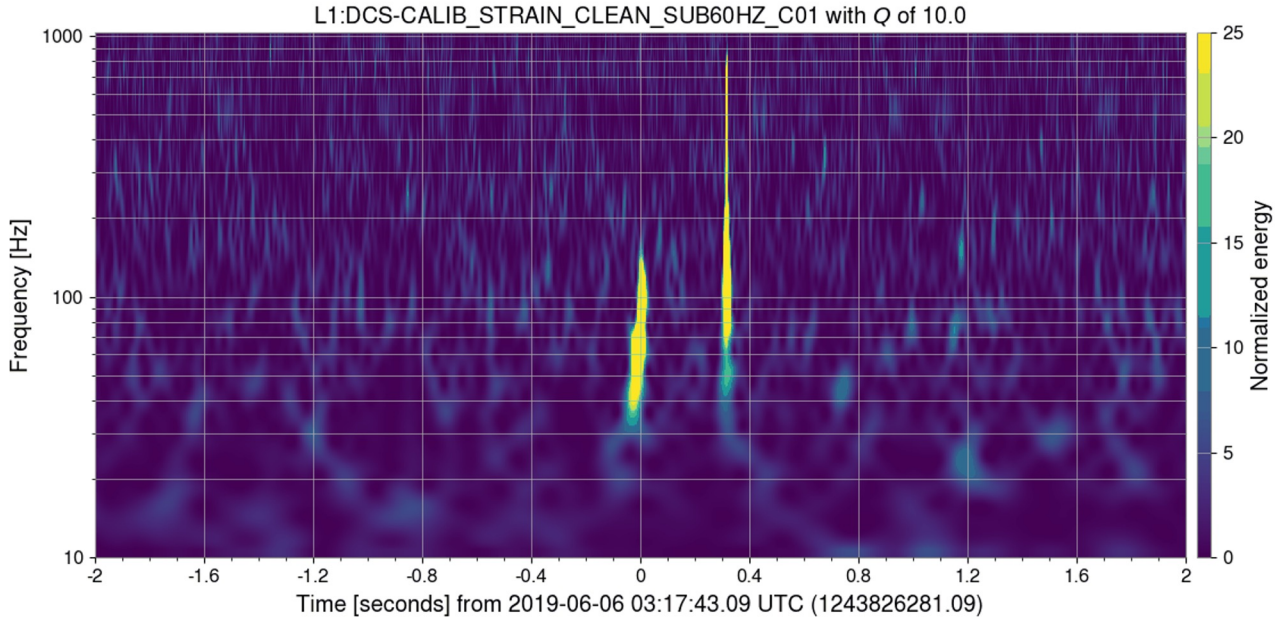
Detecting hierarchical triples with LISA

THE UNIVERSITY
OF BRITISH COLUMBIA

Parameter Estimation of GW in the Presence of Detector Glitches - Niko Lecoeuche

- Three GW signals and three glitch classes chosen
- Simulated GW signal injected at different points in time relative to LLO glitch
- Parameter estimation run for signal at each injection point
- Posterior distributions compared to determine which parameters affected most, what constitutes a “safe” time separation between signal and glitch



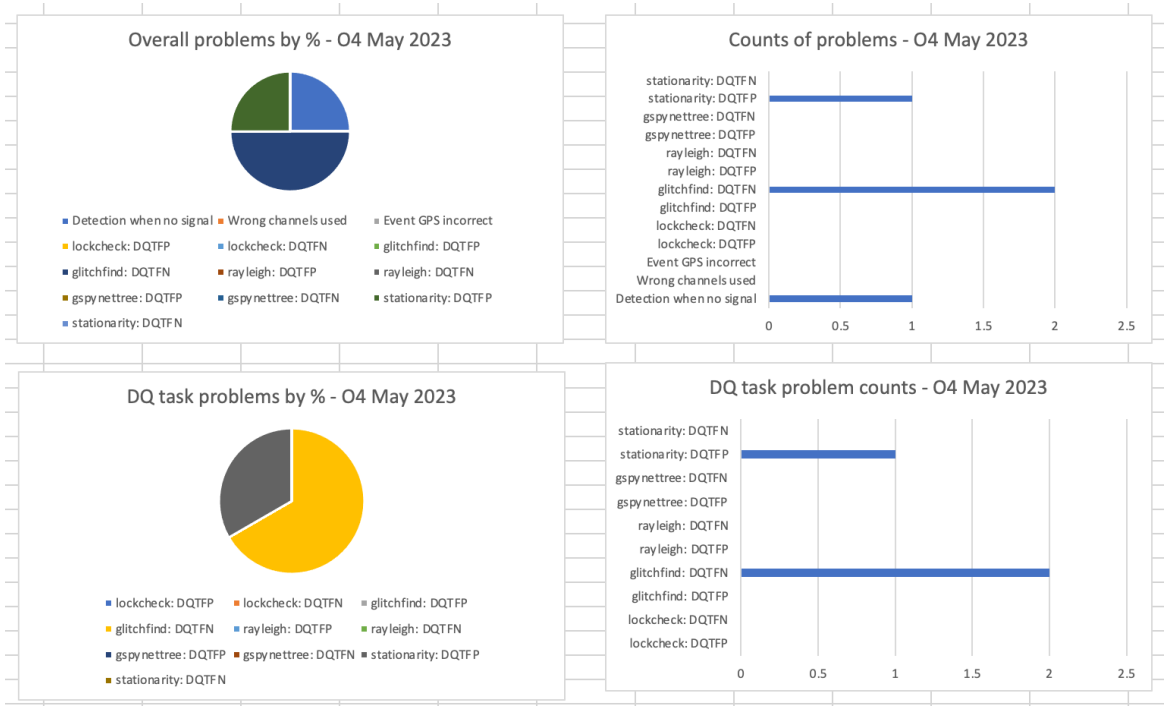


Data analysis of DQRs during ER15 + O4

Caitlin Rawcliffe – Mitacs GRI @ UBC summer 2023

- Finding and reporting discrepancies between automated DQR results compared to visual intuition on candidate events during O4 and available data from ER15 for further investigation and mitigation in the future
- Identifying trends between DQRs reporting false positives/negatives for further investigation
- Event validation shadowing and shifts during O4 (June to July 2023)
- DQ shift shadowing (July 2023)

		Date	Candidate	GPS start	GPS end	logged?	LHO notes	LLO notes	V1 notes	agreement?	Conclusion	C2 (if needed)	DQ test conclusion	Own notes
Colour code:		230426	a	1366502541.45+-0.1	1366502541.45+0.05	N	Not observing, a	O3 inj - NO, glit	Not observing	1	Wrong channels used			Channel for GSpyNetTree L1 was incorrect
0	All fine		aa	1366509523.78-0.5	1366509523.78+0.5	N	NO, loud noise l	NO, excess nois	NO	2	Wrong channels used		glitchfind: DQTFN	No injection - set off by H1 noise, GSpyNe
1	Minor error		ac	1366509988.67-0.1	1366509988.67+0.1	N	NO, loud noise g	O3 inj - NO, no	NO	1	Wrong channels used			
2	DQ tasks diff		ad	1366510695.14-0.1	1366510695.14+0.05	N	NO	O3 inj - NO, GS	NO	1	Wrong channels used			Channels for Rayleigh, for glitchfind and fc
			ae	1366510775.96-100	1366510775.96+0.1	N	NO	O3 inj - NO, wr	NO	1	Wrong channels used			Why is GSpyNetTree predicting chirps with
Count:			af	1366510771.78-50	1366510771.78+4.5	N	NO, error on sta	O3 inj - NO, pea	NO, error on stat	2	Event GPS incorrect	Wrong channels	gspynettree: DQTFP	Peak of L1 inj isn't the identified GPS time
0	5		aj	1366512081.28-0.1	1366512081.28+0.1	N	NO...DQ.GSNT	O3 inj - NO, GS	NO, rayleigh DQ	2	Wrong channels used		gspynettree: DQTFN	Channels incorrect for L1, GSpyNetTree DC
1	53		ak	1366512485	1366512485	N	NO, loud noise g	NO	NO, excess back	2	Detection when no signal	Wrong channels	used	No signal detected from any detectors (!),
2	35		am	1366514136.52-0.1	1366514136.52+0.1	N	NO, blip at arou	O3 inj? - NO, G	NO, rayleigh DQ	0	Wrong channels used			Probably a glitch and not an inj, incorrectly
			ao	1366515820.66-0.1	1366515820.66+0.1	N	NO, detected Ko	O3 inj - NO, ray	NO, rayleigh DQ	1	Wrong channels used			L1 wrong channels
Total:	93		au	1366517869.78-0.1	1366517869.78+0.05	N	NO, chirp falsely	O3 inj - NO, DQ	NO, rayleigh DQ	1	Wrong channels used			L1 wrong channels
			ax	1366519468.82	1366519468.82	N	NO, glitchfind a	NO, loud glitch	NO, loud noise at	2	Wrong channels used		glitchfind: DQTFN	H1 glitchfind false DQ issue
Percentages:			ba	1366520568.71-1.2	1366520568.71+0.1	N	NO	O3 inj - NO, wr	NO, small blips f	1	Wrong channels used			L1 wrong channels
0	5%		bf	1366521955.65+0.2	1366521955.65+0.6	N	Noise blip at +0.	NO	NO	0	Wrong channels used			Falsely notified, signal from H1 shown tho
1	57%		bh	1366522936.52-3.0	1366522936.52+6.0	N	NO, DQ task erro	O3 inj - NO, eve	NO, DQ task erro	2	Event GPS incorrect	Wrong channels	used	Peak of L1 inj isn't the identified GPS time
2	38%		bi	1366522941.82-6.0	1366522941.82+0.4	N	NO, stationarity	O3 inj - NO, lou	NO, rayleigh DQ	1	Wrong channels used			No glitch detected overlapping the event i
			bj	1366522981.75	1366522981.75	N	NO, glitchfind id	NO, excess nois	NO? (Lockcheck p	2	Wrong channels used		lockcheck: DQTFP	Lockcheck DQ test passes in V1 (!) Falsely
	means inj		bl	1366524100.88	1366524100.88	N	NO, GSNT finds	NO, loud blip fo	NO, excess back	2	Detection when no signal	Wrong channels	glitchfind: DQTFN	Excess noise from V1 glitchfind, no signal
	means OBS		bm	1366524248.78-0.1	1366524248.78+0.1	N	NO, glitchfind id	O3 inj - NO, fals	NO, DQ issues: ra	2	Wrong channels used		glitchfind: DQTFN	L1: glitchfind false, GSNT false prediction(
NO	mean not OBS		bq	1366524793.50-0.1	1366524793.50+0.1	N	NO, Koi fish prec	O3 inj (SNR < 8	NO, rayleigh DQ	1	Wrong channels used			L1 wrong channels
			br	1366525413.04-0.8	1366525413.04+0.1	N	NO, glitchfind D	NO, glitchfind i	NO, all DQ tasks	2	Detection when no signal	Wrong channels	glitchfind: DQTFN	Falsely notified, due to L1 glitch signal tha
			bt	1366525548.66-0.3	1366525548.66	N	NO, DQ issues: s	NO	NO, DQ errors: ra	0	Wrong channels used			Falsely notified, signal from H1 shown tho
			bv	1366526439.63-0.1	1366526439.63+0.1	N	NO	O3 inj- NO	NO, rayleigh DQ	1	Wrong channels used			L1 wrong channels
			bx	1366527482.24	1366527482.24+4.0	N	NO, blip of SNR	NO	NO, DQ issues: gl	0	Wrong channels used			Falsely notified, due to H1 glitch signal, re
			bz	1366527774.10-0.1	1366527774.10+0.1	N	NO	O3 inj? - NO, nc	NO, rayleigh DQ	1	Wrong channels used			Cannot analyse properly due to L1 wrong c
			c	1366503099.22-0.5	1366503099.22+0.1	N	NO, DQ errors: l	NO, low freq bli	NO, rayleigh DQ	0	Wrong channels used			Low freq blip at L1 on CLEAN channel, fals
			ca	1366528038.16-7.0	1366528038.16+6.0	N	NO	NO, small noise	NO, excess noise	2	Detection when no signal	Wrong channels	glitchfind: DQTFP	Low freq blip in L1 omegascan, V1 glitchfi
			cf	1366528955.77-0.1	1366528955.77+0.1	N	NO	O3 inj - NO, GS	NO, rayleigh DQ	1	Wrong channels used			Wrong channels for L1

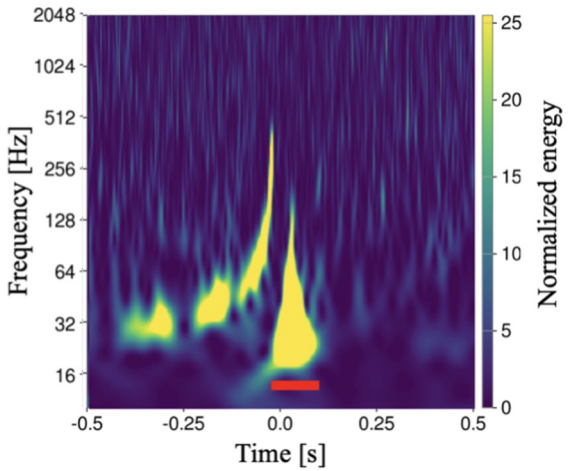


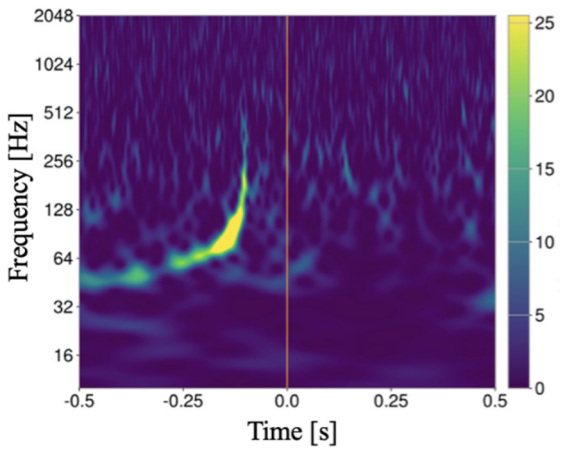
Gravity Spy Convolutional Neural **Net**work Decision **Tree**

Sofía Álvarez-López, Dhatri Raghunathan, Ben Scully.

A decision tree sorted via total GW candidate mass, made up of three GW signal vs glitch classifiers.

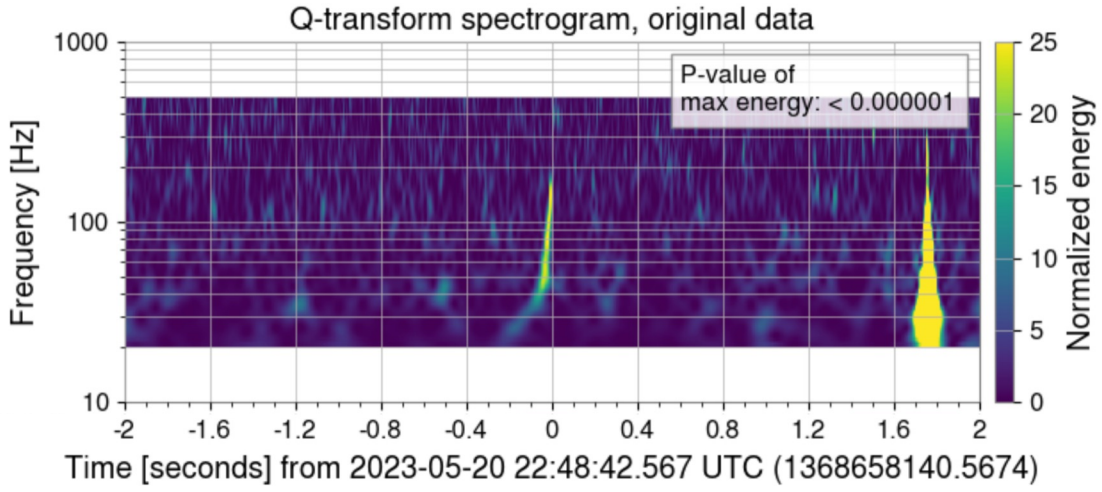
- Three multi-label CNN classifiers that leverage the InceptionV3 architecture, trained with simulated GWs, and morphologically similar glitches.
- Also includes most common LIGO glitches during O3.
- One of the tasks of the LIGO-Virgo Data Quality Report, used for GW candidate event validation.
- Robust to a broad array of background noise.
- Robust to GWs and glitches occurring in close proximity (happened in O3 with 24% of candidate events).
- Robust to candidate events with merger times shifted ± 0.5 seconds.
- **More than 95% accuracy in the total mass range 5 M⊙ to 350 M⊙**



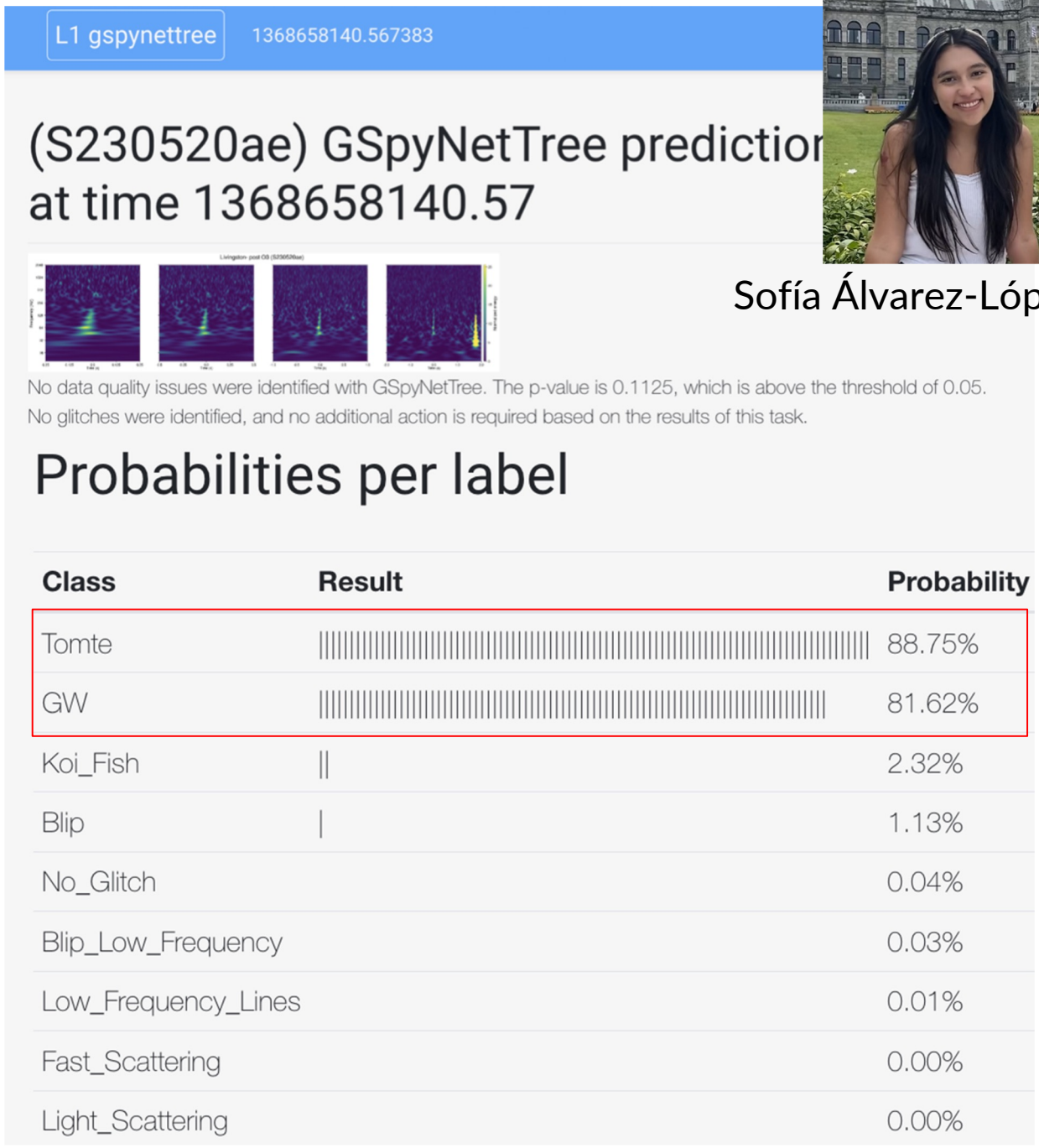


Results on candidate event S230520ae

- One of the significant events of ER15.
- A glitch occurred in close proximity of the GW event.
- Shows full potential of GSpyNetTree on identifying glitches in the proximity of GWs.



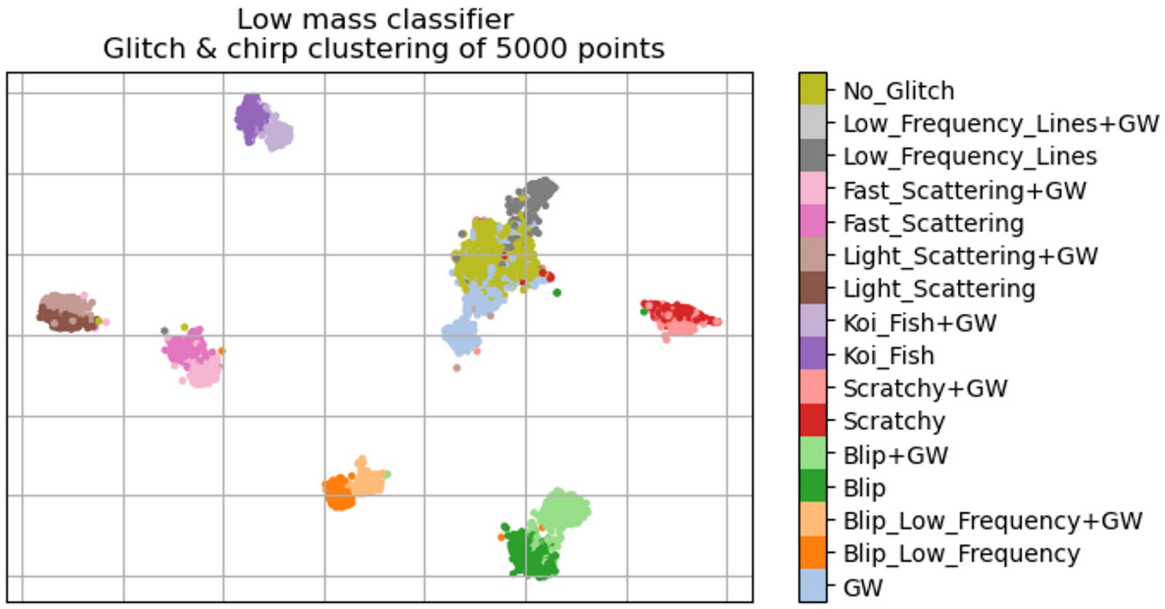
Spectrogram adapted from the GlitchFind task.

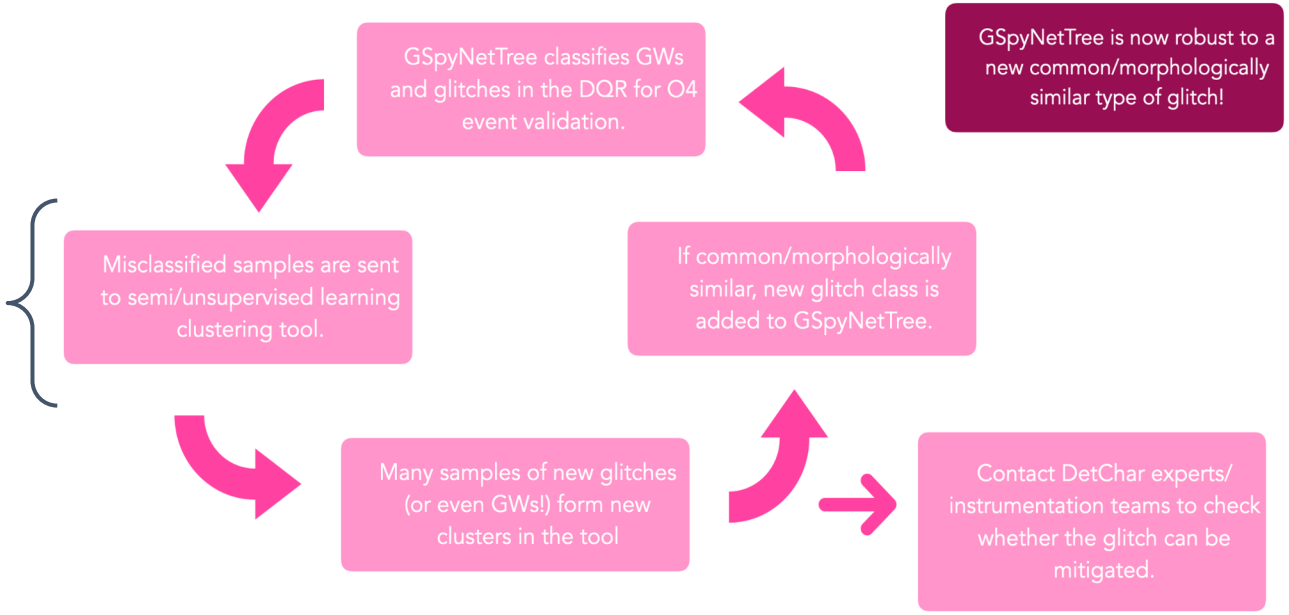


Sofía Álvarez-López

Dream architecture - semi/unsupervised clustering tool

Ben Scully





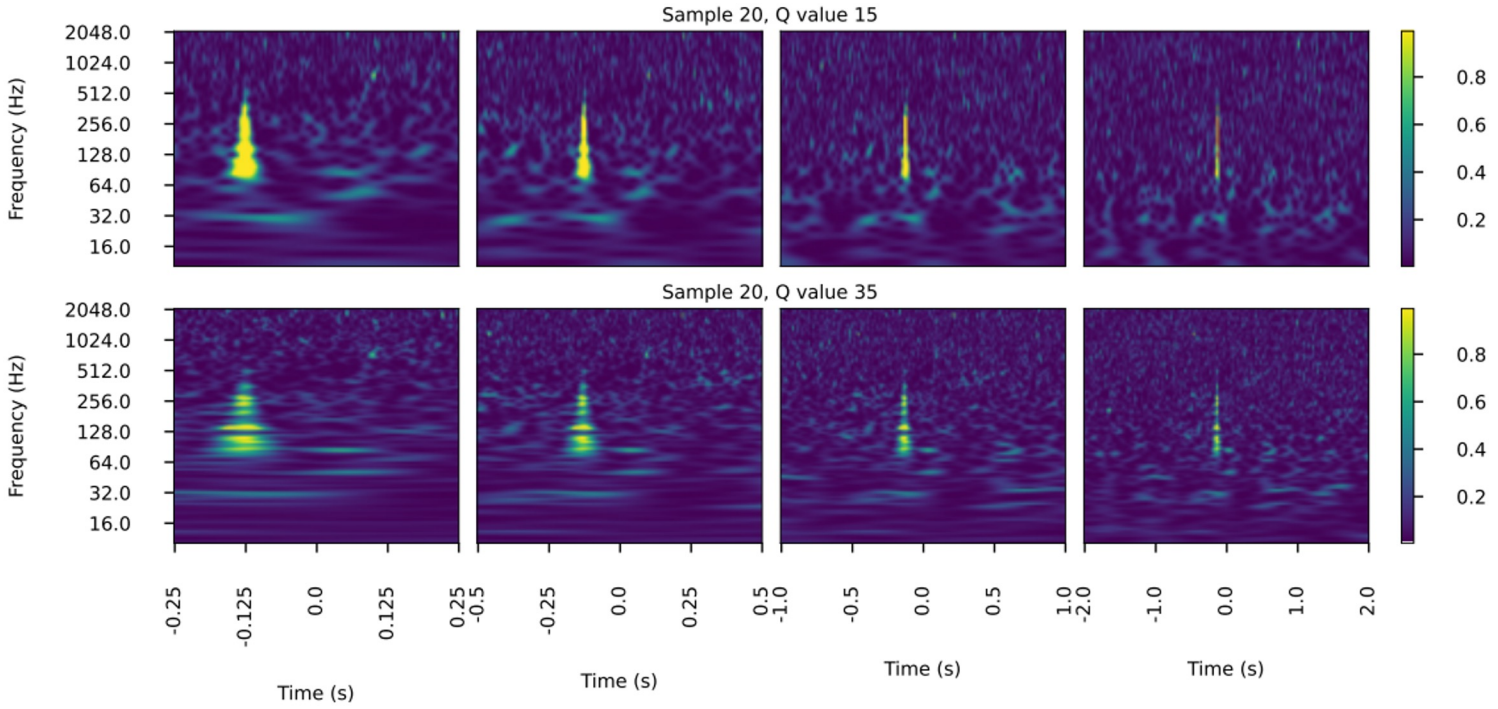
- Extract second to last layer from CNN
- Use PCA and TSNE to project characteristic vector down to two dimensions

- See how misidentified signals cluster with existing signals

Optimize the feature set (multi-duration images of time-frequency spectrograms)

Dhatri Raghunathan

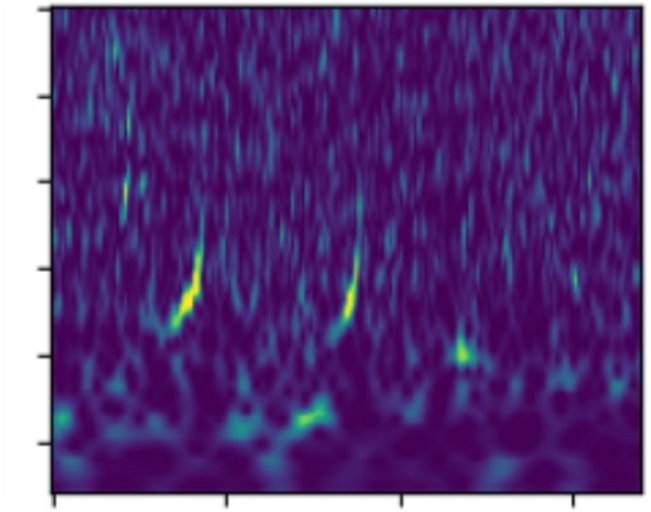
MIT JACS



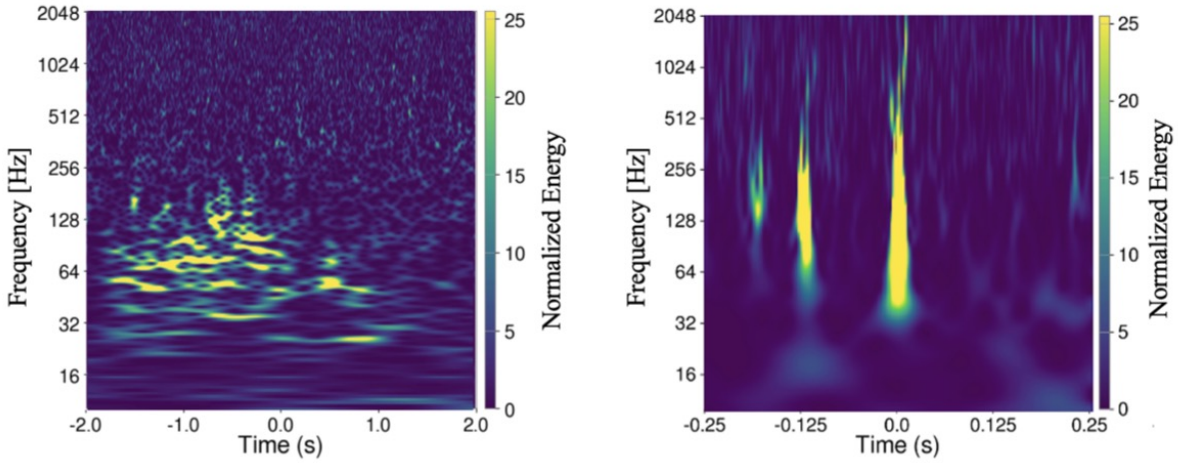
- Experiment with different Q-values to optimize time-frequency spectrograms to best capture power in the data for each class in the context of each classifier.
- Aim to find a recommended set of Q-values for each class and classifier, retrain the model to be deployed for the rest of O4.

Honours Theses and MSc projects 2023

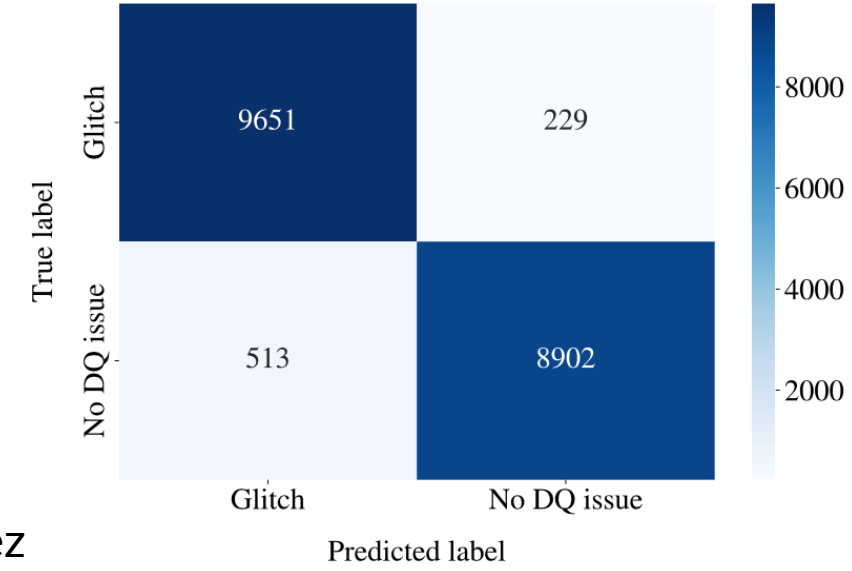
Steven Hsueh

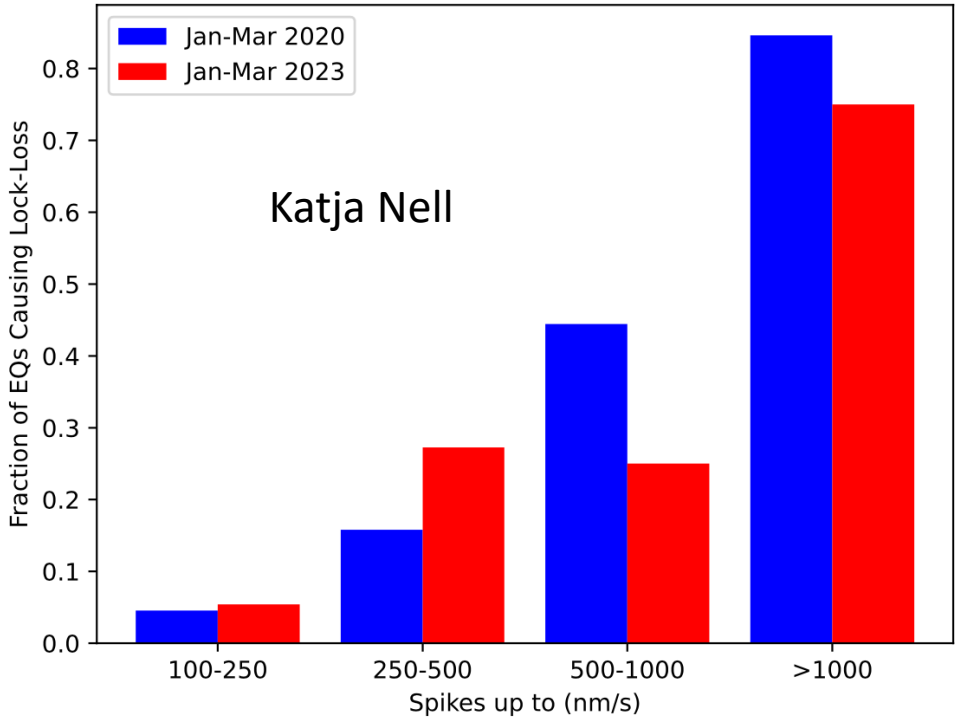


Franz Herbst



Sofía Álvarez-López





Highlighted short-authorlist papers from the past year

Preprints:

- GSpyNetTree: A signal-vs-glitch classifier for gravitational-wave event candidates. **S. Alvarez-Lopez, A. Liyanage, J. Ding**, R. Ng, **J. McIver**. arXiv 2304.09977 (2023)
- Waves in a Forest: A Random Forest Classifier to Distinguish between Gravitational Waves and Detector Glitches. **N. Shah, A. M. Knee,** D. Stenning, **J. McIver**. arXiv 2306.13787 (2023)

Published:

- *A Rosetta Stone for Eccentric Gravitational Waveform Models*. **A. Knee**, I. M. Romero-Shaw, P. D. Lasky, **J. McIver**, E. Thrane. ApJ 936, 2 (2022)
- *Prospects for reconstructing the gravitational-wave signals from core-collapse supernovae with Advanced LIGO-Virgo and the BayesWave algorithm*. **N. Raza**, **J.McIver**, G. Dalya, P. Raffai. Phys. Rev. D.106, 063014 (2022)
- *Impact of noise transients on low latency gravitational-wave event localization*. R. Macas, J. Pooley, L. K. Nuttall, D. Davis, M. J. Dyer, **Y. Lecoeuche**, J. D. Lyman, **J. McIver, K. Rink**. Phys Rev D 105, 103031 (2022)
- *Parameterised population models of transient non-Gaussian noise in the LIGO gravitational-wave detectors*. G. Ashton, **S. Thiele, Y. Lecoeuche, J. McIver**, and L.K. Nuttall. Class. Quant. Grav. 39, 175004 (2022)
- *UniMAP: Model-free detection of unclassified noise transients in LIGO-Virgo data using the Temporal Outlier Factor*. **J. Ding**, R. Ng, **J. McIver**. Class. Quant. Grav. 39, 135011 (2022)

Not GWs, but also:

- *Supporting students' self-regulated learning in an introductory physics course*. Georg Rieger, **Jess McIver**, Silvia Mazabel, Eric W. Burkholder. The Physics Teacher, 61, 1 (2023)
- *Getting more out of midterm assessments.* G. W. Rieger, **J. McIver**, et al. The Physics Teacher, 61, 207 (2023)

UBC LIGO team:
GW detector coatings

Tomorrow! A talk by Jeff Young highlighting recent efforts at the Stuart Blusson Quantum Matter Institute at UBC

Please also welcome Henry Mullock, a co-op student and one of the newest members of the UBC coatings team
(and Steven Blaber, a new postdoc, currently in Vancouver)

UBC-TRIUMF LISA group

Alan Knee, Evan Goetz,
Jess McIver, David Morrissey, Scott Oser

LISA CONSORTIUM

esa

Gravitational Waves at LISA and Big Science Questions

David Morrissey, TRIUMF

- LISA will address some of the major science drivers of the Canadian Astronomy (CASCA) and Subatomic Physics (SAP) Long Range Plans:
  - How did the Universe begin and what is it made of? (CASCA LRP)
  - What are the extreme conditions of the Universe? (CASCA LRP)
  - How have stars and galaxies changed over cosmic time? (CASCA LRP)
  - What are the fundamental building blocks of matter and what is the fundamental nature of space and time? (SAP LRP)
- These questions connect to theoretical research at UBC and TRIUMF:
  - Nature, cosmological formation, and signals of dark matter
  - GW emission from new physics such as cosmological phase transitions and cosmic strings
  - Testing the history and evolution of the pre-CMB cosmos with GW standard candles.
  - Multimessenger astronomy for determining to origins of the elements and the nature of stars.
  - See for example https://arxiv.org/abs/1912.08832 and https://arxiv.org/abs/1808.08968 for TRIUMF theory contributions.

The UBC CHIME team

Tune in Thursday June 29th at 10am Pacific for an exciting announcement! – Ingrid Stairs

(UBC team: we'll join the NANOGrav watch party in Hennings 309!)

The search for B-modes at UBC

Recent UBC grad, now Caltech postdoctoral fellow, Sofia Fatigoni at the South Pole installing electronics she built for the Bicep Array to get 12,000 bolometers on the sky in a B-mode search.

A similar number will be deployed this season.

-Mark Halpern

The ground screen for CGEM at the Dominion Radio Astrophysical Observatory. The pointing system, reflector and this ground screen are all at the DRAO and the radiometer is under construction at UBC.

The system measures polarized foregrounds at 9 GHz to help clean contamination by Galactic synchrotron from direct B-mode searches made at 150 GHz.

-Mark Halpern

CGEM: the Canadian Galactic Emission Mapper

Photo by Mark Halpern
DRAO, BC

SACNAS 2023 is in the PNW!

There will be at least one GW session and booth.