



Collaborations Funding Final Report

We held the Canadian Multi-Messenger Astrophysics Workshop at McGill University Faculty Club from 28-30 January 2020. This meeting was enabled by the generous support from the McDonald Institute through the Novel Collaboration Competition, which leveraged additional support from the McGill Space Institute and the McGill Department of Physics. This workshop included an opening reception on the evening of January 28, and talks on January 29/30. A total of 39 registrants attended (close to the 40 projected in our workshop proposal), including 21 outside of McGill. There were a total of 22 talks, and 4 discussion sessions spread across 2 full days. Attached to this report are (1) a list of all participant, (2) a schedule of the events, and (3) a detailed report summarizing each talk and discussion session. Additional information (including slides of presentation and organizer contact information) can be found at the workshop website: <https://nyx.physics.mcgill.ca/e/MMW2020>.

Research Impact

The goals of this workshop were to (1) bring together the Canadian astronomical, gravitational wave, and neutrino communities to learn about each of these different ‘cosmic messengers’, and (2) catalyze Canadian collaborations on multi-messenger science programs across different facilities/experiments.

The first goal of bringing together Canadian researchers interested in multi-messenger astrophysics was accomplished through the carefully planned talks schedule and discussion sessions. This workshop was the first of its kind in Canada, and most attendees had not previously collaborated across different cosmic messengers. Since many attendees from one cosmic messenger community (e.g. observational astronomy) are likely to be less familiar with the science and methods of another community (e.g., neutrino detection), we scheduled four longer introductory talks at the beginning of the workshop to provide more background and ensure full participation. These talks were entitled *Gravitational-Wave Sources and Detection* (Miriam Cabero Muller), *Electromagnetic Observations of Multi-Messenger Sources* (Maria Drout), *Nucleosynthesis and Thermal Neutrinos* (Daniel Siegel), and *Radio Follow-up of Multi-Messenger Sources and High-Energy Neutrinos* (Gregory Sivakoff).

The second goal of catalyzing Canadian collaborations in multi-messenger astrophysics was accomplished through the discussion sessions, and more informal conversations during breaks. We specifically set aside 2 discussion sessions each day that focused on different aspects of collaboration, such as the question of ‘What are unique opportunities for Canadian research in multi-messenger astrophysics?’. For example, Greg Sivakoff presented results from multi-messenger radio follow-up of the first blazar detected in high-energy neutrinos by IceCube. This sparked discussion amongst several astronomers to collaborate on optical spectroscopic observations of these neutrino-emitting blazars. Furthermore, this workshop was the first time a

group of multi-messenger gravitational wave researchers in Canada have gathered, and they used this opportunity to plan future telescope programs for LIGO/Virgo follow-up.

Equity, Diversity, and Inclusion (EDI)

To ensure an inclusive atmosphere in our workshop, we focused on undertaking two main programmatic steps:

- (1) *Ensure that talks were assigned in an equitable manner.* To ensure that talks were not only given by senior researchers and to give equity-seeking groups a voice, we chose to give a 20min talk to any attendee who requested a talk. This successfully resulted in a diverse line-up of speakers, and 11 of the 22 talks at this workshop were given by early-career researchers (either graduate students or postdocs), including 6 speakers who we supported with EDI travel funds.
- (2) *Provide travel funding to researchers from equity-seeking groups.* These equity-seeking groups included racialized persons, underrepresented genders, sexual minorities, and early-career researchers. Furthermore, we also solicited funding requests for any child/elderly care during the workshop, although no funding requests for these purposes were received. In the original meeting announcement, we encouraged and solicited requests for these funds. We subsequently received 8 requests, and were able to successfully fund all of their travel expenses (including transportation, accommodations, and food) thanks to the additional EDI funding from the McDonald Institute. The attendees receiving these EDI funds are:

Adaze Ibik (graduate student at U. of Toronto)

Remington Hill (graduate student at Laurentian University)

Aaron Tohuavohu (graduate student at U. of Toronto)

Miriam Cabero Muller (postdoc at UBC)

Katelyn Breivik (postdoc at the Canadian Institute for Theoretical Astrophysics)

Sarah Gossan (postdoc at the Canadian Institute for Theoretical Astrophysics)

Luis Filipe Longo Michi (visiting graduate student at Perimeter Institute)

Hannah Dykaar (graduate student at U. of Toronto)

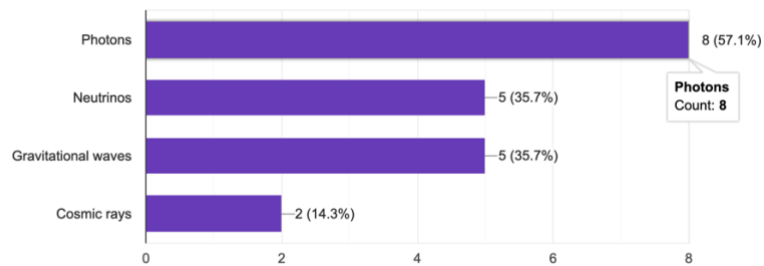
Other Application Commitments

As part of our workshop commitments, we provide a detailed report (see attached) that summarizes each talk during the workshop, as well as the discussions.

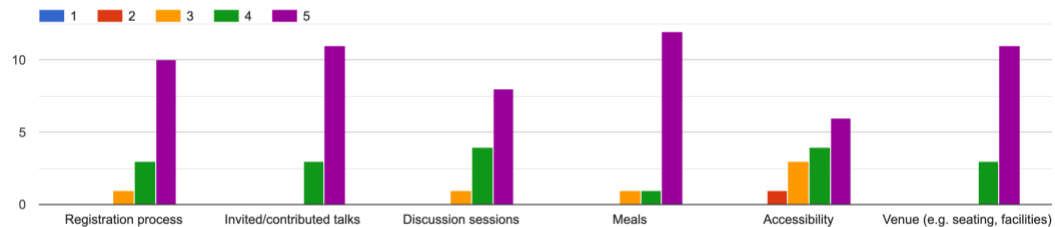


Subsequent to the workshop, we also solicited feedback on the organization and programming of the workshop, via an anonymous Google Forms. We received 14 feedback submissions, which were overwhelmingly positive and summarized in the charts below:

Please indicate your primary cosmic messenger(s) (select all that apply)
14 responses

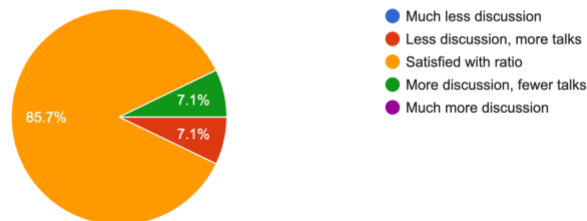


Please rate your level of satisfaction with the following aspects of the 2020 Canadian MMA Workshop: (1= dissatisfied, 2=somewhat dissatisfied, 3= neither satisfied nor dissatisfied, 4=somewhat satisfied, 5=satisfied)



Were you satisfied with the number of talks versus the amount of time allowed for discussion?
Would you prefer more discussion and fewer talks, or vice-versa?

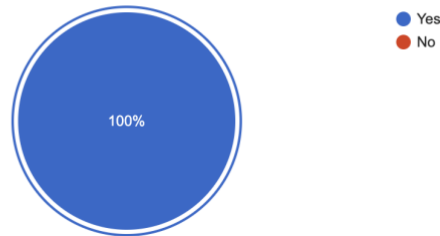
14 responses





Would you attend a similarly-oriented workshop one year from now?

14 responses



Feedback

We thank the McDonald Institute for their generous support of this workshop. One issue we encountered was in the timing of the additional \$4,000 in EDI funding for travel, childcare, etc. specifically for attendees from underrepresented groups. Although several attendees from these groups requested funding upon registration, this extra funding was not approved by MI until just a few days before the workshop. This was in part due to our own late application for these funds, which arose due to some confusion about how to make the EDI funding request. Since these participants' attendance to this conference hinged on the availability of the EDI travel funding, they were not able to make travel arrangements until the last minute. For future workshops, we suggest that these EDI funds be provided upfront along with the primary workshop funding, to facilitate planning of attendee travel, and/or for the EDI funding request process to be clarified in the award letter. We emphasize, however, that the availability of these EDI funds made a large and positive impact on our ability to include junior scientists in the workshop and we strongly recommend that this program be continued.

Canadian Multi-Messenger Astrophysics Workshop, 28-29 January 2020

<div> <div>● Breakfast</div> <div>● Discussion</div> <div>● Talks</div> <div>● Welcome address, territorial acknowledgement, and code of conduct</div> </div>		Day I Schedule
09:00	Breakfast	
	<i>Billiard Room, McGill University Faculty Club</i>	08:30 - 09:00
	Welcome address, territorial acknowledgement, and code of conduct	
	<i>Billiard Room, McGill University Faculty Club</i>	09:00 - 09:15
	Gravitational-Wave Sources and Detection	<i>Miriam Cabero Muller</i>
	<i>Billiard Room, McGill University Faculty Club</i>	09:15 - 09:45
10:00	Multimessenger transient theory in Canada	<i>Rodrigo Fernández</i>
	<i>Billiard Room, McGill University Faculty Club</i>	09:45 - 10:05
	Electromagnetic Observations of Multi-Messenger Sources and r-process Nucleosynthesis	<i>Maria Drouot</i>
	<i>Billiard Room, McGill University Faculty Club</i>	10:05 - 10:35
	Coffee break	
	<i>Billiard Room, McGill University Faculty Club</i>	10:35 - 11:00
11:00	Nucleosynthesis and Thermal Neutrinos	<i>Daniel Siegel</i>
	<i>Billiard Room, McGill University Faculty Club</i>	11:00 - 11:30
	Canadian Radio Follow-up of Multi-Messenger Sources and High-Energy Neutrinos	<i>Greg Sivakoff</i>
	<i>Billiard Room, McGill University Faculty Club</i>	11:30 - 12:00
12:00	Discussion: funding, applications, and instruments - how and when do we get our data?	
	<i>Billiard Room, McGill University Faculty Club</i>	12:00 - 12:30
13:00	Lunch	
	<i>Billiard Room, McGill University Faculty Club</i>	12:30 - 14:00
14:00	Double White Dwarf Binaries as Multi-Messenger Sources	<i>Katelyn Breivik</i>
	<i>Billiard Room, McGill University Faculty Club</i>	14:00 - 14:20
	Hunting High-Energy Counterparts to Gravitational Wave Events	<i>Aaron Tohuvaohu</i>
	<i>Billiard Room, McGill University Faculty Club</i>	14:20 - 14:40
	X-ray Observations of GW170817: the First Binary Neutron Star Merger	<i>Daryl Haggard</i>
	<i>Billiard Room, McGill University Faculty Club</i>	14:40 - 15:00
15:00	Coffee break	
	<i>Billiard Room, McGill University Faculty Club</i>	15:00 - 15:30
	Current and Future Canadian optical/infrared Opportunities for Multi-Messenger Follow-up	<i>John Ruan</i>
	<i>Billiard Room, McGill University Faculty Club</i>	15:30 - 15:50
16:00	Optical Imaging Follow-up of GW190814: the First Possible Black Hole - Neutron Star Merger	<i>Nicholas Vieira</i>
	<i>Billiard Room, McGill University Faculty Club</i>	15:50 - 16:10
	Discussion: recruitment, training, and junior scientist needs	<i>Nicholas Vieira, Soud Al Kharusi</i>
	<i>Billiard Room, McGill University Faculty Club</i>	16:10 - 17:00
17:00		

<div> <div>Breakfast</div> <div>Closing remarks</div> <div>Discussion</div> <div>Talks</div> </div>			Day 2 Schedule	
09:00	Breakfast		Billiard Room, McGill University Faculty Club	08:30 - 09:00
	Probing Core-Collapse Supernova Physics in the Multi-Messenger Era	Sarah Gossan	Billiard Room, McGill University Faculty Club	09:00 - 09:20
	Neutrino and Multi-Messenger Signals	Liliana Caballero	Billiard Room, McGill University Faculty Club	09:20 - 09:40
	SuperNova Early Warning System 2.0	Clarence Virtue	Billiard Room, McGill University Faculty Club	09:40 - 10:00
10:00	SNO+ and Supernova Detection	Erica Caden	Billiard Room, McGill University Faculty Club	10:00 - 10:20
	Coffee break		Billiard Room, McGill University Faculty Club	10:20 - 10:50
11:00	New HALO-1kT and Future Prospects of Supernova Neutrino Flux Reconstruction	Andrea Gallo Rosso	Billiard Room, McGill University Faculty Club	10:50 - 11:10
	SNEWS 2.0 implementation for HALO-1kT	Remington Hill	Billiard Room, McGill University Faculty Club	11:10 - 11:30
	The P-ONE Neutrino Detector	Carsten Krauss	Billiard Room, McGill University Faculty Club	11:30 - 11:50
12:00	Discussion: strengths and weaknesses in our communities		John Ruan	11:50 - 12:30
			Billiard Room, McGill University Faculty Club	
13:00	Lunch			
			Billiard Room, McGill University Faculty Club	12:30 - 14:00
14:00	Multi-Messenger Observations with VERITAS	Matthew Lundy	Billiard Room, McGill University Faculty Club	14:00 - 14:20
	Searching for Majorana Neutrinos with nEXO	Thomas Brunner	Billiard Room, McGill University Faculty Club	14:20 - 14:40
	Supernova Neutrino Detection with nEXO	Soud Al Kharusi	Billiard Room, McGill University Faculty Club	14:40 - 14:50
15:00	Discussion: topic TBA		Thomas Brunner	14:50 - 15:30
			Billiard Room, McGill University Faculty Club	
16:00	Coffee break		Billiard Room, McGill University Faculty Club	15:30 - 16:00
	Orbital Effects in Perturbations around Exotic Compact Objects	Luís Felipe Longo Micchi	Billiard Room, McGill University Faculty Club	16:00 - 16:20
	TBA	Jim Cline	Billiard Room, McGill University Faculty Club	16:20 - 16:40
	Closing remarks		Billiard Room, McGill University Faculty Club	16:40 - 17:00
17:00				

Participant List

39 participants

First Name	Last Name	Affiliation
Aaron	Tohuvavohu	University of Toronto
Adaeze	Ibik	University of Toronto
Andrea	Gallo Rosso	Laurentian University
Carsten	Krauss	University of Alberta
Clarence	Virtue	Laurentian University / SNOLAB
Constanza	Echiburú	McGill University
Daniel	Siegel	Perimeter Institute for Theoretical Phy...
Daryl	Haggard	McGill University
Erica	Caden	SNOLAB
Gregory	Sivakoff	University of Alberta
Hannah	Dykaar	University of Toronto
Jim	Cline	McGill
John	Ruan	McGill University
Julie	Hlavacek-Larrondo	Université de Montréal

Katelyn	Breivik	CITA
Katie	Savard	McGill
Kelly	Lepo	McGill University
Ken	Ragan	McGill University/Physics
Liliana	Caballero	University of Guelph
Luís Felipe	Longo Micchi	UFABC (Brazil) - Perimeter Institute
Maria	Drout	University of Toronto
Matheus	Pessôa	McGill University
Matthew	Dutcher	University of Guelph
Matthew	Lundy	McGill University
Miriam	Cabero Muller	The University of British Columbia
Myriam	Prasow-Émond	Université de Montréal
Nicholas	Vieira	McGill University
Remington	Hill	Laurentian University
Rodrigo	Fernandez	University of Alberta
Sabrina	Berger	McGill
Sajan	Kumar	McGill University

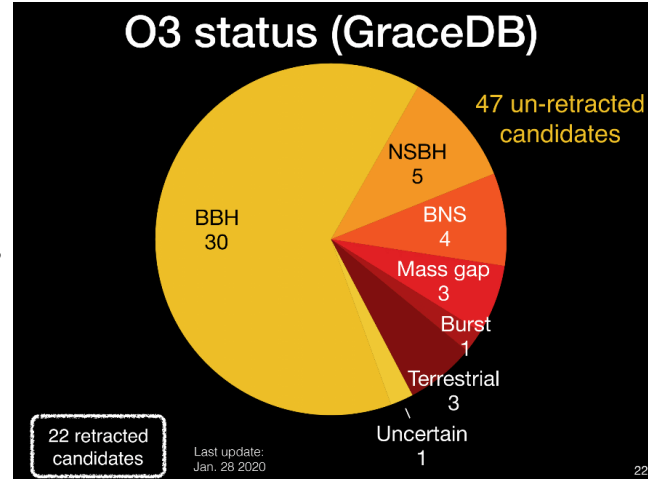
Sarah	Gossan	Canadian Institute for Theoretical Astr...
Soud	Al Kharusi	McGill University
Stephan	O'Brien	McGill University
Thomas	Brunner	McGill and TRIUMF
Thomas	MCELROY	McGill University
Théophile	Bégin	Université de Montréal
Valerie	Desharnais	McGill University
Xiangyu	Jin	McGill University

Canadian Multi-Messenger Astrophysics Workshop

Gravitational-Wave Sources and Detection

Miriam Cabero Muller

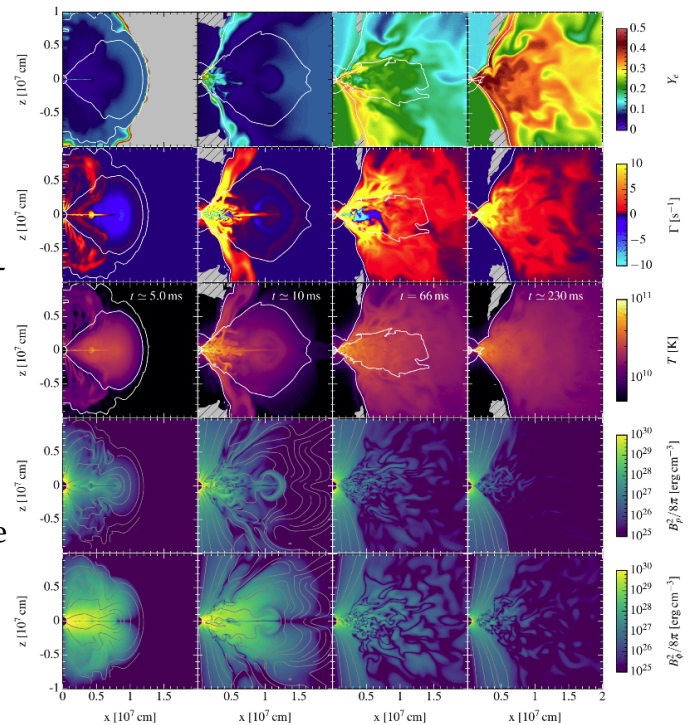
In this talk, the status of both the internal and external work being done on LIGO was presented. To begin, a brief introduction to the field, and its unique challenges was shown (interesting noise sources/signatures). This was followed by the highlighting of gravitational wave event candidates that would be of general interest to the community. A specific focus was placed on the recent results of O3, with a brief discussion of the future of the field.



Multimessenger transient theory in Canada

Rodrigo Fernández

The current status of the modeling of multi-messenger astronomy in Canada was introduced with a focus on two types of transients. The modeling of core collapse supernova and of neutron star mergers was motivated in the context of providing robust predictions for multi-messenger follow-up. Ongoing modeling of the winds from remnant accretion disks was presented, and the impact of introducing magnetic fields on r-process nucleosynthesis was shown. Additional work was also presented, and the projects from individuals across Canada were highlighted. In the post discussion, a focus was placed on how the UV is a powerful tool for discriminating between these models, and that there may not be an observatory capable of providing these necessary observations.

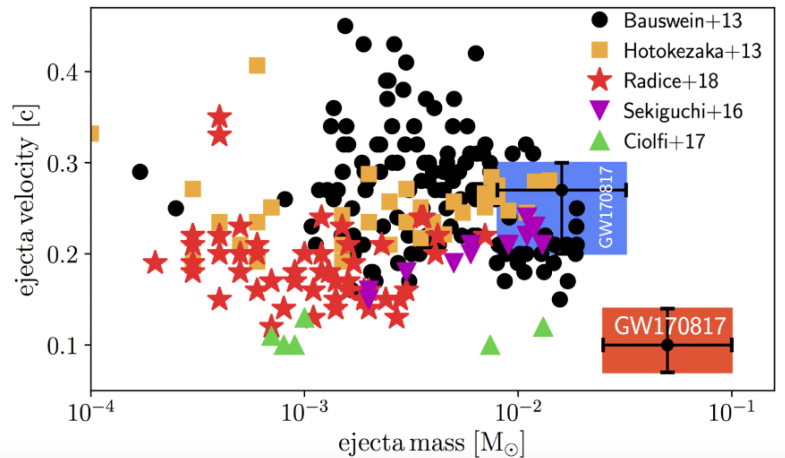


Canadian Multi-Messenger Astrophysics Workshop

Electromagnetic Observations of Multi-Messenger Sources and r-process Nucleosynthesis

Maria Drout

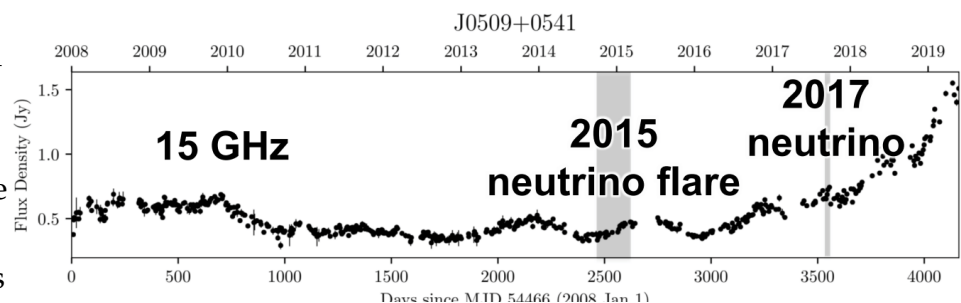
The modeling of multi-messenger sources is of critical importance in understanding the processes that underly many observational phenomena. In this talk, a focus was placed on describing the optical impact of tidal tails and other ejecta. Additionally, it was shown how this modeling can be used to extract information on the r-process. Some of the open questions in the field, and the discrepancies in these models were also presented. The post talk discussion centered on some of these aspects, with questions like “What are the observations that need to take place to compliment this modeling?” in addition to a discussion of a controversial spectral metallic line observation.



Canadian Radio Follow-up of Multi-Messenger Sources and High-Energy Neutrinos

Greg Sivakoff

In light of the recent results, potentially linking the multi-wavelength flaring of a blazar with a series of neutrino event, this talk discussed the future of blazar observations in a multi-messenger context. This talk investigated the connection between active galactic nuclei variability, and neutrino fluxes in the very high energy regime. Preliminary results were shown that appeared to demonstrate rapid spectral evolution for neutrino blazar candidates on a daily timescale. The future of the Very Large Array follow-up for these sources was also presented and a discussion was had apropos of the importance of these non-thermal observations.

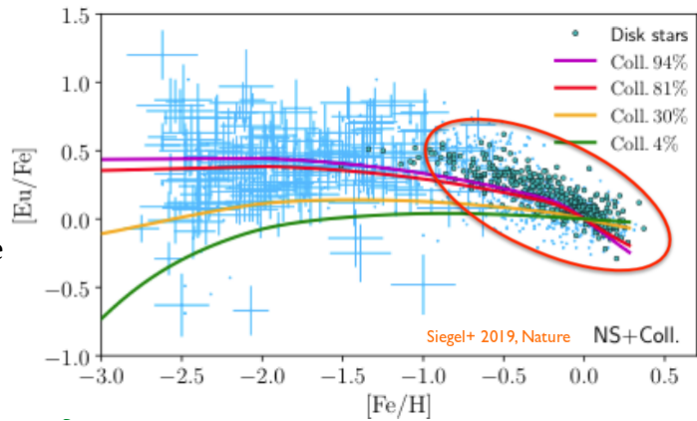


Canadian Multi-Messenger Astrophysics Workshop

Nucleosynthesis and Thermal Neutrinos

Daniel Siegel

In this talk the r-process was once again focused upon. Some of the uncertainties in the evolution from individual source simulations were described. The macro properties of the metal content of the universe was connected with the simulations of individual cataclysmic events. The specific contribution of collapsars to the overall metal density of the universe was stressed, and discussed in more detail after the talk. Constraints on the fraction of collapsars were included in this discussion, leading to the surprising estimation of a 80% fractional contribution to the metal content of the universe.



Discussion: funding, applications, and instruments - how and when do we get our data?

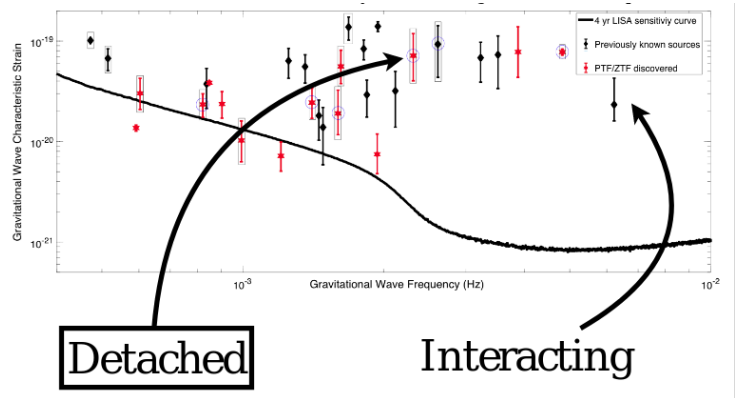
For this discussion, the attendees split into small groups of ~5-10 people. Since there was a medley of people from different fields of physics, different career stage, and from all across Canada, the sources of funding and data varied dramatically. Within one group, the discussion began with an brief introduction to X-ray proposal schedule (2-3 proposals per year), as well as a description of archival proposals. These archival proposals, where an individual does not request new time only funding for archival searches through the large telescope datasets, were a novel idea to some of the particle physics oriented members of the discussion. Moving from the rapid pace of the astronomy proposal schedule, we had a description of the more long term 5-10-15 year plans that were more normal in large particle physics experiments. This brought up CFI, and NSERC, where the differences and limits of both were discussed. For example, NSERC was more flexible but did not support the larger investments needed for hardware based projects. Finally, a discussion of how this applied to theoretical physics was approached. Specifically, many of the same issues with limited hardware affected both fields. The lack of a competitive supercomputer in Canada was described as a limit on the kinds of science one is capable of performing. An overall theme of the difference between funding people, and funding experiments was discussed throughout.

Canadian Multi-Messenger Astrophysics Workshop

Double White Dwarf Binaries as Multi-Messenger Sources

Katelyn Breivik

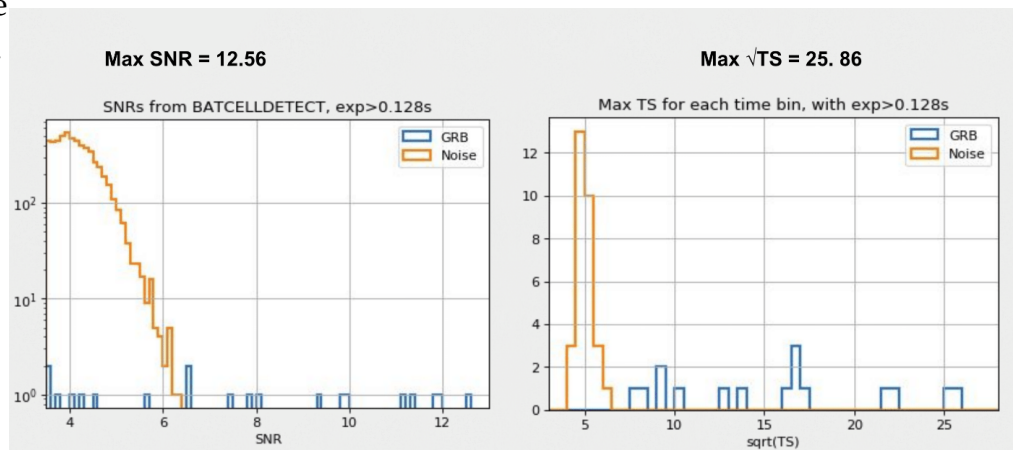
LISA is an interesting future gravitational wave detector that opens up an entirely new frequency space to explore. Within this new band of parameter space, one of the sources of unique interest is double white dwarf binaries. These systems, which are undetectable by the current generation of instruments, will be observable to LISA. Many of the estimates of the possible systems that LISA will be able to measure is ongoing and is simultaneously expanding our knowledge of the population of compact binaries. This talk described many of the potentially exciting types of observations that will be able to be performed by LISA in conjunction with the modern suit of ground and spaced based observatories.



Hunting High-Energy Counterparts to Gravitational Wave Events

Aaron Tohuvaohu

The GUANO program on the Swift satellite was discussed. The speaker presented the way Swift was tackling the two large problems of the multi-messenger observations, how to respond rapidly to triggers, and how to survey a large area of sky covered by the uncertainty regions of these



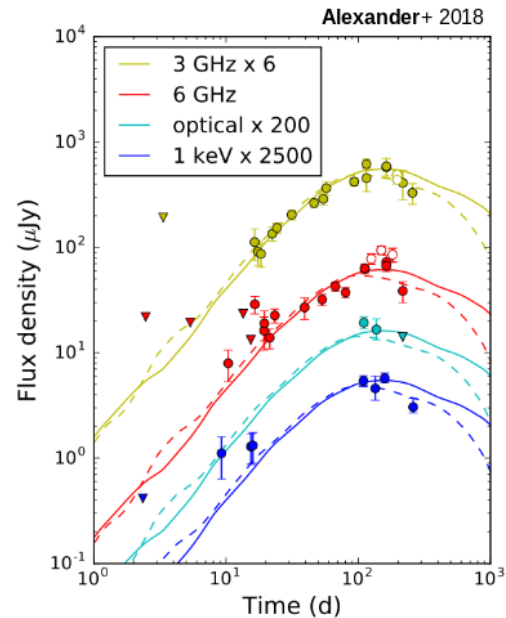
events. In addition to the GUANO program, this involved the Gravitational Wave Treasury Map, a program for collaboration with multiple telescopes across the sky to communicate their current pointings in order to allow for a more effective tiling of said uncertainty region (by decreasing overlap between individual telescopes). The future of potential rapid follow-up of gravitational wave events with Swift was also discussed.

Canadian Multi-Messenger Astrophysics Workshop

X-ray Observations of GW170817: the First Binary Neutron Star Merger

Daryl Haggard

In this talk, the X-ray follow-up of GW170817 was presented. This involved not only discussing the science that has come from these observations, but also some of the challenges that came throughout the observing campaign. A brief introduction to the event class and the Chandra instrument was also presented. After initially discussing why this particular gravitational event differed from other, more typical events, there was also some discussion of the estimates made half-way through the campaign when these follow-up observations were delayed due to a solar system based obstruction. Finally, the talk completed with supplementary discussion about simultaneity of radio data and ATHENA that may be possible in the near future.



Current and Future Canadian optical/infrared Opportunities for Multi-Messenger Follow-up

John Ruan

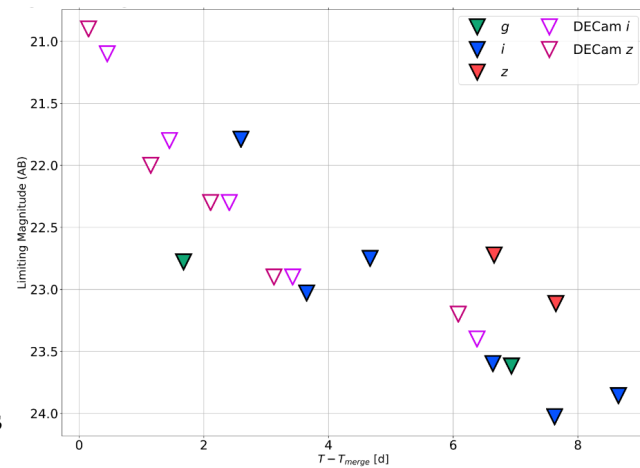
Where does multi-messenger astronomy programs fit in the future landscape of Canadian astrophysics? The current generation of programs involve many instruments that Canada has dedicated time on (Gemini, CFHT, etc..) and involves the follow-up of neutrino and gravitational wave events. Future programs that have been proposed/accepted have the potential for a great Canadian involvement if we are able apply ourselves to these programs. This generation involves optical telescopes like TMT and JWST, but may also include a UV telescope like CASTOR. Much of the discussion following this talk focused on the funding of a future generation of UV telescopes and whether it would be most beneficial to get involved with a larger scale project like CASTOR, or whether it could potentially be more interesting to become engaged with a smaller dedicated space-based cube-sat.

Canadian Multi-Messenger Astrophysics Workshop

Optical Imaging Follow-up of GW190814: the First Possible Black Hole - Neutron Star Merger

Nicholas Vieira

Similar to other talks, in this presentation the problems of large area tessellated pointings were tackled. Large swaths of uncertainty regions were covered by CFHT in the search for transients that could correspond to GW190819. With a larger observing campaign like this, many signatures can appear to be a supernova until removed. This talk described the lengthy process that is involved in removing known transients with cross-catalog correlations. Sporadic transients though, like cosmic rays, cannot be directly removed and instead require an automated identification pipeline to be created. The speaker presented their pathway in creating such a pipeline using novel techniques such as machine learning.



Discussion: recruitment, training, and junior scientist needs

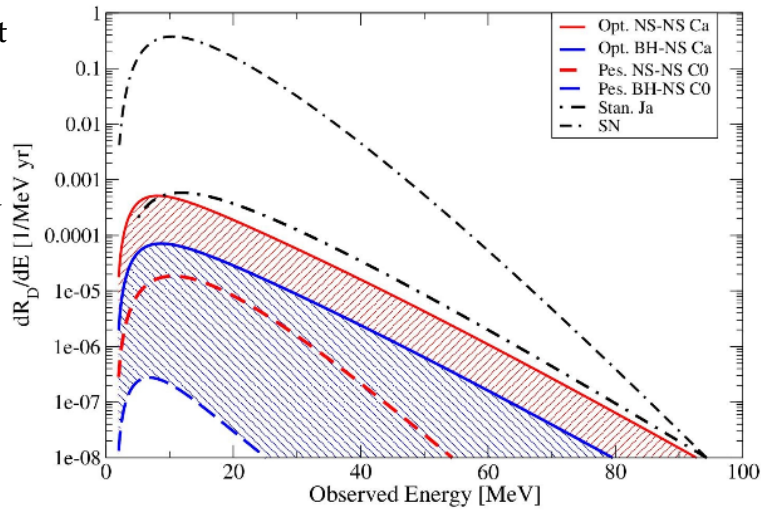
Due to the broad ranges of backgrounds, the questions in this discussion centered primarily around some the difficulties that people experienced or have seen other experience. One thing that was noticed in our discussion was that the importance of coding is rapidly becoming a necessity, yet in many ways our system lags behind this trend. It instead ends up favoring undergraduates who were lucky to be introduced to coding prior to university. When recruiting students, often coding is one of the most sought-after skills, yet it is often still developed outside of the traditional academic streams. This however is just another symptom of the rapid changes that an individual undergoes when transitioning through the multiple phases of academia. One's role as an undergraduate is far different than one's role as a graduate student. Not just in terms of your professional requirements, but also that there exists a lot of collaborative politics that become more prominent as one's career evolves. Multi-messenger work requires interacting with many of these large and small collaborations so within this sub-discipline, perhaps the effect of these politics are more pronounced. Although no clear solution to these collaborative issues arose, one solution to the training gap was suggested in the form of a Canadian multi-messenger summer school. It was agreed though that a more productive session would be a meeting like this one, improved using the lessons learned by holding this inaugural meeting.

Canadian Multi-Messenger Astrophysics Workshop

Neutrino and Multi-Messenger Signals

Liliana Caballero

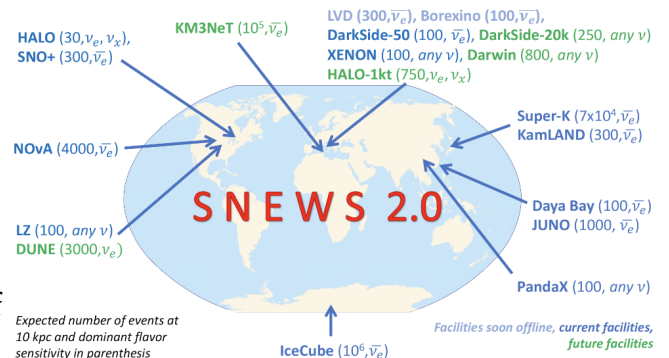
By measuring neutrinos from supernova it is clear that we have a window into the center of these important events, but how does this translate into fundamental physics? During this talk, the topic of how neutrinos provide information on these explosive stellar mechanisms through both their direct detection and their impact on heavy element synthesis was explored. It was also discussed how neutrinos may be able to provide key insights into the equation of state of neutron stars. In addition, the importance of relic neutrinos was introduced with reference to its impact on star formation, mergers, and collapsar rate amongst other observables.



SuperNova Early Warning System 2.0

Clarence Virtue

SNEWS is a critical network that will allow temporal coincidences of neutrino events to be quickly distributed to all of the relevant facilities. Supernovae neutrinos act as an early warning of a galactic supernovae for electromagnetic observers. Coincident neutrino events between multiple detectors is critical in enhancing the sensitivity of our global network and verifying the significance of events between multiple detectors where local effects may create signals that mimic supernovae. This talk described the history and structure of such a network, and the recent developments that are ongoing. The unique difficulty in operating the SNEWS alert system, where alerts are only expected every ~100 years, was also summarized.

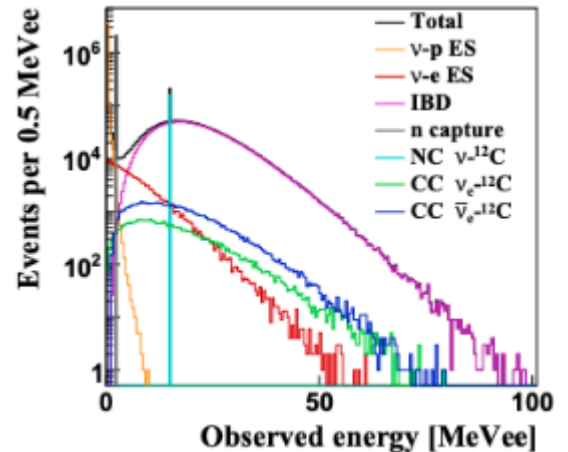


Canadian Multi-Messenger Astrophysics Workshop

SNO+ and Supernova Detection

Erica Caden

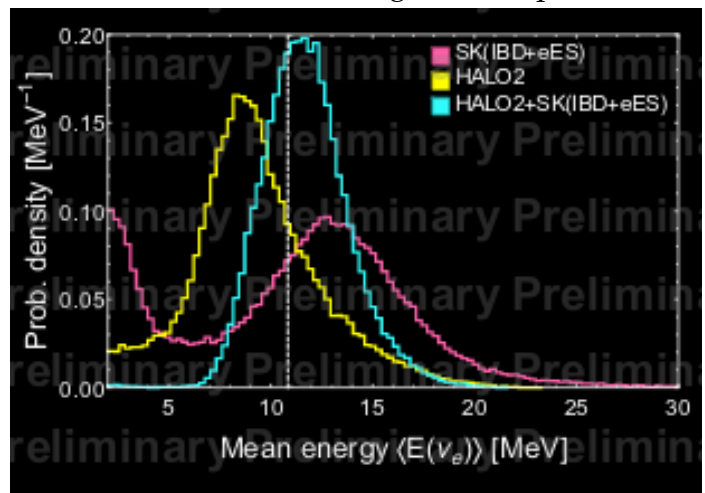
SNO+ is the recent upgrade to the Sudbury Neutrino Observatory where the plan is to transition from a water to a scintillator detector. Although the primary science goal of this detector is to study double beta decay, the detection of supernovae provide a novel addition to the detector's science goals. In addition to simulations, in order to estimate the expected signal from a supernovae a calibration source is in the process of being developed. The development of this source will allow the detector to prepare for the large and rapid signal of a supernovae. The trigger and backend for this pipeline was discussed as well as a summary of the current ongoing work that is required to complete the transition to SNO+ while continuing to operate the detector and gather calibration data.



New HALO-1kT and Future Prospects of Supernova Neutrino Flux Reconstruction

The justification for HALO-1kT was discussed in the context of a future galactic supernovae.

A dedicated detector for measuring supernovae neutrinos solves many of the problems that are attached to systems with multiple important science goals. The estimated rate for galactic supernovae make these events a “once-in-a-lifetime” occurrence. In many of the most complex modern detectors there is a natural deadtime that is necessary for upgrades and maintenance. Having a detector that is



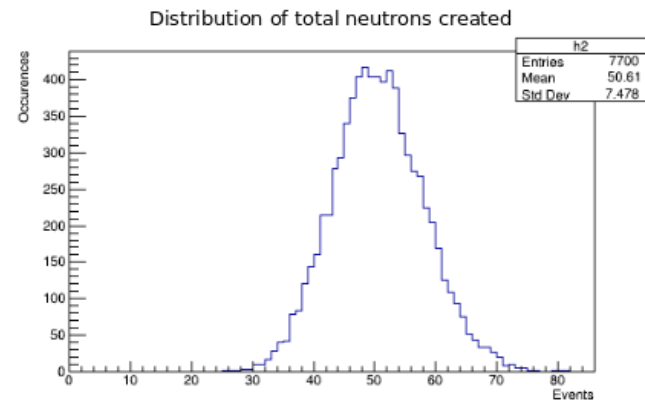
stable, low maintenance, with a high livetime and long lifetime helps to alleviate the possibility of missing these critical events. HALO-1kT is a proposed lead detector that is sensitive to electron neutrinos which matches all of the above criteria. This talk describes the detector as well as the estimated sensitivity to supernovae, derived through simulations.

Canadian Multi-Messenger Astrophysics Workshop

SNEWS 2.0 implementation for HALO-1kT

Remington Hill

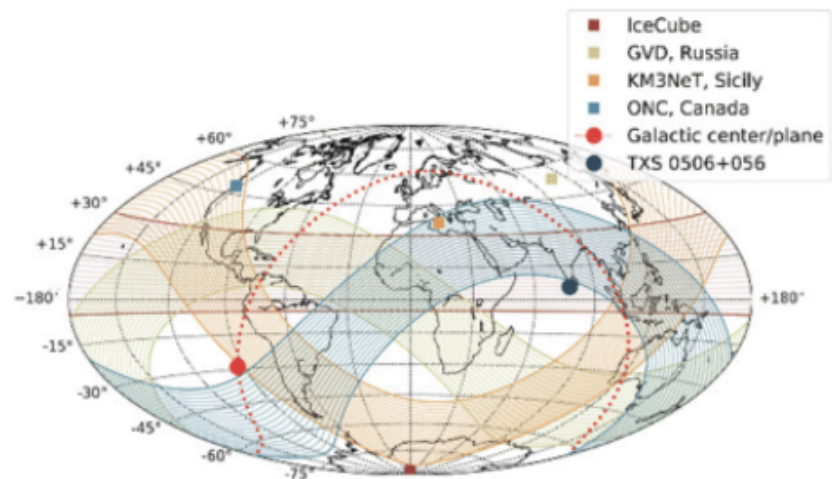
HALO-1kT is a dedicated lead neutrino detector that could play a critical role in galactic supernova alerts as a part of the SNEWS network. Reconstructing the time of the initial supernova is quite a difficult task to complete with the low statistics and rapid rate changes present in the detection of supernova from a detector like HALO-1kT. This talk introduced the initial methodology behind developing a technique for reconstruction as well as presenting future plans to finish this development for HALO and expand to SNO+. In addition, some of the challenges and uncertainties that arose from this modeling and the simulations were presented.



The P-ONE Neutrino Detector

Carsten Krauss

A summary status for P-ONE was discussed as well as the future goals for the project. Neutrino astronomy is already being performed at major observatories across the world but due to their location across the Earth there are gaps in sky sensitivity. The combined sensitivity of multiple detectors, in addition to all sky coverage, significantly increases our likelihood to associate neutrinos with a variety of multi-messenger sources. P-ONE seeks to fill this gap. The state of in water calibration was discussed as well as the plan for the 2022 deployment of optical modules.

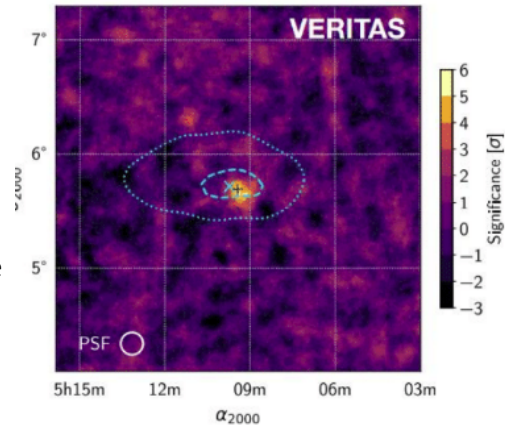


Canadian Multi-Messenger Astrophysics Workshop

Multi-Messenger Observations with VERITAS

Matthew Lundy

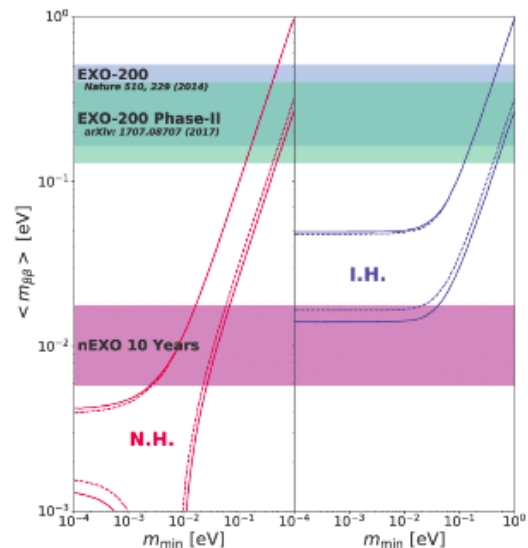
In this talk an broad overview of many observing programs was discussed. Gamma-rays at TeV energies are important probes to constrain some of the most energetic phenomena that are just now beginning to be observed by other messengers. Following up these sources requires novel techniques in how observations are performed and analyzed. These techniques, in addition to the new back end for their dedicated optical observations, were discussed in the context of a variety of different source classes including AGN flares, gravitational wave events, and fast radio bursts.



Searching for Majorana Neutrinos with nEXO

Thomas Brunner

An introduction to the nEXO experiment was given as well as a general introduction to the field of neutrino-less double beta decay. Many open questions remain about our understanding of neutrinos. What is the absolute mass scale? Is the neutrino a Dirac or Majorana particle? Neutrino-less double beta decay is one pathway with which we can be sensitive to the difference in these predictions. One attempt to answer these fundamental questions was EXO-200, an earlier TPC that attempted to search for this decay pathway. This project is now planned to move into it's next phase, nEXO, whose projected sensitivity makes it the most promising approach to search for Majorana neutrinos in the 10 years following it's commissioning . These estimates were presented as well as a description of the instrument itself.

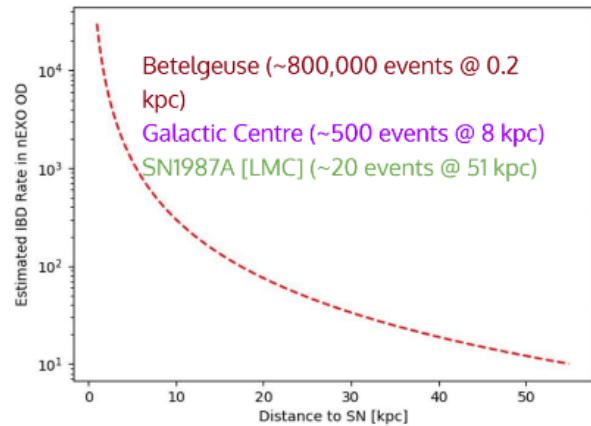


Canadian Multi-Messenger Astrophysics Workshop

Supernova Neutrino Detection with nEXO

Soud Al Kharusi

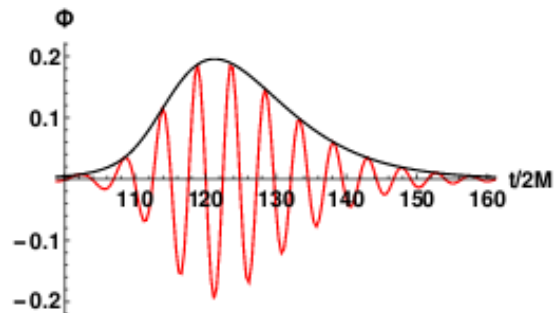
During a galactic supernova event, one of the most important tracers of the fundamental physics occurring in the r-process will be neutrinos. Dedicated detectors will certainly play an important role, but measurements may also be made at experiments like nEXO, whose primary goal is the search for neutrino-less double beta decay. The rates of measured neutrino events in nEXO, through different interactions, was discussed throughout this talk. With the predicted sensitivity of nEXO and the rate of the inverse beta decay signal in the outer detector, it is possible that nEXO could consider SN neutrino signals to ~ 10 kpc. The implication of this as well as an overview of this calculation was presented throughout the talk.



Orbital Effects in Perturbations around Exotic Compact Objects

Luís Felipe Longo Micchi

Gravitational wave events are interesting phenomena in and of themselves, however there also exists tentative evidence for gravitational wave echoes. These echoes may provide a path to understand the quantum nature of black holes and decode the event horizon. In this talk, predictions on the form of these echoes was made directly from numerical solutions to the Teukolsky equation. A bi-product of this study was the emergence of a beating effect in these echoes, a quantitative description of which was given at the end of this talk. This was presented alongside a summary of the observables predicted by this study.



Canadian Multi-Messenger Astrophysics Workshop

Dark matter direct/indirect detection complementarity

Jim Cline

Dark matter existed as an interesting potential multi-messenger source with many ongoing searches acting in parallel with theoretical developments. In this presentation, the challenges present in the theoretical side of dark matter development was shown in the context of recent observations and limits placed by a variety of different experiments. The strong constraints of the direct and indirect searches coupled with the hints of self-interactions in the galaxy makes fitting everything into a unified model difficult. However, elegant solutions continue to exist with sterile neutrinos amongst others discussed throughout this talk.

