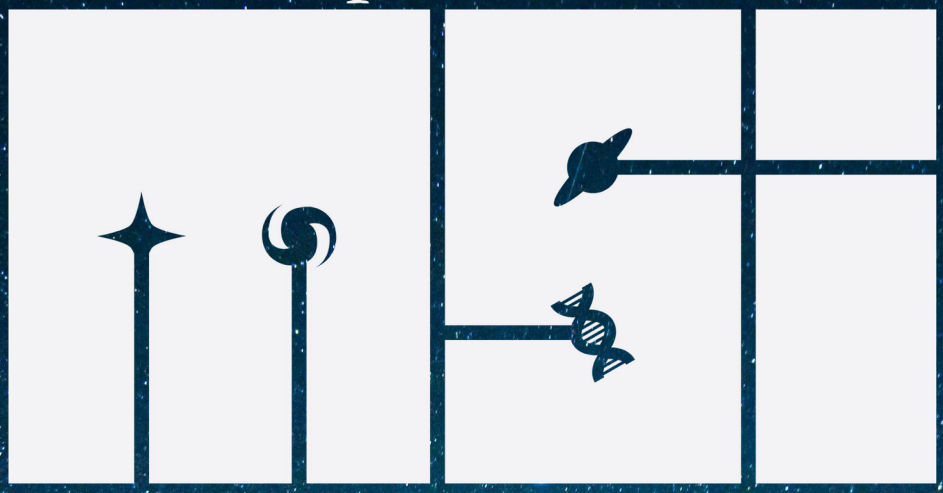
Institut Spatial de McGill



McGill Space Institute

Annual Report

09/2018 - 12/2019

Our annual reports can be found on our website

Table of Contents

About the MSI

Research Highlights

Outreach

Inreach

People

Impact

Welcome

A Message from the MSI Director, Prof. Vicky Kaspi

An interdisciplinary research centre, made up of researchers from an interesting diversity of backgrounds and domains, is far more than the sum of its parts. Yes, the brilliant faculty and the energetic trainees they mentor they mentor -- many of whom are supported by a generous gift from the Trottier Family Foundation -- are the lifeblood of a research centre like the McGill Space Institute. But it is the coming together, the *interaction*, that brings the energy and magic.

The stories and photos in this 2019 Annual Report are a testament to what we achieved and enjoyed on a daily basis in MSI in the past year. But they are also jarring, a reminder of what the 2020 COVID-19 situation has halted, at least temporarily. Though most MSI research and events, from AstroNights to discussion groups, have seamlessly moved online as of the writing of this Message, the images herein remind us of how wonderful it was when we were physically together. As MSI Director, I look forward to the day, hopefully soon, when we can safely meet again at our MSI 'hub' at 3550 University, share thoughts and calculations, as we did throughout 2019. In the meantime, our online studies of space and the cosmos are comforting; the vastness of the Universe we ponder puts into perspective this tiny planet's current challenge. I am certain that human innovation, perseverance and ingenuity -- the ultimate fibre of MSI -- will overcome COVID-19, as well as an array of far more distant but no less complex challenges.

A Message from the MSI Associate Director, Prof. Andrew Cumming

Welcome to this year's annual report! This is the 4th annual report that we have prepared for MSI, and it is remarkable to see how the Institute has grown and the range of accomplishments of MSI members. It is amazing that we now live in times when detection of merging compact objects using gravitational waves is commonplace, we are well on the way to discovering life on other planets, and peering back into the earliest stages of the Universe and galaxy formation (see "Research Highlights", p. 8-14).

A key strength of MSI is its community. Many visitors to MSI have commented to me afterwards that we have a very special collaborative and positive culture. This has always been the goal: to bring researchers from a diverse range of backgrounds together in an informal and friendly atmosphere, and I think the results speak for themselves. But of course we still have a long way to go in tackling underrepresentation in astrophysics and other sciences. Institute members have been working hard on issues related to Equity, Diversity and Inclusion. In the weekly EDI discussion group (p.27), there have been many conversations about the EDI literature and the best practises that we can adopt to help tackle this problem. EDI considerations are a key part of our discussions during student and postdoc fellowship competitions. Most recently in response to the Black Lives Matter protests around the world, MSI members have played a leading role in Department discussions about changes that we can make to ensure our research environment is welcoming, accessible, and safe for all. Thanks to all those who have participated: the hard work and involvement of MSI members has been inspiring to see, and a great example of the MSI community at work.

About MSI

Who we are

The McGill Space Institute (MSI) is an interdisciplinary research centre that brings together researchers engaged in astrophysics, planetary science, atmospheric science, astrobiology and other space-related research

Mission

The McGill Space Institute advances the frontiers of space-related science by fostering world-class research, training, and community engagement.

Vision

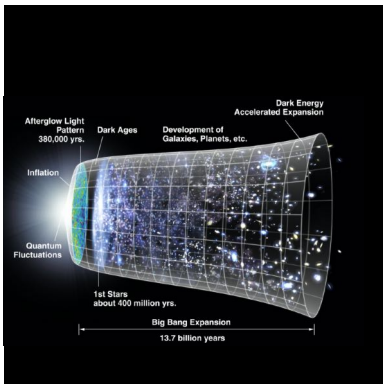
The main goals of the Institute are to:

- Provide an intellectual home for faculty, research staff, and students engaged in astrophysics, planetary science, and other space-related research at McGill.
- Support the development of technology and instrumentation for space-related research.
- Foster cross-fertilization and interdisciplinary interactions and collaborations among Institute members in Institute-relevant research areas.
- Share with students, educators, and the public an understanding of and an appreciation for the goals, techniques and results of the Institute's research.

Institut Spatial de McGill

McGill Space Institute

Research Areas



Early Universe and Theoretical Cosmology

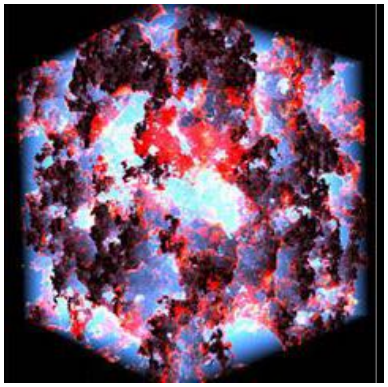
Robert Brandenberger, Jim Cline

The theoretical cosmology group works to explain the history of the very early Universe and to provide an explanation of the large scale structure in the Universe. They create models using input from new fundamental physics such as superstring theory, dark matter particle theories, and particle physics beyond the standard model. They also explore ways to test these new models with cutting-edge observations of the cosmic microwave background, large-scale structure, the neutral hydrogen 21-cm line, cosmic rays, and data from the Large Hadron Collider.

Experimental and Observational Cosmology

Cynthia Chiang, Matt Dobbs, Adrian Liu, Jonathan Sievers

The McGill Experimental Cosmology group designs and builds new instrumentation for observational cosmology and develops analysis techniques for upcoming large cosmological surveys, including surveys of the cosmic microwave background and the 21 cm line of neutral hydrogen. They deploy and operate instruments wherever the observing conditions are best — from the geographic South Pole to the top of the Stratosphere to the South African desert, as well as analyze and interpret the data from these experiments to gain a better understanding of the origin, fate, and fundamental constituents of the Universe.



Low-Frequency Cosmology

Cynthia Chiang, Adrian Liu, Jonathan Sievers

The low-frequency radio sky represents a new frontier in observational astrophysics and cosmology. This regime is a largely unobserved band of the electromagnetic spectrum, and holds the promise of revealing new astrophysical phenomenology. Moreover, our 21cm cosmology telescopes (ALBATROS, HERA, MIST, PRIZM) targeting this band have the potential to provide the first observations of a poorly understood portion of the cosmic timeline, Cosmic Dawn (when the first stars and galaxies lit up our Universe) and the Epoch of Reionization (when these first luminous objects dramatically transformed our Universe by ionizing almost all the hydrogen in the intergalactic medium).

Gamma Ray Astrophysics

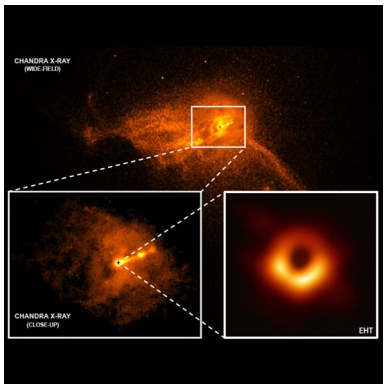
David Hanna, Ken Ragan

The Gamma Ray Astrophysics group is part of the VERITAS collaboration, which operates an array of four 12-m imaging atmospheric Cherenkov telescopes in southern Arizona. With this instrument they carry out a program of very-high-energy (VHE) gamma-ray astronomy, observing photons with energy in the range from 50 GeV to 50 TeV. Sources of such photons are among the most violent and exotic in the Universe and include supernova remnants and pulsar wind nebulae in our galaxy, as well as blazar-class active galactic nuclei (AGNs) at cosmological distances. The group also develops instrumentation for the VERITAS detector including calibration and characterization devices.

Supermassive Black Holes

Daryl Haggard

Our studies of supermassive black holes span from their large scale environments to photons circling at the edge of the event horizon. The supermassive black hole group is a part of the Event Horizon Telescope Collaboration and the LISA Consortium, along with several international teams that coordinate multi-wavelength (and soon multi-messenger) programs to characterize these systems and probe fundamental questions including, is general relativity valid in the strong-gravity regime?, how are jets launched?, what physics governs accretion flows near the event horizon?



Radio Transients

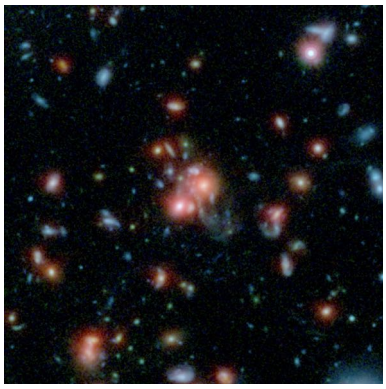
Vicky Kaspi, Matt Dobbs

The radio transients group studies short-duration flashes of radio waves from new and unexpected astrophysical phenomena. Their most active area of research is in Fast Radio Bursts (FRBs), mysterious, powerful, millisecond-long flashes of radio waves that originate outside of the Milky Way galaxy. To study these phenomena, the group uses several world-class radio observatories, including the Arecibo Observatory, the Green Bank Telescope, and the newly-built CHIME telescope.

Galaxy Evolution and Active Galactic Nuclei

Daryl Haggard, Tracy Webb

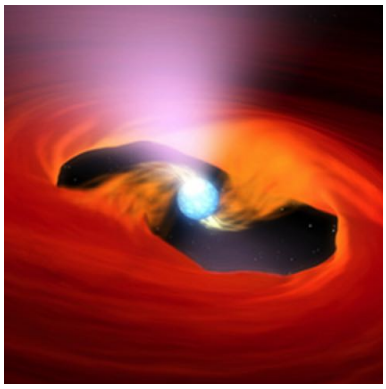
The galaxy evolution group is interested in understanding when galaxies form the bulk of their stellar mass; what drives and later shuts down this process; how the local environment of galaxies affect their evolution and growth; and how growing supermassive black holes (AGN) interact with their host galaxies and within galaxy clusters. We also study our own supermassive black hole, SgrA✳, and its interactions with the Milky Way galaxy.



Nuclear Astrophysics

Andrew Cumming

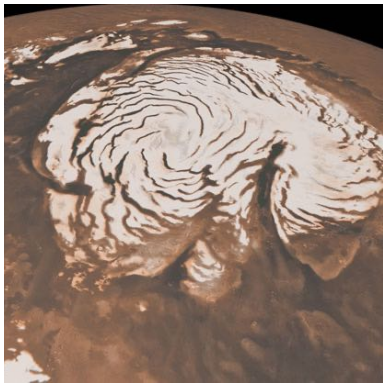
Nuclear astrophysics, at the intersection of astrophysics and nuclear physics, is the study of the origin of the chemical elements in stars and supernovae, explosive events such as supernovae, classical novae, and X-ray bursts, and the properties of matter at high densities as found in the interiors of neutron stars. We focus on developing connections between nuclear properties and astrophysical observations through the study of neutron stars, in particular by modelling the transient behaviour of accreting neutron stars on timescales of seconds to years. McGill is an Associate Member of the Joint Institute for Nuclear Astrophysics - Centre for Evolution of the Elements (JINA/CEE).



Planetary Surfaces

Natalya Gomez

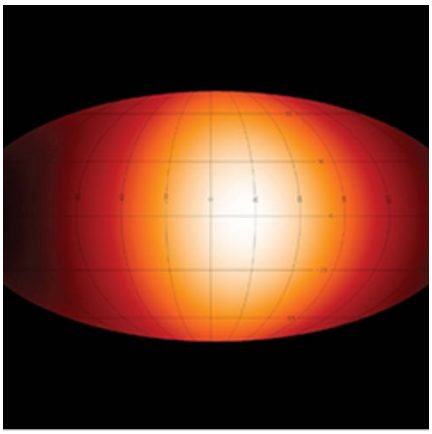
Members of the planetary surface group, led by Natalya Gomez, research models of the interactions between ice, water, climate and planetary interiors, and how these connections change planets surfaces through time. These models are applicable to both the Earth and other rocky, icy planets and moons in the Solar System.



Compact Objects

Andrew Cumming, Daryl Haggard, Vicky Kaspi

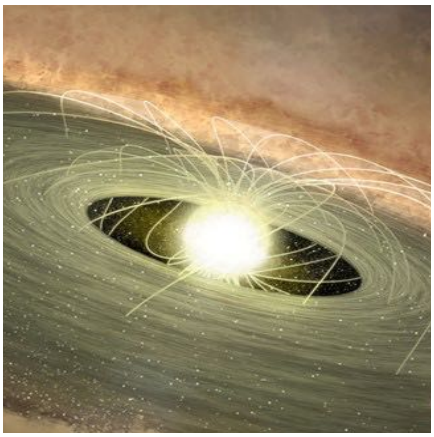
The compact object group studies white dwarfs, pulsars and other highly magnetized neutron stars, and stellar-mass black holes. The observational pulsar group is involved in several projects including: searches for radio pulsars; using pulsar timing arrays to detect gravitational waves; X-ray observations of magnetars; and developing pulsar instrumentation and algorithms for the CHIME telescope. Our multi-messenger group pursues intensive campaigns to identify and characterize kilonova and other electromagnetic counterparts to gravitational waves sources. The theory group studies the structure of neutron stars and how to use observations to constrain the physical processes operating in their interiors. They investigate the origin and evolution of neutron stars' spin and magnetism, interior structure, and the properties of neutron stars in close binary systems.



Climates and Atmospheres of Exoplanets

Nicolas Cowan, Andrew Cumming, Yi Huang, Tim Merlis

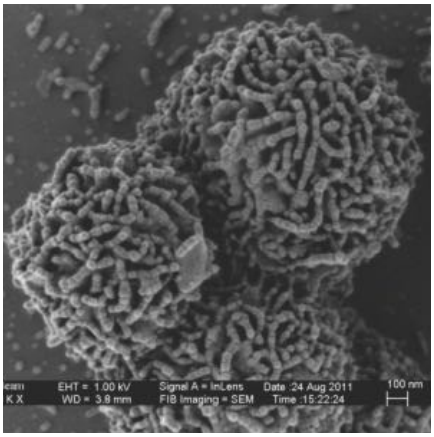
The extrasolar planet climate and atmosphere group works to characterize exoplanets using both observational evidence and climate modelling. Observational evidence for exoplanetary atmospheres comes from a variety of sources, including changes in brightness of the planet over time, spectroscopy, and upcoming next-generation direct-imaging experiments. Members also use computer models to expose the physical mechanisms of planet atmospheres by expanding climate models beyond the conditions found on Earth, to simulate the wide range of possibilities of atmospheres on exoplanets. Much of this work is carried out as part of the Institute for Research on Exoplanets (iREx).



Formation and Evolution of Stars and Planets

Eve Lee, Andrew Cumming

The large number and diversity of known exoplanets provides an opportunity to learn about how planets form and evolve, and the physical processes that operate in their atmospheres and interiors. The challenge is to draw connections between the observed properties of exoplanets or Solar System planets and theories of their formation, structure, and evolution. We use a variety of theoretical tools to identify the key physical processes behind the observed diversity of planetary systems, from super-Earths to gas giants. We study a wide range of topics from the earliest evolution of star-forming environments, protoplanetary disk evolution, disk-star-planet interaction, formation of planetary atmospheres, the dynamical interactions within planetary systems after birth, and the structural evolution of gas giants.



Astrobiology and Extraterrestrial Biosignatures

Nagissa Mahmoudi, Lyle Whyte, Nicolas Cowan

The Astrobiology and Extraterrestrial Biosignatures group focuses on examining microbial biodiversity and ecology in the Canadian High Arctic and the Antarctic dry valleys where very unique habitats exist, using both classical microbiology and novel genomics-based molecular techniques for studying microbial communities. Understanding what types of microorganisms could survive in these types of soils, as well as detecting biosignatures is important to understanding what future missions could look for in near surface water ice on Mars in the north polar regions or other cold, rocky places in the solar system. In parallel with the search for life in habitable extraterrestrial environments within the Solar System, members of the group use cutting edge telescopes on the ground and in space to establish the habitability of nearby temperate terrestrial exoplanets and to search their atmospheres for signs of life.

MSI by the Numbers

19 Faculty Members

22 Postdoctoral fellows

73 Graduate Students

from **12** countries

13 Research Areas

4 Departments

16 Public AstroNights

605 Sandwiches eaten during

19 Monday Lunch Talks

< 7700 Cookies @ MSI tea

7 Weekly discussion groups

149 Journal Articles

55 Seminars

Spotlight: New MSI Faculty Members 2019

In 2019, MSI was thrilled to welcome two new faculty members, Eve J. Lee (Department of Physics) and Nagissa Mahmoudhi (Department of Earth & Planetary Sciences). We're looking forward to everything that they'll contribute to the MSI community!

Eve J. Lee, Assistant Professor of Physics

Eve J. Lee joined the Physics Department as an Assistant Professor and the MSI as a Faculty Member in Fall 2019. She is a theoretical astrophysicist studying the formation of stars and planets. The overall goal of her research is to uncover the origin of diversity in planetary systems: to understand what we have observed and to predict what we may discover through future missions. Specific topics of her research include (but are not limited to) the dynamics of star formation in giant molecular clouds, dust-gas interaction, the origin of planetary atmospheres, the orbital architecture of planetary systems, star-disk-planet interaction, and the dynamics of debris disks. Prior to joining the MSI, she was a Sherman Fairchild Postdoctoral Scholar in Theoretical Physics/Astrophysics at Caltech.

Nagissa Mahmoudi, Assistant Professor of EPS

Nagissa Mahmoudi joined the Department of Earth and Planetary Sciences as an Assistant Professor in 2019 and became an MSI Faculty Member shortly thereafter. Her research focuses on microbial processes that mediate the fate and transformation of organic compounds in coastal and marine environments, and seeks to understand microbial controls on the mineralization of natural organic matter as well as organic contaminants such as petroleum hydrocarbons. Her research employs a variety of field and laboratory based tools, ranging from experimental microbiology to isotope geochemistry, to connect microbial pathways and interactions with biogeochemical transformations. The information produced through this work will help create a robust understanding of the molecular-scale processes that govern carbon cycling in aquatic environments. Before coming to McGill, she completed postdoctoral research at the University of Tennessee at Knoxville and at Harvard University.

Exploring the Cosmos from Nunavut

Around 400,000 years after the big bang, the universe cooled sufficiently for neutral hydrogen atoms to form for the first time. The following period, known as the "dark ages," lasted for a few hundred million years until the first stars began to ignite during "cosmic dawn." Both of these epochs are uncharted territory and ripe for new discoveries; the first and only tentative detection of cosmic dawn was reported by the EDGES experiment in 2018, and the dark ages is entirely unexplored to date.

Fortunately, the Universe has given observers an extremely powerful tool for probing the distant past: neutral hydrogen atoms naturally emit light with a wavelength of 21 cm, and because the Universe is expanding, this wavelength is stretched or "redshifted" in proportion to how far away (or, equivalently, how long ago) the hydrogen emitted its light. Thus, by measuring the sky at radio frequencies, it is possible to access specific epochs of the Universe's history by tuning one's telescope to the appropriate wavelengths.

The required observational frequencies (<150 MHz) for Cosmic Dawn and the Dark Ages are exceptionally difficult to measure because of contamination from terrestrial radio-frequency interference (RFI) and ionospheric effects. Instruments aiming to make these measurements must operate from remote locations where RFI is minimized and ionospheric conditions are quiet: polar latitudes, especially at night during solar minima, are excellent candidates.

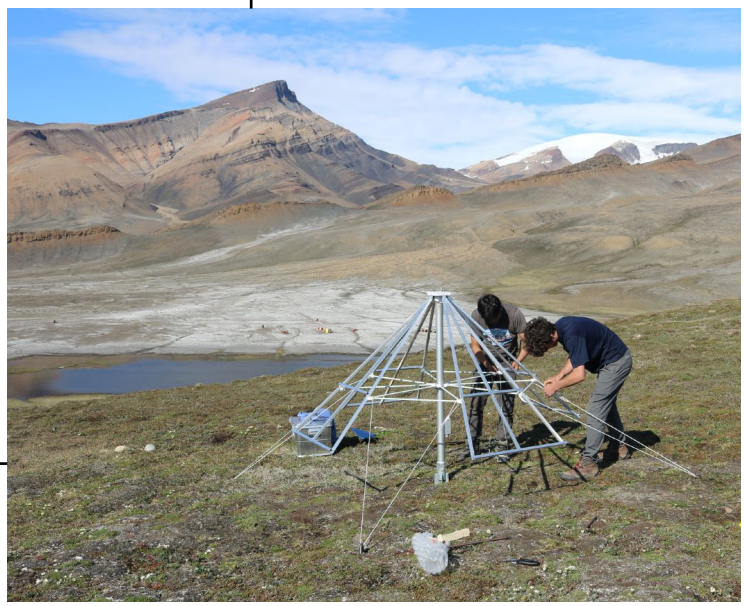
Prof. H. Cynthia Chiang is leading a new research program to perform the first radio astronomy observations from the Canadian High Arctic. In summer 2019, she and her team (research fellow Dr. Raul Monsalve and undergraduate Taj Dyson) deployed new radio instrumentation at the McGill Arctic Research Station (MARS) at Expedition Fjord on Axel Heiberg Island. Preliminary observations suggest that MARS is an exceptionally quiet site for radio astronomy work. In particular, there is no persistent visible transmission from FM radio stations (88-108 MHz), one of the most pernicious contaminants for experiments aiming to observe the low frequency sky.

Over the next few years, Prof. Chiang's team will install several other radio antennas near MARS with the observational goals of 1) weighing in on the EDGES detection of cosmic dawn, and 2) imaging the low-frequency sky as a first step toward laying the groundwork for future explorations of the cosmic dark ages. The inaugural 2019 campaign has demonstrated that the Canadian High Arctic is a unique environment that offers some of the cleanest conditions in the world for observing the radio sky.

Prof. H. Cynthia Chiang *is an Associate Professor of Physics at McGill. The primary focus of her research is observational cosmology and instrumentation development. She specializes in precision measurements of redshifted 21-cm emission of neutral hydrogen and the cosmic microwave background.*

Why this is important

Almost nothing is known about the very first stars that were born in our Universe, and detecting their signals at radio wavelengths is exceptionally challenging. McGill researchers have demonstrated that the High Arctic presents a unique Canadian geographic advantage that may allow us to open a brand new window on the radio sky.



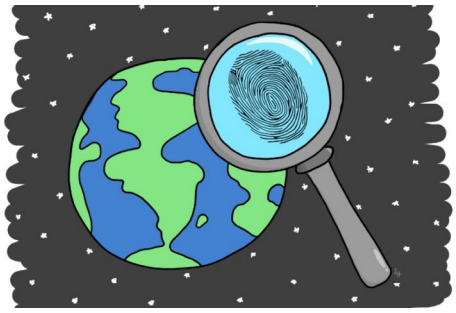
Top right: Prof. Chiang and undergraduate Taj Dyson on an RFI survey near MARS.. Right: Research fellow Raul Monsalve and Taj Dyson install the instrument. (Image credits: Prof. Cynthia Chiang)

The Fingerprint of Life in the Transit Spectrum of Earth

Evelyn Macdonald *recently completed a BSc in Honours Physics with a Minor in German at McGill University and began a PhD in Physics at the University of Toronto fall 2019.* ***Nicolas Cowan*** *is an Associate Professor in the departments of Earth & Planetary Sciences and Physics, and the Canada Research Chair in Planetary Climate.*

Why this is important

Soon, we will be searching for life on exoplanets with transit spectroscopy using the James Webb Space Telescope. Macdonald and Cowan's transit spectrum of Earth could serve as a benchmark in the search for exoplanets that are habitable.

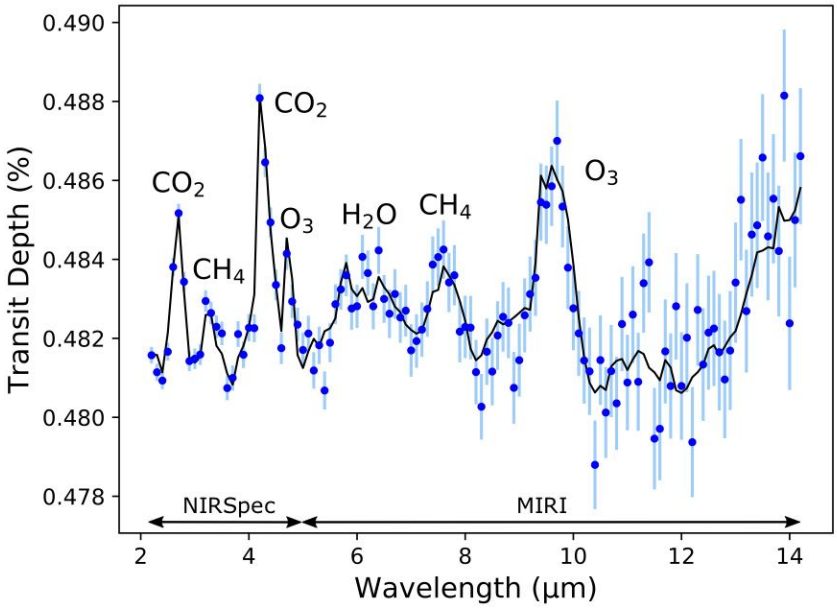


We will soon search for life on exoplanets with transit spectroscopy using the James Webb Space Telescope, but how would Earth's infrared transit spectrum appear to distant observers?

Evelyn Macdonald and Prof. Nicolas Cowan used data from SCISAT — a Canadian satellite launched in 2003 to help scientists understand the depletion of the ozone layer — to construct a transit spectrum of Earth in infrared light. Astronomers can tell what molecules are in a planet's atmosphere by looking at how starlight is filtered through the atmosphere, but they must wait for a planet to pass — or transit — in front of the star to make this observation. Macdonald and Cowan's transit spectrum of Earth could serve as a benchmark in the search for exoplanets that are habitable, or even inhabited.

The idea of drawing a link between data gathered by a satellite orbiting the Earth and telescope observations of a distant planet emerged when exoplanet specialist Cowan spoke with Yi Huang, a McGill Professor of Atmospheric and Oceanic Sciences and fellow member of the MSI, at an interdisciplinary Planet Lunch. Cowan was describing transit spectroscopy of exoplanets when Huang pointed out a striking resemblance to SCISAT's viewing geometry of the Earth. "I thought this sounded great," Cowan recalls. "And, like you always do with these things, jotted it down on a piece of paper and forgot about it – until I had an undergrad student who wanted to do her thesis with me."

That student was Evelyn Macdonald, a Montrealer whose childhood interest in space had led her to pursue an honours physics degree at McGill. Such was her motivation that Macdonald completed her thesis a full year before she had finished her other degree requirements. Cowan recognized the manuscript's potential for publication and encouraged Macdonald to develop it further. Backed by an undergraduate research award from McGill and a Trottier Excellence Grant from the Institute for Research on Exoplanets, Macdonald spent the following summer doing just that.



Top left: Whimsical art (Credit: Leanne Young / The McGill Tribune) Bottom left: Infrared transit spectrum of Earth showing atmospheric biosignatures (Source: Macdonald, E. J., & Cowan, N. B. (2019). An empirical infrared transit spectrum of Earth: opacity windows and biosignatures. Monthly Notices of the Royal Astronomical Society, 489(1), 196-204.

Detection of Multiple Repeating Fast Radio Bursts

Fast Radio Bursts (FRBs) consist of short (few ms) bursts of radio waves, which arrive at Earth from far outside our own Galaxy, and likely from cosmological distances. Their origins are unknown, although leading models involve compact objects, either neutron stars, or objects interacting with black holes. FRBs are notoriously difficult to study, as although they are ubiquitous, where and when one arrives cannot in general be predicted.

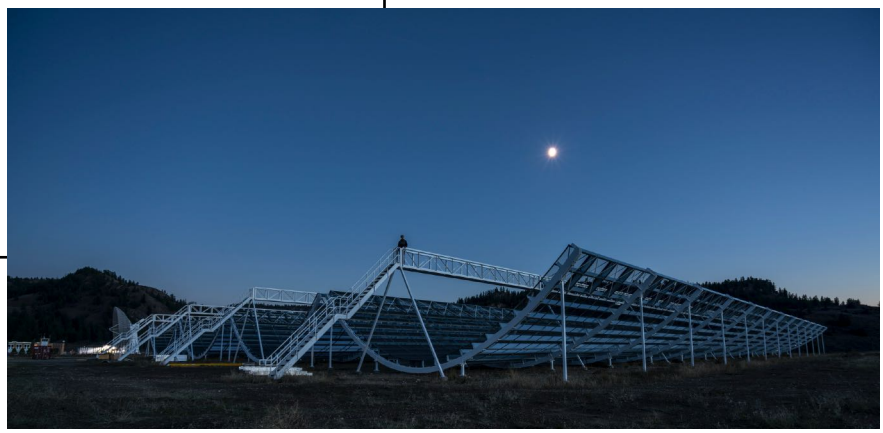
The Canadian Hydrogen Intensity Mapping Experiment is a new Canadian radio telescope designed and built to study the accelerating Universe. Consisting of 4 100m x 20m cylindrical reflectors with no moving parts, CHIME is a "digital" telescope that can "see" over 200 square degrees of the sky at any one time -- an orders-of-magnitude larger field-of-view compared with conventional radio telescopes. So large a field-of-view is very useful for studying a transient phenomenon like FRBs, as CHIME's chances of "seeing" an FRB is larger than for other telescopes. Major components of CHIME's correlator "brain" -- which handles the signals from CHIME's 1024 antennas -- were built in Prof. Matt Dobbs' McGill Cosmology Lab. Subsequently, a special-purpose Fast Radio Burst detector was added to CHIME by teams led by Profs. Vicky Kaspi and Matt Dobbs, to study the transient FRB phenomenon.

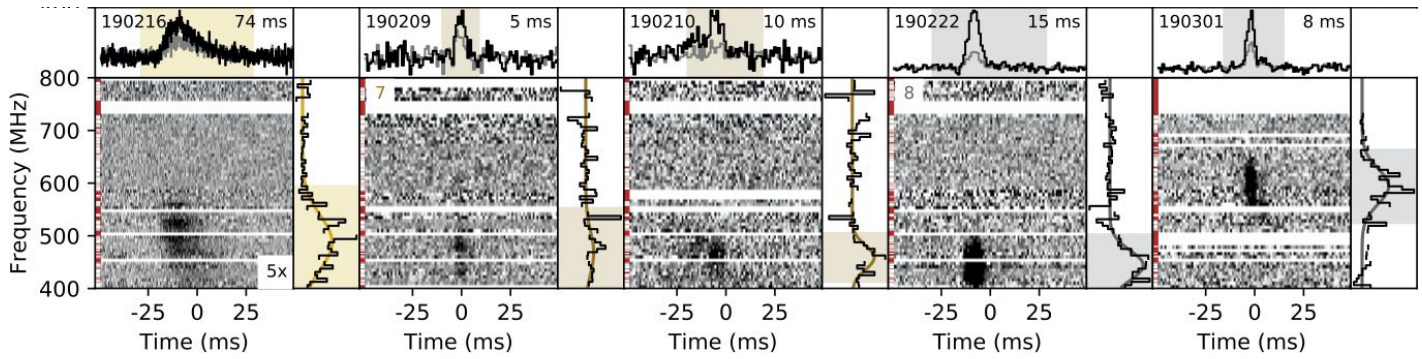
In 2019, the CHIME/FRB project "burst" onto the FRB scene in two adjacent papers published in Nature, the first announcing the detection of FRBs down to radio frequencies of 400 MHz (the lowest that had yet been seen), along with the discovery of only the second ever "repeating" FRB source. The result was highlighted on the cover of the January edition of Nature. The CHIME/FRB team quickly followed up these discoveries with the 2019 announcement of the discovery of an additional 8 repeating sources, effectively revolutionizing the FRB field and enabling astrophysicists worldwide to begin to study this newly recognized astrophysical source class.

*The **CHIME/FRB Collaboration** is led by McGill and involves nearly two dozen MSI undergraduates, graduate students, postdocs and staff, led by MSI **Professors Vicky Kaspi** and **Matt Dobbs.***

Why this is important

Fast Radio Bursts (FRBs) are one of the most interesting puzzles in modern astrophysics. Consisting of few-millisecond-duration bursts of radio waves, FRBs are arriving from far outside our Milky Way galaxy over 1000 times per day across the full sky, demonstrating they are ubiquitous in the Universe. Their origin is unknown. Studying them is challenging as they are unpredictable and transient. Canada's new CHIME radio telescope is a world-leading FRB detector and began full operations in 2019.





Right: The CHIME Telescope (Credit: CHIME Collaboaration). Bottom: Waterfall plots for some of the repeating FRBs detected by CHIME. (Source: CHIME/FRB Collaboration (2019), https://arxiv.org/abs/1908.03507

A microbial life detection system for space missions

Prof. Lyle Whyte *is a Professor in the Department of Natural Resource Sciences. His research focuses on characterizing the microbial community and biodiversity of Canadian Arctic environments as analogs for Mars, Enceladus, and Europa.* ***Dr. Isabelle Raymond-Bouchard*** *is a MSI postdoctoral research fellow.* ***Dr. Miguel Angel Fernández Martínez*** *is a McGill postdoctoral research fellow.* ***Catherine Maggiori, Brady O'Connor, and Olivia Blenner-Hassett*** *are PhD student fellows at the MSI.* ***David Touchette*** *is an MSc student fellow at the MSI.*

Why this is important

The search for life in our solar system is among the highest priorities for space science, yet no modern instrument payload (on a rover/spacecraft) is able to definitively detect signs of life. The very recent detection of higher volumes of methane and oxygen on Mars, and the findings of water vapour over the icy surfaces of Europa and Enceladus, are strong indicators for potential habitability. Prof. Lyle Whyte's lab is developing the 'MICRO-life detection platform' to be capable of definitive life detection.

As public and private space sector activity increases, with plans for additional landers and sample caches for return to Earth, it's important that we look for the presence of native microbial life in these environments before irreversible contamination occurs. The search for life in our solar system is among the highest priorities for space science, yet no modern instrument payload (on a rover/spacecraft) is able to definitively detect signs of life. The very recent detection of higher volumes of methane and oxygen on Mars, together with the findings of water vapour over the icy surfaces of Europa and Enceladus, are strong indicators for potential habitability. Therefore, Prof. Lyle Whyte's lab is developing the 'MICRO-life detection platform' to be capable of definitive life detection.

In the past year, the Whyte lab has continued with the successful tests of different life detection instruments, increasing their automation, robustness, and sensitivity in a variety of Arctic subzero environments and desert locations in North America. These environments are considered terrestrial analogs of Mars and the Icy Moons, i.e. Enceladus and Europa. As a future goal, the combination of these instruments will be developed into a fully optimized platform for microbial life detection (the 'MICRO-life detection platform') and is expected to be integrated into future planetary exploration space missions. Specifically, these instruments are:

- **The MagLysis,** an automated biomolecule extraction unit focusing on DNA. DNA is an unambiguous sign of life and must be extracted from microbial cells for successful detection. DNA sequencing is then performed with the MinION, an ultralight and portable DNA sequencer. MinION sequencing in the Canadian High Arctic and North American desert environments showed diverse microbial communities mainly consisting of extremophiles, and also identified a detection limit of 100 cells/g for the MinION as published in Maggiori et al., 2020.
- A **Microbial Activity MicroAssay** (µMAMA), which detects and characterizes living microbial communities based on their metabolic activity using a colourimetric assay. This instrument is able to detect a broad number of metabolisms, including carbon cycling, lithotrophic and anaerobic pathways. This approach yielded positive results with as low as 1000 yeast cells and 4000 bacterial cells.
- The **Cryo-iPlate**, a novel culturing method used to isolate microorganisms from the environment. It allows for culturing of microorganisms in their natural environment and isolation of previously inaccessible microorganisms. Hundreds of diverse and unique Arctic bacterial strains have been cultured in situ using the Cryo-iPlate. This technique has shed light on the traits required for life in extreme cryo-environments, as well as the deep characterization of new microbial strains.

David Touchette, Ianina Altshuler, and Catherine Maggiori (MSI PhD) atop White Glacier on Axel Heiberg Island in the Canadian High Arctic testing an automated ice core drill developed in collaboration with Prof. A. Ellery from U. Carleton as part of a CSA FAST-funded project. (Image credit: David Touchette)

A Deep CFHT Optical Search for a Counterpart to the Possible Neutron Star – Black Hole Merger

The first detection of a merger between two neutron stars in both gravitational waves and light thrilled astronomers across the international community in late 2017. Now, an even more exotic merger and another first may have occurred: the merging of a neutron star and a black hole.

As they perform their final dance and spiral towards each other, a neutron star and black hole produce gravitational waves – ripples in the fabric of spacetime itself – which can be detected by specially designed detectors such as LIGO and Virgo. At the same time, the neutron star is shredded into free neutrons which then rapidly combine to form the heaviest elements in the Universe, including gold, platinum, and uranium. These elements shine in visible and infrared light in a rapidly-evolving 'kilonova', and astronomers with conventional telescopes can then join in.

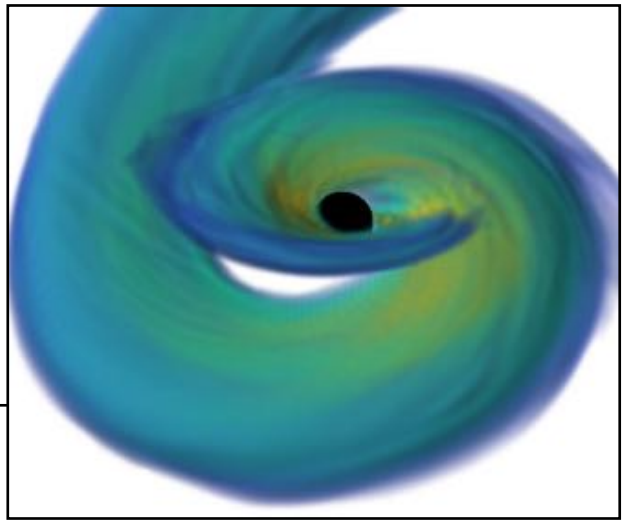
On 14 August 2019, the LIGO and Virgo detectors found an extremely strong gravitational wave signal which was potentially produced by the merger of a neutron star and black hole, now named GW190814. Nick Vieira, Dr. John Ruan, Prof. Daryl Haggard of McGill University, and Prof. Maria Drout of University of Toronto, led an imaging campaign to search for a kilonova counterpart to GW190814 in visible/infrared light with the Canada-France-Hawaii Telescope (CFHT). These CFHT observations were among the deepest and most valuable of those reported by the dozens of teams across the world who engaged in similar campaigns. This Canadian-led team did not detect any such counterpart, nor did any other teams. However, their deep CFHT imaging campaign allowed them to place the tightest constraint to-date on the mass of the neutron star which was consumed by the black hole. They found that at least 97% of a standard neutron star must have been immediately swallowed by the black hole, or, the lighter object must itself have been a black hole. LIGO/Virgo announced in June 2020 that the mass of the lighter object makes it either the heaviest neutron star or lightest black hole ever detected, adding to the mystery of this exciting new system and highlighting the value of the CFHT observations.

These observations reiterated the ability of the CFHT, led by a Canadian collaboration, to play a leading role in 'multi-messenger' astronomy. In the future, the team will employ CFHT, Gemini, and other observatories to search for counterparts to exciting new gravitational wave events, with an eye toward making the first multi-messenger detection of the merger between a neutron star and black hole, when it occurs.

Nick Vieira *is a M.Sc. student working under the supervision of* ***Prof. Daryl Haggard*** *and* ***Dr. John Ruan*** *at the McGill Space Institute. He works on visible/infrared follow-up of gravitational wave sources.*

Why this is important

The 'multi-messenger' detection of a merger between a neutron star and a black hole in both gravitational waves and light would be the first direct proof that such a system exists, and the insights gained by combining these messengers greatly exceeds those gained by using either messenger alone.



Top right: Canada-France-Hawaii Telescope (Credit: (c) Jean-Charles Cuillandre)
Bottom right: Merger simulation [Source: Foucart+17, https://arxiv.org/pdf/1611.01159.pdf]

A Direct Glimpse into Cosmic Dawn

Prof. Adrian Liu *is a William Dawson Scholar and Assistant Professor in the Department of Physics and the McGill Space Institute.*

Why this is important

The origin story of how our Universe came to be is substantially incomplete, but the next few years will fill in a crucial part of our cosmic timeline—the era of Cosmic Dawn, when the first stars and galaxies formed.

Ugh. Spikes. All over the place. I'm in my office, staring at my computer screen. We're looking at data fresh from a night's worth of observations using our radio telescopes in the South African Desert. We were looking forward to a good morning's worth of data analysis, admiring the smooth undulating patterns that we've come to associate with the Milky Way Galaxy. Instead, the spikes we see are indicative of someone operating a radio transmitter—illegally.

The hunt for the culprit begins. We message our international collaborators, giving them the few clues that we have: the rough time when this happened, and any location- and radio frequency-information that we've gleaned from our crummy data. They'll investigate the cause, with our team on the ground possibly even driving out on their diesel jeeps to look for the source of the transmission. (Not gasoline—those vehicles produce their own radio pollution). As for us, all we can do is wait.

The HERA telescope array in South Africa. The array is a large grid of 14 meter (42 ft) diameter non-tracking dishes packed into a hexagonal grid 300 m (900ft) across.(Images courtesy of the HERA Collaboration.)

But we won't have to wait long, for this is an incredibly exciting time for the Hydrogen Epoch of Reionization Array (HERA). HERA (pictured at left) is a radio telescope being built in the South African Karoo Desert. When construction is complete, HERA will consist of 350 radio dishes operating in concert as one giant supertelescope that is about a mile across. the frequency range and sensitivity of HERA is custom-designed to detect faint---and ancient---radio waves emitted by hydrogen atoms. These waves were emitted during an epoch known as Cosmic Dawn, when the first stars and galaxies were formed. This was a crucial moment in our Universe's history, but It has never been directly observed. HERA will change this.

The next year will be an exciting time for HERA researchers at McGill. We are currently preparing the first HERA upper limits on the strength of the aforementioned radio signal from the early Universe. Within the next year or two, these upper limits will significantly impact our understanding of the environment in which the first galaxies formed. For instance, we will place constraints on the temperature of the intergalactic medium during that epoch, slowly building up a complete picture of what our Universe was like during Cosmic Dawn: what were the first galaxies like? Were they like the galaxies we see today, or were they substantially different? Did they emit strongly in ultraviolet? In X-rays? How many of these galaxies were there, and how many of them were large galaxies? What role did dark matter play in all of this? At McGill, we not only have front-row seats on this journey; as a full partner institution of HERA, we play a crucial part in this exciting quest to complete our understanding of Cosmic Dawn.

A Little Theory of Everything

The standard model of particle physics is tremendously successful in describing the properties of the known particles, but it doesn't account for several key phenomena that we think must be there. Cosmological inflation is widely believed to provide the seed density perturbations in the early Universe that condensed to form galaxies, stars, and planets. Dark matter is known to also be crucial in this process. And our existence depends on there being more matter than antimatter in the Universe. All of these are unexplained by the standard model, which also fails to account for the tiny observed masses of neutrinos.

In our work, we provided a new framework to supply these missing ingredients in a novel and economical way, that ties them closely together rather than considering them as disconnected pieces of a puzzle. First we proposed a new theory of inflation (when the Universe undergoes a super-fast period of expansion) that produces the particle-antiparticle asymmetry during inflation instead of afterwards, as is normally assumed. In other words we don't need a separate mechanism to make the asymmetry: inflation does it for us.

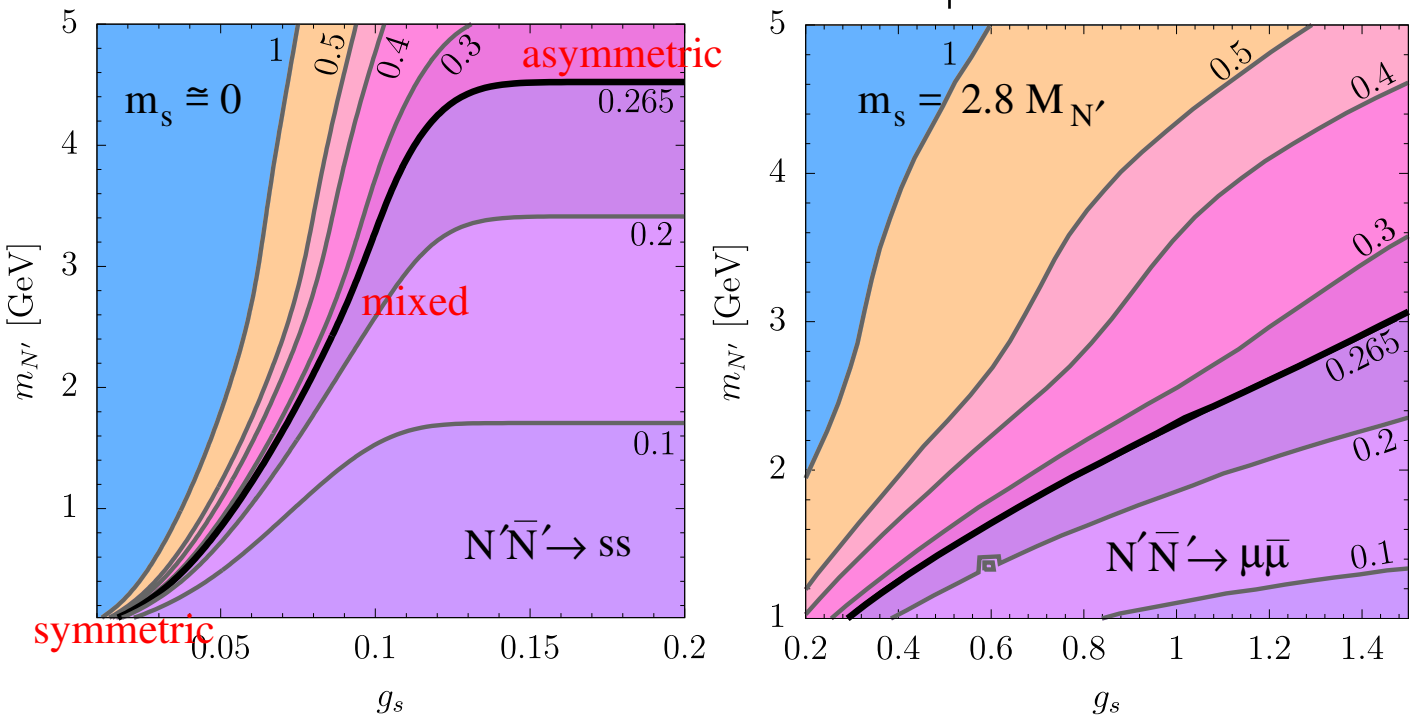
This asymmetry is originally stored in three new species of heavy neutrinos (called Heavy Neutral Leptons, HNLs). Two of these transfer the asymmetry from the inflation to standard model particles, eventually becoming the ordinary matter that comprises us. The third is the dark matter, with a mass of the same order as that of the proton. Our theory predicts it is a stable particle (as dark matter should be) if the lightest neutrino is exactly massless, which is a surprising connection between two particles that are usually assumed to be unrelated. The two other HNLs are unstable and can be discovered in laboratory experiments that are currently under development.

Prof. James Cline *specializes in particle physics and cosmology, and the early Universe phenomena that link them.* ***Matteo Puel*** *is a Ph.D. student working with Prof. Cline.* ***Dr. Takashi Toma*** *is a former Research Associate with strong expertise on dark matter theories, who recently moved to Kanezawa University in Japan.*

Why this is important

We present a minimal framework that supplies all the ingredients missing from the standard model of particle physics — inflation, baryogenesis, dark matter, and the origin of neutrino masses —and ties them together in an interesting and testable way.

Below: Predictions for the dark matter particle mass, coupling, and density from the theory. [Source: arXiv:2001.11505]



Education & Public Outreach

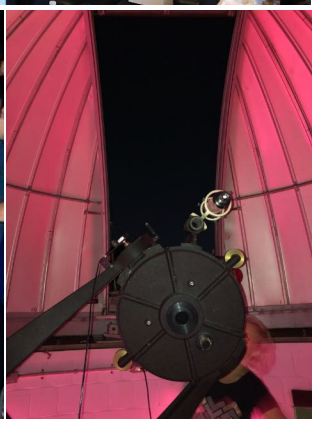
AstroMcGill serves as the education and public outreach (EPO) branch of the McGill Space Institute. It was founded in 2011 by an enthusiastic group of graduate students and post-doctoral fellows and its activities continue to be student-led. AstroMcGill has made a name for itself in Montreal over the past few years and is often invited to participate in events organized by various organizations in Montreal and its surroundings. Outreach activities range from monthly events like public lectures to one-time events for smaller audiences, including hosting visiting school groups, observing nights at summer camps, and presentations and tours of the observatory for McGill employees. AstroMcGill often works in close collaboration with outreach groups in its member departments, such as the Physics Outreach group and the newly-created EPS outreach group, to offer a robust set of education and outreach activities for the Montreal community.

Public Lectures

AstroMcGill's flagship activity is Public AstroNight, a monthly public talk given by a professional astronomer and aimed at a broad audience. Speakers are often MSI or McGill Physics professors, postdoctoral fellows, or graduate students, although recently invited speakers from other institutions are becoming more common. After the lecture, student volunteers often lead night sky observations with portable telescopes (weather permitting). These talks attract an average of about 250 people, with another 700 people usually watching the recorded live-stream on the event's Facebook page. In Fall 2019, Public AstroNight merged with the Physics Matter's public lecture series to become Public AstroPhysics night.

Astronomy on Tap

Astronomy on Tap events feature accessible, engaging presentations on topics in astronomy and space science plus astronomy-themed trivia games and prizes. Events are held in local pubs on the last Tuesday of the month and alternate between English and French nights, with members of iREx hosting the French events.



Eurêka! Festival

AstroMcGill contributed to two tables at the 13th edition of the Eurêka! Festival, Quebec's biggest science festival. The first, in collaboration with the Centre de Recherche en Astrophysique (CRAQ), was titled "Journey to New Worlds" and presented exoplanet themed topics such as what ingredients are needed to make a habitable world. Visitors also were able to gaze through a solar telescope. The second table, titled "Science in Motion", was in collaboration with the Faculty of Science, Women in Physics, and Physics Matters. This table exhibited a magnetic levitation train constructed of 3D printed rail containing strong magnets and a superconductor "train" cooled with liquid nitrogen that would float along the mobius strip track. The table also featured a "Draw a Scientist" activity and an infrared camera demonstration.

Explorations Summer Camp

AstroMcGill contributed two demonstrations for the 2019 McGill Explorations Summer Camp. An MSI graduate student presented a hands-on demonstration of the exoplanet transit method using a laptop camera and styrofoam balls of different sizes and colours. A MSI faculty member also presented a demonstration about black holes.

McGill Teacher Inquiry Institute

The McGill Teacher Inquiry Institute is a half-day program that targets primary school teachers from the English-language Lester B. Pearson school board who self-identified as uncomfortable with teaching science in their classrooms. The Inquiry Institute gives teachers a safe space to address anxieties related to teaching science topics, access to student volunteers who act as subject matter experts, and appropriate hands-on, inquiry-based lesson plans to use in their classrooms. In 2019, AstroMcGill collaborated with Physics Matters in leading an inquiry-based activity on the phases of the moon.

AstroMcGill is very active on social media. Its Facebook following grew by 20% last year (the same growth rate as last year), and now totals over 5200 followers. Additionally, AstroMcGill regularly has over 500 people interested in its events. The AstroMcGill Twitter account (@AstroMcGill) has over 2000 followers. There are also more than 1400 people subscribed to the joint mailing list between AstroMcGill and Physics Matters. AstroMcGill also has a YouTube page with 38 videos totalling nearly 9000 views.

Public AstroNights

Pinging space rocks at the Arecibo Observatory
Dr. Flaviane Venditti
Arecibo Observatory
20 September, 2018

À la recherche de neutrinos et de l'origine des rayons cosmiques
Étienne Bourbeau
Niels Bohr Institute, University of Copenhagen
11 October, 2018

The Search for Life on Mars is About to Get Serious
Profs. Lyle Whyte & Richard Leveille
McGill University
22 November, 2018

Neutron Stars: Extraordinary Cosmic Laboratories for Physicists
Dr. Vanessa Graber
McGill University
13 December, 2018

Psyche: Journey to a Metal World
Prof. Lindy Elkins-Tanton
Arizona State University
31 January, 2019

Searching for Cosmic Dawn
Prof. Cynthia Chiang
McGill University
21 February, 2019

Black Holes at Cosmic Dawn
Dr. Jordan Mirocha
McGill University
21 March, 2019

Fast Radio Bursts: Sparks from across the Universe
Dr. Shriharsh Tendulkar
McGill University
18 April, 2019

The Event Horizon Telescope: Seeing the Unseeable
Prof. Shep Doeleman
Event Horizon
01 May, 2019

Melting Ice in a Warming Climate
Prof. Natalya Gomez
McGill University
16 May, 2019

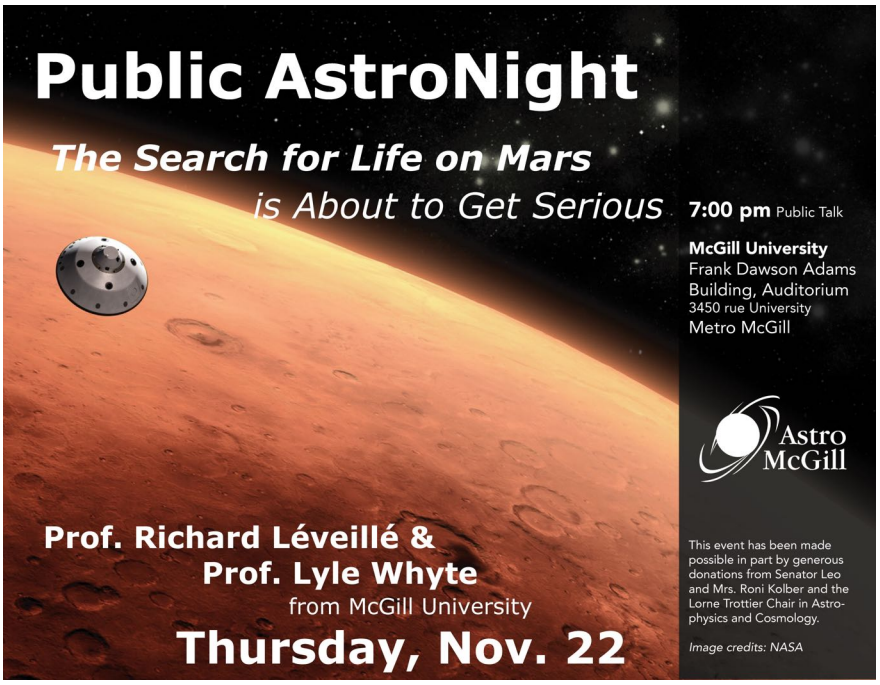
Imaging (and Imagining) Black Holes
Prof. Sera Markoff
University of Amsterdam
19 June, 2019

Origins: How the Earth Shaped Human History
Prof. Lewis Dartnell
University of Westminster
18 September, 2019

Cosmic Dawn: The Search for the First Stars
Prof. Jeff Peterson
Carnegie Mellon University
08 October, 2019

String Theory: How the Universe Speaks in Numbers
Anh-Khoi Trinh
McGill University
21 November, 2019

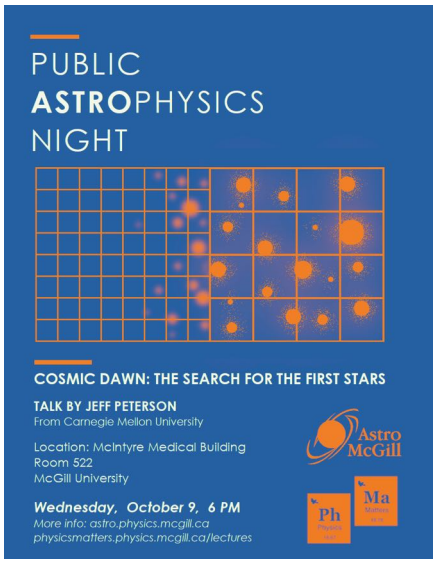
The Oldest Light in the Universe
Prof. Jon Sievers
McGill University
05 December, 2019

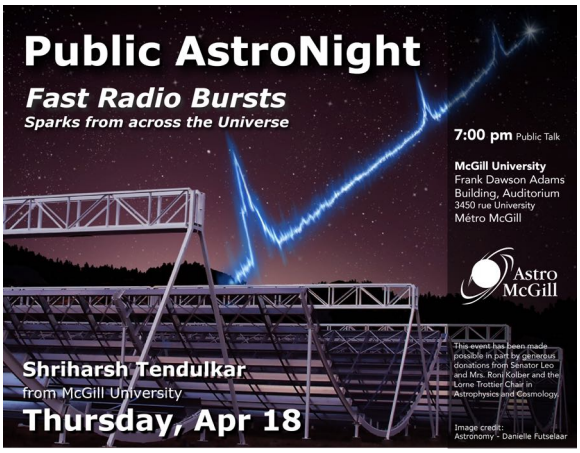

Public AstroNight
The Search for Life on Mars
is About to Get Serious
7:00 pm Public Talk
McGill University
Frank Dawson Adams
Building, Auditorium
3450 rue University
Metro McGill
Astro McGill
Prof. Richard Léveillé &
Prof. Lyle Whyte
from McGill University
Thursday, Nov. 22
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.
Image credits: NASA


Public AstroNight
À la recherche de neutrinos
et de l'origine des rayons cosmiques
7:00 pm conférence au grand public
McGill University
Frank Dawson Adams Building, Auditorium
3450 rue University
Métro McGill
Astro McGill
Étienne Bourbeau
de University of Copenhagen
Jeudi, 11 octobre
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.

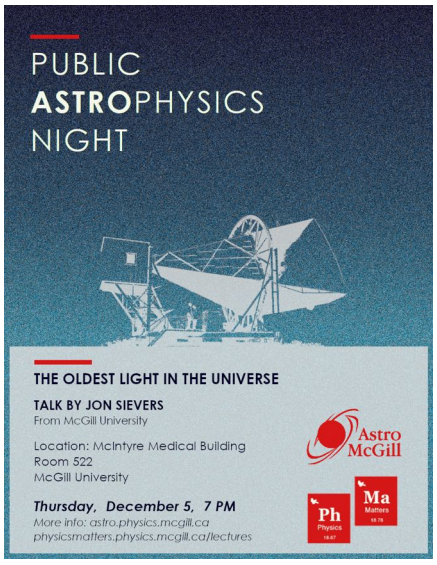

Public Astro Night
Psyche: Journey to a Metal World
7:00 PM Public Talk
McGill University
Frank Dawson Adams
Building, Auditorium
3450 Rue University
Metro McGill
Astro McGill
Lindy Elkins-Tanton
Arizona State University
Thursday, January 31st
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.
Image credits: ASU

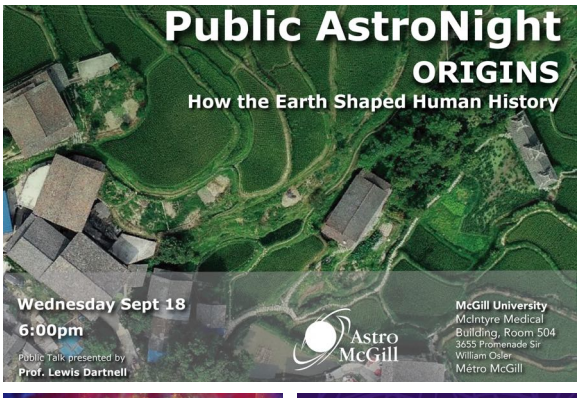

Public AstroNight
Pinging space rocks
at the Arecibo Observatory
7:00 pm Public Talk
McGill University
McConnell room 204
3480 rue University
Metro McGill
Astro McGill
Dr. Flaviane Venditti
from Arecibo Observatory
Thursday, Sept. 20
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.
Image credits: the Arecibo Observatory


PUBLIC
ASTROPHYSICS
NIGHT
COSMIC DAWN: THE SEARCH FOR THE FIRST STARS
TALK BY JEFF PETERSON
From Carnegie Mellon University
Location: McIntyre Medical Building
Room 522
McGill University
Wednesday, October 9, 6 PM
More info: astro.physics.mcgill.ca
physicsmatters.physics.mcgill.ca/lectures
Astro McGill
Ph
Ma

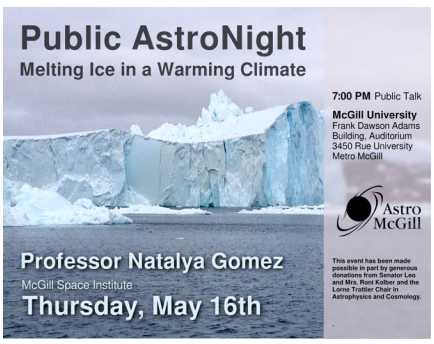

Public AstroNight
Fast Radio Bursts
Sparks from across the Universe
7:00 pm Public Talk
McGill University
Frank Dawson Adams
Building, Auditorium
3450 rue University
Métro McGill
Astro McGill
Shriharsh Tendulkar
from McGill University
Thursday, Apr 18
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.
Image credit: Astronomy - Danielle Futselaar

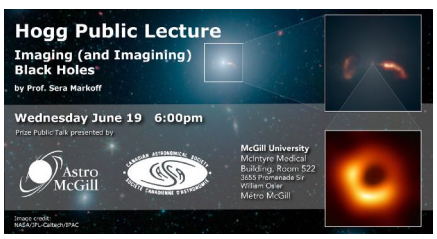

Public AstroNight
Black Holes at Cosmic Dawn
7:00 PM Public Talk
McGill University
McConnell Engineering
Building, Room 204
3840 rue University
Metro McGill
Astro McGill
Dr. Jordan Mirocha
McGill Space Institute
Thursday, March 21st
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.
Image credits: NASA

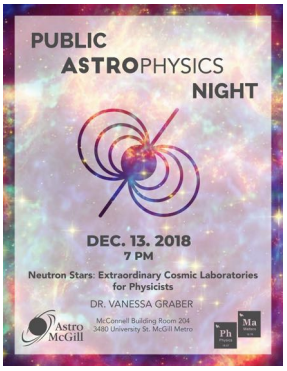

PUBLIC
ASTROPHYSICS
NIGHT
THE OLDEST LIGHT IN THE UNIVERSE
TALK BY JON SIEVERS
From McGill University
Location: McIntyre Medical Building
Room 522
McGill University
Thursday, December 5, 7 PM
More info: astro.physics.mcgill.ca
physicsmatters.physics.mcgill.ca/lectures
Astro McGill
Ph
Ma

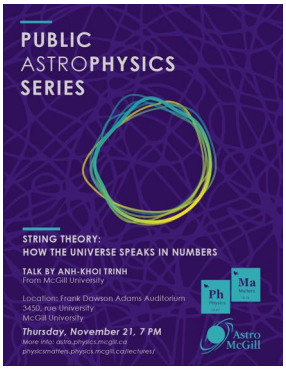

Public AstroNight
ORIGINS
How the Earth Shaped Human History
Wednesday Sept 18
6:00pm
Public Talk presented by
Prof. Lewis Dartnell
Astro McGill
McGill University
McIntyre Medical
Building, Room 504
3655 Promenade Sir
William Osler
Métro McGill


Public AstroNight
Searching for Cosmic Dawn
7:00 pm Public Talk
McGill University
McConnell 204
3480 rue University
Métro McGill
Astro McGill
Cynthia Chiang
from McGill University
Thursday, Feb 21
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.


Public AstroNight
Melting Ice in a Warming Climate
7:00 PM Public Talk
McGill University
Frank Dawson Adams
Building, Auditorium
3450 Rue University
Metro McGill
Astro McGill
Professor Natalya Gomez
McGill Space Institute
Thursday, May 16th
This event has been made possible in part by generous donations from Senator Leo and Mrs. Roni Kolber and the Lorne Trottier Chair in Astrophysics and Cosmology.

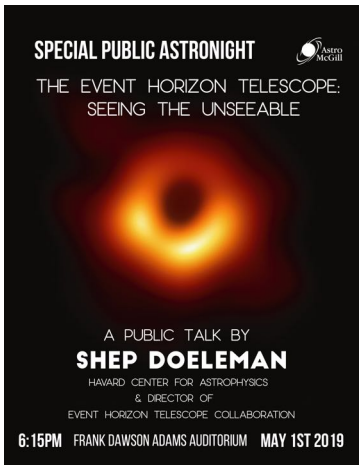

Hogg Public Lecture
Imaging (and Imagining)
Black Holes
by Prof. Sera Markoff
Wednesday June 19 6:00pm
Prize Public Talk presented by
Astro McGill
McGill University
McIntyre Medical
Building, Room 522
3655 Promenade Sir
William Osler
Métro McGill
Image credit:
NASA/JPL-Caltech/STScI


PUBLIC
ASTROPHYSICS
NIGHT
DEC. 13. 2018
7 PM
Neutron Stars: Extraordinary Cosmic Laboratories for Physicists
DR. VANESSA GRABER
Astro McGill
McConnell Building Room 204
3480 University St. McGill Metro
Ph
Ma


PUBLIC
ASTROPHYSICS
SERIES
STRING THEORY:
HOW THE UNIVERSE SPEAKS IN NUMBERS
TALK BY ANH-KHOI TRINH
From McGill University
Location: Frank Dawson Adams Auditorium
3450, rue University
McGill University
Thursday, November 21, 7 PM
More info: astro.physics.mcgill.ca
physicsmatters.physics.mcgill.ca/lectures/
Ph
Ma
Astro McGill

Spotlight: The First Ever Image of a Black Hole

In April 2019, the Event Horizon Telescope (EHT) Collaboration (of which MSI **Prof. Daryl Haggard** is a member) unveiled the first direct image of a black hole. The image reveals the supermassive black hole at the centre of Messier 87, a galaxy in the nearby Virgo galaxy cluster. The shadow created by the gravitational bending and capture of light by the event horizon of the black hole allowed its enormous mass (6.5 million times that of our Sun) to be measured. The resulting image of a bright ring marking where light orbits the black hole, surrounding a dark region where light cannot escape the black hole's gravitational pull, matched expectations from Einstein's theory of gravity.



The EHT used very-long-baseline interferometry (VLBI) to link eight radio telescopes from around the world synchronized to each other with a network of atomic clocks and thus form an Earth-sized virtual telescope with unprecedented resolution and sensitivity. The EHT team then combined petabytes of raw data from the telescopes using highly specialised supercomputers and analysed the data with novel algorithms and techniques in order to produce the image. The EHT collaboration is a shining example of global collaborative science, bringing together over 200 researchers from over 13 institutions around the world.

The MSI organized a series of events around the monumental discovery. Over 70 members of the MSI and the Physics department packed the MSI conference room and lounge to watch the press conference where the image was unveiled. In May of 2019, the MSI was thrilled to host a visit from the Director of the EHT, Shep Doeleman. Dr. Doeleman gave a scientific lecture to the MSI & Physics department, which drew an audience of over 100. Our graduate students and postdoctoral fellows also got the opportunity to interact with Dr. Doeleman over coffee and snacks. The visit was capped by Dr. Doeleman's public lecture "The Event Horizon Telescope: Seeing the Unseeable", which drew almost 700 people and filled McGill's largest auditorium to capacity. It was our most popular lecture to date; tickets to the free public lecture were gone within 24 hours!

Astronomy on Tap

Starting in January 2017, Montreal became a satellite location of the Astronomy on Tap (AoT) popular series, joining more than 70 cities around the world. AoT are free events aiming at making space-related research more accessible to the community by combining short, engaging science presentations with themed trivia games and prizes in a social venue. Unlike most traditional outreach efforts, which generally target people that have already been exposed to scientific public outreach such as public lectures on university campuses, AoT reaches a more diverse audience of adults in a location where people gather to socialize. AoT is also more informal, engaging and relatable than traditional hour-long lectures, which helps AstroMcGill reach an audience that is new to astronomy and space sciences. Initiated by AstroMcGill, AoT MTL are now jointly organized by the Institute for research on exoplanets (iREx), the Centre de recherche en astrophysique du Québec (CRAQ) and AstroMcGill.

In order to share science with Montreal's communities as broadly as possible, AoT MTL monthly events alternate between English and French nights at McLean's Pub (venue capacity of around 100 people) and Pub Ile Noire (capacity of 80 people), respectively. Montreal was the first satellite location to have bilingual AoT events, and has served as a model for other satellite locations (e.g., English/Hungarian AoT in Budapest, Hungary and English/German AoT in Heidelberg, Germany). In November 2019, we organized our first fully-bilingual night at Les Sans-Taverne in Pointe St Charles; one presentation was offered in French; the other in English, and our two trivia games were carried-out in both French and English. It was also our first event that was open to families. Similarly to all our other AoT events, the venue was at full capacity, and many families with young children actively participated.

AoT MTL's popularity has drawn praise from both bar owners, who are notably pleased with the lucrative opportunity AoT offers by bringing crowds to their establishments on slow weeknights, and patrons, who enjoy interacting with professional astronomers in a casual setting. AoT also offers a unique opportunity for scientists at all levels to develop professional skills such as networking, stage presence and vocal projection, and delivering scientific yet non-technical presentations for general audiences.

MSI in the Media

Bridget Andersen
Eight new repeating fast radio bursts detected * **Phys Org** * 19 Aug 2019

Robert Brandenberger
Canadian scientists slam male physicist's 'discriminatory' speech on gender issues * **CBC** * 06 Oct 2018

Pragya Chawla
Mysterious radio signals from deep space picked up by Canadian astronomers * **Metro** * 20 Aug 2019

The weird, repeating signals from deep space just tripled * **cnet** * 19 Aug 2019

Cynthia Chiang
South Africa's HIRAX Telescope Driving Industry Engagements * **Space in Africa** * 17 Oct 2019
The quest to unlock the secrets of the baby Universe * **Nature** * 14 Aug 2019

Nicolas Cowan
Earth's "fingerprint" could one day help us find a habitable exoplanet * **MIT Technology Review** * 02 Sep 2019

Canadian astronomers determine Earth's fingerprint in hopes of finding habitable planets beyond the Solar System * **McGill Newsroom** * 28 Aug 2019

"Clouds of Rock" –Nighsides of Hot Jupiter Exoplanets * **Daily Galaxy** * 27 Aug 2019

What Extraterrestrial Astronomers "Would See if They Observed Earth" * **Daily Galaxy** * 29 Aug 2019

Lisa Dang
The dark side of extrasolar planets share surprisingly similar temperatures * **Science Daily** * 27 Aug 2019

Matt Dobbs
McGill researchers receive $6.5M in funding from the CFI and the Government of Quebec * McGill Newsroom * 12 Aug 2019

Scientist behind massive telescope near Penticton wins prestigious fellowship * Global News * 06 May 2019

McGill team awarded contract to advance potential Canadian contribution for LiteBIRD space telescope * McGill Newsroom * 26 Nov 2019

Matt Dobbs awarded 2019 Killam Research Fellowship in Natural Sciences * CRAQ * 25 Apr 2019

Rene Doyon
Et si 2030, c'était maintenant? * Radio Canada * 01 Jan 2020

Natalya Gomez
Melting ice sheets may cause 'climate chaos' according to new modelling * EurekAlert! * 06 Feb 2019

Antarctic, Greenland melt will really mess up Canadian weather, study finds * CBC * 08 Feb 2019

Rethinking the way science is taught * McGill Reporter * 25 Nov 2019

Vanessa Graber
Pulsar glitch suggests superfluid layers lie within neutron star * physicsworld * 15 Aug 2019

Glitch in neutron star reveals its hidden secrets * McGill Reporter * 21 Aug 2019

Neutron Star 'Glitch' Reveals Engine That Powers Rotation * Courthouse News * 12 Aug 2019

Neutron Star Suffers a "Glitch", Gives Astronomers a Glimpse Into How They Work * Universe Today * 14 Aug 2019

Daryl Haggard
A look back at 2019: Who were McGill's ground breakers and difference makers? * McGill Reporter * 24 Dec 2019

Daryl Haggard, Simon Caron-Huot win 2020 Breakthrough Prizes for Physics * McGill Reporter * 01 Nov 2019

Personnalité de la semaine: Daryl Haggard * La Presse * 21 Apr 2019

What is a black hole and why is it so elusive? * CTV News * Apr 2019

Astronomers Capture First Image of a Black Hole * McGill Newsroom * 10 Apr 2019

Astrophysicist Takes a Fresh Look at the Universe * University Affairs * 03 Dec 2018

IT'S HERE: The First-Ever Close-Up of a Black Hole * LiveScience * 10 Apr 2019

Timothy Hallatt
Researchers investigate interstellar bodies originating from beyond our solar system * Phys Org * 08 Nov 2019

David Hanna
The highest-energy photons ever seen hail from the Crab Nebula * ScienceNews * 24 Jun 2019

Oscar Hernandez
There Might Be Cracks in the Universe — But We Can't See Them from Earth * Space.com * 02 Dec 2019

Are there Invisible Cracks in Spacetime Left Over From the Birth of the Universe? * Syfy Wire * 02 Dec 2019

Yi Huang
In Search of Habitable Worlds Beyond Our Solar System, Astronomers Determine Earth's Fingerprint * SciTechDaily * 01 Sep 2019

Student project could help astronomers search for Earth-like planets * McGill Reporter * 28 Aug 2019

Xiangyu Jin

30 'Homeless' Binary Stars Spotted Drifting in the Void Outside Any Known Galaxy * LiveScience * 30 May 2019

Chandra Space Telescope Sees Star Pairs Ejected From Galaxies * Discover * 03 Jun 2019

Astronomers are Finding Binary Pairs of Stars Thrown out of Galaxies Together * Universe Today * 29 May 2019

Stars expelled two-by-two * Cosmos Magazine * 30 May 2019

Space Photos of the Week: How Stars Get 86'd * Wired * 01 Jun 2019

Vicky Kaspi

New Canadian telescope detecting more brief, powerful radio blasts from far beyond our galaxy * Globe and Mail * 09 Jan 2019

Montreal girl, 6, explores the sky with McGill astrophysicist * Montreal Gazette * 20 Aug 2019

The 4 women on Nature's 'People who mattered in Science in 2019' list * Women's agenda * 17 Dec 2019

CHIME telescope Fast Radio Burst project earns spot in Nature 2019 list * McGill Reporter * 17 Dec 2019

Canadian astronomers find 8 more mysterious repeating fast radio bursts from space * CBC * 17 Aug 2019

A homespun Canadian telescope could explain mysterious radio signals from the distant Universe * AAAS * 14 Mar 2019

Dylan Keating

Hot Jupiters Have Rocky Clouds on Their Nightsides * sci-news * 29 Aug 2019

The dark side of extrasolar planets share surprisingly similar temperatures * McGill Newsroom * 26 Aug 2019

Temp Suggests Rocky Clouds on Hot Jupiter 'Nightsides' * Futurity * 26 Aug 2019

Eve Lee

Cotton candy super-puff worlds found in Kepler 51 star system * Slashgear * 27 Dec 2019

Richard Leveille

Lava Tubes on Earth Could Prepare Us for Life on the Moon and Mars * How Stuff Works * 11 Feb 2019

Adrian Liu

Thirteen early-career researchers explore new frontiers * McGill Newsroom * 23 May 2019

Nagissa Mahmouhdi

McGill researchers receive $3.7M in funding from the Canada Foundation for Innovation and the Government of Quebec * McGill Newsroom * 13 Mar 2019

Arun Naidu

Canada's CHIME telescope detects second repeating fast radio burst * McGill Newsroom * 09 Jan 2019

Repeated Radio Signals From Galaxy 1.5 Billion Light Years Away Discovered: Scientists * The Epoch Times * 14 Feb 2019

New Telescope Picks Up Radio Signals from Deep Space * Technology Networks * 14 Jan 2019

Emilie Parent

PALFA survey reveals eight new millisecond pulsars * Phys.org * 04 Sep 2019

Ziggy Pleunis

MSN | Astronomers Have Detected a Whopping 8 New Repeating Signals From Deep Space * McGill Newsroom * 14 Aug 2019

Astronomers detect 8 new mysterious repeating radio signals from deep space * WTSP * 14 Aug 2019

Giant Radio Telescope in China Just Detected Repeating Signals From Across Space * Sciencealert * 10 Sep 2019

Astronomers Have Detected a Whopping 8 New Repeating Signals From Deep Space * sciencealert * 14 Aug 2019

Ken Ragan

Learning to love physics * McGIll Tribune * 03 Dec 2019

SNOLAB Board Appoints New ED * Interactions * 22 Nov 2019

SNOLAB head agrees to three-year contract extension * Sudbury * 24 Nov 2019

Shriharsh Tendulkar

We have spotted 8 more mysterious repeating radio bursts from space * NewScientist * 19 Aug 2019

Mysterious radio signals from deep space detected * BBC * 09 Jan 2019

A homespun Canadian telescope could explain mysterious radio signals from the distant universe * Sciencemag * 14 Mar 2019

Inreach - Life at MSI

Fostering cross-fertilization and interdisciplinary interactions and collaborations among Institute members is one of the the main missions of MSI. We strive to provide as many opportunities as we can for students, postdoctoral fellows, faculty members, and visiting scholars to share their research and learn from each other. From seminar series to discussion groups to journal clubs, there's never a dull moment at the MSI!

Workshops & Conferences

The MSI allocates part of its annual budget towards providing financial support for conferences organized at McGill University by MSI members, which further the mission and vision of the MSI.

AGM of the Canadian Astronomy Society

The 2019 Annual General Meeting of the Canadian Astronomy Society (CASCA) took place at McGill University in June 2019 and brought together over 400 astronomers from across Canada. MSI provided both financial and in-kind support to make the conference a success; both the local organizing committee and the scientific organizing committee were mostly comprised of MSI members, as were most of the student volunteers who ensured that the 4-day event ran smoothly.

Women in Physics Canada Conference

In June 2019, McGill hosted the Women in Physics Canada Conference, which brought together over 140 undergraduate students, graduate students, postdocs, and professors from across the country. The main objective of the event is to support and encourage junior physicists who identify as a gender minority or under-represented group to persist in the field; 80% of the attendees identified as belonging to an under-represented group. The 3-day program included scientific talks given by renowned female physicists (including the MSI's own Prof. Vicky Kaspi & Prof. Natalya Gomez), student presentations, panel discussions (ranging from career paths in physics, mental health, and equity), and interactive workshops on creating inclusive environments. MSI members were deeply involved at all levels of the conference, from the organizing committee, to speakers, attendees, and volunteers. The conference was a success; the majority of attendees lauded the balance of scientific and equity content, and the sense of community embodied by the conference.

Second Global 21-cm Cosmology Conference

In October 2019, MSI members affiliated with the cosmology group hosted the Second Global 21cm Workshop at McGill University. The workshop brought together about 50 participants from across the world to discuss recent progress from all the Global 21cm experiments. Talks ranged from theory to data analysis, and, above all, instrumental development and field work. The conference also included several discussion sessions spanning the most important aspects and concerns being raised and addressed in 21 cm cosmology today.

MSI Jamboree

The MSI kicks off every academic year with the MSI Jamboree, where we showcase who we are and the breadth of research that we do to new and returning students, postdoctoral fellows, and faculty members. This year's Jamboree took place on September 5, 2019 and was our most ambitious yet; an impressive 20 MSI-affiliated faculty members from all 4 member departments gave quick overviews of their research groups and ongoing projects, in just under two hours! Highlights from this year's Jamboree included a remote video presentation from the beaches of Australia and the introduction of our newest MSI faculty members, Nagissa Mahmoudi (who joined us in April 2019) and Eve Lee (August 2019). The Jamboree was well-attended, with over 70 attendees filling the Rutherford Physics Building's Bell Room to capacity and overflowing into the hallway. The research showcase was followed by wine and cheese in the MSI Lounge. The Jamboree was an overall success and set the tone for what is sure to be an exciting year!

Seminars

The MSI runs two regular seminar series, the MSI Seminar Series and the Joint Astrophysics Seminar Series. MSI Seminars are intended to be accessible to scientists from the entire breadth of backgrounds at MSI, including, physics, planetary science, geology, atmospheric science, and astrobiology. Joint Astrophysics seminars, which are organized in conjunction with the Centre de recherche en astrophysique du Québec (CRAQ), are aimed at astronomers and astrophysicists.

MSI Seminars

Jonathan Gagne
IRex (Institut de recherche sur les exoplanètes), Université de Montréal
11 September, 2018
'The Missing Members of Nearby Young Associations'

Robin Wordsworth
Harvard University
25 September, 2018
'Mars as a case study of an intermittently habitable planet'

Jonathan Pober
Brown University
09 October, 2018
'Observing the Early Universe with 21 cm Cosmology'

Audrey Bouvier
University of Western Ontario
23 October, 2018
'Planetary materials: recorders of the formation of the Solar System and planets '

Ann-Marie Madigan
University of Colorado Boulder
06 November, 2018
'The Importance of Being Eccentric'

MacKenzie Warren
Michigan State University
20 November, 2018
'Studying the sensitivities of multimessenger signals from populations of core-collapse supernovae'

Samantha Lawler
NRC-Herzberg
04 December, 2018
'Planet 9 or Planet Nein? Discoveries in the Outer Solar System

Robyn Sanderson
University of Pennsylvania
08 January, 2019
'Insights into dark matter from the stellar halos of galaxies'

Frederik J Simons
Princeton University
22 January, 2019
'Studying Planetary Lithospheres Using Modern Localization Methods'

Jordan Mirocha
McGill University
05 February, 2019
'New directions in galaxy formation and cosmology following the EDGES 78 MHz detection'

Siamak Ravanbakhsh
UBC
19 February, 2019
'Opportunities for Applications of Deep Learning in Cosmology'

Jun Yang
Peking University
12 March, 2019
'Climate and Habitability of Tidally Locked Planets'

Nathan Kaib
University of Oklahoma
26 March, 2019
'Constraining the Past and Present Distant Solar System with Real and Simulated Trans-Neptunian Objects'

Nagissa Mahmoudi
McGill University
09 April, 2019
'What's on the menu? Investigating the selective diet of microbes using novel isotopic tools'

Curtis Williams
UC Davis
17 September, 2019
'Origin of volatiles in Earth's mantle'

Christopher Smeenk
Western University
01 October, 2019
'General Relativity Stands Alone?'

Anil Seth
University of Utah
15 October, 2019
'Black Holes in Low Mass Galaxies'

Taylor Perron
MIT
29 October, 2019
'The rivers and seas of Titan'

John Moores
York University
12 November, 2019
'The Mystery of Methane on Mars: Fact, Folly or Figment?'

Bekki Dawson
Penn State University
26 November, 2019
'Inner Solar Systems'

Isaac Smith
York University
10 December, 2019
'From ice crystals to ice caps, the climate of Mars as seen at the poles'

AstroPhysics Seminars

Peter Behroozi
University of Arizona
18 September, 2018
'Automated Physics Recovery from Galaxy Observations'

Simeon Bird
UC Riverside
02 October, 2018
'Did LIGO Detect Dark Matter?'

Cora Dvorkin
Harvard University
16 October, 2018
'Looking for Dark Matter off the Beaten Track'

Charlotte Mason
Smithsonian Astrophysical Observatory
30 October, 2018
'What Can Galaxies Tell Us About Reionization?'

Gregg Hallinan
Caltech
13 November, 2018
'Imaging All the Sky All the Time in Search of Radio Exoplanets'

Maria Drout
University of Toronto
27 November, 2018
'The Evolution, Influence, and Ultimate Fate of Massive Stars: Transient Phenomena and Stellar Astrophysics in the Era of Wide-Field Surveys'

Abigail Stevens
Michigan State University
11 December, 2018
'Mapping Matter in Strong Gravity: Spectral-Timing of Black Holes and Neutron Stars'

James Aguirre
University of Pennsylvania
15 January, 2019
The Terahertz Intensity Mapper (TIM)

Enrico Ramirez-Ruiz
UC Santa Cruz
29 January, 2019
'Heavy Element Synthesis in the Universe'

Emmanuel Fonseca, Seth Seigel & Shriharsh Tendulkar
McGill University
12 February, 2019
'Probing the Radio-Transient Universe with CHIME'

Alice Harpole
Stony Brook
19 March, 2019
'Modelling low Mach number astrophysical flows'

Evgenya Shkolnik
Arizona State University
02 April, 2019
'Blast from the Past: The Evolution of Ultraviolet Emission and Flaring from Low-Mass Stars and its Implications for Habitable Zone Planets'

Pawan Kumar
UT Austin
16 April, 2019
'Radiation mechanism of Fast Radio Bursts'

Richard Plotkin
University of Nevada - Reno
10 September, 2019
'Relativistic Jets from Weakly Accreting Black Holes'

James Rhoads
NASA Goddard
24 September, 2019
'Probing Inhomogeneous Reionization with Lyman alpha Surveys: From the ground to WFIRST'

Brian Metzger
Columbia University
08 October, 2019
'Deciphering the Engines of Fast Radio Bursts'

Laura Fissel
National Radio Astronomy Observatory
22 October, 2019
'Studying Star Formation from the Stratosphere'

Susan Clark
Institute for Advanced Study
05 November, 2019
'The Magnetic Interstellar Medium in Three Dimensions'

Adi Foord
University of Michigan
19 November, 2019
'Quantifying the rate of dual-AGN with BAYMAX'

Special Seminars

Joanna Rankin
University of Vermont
13 September, 2018
'What XMM X-ray and Arecibo Radio Observations of Pulsar B0823+26 Have to Teach Us'

Romain Teyssier
University of Zurich
18 October, 2018
'Recent Advances in Computational Cosmology'

Dana Simard
University of Toronto
08 November, 2018
'Reconstructing complex pulsar scattering environments with global VLBI'

Raul Monsalve
McGill University
18 December, 2018
'An Absorption Feature in the Sky-Averaged Radio Spectrum'

Edgar A. Bering III
University of Houston
14 February, 2019
'The X-Ray Aurora'

Lorne Nelson
Bishop's University
04 April, 2019
'Self Induced Irradiation Cycles in Neutron Star Binaries'

Kelly Gourdji
University of Amsterdam
10 May, 2019
'FRBs and Radio Signatures of Gravitational Wave Merger Events'

Hamsa Padmanabhan
CITA - University of Toronto
25 June, 2019
'Mapping the Baryonic Universe: From Reionization to Present-Day Galaxies'

Kenzie Nimmo
University of Amsterdam
18 July, 2019
'Targeted Searches for FRBs Using the EVN'

Kostas Gourgouliatos
Durham University
29 August, 2019
'Electric currents in the crust and the magnetosphere of neutron stars'

Liam Connor
University of Amsterdam
03 September, 2019
'Navigating the New Epoch of FRB Discovery'

Patrick Breysse
CITA
16 September, 2019
'High-redshift astrophysics using every photon'

Nienke van der Marel
NRC Herzberg
25 September, 2019
'A look into the birth cradles of planets with ALMA: signatures of planet formation in protoplanetary disks'

Katia Moskvitch
Science Writer
07 October, 2019
'Science & Journalism: Errors = Media x Confusion ^2'

Francisco Castillo
Pontificia Universidad Catolica de Chile
19 December, 2019
'Two-fluid simulations of the magnetic field evolution in neutron star cores in the weak-coupling regime'

Weekly Discussion Groups

MSI Lunch Talks

The Monday Lunch Talk series provides a forum for MSI grad students, postdoctoral fellows, and faculty members to give short presentations over lunch and then engage in an extended, informal discussion. These lunch discussions are held every other Monday year-round, on weeks where there is no MSI seminar. Speakers are limited to three slides (with unlimited blackboard usage) and are asked to prepare 10 minutes of material for a 30 minute slot; the remaining 20 minutes are filled by questions from the audience and discussion. Speakers may use the opportunity to talk about their research, practice a conference presentation, discuss an interesting finding in their field, or dive deeper into a subject outside their expertise that they'd like to learn more about. Lunch talk topics in 2019 ranged from life as a winter-over at the South Pole Telescope, to a history of stellar winds, to a discussion of how to talk to the press about your research. MSI Lunch Talks are well- attended, regularly drawing anywhere from 25 to 45 participants.

Planet Lunch

The Planet Lunch series brings together about 20 researchers from the Departments of Earth and Planetary Sciences, Atmospheric and Oceanic Sciences, and Physics for a weekly lunch discussion. By bringing together this diverse group, the goal is to apply expertise on geology and planetary atmospheres as studied in our Solar System to exoplanets. In this way we can achieve a much better understanding of what we are learning from the observational data on exoplanets, which is much less detailed than for our Solar System planets. Experience derived from Solar System studies also guide the development of future astronomical facilities to study exoplanets. Each term, the group chooses a theme or particular area of planetary science that they want to learn more about, and each week someone leads a discussion about a paper or a topic related to that theme. In 2019, topics included icy worlds (with a focus on tidal/radiogenic heating, oceans under ice, sea ice rheology, detecting icy worlds), the origins of life, the interior structure and dynamics of planets, and the history and future of Earth (from planet formation to tidal spin-down of Earth, runaway/moist greenhouses, and feedback between life and planets).

Black Hole Lunch

The Black Hole Lunch series is an informal gathering and discussion that centres on supermassive black hole (SMBH) research. The group derives mostly from the research teams of Daryl Haggard (McGill), Julie Hlavacek-Larrondo (UdeM), and Tracy Webb (McGill), but is open to all researchers with McGill/MSI and the University of Montreal. Meetings alternate between McGill and UdeM, where attendees tackle core concepts including growth, feeding, and feedback from SMBHs. They also discuss observational and theoretical challenges and share new discoveries and research findings. This gathering of black hole enthusiasts led to a more formal research collaboration between Profs. Webb, Haggard, and Hlavacek-Larrondo, the "Montreal Black Hole Collaboration" (MCH CoLAB), funded by Fonds de recherche du Quebec - Nature et tecnologies (FRQNT). In the past year, Black Hole Lunch hosted Adi Foord, who led a discussion focused on detection of binary black holes in archival X-ray data, and Marta Volonteri, for a discussion on direct collapse and other formation mechanisms for black hole "seeds".

Random Papers Discussion

The goal of Random Papers is to gain a broad view of current astrophysics research. Each week we run a script to choose 5 random papers published in the last month in refereed astrophysics journals. This gives a different slice of the literature than the typical astro-ph discussion, with papers from outside our own research areas or those that might not otherwise be chosen for discussion. Rather than reading each paper in depth, the goal is to focus on the big picture, with questions such as: How would we summarize the paper in a few sentences? What are the key figures in the paper? What analysis methods are used? Why is this paper being written, and Why now?

Education, Public Outreach, Equity, Diversity & Inclusivity Discussion

EPOD (Education, Public Outreach, Equity, Diversity and Inclusion) Discussion is a weekly discussion group run by the MSI coordinator. In the past year, its mandate has broadened to topics at the intersection of education, equity, and inclusion. EPOD discussions are paper-based, but the paper is usually meant to be a way of framing the discussion of a broader issue. We have also discussed various best practices reports that have been released in the past two years from professional bodies like the AAS, the AIP, and CASCA. MSI members are encouraged to suggest topics and lead the discussion if they so choose! EPOD is meant to give people a space in which to learn about and talk about equity, diversity, and inclusion and how these issues intersect with academia and education. It is also a space in which to source best practices and think about what kind of changes we can implement as a research centre to become a more inclusive and welcoming space for underrepresented groups. In the past year we also introduced EPOD Hack Sessions, where we pick a topic we have discussed and try to tackle a specific project that relates to it. So far we have carried out a quantitative study of the gender breakdown of the department and we started writing a climate survey (which then went on to be its own task force). Preliminary results of the former went on to become the basis of a conference presentation and two posters.

Astro-PH Discussion

Astro-ph is a weekly journal discussion that takes place every Friday morning at the MSI over donuts and coffee. It is an open and intellectual discussion where people can feel free to share something they've learned from an interesting paper without criticism, and where the astronomy community at McGill can learn from one another. It lasts around 30 minutes and is named so because of the arXiv tag from where nearly all our papers come: astro-ph!

Cosmo-PH Discussion

Cosmo-ph is a weekly journal club at MSI focused on keeping up with recent results in observational and theoretical cosmology. Discussions are generally led by graduate students and postdocs, and feature papers that have appeared on the arxiv in the last few weeks. Attendees include researchers at all career stages, with expertise spanning a broad range, from instrumentation, to observations and data analysis, to high-energy particle theory.

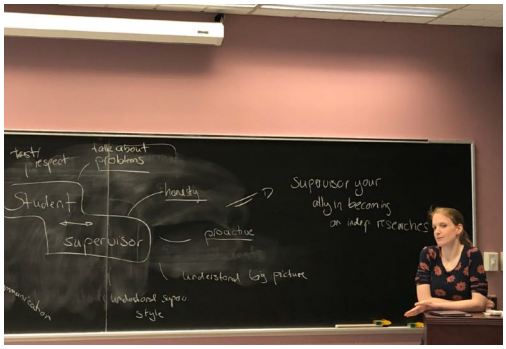
Neutron Star Discussion

Neutron stars are a common thread that join multiple research groups at MSI. They are a possible source of at least some Fast Radio Bursts, being detected in large numbers by CHIME (Prof. Kaspi's & Prof. Dobbs's groups), the discovery of a neutron star merger by LIGO has opened up a new way of studying these exotic objects (Prof. Haggard's group), and they are associated with emission at all astronomical wavelengths, including the highest energy photons (Profs. Hanna and Ragan). These new observational discoveries are challenging theories of how neutron stars form and evolve, and what matter is like in their dense interiors (Prof. Cumming). Each week, researchers from across MSI come together to discuss the latest papers and discoveries involving neutron stars in an informal setting.

MSI Undergraduate Summer Program

Every summer since its inception, MSI hosts undergraduate summer research students from McGill and universities across the world. Building upon the incredible success of last year's program, in Summer 2019 the MSI was asked to join forces with the Department of Physics to host a joint summer program for all undergraduates conducting summer research with MSI-affiliated or Physics-affiliated professors. This combined program hosted over 60 undergraduate summer researchers, of which approximately 25 were working with MSI researchers, our largest cohort yet!

Although undergraduate researchers are hired to work in a particular professor's research group, they are encouraged to take part in all MSI activities, including seminars, journal clubs, and informal discussions. Thanks to the friendly community and welcoming environment of the MSI, summer undergraduate researchers gain exposure to many different research areas well beyond their own group.



Professional development discussions

A unique feature of the MSI summer undergraduate research program is a weekly seminar series for the undergraduate interns. The format of these weekly seminars is a casual discussion, organized by MSI Coordinator Carolina Cruz-Vinaccia and MSI Postdoctoral Fellow John Ruan, with immense help from various other MSI members. Discussion topics centre primarily around professional development, such as 'how to give effective talks', 'how to write scientific papers', 'applying to graduate school', and 'pursuing non-academic careers'. This year's program also emphasized non-academic topics that impact researchers, such as dealing with frustration, how to tackle impostor syndrome, and a workshop on diversity and inclusion in STEM (co-led by the McGill Women in Physics Committee).

The primary goal of this weekly seminar series is to provide guidance and mentorship for students at the earliest stage of their research careers, when they often feel lost and isolated in their work. However, an important secondary benefit of these weekly lunch seminars is to foster a sense of community amongst the undergraduate summer researchers, and ensure that they become familiar with their peers. The seminars were well attended (average of ~30 students per week, despite travel, vacation plans, etc.), and our end-of-summer survey evaluations showed unanimous support from the undergraduates for this effort.

Summer Undergraduate Research Showcase

At the end of the summer, we organized a Summer Undergraduate Research Showcase, where undergraduate summer researchers were given the opportunity to present the results of their project to the entire MSI and Physics department. The undergraduate research projects covered a wide range of topics that reflected the diverse and interdisciplinary nature of the MSI. For example, undergraduate students worked on algorithms to mitigate radio interference in detecting fast radio bursts using the Canadian Hydrogen Intensity Mapping Experiment, optical imaging of the first merger between a neutron star and a black hole detected through gravitational waves, and methods to reconstruct maps of the surfaces of exoplanets. The presentations were extremely impressive and well-received by the audience. The organizers are eager to build on the success of the MSI summer undergraduate research program next summer, and thank the MSI and the Physics Department for funding the weekly lunch seminars!

MSI Fellowships

McGill Space Institute Fellowships are made possible by a generous $1 million donation from the **Trottier Family Foundation** to support MSI postdoctoral researchers and graduate students. McGill Space Institute Postdoctoral Fellowships are awarded by a committee of faculty members who span different fields of the MSI and recognize excellence in research. All MSI graduate students receive a portion of their funding from the Trottier Family Foundation's gift.

MSI Postdoctoral Fellows

Suddhasattwa Brahma

Physics
Prof. Robert Brandenberger's Group
Dr. Brahma joined the MSI as an MSI postdoctoral fellow in Fall 2019. His research interests include early universe cosmology and implications of quantum gravity for cosmological observations. Currently, he's been working on different quantum aspects of de Sitter space, and its relationship with string theory, besides looking at alternative models of dark energy.

Thomas Navarro

Earth & Planetary Sciences
Prof. Natalya Gomez, Prof. Nicolas Cowan, Prof. Tim Merlis
Dr. Navarro joined the MSI as an MSI postdoctoral fellow in Fall 2019. Dr Navarro explores the meteorology and climate of terrestrial planets with general circulation models and observations. His research interests are the Martian dust and water cycles, Venus' atmospheric circulation, and the possible climates of tidally locked exoplanets.

Isabelle Raymond-Bouchard

Natural Resource Sciences
Prof. Lyle Whyte's Group
Dr. Raymond-Bouchard has been an MSI Postdoctoral Fellow since Fall 2017. Her research interests include astrobiology, the development of novel methods for life detection, and the study of microbes and their adaptations to extreme environments.

John Ruan

Physics
Prof. Daryl Haggard's Group
Dr. Ruan has been an MSI Postdoctoral Fellow since Fall 2017. His research interests include multi-wavelength & multi-messenger astronomy, active galactic nuclei (AGN) variability, accretion state transitions, AGN/X-ray binary connection, electromagnetic counterparts to gravitational waves and cosmic neutrinos.

Heath Shipley

Physics
Prof. Tracy Webbs's Group
Dr. Shipley has been an MSI Postdoctoral Fellow since Fall 2018. Hisresearch interests include extra-galactic astronomy, particularly galaxy evolution with focus on active galaxies, active galactic nuclei, galaxy and supermassive black hole coevolution utilizing the entire electromagnetic spectrum.

Yuwei Wang

Atmospheric & Oceanic Sciences
Prof. Yi Huang's Group
Dr. Wang has been an MSI Postdoctoral Fellow since Fall 2018. His research interests include radiative, convective and dynamical adjustments, climate dynamics of Earth and exoplanets, and radiative transfer.

Awards

Faculty Members

Nicolas Cowan
- Harvey B. Richer Gold Medal 2019, Canadian Astronomical Society
- Canada Research Chair in Planetary Climate (Tier 2)

Matt Dobbs
2019 Killam Research Fellowship In Natural Sciences

Natalya Gomez
AGU Cryosphere Early Career Award

Daryl Haggard
- Breakthrough Prize in Fundamental Physics
- Canada Research Chair in Multi-messenger Astrophysics (Tier 2)

Vicky Kaspi
- 2019 John David Jackson Award for Excellence in Teaching (Dept of Physics)
- 2019 Nature's Top 10 People Who Mattered in Science

Adrian Liu
CIFAR Azrieli Global Scholar 2018

Postdoctoral Fellows

Daniele Michilli
Banting Postdoctoral Fellow 2019

Graduate Students

Omar Alaryani
UAE Fellowship in Science & Engineering

Mesbah Alsarraj
Al-Ghurair STEM Scholarship

Bridget Andersen
Chawlke-Rowles Fellowship

Taylor Bell
NSERC PGS-D

Mohit Bhardwaj
FRQNT Doctoral Scholarship

Blenner-Hasset/Olivia
FRQNT Doctoral Scholarship

Hope Boyce
NSERC PGS-D

Pragya Chawla
FRQNT Doctoral Scholarship

Vincent Comeau
FRQNT Master's Scholarship

Bryce Cyr
Vanier Canada Graduate Scholarship 2019

Lisa Dang
- Special Recognition to the Principal Prize for Public Engagement
- NSERC PGS-D

Valérie Desharnais
Wolfe Fellowship

Constanza Echiburu
Wolfe Fellowship

Simon Guichandut
FRQNT Master's Scholarship

Holly Han
Geraldine Davidson Fellowship

Benoit Laurent
NSERC CGS-M (Canada Graduate Scholarship, Masters)

Catherine Maggiori
NSERC PGS-D

Gabrielle Mitchell
NSERC CGS-M (Canada Graduate Scholarship, Masters)

Melissa Marquette
Wares Fellowship, EPS Department

Keavin Moore
Tomlinson Fellowship

Emilie Parent
Vanier Canada Graduate Scholarship 2018

Ziggy Pleunis
Schulich Fellowship

David Purnell
Geraldine Davidson Fellowship

Maclean Rouble
Wolfe Fellowship

Jean-Samuel Roux
FRQNT Master's Scholarship

MSI Members

Faculty Members

Robert Brandenberger	Phys
Cynthia Chiang	Phys
Jim Cline	Phys
Nicolas Cowan	Phys & EPS
Andrew Cumming	Phys
Matt Dobbs	Phys
René Doyon	Phys
Natalya Gomez	EPS
Daryl Haggard	Phys
David Hanna	Phys
Yi Huang	AOS
Vicky Kaspi	Phys
Eve Lee	Phys
Adrian Liu	Phys
Nagissa Mahmoudi	EPS
Timothy Merlis	AOS
Ken Ragan	Phys
Jonathan Sievers	Phys
Tracy Webb	Phys
Lyle Whyte	NRS

Associate Members

Oscar Hernandez	Phys
Richard Leveille	Phys

Postdoctoral Fellows

Suddhasattwa Brahma	Phys
Matt Caplan	Phys
Erik Chan	EPS
Jonathan Cornell	Phys
Emmanuel Fonseca	Phys
Vanessa Graber	Phys
Sajan Kumar	Phys
Daniele Michilli	Phys
Jordan Mirocha	Phys
Raul Monsalve	Phys
Arun Naidu	Phys
Thomas Navarro	EPS
Isabelle Raymond-Bouchard	NRS
John Ruan	Phys
Heath Shipley	Phys
Seth Siegel	Phys
Saurabh Singh	Phys
Shriharsh Tendulkar	Phys
Yuwei Wang	AOS
Dallas Wulf	Phys
Ben Zitzer	Phys
Fernando Zago	Phys

Staff

Carolina Cruz-Vinaccia	*MSI Coordinator*

Graduate Students

Soud Al Karusi	Phys
Omar Alaryani	Phys
Mesbah Alsarraj	Phys
Bridget Andersen	Phys
Capucine Barfety	Phys
Taylor Bell	Phys
Sabrina Berger	Phys
Mohit Bhardwaj	Phys
Olivia Blenner-Hasset	NRS
Paula Boubel	Phys
Elie Bouffard	Phys
Hope Boyce	Phys
Paul Charlton	Phys
Pragya Chawla	Phys
Jeremie Choquette	Phys
Vincent Comeau	Phys
João Corrêa Buschinelli	Phys
Disrael Cunha	Phys
Alice Curtin	Phys
Bryce Cyr	Phys
Lisa Dang	Phys
Sreela Das	Phys
Valérie Desharnais	Phys
Constanza Echiburu	Phys
Emma Ellingwood	Phys
Guilherme Franzmann	Phys
Hannah Fronenberg	Phys
Rafael Fuentes	Phys
Samskruthi Ganjam	Phys
Erin Gibbons	EPS
Simon Guichandot	Phys
Clare Guimond	EPS
Timothy Hallatt	Phys
Holly Han	EPS
Xiangyu Jin	Phys
Alexandre Josephy	Phys
Zarif Kader	Phys
Dylan Keating	Phys
Marie-Pier Labonte	AOS
Samuel Laliberte	Phys
Julia Lascar	Phys
Benoit Laurent	Phys
Tsen-Yuan Lin	Phys
Matthew Lundy	Phys
Catherin Maggiori	NRS
Melissa Marquette	EPS
Elizabeth "Lisa" McBride	Phys
Tristan Ménard	Phys
Melissa Mendes Silva	Phys
Marcus Merryfield	Phys
Gabrielle Mitchell	Phys
Joshua Montgomery	Phys
Keavin Moore	EPS
Matthew Muscat	Phys
Gavin Noble	Phys
Brady O'Connor	NRS
Deniz Olcek	Phys
Michael Pagano	Phys
Emilie Parent	Phys
Matheus Pessoa	Phys
Ziggy Pleunis	Phys
Matteo Puel	Phys
David Purnell	EPS
Jerome Quintin	Phys
Thomas Rosin	Phys
Maclean Rouble	Phys
Jean-Samuel Roux	Phys
Andrew Sikora	Phys
David Touchette	NRS
Felix Valin	Phys
Jeannette Wan	EPS
Ziwei Wang	Phys
Andrew Zwaniga	Phys

Undergraduate Students

Agnibha Banerjee	Phys
Joelle-Marie Begin Miolan	Phys
Ian Benlolo	Phys
Youssef Bestavros	Phys
Claudia Bielecki	Phys
Mathieu Bruneault	Phys
Etienne Camphuis	Phys
Dixin Chen	Phys
Taj Dyson	Phys
Jakob Faber	Phys
Samuel Gagnon-Hartman	Phys
Ingrid Gendron	EPS
Leo Goutte	Phys
Christian Hellum Bye	Phys
Emilie Laflèche	Phys
Henri Lamarre	Phys
Ronan Legin	Phys
Mathilde Malin	Phys
Damien Pinto	Phys
Eduardo Ploerer	Phys
Andres Ross	Phys
Prashant Shukla	Phys
Simon Tartakovsky	Phys
Nicholas Vieira	Phys
Lan Xi Zhu	Phys

Former MSI Members: Where are they Now?

Postdoctoral Fellows

Matthew Caplan
Assistant Professor of Physics
Illinois State University (USA)

Erik Chan
Research Associate
Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences (Germany)

Jonathan Cornell
Assistant Professor of Physics
Weber State University (USA)

Vanessa Graber
Senior Postdoctoral Researcher
Institute for Space Sciences (ICE-CSIC) (Spain)

Melania Nynka
Research Scientist
MIT Kavli Institute for Astrophysics and Space Research (USA)

Holly Sheets
Lecturer
Albion College (USA)

Shriharsh Tendulkar
Assistant Professor of Physics
Tata Institute of Fundamental Research (TIFR, Mumbai) / National Centre for Radio Astrophysics (NCRA, Pune)

Takashi Toma
Assistant Professor
Institute of Liberal Arts and Science Kanazawa University (Japan)

Benjamin Zitzer
Systems Engineer
L3Harris Technologies

Graduate Students

Elie Bouffard
Analyst/programmer
GIRO Montreal

Jeremie Choquette
Continuing Education Instructor
Dawson College, Montreal

Disrael Cunha
Postdoctoral Fellow
Universite Louvain (Belgium)

Sreela Das
Data Analyst
GradeSlam

Guilherme Franzmann
Postdoctoral Fellow
NORDITA (Sweden)

Juan Mena Parra
Postdoctoral Scholar, Kavli Postdoctoral Fellow
MIT Kavli Institute for Astrophysics and Space Research (USA)

Gavin Noble
PhD Candidate
University of Toronto (as of Fall 2020)

Jerome Quintin
Postdoctoral Fellow
Max Planck Institute for Gravitational Physics, Potsdam (Germany)

Jonathan Tyler
Research Officer
NRC Ottawa

MSI Board & Committees

MSI Board 2019

External Members

Lorne Trottier
Co-founder · Matrox

Marc Guilbert
Chief Financial Officer · Kelvin Zero Inc.

Vassiliki Kalogera
Director · CIERA Institute at Northwestern University

Internal McGill Members

Chris Manfredi
Provost

Martha Crago
Vice Principal - Research & Innovation

Bruce Lennox
Dean · Faculty of Science

MSI Members

Vicky Kaspi
Director · McGill Space Institute; Professor of Physics

Andrew Cumming
Associate Director · McGill Space Institute; Associate Professor of Physics

Matt Dobbs
Professor of Physics

Robert Brandenberger
Professor of Physics

Timothy Merlis
Associate Professor of Atmospheric & Oceanic Sciences

Isabelle Raymond-Bouchard
Postdoctoral Fellow, Natural Resource Sciences

Emilie Parent
PhD Student, Physics

MSI Committees

Fellowships Committee

Natalya Gomez [Co-Chair]
Assistant Professor, EPS

Adrian Liu [Co-Chair]
Assistant Professor, Physics

Robert Brandenberger
Professor, Physics

Tracy Webb
Associate Professor, Physics

MSI Seminar Committee

Adrian Liu [Co-Chair]
Assistant Professor, Physics

Eve Lee [Co-Chair]
Assistant Professor, Physics

Daniele Michilli
Postdoctoral Fellow, Physics

Raul Monsalve
Postdoctoral Fellow, Physics

Thomas Navarro
Postdoctoral Fellow, EPS

John Ruan
Postdoctoral Fellow, Physics

Carolina Cruz-Vinaccia
MSI Coordinator

AstroMcGill Steering Committee

Daryl Haggard
Associate Professor, Physics

Bridget Andersen
PhD Student, Physics

Taylor Bell
PhD Student, Physics

Lisa Dang
PhD Student, Physics

Emilie Parent
PhD Student, Physics

John Ruan
Postdoctoral Fellow, Physics

Carolina Cruz-Vinaccia
MSI Coordinator

Facilities Used by MSI Members

Laboratory and Computing Facilities

The McGill Cosmology Instrumentation Laboratory
(Dobbs)
Develops complex digital and ultra-low noise analog cryogenic electronics for astrophysics. Includes separate labs for radio instrumentation and mm-wave instrumentation.

The Gamma-ray Astronomy Laboratory
(Hanna, Ragan)
Develops instrumentation for astroparticle and particle physics detectors.

Prof. Whyte's laboratory
One of the few laboratories worldwide with the facilities to perform fundamental studies at subzero temperatures for molecular biology/microbiology and astrobiology-related investigations.

The McGill High Arctic Research Station (MARS)
(Whyte, Chiang)
Supports field research activities consisting of sample acquisition, some limited laboratory microbial and molecular analyses, and in situ analyses for microbial activity. Also used for low-frequency radio astronomy observations.

McGill Radio Lab
(Chiang)
Develops radio instrumentation for observational cosmology experiments.

Guillimin supercomputer
(Haggard, Huang, Kaspi, Gomez, Ragan, Hanna)
Owned and administered by Compute Canada and Calcul Quebec

Béluga supercomputer
(Lee, Kaspi)
Owned and administered by Compute Canada and Calcul Quebec

Ground-based Telescopes

Observatoire du Mont-Mégantic
(Cowan, Haggard)

The Canadian Hydrogen Intensity Mapping Experiment, CHIME
(Dobbs, Hanna, Kaspi)

Pulsar backend recording and analysis system for CHIME
(Kaspi, Dobbs)

W.M. Keck Observatory
(Webb)

Canada-France-Hawaii Telescope
(Cowan, Haggard, Webb)

VERITAS Gamma-ray Telescope
(Hanna, Ragan)

South Pole Telescope, mm-wave, Cosmic Microwave Background
(Dobbs)

POLARBEAR & the Simon's Array, mm-wave, Cosmic Microwave Background
(Dobbs)

Atacama Large Millimeter Array
(Webb)

Arecibo Observatory, Radio wavelengths
(Kaspi)

Green Bank Telescope, Radio wavelengths
(Kaspi)

Jansky Very Large Array, Radio wavelengths
(Haggard, Kaspi, Webb)

Large Millimeter Telescope Alfonso Serrano
(Webb)

Anglo-Australian Telescope
(Webb)

Probing Radio Intensity at high-Z from Marion (PRIZM)
(Chiang, Sievers)

The Hydrogen and Intensity Real-time Analysis eXperiment (HIRAX)
(Chiang, Dobbs, Sievers)

C-Band All Sky Survey (C-BASS)
(Chiang, Sievers)

The Hydrogen Epoch of Reionization Array (HERA)
(Liu)

Gemini Observatory
(Haggard, Webb)

James Clerk Maxwell Telescope
(Haggard)

Event Horizon Telescope Array
(Haggard)

Space-based Telescope Facilities

EBEX stratospheric balloon telescope
(Dobbs)
Co-built in the McGill Cosmology Instrumentation Laboratory, funded by NASA and the CSA.

NASA/Hubble Space Telescope
(Cowan, Webb)

NASA/Kepler Mission
(Cowan)

NASA/Swift X-ray Telescope
(Cumming, Haggard, Kaspi)

NASA/Neutron Star Interior Composition Explorer, NICER
(Kaspi)

NASA/NuSTAR X-ray Mission
(Cumming, Kaspi)

NASA/Chandra X-ray Observatory
(Haggard, Kaspi, Webb)

ESA/XMM-Newton X-ray Telescope
(Cumming, Haggard, Kaspi, Webb)

NASA Spitzer Space Telescope
(Haggard, Cowan, Webb)

NASA/Fermi mission
(Ragan)

NASA/Transiting Exoplanet Survey Satellite
(Lee)

MSI Faculty Collaborations

ARIEL Atmospheric Remote-sensing Infrared Exoplanet Large-survey
(Cowan)
Other participating countries:
✳ UK ✳ France ✳ Italy ✳ Poland ✳ Belgium ✳ Spain ✳ the Netherlands ✳ Austria ✳ Denmark ✳ Ireland ✳ Norway ✳ Sweden ✳ Czech Republic ✳ Hungary ✳ Portugal ✳ Germany ✳ Estonia

C-BASS: C-Band All Sky Survey
(Chiang, Sievers)
Other participating institutions:
✳ University of Oxford ✳ King Abdulaziz City for Science and Technology ✳ University of Manchester ✳ University of KwaZulu-Natal ✳Rhodes University ✳ SKA-South Africa ✳ Caltech

CASE Contribution to ARIEL Spectroscopy of Exoplanets
(Cowan)
Other participating institutions:
✳ Jet Propulsion Laboratory ✳ Arizona State University ✳ University of Arizona ✳ UC Santa Cruz, University of Chicago ✳ Smithsonian Astrophysical Observatory ✳ Penn State University, Space Science Institute ✳ Grinnell College ✳ INAF-Osservatorio Astronomico di Palermo ✳ Space Telescope Science Institute

CASTOR - Cosmological Advanced Survey Telescope for Optical and Ultraviolet Research
(Haggard, Cowan)
Other participating institutions:
✳ ABB ✳ Athabasca University ✳ Bishop's University ✳ Caltech ✳ Drexel University ✳ Dunlap Institute ✳ Honeywell ✳ The Infrared Processing and Analysis Center ✳ Jet Propulsion Laboratory ✳ McMaster University ✳ NRC-Herzberg ✳ Queen's University Belfast ✳ Royal Military College ✳ The Royal Observatory, Edinburgh ✳ St. Mary's University ✳ Subaru-NAOJ ✳ UC Riverside ✳ University of Alberta ✳ University of Arizona ✳ Universite de Laval ✳ University of British Columbia ✳ University of Calgary ✳ University of Manitoba ✳ University of Montreal ✳ University of Paris ✳ University of Potsdam ✳ University of Toronto ✳ University of Victoria ✳ University of Waterloo ✳ University of Victoria ✳ University of Washington ✳ University of Waterloo ✳ Western University ✳ York University

CHIME The Canadian Hydrogen Intensity Mapping Experiment
Cosmology (Dobbs) and Fast Radio Burst (Kaspi, Dobbs)
Other participating institutions:
✳ Dominion Radio Astrophysical Observatory ✳ University of British Columbia ✳ University of Toronto ✳ U.S. National Radio Astronomy Observatory ✳ Perimeter Institute ✳ West Virginia university ✳ Yale University ✳ MIT

Colibri - Canadian High-Resolution X-ray Telescope
(Haggard, Cumming)
Other participating institutions:
✳ St. Mary's University ✳ Western University ✳ Queen's University ✳ TRIUMF ✳ Bishop's University ✳ University of British Columbia ✳ University of Alberta ✳ University of Manitoba

D3A - Deep Dish Development Array
(Chiang, Dobbs, Sievers)
Other participating institutions:
✳ National Research Council ✳ Dominion Radio Astrophysical Observatory ✳ University of Toronto

EPPE Extrasolar Planet Polarimetry Explorer
(Cowan)
Other participating institutions:
✳Western Ontario ✳ Magellan Aerospace ✳ NRC Hertzberg

Event Horizon Telescope Collaboration
(Haggard)
Other participating institutions:
✳ Academia Sinica Institute of Astronomy and Astrophysics ✳ Barnard College ✳ Boston University ✳Caltech Directory ✳ Chinese Academy of Sciences ✳ Columbia University ✳ Goethe University of Frankfurt ✳ Harvard University ✳ Harvard-Smithsonian Center for Astrophysics ✳Instituto de Astrofísica de Andalucía ✳ Jagiellonian University ✳ Jet Propulsion Laboratory ✳ Kavli Institute for Astronomy and Astrophysics at Peking University ✳ Korea Astronomy and Space Science Institute ✳ Max Planck Institute for Extraterrestrial Physics ✳ Max Planck Institute for Radio Astronomy ✳ McGill University ✳ MIT ✳ MIT Haystack Observatory ✳ National Astronomical Observatory of Japan ✳ National Institute of Astrophysics, Rome ✳ National Radio Astronomy Observatory ✳ National Taiwan University ✳ Peking University✳ Perimeter Institute ✳ Purdue University ✳ Purple Mountain Observatory✳ Radboud University ✳ Shanghai Astronomical Observatory ✳ Steward Observatory ✳ The Pennsylvania State University ✳ Universidad de Concepción ✳ University of Amsterdam ✳University of Arizona ✳ University of California, Los Angeles ✳ University of Heidelberg ✳ University of Köln ✳ University of Manchester ✳ University of Maryland ✳ University of Massachusetts ✳ University of Michigan ✳ University of Padova ✳ University of Tokyo ✳ University of Waterloo ✳ Villanova University ✳ Würzburg University

GBNCC The Green Bank North Celestial Cap pulsar survey
(Kaspi)
Other participating institutions:
✳ ASTRON ✳ National Radio Astronomy Observatory ✳ Universiteit van Amsterdam ✳ University of British Columbia ✳ University of New Mexico ✳ University of Texas at Brownsville ✳ University of Virginia ✳ West Virginia University on ✳ Western Michigan University

HELIX - High Energy Light Ion eXperiment
(Hanna)
Other participating institutions:
✳ University of Chicago ✳ Penn State University ✳ Ohio State University ✳ University of Michigan ✳ Indiana University ✳ Northern Kentucky University

HERA - The Hydrogen Epoch of Reionization Array
(Liu)
Other participating institutions:
Arizona State University ✳ Brown University ✳ University of California Berkeley ✳ University of California Los Angeles ✳ University of Cambridge ✳ Massachusetts Institute of Technology ✳ National Radio Astronomy Observatory ✳ University of Pennsylvania ✳ Scuola Normale Superiore di Pisa ✳ SKA-South Africa ✳ University of Washington

HIRAX
(Chiang, Dobbs, Sievers)
Other participating institutions
✳University of KwaZulu-Natal ✳ NRF-SARAO South African Radio Astronomy Observatory ✳ Durban University of Technology ✳ University of Cape Town ✳ Rhodes University ✳ Universiteit Stellenbosch University ✳ University of the Western Cape ✳ Botswana International University of Science and Technology ✳ African Institute for Mathematical Sciences ✳ APC Laboratoire Astroparticule & Cosmologie ✳ UBC ✳ Carnegie Mellon University ✳CITA ✳ ETH Zürich ✳ Université de Géneve ✳ IUCAA Inter-University Centre for Astronomy and Astrophysics ✳ NASA JPL Caltech ✳ University of Oxford ✳ Perimeter Institute ✳ University of Toronto ✳ West Virginia University ✳ University of Wisconsin - Madison ✳ Yale University

JINA/CEE Joint Institute for Nuclear Astrophysics - Centre for Evolution of the Elements
(Cumming)
Other participating institutions:
✳ Argonne National Laboratory ✳ Arizona State University ✳ Cluster of Excellence Origin and Structure of the Universe ✳ GSI Helmholtz Centre for Heavy Ion Research ✳ Florida State University ✳ Los Alamos National Laboratory ✳ Michigan State University ✳ Monash University ✳ North Carolina State University ✳ Nuclear Astrophysics Virtual Institute ✳ Nuclear Computational Low Energy Initiative ✳ Ohio State University ✳ Ohio University ✳ Princeton University ✳ Shanghai Jiao Tong University ✳ TRIUMF ✳ University of Chicago ✳ University of Minnesota ✳ University of Notre Dame ✳ University of Sao Paulo ✳ University of Victoria ✳ University of Washington

LISA Consortium
(Haggard)
Participating countries:
Germany ✳ Italy ✳ France ✳ UK ✳ Switzerland ✳ Spain ✳ Denmark ✳ The Netherlands ✳ Belgium ✳ Portugal ✳ Sweden ✳ Hungary ✳ Romania ✳ Canada ✳ USA

Maunakea Spectroscopic Explorer
(Haggard, Webb)
Other participating institutions:
✳ National Research Council (Canada) ✳ CNRS (France) ✳ University of Hawaii (United States) ✳ AAO Macquarie (Australia) ✳ Indian Institute of Astrophysics (IIA) ✳ NAOC (China) ✳ NOAO (United States) ✳ Texas A&M (United States)

MBH CoLAB Montréal Black Hole Collaboration
(Haggard, Webb)
Other participating institutions:
✳*Université de Montréal*

MIST - Mapper of the IGM Spin Temperature
(Chiang, Sievers)
Other participating institutions:
✳ Universidad Católica de la Santísima Concepción ✳ Universidad de Chile ✳ National Radio Astronomy Observatory

NANOGrav The search for gravitational waves using pulsars
(Kaspi)
Other participating institutions:
✳ California Institute of Technology ✳ Cornell University ✳ Franklin and Marshall College ✳ Hillsdale College ✳ Huazhong University of Science and Technology ✳ Jet Propulsion Laboratory ✳ Lafayette College ✳ Montana State University ✳ NASA Goddard Space Flight Center ✳ National Radio Astronomy Observatory ✳ Naval Research Laboratory ✳ Notre Dame of Maryland University ✳ Oberlin College ✳ Penn State University ✳ University of Alabama ✳ University of British Columbia ✳ University of California, Berkeley ✳ University of East Anglia ✳ University of Maryland ✳ University of Texas Rio Grande Valley ✳ University of Vermont ✳ University of Washington Bothell ✳ University of Wisconsin Milwaukee ✳ West Virginia University

NICER NASA's Neutron Star Interior Composition Explorer
(Kaspi)
Other participating institutions:
MIT Kavli Institute for Astrophysics and Space Research ✳ NASA Goddard Space Flight Center ✳ Noqsi Aerospace

NIRISS Near-InfraRed Imager and Slitless Spectrograph, James Webb Space Telescope
(Cowan)
Other participating institutions:
Cornell University ✳ COM DEV ✳ National Research Council Canada ✳ Saint Mary's University ✳ Space Telescope Science Institute (STScI) ✳ Swiss
Federal Institute of Technology Zurich ✳ Université de Montréal ✳ University of Rochester ✳ University of Toronto ✳ York University

NIRPS Near Infrared Planet Spectrograph
(Cowan)
Other participating countries:
✳Switzerland ✳ France ✳ Brazil ✳ Portugal ✳ Spain

PALFA Pulsar Arecibo L-Band Feed Array survey
(Kaspi)
Other participating institutions:
✳ Albert Einstein Institute ✳ ASTRON ✳ Columbia University ✳ Cornell University ✳ Franklin and Marshall College ✳ Jodrell Bank Center for Astrophysics ✳ Lafayette College ✳Max-Planck-Institut für Radioastronomie ✳ National Radio Astronomy Observatory ✳ National Radio Astronomy Observatory ✳ Naval

Research Laboratory ✳ University of British Columbia ✳ University of East Anglia✳ University of New Mexico ✳ University of Texas at Brownsville ✳ University of Wisconsin - Milwaukee ✳ West Virginia University

POLARBEAR
(Dobbs)
Other participating institutions:
Cardiff University ✳ Imperial College ✳ KEK, High Energy Accelerator Research Organization ✳ Lawrence Berkeley National Lab ✳ Paris Diderot University ✳ University of California, Berkeley ✳ University of California, San Diego ✳ University of Colorado at Boulder

PITCH BLACK - JCMT Large Program
(Haggard)
Other participating institutions:
East Asian Observatory ✳ University of Oxford ✳ Curtin University ✳ Nihon University ✳ New York University Abu Dhabi ✳ University of Amsterdam ✳ University of Alberta ✳ Chinese Institute of High Energy Physics ✳ Shanghai Astronomical Observatory ✳ Academia Sinica Institute of Astronomy and Astrophysics ✳ INAF-Rome Observatory ✳ Chalmers University ✳ University of Durham ✳ University of Southampton ✳ McGill University ✳ Institut Teknologi Bandung ✳ Tokyo Tech University ✳ National Tsing Hua University ✳ Shibaura Institute of Technology ✳ Texas Tech University ✳ Ehime University ✳ University of the Chinese Academy of Sciences ✳ Kyoto University

PRIZM/ALBATROS
(Chiang, Sievers)
Other participating institutions:
✳ University of KwaZulu-Natal ✳ Carnegie Mellon ✳ University of California at Berkeley ✳ Square Kilometre Array - South Africa ✳ South African National Space Agency

The Simons Observatory
(Dobbs, Sievers)
Other participating institutions:
✳ Lawrence Berkeley National Laboratory ✳ Princeton University ✳ Universityvof California, San Diego ✳ University of California, Berkeley ✳ University of Pennsylvania

SpARCS the Spitzer Adaptation of the Red-Sequence Cluster Method
(Webb)
Other participating institutions:
University of California - Riverside Irvine ✳ University of Toronto ✳ York University ✳ MIT ✳ University of Montreal ✳ Australian Astronomical Observatory ✳ University of Concepcion, Chile ✳ University of Waterloo ✳ Argelander-Instiut fur Astronomie, Bonn, Germany ✳ National Radio Astronomy Observatory ✳ Universidad Andrés Bello, Chile ✳ Spitzer Science Centre/Caltech, ✳ CEA Saclay, France, ✳ University Innsbruk, Austria

SPIRou Spectro-Polarimetre Infra-Rouge Science Legacy Survey
(Cowan, Lee)
Other participating countries:
✳France ✳ Brazil ✳ Taiwan ✳ Switzerland ✳ Portugal

SPT The South Pole Telescope
(Dobbs)
Other participating institutions:
Argonne National Lab ✳ Case-Western Reserve University ✳ Fermilab ✳ University of California, Berkeley ✳ University of Chicago ✳ University of Colorado, Boulder ✳ University of Illinois at Urbana-Champaign

The Simons Array
(Dobbs)
Other participating institutions:
Cardiff University ✳ Dalhousie University ✳ High Energy Accelerator Research Organization, KEK ✳ Imperial College London ✳ Japan Aerospace Exploration Agency ✳ Lawrence Berkeley National Laboratory ✳ NASA Goddard Space Flight Center ✳ National Institute for Fusion Science ✳ Osaka University ✳ Princeton University ✳ The Graduate University for Advanced Studies ✳ Three-Speed Logic, Inc. ✳ University of California, Berkeley ✳ University of California, San Diego ✳ University of Chicago ✳ University of Colorado at Boulder ✳ University of Melbourne ✳ University of Paris Diderot ✳ University of Tokyo

VERITAS
(Hanna, Ragan)
Other participating institutions:
✳Barnard College ✳ Columbia University ✳ Cork Institute of Technology ✳ Georgia Institute of Technology ✳Iowa State University ✳ National University of Ireland, Galway ✳ Purdue University ✳ Smithsonian Astrophysical Observatory ✳ University College Dublin ✳ UCLA ✳ UC Santa Cruz ✳ University of Chicago ✳University of Delaware ✳ University of Iowa ✳ University of Minnesota ✳University of Utah ✳ Washington University, St. Louis

Publications

Aaboud, M., Aad, G., Abbott, B., & **Das, S**. et al. (2019). Combinations of single-top-quark production cross-section measurements and\| f LV V tb\| determinations at s $$ \sqrt {s} $$= 7 and 8 TeV with the ATLAS and CMS experiments. *Journal of high energy physics*, *2019*(1902.07158), 1-81.

Aad, G., Abbott, B., Abbott, D., **Lin, T.** et al. (2019). ATLAS b-jet identification performance and efficiency measurement with t\ \textbackslashbar\t\\ events in pp collisions at \ensuremath\sqrt\s\=13 TeV. *European Physical Journal C, 79*(11), 970.

Aaboud, M., Aad, G., Abbott, B., **Lin, T.** et al. (2019). A strategy for a general search for new phenomena using data-derived signal regions and its application within the ATLAS experiment *European Physical Journal C, 79*(2), 120.

Aaboud, M., Aad, G., Abbott, B. **Lin, T.** et al. (2019). Combination of Searches for Invisible Higgs Boson Decays with the ATLAS Experiment. *Physical Review Letters, 122*(23), 231801.

Abbott, T. M. C., Abdalla, F. B., Alarcon, A., … **Dobbs, M.A.** et al (2019). Dark Energy Survey year 1 results: Joint analysis of galaxy clustering, galaxy lensing, and CMB lensing two-point functions. *Physical Review D*, 100(2), 023541.

Abeysekara, A. U., Archer, A., Benbow, W … **Hanna, D.**, **Kumar, S, Ragan, K.**, **Zitzer, B** .et al. (*2019*). *Measurement of the extragalactic background light spectral energy distribution with VERITAS. The Astrophysical Journal, 885(2), 150.*

Ade, P., Aguirre, J., Ahmed, Z., … **Sievers,** J., **Zago, F.,** .et al. (2019). The Simons Observatory: science goals and forecasts. *Journal of Cosmology and Astroparticle Physics*, *2019*(02), p.056.

Ahmed, Z., Alonso, D., Amin, M. A., & **Wulf, D** et al. (2019). Research and Development for HI Intensity Mapping. *arXiv preprint arXiv:1907.13090*.

Alexander, S., Gates, S. J., Jenks, L., Koutrolikos, K., & **McDonough, E.** (2019). Higher spin supersymmetry at the cosmological collider: sculpting SUSY rilles in the CMB. *Journal of High Energy Physics*, *2019*(10), 156.

Aloisi, R., Cruz, A., … **Chawla, P.**, Daniels, L., **Fonseca, E.,** .**Kaspi, V.** et al. (2019). The Green Bank North Celestial Cap Pulsar Survey. IV. Four New Timing Solutions.*The Astrophysical Journal, 875*(1), 19.

Aloisi, R., Cruz, A.,…**Chawla, P.**, Daniels, N.,**Fonseca, E., Kaspi, V.,** … et al.(2019). Clocking Stars with Radio Telescopes: Timing Four Pulsars from the GBNCC Survey. *AAS*, 233, 153-07.

Amiri, M., Bandura, K., **Bhardwaj, M., Boubel, P., Boyle, P., Brar, C.,**… **Chawla, P.**, … **Dobbs, M**, …, **Fonseca, E.**, … **Hanna, D.**, … J**osephy, A.**, **Kaspi, V**, … **Naidu, A.**, … **Pleunis, Z.**, … **Siegel, S.**, … **Tendulkar, S.** et al (2019). Observations of fast radio bursts at frequencies down to 400 megahertz. arXiv preprint arXiv:1901.04524.

Anderson, A. J., Ade, P. A. R., Ahmed, Z., … **Dobbs, M.A.**, … **Montgomery, J** et al. (2019). Performance of Al–Mn Transition-Edge Sensor Bolometers in SPT-3G. *Journal of Low Temperature Physics*, 1-10.

Archer, A., Benbow, W., Bird, R, … **Hanna, D.**, **Kumar, S.**, **Ragan, K.**, **Tyler, J.**, … **Zitzer, B** .et al.(2019). A Search for Pulsed Very High-Energy Gamma Rays from Thirteen Young Pulsars in Archival VERITAS Data. *The Astrophysical Journal*, 876(2), 95.

Ashton, G., Lasky, P. D., **Graber, V**., & Palfreyman, J. (2019). Rotational evolution of the Vela pulsar during the 2016 glitch. *Nature Astronomy*, *3*(12), 1143-1148.

Athron, P., Balázs, C., Buckley, A., **Cornell, J. M.,** … et al.(2019). Combined collider constraints on neutralinos and charginos. *The European Physical Journal C*, 79(5), 395.

Athron, P., Balázs, C., Beniwal, A., … **Cornell, J. M.,** … et al.(2019). Global analyses of Higgs portal singlet dark matter models using GAMBIT. *The European Physical Journal C*, 79(1), 1-28.

Beaty, D. W., Hipkin, V. J., Caudill, C. M., … **Maggiori, C.,** ... et al. (2019). Geological evaluation of the MSRAD field site by a human field party: Implications for rover-based exploration operations and for the future human exploration of Mars. *Planetary and Space Science*, *171*, 34-49.

Beatty, T., **Bell, T.,** … **Cowan,** N.B., **Dang, L.**, … **Keating, D.**, et al.(2019). The Global Climates, Clouds, and Dynamics of the Hottest Jupiters. In *AAS/Division for Extreme Solar Systems Abstracts* (pp. 500.05).

Bell, T., Zhang, M., Cubillos, P.**, Dang, L.,** … **Cowan, N.B.** et al. (2019). Mass Loss from the Exoplanet WASP-12b Inferred from Spitzer Phase Curves. In *AAS/Division for Extreme Solar Systems Abstracts* (pp. 201.03).

Bender, A., Anderson, A., Avva, P.,… **Dobbs, M.A.,** … **Montgomery, J., Noble, G.,** et al. (2019). On-Sky Performance of the SPT-3G Frequency-Domain Multiplexed Readout *Journal of Low Temperature Physics*.

Benbow, W., Bird, R., Brill, A., Brose, R., Chromey, A. J., … **Hanna, D.** …**Ragan,** K. et al (2019). Direct measurement of stellar angular diameters by the VERITAS Cherenkov telescopes. *Nature Astronomy*, 3(6), 511-516.

Berger, S., & Law, C. (2019, January). Characterizing the sensitivity of realfast at the Very Large Array to fast radio bursts. *American Astronomical Society Meeting Abstracts# 233* (Vol. 233).

Bocquet, S., Dietrich, J. P., … **Dobbs, M.A.** et al (2019). Cluster cosmology constraints from the 2500 deg2 SPT-SZ survey: inclusion of weak gravitational lensing data from Magellan and the Hubble Space Telescope. *The Astrophysical Journal*, 878(1), 55.

Bouffard, E ., Haggard, D., Nowak, J., Markoff, S., & Baganoff, F. (2019). No Sign of G2's Encounter Affecting Sgr A*'s X-Ray Flaring Rate from Chandra Observations. *The Astrophysical Journal, 884*(2), 148.

Boyce, H., Haggard, D., … et al.(2019). Simultaneous X-Ray and Infrared Observations of Sagittarius A*'s Variability. *The Astrophysical Journal, 871*(2), 161.

Brandenberger, R., Costa, R.**, Franzmann, G.,** & Weltman, A. (2019). T-dual cosmological solutions in double field theory. *Physical Review D*, *99*(2), 023531.

Bernardo, H., **Brandenberger, R.**, & **Franzmann, G.** (2019). T-dual cosmological solutions in double field theory. II. Physical Review D, 99(6), 063521.

Brandenberger, R., Fröhlich, J., & Namba, R. (2019). Unified Dark Matter, Dark Energy and baryogenesis via a "cosmological wetting transition". *Journal of Cosmology and Astroparticle Physics*, 2019(09), 069.

Brandenberger, R. (2019). Is the spectrum of gravitational waves the "Holy Grail" of inflation?. *The European Physical Journal C*, 79(5), 1-11.

Brandenberger, R., et al (2019). . *Journal of Cosmology and Astroparticle Physics,* 2019(02), 043.

Brandenberger, R., Cyr, B., & Shi, R. (2019). Constraints on superconducting cosmic strings from the global 21-cm signal before reionization. *Journal of Cosmology and Astroparticle Physics, 2019*(9), 009.

Brandenberger, R., Cyr, B., & Schaeffer, T. (2019). On the possible enhancement of the global 21-cm signal at reionization from the decay of cosmic string cusps. *Journal of Cosmology and Astroparticle Physics, 2019*(4), 020.

Bringmann, T., **Cline, J. M.**, & **Cornell, J. M.** (2019). Baryogenesis from neutron-dark matter oscillations. *Physical Review D*, 99(3), 035024.

Chan, M. A., Hinman, N. W., Potter-McIntyre, S. L., **Leveille, R.** et al (2019). Deciphering biosignatures in planetary contexts. Astrobiology, 19(9), 1075-1102.

Chan-Yam, K., Goordial, J., Greer, C., Davila, A., McKay, C. P., & **Whyte, L.** (2019). Microbial activity and habitability of an Antarctic dry valley water track. *Astrobiology*, 19(6), 757-770.

Charlton, P., Ruan, J., Haggard, D., … et al. (2019). Gemini Imaging of the Host Galaxies of Changing-look Quasars. *The Astrophysical Journal, 876*(1), 75.

Cheale, R. A., Geach, J. E., Edge, A. C., **Webb, T. M.**, et al (2019). The SCUBA-2 Cluster Snapshot Survey–I. Catalogue of lensed galaxies and submillimetre-bright central galaxies. *Monthly Notices of the RAS*, 484(2), 2757-2778.

CHIME/FRB Collaboration, Amiri, M., Bandura, M., **Boubel, P.**, … **Dobbs, M.,** … **Fonseca, E.,** … **Hanna, D.**, … **Josephy, A., Kaspi, V.,** … **Michilli, D.**, Milutinovic, C., **Naidu, A.,**…et al..(2019). A second source of repeating fast radio bursts. *Nature, 566*(7743), 235-238.

CHIME/FRB Collaboration, **Andersen, B. C.**, … **Boubel, P.**, … **Dobbs, M.,** … **Fonseca, E.,** … **Josephy, A., Kaspi, V. M.**, … **Michilli, D.**, … **Naidu, A.**, … **Patel, C.,** … **Pleunis, Z.**, … **Siegel, S. R.**, **Singh, S.**, …**Tendulkar, S. P.**, … **Zwaniga, A. V**. et al..(2019). CHIME/FRB Discovery of Eight New Repeating Fast Radio Burst Sources. *Astrophysical Journal, Letters, 885*(1), L24.

Choquette, J., Cline, J. M., & Cornell, J. M. (2019). Early formation of supermassive black holes via dark matter self-interactions. *Journal of Cosmology and Astroparticle Physics*, 2019(07), 036.

Ciuca, R., & **Hernández, O. F.** (2019). Inferring cosmic string tension through the neural network prediction of string locations in CMB maps. *Monthly Notices of the RAS*, 483(4), 5179-5187.

Ciuca, R., **Hernández, O. F.**, & Wolman, M. (2019). A convolutional neural network for cosmic string detection in CMB temperature maps. *Monthly Notices of the RAS*, 485(1), 1377-1383.

Cline, J. M., Gross, C., & Xue, W. (2019). Can the ANITA anomalous events be due to new physics? *Physical Review D*, 100(1), 015031.

Cline, J. M., & **Toma, T.** (2019). Pseudo-Goldstone dark matter confronts cosmic ray and collider anomalies. *Physical Review D*, 100(3), 035023.

Cloutier, R., Astudillo-Defru, N., **Doyon, R.**, et al (2019). Confirmation of the radial velocity super-Earth K2-18c with HARPS and CARMENES. *Astronomy & Astrophysics*, 621, A49.

Cloutier, R., Astudillo-Defru, N., Bonfils, X., … **Doyon, R.** et al (2019). Characterization of the L 98-59 multi-planetary system with HARPS-Mass characterization of a hot super-Earth, a sub-Neptune, and a mass upper limit on the third planet. *Astronomy & Astrophysics*, *629*, A111.

Comeau, V., Fortin, J. F., & Skiba, W. (2019). Further Results on a Function Relevant for Conformal Blocks. *arXiv preprint arXiv:1902.08598*.

Cooray, A., Aguirre, J., Ali-Haimoud, Y., & **Mirocha, J.**, .et al.(2019). Cosmic dawn and reionization: Astrophysics in the final frontier. *arXiv preprint arXiv:1903.03629*.

Costa, R., Cuzinatto, R., **Franzmann, G.,** & Ferreira, G. (2019). Covariant c-flation: A variational approach. *International Journal of Modern Physics D, 28*(9), 1950119.

Dang, L., Calchi Novati, S., & Carey, S. (2019, August). Getting Better at Measuring the Galactic Distribution of Planets with Spitzer. In *AAS/Division for Extreme Solar Systems Abstracts* (Vol. 4).

De Rosa, R. J., Nielsen, E. L., Rameau, J., … **Doyon, R.** et al (2019). Detection of a low-mass stellar companion to the accelerating A2IV star HR 1645. *The Astronomical Journal*, 158(6), 226.

Dickinson, C., Barr, A., **Chiang, H. C.**, .. **Sievers,** J., et al (2019). The C-Band All-Sky Survey (C-BASS): constraining diffuse galactic radio emission in the north celestial pole region. *Monthly Notices of the RAS*, 485(2), 2844-2860.

Didier, J., Miller, A. D., Araujo, D. … **Dobbs, M.A** et al. (2019). Intensity-coupled Polarization in Instruments with a Continuously Rotating Half-wave Plate. *The Astrophysical Journal*, 876(1), 54.

Doan, A., Eracleous, M., Anderson, P., Runnoe, J., **Ruan, J.,** Clausen, D., LaMassa, C., Morganson, E., & Yue, S. (2019). UV Spectra of Three Changing-Look Quasars and Tests of Scenarios for Their Transformations. *American Astronomical Society Meeting Abstracts #233* (pp. 242.23).

Donner, J., Verbiest, J., Tiburzi, S., **Michilli, D.,** Serylak, J., Horneffer, A., Kramer, J.M., Künsemöller, J., Hoeft, M., & Miskolczi, A. (2019). First detection of frequency-dependent, time-variable dispersion measures. *Astronomy and Astrophysics, 624*, A22

Event Horizon Telescope Collaboration. Azulay, R., Baczko, A. K., Britzen, S., Desvignes, G., …**Haggard, D.** et al (2019). First M87 event horizon telescope results. I. The shadow of the supermassive black hole. *The Astrophysical Journal Letters*, 875(1), L1.

Event Horizon Telescope Collaboration. Akiyama, K., Alberdi, A., Alef, W., Asada, K., Azulay, R., … **Haggard, D**. et al (2019). First M87 event horizon telescope results. V. Physical origin of the asymmetric ring. *The Astrophysical Journal Letters*, 875(1), L5.

Fairén, A. G., Schulze-Makuch, D., **Whyte, L.**, et al (2019). Planetary protection and the astrobiological exploration of Mars: proactive steps in moving forward. *Advances in Space Research*, 63(5), 1491-1497.

Feng, J., & **Huang, Y.** (2019). Diffusivity-Factor Approximation for Spectral Outgoing Longwave Radiation. *Journal of the Atmospheric Sciences,* 76(7), 2171-2180.

Ferreira, E., **Brandenberger, R., Franzmann, G.,** & Khoury, R. (2019). Unified superfluid dark sector. *Journal of Cosmology and Astroparticle Physics, 2019*(8), 027.

Gillet, N., Mesinger, A., Greig, B., **Liu, A.**, & Ucci, G. (2019). Deep learning from 21-cm tomography of the cosmic dawn and reionization. *Monthly Notices of the RAS*, 484(1), 282-293.

Gourdji, K., **Michilli, D.,** Spitler, J., Seymour, A., & Cordes, S. (2019). A Sample of Low-energy Bursts from FRB 121102. *Astrophysical Journal, Letters, 877*(2), L19.

Golledge, N. R., Keller, E. D., **Gomez, N.** et al (2019). Global environmental consequences of twenty-first-century ice-sheet melt. *Nature*, 566 (7742), 65-72.

Goodwin, A.J., Galloway, D.K., Heger, A., **Cumming, A.**, Johnston, Z. (2019) A Bayesian approach to matching thermonuclear X-ray burst observations with models *Monthly Notices of the RAS,* 490.2 (pp. 2228-2240)

Greenbaum, A. Z., Cheetham, A., Sivaramakrishnan, A., … **Doyon, R.** et al (2019). Performance of the Gemini Planet Imager Non-redundant Mask and Spectroscopy of Two Close-separation Binaries: HR 2690 and HD 142527. *The Astronomical Journal*, 157(6), 249.

Guimond, C. M., & **Cowan, N. B**. (2019). Three direct imaging epochs could constrain the orbit of Earth 2.0 inside the habitable zone. *The Astronomical Journal*, 157(5), 188.

Gupta, N., Reichardt, C., Ade, A., … **Chiang, H.C.**, …**Dobbs, M.A.**, … **Montgomery, J** & **Noble, G** et al. (2019). Fractional polarization of extragalactic sources in the 500 deg square SPTpol survey. *Monthly Notices of the RAS, 490*(4), 5712-5721.

Haggard, D., Nynka, M., Mon, B., de la Cruz Hernandez, N., et al (2019). Chandra Spectral and Timing Analysis of Sgr A*'s Brightest X-Ray Flares. The Astrophysical Journal, 886(2), 96.

Haggard, D., Boyce, H., & Nynka, M. (2019). A Multiwavelength Exploration of Sgr A*'s Event Horizon Dynamics. *AAS/High Energy Astrophysics Division* (pp. 101.05).

Hassan, S., **Liu, A.**, Kohn, S., & La Plante, P. (2019). Identifying reionization sources from 21 cm maps using Convolutional Neural Networks. *Monthly Notices of the RAS*, 483(2), 2524-2537.

Hazumi, M., Ade, P. A., Akiba, Y., … **Dobbs, M.A.** et al (2019). Litebird: A satellite for the studies of b-mode polarization and inflation from cosmic background radiation detection. *Journal of Low Temperature Physics*, 194(5-6), 443-452.

Heisenberg, L., Bartelmann, M., **Brandenberger, R.**, & Refregier, A. (2018). Dark energy in the swampland. *Physical Review D, 98(12).*

Heisenberg, L., Bartelmann, M., **Brandenberger, R**., & Refregier, A. (2019). Dark energy in the swampland II. *SCIENCE CHINA Physics, Mechanics & Astronomy, 62*(9), 990421.

Heisenberg, L., Bartelmann, M., **Brandenberger, R.**, & Refregier, A. *(2019).* Horndeski gravity in the swampland. *Physical Review D, 99*(12).

Hessels, J., Spitler, L., Seymour, J., …**S. Chatterjee**, …., **Michilli, D.,** … **Kaspi, V.,** … **Tendulkar, S.** et al.(2019). FRB 121102 Bursts Show Complex Time-Frequency Structure. *Astrophysical Journal, Letters, 876*(2), L23.

Huang, Y., & **Wang, Y.** (2019). How does radiation code accuracy matter?. *Journal of Geophysical Research: Atmospheres*, *124*(20), 10742-10752.

Huang, Y., Chou, G., Xie, Y., & Soulard, N. (2019). Radiative control of the interannual variability of Arctic sea ice. *Geophysical Research Letters*, 46(16), 9899-9908.

Jaeckel, F. T., Ambarish, C. V., Christensen, N., & **Wulf, D** et al.(2019). Energy calibration of high-resolution X-Ray TES microcalorimeters with 3 eV optical photons. *IEEE Transactions on Applied Superconductivity*, *29*(5), 1-4.

Jean, J.M., Bozzo, E., … **Cumming, A.** Et al (2019). Observatory science with eXTP. SCIENCE CHINA Physics, Mechanics & Astronomy 62.2 (2019): 29506

Jew, L., Taylor, A. C., Jones, M. E., Barr, A., **Chiang, H. C.**, **Sievers,** J., et al (2019). The C-Band All-Sky Survey (C-BASS): Simulated parametric fitting in single pixels in total intensity and polarization. *Monthly Notices of the RAS*, 490(2), 2958-2975.

Jiang, J. H., Ji, X., **Cowan, N.B.**, Hu, R., & Zhu, Z. (2019). Empirical Predictions for the Period Distribution of Planets to Be Discovered by the Transiting Exoplanet Survey Satellite. *The Astronomical Journal,* 158(2), 96.

Jin, X., Hou, M., Zhu, Z., & Li, Z. (2019). Chandra Detection of Intracluster X-Ray Sources in Fornax. *The Astrophysical Journal, 876*(1), 53.

Josephy, A., Chawla, P., Fonseca, E., … Patel, C., Pleunis, Z., … **Andersen, B. C**., …**Bhardwaj, M**., … **Dobbs, M.,** … **Kaspi, V. M**., … **Michilli, D.,** … **Naidu, A.**, … **Siegel, S. R.,** …**Tendulkar, S. P**., … **Zwaniga, A. V.** et al. (2019). CHIME/FRB Detection of the Original Repeating Fast Radio Burst Source FRB 121102. *The Astrophysical Journal Letters*, *882*(2), p.L18.

Keating, D., Cowan, N., & Dang, L. (2019). Uniformly hot nightside temperatures on short-period gas giants. *AAS/Division for Extreme Solar Systems Abstracts* (pp. 326.16).

Kerrigan, J., Plante, P. L., Kohn, S., Pober, J. C., … **Liu, A.,** et al. (2019). Optimizing sparse RFI prediction using deep learning. *Monthly Notices of the RAS*, 488(2), 2605-2615.

Kleinboehl, A., **Navarro, T.,** & Kass, D. M. (2019). Venus Climate Sounder–A Limb Infrared Radiometer for the Middle Atmosphere of Venus. In *AGU Fall Meeting 2019*. AGU.

Kohn, S. A., Aguirre, J. E., La Plante, P., … **Liu, A.**, et al (2019). The HERA-19 Commissioning Array: Direction-dependent Effects. *The Astrophysical Journal*, 882(1), 58.

Kolopanis, M., Jacobs, D. C., Cheng, C., … **Liu, A.**, et al (2019). A Simplified, Lossless Reanalysis of PAPER-64. *The Astrophysical Journal*, 883(2), 133.

Laliberte, S., & **Brandenberger, R.** (2019). String gases and the Swampland. *arXiv preprint arXiv:1911.00199*.

Labonté, M., & Merlis, T.M. (2019). Evaluation of Extreme Precipitation Changes Using a Passive Water Vapor Tracer. In *AGU Fall Meeting Abstracts* (pp. A32F-03).

Lam, M. T., Ellis, J. A., Grillo, G., … **Fonseca, E** et al.(2019). A second chromatic timing event of interstellar origin toward PSR J1713+ 0747. *The Astrophysical Journal*, *861*(2), 132.

Law, C., Omand, C., Kashiyama, K., **Tendulkar, S.,** et al.(2019). A Search for Late-time Radio Emission and Fast Radio Bursts from Superluminous Supernovae. *The Astrophysical Journal, 886*(1), 24.

Li, Y., Thompson, D. W., Bony, S., & **Merlis, T. M**. (2019). Thermodynamic control on the poleward shift of the extratropical jet in climate change simulations: The role of rising high clouds and their radiative effects. *Journal of Climate*, 32(3), 917-934.

Liu, A., Aguirre, J., Ali-Haimoud, M., & **Mirocha, J.**, et al.(2019). Cosmology with the Highly Redshifted 21 cm Line|*baas, 51*(3), 63.

Liu, A., Foreman, S., Padmanabhan, H., **Chiang, H.C.**, **Siegel, S.**, **Wulf, D.**, **Sievers, J.**, **Dobbs, M.A.**, Vanderlinde, K..(2019). Low-redshift 21cm Cosmology in Canada. *arXiv preprint arXiv:1910.02889*.

Macdonald, E. J., & **Cowan, N. B.** (2019). An empirical infrared transit spectrum of Earth: opacity windows and biosignatures. *Monthly Notices of the RAS*, 489(1), 196-204.

MacLeod, C., Green, P., Anderson, A., … **Ruan, J.,** … et al.(2019). Changing-look Quasar Candidates: First Results from Follow-up Spectroscopy of Highly Optically Variable Quasars. *The Astrophysical Journal,, 874*(1), 8.

Madhavacheril, M. S., Battaglia, N., Smith, K. M., & **Sievers, J. L.** (2019). Cosmology with the kinematic Sunyaev-Zeldovich effect: Breaking the optical depth degeneracy with fast radio bursts. *Physical Review D*, 100(10), 103532.

Maher, P., Gerber, E. P., **Merlis, T. M.**, et al (2019). Model hierarchies for understanding atmospheric circulation. *Reviews of Geophysics*, 57(2), 250-280.

Maggiori, C., Raymond-Bouchard, I., & Whyte, L. G. (2019). Life detection in Mars analogue environments using MinION sequencing. In *2019 Astrobiology Science Conference*. AGU.

Men, Y., Aggarwal, K., Li, D., …**Tendulkar, S.,** … et al.(2019). Non-detection of fast radio bursts from six gamma-ray burst remnants with possible magnetar engines. *Monthly Notices of the RAS, 489*(3), 3643-3647.

Ment, K., Dittmann, J. A., Astudillo-Defru, N., … **Doyon, R.** et al (2019). A second terrestrial planet orbiting the nearby M dwarf LHS 1140. The Astronomical Journal, 157(1), 32.

Menzel, M. E., & **Merlis, T. M.** (2019). Connecting direct effects of CO2 radiative forcing to ocean heat uptake and circulation. *Journal of Advances in Modeling Earth Systems*, 11(7), 2163-2176.

Miles-Páez, P. A., Metchev, S., **Cowan, N.B.** et al (2019). Cloud Atlas: Variability in and out of the Water Band in the Planetary-mass HD 203030B Points to Cloud Sedimentation in Low-gravity L Dwarfs. *The Astrophysical Journal*, 883(2), 181.

Mocanu, L. M., Crawford, T. M., Aylor, K., … **Dobbs, M.A.** et al (2019). Consistency of cosmic microwave background temperature measurements in three frequency bands in the 2500-square-degree SPT-SZ survey. Journal of Cosmology and Astroparticle Physics, 2019(07), 038.

Monsalve, R.A., … et al.(2019). Results from EDGES High-Band. III. New Constraints on Parameters of the Early Universe. *The Astrophysical Journal, 875*(1), 67.

Moore, K., Scholz, A., & Jayawardhana, R. (2019). The Rotation-disk Connection in Young Brown Dwarfs: Strong Evidence for Early Rotational Braking. *The Astrophysical Journal, 872*(2), 159.

Mori, K., Hailey, C. J., Mandel, S., … **Haggard, D.** et al (2019). NuSTAR and Chandra observations of new X-ray transients in the central parsec of the Galaxy. *The Astrophysical Journal*, 885(2), 142.

Mozdzen, T., Mahesh, N., **Monsalve, R.A.,** & Bowman, J. (2019). Spectral index of the diffuse radio background between 50 and 100 MHz. *Monthly Notices of the RAS, 483*(4), 4411-4423.

Mozdzen, T., Mahesh, N., **Monsalve, R.,** & Bowman, J. (2019). Spectral Index of the Diffuse Radio Sky as Measured by EDGES using the Lowband (50-100 MHz) Antenna. *American Astronomical Society Meeting Abstracts #233* (pp. 334.05).

Ni, J., Leveille, R., & Douglas, P. (2019). Examining possibilities for speleothem biosignatures in Mars lava tubes based on Californian lava tubes. *AGU Fall Meeting Abstracts* (pp. U11C-05).

Nielsen, E. L., De Rosa, R. J., Macintosh, B., … **Doyon, R** et al (2019). The Gemini Planet Imager Exoplanet Survey: giant planet and brown dwarf demographics from 10 to 100 au. The Astronomical Journal, 158(1), 13.

Niblaeus, C., **Cornell, J.M.,** & Edsjö, J. Effect of polarization and choice of event generator on spectra from dark matter annihilations. *Journal of Cosmology and Astroparticle Physics* 10 (2019) 10, 079.

Noble, A. G., Muzzin, A., McDonald, M., **Webb, T. M. A.**, et al (2019). Resolving CO (2– 1) in z~ 1.6 Gas-rich Cluster Galaxies with ALMA: Rotating Molecular Gas Disks with Possible Signatures of Gas Stripping. *The Astrophysical Journal*, 870(2), 56.

O'Connor, B., Leveille, R. J., & Whyte, L. G. (2019, June). Using Earth Lava Tube Cryoenvironments as Analogs to Inform the Search for Life on Mars. In *2019 Astrobiology Science Conference*. AGU.

Ölçek, D., Charbonneau, P., Lemerle, A., Longpré, G., & Boileau, F. (2019). Grand Activity Minima and Maxima via Dual Dynamos. *Solar Physics, 294*(7), 99.

Omori, Y., Baxter, E. J., … **Dobbs, M.A.** et al (2019). Dark Energy Survey Year 1 Results: Cross-correlation between Dark Energy Survey Y1 galaxy weak lensing and South Pole Telescope+ P l a n c k CMB weak lensing. *Physical Review D*, 100(4), 043517

Omori, Y., Giannantonio, T., Porredon, A., .**Dobbs, M.A**. et al (2019). Dark Energy Survey Year 1 Results: Tomographic cross-correlations between Dark Energy Survey galaxies and CMB lensing from South Pole Telescope+ Planck. *Physical Review D*, 100(4), 043501.

Osinski, G. R., Battler, M., Caudill, C. M., … **Maggiori, C** et al.(2019). The CanMars Mars sample return analogue mission. *Planetary and Space Science*, *166*, 110-130.

Owen, E., Wu, K., **Jin, X.,** & Kataoka, N. (2019). Starburst and post-starburst high-redshift protogalaxies. The feedback impact of high energy cosmic rays. *Astronomy and Astrophysics, 626*, A85.

Parent, E., Kaspi, V., … **Patel, C.,** … et al. (2019). Eight Millisecond Pulsars Discovered in the Arecibo PALFA Survey. *The Astrophysical Journal, 886*(2), 148.

Parikh, A.S., Wijnands, R., …, **Cumming, A.** et al (2019). Consistent accretion-induced heating of the neutron-star crust in MXB 1659– 29 during two different outbursts. Astronomy & Astrophysics, 624 (A84).

Pass, E. K., **Cowan, N. B.**, Cubillos, P. E., & Sklar, J. G. (2019). Estimating dayside effective temperatures of hot Jupiters and associated uncertainties through Gaussian process regression. *Monthly Notices of the RAS*, 489(1), 941-950.

Perera, B., DeCesar, M., Demorest, M., **Fonseca, J.**, et al. (2019). The International Pulsar Timing Array: second data release. *Monthly Notices of the RAS, 490*(4), 4666-4687.

Peterson, D., Scholz, A., **Moore, R.,** Aigrain, S., & Stelzer, B. (2019). A Universal Spin-Mass Relation for Brown Dwarfs and Planets. In *American Astronomical Society Meeting Abstracts 234* (pp. 322.02).

Platts, E., Weltman, A., Walters, A., **Tendulkar, S.,** & Kandhai, S. (2019). A living theory catalogue for fast radio bursts. *Physics Reports, 821*, 1-27.

Plotkin, R., Miller-Jones, J., Chomiuk, J., **Ruan, J.,** et al. (2019). Radio Variability from a Quiescent Stellar-mass Black Hole Jet. *The Astrophysical Journal 874*(1), 13.

Prat, J., Baxter, E., Shin, T., … **Dobbs, M.A.** et al (2019). Cosmological lensing ratios with DES Y1, SPT, and Planck. *Monthly Notices of the RAS*, 487(1), 1363-1379.

Raghunathan, S., Patil, S., Baxter, E.,…, **Chiang, H.C.**, …**Dobbs, M.A.**, … **Noble, G.I** et al.(2019). Detection of CMB-cluster lensing using polarization data from SPTpol. *Physical review letters*, *123*(18), 181301.

Raghunathan, S., Patil, S., Baxter, E., … **Chiang, H.C.**,… **Dobbs, M.A.**, … **Montgomery, J** et al. (2019). Mass Calibration of Optically Selected DES Clusters Using a Measurement of CMB-cluster Lensing with SPTpol Data. *The Astrophysical Journal, 872*(2), 170.

Ren, B., Choquet, E., Perrin, M. D., … **Doyon, R.** et al (2019). An Exo–Kuiper Belt with an Extended Halo around HD 191089 in Scattered Light. The Astrophysical Journal, 882(1), 64.

Rivera, J., Baker, A. J., Gallardo, P. A., … **Sievers, J.**, et al (2019). The Atacama Cosmology Telescope: CO (J= 3–2) Mapping and Lens Modeling of an ACT-selected Dusty Star-forming Galaxy. *The Astrophysical Journal*, 879(2), 95.

Roulston, B., Green, P., **Ruan, J.,** et al. (2019). The Time-domain Spectroscopic Survey: Radial Velocity Variability in Dwarf Carbon Stars. *The Astrophysical Journal 877*(1), 44.

Ruan, J., … **Haggard, D.,** et al. (2019). The Analogous Structure of Accretion Flows in Supermassive and Stellar Mass Black Holes: New Insights from Faded Changing-look Quasars. *The Astrophysical Journal, 883*(1), 76.

Ruan, J., … **Haggard, D.,** et al. (2019). The Analogous Structure of Accretion Flows in Supermassive and Stellar Mass Black Holes. In *AAS/High Energy Astrophysics Division* (pp. 106.44).

Sameer, S., Brandt, W., Anderson, S., & **Ruan, J.,** et al. (2019). X-ray and multi-epoch optical/UV investigations of BAL to non-BAL quasar transformations*mnras, 482*(1), 1121-1134.

Sanidas, S., Cooper, S., Bassa, J., … **Michilli, D.,** et al. (2019). The LOFAR Tied-Array All-Sky Survey (LOTAAS): Survey overview and initial pulsar discoveries. *Astronomy and Astrophysics, 626*, A104.

Scalzo, R., **Parent, E.,** … et al.(2019). Probing type Ia supernova properties using bolometric light curves from the Carnegie Supernova Project and the CfA Supernova Group. *Monthly Notices of the RAS, 483*(1), 628-647.

Singh, S., & Subrahmanyan, R. (2019). The Redshifted 21 cm Signal in the EDGES Low-band Spectrum. *The Astrophysical Journal, 880*(1), 26.

Sobey, C., Bilous, A., Grie\ssmeier, J., … **Michilli, D.** et al. (2019). Low-frequency Faraday rotation measures towards pulsars using LOFAR: probing the 3D Galactic halo magnetic field*mnras, 484*(3), 3646-3664.

Stovall, K., Freire, P., Antoniadis, M., … **Fonseca, E** et al.(2019). PSR J2234+0611: A New Laboratory for Stellar Evolution. *The Astrophysical Journal, 870*(2), 74.

Stromberg, J. M., Parkinson, A., Morison, M., … **Leveille, R.**, **Maggiori, C.,**& **Whyte, L**. et al.(2019). Biosignature detection by Mars rover equivalent instruments in samples from the CanMars Mars Sample Return Analogue Deployment. *Planetary and Space Science*, *176*, 104683.

Trudeau, A., **Webb, T.M.A.**, Hlavacek-Larrondo, J., et al. (2019). Multiwavelength radio observations of a brightest cluster galaxy at z= 1.71: detection of a modest active galactic nucleus and evidence for extended star formation. *Monthly Notices of the RAS*, 487(1), 1210-1217.

Viero, M. P., Reichardt, C. L., Benson, B. A., … **Dobbs, M.A.** et al (2019). Measurements of the Cross-spectra of the Cosmic Infrared and Microwave Backgrounds from 95 to 1200 GHz. *The Astrophysical Journal*, 881(2), 96.

Walters, A., Ma, Y. Z., **Sievers, J.**, & Weltman, A. (2019). Probing diffuse gas with fast radio bursts. Physical Review D, 100(10), 103519.

Wang, J., Ni, R., Lin, J., Tan, X., Tong, D., Zhao, H., ... & **Huang, Y**. (2019). Socioeconomic and atmospheric factors affecting aerosol radiative forcing: production-based versus consumption-based perspective. *Atmospheric Environment*, 200, 197-207.

White, J. A., Aufdenberg, J., Boley, A. C.,. **Sievers, J.**, et al (2019). The MESAS Project: Long-wavelength Follow-up Observations of Sirius A. *The Astrophysical Journal,* 875(1), 55.

Whitehouse, P. L., **Gomez, N**., King, M. A., & Wiens, D. A. (2019). Solid Earth change and the evolution of the Antarctic Ice Sheet. *Nature communications*, 10(1), 1-14.

Wold, I. G., Kawinwanichakij, L., Stevans, M. L., … **Shipley, H.,** et al.(2019). The Spitzer-HETDEX Exploratory Large Area Survey. II. The Dark Energy Camera and Spitzer/IRAC Multiwavelength Catalog. *The Astrophysical Journal Supplement Series*, *240*(1), 5.

Wu, W. L. K., Mocanu, L. M., Ade, P. A. R., … **Chiang, H.C.**,…, **Dobbs, M.A.**, … **Noble, G.I** … **Montgomery, J** et al. (2019). A measurement of the cosmic microwave background lensing potential and power spectrum from 500 deg2 of sptpol temperature and polarization data. *The Astrophysical Journal*, *884*(1), 70.

Wulf, D., et al.(2019). A High Spectral Resolution Study of the Soft X-Ray Background with the X-Ray Quantum Calorimeter. *The Astrophysical Journal*, *884*(2), 120.

Xia, Y., **Huang, Y.**, Hu, Y., & Yang, J. (2019). Impacts of tropical tropopause warming on the stratospheric water vapor. *Climate Dynamics*, 53(5-6), 3409-3418.

Yang, J., Leconte, J., Wolf, E. T., **Merlis, T**., Koll, D. D., Forget, F., & Abbot, D. S. (2019). Simulations of Water Vapor and Clouds on Rapidly Rotating and Tidally Locked Planets: A 3D Model Intercomparison. *The Astrophysical Journal*, 875(1), 46.

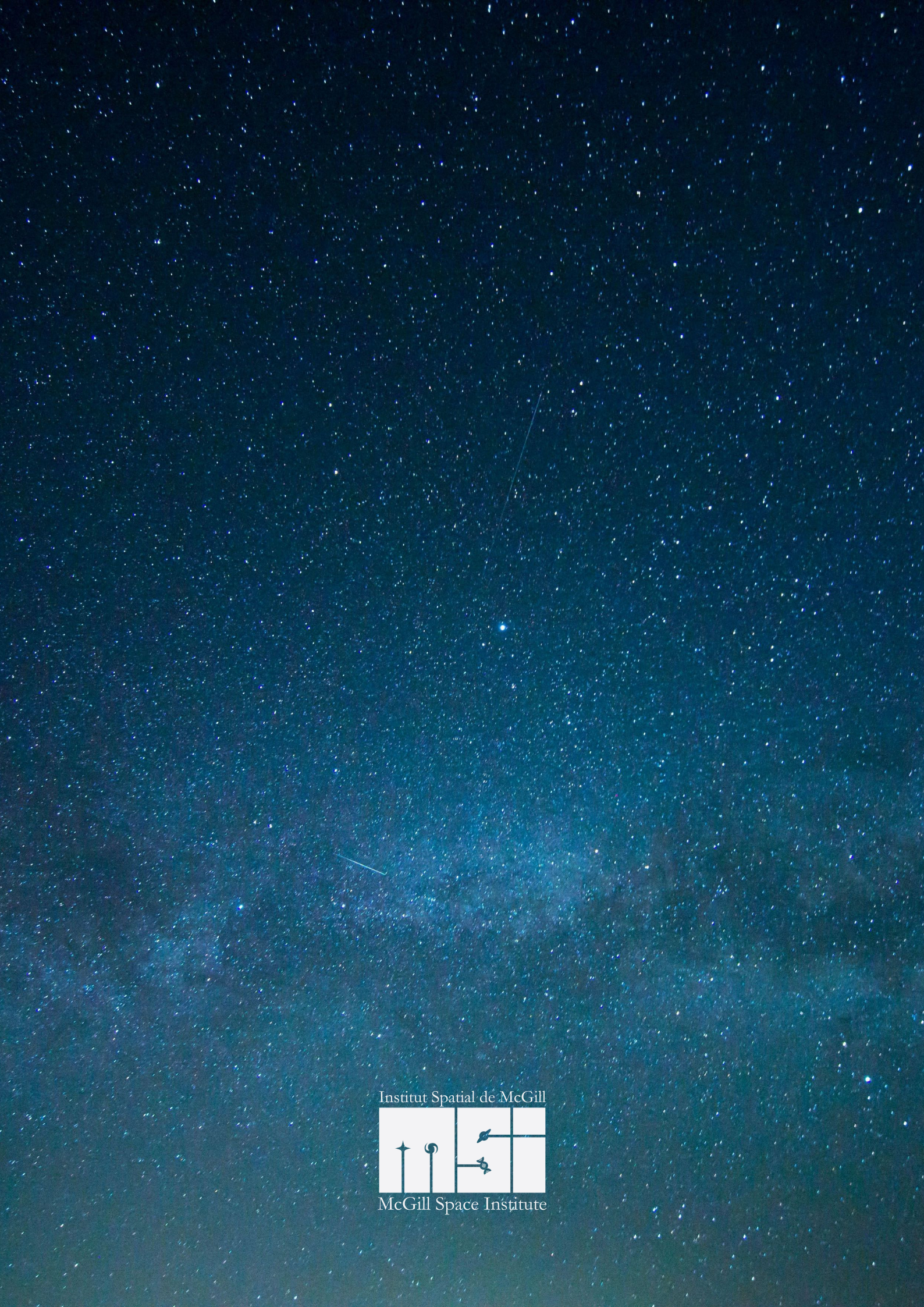
Zago, F., & Kosowsky, A. (2019). Quantum particle production effects on the cosmic expansion. *Physical Review D*, *100*(4), 045023.

Zellem, R. T., Swain, M. R., **Cowan, N. B.**, et al (2019). Constraining exoplanet metallicities and aerosols with the contribution to ARIEL spectroscopy of exoplanets (CASE). *Publications of the Astronomical Society of the Pacific*, 131(1003), 094401.

Zhou, Y., Apai, D., Lew, B. W., … **Cowan,** N.B., et al (2019). Cloud Atlas: High-contrast Time-resolved Observations of Planetary-mass Companions. The Astronomical Journal, 157(3), 128.

Zhu, T., **Huang, Y**., & Wei, H. (2019). Estimating Climate Feedbacks Using a Neural Network. *Journal of Geophysical Research: Atmospheres*, 124(6), 3246-3258.

Zhu, W. W., Freire, P. C. C., Knispel, B., Allen, B., … **Kaspi, V.** et al (2019). Mass measurements for two binary pulsars discovered in the PALFA survey. *The Astrophysical Journal*, 881(2), 165.


Institut Spatial de McGill
McGill Space Institute