Institut Spatial de McGill

McGill Space Institute

# Annual Report 2020

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# Welcome

## A Message from the MSI Director, Prof. Vicky Kaspi

Interdisciplinary research centres like the McGill Space Institute normally thrive on the interactions among its members. From Professor/student research discussions, to peer to peer conversations over coffee, the exchange of ideas, of thoughts, of visions is what ultimately drives creativity and productivity. The past year, with the continuing pandemic related campus closure, has certainly challenged us at MSI in real ways. But a glance through this Annual Report tells an amazing story: in spite of being confined to our homes and forced online for so many months, research and discussion at MSI has found ways to continue to shine. The number of publications and research achievements this past year is wonderful to see. From lava planets to the early Universe, from fast radio bursts to polar ice sheets, from galaxy clusters to event horizons, MSI members have managed to accomplish so much world-class research during this lockdown year. We should be proud: in spite of it all, we have persevered and kept ourselves inspired and productive. And with vaccination rates rising, we can be hopeful of a return to some form of "normal," when we can be together once again, and MSI can return to being the bustling and invigorating discussion-filled hub for all space-related science on campus. I predict we will be stronger for what we've been through, with renewed appreciation for the importance of face-to-face interactions, precisely what MSI was designed to foster. I look forward to welcoming you all when that happens.

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

Welcome to the MSI Annual Report for 2020! This has been another year of remarkable research achievements by MSI students, postdocs and faculty. One of my favourites this year is the paper by graduate students Michael Pagano and Hannah Fronenberg, who had an idea for a side project after talking to one of our seminar speakers at lunch (“Using FRBs as Cosmic Flashlights”, p 15). This is a fantastic example of how MSI can bring together researchers from different areas and catalyze new research ideas.

Of course the story of this year was that the global pandemic forced us to take our activities online. Looking through this report, what is striking to me is not only how MSI members worked together to enable this to happen, but also used this as an opportunity to rethink and try new approaches. Our seminars and public lectures were streamed live, allowing us to engage a broader audience than usual, as well as try new formats such as the special event on Exoplanet Climates in October (p 23). In outreach, new initiatives included Virtual Star Parties (“Education and Public Outreach”, p 18) and the very successful online Astro Trivia Night (p 22). Many of these activities were led and organized by MSI Coordinator Carolina Cruz-Vinaccia who played a central role in keeping activities going and researchers connected during the campus shutdown. Last year was also a very active year for EDI initiatives (p. 32), with MSI members taking leading roles.

It has been truly inspiring to see MSI community members come together during the pandemic. The challenge for the next year will be to keep the successful aspects of the virtual world as we start to meet in person again. I'm looking forward to seeing everyone in 3550 in the near future!

# About the MSI

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 at McGill University. We have a vibrant and interactive community of over 120 researchers at all levels, including faculty members, postdoctoral researchers, graduate students, and undergraduate students. The MSI was established in 2015 thanks to a generous gift from the Trottier Family Foundation.

The main goals of the Institute are to:

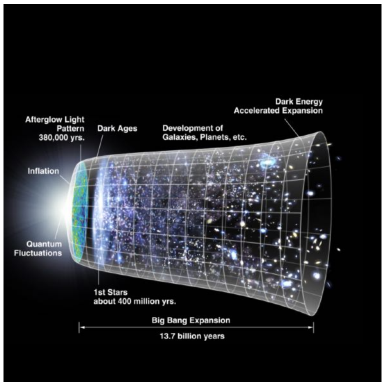
- Provide an intellectual home for faculty, research staff, and students engaged in astrophysics, planetary science, and other space-related research at McGill.
- Support the development of technology and instrumentation for space-related research.
- Foster cross-fertilization and interdisciplinary interactions 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.

The intellectual hub of the Institute is at 3550 University, where many of the Institute members work, collaborate with visitors, and Institute events are held.

Institut Spatial de McGill

McGill Space Institute

# Research Areas




## Early Universe and Theoretical Cosmology

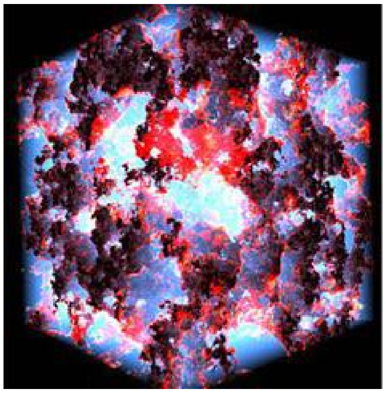
*Robert Brandenberger, Jim Cline*

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.

## Radio Transients

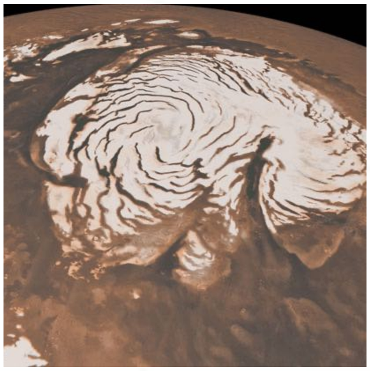
*Matt Dobbs, Vicky Kaspi, Jonathan Sievers*

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, particularly the newly-built CHIME telescope located in Penticton, British Columbia.

## Planetary Surfaces

*Natalya Gomez*

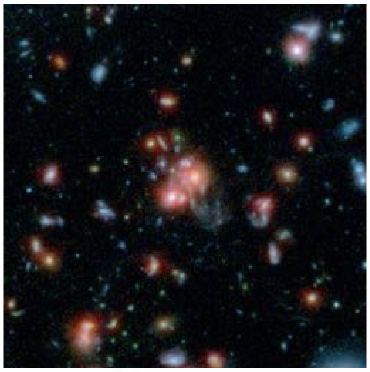
Members of the planetary surface group, led by Natalya Gomez, research models of the interactions between ice, water, climate and planetary interiors, and how these connections change planets' surfaces through time. These models are applicable to both the Earth and other rocky, icy planets and moons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



## Galaxy Evolution and Active Galactic Nuclei

*Daryl Haggard, Tracy Webb*

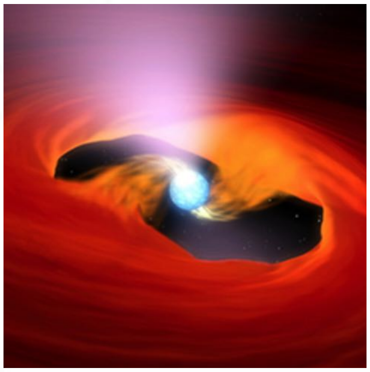
The galaxy evolution group is interested in understanding when galaxies form the bulk of their stellar mass; what drives and later shuts down this process; how the local environment of galaxies affect their evolution and growth; and how growing supermassive black holes (AGN) interact with their host 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*

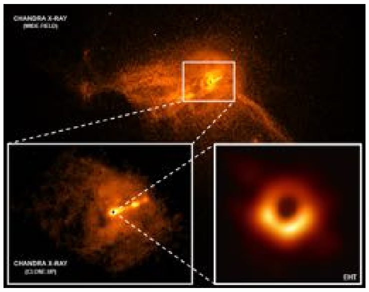
Nuclear astrophysics, at the intersection of astrophysics and nuclear physics, is the study of the origin of the chemical elements in stars and supernovae, explosive events such as supernovae, classical novae, and X-ray bursts, and the properties of matter at high densities as found in the interiors 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).



## Supermassive Black Holes

*Daryl Haggard*

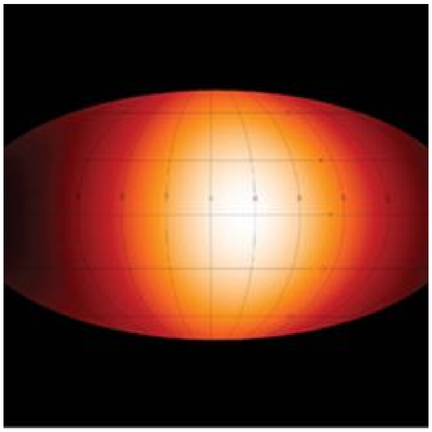
Our studies of supermassive black holes span from their large scale environments to photons circling at the edge of the event horizon. The supermassive black hole group is a part of the Event Horizon Telescope Collaboration and the LISA Consortium, along with several international teams that coordinate 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?



## Compact Objects

*Andrew Cumming, Daryl Haggard, Vicky Kaspi*

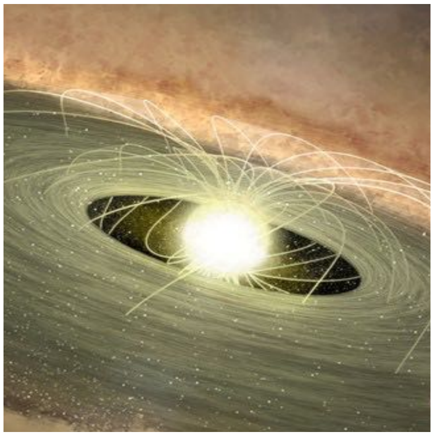
The compact object group studies white dwarfs, pulsars and other highly magnetized neutron stars, and stellar-mass black holes. The observational pulsar group is involved in several projects including: searches for radio pulsars; pulsar timing, and X-ray observations of energetic pulsars and magnetars. Our multi-messenger group pursues intensive campaigns to identify and characterize kilonova and other electromagnetic counterparts to gravitational wave 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*

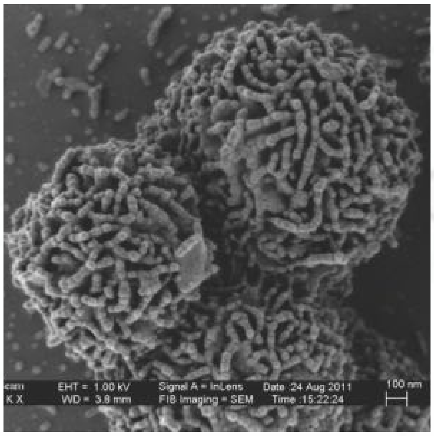
The extrasolar planet climate and atmosphere group works to characterize exoplanets using both observational evidence and climate modelling. Observational evidence for exoplanetary atmospheres comes from a variety of sources, including changes in brightness of the planet over time, spectroscopy, and 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

**25** Postdoctoral Fellows

**13** Research Areas

**73** Graduate Students

**26** Summer Undergraduates

**4** Departments

**7** Weekly Discussion Groups

**181** Journal Articles

**26** Virtual Seminars

**9** Virtual Public Lectures

**$10^{53}$** Hours on Zoom

**45** % of Zoom meetings attended in pyjamas

**3** Livestreamed Panels

**∞** Loaves of bread baked

**18** New hobbies undertaken

**17** New hobbies tucked to the back of a closet

**1** Virtual Trivia Night

**1** Carol **4** Limericks **1** Rap

Written & performed at the holiday party

# CHIME/FRB detects most powerful radio burst ever seen from a magnetar

*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 a relatively newly discovered astrophysical phenomenon. These short duration radio bursts are known to be coming from far outside our Milky Way galaxy, but are of unknown origin. The CHIME/FRB Project is making significant progress toward identifying the nature of these sources, and also laying groundwork for their great potential as probes of structure in the Universe.*

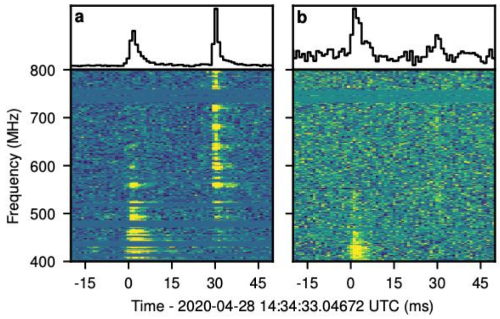
On April 28, 2020, the newly constructed CHIME radio telescope and its Fast Radio Burst (FRB) instrument detected by far the most powerful radio burst ever seen from a magnetar. FRBs were first reported in 2007 but until recently were a major astrophysical mystery. Consisting of few-millisecond bursts coming from cosmological distances, FRBs must be titanic radio explosions. Yet astronomers have been baffled regarding their origins. For a while, in spite of their inferred ubiquity, models for FRBs outnumbered detected sources! Published theoretical ideas ranged from merging neutron stars to primordial black hole evaporation to cosmic string cusps to disk debris near the event horizon of a supermassive black hole.

The CHIME/FRB Project turned on in 2018 and has been discovering hundreds of FRBs, thanks to the telescope's enormous size (equivalent to five hockey arenas), unique cylindrical design and powerful correlator which digests some 13 Tb per second, enabling observations of over 1000 independent positions or "beams" on the sky. The FRB instrument carries out this search in real time, thanks to a powerful software search engine designed and implemented by students, postdocs and programmers at McGill, U. Toronto, UBC and the Perimeter Institute.

Unexpectedly, on April 28, 2020, during routine operations, CHIME/FRB detected two closely spaced radio bursts so powerful they lit up several dozen of its sky beams at once. The source of the event was immediately identified not as coming from a cosmological distance as with previously observed FRBs, but rather from our own backyard here in the Milky Way. The source was the previously known Galactic magnetar SGR 1935+2154, which had never before been seen to emit radio bursts, much less explosions far more powerful than any radio burst yet seen from a magnetar. Simultaneously, a subset of the CHIME/FRB team from U. Toronto detected the same event at a small 10-m telescope being used as a testbed in the Algonquin Park in Ontario.

The CHIME/FRB discovery demonstrates that magnetars are capable of producing radio bursts of brightness comparable (though still somewhat smaller than) those of some FRBs. This provided a "smoking gun" to prove that at least some FRBs are magnetars. This discovery was identified by both Nature and Science magazines as among the most important scientific discoveries of 2020.

However, the discovery does not prove that all or even most FRBs - particularly the most luminous - are magnetars. The SGR 1935+2154 burst, though intense, was still at least a million times less luminous than those from the most distant known FRBs. Only time will tell whether FRBs represent a variety of source classes, or whether the April 28 event was the Rosetta Stone for the entire class.




*Top: The double burst from Milky Way magnetar SGR 1935+2154 , shown both in time and in radio frequency, as observed on April 28, 2020 by (a) CHIME/FRB and (b) the 10-m radio telescope in the Algonquin Provincial Park, Ontario (Credit: CHIME/FRB Collaboration, 2020, Nature, 587, 54-58). Bottom: the CHIME telescope ((Credit: the CHIME Collaboration).*

# Uncovering the origin of super-Earths and mini-Neptunes

Our Galaxy abounds with super-Earths and min-Neptunes up to four times the size of our own planet. Super-Earths were thought to be the remnant rocky cores of mini-Neptunes whose gassy atmospheres were blown away by radiation from host stars. This theory predicts that our Galaxy has very few Earth-sized and smaller exoplanets. However, recent observations show this may not be the case.

A new study led by Prof. Eve Lee and undergraduate Nicholas Connors shows that some of these exoplanets never had gaseous atmospheres to begin with, shedding new light on their mysterious origins. Using analytic and numerical calculations that track thermal evolution of planets based on how massive their rocky cores are, how far they are from their host stars, and how hot the surrounding gas is, Lee & Connors demonstrate that not all super-Earths are remnants of mini-Neptunes. Rather, the exoplanets were formed by a single distribution of rocks, born in a spinning disk of gas and dust around host stars.

Rocks larger than the moon can gravitationally attract surrounding gas to form a shell around themselves. Over time this shell of gas cools down and shrinks, creating space for more surrounding gas to be pulled in, and causing the exoplanet to grow. Once the entire shell cools down to the same temperature as the surrounding nebular gas, the shell can no longer shrink and growth stops.

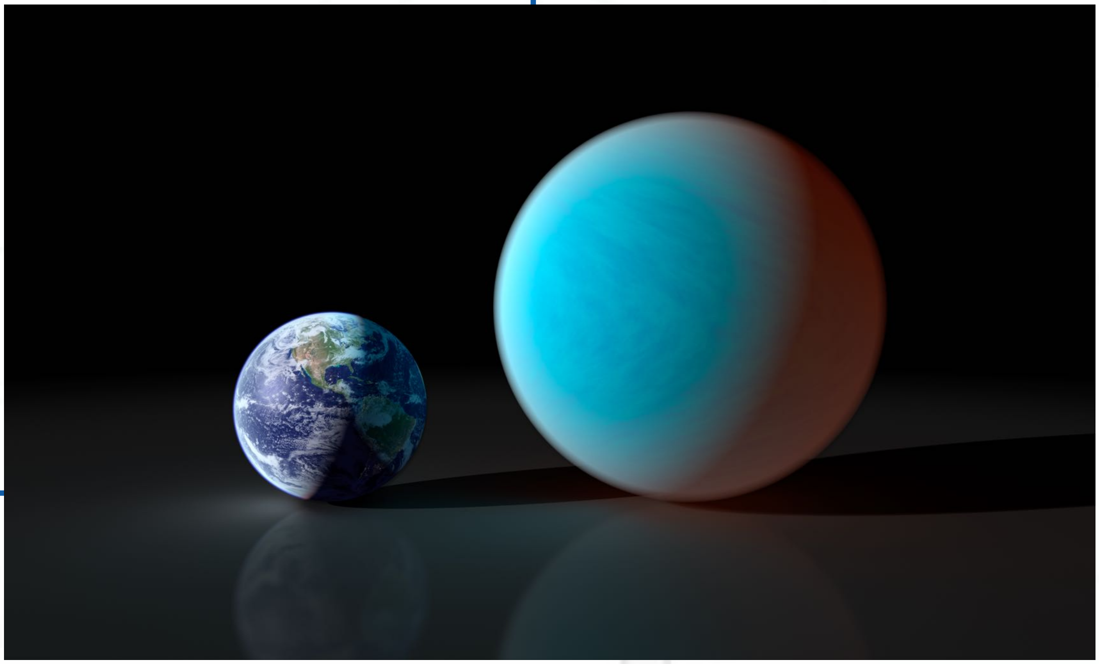
For cores smaller than the Earth, this shell is so tiny that they practically remain rocky exoplanets. The distinction between super-Earths and mini-Neptunes comes about from the ability of these rocks to grow and retain gas shells. "Our findings help explain the origin of the two populations of exoplanets, and furthermore, it opens up the possibility that rocky Earths and mini-Earths may be just as common as their larger counterparts," says Lee.

*__Prof. Eve J. Lee__ is a William Dawson Scholar and Assistant Professor in the Department of Physics. __Nicholas J. Connors__ is a Physics and Computer Science joint major student at McGill.*

**_Why this is important_**

*Super-Earths and mini-Neptunes do not exist in the solar system yet they are the most common outside of our own. Our study probes the origin of these planets and provides a theory that can predict how common Earths and mini-Earths are in our Galaxy that is testable with upcoming telescopes.*

*__Citation__: Lee, E J. & Connors, N. J. (2021) "Primordial Radius Gap and Potentially Broad Core Mass Distributions of Super-Earths and Sub-Neptunes" The Astrophysical Journal, Volume 908, Issue 1, id.32, 9 pp.*



*Artist's concept image of super-Earth shown next to Earth. Source: NASA/JPL-Caltech/R. Hurt (SSC)*

# Searching for the birth of the first stars

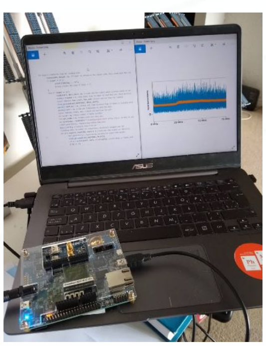
***Dr. Raul Monsalve** is a Research Associate in the McGill Physics Department and a co-PI of MIST. Other MSI team members on MIST include undergraduates **Christian Bye, Ian Hendricksen**, and **Erika Hornecker**; MSc student **Matheus Pessoâ**; and faculty members **H. Cynthia Chiang** and **Jonathan Sievers**.*

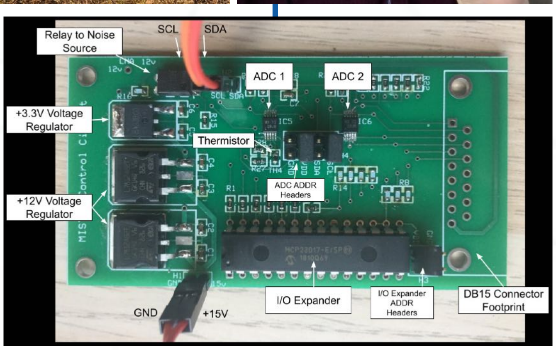
**Why this is important**

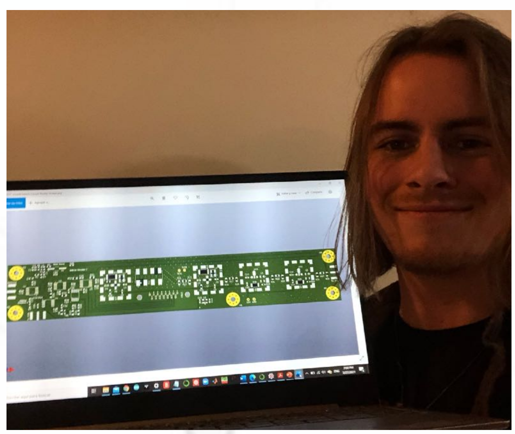
*Almost nothing is known about the very first stars that ignited in our universe, and detecting their signals at radio wavelengths is exceptionally challenging. McGill plays a leading role in the MIST experiment, which uses state-of-the-art technology to shed new light upon this elusive signal.*

About 100 million years after the Big Bang, the first stars ignited in the universe during a period known as "cosmic dawn." When these first luminous sources appeared, they emitted UV and X-ray radiation that interacted with the surrounding neutral hydrogen gas that pervaded the universe. 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 the period of cosmic dawn and probe the nature of the first stars by literally tuning one's telescope to the appropriate wavelengths.

The first and only tentative detection of the cosmic dawn signal was reported by the EDGES experiment in 2018. Cosmic dawn measurements are exceptionally challenging because they demand stringent control over instrumental uncertainties and other potential signal contaminants. Dr. Raul Monsalve is leading the Mapper of the IGM Spin Temperature (MIST), a new experiment that aims to probe cosmic dawn and elucidate the nature of the first stars. Dr. Monsalve and other MSI team members have built the MIST instrument from the ground up, and the design has been carefully optimized to minimize instrumental systematic errors. Areas of active research and development have included the antenna (Matheus Pessoâ), front-end electronics (Ian Hendricksen, Erika Hornecker), and readout electronics (Christian Bye). Despite the challenges of COVID isolation, the modular nature of MIST has allowed team members to work on small subsystems from home, using makeshift MacGyver-like setups to forge ahead on instrumentation development. The construction of MIST is nearly complete, and the instrument will ultimately observe from multiple radio-quiet sites, including the McGill Arctic Research Station on Axel Heiberg Island, Nunavut, and the Atacama desert in northern Chile.





*Clockwise from top left: Matheus Pessoâ testing a MIST antenna prototype on the McGill campus;; Christian Bye testing a low-cost analog to digital converter; Ian Hendricksen and his design for a miniaturized MIST front-end electronics board; control circuitry for an ultra-portable version of MIST, designed and constructed by Erika Hornecker; Christian Bye's home set up.*

# Supersonic winds, rocky rains forecasted on lava planet

Among the most extreme planets discovered beyond the edges of our solar system are lava planets: fiery hot worlds that circle so close to their host star that some regions are likely oceans of molten lava. We used computer simulations to predict the conditions on K2-141b, an Earth-size exoplanet with a surface, ocean, and atmosphere all made up of the same ingredients: rocks. In analyzing the illumination pattern of the exoplanet, we discovered that about two-thirds of K2-141b faces perpetual daylight – rather than the illuminated hemisphere we are used to on Earth.

The night side experiences frigid temperatures of below -200 C. The day side of the exoplanet, at an estimated 3000 C, is hot enough to not only melt rocks but vaporize them as well, ultimately creating a thin atmosphere in some areas. Remarkably, the rock vapour atmosphere created by the extreme heat undergoes precipitation. Just like the water cycle on Earth, where water evaporates, rises into the atmosphere, condenses, and falls back as rain, so too does the sodium, silicon monoxide, and silicon dioxide on K2-141b. On Earth, rain flows back into the oceans, where it will once more evaporate and the water cycle is repeated. On K2-141b, the mineral vapour formed by evaporated rock is swept to the frigid night side by supersonic winds and rocks "rain" back down into a magma ocean. The resulting currents flow back to the hot day side of the exoplanet, where rock evaporates once more.

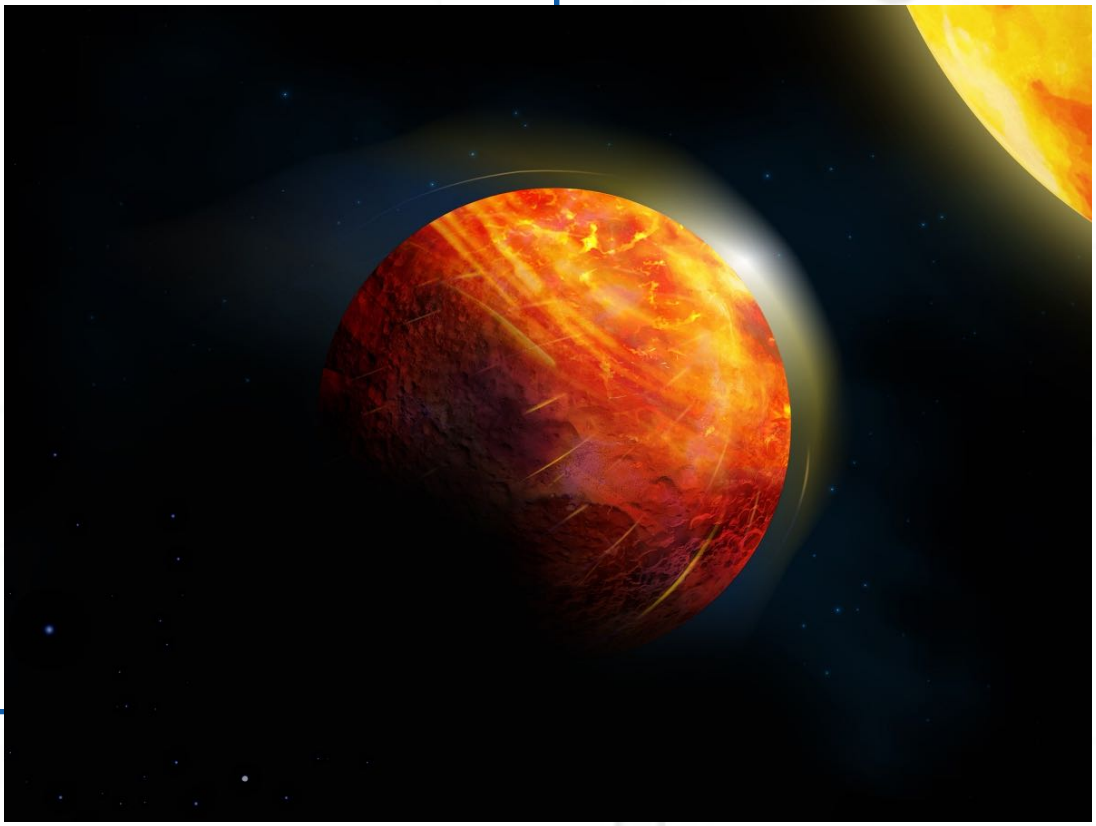
Still, the cycle on K2-141b is not as stable as the one on Earth, we found. The return flow of the magma ocean to the day side is slow, and as a result we predicted that the mineral composition will change over time, eventually changing the very surface and atmosphere of K2-141b.

***Citation***: *Nguyen, T.G., Cowan, N.B., Banerjee, A., Moores, J.E. (2020). Modelling the atmosphere of lava planet K2-141b: implications for low- and high-resolution spectroscopy. MNRAS, Vol. 499, Issue 4,*

*Giang Nguyen is a PhD student at York University. He performed this research with MSI professor Nicolas Cowan as part of an interdisciplinary research rotation. Agnibha Banerjee is an undergraduate at the Indian Institute of Science Education and Research and was a MITACS Globalink fellow in the MSI summer 2019. John Moores is a professor at York University.*

***Why this is important***

*Lava planets offer a glimpse of what planets like the Earth must have looked like when they first formed.*



*Artist's rendition of a lava Planet. Credit: Julie Roussy, McGill Graphic Design and Getty Images.*

# Solving the cusp/core problem of galaxies and galactic clusters

*James Cline (MSI prof.), Matteo Puel and Guillermo Gambini (MSI Ph.D. students from Italy and Peru, respectively) and Sam McDermott (Schramm Fellow, Fermilab, U.S.)*

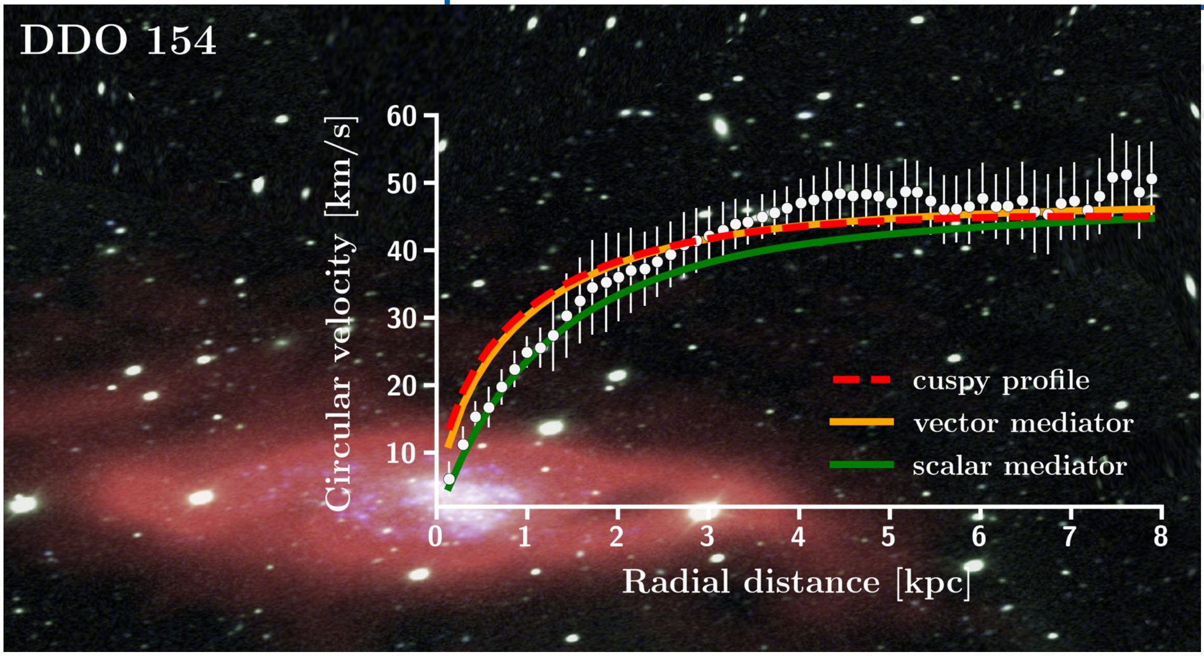
**Why this is important**

*This is a novel solution to an outstanding discrepancy between predictions and observations of the inner density profiles of dark matter halos.*

**Citation**: *J.M. Cline, G. Gambini, S.D. Mcdermott and M. Puel, "Late-Time Dark Matter Oscillations and the Core-Cusp Problem," arXiv:2010.12583. Accepted for publication in Journal of High Energy Physics.*

For many years, supercomputer simulations of structure formation in the early universe have predicted that galaxies and clusters of galaxies should have cuspy dark matter density profiles near their centres, whereas observations of stars' rotational velocities indicate a smooth (cored) behaviour. The discrepancy, known as "core-cusp problem" might be explained by complications from the ordinary visible matter, or self-interactions between the dark matter particles, but there is no consensus yet. We proposed a novel possibility: oscillations between dark matter and its antiparticle could become active at the time of structure formation, leading to enhanced annihilation between the two in the densest regions, and a consequent lowering of density in the centres of galaxies and galactic clusters. We showed that this could simultaneously explain both kinds of systems if the dark matter is light (around 65 MeV) and can annihilate into light scalar or vector particles.

The figure illustrates that annihilation of dark matter into scalar particles can explain the cored density profile of the smallest (dwarf spheroidal) galaxies and therefore their observed rotation curve, while annihilation into vector particles give a negligible contribution in such systems. We showed that the trend is opposite in the largest clusters of galaxies, where annihilations into vector particles dominate over those into scalar particles. The difference between these two annihilation channels arises because dark matter has larger velocities in galactic clusters than in small galaxies. As a consequence, a model in which dark matter can annihilate into either kind of particle can simultaneously solve the core/cusp problem in both kinds of systems. Improved future observations of rotation curves, with smaller errors, would be able to distinguish our proposal from the self-interacting dark matter scenario, which predicts somewhat different shapes for the density profiles.




*Caption: Example of rotation curve (star circular velocity vs.radial distance) for the dwarf spheroidal galaxy DDO 154.The white dots with error bars represent observational data, the red dashed curve is the prediction from supercomputer simulations within the standard cosmological model, the orange and green lines are the result from dark matter annihilations into vector and scalar particles, respectively.*

# Polar Ice Sheets connected across oceans

Prof. Natalya Gomez led a study published in *Nature* simulating the Earth's ice sheets and oceans through the last Ice Age and showing that polar ice sheets located on different ends of the Earth can 'talk to each other' through sea level changes. Retreat of one ice sheet causes sea levels to rise at the edge of another ice sheet thousands of kilometers away and drives that ice sheet to retreat too.

Using a new type of numerical model that simultaneously captures the dynamics and flow of ice along with the physics of global sea level changes, we looked at how this effect played out over the last 40,000 years, leading into and out of the last ice age. During the peak of the last ice age 20,000 years ago, sheets of ice several kilometers thick covered much of North America and Northern Europe, and the Antarctic ice sheet on the South pole was larger. A volume of ice equivalent to 130 meters of global sea level rise was locked up in ice sheets at this time, and much of that was in the Northern Hemisphere. (We encourage you to step outside or go to a window, look up, and imagine what 3 kilometers of ice on top of you would look like before reading on.)

Following this period of peak ice cover, ice retreated in the Northern Hemisphere, raising sea levels in Antarctica, which drove the Antarctic ice sheet to retreat sooner, faster and further than when we neglect this sea level teleconnection effect. Including the effect allowed us to explain a range of geological indicators of past changes. For example, they looked at the elevation of past shorelines, the timing of when land beneath the ice was exposed to the sun as the ice sheet retreated, marks left behind by the edge of the ice sheet as it retreated, and one of the key records we focused on – "iceberg-rafted debris". Iceberg rafted debris consists of rocks found in cores taken out of sediment on the ocean floor around Antarctica. These rocks were once locked up in ice on the continent, caught a ride out into the ocean in icebergs (like the one depicted in the picture) , and sunk to form layers on the ocean floor when the icebergs melted. The rocks show us that as the Antarctic ice sheet was retreating after the ice age, there were intermittent bursts of accelerated ice loss when a lot of icebergs were ejected. Their Antarctic ice sheet model simulations were able to capture this behavior when we let the ice sheets in the model 'talk' to each other.

The Earth system is so interconnected with change in one part driving change in another. Drawing on many different types of data and developing a model that connects different parts of the Earth system were key to understanding how and why the Antarctic ice sheet evolved in the past. And this holistic view can in turn shed light on how it may respond in our future warming climate.

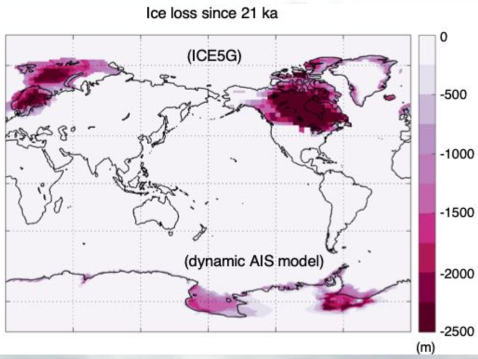
*Top right: Ice cover during the last ice age; Gomez, N (2020). Bottom right: Iceberg and research vessel Marion Dufresne II in the Scotia Sea during the coring campaign to retrieve sites MD07-3133 and MD07-3134 (taken in 2007).*

*__Prof. Natalya Gomez__ is an associate Professor in Earth and Planetary Sciences Department at McGill University and a Canada Research Chair in Ice Sheet – Sea Level Interactions.*

### *Why this is important*

*This work helps us to better understand the physics and drivers of the polar ice sheets and global sea levels, and to solve the mystery of what caused past changes that we see in geological records. This insight can in turn be used to better understand the future of ice and water on Earth and shed light on the climate of other planets in and outside of our solar system.*

**Citation:** *Gomez, N., Weber, M. E., Clark, P. U., Mitrovica, J. X., & Han, H. K. (2020). Antarctic ice dynamics amplified by Northern Hemisphere sea-level forcing. Nature, 587(7835), 600-604.*




# A Challenge to inflationary cosmology

***Prof. Robert Brandenberger*** *is a Canada Research Chair (Tier 1) and Professor of Physics in the McGill Physics Department*

***Citation:*** *Bedroya, A.,* ***Brandenberger, R****., Loverde, M., & Vafa, C. (2020). Trans-Planckian censorship and inflationary cosmology. Physical Review D, 101(10), 103502.*

**Why this is important**

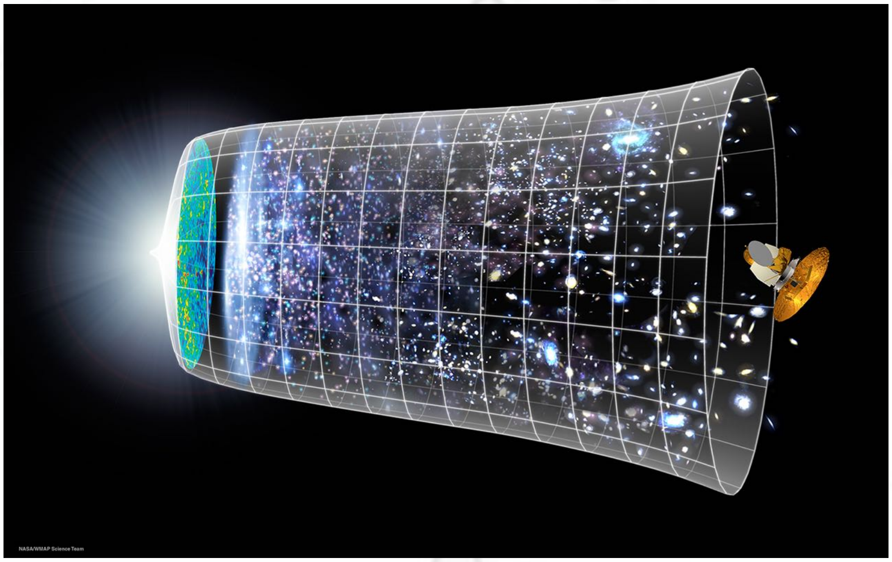
*We propose a general criterion for a cosmo-logical model to be consistent with quantum gravity, a criterion which severely constrains inflationary cosmology.*

The emergence of the universe from a hot primordial fireball is now well established through a wide range of observations. On the other hand, the nature of this initial hot dense state remains uncertain. An understanding of this initial state is important in order to explain the origin of the structure which we now observe as anisotropies in the cosmic microwave background, the distribution of galaxies, and much more. In the early 1980s, a possible scenario, the inflationary universe, was proposed. It involves a period of exponential expansion of space during the early stages of the primordial fireball, and quantum fluctuations during that phase lead to the seed inhomogeneities which develop into the structure which we observe today. Inflation has become the standard paradigm of early universe cosmology, in spite of the fact that we do not have a good theory of inflation based on a consistent theoretical framework. Even worse, models of inflation are not internally consistent since the exponential expansion of space leads to the fact that the wavelength of fluctuations which we observe today (e.g. the structure on the scale of galaxies) emerges at early times with a length smaller than the Planck length, a regime where the models break down.

Prof. Brandenberger and his collaborators put forward a general criterion, the `Trans-Planckian Censorship Conjecture" (TCC), which cosmological models consistent with quantum gravity must satisfy. The criterion states no consistent model of fundamental physics can lead to a cosmological model in which waves with an initial wavelength smaller than the Planck length are stretched to become cosmologically visible. This criterion is analogous to Penrose' Cosmic Censorship Hypothesis which postulates that no consistent quantum theory of gravity should have solutions which correspond to black holes with charge greater than the mass. Such black holes would have naked singularities and would prevent us from doing consistent physics. Penrose argued that even though the Einstein equations (which are valid at low energies and curvatures) admit such solutions, these solutions should be inconsistent with a fundamental theory. In analogy to this, we argue that cosmological models in which the ``trans-Planckian" region becomes visible to a late time observer performing cosmological measurements must be inconsistent with fundamental theory.

This criterion severely constrains inflationary models. All simple models of inflation are ruled out, and the surviving ones have inflation occurring at very low energy scales. Like in other early universe scenarios, in inflationary models gravitational waves are generated. Their amplitude is determined by the energy scale of inflation, and models of inflation which obey the TCC thus lead to a vanishingly small amplitude of gravitational waves.

Alternative early universe models such as the String Gas Cosmology' paradigm which Brandenberger and Vafa proposed many years ago and which is well motivated by superstring theory, do not involve a period of accelerated expansion of space in the early universe and hence satisfy the new consistency criterion. Thus, Brandenberger et al's work indicates that from the point of view of fundamental theory (e.g. superstring theory), models of the early universe which do not involve a period of inflation are preferable compared to those which make us of inflation. This shows that a paradigm shift in our understanding of the very early universe is required.



# Using FRBs as cosmic flashlights

Two of the most mysterious problems in astrophysics and cosmology today are, "What generates Fast Radio Bursts (FRBs)?" and "How did the entire universe become reionized by the first generation of stars and galaxies?" While both questions have garnered the interest of many scientists, as cosmologists, we seek to address the latter.

During the early times in our universe's history, the cosmos was not the galaxy filled place it is today. When the universe was a mere tens of million years old, there were no stars or galaxies to be found, but instead neutral atoms populated all of space. Slowly but surely, due to gravitational collapse, these atoms got together to form the first generation of stars. Eventually young galaxies began to take shape and they drastically changed the environment around them. UV photons emitted from these galaxies, encountered the neutral hydrogen still floating in the intergalactic medium (IGM) ionizing this hydrogen and introducing a large number of free electrons into the IGM. This continued until the entire IGM was ionized. This process called reionization is something we cosmologists desperately want to understand, but also something that is notoriously difficult to study.

FRBs, on the other hand, are short, bright bursts of electromagnetic radiation, the source of which remains unknown. Despite uncertainties about the progenitor, we decided to explore whether FRBs can be used as tools for studying the ionization fraction in the IGM, and in particular, whether FRBs can help us distinguish between different reionization scenarios. This electromagnetic radiation gets dispersed on its way to us, meaning that every time a photon encounters an electron, the photon's travel time gets delayed. In this sense, FRBs are like cosmic flashlights because, through studying their dispersion measure, we can learn about the electron density between us and the source of the burst. Since the process of reionization introduces electrons into the IGM, FRBs that are emitted during reionization should be able to track this change, this reionization process, throughout cosmic history. It turns out that FRBs are indeed sensitive to different reionization models . We also find that with small samples of FRBs one is able to rule out certain reionization scenarios and with a very large sample, one is able to constrain the reionization scenario. We are only now entering the early days of FRB cosmology and we are excited about new cosmological discoveries that will result from advances in the detection of transients!

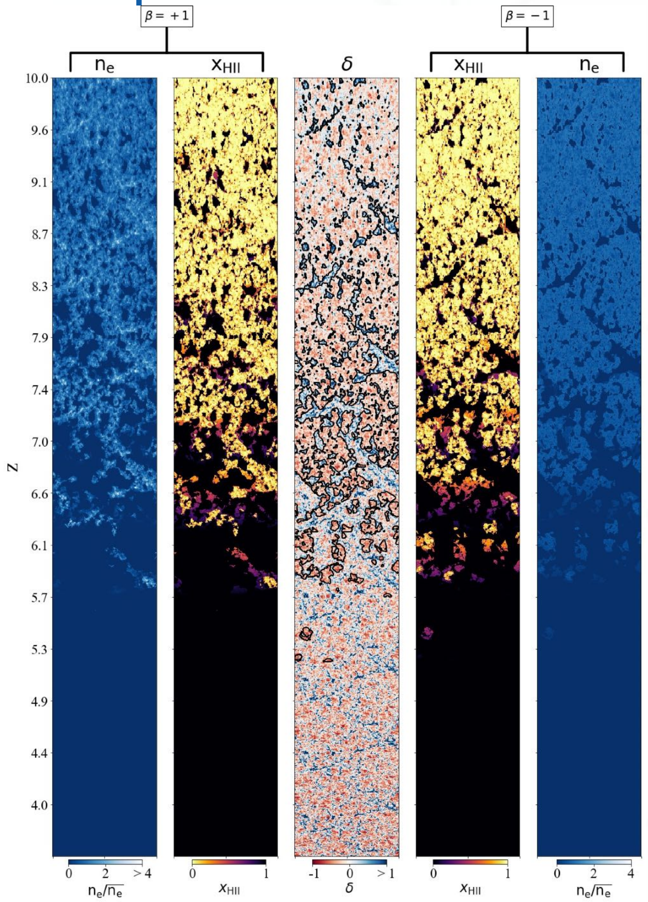
***Two cosmology students studying transients?***

*Yes, we find it as surprising as you do, as did our supervisor, from whom we kept this project a secret for many months! In October 2020, Dr. Wenbin Lu gave a wonderful MSI seminar about FRB progenitor theories after which he mentioned that FRBs might be used to study reionization. The two of us took interest in this idea and after one short zoom call with Wenbin to discuss this in more detail, we were off on our first solo research journey!*

*Michael Pagano and Hannah Fronenberg are MSI graduate students under the supervision of Prof. Adrian Liu. Michael is working toward completing his PhD and is investigating the Epoch of Reionization (EoR) using various observational probes. Hannah is completing her MSc, studying how to use cross-correlations to study the EoR, and will continue as a PhD student at the MSI this fall. In their spare time they like to think about FRBs!*

***Citation***: *Pagano, M., & Fronenberg, H. (2021, March 04). Constraining the epoch of reionization with highly dispersed fast radio bursts. Retrieved April 13, 2021, from https://arxiv.org/abs/2103.03252*

***Below:*** *The middle panel shows the density field of the universe as a function of time where time runs from oldest at the top to today at the bottom. The two panels adjacent to it show the ionization field for two different reionization scenarios, and the two furthest panels from the centre show the resultant electron number density field.*

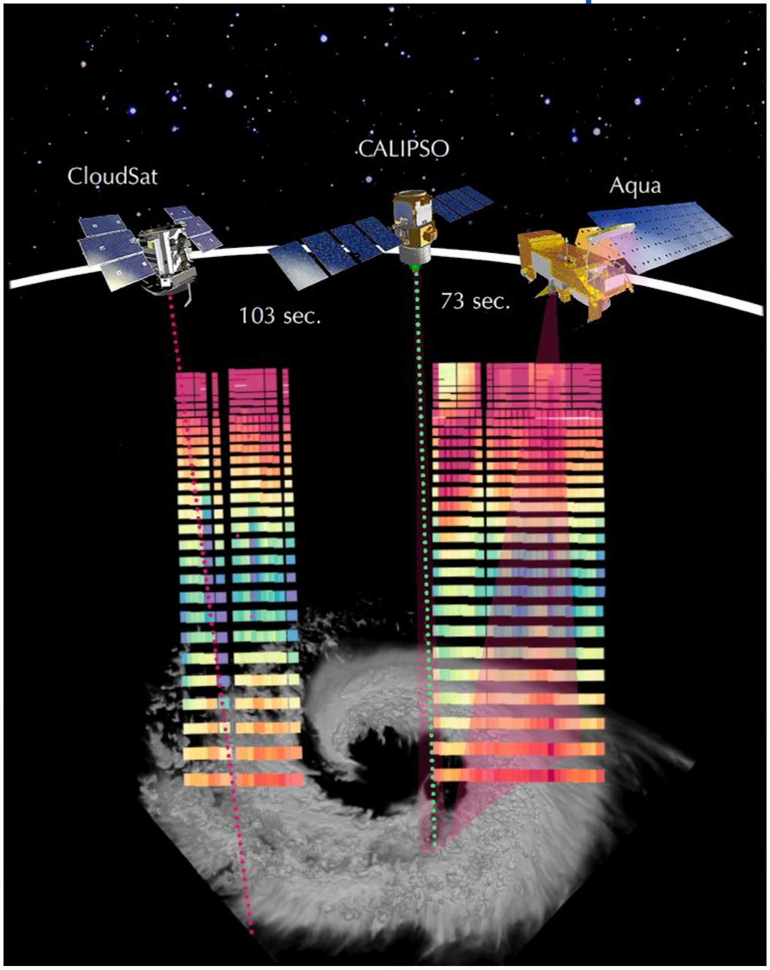


# Detecting above-storm atmospheric conditions from space

*Jing Feng is a Ph.D. student working with Prof. Yi Huang, an associate professor in the Department of Atmospheric and Oceanic Sciences.*

***Citation:*** *Feng, J., Huang, Y., and Qu, Z. An observing system simulation experiment (OSSE)-based assessment of the retrieval of above-cloud temperature and water vapor using hyperspectral infrared sounder, Atmos. Meas. Tech. Discuss. [preprint]. Feng, J. and Huang, Y. Impacts of tropical cyclones on the thermodynamic conditions in the tropical tropopause layer observed by A-train satellites, Atmos. Chem. Phys. Discuss. [preprint].*

*Below: Temperature fields detected by the synergistic retrieval method using multiple A-Train instruments.*




Deep convective storms are fundamental to human activities and the earth's climate system. The most energetic storms can greatly perturb the thermodynamic conditions in the upper-troposphere and lower-stratosphere. However, this process is poorly understood, due to a lack of observations, which are challenging especially in cloudy conditions. From the ground, the operational radiosonde system does not perform well in the cold environment at such high altitudes. From space, the presence of clouds can be an issue for the retrieval algorithm of infrared sensors, which tries to extract clear-sky radiances by contrasting neighbouring scenes. Consequently, current space-borne infrared sensors fail to capture the atmospheric properties above overcast clouds.

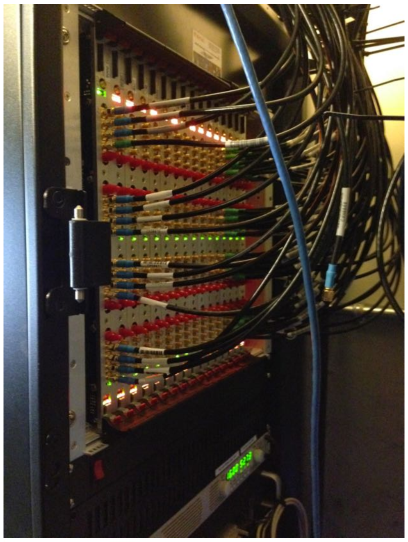
Recently, Jing Feng and Prof. Yi Huang have developed an innovative, cloud-assisted approach to retrieve temperature and humidity profiles above convective storms. This method takes the advantage of simultaneous observations from NASA's A-Train satellite constellation. Multiple instruments are being used, which include the Atmospheric infrared sounder (AIRS), the cloud precipitation radar (CPR), and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). The combination of these instruments provides the sensitivity to temperature and humidity profiles above the convective storms, as well as the vertical distribution of ice mass near the cloud top.

By applying this synergistic retrieval method, they have developed a dataset of thermodynamic profiles for tropical cyclone events passed over by A-Train satellites from 2006 to 2015. Compared to other satellite datasets, it has unique advantages in a small sampling size (~10 km) and validated precision in cloudy conditions.

### *Why this is important*

*This project develops a method to retrieve thermodynamic variables above convective storms by using satellite observations from hyperspectral infrared sounder and active sensors collectively. By applying this method, an infrared hyperspectra-based dataset of collocated temperature and humidity profiles above convective storms is constructed, which is the first of its kind.*

# $23M New funding to build revolutionary Canadian radio telescope



Canada has emerged as a world leader in radio astronomy due, in part, to the game-changing, Canadian Hydrogen Intensity Mapping Experiment (CHIME) which has become the world's foremost facility for detecting and understanding fast radio bursts (FRBs) and is currently mapping the large scale structure in the universe.

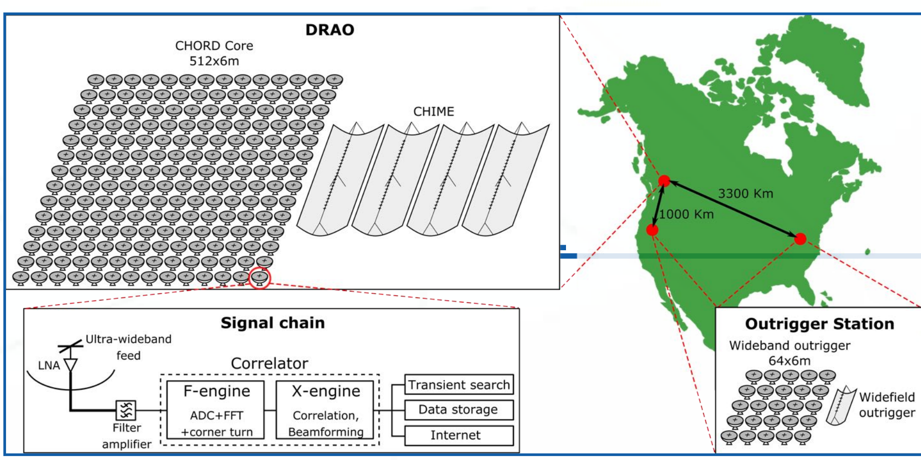
A pan-Canadian team including McGill Space Institute faculty Prof. Cynthia Chiang, Prof. Matt Dobbs (project Director), Prof. Daryl Haggard, Prof. Vicky Kaspi, Prof. Adrian Liu, and Prof. Jon Sievers was recently awarded $23M funding from the Canadian Foundation for Innovation to design and build the Canadian Hydrogen Observatory and Radio-transient Detector (CHORD).

CHORD offers unprecedented observational capabilities, from real-time sub-arcsecond transient localization, to a higher wideband mapping speed than any telescope currently operating. This world-leading facility will allow Canadian astronomers to address three of the most exciting areas in physics today: (1) elucidating the nature of fast radio bursts and their precise location within galactic hosts; (2) mapping the distribution of matter on cosmic scales to reveal the evolution of structure in the Universe; and (3) probing fundamental physics parameters, such as testing General Relativity.

CHORD will build directly on CHIME's success. While CHIME was a discovery machine, breaking new ground in telescope design and unlocking a new class of observations, CHORD will be a precision observatory, honing in on the details of the complicated cosmology and astrophysics that govern the physics of the universe and compact objects like FRBs.

CHORD will leverage advances in digital and radio-frequency technologies to study the transient and cosmic-radio sky in previously impossible ways. This next-generation instrument will build on the team's revolutionary digital correlator technology developed for CHIME, alongside new wideband technologies and National Research Council investment in cutting-edge composite reflectors. CHORD will deliver an order-of-magnitude increase in wide-band survey speed and increase the bandwidth by a factor of three.

Construction of CHORD will begin in 2022 with first observations in 2024.




*From top: A CHIME-like correlator forms the heart of the complex signal processing for CHORD; a prototype CHORD dish, half the diameter of the full design, built in 2019/2020 and tested on sky for performance; overview of the CHORD instrument.*

# Education & Public Outreach

MSI runs a variety of public outreach programs, from monthly events like public lectures to one-time events for smaller audiences both within and outside the McGill community. Many of our outreach events are run under the banner of **AstroMcGill**, which was founded in 2011 by an enthusiastic group of graduate students and post-doctoral fellows.

Over its almost decade of history, AstroMcGill has forged multiple partnerships with other outreach groups, both within and outside McGill, in order to offer a robust set of education and public engagement activities for the Montreal community. We regularly collaborate with outreach groups in the MSI's member departments (Physics Outreach, SMoRes), the Faculty of Science's outreach groups, the Institute for research on exoplanets (iREx), and the Centre de recherche en astrophysique du Québec (CRAQ). AstroMcGill has also made a name for itself in the broader Montreal community and is often invited to participate in events organized by various organizations in Montreal and its surroundings.


Outreach looked a little different this year due to the COVID-19 pandemic. All of MSI's outreach programs successfully moved online in May 2020 and we were even able to add a few new ones! **Public AstroPhysics Nights** (see page 20), our public lecture series run in collaboration with Physics Matters, moved to Facebook Live but kept its enthusiastic audience by experimenting with a mix of more traditional lectures and some live panels. **Astronomy on Tap** (page 22) was unfortunately put on hiatus when bars closed, but we pivoted to **Astronomy Trivia Night**, which will now be part of our regular roster of events. We also launched a new series of **Special MSI Public Lectures**, featuring world-class speakers from top universities across North America.


*From top: Poster for September's Virtual Star Party; MSI grad student Matthew Lundy doing a demo of the telescope for a group of students in February 2020; Prof. Daryl Haggard giving a virtual public lecture in September 2020. Opposite page: MSI grad student Nicholas Vieira giving a virtual talk at Dyer Observatory's Virtual Star Party; MSI grad student Taylor Bell presenting at July's Comet Q&A: Comet Neowise.*

The turn towards virtual public outreach resulted in interesting new collaborations, especially with non-local partners. In Summer 2020, MSI was invited by Vanderbilt University's Dyer Observatory in Tennessee to be a partner for their **Virtual Star Parties**, virtual observing nights where presenters take turns showing views through their telescopes and discussing what is being shown or discussing another topic of astronomy. Vanderbilt provides the remotely operated telescope observing and MSI provides speakers. We participated in three star parties, which were great fun for speakers and participants alike!

We also hosted a special event when the Comet NEOWISE was visible from Montreal in July 2020. Our graduate students hosted **Comet Q&A: Comet NEOWISE**, a virtual event where participants learned what exactly a comet is and how to observe it. A short presentation was followed by a Q&A session where people asked their burning comet questions, and a trivia game with prizes.

We're thrilled that the ingenuity and dedication of our outreach volunteers allowed for a seamless transition, a broader variety of programming, and a wider reach that we intend to maintain going forward.



## Spotlight: Social Media

Social media was a crucial tool to engage with our audience during the pandemic. All of our public lectures were streamed on Facebook Live or YouTube Live, where audiences could interact with our speakers directly in real time. MSI and AstroMcGill both saw significant growth in their followings across our existing channels (Facebook, Instagram, and Twitter) and our new ones (like the MSI YouTube).

| | | |
|---|---|---|
| Twitter | @astromcgill | 2,264 followers |
| | @mcgillMSI | 1,089 followers |
| Facebook | AstroMcGill | 6,069 followers |
| | McGillSpaceInstitute | 1,876 followers |
| Instagram | @astromcgill | 733 followers |
| | @mcgillspacinstitute | 891 followers |
| YouTube | AstroMcGill | 325 subscribers |
| | McGill Space Institute | 100 subscribers |

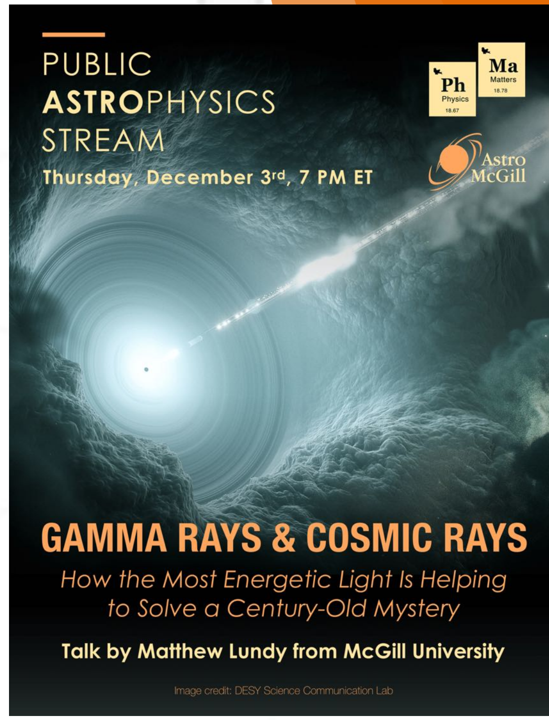
# Public AstroNights

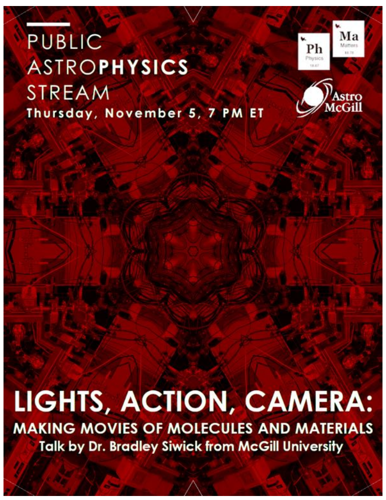
Public AstroNights (now Public AstroPhysics Nights) have been a mainstay of AstroMcGill's outreach efforts since 2011 and are now run in collaboration with Physics Matters. Every month, a professional astronomer or physics gives a public talk aimed at a broad audience. Speakers are often MSI or McGill Physics professors, postdoctoral fellows, or graduate students, although we also welcome invited speakers from other institutions. Pre-COVID, lectures typically attracted a live audience of about 200 people, plus another 700 watching the recorded talks afterwards.

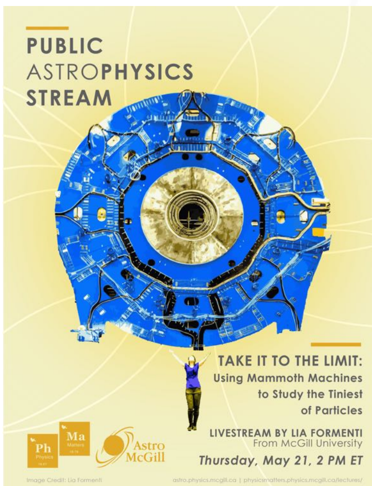
During the COVID-19 pandemic, our lectures moved online, taking place on Zoom and Facebook Live. The virtual format allowed us to experiment with different kinds of talks, from panels about life as an astronomer in the South Pole, Q&A sessions with experts, and more traditional lectures. Our audience remained as enthusiastic as ever, with live viewership of up to 200 participants and post-event views that added 600 to 1900 viewers.

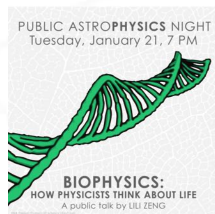
| | |
|---|---|
| **JAN. 21** | **Biophysics: How Physicists Think About Life**<br>Lili Zeng *(McGill Physics)* |
| **MAY 06** | **Life as an Astronomer at the South Pole: A Live Panel**<br>Prof. Cynthia Chiang *(MSI)*, Maclean Rouble *(MSI)*, Joshua Montgomery *(MSI)* |
| **MAY 21** | **Take it to the Limit: Mammoth Machines and the Tiniest Particles**<br>Lia Formenti *(McGill Physics)* |
| **JUN 02** | **Life as a Theoretical Physicist: A Live Panel**<br>Prof. Jim Cline *(MSI)*, Prof. Eve Lee *(MSI)*, Prof. Sarah Harrison *(McGill Physics)*, Anh-Khoi Trinh *(McGill Physics)* |
| **JUN 22** | **Fast Radio Bursts: How These Big Booms Are Changing the Landscape of Radio Astronomy**<br>Marcus Merryfield *(MSI)* |
| **JUN 30** | **Is it Still Physics?**<br>Prof. Paul François *(McGill Physics)* |
| **JUL 24** | **Comet Q&A: Comet NEOWISE**<br>Taylor Bell *(MSI)* |
| **SEP 10** | **Observing Black Holes Large and Small**<br>Prof. Daryl Haggard *(MSI)* |
| **NOV 05** | **Lights, Action, Camera: Making Movies of Molecules and Materials**<br>Prof. Bradley Siwick *(McGill Physics)* |
| **DEC 03** | **Gamma Rays & Cosmic Rays: How the Most Energetic Light is Helping Solve a Century-Old Mystery**<br>Matthew Lundy *(MSI)* |

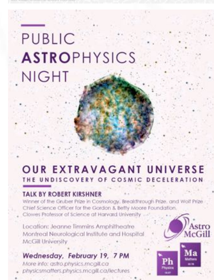

PUBLIC
ASTROPHYSICS
STREAM
Astro McGill
Ph Physics
Ma Matters
OBSERVING
BLACK HOLES
LARGE AND SMALL
Talk by Prof. Daryl Haggard
from McGill University
THURSDAY SEPTEMBER 10, 2020 7PM ET

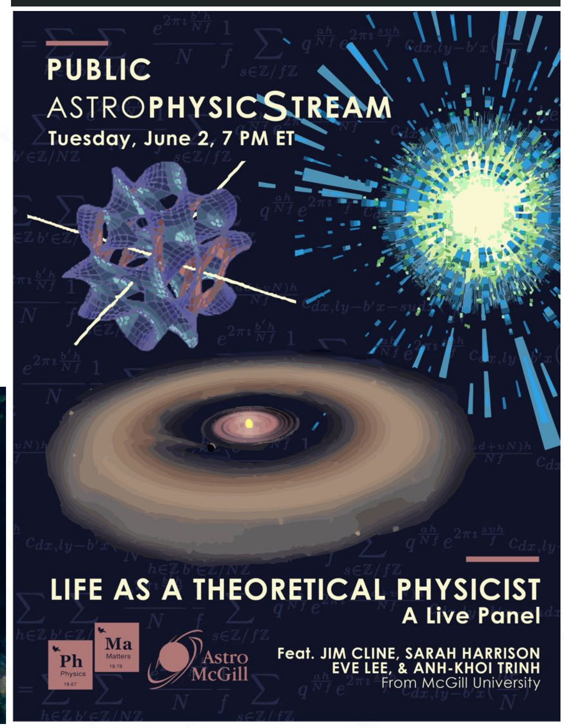

PUBLIC
ASTROPHYSICS
STREAM
Thursday, December 3rd, 7 PM ET
Ph Physics
Ma Matters
Astro McGill
GAMMA RAYS & COSMIC RAYS
How the Most Energetic Light Is Helping
to Solve a Century-Old Mystery
Talk by Matthew Lundy from McGill University
Image credit: DESY Science Communication Lab


PUBLIC
ASTROPHYSICS
STREAM
Thursday, November 5, 7 PM ET
Ph
Ma
Astro McGill
LIGHTS, ACTION, CAMERA:
MAKING MOVIES OF MOLECULES AND MATERIALS
Talk by Dr. Bradley Siwick from McGill University

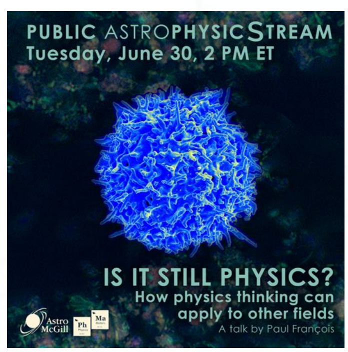

PUBLIC
ASTROPHYSICS
STREAM
TAKE IT TO THE LIMIT:
Using Mammoth Machines
to Study the Tiniest
of Particles
LIVESTREAM BY LIA FORMENTI
From McGill University
Thursday, May 21, 2 PM ET
Ph
Ma
Astro McGill


PUBLIC ASTROPHYSICS NIGHT
Tuesday, January 21, 7 PM
BIOPHYSICS:
HOW PHYSICISTS THINK ABOUT LIFE
A public talk by LILI ZENG


PUBLIC
ASTROPHYSICS
NIGHT
OUR EXTRAVAGANT UNIVERSE
THE UNDISCOVERY OF COSMIC DECELERATION
TALK BY ROBERT KIRSHNER
Astro McGill
Wednesday, February 19, 7 PM
Ph
Ma


PUBLIC
ASTROPHYSICSTREAM
Tuesday, June 2, 7 PM ET
LIFE AS A THEORETICAL PHYSICIST
A Live Panel
Ph Physics
Ma Matters
Astro McGill
Feat. JIM CLINE, SARAH HARRISON
EVE LEE, & ANH-KHOI TRINH
From McGill University


PUBLIC
ASTROPHYSICS
STREAM
Monday, June 22, 7 PM ET
Ph Physics
Ma Matters
Astro McGill
FAST RADIO BURSTS
HOW THESE BIG BOOMS ARE CHANGING
THE LANDSCAPE OF RADIO ASTRONOMY
Talk by Marcus Merryfield from McGill University

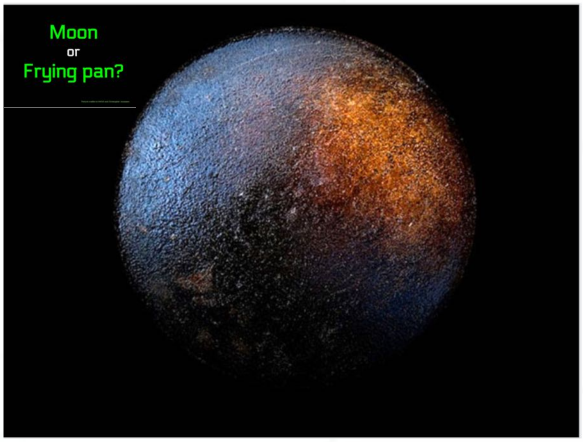

PUBLIC ASTROPHYSICSTREAM
Tuesday, June 30, 2 PM ET
IS IT STILL PHYSICS?
How physics thinking can
apply to other fields
A talk by Paul François
Astro McGill
Ph
Ma


LIFE AS AN ASTRONOMER AT
THE SOUTH POLE
A livestream with Maclean Rouble, Cynthia Chiang & Josh Montgomery
Ph
Ma
Wed., 06 May | 12 pm Eastern Time
Astro McGill

# Astronomy on Tap


Montreal has been a satellite location of the popular Astronomy on Tap (AoT) series since 2017. Initiated by AstroMcGill, AoT MTL is now jointly organized by the Institute for Research on on Exoplanets (iREx), the Centre de recherche en astrophysique du Québec (CRAQ) and AstroMcGill. AoT are free events aimed 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, 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.

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. 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.




# Astro Trivia Night

The COVID pandemic put AoT on pause, but we re-harnessed its energy into our very first Virtual Astronomy Trivia Night in November 2020. Games became the main event, with mini-science talks taking place in between rounds of trivia. Three rounds of trivia tested our participant's knowledge of the mysteries of the Cosmos, ranging from deciphering weird astronomy acronyms to properly dating astronomy pictures, and telling dirty frying pans apart from Moons (a feat that proves much harder than it seems). Participants were still able to pick up some new astronomy knowledge and interact with astronomers during the 5-minute research talks in between each round.


Trivia Night was a rousing success, with over 75 people playing, either alone or in teams. The top 3 teams won some MSI-themed merchandise, and competition was fierce! Thanks to our audience's enthusiastic response, trivia nights are now part of our regular rotation of events going forward.

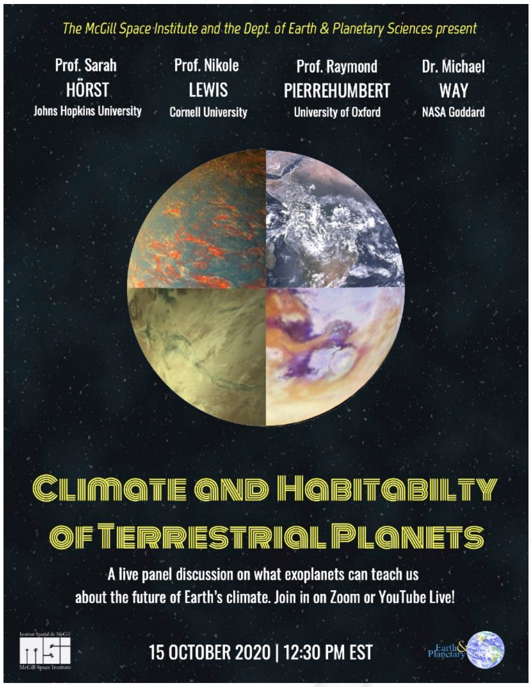

*From top: MSI postdoc John Ruan at Astronomy on Tap on March 4, 2020; one of the games from Astro Trivia Night; AoT coasters; poster for our last in-person AoT in March 2020; the "Cosmojito", a signature cocktail for Astro Trivia Night; poster for Trivia night.*

# Special MSI Public Lectures

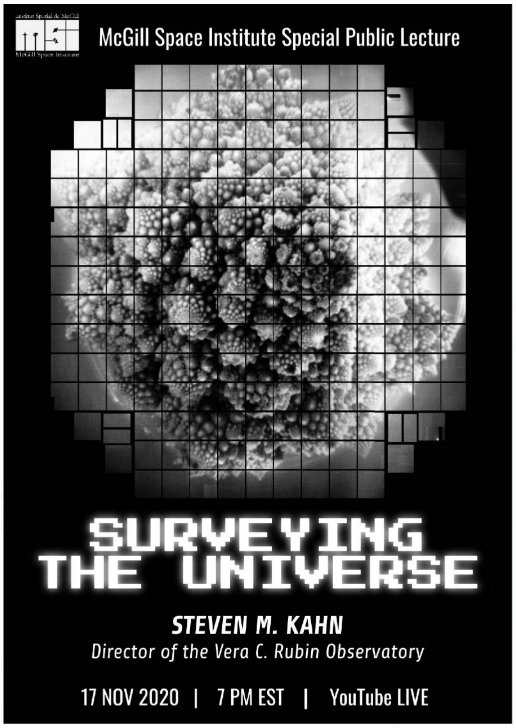
## Climate & Habitability of Terrestrial Exoplanets: A Panel Discussion

What can the climates of other planets, both within and outside our Solar System, tell us about Earth's climate trajectory? On October 12, 2020, MSI collaborated with the McGill Department of Earth & Planetary Sciences to host ***Climate & Habitability of Terrestrial Planets***, a live-streamed moderated panel discussion with 4 top planetary experts from across North America and Europe. Our speakers were **Raymond Pierrehumbert** (Halley Professor of Physics, University of Oxford), **Nikole Lewis** (Assist. Prof. of Astronomy, Cornell University; Deputy Director, Carl Sagan Institute); **Michael Way** (NASA Goddard Institute for Space Science, and **Sarah Hörst** (Assist.Prof. of Earth and Planetary Sciences, Johns Hopkins University).

The moderated panel discussion, hosted by MSI Prof. Nicolas Cowan, was followed by a Q&A session where our panelists took questions from the audience. Our panelists covered questions from what we mean by an exoplanet's "climate" and how we measure it, to what we can predict about the climate for exoplanets, to what Earth's climate tells us about exoplanets and Solar System worlds (and what they could tell us about Earth!). Over 300 people joined the event on both Zoom and YouTube Live, participating in a lively discussion that lasted close to 2 hours!




## Surveying the Universe



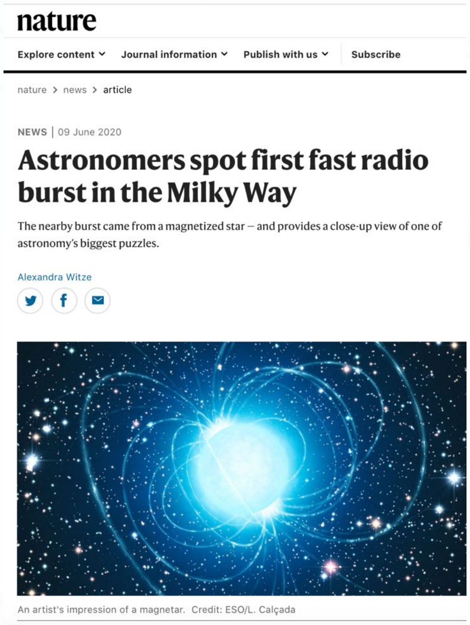

On November 17, 2020, we had the honour of (virtually) hosting a public talk by **Steven M. Kahn**, Cassius Lamb Kirk Professor in the Natural Sciences, Stanford University, and Director of the Vera C. Rubin Observatory. Prof. Kahn described the design and development of the Vera C. Rubin Observatory, a new and unique major astronomical facility under development in Chile with funding from the U.S. National Science Foundation and U.S. Department of Energy. The Rubin Observatory is a large-aperture, wide-field ground-based telescope designed to perform a ten-year, time-domain survey of the entire southern hemisphere of sky in six optical colour bands. He walked us through how the observatory will photograph every part of the southern sky nearly 1,000 times over its planned decade of operations. He expects that it will discover nearly 20 billion new galaxies, and a comparable number of stars – the first time in human history when we will know of more objects in the Universe than there are people on Earth. A diverse array of distinct science investigations will be enabled by the resulting database, ranging from studies of small moving bodies in the solar system to the structure and evolution of the Universe as a whole. The talk was followed by a Q&A where we took questions from our very enthusiastic audience, so many that we ran out of time. Prof. Kahn's lecture was very well received; around 200 people watched the livestream, and the recording has over 400 views!

# MSI in the Media

- Chercheurs en or, *La Presse+*, 01 Jan 2020 [**Daryl Haggard**]
- Mysterious repeating fast radio burst traced to nearby galaxy, *CNN*, 06 Jan 6 2020 [**CHIME/FRB**]
- Fast radio burst tracked down to a nearby galaxy, *McGill Reporter,* 10 Jan 2020. [**CHIME/FRB, Vicky Kaspi, Daniele Michili, Mohit Bhardwaj**]
- Canadian scientists trace 2nd strange radio signal to nearby galaxy, *CBC News*, 18 Jan 2020 [**CHIME/FRB**]
- Mort d'un portraitiste de l'Univers, *Le Devoir*, 01 Feb 2020 [**Tracy Webb**]
- Comparing Black Holes Large and Small, *AAS Nova*, 03 Feb 2020 [**John Ruan**]
- Another successful WE Day Montreal is complete, *The Suburban*, 07 Feb 2020 [**Daryl Haggard**]
- À l'écoute de l'Univers, *Le Devoir,* 29 Feb 2020 [**Vicky Kaspi**]
- Weather forecast for this exoplanet: iron rain, *CBC News*, 11 March 2020 [**Eve Lee**]
- ¿Nos contactan? Detectan nueve señales misteriosas en el espacio que no tienen explicación, *RPP Noticias (Peru)*, 26 March 2020 [**Emmanuel Fonseca**]
- Fast radio bursts could be distant magnetars, new evidence suggests, *Astronomy*, 04 May 2020 [**CHIME/FRB**]
- The Era of Anomalies, *Physics APS*, 14 May 14 [**Jim Cline**]
- Galactic flash points to long-sought source for enigmatic radio bursts, *Science*, 08 Jun 2020 [**Vicky Kaspi**]
- Astronomers spot first fast radio burst in the Milky Way, *Nature*, 09 Jun 2020 [**CHIME/FRB**]
- A Surprise Discovery Points to the Source of Fast Radio Bursts, *Quanta Magazine*, 11Jun 2020 [**CHIME/FRB**]
- Astronomers spot repeating radio burst patterns from deep space, *Popular Science*, 14 Jun 2020 [**Emmanuel Fonseca**]
- A Cosmic Baby Is Discovered, and It's Brilliant, *NASA JPL Newsroom,* 17 Jun 2020 [**Vicky Kaspi**]
- Transit spectroscopy in action, *Scientist Live,* 22 Jun 2020 [**Nicolas Cowan**]
- Una de las lunas de Júpiter podría ser habitable: La NASA descubre un océano subterráneo que pudiera albergar vida, *Futuro360 (Chile)*, 26 Jun 2020, [**Lyle Whyte**]
- CRC announces new and renewed chairs for McGill Profs, *McGill Newsroom,* 09 Jul 2020 [**Daryl Haggard**]
- Quand le pergélisol fond, *La Presse*, 19 Jul 2020 [**Nagissa Mahmoudi**]
- Comet NEOWISE, *CJAD 800: The Elias Makos Show*, 22 Jul 2020 [**Taylor Bell**]
- These Microbes May Have Survived 100 Million Years Beneath the Seafloor, *The New York Times*, 28 Jul 2020 [**Nagissa Mahmoudi**]


- La NASA à la conquête de Mars, *Radio-Canada*, 30 Jul 2020 [**Richard Leveille**]
- Black Hole Fails to Do Its Job, *NASA Newsroom*, 03 Aug 2020 [**Tracy Webb**]
- Here's What Happens When a Supermassive Black Hole Fails to Do Its Job, *SciTech Daily*, 14 Aug 2020 [**Tracy Webb**]
- Interstellar visitor 'Oumuamua could still be alien technology, new study hints, *LiveScience*, 15 Aug 2020 [**Tim Hallatt**]
- Un biomarqueur d´ecouvert dans l'atmosph`ere de Venus: un signe de vie?, *Quebec Science,* 14 sept, 2020 [**Nicolas Cowan**]
- Astronomers may have found hints of life in clouds of Venus, *CBC News*, 14 Sep 2020 [**Nicolas Cowan**]
- Searching the stars for supermassive black holes, *McGill Tribune,* 22 Sep 2020 [**Daryl Haggard**]
- Going Supernova: The swan song of a dying star, *McGill Tribune*, 20 Oct 2020 [**Vicky Kaspi**]
- Super-Hot Planet 'Shouldn't Exist', And Yet It Persists, *Forbes*, 27 Oct 2020 [**Nicolas Cowan**]
- La stella morta che spiega i lampi radio veloci, *Media INAF (Italy)*, 04 Nov 2020 [**Daniele Michilli**]
- Enigmatic fast radio burst pinned on magnetised dead star, *BBC News*, 04 Nov 2020 [**CHIME/FRB**]
- Fast radio burst may have come from the Milky Way, *CNN*, 04 Nov 2020 [**CHIME/FRB**]
- Tracing the origins of fast radio bursts, *Cosmos Magazine*, 05 Nov 2020 [**Daniele Michilli**]
- Mysterious radio signal spotted in Milky Way for first time, *National Geographic*, 05 Nov 2020 [**Daniele Michilli**]
- Astronomers discover likely source of strange radio bursts from space, *CBC News*, 05 Nov 2020 [**CHIME/FRB**]
- Meet The Hell Planet With A Magma Ocean And Rocky Rain, *EarthSky News*, 11 Nov 2020 [**Nicolas Cowan**]
- McGill researchers awarded $1.5 million in NRC collaborative funding, *McGill Reporter*, 16 Nov 2020 [**Vicky Kaspi, Lyle Whyte**]
- Repeated radio bursts from nearby star suggest such signals are common, *New Scientist*, 16 Nov 2020 [**Daniele Michilli**]
- McGill celebrates investigators named to Highly Cited Researchers 2020 List, *McGill Reporter*, 18 Nov 2020 [**Vicky Kaspi**]
- Les glaces de l'hémisphère Nord agissent sur celles de l'hémisphère Sud, *RTS*, 30 Nov 2020 [**Natalya Gomez**]
- La conexión de los polos, *Diario Sur*, 01 Dec 2020 [**Natalya Gomez**]
- Daniele Michilli, intervista all'umbro che ha captato il primo lampo radio veloce nella Via Lattea, *Radio Gente Umbra (Italy)* 02 Dec 2020

Daniele Michilli (a sinistra) intervistato da Alessio Vissani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NEWS | 09 June 2020

**Astronomers spot first fast radio burst in the Milky Way**

The nearby burst came from a magnetized star – and provides a close-up view of one of astronomy's biggest puzzles.

Alexandra Witze

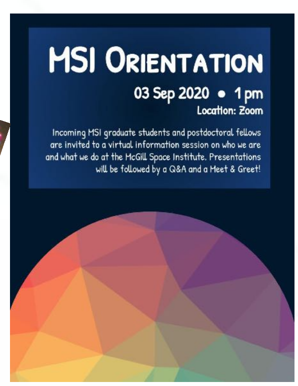
An artist's impression of a magnetar. Credit: ESO/L. Calçada

# Inreach: Life @ MSI

Fostering cross-fertilization of ideas, 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 MSI!

The COVID-19 pandemic meant that our activities looked a little different this year, but we were able to keep up the sense of community that makes MSI unique. All of our discussion groups and seminars moved online, as did our celebration of the beginning of the academic year (the MSI Jamboree). Even our annual Solstice Party went virtual, with over 40 MSI members joining in the festivities, which included holiday card-making and a song/limerick competition that we're fully planning to maintain once we're able to celebrate again together!





# A Week @ MSI

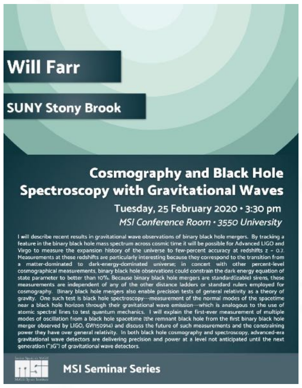
| | |
|---|---|
| Mon | MSI Lunch Talks<br>Random Papers Discussion |
| Tues | MSI & Astro Seminars<br>Grad meeting w/ seminar speaker<br>Summer student discussion group |
| Wed | EPOD Discussion |
| Thu | Neutron Star Discussion |
| Fri | astro-PH Discussion<br>Planet Lunch<br>cosmo-PH Discussion |

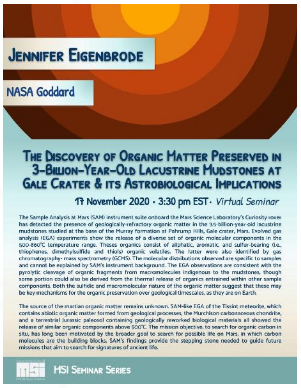
# Seminars

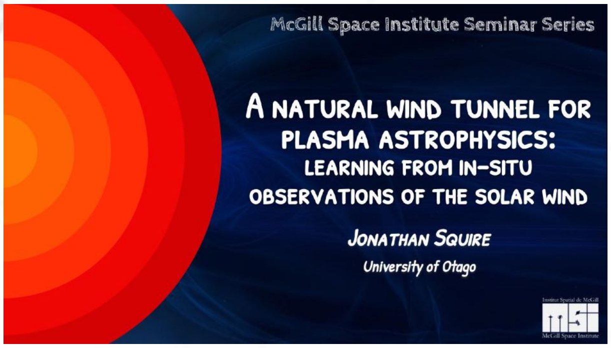
The MSI runs two regular seminar series, the MSI Seminar Series and the Joint Astrophysics Seminar Series. MSI Seminars are intended to be accessible to scientists from the entire breadth of backgrounds at MSI, including physics, planetary science, geology, atmospheric science, and astrobiology. Joint Astrophysics Seminars, which are organized in conjunction with the Centre de recherche en astrophysique du Québec (CRAQ), are aimed at astronomers and astrophysicists. Although the COVID-19 pandemic led to the cancellation of our seminar series in March and April 2020, both series moved online successfully and resumed as virtual seminars in Fall 2020. Most seminars from Fall 2020 can be viewed on the MSI's YouTube channel.

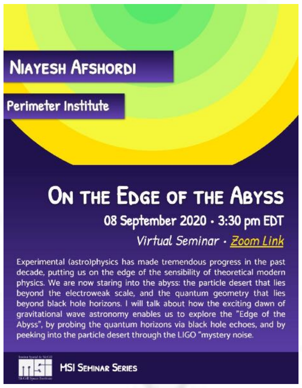
## MSI Seminars

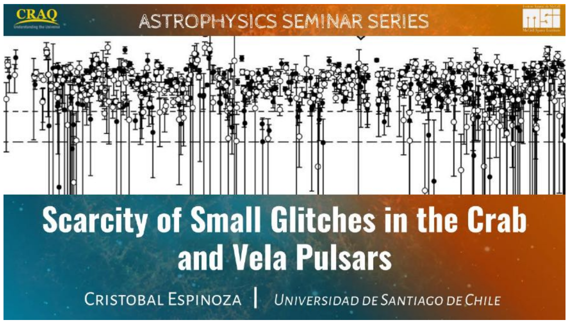
| | |
|---|---|
| Jan. 14 | **Erik Kuulkers** *(ESA)*<br>'Lunar geochemical and Galactic astronomy X-ray observations with Apollo 15 and 16' |
| Jan. 28 | **Rodrigo Fernandez** *(University of Alberta)*<br>'Mass ejection, compact objects, and electromagnetic transients' |
| Feb. 11 | **Laurie Barge** *(Caltech)*<br>'Detecting Signs of Life and its Origin on Other Planets' |
| Feb. 25 | **Will Farr** *(SUNY Stony Brook)*<br>'Cosmography and Black Hole Spectroscopy with Gravitational Waves' |
| Sep. 08 | **Niayesh Ashfordi** *(Perimeter Institute)*<br>'On the Edge of the Abyss' |
| Sep. 22 | **Jess McIver** *(UBC)*<br>'The latest results from LIGO and Virgo' |
| Oct. 06 | **Jono Squire** *(University of Otago)*<br>'A natural wind tunnel for plasma astrophysics: learning from in-situ observations of the solar wind' |
| Oct. 20 | **Stephanie Wissel** *(Pennsylvania State University)*<br>'Prospects and Progress in Radio Searches for Ultra-High-Energy Neutrinos' |
| Nov. 03 | **Frances Rivera-Hernandez** *(Dartmouth College)*<br>'From Grains to Landscapes: Reconstructing Martian Environments at Multiple Scales' |
| Nov. 17 | **Jennifer Eigenbrode** *(NASA Goddard)*<br>'The Discovery of Organic Matter Preserved in 3-Billion-Year-Old Lacustrine Mudstones at Gale Crater, Mars and Its Astrobiological Implications' |
| Dec. 01 | **Vishal Gajjar, Karen Perez, Bryan Brzycki**<br>'On the Breakthrough Listen's radio technosignature searches' |

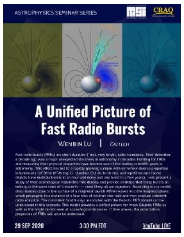



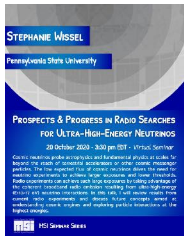



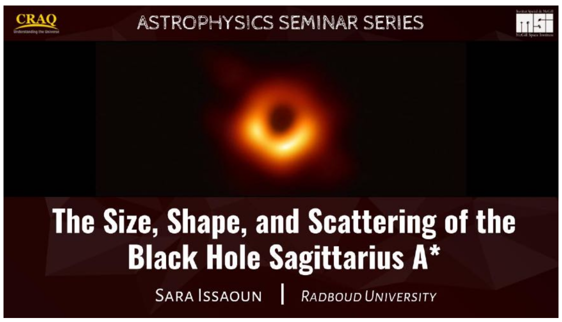



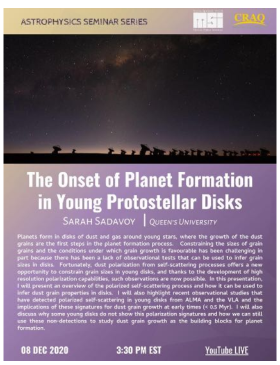



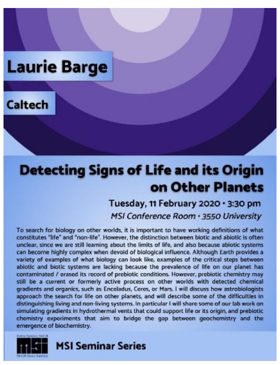



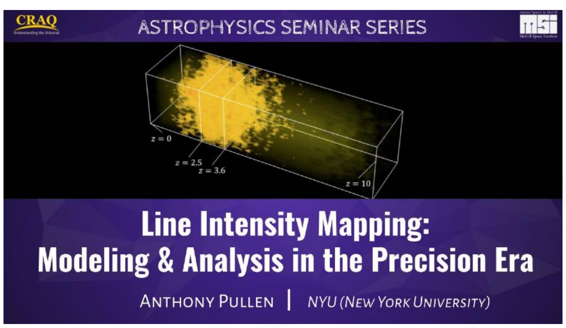


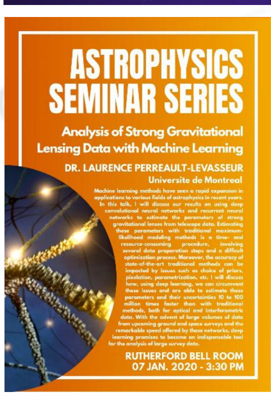


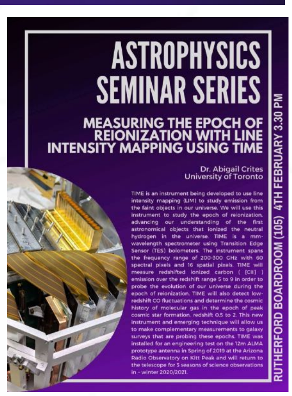




# Astrophysics Seminars

| | |
|---|---|
| Jan. 07 | **Laurence Levasseur (UdeM)**<br>'Analysis of Strong Gravitational Lensing Data with Machine Learning' |
| Jan. 21 | **Alex von Engelen (CITA)**<br>'The CMB as a backlight' |
| Feb. 04 | **Abigail Crites (University of Toronto)**<br>'Measuring the Epoch of Reionization with Line Intensity Mapping using TIME'' |
| Feb. 18 | **Michael Lam (Rochester Institute of Technology)**<br>'Astrophysics with the NANOGrav Pulsar Timing Array'' |
| Sep. 15 | **Sara Issaoun (Radboud University)**<br>'The Size, Shape, and Scattering of the Black Hole Sagittarius A*' |
| Sep. 29 | **Wenbin Lu (Caltech)**<br>'A Unified Understanding of Fast Radio Bursts' |
| Oct. 13 | **Ting Li (Princeton University & Carnegie Observatories)**<br>'The Southern Stellar Stream Spectroscopic Survey (S5): Overview and Latest Science Results' |
| Oct. 27 | **Anthony Pullen (NYU)**<br>'Line Intensity Mapping: Modeling & Analysis in the Precision Era' |
| Nov. 10 | **Jon Gudmundsson (Stockholm University)**<br>'Simulating optical systematics in next-generation CMB experiments' |
| Nov. 24 | **Cristóbal Espinoza (Universidad de Santiago de Chile)**<br>'Scarcity of Small Glitches in the Crab and Vela Pulsars' |
| Dec. 08 | **Sarah Sadavoy (Queen's University)**<br>'The Onset of Planet Formation in Young Protostellar Disks' |

# 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. Due to the COVID-19 pandemic, Lunch Talks moved online in April 2020. Speakers are limited to five slides (with unlimited blackboard usage) and are asked to prepare 15 minutes of material for a 30 minute slot; the remaining 15 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. 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.

## 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" (MBH CoLAB), funded by Fonds de recherche du Quebec - Nature et tecnologies (FRQNT).

## 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 that deals with 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. The discussion is targeted at MSI members at all levels but we regularly welcome participants from the Physics department. More information about EPOD, including a list of topics discussed in 2020, can be found on page xx.

## Astro-ph Discussion

Astro-ph is a weekly journal discussion that takes place every Friday morning at MSI over donuts and coffee. This year, it moved to an online format while we were all working from home 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.

# Equity, Diversity & Inclusion

The MSI is committed to diversity, equity, and inclusion within the community. Fostering and sustaining an equitable and inclusive environment —one which recognizes the diversity of backgrounds, identities, and expectations— strengthens our community and our research. MSI works closely with the EDI Committee in the Physics Department, and collaborates with the EDI Committee in Earth & Planetary Sciences.

## EPOD Discussion & Hack Sessions

EPOD (Education, Public Outreach, Equity, Diversity and Inclusion) Discussion is a weekly discussion group run by the MSI coordinator. EPOD has been a mainstay of the MSI's activities since its founding, and the mandate of the group has evolved and changed to meet the needs and interests of the MSI's members. EPOD discussions explore issues at the intersection of education, equity, and inclusion. Discussions are paper-based (usually on either a journal article or occasionally a best practices report), but the paper is usually meant to be a way of framing the discussion of a broader issue. MSI members are encouraged to suggest topics and lead the discussion if they so choose! EPOD is meant to be both a learning space and a place to think about the changes we can implement to become a more inclusive and welcoming space. The discussion is targeted at MSI members at all levels but we regularly welcome participants from the Physics department.

Starting in January 2019, we introduced EPOD Hack Sessions, where we pick a topic we've discussed at EPOD and try to tackle a specific project that relates to it. Hack sessions are meant to help EPOD participants use the knowledge they've gained to produce something concrete and actionable, even if it's small. EPOD hack projects include a quantitative study of the gender breakdown of the department, the beginnings of a climate survey (which then went on to become its own task force, see below), and a set of guidelines for thinking about the ethical impact of physics/astronomy research.

***EPOD Discussion Topics - 2020***

- *14-Jan-2020: Gender differences in how scientists present the importance of their research*
- *21-Jan-2020: The Nonbinary Fraction: Looking Towards the Future of Gender Equity in Astronomy*
- *28-Jan-2020: Mental health and graduate school*
- *04-Feb-2020: Inclusive scientific meetings*
- *11-Feb-2020: AIP task force's report on increasing the fraction of African American students in physics and astronomy*
- *25-Feb-2020: Incorporating Universal Design into physics education*
- *13-May-2020: Educational supports and career goals of five women in a graduate astronomy program*
- *20-May-2020: The Importance of High School Physics Teachers for Female Students' Physics Identity and Persistence*
- *03-June-2020: Inclusivity-driven design for general education astronomy courses*
- *10-June-2020: BLM and Antiracism in Academia*
- *17-June-2020: Hack session: Drafting a Values Statement*
- *08-July-2020: Implicit racial bias and performance in the classroom*
- *15-July-2020: McGill's EDI Strategic Plan*
- *22-July-2020: Supporting Black women physicists*
- *29-July-2020: Black physics identity*
- *05-Aug-2020: Gender differences in recommendation letters for postdoctoral fellowships in geoscience*
- *12-Aug-2020: Associations between learning assistants, passing introductory physics, and equity*
- *16-Sep-2020: (Un)conscious Bias in the Astronomical Profession: Universal Recommendations to improve Fairness, Inclusiveness, and Representation*
- *23-Sep-2020: Burdens and benefits of diversity work: emotion management in STEM doctoral students*
- *30-Sep-2020: Female and male students' attitudes and approaches to physics problem solving*
- *07-Oct-2020: McGill's Action Plan to Address Anti-Black Racism*
- *13-Oct-2020: Impact of astronomy on climate change (Part 1)*
- *20-Oct-2020: Impact of astronomy on climate change (Part 2)*
- *06-Nov-2020: Privilege, power and leadership in academia*
- *11-Nov-2020: Demographics and representativeness of*

## Town Hall on Anti-Black Racism

On June 10, 2020 the MSI coordinator, along with the Physics EDI Committee, organized a Town Hall on systemic racism as the MSI/Physics Department's participation in #ShutDownSTEM. Over 90 members of the Physics department and the McGill Space Institute participated in the 2-hour long discussion. The town hall served not just as an outlet for people to discuss how they felt about the murder of George Floyd, but also as a place to learn about the impact of systemic racism in academia. In order to harness the urgency that our graduate students felt to take action, we structured the town hall so that we could crowdsource priorities and actions that the community cares about the most. We gathered over 6 pages of suggestions for actions to tackle anti-Black racism and under-representation in Physics in general, which then became the basis for the Physics EDI Action Plan.

## Action Plan Work Sessions

In August 2020, the EDI committee began working on an EDI Action Plan, based on the suggestions we gathered during the town hall. The work began during an EPOD hack session, led by the MSI Coordinator, which brought together group of over 20 students, faculty, and staff from MSI and Physics. We came up with a framework to map the suggestions gathered during the Town Hall to align with McGill's Strategic Plan on Anti-Black racism and McGill's EDI plan. The group then met weekly for the following two months to develop the first draft of the action plan. The draft plan was then passed on to the McGill Physics EDI Committee, on which various MSI members sit, for implementation. MSI members have taken the lead on several action plan items, including the Climate Survey (see below), strengthening the pipeline for people from under-represented groups, normalization of EDI discussions (during EPOD and in other contexts), and improving the onboarding of new members. MSI will continue to take an active role in implementing the action plan in order to make our environment more equitable and inclusive.

## Climate Survey

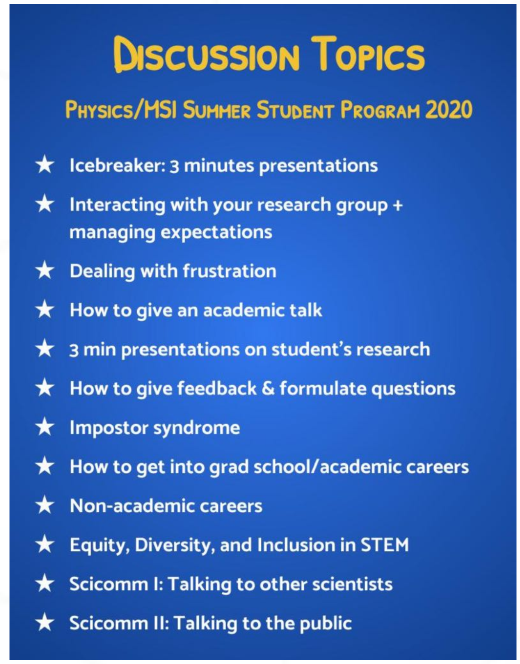
The initial drive for a climate survey came out of an EPOD discussion in late 2019. The intention was to have a baseline of where we stand, to inform the changes needed to create a more inclusive environment. After learning that a group of graduate and undergraduate students in Physics was working on a similar survey, we decided to join forces and design just one survey to be deployed in Physics and MSI. The Climate Survey Task Force began working together in November 2019 to design the survey and develop the appropriate strategy for data collection and analysis. COVID altered our timelines, but we deployed the survey in September 2020. The results were analysed over the Fall of 2020, with the final report due to be presented and published in 2021. The MSI will continue to be involved in future iterations of the climate survey, which we plan to run on a bi-yearly basis.

## Addressing Areas of Under-representation

Despite improvements in the past decade, minority groups (including but not limited to racial and gender minorities) continue to be underrepresented in the field of astronomy. Our institute is not exempt. While preparing a report on the activities of the MSI Fellowships Committee in 2019, the committee identified that women were significantly under-represented in the postdoctoral fellow population of the MSI. To address it, we explicitly made improving diversity (and in particular gender diversity) one of the goals of the committee that year. We implemented best practices during the application and evaluation process to reduce bias. Generating awareness about the issue allowed us address it; 50% of our incoming MSI postdoctoral fellows in 2020 were women. We understand that there is still more work to be done and we are committed to continuing our efforts. For the 2021 cycle, we have continued our efforts and are looking at how to do the same for racial diversity, particularly to address the lack of Black and Indigenous postdocs.

# 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, the MSI was once 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. Due to the COVID-19 pandemic, the program was hosted entirely virtually. Weekly Zoom meetings and a Slack workspace helped us build a sense of community while working remotely. 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 students. The format of these weekly seminars is a casual discussion, organized by MSI Coordinator Carolina Cruz-Vinaccia, MSI Postdoctoral Fellow Dallas Wulf, and Physics Undergraduate Advisor Kelly Lepo, with immense help from various other MSI members. 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 seminars is to foster a sense of community amongst the undergraduate summer researchers, and ensure that they become familiar with their peers. This was especially important this year.

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". The 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. The overarching theme of this year's program was communicating science, both to other scientists and to the public. Students had multiple opportunities to practice their communication skills, from informal 3 minute talks about anything they liked (which gave us a great opportunity to get to know them better!), to 10-minute talks about their research projects.


## Undergraduate Poster Session & Research Showcase

At the end of the summer, we organized a virtual Summer Undergraduate Poster Session & 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. The presentations were extremely impressive and well-received by the audience.

# Awards

## Faculty Members

**Nicolas Cowan**
- Heising-Simons Scialog Fellow: Signatures of Life in the Universe

**Daryl Haggard**
- 2020 Breakthrough Prize in Fundamental Physics
- 2020 Principal's Prize for Outstanding Emerging Researchers

**Vicky Kaspi**
- Bakerian Medal and Lecture from the Royal Society
- 2020 McGill Alumni Association David Johnston Faculty & Staff Award

**Adrian Liu**
- 2020 Sloan Research Fellowship

**Ken Ragan**
- CAP medal for Excellence in Teaching Undergraduate Physics

**CHIME Team**
- 2020 Governor General's Innovation Award

## Graduate Students

**Bridget Andersen**
- FRQNT Doctoral Scholarship

**Hope Boyce**
- L'Oréal Canada France Canada Research Fund 2020 Fellow

**Vincent Comeau**
- FRQNT Master's Scholarship

**Rafael Fuentes**
- MITACS Research Training Award
- Schulich Graduate Fellowship

**Samskruthi Ganjam**
- MITACS Research Training Award

**Timothy Hallatt**
- NSERC CGS-M Alexander Graham Bell Scholarship
- Technologies for Exoplanet Science (TEPS-CREATE)

**Marcus Merryfield**
- NSERC PGS-D

**David Purnell**
- Jerome M. Paros Scholarship in in Geophysical Instrumentation (AGU)
- Leroy Fellowship (McGill / EPS)

**Maclean Rouble**
- MITACS Research Training Award

**Jean-Samuel Roux**
- NSERC PGS-D

**Andrew Sikora**
- NSERC CGS-M

**Jeannette Wan**
- Robert Wares Fellowship

# 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 has been an MSI postdoctoral fellow since 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 has been an MSI postdoctoral fellow since 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.

### John Ruan

*Physics ❈ Prof. Daryl Haggard's Group*

Dr. Ruan was an MSI Postdoctoral Fellow from Fall 2017 to August 2020. As of Fall 2020, he has accepted a position as Assistant Professor at Bishop's University. 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 was an MSI Postdoctoral Fellow from Fall 2018 to Summer 2020. His research interests include extragalactic 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.

## Dallas Wulf

*Physics ❊ Prof. Matt Dobb's Group*

Dr. Wulf has been an MSI postdoctoral fellow since January 2019. His research interests include instrumentation for radio interferometry, with applications in 21cm cosmology, the interstellar medium, and radio transients. He is also interested in physics education research.

## Fernando Zago

*Physics ❊ Prof. Jon Sievers's Group*

Dr. Zago has been an MSI postdoctoral fellow since Fall 2019. His research interests range from theoretical early-universe cosmology to the analysis of astrophysical data. Lately, his work has concetnrated on the development of computational tools geared towards the extraction of cosmological signals from radio and microwave observations of the sky.

# Incoming MSI Postdoctoral Fellows: 2020

## Kristen Dage

*Physics ❊ Prof. Daryl Haggard's Group*

Dr. Dage joined MSI as a MSI postdoctoral fellow in Fall 2020. Her research is focused on studying the population of X-ray binaries in globular clusters, with a focus on ultraluminous X-ray sources, which provide observational evidence of the extent of black holes in extragalactic globular clusters, as well as the nature of the clusters that host them.

## Aaron Pearlman

*Physics ❊ Prof. Vicky Kaspi's Group*

Dr. Pearlman joined MSI in as an MSI postdoctoral fellow in Fall 2020. His research interests include studies of fast radio bursts (FRBs) and their host environments, multiwavelength observations of FRBs, magnetars, and pulsars, developing novel algorithms for FRB and pulsar searches, and searching for pulsars in extreme environments. Dr. Pearlman is currently working on precisely localizing FRBs on the sky using the CHIME/FRB radio telescope and several outrigger radio telescopes that are under rapid development as part of the CHIME/FRB Outrigger project.

## Peter Sims

*Physics ❊ Prof. Jon Sievers's Group*

Dr. Sims joined MSI as an MSI postdoctoral fellow in Fall 2020. He is a cosmologist interested in the formation of structure in the early Universe. His current research focuses on the development and application of Bayesian data analysis techniques to enable observational probes of the redshifted 21 cm hyperfine line of neutral hydrogen gas during Cosmic Dawn and the Epoch of Reionization, when the first stars, proto-galaxies, and black holes formed, and the extraction of astrophysical and cosmological information encoded in observations of these early periods of the Universe's history.

# MSI MEMBERS

## Faculty Members

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

## Associate Members

Oscar Hernandez
Richard Leveille

## Staff

Carolina Cruz-Vinaccia

## Postdoctoral Fellows

Gonzalo Alonso-Alvarez
Suddhasattwa Brahma
Kristen Dage
Miguel Angel Fernandez
Emmanuel Fonseca
Adélie Gorce
Mona Jalilvand
Adam Lanman
Daniele Michilli
Jordan Mirocha
Raul Monsalve
Thomas Navarro
Stephan O'Brien
Aaron Pearlman
Emily Petroff
John Ruan
Heath Shipley
Peter Sims
Saurabh Singh
Chia Min Tan
Yuwei Wang
Dallas Wulf
Maryam Yousefi
Fernando Zago

## Graduate Students

Soud Al Karusi
Omar Alaryani
Mesbah Alsarraj
Bridget Andersen
Capucine Barfety
Taylor Bell
Sabrina Berger
Mohit Bhardwaj
Olivia Blenner-Hasset
Hope Boyce
Paul Charlton
Pragya Chawla
Paul Chouha
Razvan Ciuca
Vincent Comeau
João Corrêa Buschinelli
Alice Curtin
Bryce Cyr
Lisa Dang
Amanda Di Nitto
Constanza Echiburu
Aline Favero
Kelly Ann Foran
Hannah Fronenberg
Rafael Fuentes
Guillermo Gambini
Samskruthi Ganjam
Erin Gibbons
Simon Guichandot
Timothy Hallatt
Holly Han
Lawrence Herman
Hao Jiao
Xiangyu Jin
Alexandre Josephy
Zarif Kader
Dylan Keating
Marie-Pier Labonte
Samuel Laliberte
Julia Lascar
Benoit Laurent
Anan Lu
Matthew Lundy
Catherin Maggiori
Melissa Marquette
Elizabeth "Lisa" McBride
Tristan Ménard
Melissa Mendes Silva
Marcus Merryfield
Gabrielle Mitchell
Joshua Montgomery
Keavin Moore
Karishma Moorthy
Brady O'Connor
Deniz Olcek
Michael Pagano
Xinyu Pan
Emilie Parent
Robert Pascua
Matheus Pessoa
Elizabeth Pieters
Ziggy Pleunis
Matteo Puel
David Purnell
Maclean Rouble
Jean-Samuel Roux
Andrew Sikora
David Touchette
Nicolas Vieira
Jeannette Wan
Ziwei Wang
Andrew Zwaniga

## Undergraduate Students

Joëlle-Marie Bégin Miolan
Félix Bilodeau-Chagnon
Audrey Bourdon
Daniela Breitman
Margaret Bruna
Mathieu Bruneault
Taylor Dibblee-Barkman
Taj Dyson
Iman Fahmy
Anna Gagnebin
Samuel Gagnon-Hartman
Ian Hendricksen
Erika Hornecker
Elisa Jacquet
Numa Karolinski
Emma Klemets
William Laplante
Ronan Legin
Jeffrey Morais
Julia Morales Aguirre
Chloé Robeyns
Jeremy Roffman
Katie Savard
Simon Tartakovsky

# MSI Board & Committees

## MSI Board 2020

### 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*

**Natalya Gomez**
*Assistant Professor of Earth & Planetary Sciences*

**Dallas Wulf**
*Postdoctoral Fellow, Physics*

**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*

**Jordan Mirocha**
*Postdoctoral Fellow, Physics*

**Thomas Navarro**
*Postdoctoral Fellow, EPS*

**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 & 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**
*(Brandenberger, Haggard, Huang, Kaspi, Gomez, Ragan, Hanna)*
Owned and administered by Compute Canada and Calcul Quebec

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

**Cedar supercomputer**
*(Haggard, Liu)*
Owned and administered by Compute Canada

**Graham supercomputer**
*(Lee, Brandenberger)*
Owned and administered by Compute Canada

## 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**
*(Haggard, 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, Haggard, Webb)*

**NASA/Kepler Mission**
*(Cowan)*

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

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

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

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

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

**NASA Spitzer Space Telescope**
*(Cowan, Haggard, Webb)*

**NASA/Fermi mission**
*(Ragan)*

**NASA/Transiting Exoplanet Survey Satellite**
*(Lee)*

# MSI Faculty Collaborations

**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✳ 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

**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

**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 ✳ Queen Mary University of London ✳ University of Pennsylvania ✳ Scuola Normale Superiore di Pisa ✳ SKA-South Africa ✳ University of Washington ✳ University of Western Cape ✳ Winona State University

**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 ✳

**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 InfraRouge 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 ✳ DESY ✳ 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


Abeysekara, A. U., Archer, A., (...) **Hanna, D.**, (...), **Kumar, S.**, (...) **O'Brien, S.**, (...) **Ragan, K.** et al (2020) Evidence for Proton Acceleration up to TeV Energies Based on VERITAS and Fermi-LAT Observations of the Cas A SNR. *ApJ*, 894, 51.

Abeysekara, A. U., Benbow, W., (...) **Hanna, D.**, (...) **Kumar, S.**, (...), **Lundy, M.**, (...), **O'Brien, S.**, (...) **Ragan, K.** et al (2020) Demonstration of stellar intensity interferometry with the four VERITAS telescopes. *NatAs*, 4, 1164.

Abeysekara, A. U., Benbow, W., (...),**Kumar, S.**, (...), **O'Brien, S.**, (...) **Ragan, K.** et al (2020) The Great Markarian 421 The Great Markarian 421 Flare of 2010 February: Multiwavelength Variability and Correlation Studies. *ApJ*, 890, 97.

Abeysekara, A. U., Benbow, W., Bird, R., (...) **Hanna, D.**, (...) **Ragan, K.** et al (2020) VERITAS Detection of LS 5039 and HESS J1825-137. *APh*, 117, 102403.

Adachi, S., Aguilar Faúndez, M. A. O., Arnold, K., (..) **Dobbs, M.A.**, et al (Polarbear Collaboration) (2020) A Measurement of the CMB E-mode Angular Power Spectrum at Subdegree Scales from 670 Square Degrees of POLARBEAR Data. *ApJ*, 904, 65.

Aiola, S., Calabrese, E., Maurin, L., Naess, S., Schmitt, B.L., (...) **Sievers, J.** (...) **Zago, F.** et al (2020) The Atacama Cosmology Telescope: DR4 maps and cosmological parameters. *JCAP*, 2020, 047.

Ali-Dib, M., **Cumming, A.** & Lin, D.N.C. (2020) The imprint of the protoplanetary disc in the accretion of super-Earth envelopes. *MNRAS*, 494, 2440.

Anderson, A. J., Ade, P. A. R., (...), **Dobbs, M. A.**, (...), **Montgomery, J.**, et al (2020) Performance of Al-Mn Transition-Edge Sensor Bolometers in SPT-3G. JLTP, 199, 320.

Archer, A., Benbow, W., (...) **Hanna, D.**, (...), **Lundy, M.**, (...) **O'Brien, S.**,(...), **Ragan, K.** et al (2020) VERITAS Discovery of VHE Emission from the Radio Galaxy 3C 264: A Multiwavelength Study. *ApJ*, 896, 41.

Archer, A., Benbow, W., Bird, R.,(...), **Hanna, D.**, (...), **O'Brien, S.**, (...) **Ragan, K.** et al (2020) Probing the Properties of the Pulsar Wind in the Gamma-Ray Binary HESS J0632+057 with NuSTAR and VERITAS Observations. *ApJ*, 888, 115.

Archibald, R. F., Scholz, P., **Kaspi, V. M.**, Tendulkar, S. P., Beardmore, A. P. (2020) Two New Outbursts and Transient Hard X-Rays from 1E 1048.1-5937. *ApJ*, 889, 160.

Arriaga, P., Fitzgerald, M.P., Duchêne, G., (...), **Doyon, R.** et al (2020) Multiband Polarimetric Imaging of HR 4796A with the Gemini Planet Imager. *AJ*, 160, 79.

Astudillo-Defru, N., Cloutier, R., Wang, S. X., Teske, J., (...) **Doyon, R.** et al (2020) A hot terrestrial planet orbiting the bright M dwarf L 168-9 unveiled by TESS. *A&A*, 636, A58.

Barausse, E., Berti, E., Hertog, T., Hughes, S.A., Jetzer, P., Pani, P., Sotiriou, T.P., (...) **Haggard, D.** et al (2020) Prospects for fundamental physics with LISA. *GReGr*, 52, 81.

Bedroya, A., **Brandenberger, R.**, Loverde, M., Vafa, C. (2020) Trans-Planckian censorship and inflationary cosmology. *PhRvD*, 101, 103502.

Bembenek, E., Straub, D.N., **Merlis, T.M.** (2020) Effects of Moisture in a Two-Layer Model of the Midlatitude Jet Stream. *JAtS*, 77, 131.

Ben Achour, J., **Brahma, S.** & Uzan, J.-P. (2020) Bouncing compact objects. Part I. Quantum extension of the Oppenheimer-Snyder collapse. *JCAP*, 03, 041.

Ben Achour, J., **Brahma, S.**, Mukohyama, S. & Uzan, J.-P. (2020) Towards consistent black-to-white hole bounces from matter collapse. *JCAP*, 09, 020.

Bender, A. N., Anderson, A. J., Avva, J. S., (...), **Dobbs, M. A.**, (...), **Montgomery, J.** et al (2020) On-Sky Performance of the SPT-3G Frequency-Domain Multiplexed Readout. *JLTP*, 199, 182.

Berera, A., **Brahma, S**. & Calderon, J. (2020) Role of trans-Planckian modes in cosmology. *JHEP*, 08, 071.

**Bernardo, H.**, **Brandenberger, R.** & **Franzmann, G.** (2020) O(d, d) covariant string cosmology to all orders in α'. *JHEP*, 2020, 178.

**Bernardo, H.**, **Brandenberger, R.** & **Franzmann, G.** (2020) Solution of the size and horizon problems from classical string geometry. *JHEP*, 2020, 155.

Bianchini, F., Wu, W. L. K., (...) **Chiang, H.C.** (...) **Dobbs, M. A.**, (...), **Montgomery, J.** et al (2020) Searching for anisotropic cosmic birefringence with polarization data from SPTpol. *PhRvD*, 102, 083504.

Bianchini, F., Wu, W. L. K., (...) **Chiang, H. C.**, (...) **Dobbs, M. A.**, (...) **Montgomery, J.**, et al (2020) Constraints on Cosmological Parameters from the 500 deg SPTPOL Lensing Power Spectrum. *ApJ*, 888, 119.

Bleem, L. E., Bocquet, S., Stalder, B., Gladders, M. D., (...) **Chiang, H. C.**,(...) **Dobbs, M. A.**, (...) **Montgomery, J.**, (...), et al (2020) The SPTpol Extended Cluster Survey. *ApJS*, 247, 25.

Bojowald, M. & **Brahma, S.** (2020) Loop quantum gravity, signature change, and the no-boundary proposal. *PhRvD*, 102, 106023.

Bojowald, M., **Brahma, S.**, Ding, D. & Ronco, M. (2020) Deformed covariance in spherically symmetric vacuum models of loop quantum gravity: Consistency in Euclidean and self-dual gravity. *PhRvD*, 101, 026001.

Bouhmadi-Lopez, M., **Brahma, S.**, Chen, C.-Y., Chen, P. & Yeom, D.-H. (2020) Annihilation-to-nothing: a quantum gravitational boundary condition for the Schwarzschild black hole. *JCAP*, 11, 002.

Bouhmadi-Lopez, M., **Brahma, S.**, Chen, C.-Y., Chen, P. & Yeom, D.-H. (2020) A consistent model of non-singular Schwarzschild black hole in loop quantum gravity and its quasinormal modes. *JCAP*, 07, 066.

Bouhmadi-Lopez, M., **Brahma, S.**, Chen, C.-Y., Chen, P. and Yeom, D.-H. (2020) Asymptotic non-flatness of an effective black hole model based on loop quantum gravity. *Phys.Dark Univ.* 30 (2020) 100701.

**Brahma, S.** (2020) Trans-Planckian censorship, infl ation and excited initial states for perturbations. *PhRvD*, 101, 023526.

**Brahma, S.** (2020) Trans-Planckian censorship conjecture from the swampland distance conjecture. *PhRvD* 101, 046013.

**Brahma, S**. & Yeom, D.-H. (2020) Can a false vacuum bubble remove the singularity inside a black hole?. *EPJC*, 80, 8.

**Brahma, S.**, **Alaryani, O**. & **Brandenberger, R.** (2020) Entanglement entropy of cosmological perturbations. *PhRvD*, 102, 043529.

**Brahma, S.**, **Alaryani, O.**, **Brandenberger, R.** (2020) Entanglement entropy of cosmological perturbations. *PhRvD*, 102, 043529.

**Brahma, S**., **Brandenberger, R.**, Yeom, D. (2020) Swampland, trans-Planckian censorship and fine-tuning problem for inflation: tunnelling wavefunction to the rescue. *JCAP*, 2020, 037.

**Brandenberger, R.**, **Cyr, B.** & **Jiao, H.** (2020) Cosmic rays and spectral distortions from collapsing textures. *JCAP*, 2020, 035.

**Brandenberger, R.**, Dasgupta, K. & **Wang, Z.** (2020) Reheating after S-brane ekpyrosis. *PhRvD*, 102, 063514.

**Brandenberger, R.** & **Jiao, H.** (2020) Cosmic textures and global monopoles as seeds for super-massive black holes. *JCAP*, 2020, 002.

**Brandenberger, R.**, **Kamali, V.**, Ramos, R. O. (2020) Strengthening the de Sitter swampland conjecture in warm inflation. *JHEP*, 2020, 127.

**Brandenberger, R.** & **Wang, Z.** (2020) Nonsingular ekpyrotic cosmology with a nearly scale-invariant spectrum of cosmological perturbations and gravitational waves. *PhRvD*, 101, 063522.

**Brandenberger, R.** & **Wang, Z.** (2020) Ekpyrotic cosmology with a zero-shear S-brane. *PhRvD*, 102, 023516.**Brandenberger, R.** & Wilson-Ewing, E. (2020) Strengthening the TCC bound on inflationary cosmology. *JCAP*, 2020, 047.

Bruzzone, J.S., Metchev, S., Duchêne, G., (...) **Doyon, R.** et al (2020) Imaging the 44 au Kuiper Belt Analog Debris Ring around HD 141569A with GPI Polarimetry. *AJ*, 159, 53.

Caplan, M. E., Horowitz, C. J., **Cumming, A.** (2020) Neon Cluster Formation and Phase Separation during White Dwarf Cooling. *ApJL*, 902, L44.

Carilli, C. L., Thyagarajan, N., Kent, J., Nikolic, B., Gale-Sides, K., Kern, N. S., Bernardi, G., Mesinger, A., Matika, S., Abdurashidova, Z., (...)Liu, A., (...), **Sims,P**. et al (2020) Imaging and Modeling Data from the Hydrogen Epoch of Reionization Array. *ApJS*, 247, 67.

Chachan, Y., Jontof-Hutter, D., Knutson, H. A., (...), **Lee, E.J**., et al (2020) A Featureless Infrared Transmission Spectrum for the Super-puff Planet Kepler-79d. *AJ*, 160, 201.

**Chawla, P.**, **Andersen, B. C.**, **Bhardwaj, M.**, **Fonseca, E.**, **Josephy, A**., **Kaspi, V. M.**, **Michilli, D**., **Pleunis, Z.**, Bandura, K. M., Bassa, C. G., **Boyle, P. J.**, **Brar, C.**, (...), **Dobbs, M.**, (...) **Merryfield, M.** et al (2020) Detection of Repeating FRB 180916.J0158+65 Down to Frequencies of 300 MHz. *ApJL*, 896, L41.

**Chiang, H. C.**, **Dyson, T.**, (...) **Ménard, T.**, (...) **Sievers, J. L.**, **Tartakovsky, S**. et al (2020) The Array of Long Baseline Antennas for Taking Radio Observations from the Sub-Antarctic. *JAI*, 9, 2050019-564.

Chime/Frb Collaboration, Amiri, M., **Andersen, B. C.**, Bandura, K. M., **Bhardwaj, M.**, **Boyle, P. J.**, **Brar, C.**, **Chawla, P.**, (...), **Dobbs, M.**, (...)**Fonseca, E.**, (...) **Josephy, A.**, (...) **Kaspi, V. M.**, (...)**Merryfield, M.**, **Michilli, D.**, (...) **Pleunis, Z.**, (...) **Zwaniga, A. V.**, et al (2020) Periodic activity from a fast radio burst source. *Nature*, 582, 351.

CHIME/FRB Collab., **Andersen, B. C.**, Bandura, K. M., **Bhardwaj, M.**, Bij, A., Boyce, M. M., **Boyle, P. J.**, **Brar, C**., Cassanelli, T., **Chawla, P.**, (...) **Curtin, A. P.**, Denman, N. T., **Dobbs, M.**,(...), **Fonseca, E.**, (...) **Josephy, A.**, Kania, J. W., **Kaspi, V. M.**, (...), **Merryfield, M.**, Meyers, B. W., **Michilli, D.**, (...)**Pleunis, Z.**, (...) **Singh, S.**, (...)**Tan, C. M.**, (...) **Wulf, D.**, **Zwaniga, A. V.** et al (2020) A bright millisecond-duration radio burst from a Galactic magnetar. *Nature*, 587, 54.

Choi, S. K., Hasselfield, M., (...), Sierra, Carlos, **Sievers, J.L.**, (...), **Zago, F.** et al (2020) The Atacama Cosmology Telescope: a measurement of the Cosmic Microwave Background power spectra at 98 and 150 GHz. *JCAP*, 2020, 045.

**Ciuca, Razvan** & **Hernández, Oscar F**. (2020) Information theoretic bounds on cosmic string detection in CMB maps with noise.. *MNRAS*, 492, 1329.

**Cline, J.M.** (2020) Viable secret neutrino interactions with ultralight dark matter. *PhLB*, 802, 135182.

**Cline, J.M.** & Kainulainen, K. (2020) Electroweak baryogenesis at high bubble wall velocities. *PhRvD*, 101, 063525.

**Cline, J.M.**, **Puel, M.** & **Toma, T.** (2020) Affleck-Dine inflation. *PhRvD*, 101, 043014.

**Cline, J.M.**, **Puel, M.**, **Toma, T.**(2020) A little theory of everything, with heavy neutral leptons. *JHEP*, 2020, 39.

Cloutier, R., Eastman, J.D., Rodriguez, J.E., Astudillo-Defru, N., Bonfils, X., Mortier, A., Watson, C. A., (...), **Doyon, R.**, et al (2020) A Pair of TESS Planets Spanning the Radius Valley around the Nearby Mid-M Dwarf LTT 3780. *AJ*, 160, 3.

Cohen, A., Fialkov, A., Barkana, R. & **Monsalve, R.A.** (2020) Emulating the global 21-cm signal from Cosmic Dawn and Reionization. *MNRAS*, 495, 4845.

Crossfield, I.J.M., Dragomir, D., **Cowan, N.B.** et al (2020) Phase Curves of Hot Neptune LTT 9779b Suggest a High-metallicity Atmosphere. *ApJL*, 903, L7.

**Dage, K.C.**, Zepf, S.E., Thygesen, E. et al (2020) X-ray spectroscopy of newly identified ULXs associated with M87's globular cluster population. *MNRAS*, 497, 596.

**Dang, L.**, Calchi Novati, S., Carey, S., **Cowan, N. B.** (2020) Pixel level decorrelation in service of the Spitzer microlens parallax survey. *MNRAS*, 497, 5309.

**Das, D**., Gasda, P. J., Wiens, R. C., Berlo, K., **Leveille, R. J.** et al (2020) Boron and Lithium in Calcium Sulfate Veins: Tracking Precipitation of Diagenetic Materials in Vera Rubin Ridge, Gale Crater. *JGRE*, 125, e06301.

de Haan, T., Suzuki, A., Boyd, S. T. P., Cantor, R. H., Coerver, A., **Dobbs, M. A.** et al (2020) Recent Advances in Frequency-Multiplexed TES Readout: Vastly Reduced Parasitics and an Increase in Multiplexing Factor with Sub-Kelvin SQUIDs. *JLTP*, 199, 754.

De Rosa, R.J., Nguyen, M.M., Chilcote, J., Macintosh, B., Perrin, M.D., (...) **Doyon, R**., Esposito, T.M. et al (2020) Revised astrometric calibration of the Gemini Planet Imager. *JATIS*, 6, 015006.

De Rosa, R.J., Nielsen, E.L., Wang, J.J., Ammons, S. M., Duchêne, G., Macintosh, B. (...), **Doyon, R.** et al (2020) An Updated Visual Orbit of the Directly Imaged Exoplanet 51 Eridani b and Prospects for a Dynamical Mass Measurement with Gaia. *AJ*, 159, 1.

Dicker, S.R., Romero, C.E., Di Mascolo, L., Mroczkowski, T., **Sievers, J.**, (...), **Zago, F.** et al (2020) The Massive and Distant Clusters of WISE Survey. X. Initial Results from a Sunyaev-Zeldovich Effect Study of Massive Galaxy Clusters at z > 1 Using MUSTANG2 on the GBT. *ApJ*, 902, 144.

Dillon, J.S., Lee, M., Ali, Z.S., Parsons, A.R., Orosz, N., Nunhokee, (...) **Lanman, A.**, (...), **Liu, A.**, (...)**Pascua, R.** (...), **Sims, P.** et al (2020) Redundant-baseline calibration of the hydrogen epoch of reionization array. *MNRAS*, 499, 5840.

Donati, J. -F., Kouach, D., Moutou, C., **Doyon, R.**, et al (2020) SPIRou: NIR velocimetry and spectropolarimetry at the CFHT. *MNRAS*, 498, 5684.

Duchêne, G., Rice, M., Hom, J., Zalesky, J., Esposito, T.M., Millar-Blanchaer, M.A., Ren, B., (...) **Doyon, R.** et al (2020) The Gemini Planet Imager View of the HD 32297 Debris Disk. *AJ*, 159, 251.

Elleflot, T., Arnold, K., Barron, D., Crowley, K. T., **Dobbs, M.A**. et al (2020) Effect of Stray Impedance in Frequency-Division Multiplexed Readout of TES Sensors in POLARBEAR-2b. *JLTP*, 199, 840.

Esposito, T.M., Kalas, P., Fitzgerald, M.P., Millar-Blanchaer, M.A., Duchêne, G., (...) **Doyon, R.** et al (2020) Debris Disk Results from the Gemini Planet Imager Exoplanet Survey's Polarimetric Imaging Campaign. *AJ*, 160, 24.

Everett, W. B., Zhang, L., Crawford, T. M., Vieira, J. D., Aravena, M., (...), **Dobbs, M. A**. et al (2020) Millimeter-wave Point Sources from the 2500 Square Degree SPT-SZ Survey: Catalog and Population Statistics. ApJ, 900, 55.

Ferdman, R. D., Freire, P. C. C., Perera, B. B. P., Pol, N., (....), Hessels, J. W. T., **Kaspi, V. M.**, McLaughlin, M. A., **Parent, E.**, et al (2020) Asymmetric mass ratios for bright double neutron-star mergers. *Nature*, 583, 211.

Finner, Ky., James Jee, M., **Webb, T.** et al (2020) Constraining the Mass of the Emerging Galaxy Cluster SpARCS1049+56 at z = 1.71 with Infrared Weak Lensing. *ApJ*, 893, 10.

**Fonseca, E**., **Andersen, B. C.**, **Bhardwaj, M.**, **Chawla, P.**, Good, D. C., **Josephy, A.**, **Kaspi, V. M**., (...), **Michilli, D**., **Pleunis, Z**., (...), **Boyle, P. J.**, **Brar, C.**, (...), **Dobbs, M.**, (...), **Merryfield, M.**, **Naidu, A**., (...) **Zwaniga, A. V**., et al (2020) Nine New Repeating Fast Radio Burst Sources from CHIME/FRB. *ApJL*, 891, L6.

**Fuentes, J. R**. & **Cumming, A.** (2020) Penetration of a cooling convective layer into a stably-stratified composition gradient: Entrainment at low Prandtl number. *PhRvF*, 5, 124501.

Gallardo-Carreño I, Moreno-Paz M, Aguirre J, (...), Raymond-Bouchard I, **Maggiori C**, (...), **Whyte L**, et al (2020) A multiplex immunosensor for detecting perchlorate-reducing bacteria for environmental monitoring and planetary exploration. *Frontiers in Microbiology*, 11, 590736.

Ghosh, A,, Mertens, F., Bernardi, G., Santos, M.G., Kern, N.S., Carilli, C.L., (...), **Liu, A.** et al (2020) Foreground modelling via Gaussian process regression: an application to HERA data. *MNRAS*, 495, 2813.

**Gibbons, E**., **Léveillé, R**. & Berlo, K. (2020) Data fusion of laser-induced breakdown and Raman spectroscopies: Enhancing clay mineral identification. *AcSpe*, 170, 105905.

Gilbert, E.A., Barclay, T., Schlieder, J., Quintana, E., Hord, B.J., Kostov, V.B., (...), **Lee, E.J.** et al (2020) The First Habitable-zone Earth-sized Planet from TESS. I. Validation of the TOI-700 System. *AJ*, 160, 116.

Ginsburg, A., Anderson, L. D., Dicker, S., Romero, C., Svoboda, B., (...), **Sievers, J.L**. et al (2020) The MUSTANG Galactic Plane Survey (MGPS90) Pilot. *ApJS*, 248, 24.

**Gomez, N.**, Weber, M.E., Clark, P.U., Mitrovica, J. X., Han, H.K. (2020) Antarctic ice dynamics amplified by Northern Hemisphere sea-level forcing. *Nature*, 587, 600.

**Gorce A**., Ilic S., Douspis M., Aubert D., Langer M. (2020) Improved constraints on reionisation from CMB observations: A parameterisation of the kSZ effect. *A&A* 640, A90.

Grumitt, R. D. P., Taylor, A. C., Jew, L., (...)**Chiang, H. C.,**(...) **Sievers, J.L.** et al (2020) The C-Band All-Sky Survey: total intensity point-source detection over the northern sky. *MNRAS*, 496, 1941.

Gu, B-M & **Brandenberger, R.** (2020) Reheating and entropy perturbations in fibre inflation. *ChPhC*, 44, 015103.

**Hallatt, T.** & **Lee, E.J.** (2020) Can Large-scale Migration Explain the Giant Planet Occurrence Rate?. *ApJ*, 904, 134.

Hayden, A. -M., Wilmes, S. -B., **Gomez, N.**, Green, J. A. M., **Pan, L.**, **Han, H.**, Golledge, N. R. (2020) Multi-Century Impacts of Ice Sheet Retreat on Sea Level and Ocean Tides in Hudson Bay. *JGRC*, 125, e15104.

Henry, M., & **Merlis, T.M.** (2020) Forcing Dependence of Atmospheric Lapse Rate Changes Dominates Residual Polar Warming in Solar Radiation Management Climate Scenarios. *GeoRL*, 47, e87929.

Hlavacek-Larrondo, J., Rhea, C. L., **Webb, T.** et al (2020) Evidence of Runaway Gas Cooling in the Absence of Supermassive Black Hole Feedback at the Epoch of Cluster Formation. *ApJL*, 898, L50.

Hom, J., Patience, J., Esposito, T.M., Duchêne, G., (...) **Doyon, R.**, Follette, KB. et al (2020) First Resolved Scattered-light Images of Four Debris Disks in Scorpius-Centaurus with the Gemini Planet Imager. *AJ*, 159, 31.

Huang, H., **Huang, Y** & Hu, Y. (2020) Quantifying the energetic feedbacks in ENSO. *Climate Dynamics*, 56, 139.

Huang, N., Bleem, L. E., Stalder, B., (...) **Chiang, H. C.**, (...), **Dobbs, M. A.**, (...), **Montgomery, J.**, et al (2020) Galaxy Clusters Selected via the Sunyaev-Zel'dovich Effect in the SPTpol 100-square-degree Survey. *AJ*, 159, 110.

**Huang, Y.**, **Wang, Y.** & Huang, H. (2020) Stratospheric Water Vapor Feedback Disclosed by a Locking Experiment. *GeoRL*, 47, e87987.

**Kamali, V.** & **Brandenberger, R.** (2020) Relaxing the TCC bound on inflationary cosmology?. *EPJC*, 80, 339.

**Kamali, V.** & **Brandenberger, R.** (2020) Creating spatial flatness by combining string gas cosmology and power law inflation. *PhRvD*, 101, 103512.

Kaneko, D., Adachi, S., Ade, P. A. R., (...), **Dobbs, M.** et al (2020) Deployment of uc(Polarbear)-2A. *JLTP*, 199, 1137.

**Keating, D.**, Stevenson, K. B., **Cowan, N.B.**, Rauscher, E., Bean, J. L., **Bell, T.**, **Dang, L.** et al (2020) Smaller than Expected Bright-spot Offsets in Spitzer Phase Curves of the Hot Jupiter Qatar-1b. *AJ*, 159, 225.

Kern, N.S., Dillon, J.S., Parsons, A.R., Carilli, C., (...) **Lanman, A.**, (...) **Liu, A.**, (...) **Sims, P.** et al (2020) Absolute Calibration Strategies for the Hydrogen Epoch of Reionization Array and Their Impact on the 21 cm Power Spectrum. *ApJ*, 890, 122.

Kern, N.S., Parsons, A.R., Dillon, J.S., Lanman, A., Liu, A.,(...) Sims, P. et al (2020) Mitigating Internal Instrument Coupling for 21 cm Cosmology. II. A Method Demonstration with the Hydrogen Epoch of Reionization Array. *ApJ*, 888, 70.

Kilpatrick, B.M., Kataria, T., Lewis, N.K., (...), **Cowan, N.B.** et al (2020) Evaluating Climate Variability of the Canonical Hot-Jupiters HD 189733b and HD 209458b through Multi-epoch Eclipse Observations. *AJ*, 159, 51.

Kim, J-Y., Krichbaum, T.P., Broderick, A.E., Wielgus, M., Blackburn, L.(...), **Haggard, D.** et al (EHT Collaboration) (2020) Event Horizon Telescope imaging of the archetypal blazar 3C 279 at an extreme 20 microarcsecond resolution. *A&A*, 640, A69.

**Labonté, M.** & **Merlis, T.M.** (2020) Sensitivity of the Atmospheric Water Cycle within the Habitable Zone of a Tidally Locked, Earth-like Exoplanet. *ApJ*, 896, 31.

**Laliberte, S.** & **Brandenberger, R.** (2020) String gases and the swampland. *JCAP*, 2020, 046.

**Laliberte, S.** & **Brandenberger, R.** (2020) Ionization from cosmic strings at cosmic dawn. *PhRvD*, 101, 023528.

Lane, T. P., Paasche, Ø., Kvisvik, B., Adamson, K. R., Rodés, Á., Patton, H., **Gomez, N.**, Gheorghiu, D., Bakke, J., Hubbard, A. (2020) Elevation Changes of the Fennoscandian Ice Sheet Interior During the Last Deglaciation. *GeoRL*, 47, e88796.

LaRowe, D. E., Arndt, S., Bradley, J. A., Estes, E. R., Hoarfrost, A., Lang, S. Q., Lloyd, K. G., **Mahmoudi, N.** et al (2020) The fate of organic carbon in marine sediments - New insights from recent data and analysis. *ESRv*, 204, 103146.

**Laurent, B.** & **Cline, J.M.** (2020) Fluid equations for fast-moving electroweak bubble walls. *PhRvD*, 102, 063516.

**Lee, E.J.** & Hopkins, P.F. (2020) Most stars (and planets?) are born in intense radiation fields. *MNRAS*, 495, L86.

Lew, B.W. P., Apai, D., Marley, M., Saumon, D., (...) **Cowan, N.B.** et al (2020) Cloud Atlas: Unraveling the Vertical Cloud Structure with the Time-series Spectrophotometry of an Unusually Red Brown Dwarf. *ApJ*, 903, 15.

Lew, B.W. P., Apai, D., Zhou, Y., Radigan, J., Marley, M., Schneider, G., **Cowan, N.B** et al (2020) Cloud Atlas: Weak Color Modulations Due to Rotation in the Planetary-mass Companion GU Psc b and 11 Other Brown Dwarfs. *AJ*, 159, 125.

Li, Z., Naess, S., Aiola, S., Alonso, D., Appel, J.W., (...), **Sievers, J.L.** et al (2020) The cross correlation of the ABS and ACT maps. *JCAP*, 2020, 010.

**Liu, A.** & Shaw, J.R. (2020) Data Analysis for Precision 21 cm Cosmology. *PASP*, 132, 062001.

Liu, F., Lu, J., **Huang, Y.** et al (2020) Sensitivity of Surface Temperature to Oceanic Forcing via q-Flux Green's Function Experiments. Part III: Asymmetric Response to Warming and Cooling. *JCli*, 33, 1283.

Lowitz, A. E., Bender, A. N., Barry, P., Cecil, T. W., Chang, C. L., Divan, R., **Dobbs, M. A.**, (...), **Montgomery, J.** et al (2020) Performance of a Low-Parasitic Frequency-Domain Multiplexing Readout. *JLTP*, 199, 192.

MacDonald, M.G., Dawson, R.I., Morrison, S.J., **Lee, E.J.**, Khandelwal, A. (2020) Forming Diverse Super-Earth Systems In Situ. *ApJ*, 891, 20.

**Maggiori, C.**, Stromberg, J., Blanco, Y., Goordial, J. (...), **Whyte, L.** et al (2020) The Limits, Capabilities, and Potential for Life Detection with MinION Sequencing in a Paleochannel Mars Analog. *AsBio*, 20, 375.

Magnuson, E., Mykytczuk, N.C., Pellerin, A., (...), **Whyte, L.G.** et al (2020) Thiomicrorhabdus streamers and sulfur cycling in perennial hypersaline cold springs in the Canadian high Arctic. *Environmental microbiology*.

**Mahmoudi, N.**, Hagen, S.M., Hazen, T.C., Steen, A.D. (2020) Patterns in extracellular enzyme activity and microbial diversity in deep-sea Mediterranean sediments. *DSRI*, 158, 103231.

**Mahmoudi, N.**, Enke, T.N., Beaupré, S.R., Teske, A.P., Cordero, O.X. & Pearson, A (2020) Illuminating microbial species–specific effects on organic matter remineralization in marine sediments. *Environmental Microbiology*, 22, 1734.

Majid, W.A., **Pearlman, A.B.**, Nimmo, K. et al (2020) A Dual-band Radio Observation of FRB 121102 with the Deep Space Network and the Detection of Multiple Bursts. *ApJL*, 897, L4.

Mansfield, M., Bean, J.L., Stevenson, K.B., Komacek, T.D., **Bell, T.J.**, (...), **Cowan, N.B.**, **Dang, L.**, (...), **Keating, D.** et al (2020) Evidence for H2 Dissociation and Recombination Heat Transport in the Atmosphere of KELT-9b. *ApJL*, 888, L15.

Marcote, B., Nimmo, K., Hessels, J. W. T., (...) **Bhardwaj, M.,** Karuppusamy, R., **Kaspi, V. M.**, (...), **Andersen, B.**, (...), **Boyle, P. J.**, **Brar, C.**, (...),**Chawla, P.**, (...), **Dobbs, M.**, **Fonseca, E.**, (...), **Josephy, A.,** (...) **Zwaniga, A. V.** et al (2020) A repeating fast radio burst source localized to a nearby spiral galaxy. *Nature*, 577, 190.

Martioli, E., Hébrard, G., Moutou, C., Donati, J. -F., (...),**Doyon, R.** et al (2020) Spin-orbit alignment and magnetic activity in the young planetary system AU Mic. *A&A*, 641, L1.

Mason, B., Dicker, S., Sadavoy, S., Stanchfield, S., (...) **Sievers, J.L.** et al (2020) Confirmation of Enhanced Long-wavelength Dust Emission in OMC 2/3. *ApJ*, 893, 13.

McEwen, A. E., Spiewak, R., Swiggum, J. K., (...) **Chawla, P.**, DeCesar, M., **Kaspi, V. M.**, et al (2020) The Green Bank North Celestial Cap Pulsar Survey. V. Pulsar Census and Survey Sensitivity. *ApJ*, 892, 76.

Mebane, R., **Mirocha, J.**, & Furlanetto, S.R. (2020) The effects of Population III X-ray and Radio Backgrounds on the Cosmological 21-cm Signal. *MNRAS*, 493, 1217.

Miller, J.I., Techtmann, S., Joyner, D., **Mahmoudi, N.** et al (2020) Microbial communities across global marine basins show important compositional similarities by depth. *Mbio*, 11, e01448-20.

Miller, J.M., Swihart, S.J., Strader, J., (...)**Dage, K.C**, et al (2020) A New Candidate Transitional Millisecond Pulsar in the Subluminous Disk State: 4FGL J0407.7-5702. *ApJ*, 904, 49.

**Mirocha, J.** (2020) Prospects for distinguishing galaxy evolution models with surveys at redshifts z > 4. *MNRAS*, 499, 4534.

**Mirocha, J.**, Mason, C., & Stark, D.P. (2020) Effects of self-consistent rest-ultraviolet colours in semi-empirical galaxy formation models. *MNRAS*, 498, 2645.

**Moore, K.** & **Cowan, N.B.** (2020) Keeping M-Earths habitable in the face of atmospheric loss by sequestering water in the mantle. *MNRAS*, 496, 3786.

Moravec, E., Gonzalez, A.H., Dicker, S., Alberts, S., (...) **Sievers, J.L.**, (...), **Zago, F.** et al (2020) The Massive and Distant Clusters of WISE Survey. IX. High Radio Activity in a Merging Cluster. *ApJ*, 898, 145.

Moutou, C., Dalal, S., Donati, J. -F., Martioli, E.,, (...)Doyon, R. et al (2020) Early science with SPIRou: near-infrared radial velocity and spectropolarimetry of the planet-hosting star HD 189733. *A&A*, 642, A72.

Müller, S., Helled, R. & **Cumming, A.** (2020) The challenge of forming a fuzzy core in Jupiter. *A&A*, 638, A121.

Ng, C., Pandhi, A., **Naidu, A.**, **Fonseca, E.**, Kaspi, V. M. et al (2020) Faraday rotation measures of Northern hemisphere pulsars using CHIME/Pulsar. *MNRAS*, 496, 2836.

Ng, C., Wu, B., Ma, M., Ransom, S. M., **Naidu, A., Fonseca, E.**, **Boyle, P. J.**, **Brar, C.**, (...), **Kaspi, V. M.** et al (2020) The Discovery of Nulling and Mode-switching Pulsars with CHIME/Pulsar. *ApJ*, 903, 81.

Nguyen, M.M., De Rosa, R.J., (...)**Doyon, R.** et al (2020) HD 165054: An Astrometric Calibration Field for High-contrast Imagers in Baade's Window. *AJ*, 159, 244.

Nguyen, T.G., **Cowan, N.B.**, Banerjee, A., Moores, J.E. (2020) Modelling the atmosphere of lava planet K2-141b: implications for low- and high-resolution spectroscopy. *MNRAS*, 499, 4605.

Nielsen, E.L., De Rosa, R. J., Wang, J.J., Sahlmann, J., Kalas, (...), **Doyon, R.** et al (2020) The Gemini Planet Imager Exoplanet Survey: Dynamical Mass of the Exoplanet β Pictoris b from Combined Direct Imaging and Astrometry. *AJ*, 159, 71.

Noble, T. L., Rohling, E. J., Aitken, A. R. A., Bostock, H. C., Chase, Z., **Gomez, N.** et al (2020) The Sensitivity of the Antarctic Ice Sheet to a Changing Climate: Past, Present, and Future. *RvGeo*, 58, e00663.

Nunhokee, C.D., Parsons, A.R., Kern, N.S., Nikolic, B., Pober, (...), **Lanman, A.**, (...), **Liu, A.,** (...) **Sims, P.** et al (2020) Measuring HERA's Primary Beam in Situ: Methodology and First Results. *ApJ*, 897, 5.

Orcutt, B.N., Bradley, J.A., Brazelton, W.J., (...), **Mahmoudi, N.** et al (2020) Impacts of deep-sea mining on microbial ecosystem services. *Limnology and Oceanography*, 65, 1489.

Osherson, B., Filippini, J. P., Fu, J., Gramillano, R. V., Gualtieri, R., Shaw, E. C., Ade, P. A. R., Amiri, M., (...) **Chiang, H. C.** et al (2020) Particle Response of Antenna-Coupled TES Arrays: Results from SPIDER and the Laboratory. *JLTP*, 199, 1127.

**Pagano, M.** & **Liu, A.** (2020) Quantifying density-ionization correlations with the 21-cm power spectrum. *MNRAS*, 498, 373.

Paranjape, K., Bédard, É., **Whyte, L. G.**, et al (2020) Presence of Legionella spp. in cooling towers: the role of microbial diversity, Pseudomonas, and continuous chlorine application. *Water Research*, 169, 115252.

**Parent, E.**, **Chawla, P.**, **Kaspi, V. M.**, (...), **Fonseca, E.** et al (2020) First Discovery of a Fast Radio Burst at 350 MHz by the GBNCC Survey. *ApJ*, 904, 92.

**Pearlman, A.B.**, Majid, W.A., Prince, T.A. et al (2020) Multiwavelength Radio Observations of Two Repeating Fast Radio Burst Sources: FRB 121102 and FRB 180916.J0158+65. *ApJL*, 905, L27.

Polarbear Collaboration. Adachi, S., Aguilar Faúndez, M. A. O., Arnold, K., (...),**Dobbs, M.A.** et al (2020) A Measurement of the Degree-scale CMB B-mode Angular Power Spectrum with POLARBEAR. *ApJ*, 897, 55.

Powell, E., **Gomez, N.**, Hay, C., Latychev, K., Mitrovica, J. X. (2020) Viscous Effects in the Solid Earth Response to Modern Antarctic Ice Mass Flux: Implications for Geodetic Studies of WAIS Stability in a Warming World. *JCli*, 33, 443.

Qu, Z., **Huang, Y.**, Vaillancourt, P.A. et al (2020) Simulation of convective moistening of the extratropical lower stratosphere using a numerical weather prediction model. *ACP*, 20, 2143.

Rapetti, D., Tauscher, K., **Mirocha, J.**, & Burns, J.O. (2020) Global 21-cm signal extraction from foreground and instrumental effects. II. Efficient and Self-consistent Technique for Constraining Nonlinear Signal Models. *ApJ*, 897, 174.

Rea, N., Coti Zelati, F., Viganò, D., (...), Haggard, D. et al (2020) The X-Ray Outburst of the Galactic Center Magnetar over Six Years of Chandra Observations. ApJ, 894, 159.

Rodriguez, J.E., Vanderburg, A,, Zieba, S.,(...) **Lee, E.J.** et al (2020) The First Habitable-zone Earth-sized Planet from TESS. II. Spitzer Confirms TOI-700 d. *AJ*, 160, 117.

Romero, C.E., **Sievers, J.L.**, et al (2020) Pressure Profiles and Mass Estimates Using High-resolution Sunyaev-Zel'dovich Effect Observations of Zwicky 3146 with MUSTANG-2. *ApJ*, 891, 90.

**Rouble, M.**, **Dobbs, M.**, Gilbert, A., **Montgomery, J.**, Noble, G., Vergès, C. (2020) Transformer-Coupled TES Frequency Domain Readout Prototype. *JLTP*, 199, 780.

**Roux, J-S.** & **Cline, J.M.** (2020) Constraining galactic structures of mirror dark matter. *PhRvD*, 102, 063518.

Sayre, J. T., Reichardt, C. L., Henning, J. W., (...) **Chiang, H. C.**, (...), **Dobbs, M. A.**, (...) **Montgomery, J.** et al (2020) Measurements of B -mode polarization of the cosmic microwave background from 500 square degrees of SPTpol data. *PhRvD*, 101, 122003.

Scholz, P., Cook, A., (...) **Kaspi, V. M.**, Majid, W. A., **Naidu, A.**, **Pearlman, A. B.**, (...), **Bhardwaj, M.,** Cassanelli, T., **Chawla, P.**, (...), **Josephy, A.**, (...), **Merryfield, M.**, **Michilli, D.**, (...), **Pleunis, Z.** et al (2020) Simultaneous X-Ray and Radio Observations of the Repeating Fast Radio Burst FRB ~ 180916.J0158+65. ApJ, 901, 165.

Senchyna, P., Stark, D.P., **Mirocha, J.**, et al (2020) High-mass X-ray binaries in nearby metal-poor galaxies: on the contribution to nebular HeII emission. *MNRAS*, 494, 941.

**Sims, P.H.** & Pober, J.C. (2020) Testing for calibration systematics in the EDGES low-band data using Bayesian model selection. *MNRAS*, 492, 22.

Sugai, H., Ade, P. A. R., Akiba, Y., Alonso, D., (...), **Dobbs, M.** et al (2020) Updated Design of the CMB Polarization Experiment Satellite LiteBIRD. *JLTP*, 199, 1107.

Sun, E.W.H., Hajirezaie, S., Dooner, M., (...) **Whyte, L.G.** et al (2020) Thaumarchaea Genome Sequences from a High Arctic Active Layer. *Microbiology Resource Announcements*, 9, e00326-20.

Swihart, S.J., Strader, J., Urquhart, R., (...),**Dage, K.C.** et al (2020) A New Likely Redback Millisecond Pulsar Binary with a Massive Neutron Star: 4FGL J2333.1-5527. *ApJ*, 892, 21.

Tabata, M., Allison, P., Beatty, J.J.,(...), **Hanna, D.** et al (2020) Developing a silica aerogel radiator for the HELIX ring-imaging Cherenkov system. *NIMPA*, 952, 161879.

**Tan, C. M.**; Bassa, C. G.,Cooper, S.; (...), **Michilli, D.**, et al (2020) The LOFAR Tied-Array all-sky survey: Timing of 21 pulsars including the first binary pulsar discovered with LOFAR. *MNRAS*, 492, 5878.

Thyagarajan, N., Carilli, C.L., Nikolic, B., (...), **Lanman, A.**, (...), **Liu, A.**, (...),**Sims, P.** et al (2020) Detection of cosmic structures using the bispectrum phase. II. First results from application to cosmic reionization using the Hydrogen Epoch of Reionization Array. *PhRvD*, 102, 022002.

Valverde, J., Horan, D., Bernard, D., Fegan, S., (...), **Hanna, D.**, (...), **O'Brien, S.**, (...), **Ragan, K.** et al (2020) A Decade of Multiwavelength Observations of the TeV Blazar 1ES 1215+303: Extreme Shift of the Synchrotron Peak Frequency and Long-term Optical-Gamma-Ray Flux Increase. *ApJ*, 891, 170.

van Leeuwen, J., Mikhailov, K., Keane, E., (...), **Michilli, D.** et al (2020) LOFAR radio search for single and periodic pulses from M 31. *A&A*, 634, A3.

Vandal, T., Rameau, J. & **Doyon, R.** (2020) Dynamical Mass Estimates of the β Pictoris Planetary System through Gaussian Process Stellar Activity Modeling. *AJ*, 160, 243.

Vieira, N., Ruan, J.J., **Haggard, D.**, (...), **Boyce, H.** et al (2020) A Deep CFHT Optical Search for a Counterpart to the Possible Neutron Star-Black Hole Merger GW190814. *ApJ*, 895, 96.

Vissapragada, S., Jontof-Hutter, D. Shporer, A., Knutson, H.A., (...) **Lee, E.J** et al (2020) Diffuser-assisted Infrared Transit Photometry for Four Dynamically Interacting Kepler Systems. *AJ*, 159, 108.

**Wang, Y.** & **Huang, Y.** (2020) Understanding the Atmospheric Temperature Adjustment to CO<SUB>2</SUB> Perturbation at the Process Level. *JCli*, 33, 787.

**Wang, Y.** & **Huang, Y.** (2020) Stratospheric radiative feedback limited by the tropospheric influence in global warming. *ClDy*, 55, 2343.

**Wang, Y.** & **Huang, Y.** (2020) The Surface Warming Attributable to Stratospheric Water Vapor in CO<SUB>2</SUB>-Caused Global Warming. *JGRD*, 125, e32752.

**Wang, Z.**, **Brandenberger, R.** & Heisenberg, L. (2020) Eternal inflation, entropy bounds and the swampland. *EPJC*, 80, 864.

Wijngaarden, M.J.P., Ho, W.C.G., (...), **Cumming, A.**, et al (2020) The effect of diffusive nuclear burning in neutron star envelopes on cooling in accreting systems. *MNRAS*, 493, 4936.

**Wulf, D.**, Jaekel, F., McCammon, D., Chervenak, J. A., Eckart, M. E. (2020) Optimal filtering of overlapped pulses in microcalorimeter data. *Journal of Applied Physics*, 128, 174503.

Xia, Y., Hu, Y., Liu, J., **Huang, Y.**, et al (2020) Stratospheric Ozone-induced Cloud Radiative Effects on Antarctic Sea Ice. *AdAtS*, 37, 505.

Xia, Y., **Huang, Y.** & Hu, Y. (2020) Robust Acceleration of Stratospheric Moistening and Its Radiative Feedback Under Greenhouse Warming. *JGRD*, 125, e33090.

Zhou, Y., Apai, D., Bedin, L.R., (...), **Cowan, N.B.** et al (2020) Cloud Atlas: High-precision HST/WFC3/IR Time-resolved Observations of Directly Imaged Exoplanet HD 106906b. *AJ*, 159, 140.