Trottier Space Institute at McGill

Institut spatial Trottier de McGill

# 2022 ANNUAL REPORT

# ABOUT TSI

# 01
# ABOUT TSI

## Welcome from TSI Director Prof. Vicky Kaspi

I look to the past year with great gratitude for our beloved Space Institute. First and foremost, on behalf of all our students, postdocs, faculty, and staff, I express tremendous gratitude to the Trottier Family Foundation and Mr. Lorne Trottier, for their visionary gift to the Institute, and its exciting renaming from the McGill Space Institute to the Trottier Space Institute at McGill or simply, TSI. The Trottier gift is a landmark not only for those of us at TSI, but for the entire McGill community, encompassing support for both world-class space-related research and instrumentation, but also a powerful, and an engaging outreach effort to share with the broader public – including children and adults alike – the fruits and importance of our space-related research.

Second, I am grateful for the tremendous enthusiasm with which the TSI membership has embraced the post-COVID era. During the darkest moments of the pandemic, when many of us were isolated and alone, we wondered, "Will it ever return to normal?" Today, I'm delighted and grateful to see that not only do we have a sense of normalcy, but that it has been enhanced by our appreciation of the importance of human interaction for our professional creativity, initiative and achievement. TSI has always been about interactions – whether in seminars or workshops, at the blackboard or at daily tea, we are stronger, more productive, and better placed to excel when we work together, in person, as at last we are doing on a regular basis here in our beloved home at 3550 University.

And TSI togetherness will soon be even further enhanced by something else to be grateful for: the upcoming TSI construction project. Thanks yet again to the Trottier Family Foundation, we are actively planning for a major extension to our 3550 home, literally right in our own backyard. Expected to break ground in Summer 2024, the extension will more than double our available interaction space, and provide us with a modern, high-tech facility to complement our warm and homey beloved "Space Shack."

Finally, I am grateful for all the amazing science that TSI members are leading. From the CHIME telescope and its 3 new "Outrigger" telescopes being commissioned across North America, to the upcoming CHORD telescope that will continue the legacy of McGill leadership in Canadian radio astronomy, indeed stretching to TSI leadership in the international HERA and HIRAX radio astronomy projects, and in the Event Horizon Telescope project to study black hole event horizons, to our work with the James Webb Space Telescope, many of today's landmark and upcoming science breakthroughs are being accomplished by TSI members. TSI now plays a leadership role in the European Space Agency's upcoming Ariel mission to study exoplanets, and of course our work in Earth climate science continues to be highly relevant to efforts to understand solar system planets as well as exoplanets and the search for signs of extraterrestrial life in both. And all this amazing instrumentation and project work is guided and interpreted by an active, creative world-class theory group.

Our future here at TSI is exciting and bright – let's enjoy it together, and give thanks for the opportunity to succeed and excel on the global space research stage.

# A Message from TSI Associate Director, Prof. Ken Ragan

Welcome to the 2022 TSI Annual Report. As usual, our goal has been to provide a brief overview of a very busy and active institute. In the bustle of our individual lives as students, staff, or faculty, it's sometimes easy to overlook the overarching story - the "big picture" - of an institute like ours. The Annual Report reminds us to do that - to remember that we have an incredible and devoted staff, an accomplished cohort of students, and a world-class team of faculty, and that together our activities span the gamut from cutting-edge research to large public outreach events.

To me, in my (still relatively new) role as Associate Director, several things stand out from the last year. Firstly, recovery from the pandemic continues apace, with many, or even most, of our events back to an in-person format. Secondly, thanks to an incredibly generous donor, we are no longer the MSI but are now the TSI - the Trottier Space Institute at McGill. And finally, our team will be growing and morphing. Carolina Cruz-Vinaccia will be moving into the (new) role of Program Administrator, and in 2023 we will welcome a new Administrative Assistant and a Computing Fellow, with other positions planned. All three of these bode well for the Institute and its future, and I look forward to working with all of you towards our continued success!

# ABOUT TSI

The Trottier Space Institute at McGill (originally the McGill Space Institute) 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. TSI 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

Trottier Space Institute at McGill

Institut spatial Trottier de McGill

# The Story of a New Name: From MSI to TSI

In November 2022, the Trottier Family Foundation announced a donation of $16 million dollars to the McGill Space Institute, funding a decade's worth of groundbreaking work in space science. The generous donation fortifies our position as a leading institution in space research, ensuring ongoing discoveries and advancements in our understanding of the universe.

Half of the donation will be allocated to the construction of an annex MSI's existing building on University Street, and the remainder will go to funding trainees, while expanding programmatic and research support. Through this gift, we will be able to hire staff to develop our computational and technical capabilities, expand our inreach and outreach programs, and ensure continued smoothness of operations. The substantial contribution recognizes the pivotal role our research centre plays in unraveling mysteries such as neutron stars and fast radio burst and our potential for continuing to be at the forefront of space research nation-wide and world-wide.

In honor of this historic gift, the McGill Space Institute was renamed the Trottier Space Institute at McGill. As we close the first chapter of our research institute's story, and embark on new a phase we can't wait to see what exciting new possibilities are on the horizon for TSI and its young scientists.


*Donors Lornie Trottier and Rousselle Trottier with TSI DIrector Vicky Kaspi and members of TSI at the event celebrating the Trottier Family Foundation's historic gift on November 22, 2022. Credit: Owen Egan / Joni Dufour, McGill Reporter.*

## MSI WRAP-UP 2015-2022

**170** Students Supported by MSI Funding

MSI Postdoctoral Research Fellows **14**

**187** Seminars hosted

Outreach events organized **134**

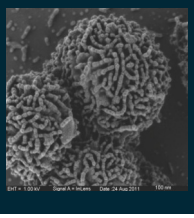
**78** MSI Lunch Talks organized

Conferences & workshops supported **21**

**1004** Journal articles published

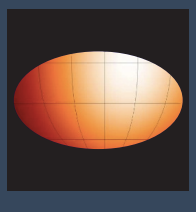
# TSI RESEARCH AREAS

## Astrobiology & Extraterrestrial Biosignatures ▪ *Nicolas Cowan, Nagissa Mahmoudi, Lyle Whyte*



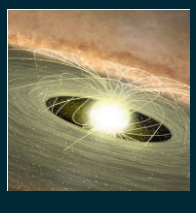
The Astrobiology and Extraterrestrial Biosignatures group examines microbial biodiversity and ecology in unique ecosystems like the Canadian High Arctic and the Antarctic dry valleys, studying microbial communities using classical microbiology and novel genomics-based molecular techniques. Understanding what types of microorganisms survive in these types of soils and detecting biosignatures provides insight into what to look for in near surface water ice on Mars or other cold, rocky places in the solar system. Members of the group also use cutting-edge telescopes to establish the habitability of nearby temperate terrestrial exoplanets and to search their atmospheres for signs of life.

## Climates and Atmospheres of Exoplanets ▪ *Nicolas Cowan, Andrew Cumming, Yi Huang*



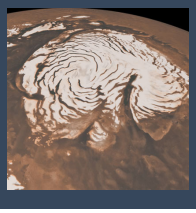
The extrasolar planet climate and atmosphere group characterizes exoplanets using observational evidence and climate modelling. Observational evidence for exoplanetary atmospheres comes from a variety of sources, including changes in brightness of the planet over time, spectroscopy, and upcoming next-generation 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 ▪ *Andrew Cumming, Eve Lee*



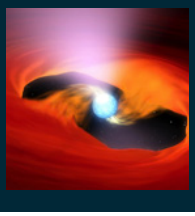
The quantity and diversity of known exoplanets provides an opportunity to learn about planetary formation, evolution, and the physical processes that operate in their atmosphere and interiors. The challenge is to connect observed properties of planets with theories of their formation, structure, and evolution. The group uses theoretical tools to identify the key physical processes behind the observed diversity of planetary systems, from super-Earths to gas giants. They study the earliest evolution of star-forming environments, protoplanetary disk evolution, disk-star-planet interaction, formation of planetary atmospheres, and dynamical interactions within planetary systems.

## Planetary Surfaces ▪ *Natalya Gomez*



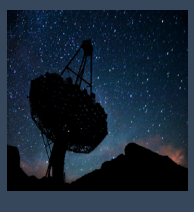
Members of the planetary surface group, led by Natalya Gomez, research models of the interactions between ice, water, climate and planetary interiors, and how these connections change planets' surfaces through time. These models are applicable to both the Earth and other rocky, icy planets and moons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

## Nuclear Astrophysics ▪ *Andrew Cumming*



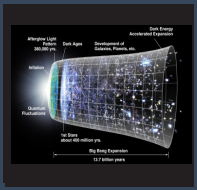
Nuclear astrophysics is the study of the origin of the chemical elements in stars and supernovae, explosive events such as supernovae, classical novae, and X-ray bursts, and the properties of matter at high densities as found in the interiors of neutron stars. We focus on developing connections between 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).

## Experimental Particle Astrophysics ▪ *Ken Ragan, David Hanna*



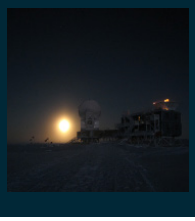
The Gamma Ray Astrophysics group is part of the VERITAS collaboration, which operates an array of four 12-m imaging atmospheric Cherenkov telescopes in southern Arizona. They carry out a program of very-high-energy (VHE) gamma-ray astronomy, observing photons with energy in the range from 50 GeV to 50 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. They also develop instrumentation for the VERITAS detector including calibration and characterization devices.

## Early Universe and Theoretical Cosmology ▪ *Robert Brandenberger, Jim Cline, Katelin Schutz*



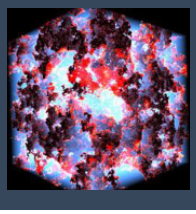
The theoretical cosmology group works to explain the history of the very early Universe and to provide an explanation of the large scale structure in the Universe. They create models using input from new fundamental physics such as superstring theory, dark matter particle theories, and particle physics 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*



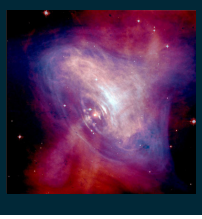
The McGill Experimental Cosmology group designs and builds new instrumentation for observational cosmology and develops analysis techniques for upcoming large cosmological surveys, including surveys of the cosmic microwave background and the 21 cm line of neutral hydrogen. They deploy and operate instruments 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 ▪ *Ken Ragan, David Hanna*



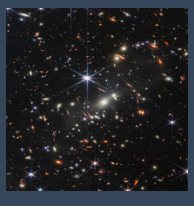
The low-frequency radio sky represents a new frontier in observational astrophysics and cosmology. This regime is a largely unobserved band of the electromagnetic spectrum, and holds the promise of revealing new astrophysical phenomenology. Our 21cm cosmology telescopes (ALBATROS, HERA, MIST, PRIZM) 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 they dramatically transformed our Universe by ionizing almost all the hydrogen in the intergalactic medium).

## 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's work includes searches for radio pulsars, pulsar timing, and X-ray observations of energetic pulsars and magnetars. The multi-messenger group identifies and characterize kilonova and other electromagnetic counterparts to gravitational wave sources. The theory group studies neutron stars' structure and how to use observations to constrain the physical processes operating in their interiors. They also investigate the origin and evolution of neutron stars' spin and magnetism and the properties of neutron stars in close binary systems.

## Galaxy Evolution, Active Galactic Nuclei ▪ *Tracy Webb, Daryl Haggard*

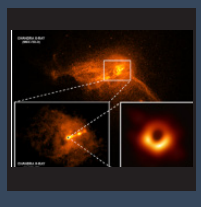


The galaxy evolution group is interested in understanding when galaxies form the bulk of their stellar mass; what drives and later shuts down this process; how the local environment of galaxies affect their evolution and growth; and how growing supermassive black holes (AGN) interact with their host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

## Radio Transients ▪ *Matt Dobbs, Vicky Kaspi, Jon 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 CHIME telescope located in Penticton, British Columbia.

## Supermassive Black Holes ▪ *Tracy Webb, 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?

# 02

# RESEARCH HIGHLIGHTS

## Observing the Cosmos from Nunavut

*Prof. H. Cynthia Chiang is an associate professor of physics at McGill, and she specializes in instrumentation development for precision measurements of redshifted 21-cm emission of neutral hydrogen. [Research highlight text coauthored by MSc student Ian Hendricksen and PhD student Larry Herman.]*

During the summer of 2022, students and researchers from the Trottier Space Institute travelled to Axel Heiberg Island , Nunavut in the Canadian High Arctic to deploy two radio astronomy experiments. Both experiments aim to probe some of the most poorly understood and largely unexplored periods of the early universe through observations of hydrogen, which naturally "glows" at radio frequencies.

The Array of Long Baseline Antennas for taking Radio Observations from the Seventy-ninth parallel (ALBATROS) will image the sky and provide new views of our Milky Way galaxy at very low frequencies, paving the way for future observations of the cosmic "dark ages," before the birth of the first stars. ALBATROS consists of multiple independent stations designed for long-term autonomous operation that observe in concert as a single instrument. The team installed the first two stations in the Arctic, which operated continuously through the winter. Team members will return in 2023 for data retrieval and the installation of additional stations.

The Mapper of the IGM Spin Temperature (MIST) aims to observe the periods before, during, and after the first stars and galaxies were born, using a single antenna to "listen" to the brightness of the sky at different wavelengths—much like listening to all stations simultaneously on a car radio. The MIST team installed and operated an antenna for a period of approximately two weeks, with careful attention towards minimizing spurious instrumental effects. The data are currently undergoing analysis, as MIST makes preparations to return to the Arctic in 2023.

***Why this is important***

One of the final frontiers in understanding the history of our universe is "cosmic dawn" and the preceding "dark ages." With novel instrumentation and carefully chosen observing sites, we are taking the first steps toward understanding these early periods of the universe's existence.

*MIST team members Ian Hendricksen and Vadym Bidula pictured with the MIST instrument near the McGill Arctic Research Station. The MIST instrument is composed of a blade dipole antenna connected to the signal-processing receiver box below the antenna, all supported by a fiberglass frame [credit: Raul Monsalves]..*

# CHIME/FRB Discovers 25 Repeating Fast Radio Burst Sources

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

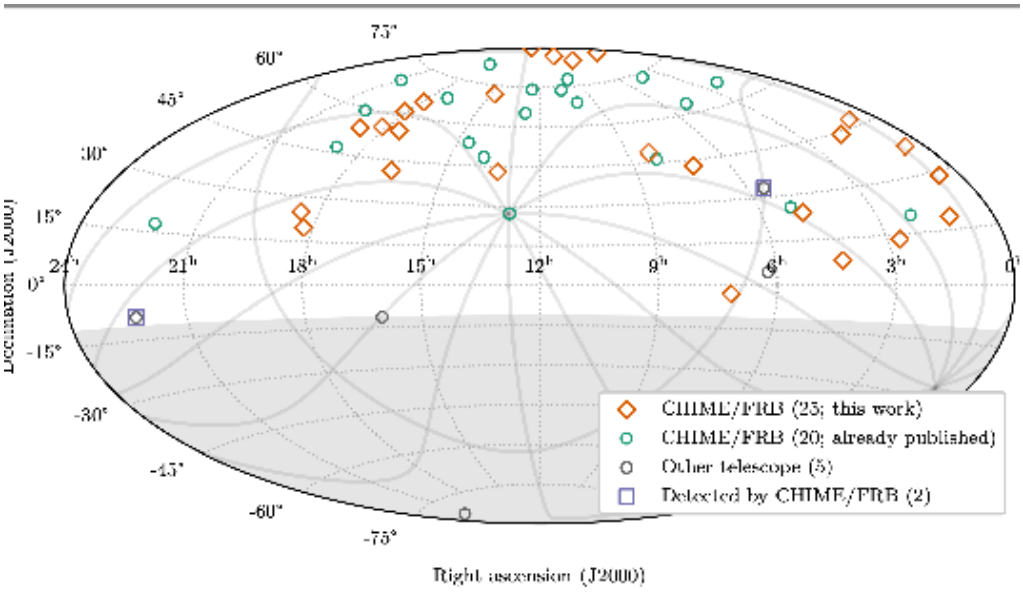
The CHIME telescope, located in Penticton, British Columbia consists of four cyclindal reflectors oriented along the North-South direction. They have no moving parts and observe the full Northern sky daily at radio frequencies between 400 and 800 MHz. The combination of CHIME's collecting area, bandwidth, and field of view make it an unrivaled radio transient detector, detecting FRBs at a cadence of a few per day. CHIME/FRB is particularly prolific at discovering repeating FRB sources; its transit design ensures regular daily visits to the same patches of sky that greatly increase the likelihood of detecting repeat bursts.

The CHIME/FRB collaboration recently reported on the discovery of 25 additional repeating FRB sources, a factor of ~2 increase in the number of published repeaters and an important contribution to the wider community studying FRBs. The release of this sample will enable observational followup that can be used to characterize the emission properties of these sources at other frequencies and, for a fraction, the possibility of precise localization and host galaxy identification.

This sample, detected between September 2019 and May 2021, joins an existing catalog of CHIME/FRB repeaters that enabled for the first time a statistical study of a wide range of burst properties. The analysis required impressive efforts to characterize the non-uniform selection biases introduced by the survey, a major contaminant in the interpretation of the results and an effort led by many current and past TSI affiliated students. The team comapred resulting burst repetition rates derived from this work to equivalent measurements from the non-repeating CHIME/FRB counterpart sample and found that the two samples could not be ruled out as arising from the same underlying population. This result directly addresses whether all FRBs repeat, an open question in the field and one with strong implications on emission models of FRBs.

While different origins for the repeating and non-repeating samples do not yet appear to be supported by the current burst rate distribution, meaningful differences are observed in the dispersion measure distributions of the two samples. This difference in dispersion measure joins other discrepancies previously reported in morphological properties of repeating and non-repeating samples, the origins of which are still unknown but may indicate astrophysical origins. While this question cannot be definitively answered with the current sample, this analysis lays important groundwork for future studies with the ever growing CHIME/FRB sample.

**Citation:** "CHIME/FRB Discovery of 25 Repeating Fast Radio Burst Sources", CHIME/FRB Collaboration (2023), ApJ 947, 2.




*telescopes (gray open circles).*

***Why this is important***

Do all fast radio bursts sources repeat? CHIME/FRB stands at the forefront of addressing this question, leveraging its unparalleled ability of detecting FRBs to amass a growing repeater catalog that enables, for the first time, a statistical comparison of the repeating and non-repeating samples.

# Looking for Dark Matter in the Mirror

*Prof. Katelin Schutz joined the TSI in 2021 and was recently was awarded the Canada Research Chair in Astrophysics Beyond the Standard Model.*

***Why this is important***

If successful, the proposed analysis could uncover dark matter axions or exclude their existence, providing valuable insights into the nature of dark matter.

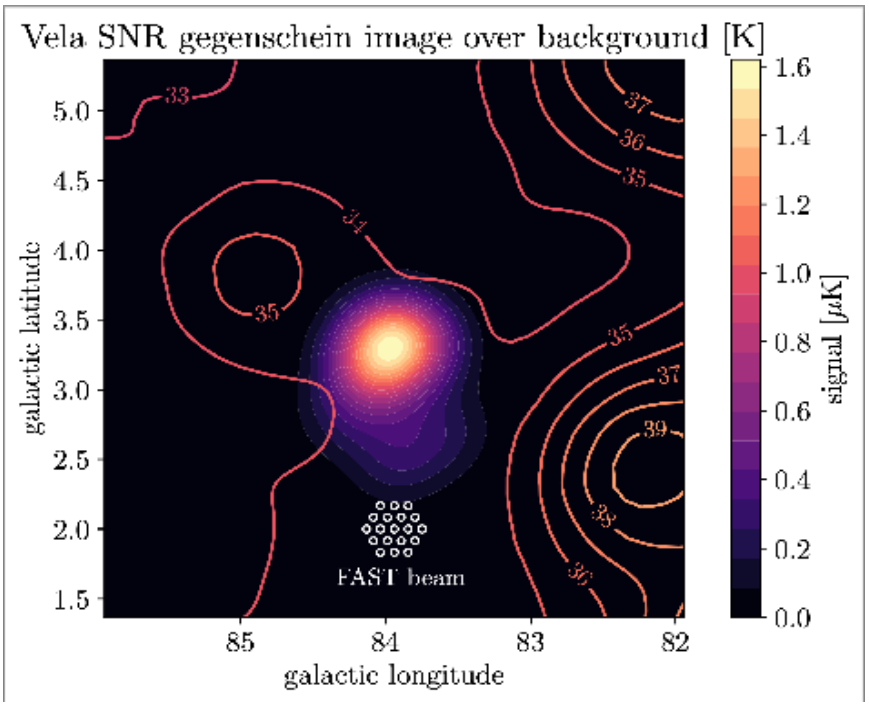
When you look in the mirror, you are seeing a younger version of yourself since the light that bounced off your face took time to hit the mirror and return to your eyes.

A similar concept, on Galactic scales, could help with the search for dark matter. One of the best dark matter candidates is the axion, which can interact with electromagnetism (albeit very weakly, otherwise they couldn't be dark matter), paving the way to a possible detection.

In 2022, TSI member Prof. Katelin Schutz published a creative new axion search strategy. Axions can decay to a pair of equal-energy photons, but strong existing constraints mean that the spontaneous decay rate is too small to be detectable. However, in the presence of background radiation, the rate for stimulated decay can be substantially higher due to the quantum phenomenon of Bose enhancement (the same thing that powers lasers). In this process, an incoming photon stimulates the decay, and the resulting photons travel back-to-back along the same axis as the incident photon, creating a spectral line mirror image. This phenomenon, known as "axion gegenschein," resembles the solar gegenschein caused by sunlight reflecting off dust particles.

Prof. Schutz proposed using supernova remnants (SNRs) as a source of photons to stimulate axion decay. SNRs are bright in radio waves today and were orders of magnitude brighter in the astrophysically-recent past, meaning that when we look at their mirror image rendered by decaying axions, we get to see how the SNRs looked when they were younger and brighter, giving a huge boost to the signal. Prof. Schutz found that with radio telescopes like FAST, CHIME, and CHORD, there may be immediate sensitivity to axion dark matter that would have previously evaded detection.

**Citation:** Axion dark matter-induced echo of supernova remnants
Yitian Sun, Katelin Schutz, Anjali Nambrath, Calvin Leung, and Kiyoshi Masui
Phys. Rev. D 105, 063007 – Published 9 March 2022



# Illuminating Cosmic Dawn

*Adrian Liu (Assistant Professor & William Dawson Scholar), Jordan Mirocha (CITA National Fellow at TSI), Saurabh Singh (Trottier Astrophysics Fellow), Adélie Gorce (TSI Astrophysics Fellow), Lisa McBride (PhD student), Bobby Pascua (PhD student), Samskruthi Ganjam (MSc student)*

***Why this is important***

World-leading radio-wavelength observations have provided new clues about the nature of first-generation galaxies.

Astronomers are used to using stars and galaxies as bright beacons that illuminate our Universe. But what do we do when we want to study Cosmic Dawn, the period in our cosmic history when the very first such beacons were busy being born? How do we study the darkness prior to first light, being deprived of the lighthouses that we have traditionally been so reliant on?

The answer turns out to be hydrogen. Even when first-generation stars and galaxies had yet to be formed, neutral hydrogen—the fuel that created these luminous objects—was already present. While hydrogen is invisible at visible wavelengths, it emits and absorbs faint radio waves. The darkness of intergalactic space is therefore a provincial human-centric (and optical-centric) viewpoint. From the perspective of a radio telescope, much of empty space is ablaze with signals, signals that can in principle be tracked before, during, and after Cosmic Dawn.

For the last few years, the Cosmic Dawn Intensity Mapping Group at McGill has been busy working on the Hydrogen Epoch of Reionization Array (HERA), a network of radio dishes in South Africa that together function as a "super telescope". HERA is one of many telescopes around the world competing to make a first detection of radio signals from Cosmic Dawn. While nobody has yet accomplished this feat, last year the HERA collaboration got the closest and set a world-leading constraint. In fact, our constraint was strong enough to rule out certain classes of theories and showed that first-generation galaxies had to emit significantly fewer X-rays than their modern counterparts.

HERA has taken baby steps towards understanding how first-generation galaxies were born. Like many baby steps, these were significant ones, and the best is yet to come. Thanks in part to TSI postdocs and graduate students, HERA will be taking its largest dataset yet this coming season, gathering yet more clues to illuminate the mystery of Cosmic Dawn.

**Citations**: HERA collaboration (2023), ApJ 945, 124. Gorce et al. (2023), MNRAS 520, 375. HERA collaboration (2022), ApJ 924, 51. HERA collaboration (2022), ApJ 925, 221

Credit: [illegible]

# Atmospheric Tides on Habitable Exoplanets

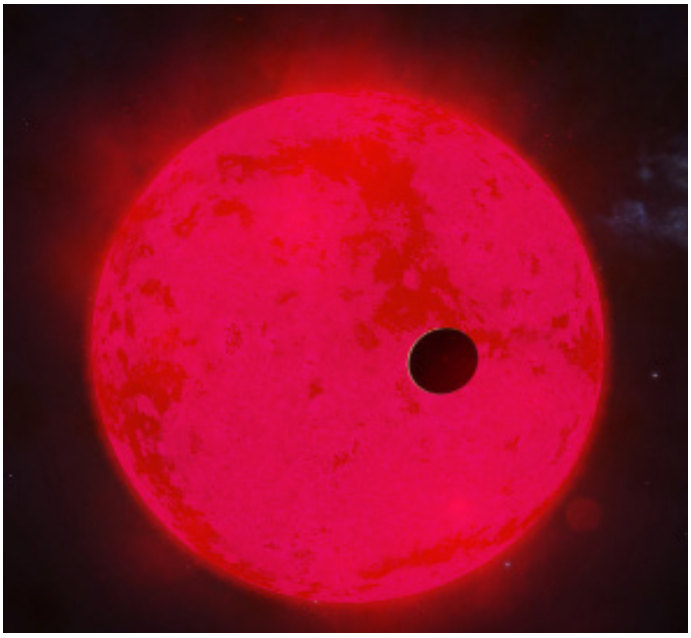
*Dr. Thomas Navarro is a former TSI postdoctoral fellow co-supervised by MSI professors Timothy Merlis (AOS, now at Princeton), Nicolas Cowan (Physics and EPS), and Natalya Gomez (EPS).*

The vast majority of temperate rocky planets in the Galaxy orbit red dwarf stars. Assessing whether these planets are habitable, or even inhabited, is one of the major drivers of exoplanet astronomy. Habitable planets orbit close to red dwarf stars, with periods of days to weeks. The tidal forces exerted on the planets are hundreds of times stronger than the tides on Earth, leading the planets to be "tide-locked", with one hemisphere in perpetual daylight and the other forever in the dark. Most red dwarfs harbor an entire system of small planets, however, and the gravitational tugs of these worlds on each other ensure that they are not in perfectly synchronous rotation. Instead, their star will move back and forth in the sky, raising tides on the planet, including its atmosphere. A similar phenomenon is known to impact the climate on Saturn's moon Titan.

TSI Fellow Navarro set out to study the impact of these atmospheric tides on potentially habitable planets orbiting red dwarfs in collaboration with atmospheric dynamicist Merlis, astronomer Cowan and geophysicist Gomez. Navarro first developed an analytic theory for the phenomenon, then implemented this new atmospheric physics into a global climate model. This force is typically neglected in models of Earth's atmosphere because it is so weak. Navarro found that atmospheric tides generate weather on these worlds, but that they don't significantly impact the average climate. This project kick-started an ongoing collaboration between these four scientists to apply the latest Earth and Planetary sciences to the question of exoplanet habitability.

Pooling their collective expertise in numerical modeling, atmospheric science, geophysics, and exoplanetary studies, they now aim to investigate the formation mechanism of ice sheets on the perpetual nightside of these planets. The concern lies in the potential entrapment of water in the form of ice on the nightside, which could impede the availability of sufficient liquid water on the dayside, posing a significant constraint on habitability. Given the absence of direct observations constraining the surface conditions of these worlds, a comprehensive model coupling climate dynamics and ice sheet flow emerges as the primary means to shed light on this critical question

**Citation:** Atmospheric Gravitational Tides of Earth-like Planets Orbiting Low-mass Stars. Navarro, Merlis, Cowan & Gomez 2022, The Planetary Science Journal, 3, 162



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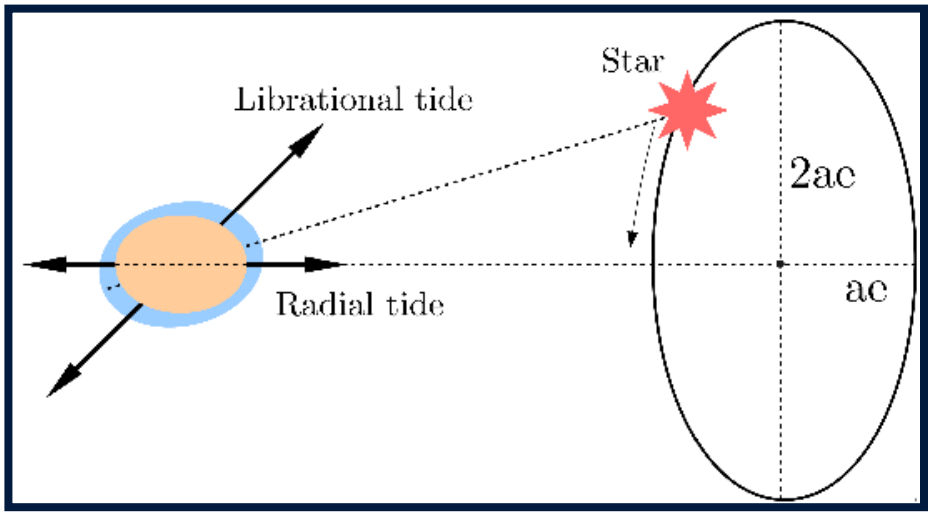



***Why this is Important***

TSI researchers from three departments come together to assess the habitability of exoplanets.

# Convectively Transported Water Vapor Plumes in the Midlatitude Lower Stratosphere

*Xun Wang is a Postdoctoral Researcher under the supervision of Prof. Yi Huang, an Associate Professor in the Department of Atmospheric and Oceanic Sciences*

Water vapor primarily exists in the troposphere, the layer of the atmosphere closest to the Earth's surface where weather phenomena occur. The stratosphere is relatively dry; however, despite it's relatively low amount, stratospheric water vapor plays a significant chemical and radiative role in climate change. As a major source of hydroxyl (OH) radicals, increases in stratospheric water vapor accelerate the stratospheric ozone loss rate. As a greenhouse gas, increases in stratospheric water vapor may result in global warming.

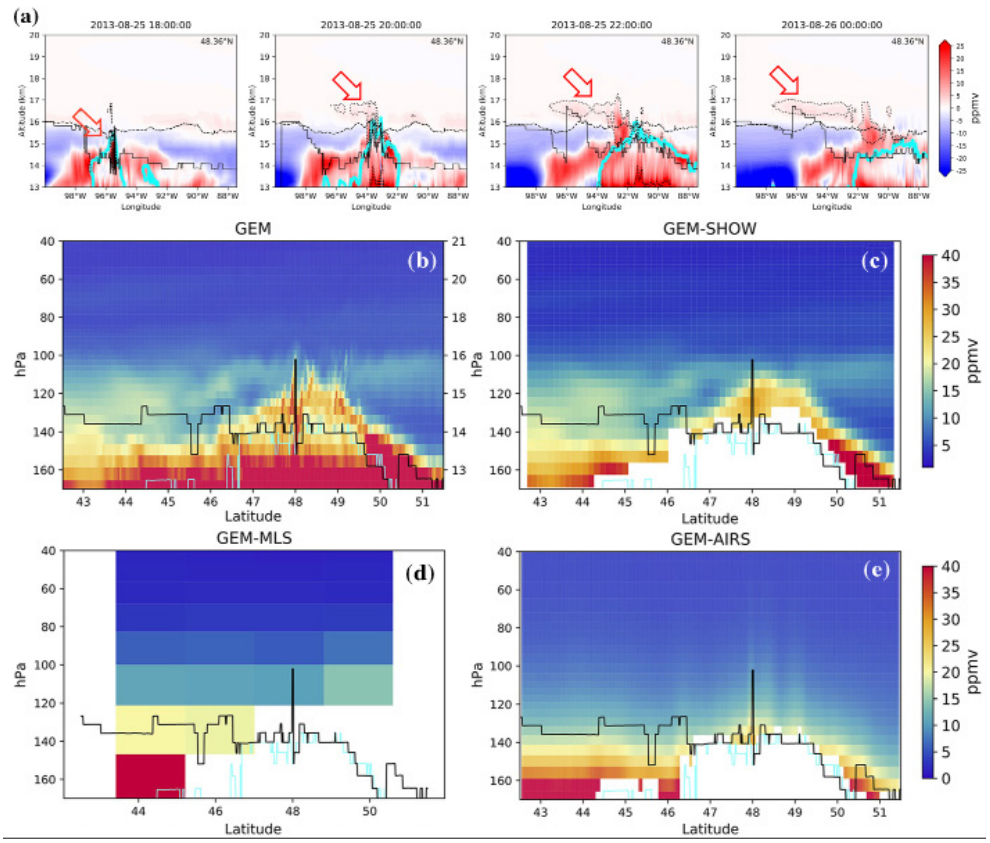
Deep convective systems, such as thunderstorms, can overshoot water-rich air into the lower stratosphere, significantly perturbing the stratospheric water vapor budget. Due to the importance of stratospheric water vapor in climate change, it is crucial to understand the transport and evolution processes of convective water vapor plumes, their observable characteristics, and whether they can be detected by satellite instruments.

Using the high-resolution Global Environmental Multiscale (GEM) model, Dr. Wang's team simulated a deep convective storm that occurred over North America on August 25, 2013, to reveal detailed transport and evolution processes of water vapor plumes that are difficult to capture with observational instruments. Their results show that multiple convective overshoots irreversibly transport water vapor into the stratosphere above 380-K potential temperature, forming a moist layer of 0.6 km with a horizontal size of about 300–400 km. The maximum water vapor mixing ratio in these plumes reaches 10.0 ppmv (4.3 ppmv anomaly). These water vapor plumes are stable and maintain the mass in the stratosphere after the convection weakens. Below 380 K, the convective water vapor plumes are closer to the cloud tops, with maximum water vapor mixing ratio of 31.1 ppmv (18.4 ppmv anomaly). Being less stable in the stratosphere, they partly return to the troposphere due to ongoing convective perturbations, resulting in half the mass reduced after the convection weakens.

Although current satellites have difficulty observing the fine structure of the convective water vapor plumes described above, a new satellite instrument under development, SHOW, with 1-km vertical and 100-km horizontal resolution will be able to verify the plume characteristics.

***Why this is important***

Deep convective storms can directly transport water vapor into the relatively dry stratosphere, which may have important impact on climate change. It is therefore crucial to understand the transport and evolution




*a) The transport and evolution processes of convective water vapor plume in the midlatitude lower stratosphere. (b)-(e) A cross section of convective cloud top and convectively transported stratospheric water vapor with horizontal resolution and vertical averaging kernels of satellite instruments applied. The instruments with lower vertical resolutions (Panels d-e) are not able to show the characteristics of the water vapor plume, while the SHOW (Panel c), with ≤ 1 km vertical resolution, is advantageous in revealing the fine structure of the water vapor plume. (Source: Wang et al., 2023)*

# Exploring uncertainties in future sea level changes

*Jeremy Roffman recently graduated with his M.Sc. from the Department of Earth and Planetary Sciences. He studied ice sheets and sea level change under the supervision of Prof. Natalya Gomez*

The melting of polar ice sheets is rapidly becoming the dominant contributor to future sea level changes. Sea level is commonly described as a uniform rise across all the world's oceans. In reality, however, the geographic pattern of ice mass loss across the Greenland and Antarctic Ice Sheets produces a unique, spatially non-uniform pattern of sea level change. The pattern of sea level change will also evolve temporally, along with the acceleration of ice mass loss or gain in some areas of the ice sheets, and with changes in the location of ice mass changes.

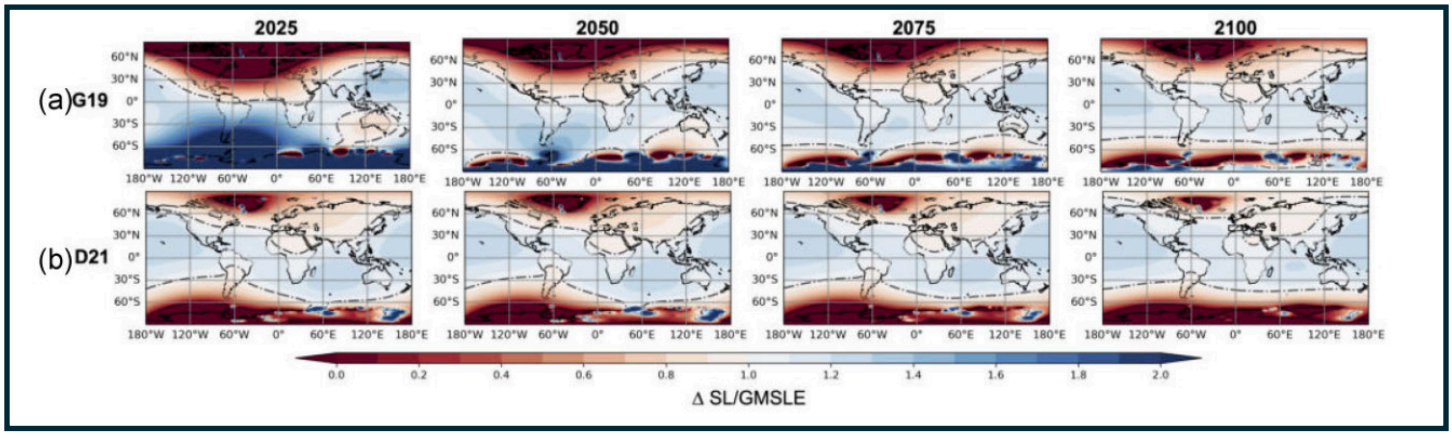
A challenge currently facing researchers is the wide range of ice sheet models, whose predictions of the future of the Greenland and Antarctic Ice Sheets differ significantly. In turn, the sea level predictions associated with each ice sheet model projection will also vary widely. In a new study by master's student Jeremy Roffman et al., authors calculate the spatially and temporally varying patterns of sea-level change that would arise from end-member Antarctic Ice Sheet evolution scenarios selected from the state-of-the-art ISMIP6 ice sheet model ensemble. The authors quantify the uncertainty in future sea level changes implied by the ensemble. By including temporal dimensionality in their projections, the authors show, for the first time, that sea-level rise along coastlines closest to the ice sheets may exceed the global average sea-level change early in the 21st century than in 2100, when sea level rise is most commonly reported in the literature. The study suggests that predictions of sea level change should take into consideration the full range of possible ice sheet evolution scenarios.

**Citation:** J. Roffman, N. Gomez, H.K Han, M. Yousefi, & S. Nowicki, Spatial and temporal variability of 21st century sea level changes, Geophysical Journal International, Volume 235, Issue 1, October 2023, Pages 342–352, https://

Citation:

***Why this is Important***

Coastal adaptation in the near future relies on accurate predictions of sea level change. This study demonstrates that it is necessary to include spatial and temporal dimensionality in 21st century sea level projections in order to fully capture the risk posed to global coastlines by mass loss from the Greenland and Antarctic ice sheets.




*Maps of normalized sea level change ( SL/GMSLE) since 2000 at 25-yr increments projected in response to two ice sheet mass balance projections. Row (a) shows sea level change associated with the GrIS and AIS mass projections of G19, whereas row (b) shows sea level in response to the Greenland mass projection of G19 combined with the Antarctic mass projection of D21. Sea level is normalized by the GMSLE at each time step (see text). Areas where sea level change is negative are saturated in red, whereas regions in which sea level change is greater than two times the GMSLE are saturated in blue. The contours where normalized sea level change is equal to one and zero are highlighted by black dashed and solid lines, respectively (Roffman et al, 2023).*

# Experimental Investigation of Microbially-Generated Organics as a Biosignature for Ocean Worlds

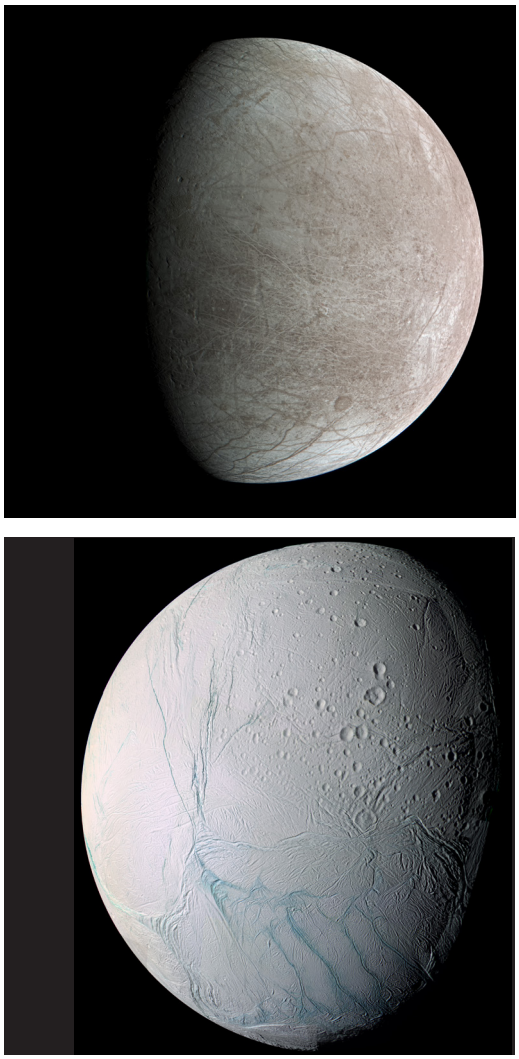
*Nagissa Mahmoudi is an Assistant Professor in the Department of Earth & Planetary Sciences. Her group's research centres on the role that microorganisms play in regulating biogeochemical carbon cycling in aquatic environments. contaminants.*

Ocean worlds are planets, moons and rocky bodies where there are substantial amounts of water, either beneath or on the surface. Enceladus (orbiting Saturn) and Europa (orbiting Jupiter) are two of the most compelling destinations in the solar system to search for evidence of biosignatures. Measurements by the Cassini Mission have led to compelling discoveries suggesting that the subsurface ocean of Enceladus is habitable and accessible via the plume ejecting ocean materials into space. Europa is also hypothesized to have hydrothermal systems resulting from radiogenic heating and tidal heating, and may also host a plume.

In a new collaboration with a scientist at NASA's Jet Propulsion Laboratory (JPL), Professor Nagissa Mahmoudi of the Department of Earth and Planetary Sciences is investigating whether microbially-produced organic compounds can be used as biosignatures for Ocean Worlds. Previous studies have shown that microorganisms in the ocean produce chemically complex and persistent compounds after consuming simple compounds (e.g. sugars). Moreover, it is suspected that these compounds are stable and can persist in the ocean for thousands of years. This makes these types of compounds ideal to explore as potential biosignatures as they are more likely to persist in environments such as the plume of Enceladus or the surface of Europa.

Prof. Mahmoudi and her students will cultivate a diverse range of different microbes found in deep-sea environments and then isolate their metabolic byproducts – in other words, their 'poop' – to get a better sense of what these compounds might look like in a plume. Subsequently, these samples will be sent to Dr. Morgan Cable at JPL for analysis with mass spectrometry to gain a deeper understanding of their chemical profiles. In addition, Dr. Cable will analyze these samples using the Hypervelocity Ice Grain System (HIGS) to determine whether these chemical fingerprints of microbial "poop" can be detected and distinguished using the same instrumental techniques on current and future missions. The HIGS system replicates plume flythrough sampling (3-6 km/s) of ice grains by an impact-induced ionization mass spectrometer.

The exploration of ocean worlds in our solar system holds tremendous importance for upcoming missions and proposed mission concepts. By carefully analyzing the chemical composition and distinct signatures associated with microbial life deep within these oceans, the team will gain valuable insights into the potential habitability and presence of life beyond Earth. Understanding the "fingerprints" of deep-sea microbial life and their unique chemical characteristics, detectable through space flight instruments, could have far-reaching implications in our search for life within these water worlds. This targeted approach enhances the effectiveness of exploration missions and ultimately increases the chances of finding definitive evidence of extraterrestrial life.



*Top: Europa in true colour imaged by the Juno spacecraft (NASA/JPL-Caltech/SwRI/MSSS/Kevin M. Gill). Bottom: false-color photo of Enceladus, that highlights its ridges, impact craters and plains (NASA/JPL/Space Science Institute*

# 03

# EDUCATION AND PUBLIC ENGAGEMENT

One of the core tenets of TSI's mission is to communicate astronomy with the public. TSI 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. We have 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 TSI'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). TSI 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.

In some ways, 2022 was a year defined by transition for our outreach projects, both in terms of our organisation and of our events. AstroMcGill, originally founded in 2011 by a group of graduate students, became TSI Outreach, cementing the centrality of public engagement to TSI's mission. Our events in the first half of year continued to take place online, transitioning to hybrid events in the summer, and then back to primarily in-person events by Fall 2022 (with an online component remaining available).

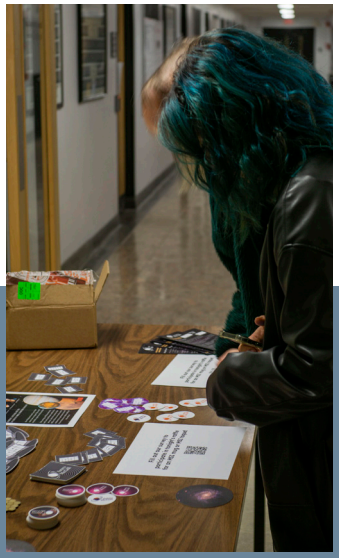
Public AstroPhysics Nights (see page xx), our public lecture series run in collaboration with Physics Matters featured a broad variety of topics and formats, including traditional talks, Q&As, and panel events. We co-hosted this year's Anna MacPherson Public Lecture, featuring Noble Laurete Jim Peebles, Astronomy Trivia Night introduced in 2020 as a more pandemic-friendly replacement to Astronomy on Tap, remained part of our regular roster of events, to the delight of our very enthusiastic participants.

Our Special TSI Public Talk series continued this year, with a live-streamed panel about the history of telescopes in April 2022, "Talking Telescopes", and an in-person talk in November 2022 all about Pluto. We also began planning for the return of Astronomy on Tap, scheduled for Spring 2023.

2022 was also a year of growth, with new activities joining our regular roster of activities. Public Observing Nights (see page xx), organised by the Observatory Coordinator at the Anna McPherson Observatory, brought people back onto campus in Fall 2022 for night-sky observing and guided tours of the Observatory. We co-founded **Science in Space: How to Telescope** with Physics Outreach and Dell Technologies, an extra-curricular program for girls and nonbinary students in grades 5 and 6. Students work in teams to build a telescope in Minecraft, under the mentorship of TSI and Physics graduate students, in order to learn about astronomical objects and how we study them.


In addition to our regular programming, TSI Outreach also participates in events organized by external partners. We took part in McGill Space Week, as part of McGill University's Bicenntennial Celebrations in May 2022, running a booth at the student group fair and organising a special panel offering a window into the lives of astronomy graduate students (page xx). We participated in 24 heures de science / AstroFest at the Planetarium, a day of astronomy-themed activities for all ages featuring groups from across the province of Quebec. We also organised an activity for Science Literacy Week at McGill focused on what extremophiles can teach us about life on other planets.

TSI also co-hosted the Physic Department's 2022 Anna McPherson Lecture, featuring Nobel Laureate Dr. Jim Peebles. As part of the in-person visit, our graduate students had the opportunity to interact with Dr. Peebles over coffee and snacks in the TSI lounge. TSI Grad Outreach Coordinator Hannah Fronenberg also had the once-in-a-lifetime opportunity to sit down with Dr. Peebles for an hour-long interview, where they delved into not just his impressive body of work, but also his advice to future Physics graduate students.



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

## Spotlight: TSI on Social Media

It is no surprise that now more than ever, people spend ample amounts of time on social media. In Fall 2022, we realized that in order for our outreach efforts to truly thrive, we needed to boost our online presence and engage more with our online community. While we increased the rate at which we post photos and updates, what has really taken off is our short form video content. We started producing instagram reels: short, 1-3 minute videos about various topics in space science. Our initial goal was to make sure that people learned something new whenever they scrolled past our posts. Since starting this initiative, we have welcomed over 1000 new followers to our online community and our videos have been viewed over 100,000 times. This new form of outreach has allowed us to engage with science enthusiasts around the world, and has helped us reach a younger audience; a demographic whose engagement was dwindling since the start of the pandemic. We are excited to see what this new chapter of outreach will bring!

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# PUBLIC ASTROPHYSICS NIGHTS

Public AstroNights (now Public AstroPhysics Nights) have been a mainstay in the Montreal astronomy scene since 2011. Originally founded by AstroMcGill in 2011, they are now run byTSI Outreach in collaboration with the Physics Department. Every month, a professional astronomer or physicist gives a public talk aimed at a broad audience. Speakers are often TSI 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.

After 2.5 years of virtual outreach, we were thrilled to be able to welcome our audience back onto the McGill campus in Fall 2022! We kept many of the improvements we had made during the pandemic to render our events more accessible, continuing to live-stream all our events and interact with the online audience as well as with those attending in person. Panels featured heavily in our Fall 2022 line-up, with a special emphasis on providing a platform for more junior academics to showcase their work.

From exoplanet research to theoretical cosmology to next generation telescopes, we're looking forward to the future of Public AstroPhysics Night!

**27 Jan** — **Prof. Kartiek Agarwal, Prof. Lillian Childress, Prof. Bill Coish** *(all: McGill, Dept. of Physics)*
'Space microbiology: microbial interactions in extremes and their uses'

**15 Feb** — **Prof. Audrey Moores** *(McGill, Dept. of Chemistry)*
'Green Chemistry: A Story of Shellfish, Synthesis, and Sustainability'

**31 Mar** — **Prof. Julie Hlavacek-Larrondo** *(Universite de Montreal)*
'Les plus gros trous noirs de l'universe'

**07 Apr** — **Sajjad Nikfahm-Khubravan,** *(McGill, Islamic Studies),* **Lauren Williams** *(McGill Library),* **Dr. Dallas Wulf** *(TSI & McGill Physics)*
'Talking Telescopes' **Special TSI Public Talk**

**28 Apr** — **Prof. Inna Sharf** *(McGIll, Dept. of Mechanical Engineering)*
'Space Debris Removal: Technologies, Missions, and Science'

**05 May** — **Nicole Ford, Lawrence Herman, Maclean Rouble** *(all: TSI & McGill, Dept. of Physics )*
'Window into the Life of an Astrophysicist'

**29 Jun** — **Prof. Stephanie Weber** *(McGill, Dept. of Biology)*
'Organelles without Borders: How Liquid Droplets Organize the Cell'

**19 Jul** — **Dr. Patrick C. Breysse** *(NYU Center for Cosmology and Particle Physics)*
'Cosmic Dawn: How the First Stars Formed and Burned Off the Fog of the Early Universe'

**28 Sep** — **Prof. Eve Lee** *(TSI & McGill Physics),* **Dr. Thomas Navarro** *(TSI & McGIll EPS),* **Jared Splinter** *(TSI & McGill Physics)*
'Planets Near and Far'

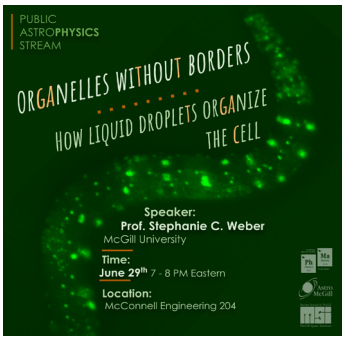
**26 Oct** — **David Gallacher** *(McGill Physics),* **Dr. Saniya Heeba** *(TSI & McGIll Physics),* **Prof. Katelin Schutz** *(TSI & McGill Physics)*
'Spitzer's Exoplanet Legacy: Population Trends from Phase Curve Observations'

**07 Nov** — **Dr. S. Alan Stern** *(PI NASA New Horizons; Southwestern Research Institute)*
'New Horizons: The Exploration of the Pluto System and Beyond' **Special TSI Public Talk**

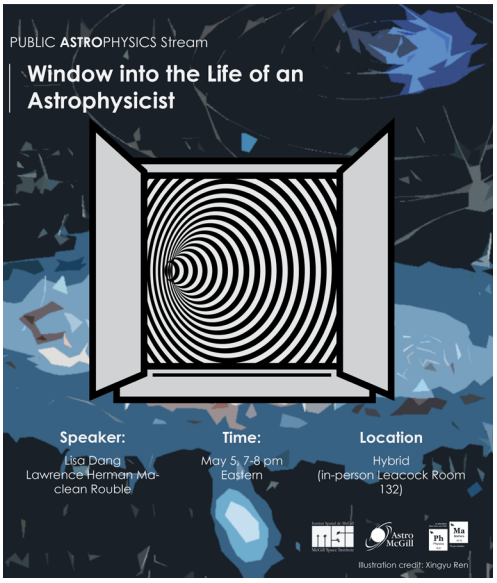
**30 Nov** — **Dr. Nathalie Nguyen-Quoc Ouellette** *(Outreach Scientist for JWST; Deputy Director, iREx)*
'Unveiling the Universe with the Webb Telescope'

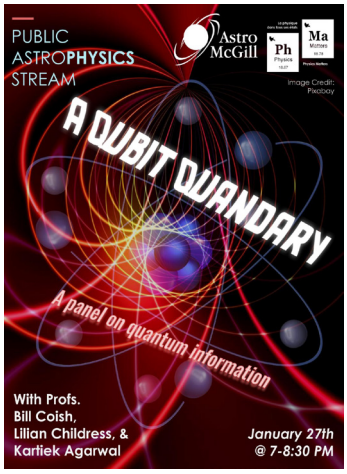

AstroMcGill and the McGill Space Institute Present...
PLANETS NEAR AND FAR
PUBLIC TALKS WITH Q&A BY
Prof. Eve Lee
Dr. Thomas Navarro
Jared Splinter
WEDNESDAY, SEPTEMBER 28TH, 7PM
LOCATION TBA

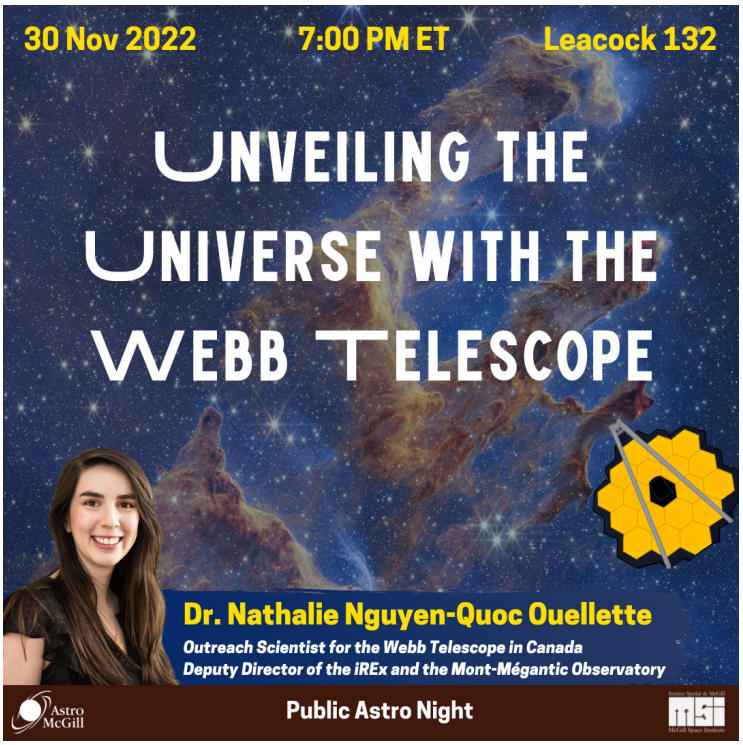

PUBLIC ASTROPHYSICS STREAM
Green Chemistry:
A Story of Shellfish, Synthesis, & Sustainability
Talk by Prof. Audrey Moores from McGill University
February 15 @ 7 PM

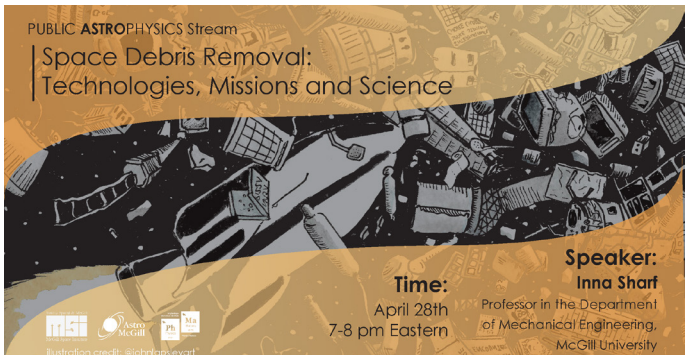

PUBLIC ASTROPHYSICS STREAM
ORGANELLES WITHOUT BORDERS
HOW LIQUID DROPLETS ORGANIZE THE CELL
Speaker:
Prof. Stephanie C. Weber
McGill University
Time:
June 29th 7 - 8 PM Eastern
Location:
McConnell Engineering 204


Special Public AstroNight
COSMIC DAWN:
HOW THE FIRST STARS FORMED AND BURNED OFF THE FOG OF THE EARLY UNIVERSE
Public talk by
Dr. Patrick Breysse (NYU)
July 19, 7-8 pm ET
McConnell Engineering, Room 204


PUBLIC ASTROPHYSICS Stream
Window into the Life of an Astrophysicist
Speaker:
Lisa Dang
Lawrence Herman Ma-clean Rouble
Time:
May 5, 7-8 pm Eastern
Location
Hybrid
(in-person Leacock Room 132)
Illustration credit: Xingyu Ren


PUBLIC ASTROPHYSICS STREAM
A QUBIT QUANDARY
A panel on quantum information
With Profs.
Bill Coish,
Lilian Childress, &
Kartiek Agarwal
January 27th
@ 7-8:30 PM


30 Nov 2022
7:00 PM ET
Leacock 132
UNVEILING THE UNIVERSE WITH THE WEBB TELESCOPE
Dr. Nathalie Nguyen-Quoc Ouellette
Outreach Scientist for the Webb Telescope in Canada
Deputy Director of the iREx and the Mont-Mégantic Observatory
Public Astro Night


PUBLIC ASTROPHYSICS Stream
Space Debris Removal:
Technologies, Missions and Science
Time:
April 28th
7-8 pm Eastern
Speaker:
Inna Sharf
Professor in the Department of Mechanical Engineering, McGill University


PUBLIC ASTROPHYSICS STREAM
LES PLUS GROS TROUS NOIRS DE L'UNIVERS
Conférence par Julie Hlavacek-Larrondo
Professeure agrégée de physique, Université de Montréal
Mardi, le 31 mars, 7-8 pm EST

# OBSERVING NIGHTS

Atop the Rutherford Physics Building here at McGill is the Anna I. MacPherson observatory. This consists of a 14-inch Celestron telescope in a dome, several smaller portable telescopes, and a small 1400 MHz radio telescope. The rooftop location provides one of the best observing experiences in Montreal for objects such as the moon, Saturn, Jupiter, nebulae, and much more.

The observatory is run by students in the Department of Physics and TSI, led by the Observatory Coordinator, graduate student Matthew Lundy.The Observatory Coordinator and a team of dedicated volunteers run a variety of observing nights aimed at different audiences, inside and outside McGill. The observatory can also occasionally accommodate visits from private groups. While a majority of observing nights take place in the Anna MacPherson Observatory, our coordinators also host off-site events using our portable telescopes.

## Public Observing Nights

Beginning in Fall 2022, the observatory also opens its doors every month to the public for "Public Observing Nights". These nights feature a guided tour of the observatory followed by observing of different astronomical targets. They have proved wildly popular, with the 60 open slots often filling up within hours of the event being advertised on our social media channels.

## McGill Observing Nights

A perk of having an observatory on campus is that we can reach out to astronomy enthusiasts from all across the university. The observatory regularly host groups from the McGill community. This year, we welcomed groups from various residence halls during the first few weeks of the Fall term. The Observatory Coordinator is also keen on exploring the observatory's potential as an educational tool for Physics students. To that end, he hosted bi-weekly observing nights for undergraduates to learn how to use the telescopes and to acquire observational astronomy skills.


## Observing with Schools

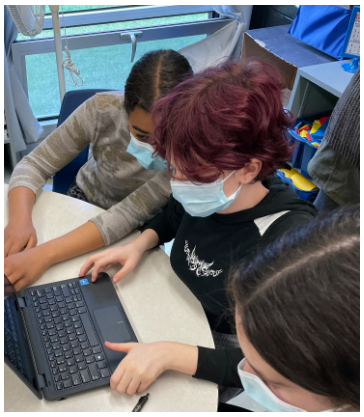
Schools and CEGEPs in the Montreal area can also request a guided observing experience either at our observatory, or an observing visit directly at the school with our smaller telescopes directly. Thie year, a Cub Scout troop had the opportunity to visit the observatory and see some of what they had learned about night-sky observing in action. We were also invited by JPPS to be a part of one of their Shabbat events, bringing together understandings of the sky from the Jewish faith with the work that astronomers do. We set up the portable telescopes for the Grade 3 class and their families, who were all delighted to not only look through the telescopes, but also to intreact with the graduate student volunteers who attended. The almost 100 attendees were thrilled, as were our volunteers, and we hope to be able to make this a recurring event.

## Off-Site Observing

Our portable telesecopes make it possible for our volunteers to take part in off-site observing events with groups both in and aoutside the city. One such event this year was organized by a professor at Concordia University, featuring Cree astronomer Wilfred Buck sharing indigenous astronomy knowledge. TSI Outreach was invited to bring the telescopes and add an observing component to the event, allowing for the audience to see some of what they were learning about.

# SCIENCE IN SPACE: HOW TO TELESCOPE

Science in Space: How to Telescope is an informal science learning program co-founded in 2022 by the Trottier Space Institute, McGill Physics, and Dell Technologies/Girls Who Game. The program is organized and run by TSi grad student Alice Curtin, TSI Program Administrator Carolina Cruz-Vinaccia, and Physics Undergrad Advisor Dr. Kim Metera. The program is aimed at girls and students of marginalised genders between the ages of 10 and 12 (grades 5-6), as research shows that the years immediately preceding the transition to high school are a crucial determinant of retention of girls in STEM. Science in Space is designed to mitigate girls' attrition from STEM by fostering a sense of belonging and community, thus increasing student engagement and confidence in using STEM to tackle real-world problems. Over the course of 6 weeks, students design and build telescopes in Minecraft with the guidance of graduate student mentors (who themselves identify as members of marginalised groups in STEM).



The program is inquiry-based and student driven; students ultimately decide which astronomical phenomena they'd like to study and design a telescope to do so. In the first half of the program, facilitators and mentors deliver the basics of astronomy through game-based activities, giving the students the foundation they need to tackle the design of the telescope in the second half. Through this program, students gain familiarity with observational astronomy, develop collaborative project design skills, and gain a sense of community in STEM. Students not only develop a community within their own school network, but also within the larger Montreal area with graduate and undergraduate student mentors who support the girls in developing their project and act as role models.

We capped off the program with a celebratory pizza party and showcase, where each group presented their telescope to the other groups, mentors, and teachers. The quality of the telescopes was impressive, with the finished product demonstrating not only the skills and knowledge they had learned, but also their creativity and sense of wonder about space. The impact on the students was apparent, particularly in the strength of the community that formed. Almost all of the student said that their favourite part of the program was working with each other, making new friends, and collaborating on the telescopes.

The pilot run of Science in Space was a resounding success; not only did we have no attrition among our initial cohort of 15, but we actually accreted a student and finished out the run with 16 participants! We plan to incorporate the feedback from stduents and teachers alike in order to build upon this success and expand the program in the coming years.

To learn more about the program, visit https://www.scienceinspace.ca/

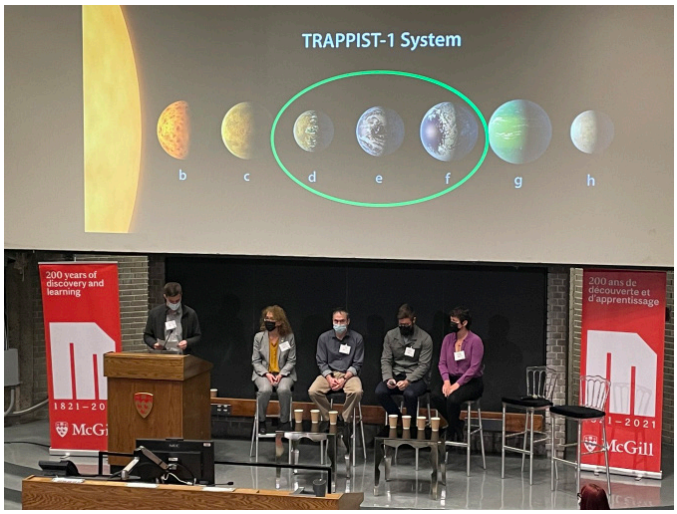
# FESTIVALS AND OTHER EVENTS

In addition to our regular programming, TSI Outreach also participates in events organized by external partners that seek to increase awareness of and access to science in general and astronomy in particular.

## Space Week at McGill

As part of McGill's Bicentennial Celebrations in May 2022, McGill hosted Space Week, a series of events that sought to showcase a shared vision of McGill and Canada's future in space and highlight contributions from McGill students, alumni, and faculty. Various TSI faculty members presented at the Space Research Conference, which brought together researchers spanning fields from healthcare to law to engineering and space science.


TSI students representing AstroMcGill had a booth at the McGill Student Aero/Space Fair, showcasing TSI's research and outreach work to the McGill community and external attendees. The fair was visited by school groups from neighbouring schools, with whom our students ran hands-on activities focusing on craters and life on other planets. We also hosted a special public panel for Space Week attendees featuring graduate student researchers at McGill, A Window into the Life of an Astrophysicist. TSI graduate students Nicole Ford, Lawrence Herman, and Maclean Roouble discussed their trajectories into astrophysics and took questions from an enthusiastic audience!



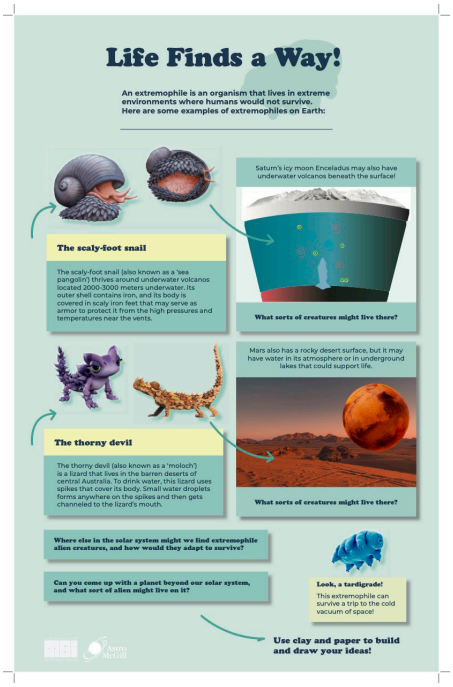

Our outreach grad students also had the unique opportunity to participate in a meet and greet with McGill alumni who went on to become astronauts: Dave Williams (BSc'76, MDCM'83, MSc'83, DSc'07), Robert Thirsk (MDCM'82), Julie Payette (BEng'86, DSc'03), David Saint-Jacques (MedResident '07), and Jennifer Sidey (BEng'11).

## 24 heures de science

24 heures de science is a province-wide celebration of science where organizations across Quebec host events and activities to increase public engagamenet with science. The event starts on Friday at noon and ends 24 hours later, giving room for evening and late-night activities. TSI has participated regularly for the last few years, either independently or in collaboration with Physics Outreach. This year's 24 heures coincided with the Planetarium's AstroFest, in which TSI participated (see below).

## AstroFest at the Planetarium

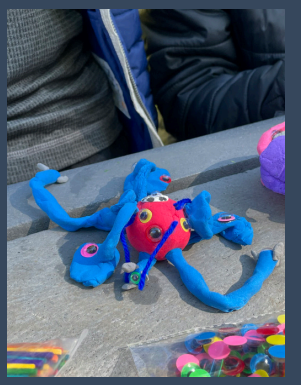
On May 7, 2022 Montreal's Planétarium Rio Tinto Alcan hosted Astrofest, a daylong event for astronomy enthusiasts of all ages. The program included arts and crafts for all age groups, presentations, an astrophotography exhibit, information booths, workshops, and a talk by Canadian Space Agency astronaut David Saint-Jacques, and nighttime observing. TSI piloted a brand new module focused around astrobiology, "Life Finds a Way", where children learn about extremophiles - organisms that thrive in extreme environments - by designing one of their own out of clay. We ask participants to think of a world other than Earth, like a planet in our solar system, a moon, or an exoplanet, and about the kind of life that could develop in different environmental conditions. The activity proved immensely popular, welcoming over 200 children (and their parents!) in the four hours that the booth was open. Additionally, volunteers from TSI also participated in the observing portion of the evening, setting up our portable telescopes for astronomy lovers to observe the night sky!

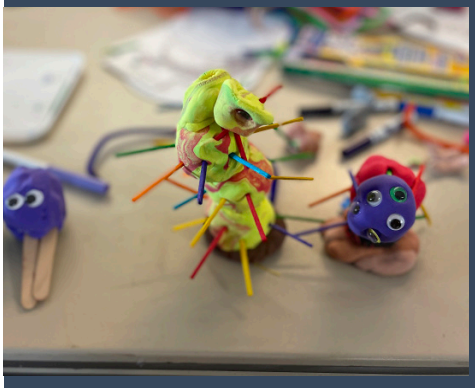


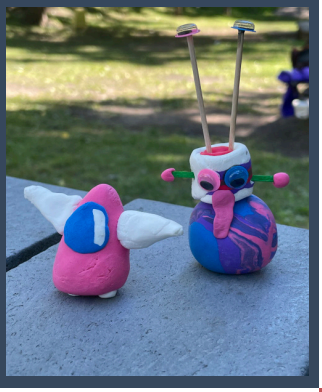

## Science Literacy Week

Science Literacy Week is a nation-wide event that showcases the many ways kids and families can explore and enjoy the diversity of Canadian science. Libraries, museums, science centres, schools and not-for-profits come together to highlight the books, movies, podcasts and events that share exciting stories of the science, discoveries and ingenuity shaping our lives. TSI Outreach participated by hosting "Life Finds a Way" welcoming children and their families to the lawn outside the Redpath Museum on Sep. 25, for a morning of extremophile-themed fun!

## Life Finds a Way: Our Menagerie of Extremophiles

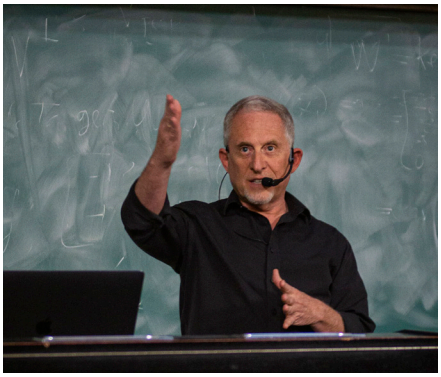





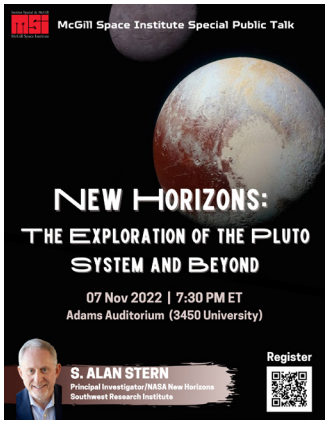


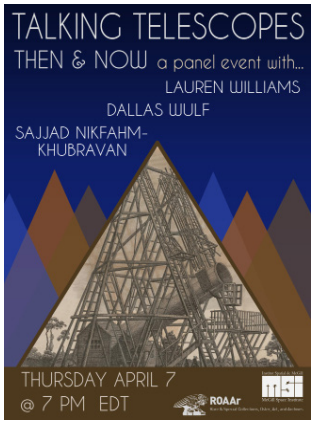
# SPECIAL TSI PUBLIC TALKS

## Talking Telescopes: Then & Now



On April 3, 2022, TSI partnered with the Rare Collections Library at McGill University to host a panel offering a unique perspective on the links between ancient and modern astronomy. TSI postdoctoral fellow Dallas Wulf talked about some of the work he has done building telescopes. Sajjad Nikfahm-Khubravan, a PhD candidate in McGill's Department of Islamic Studies discussed his research into ancient Islamic astronomy. The panel was rounded out by Lauren Williams from the McGill Library, who showcased some of the texts and artifacts that form part of McGill's collection. The virtual audience of over 400 was enthusiastic and engaged, with the number of questions exceeding the hour we had allocated for the Q&A portion. The recording has proved equally popular, garnering over 2000 views!




## New Horizons: The Exploration of the Pluto System and Beyond

On Nov. 7, 2022, we hosted our first in-person Special TSI Public Talk since 2019, featuring visiting speaker Dr. S. Alan Stern. Dr. Stern spoke in his capacity as the Principal Investogator of the New Horizons mission to an audience of over 200 astronomy enthusaists. New Horizons is NASA's mission to explore the Pluto system and the Kuiper Belt (KB). New Horizons launched in 2006 and made the first explorations of the Pluto system in July 2015 and the first exploration of any Kuiper Belt Object (KBO), a body named Arrokoth, in January 2019. It is now on an extended mission to explore the Kuiper Belt and conduct other scientific investigations only feasible from its position 54 AU from the Sun, or farther. The spacecraft carries a sophisticated payload of imagers, spectrometers, and other scientific instruments. The flyby of the Pluto system by New Horizons revealed a complex planet and satellite system. Beyond providing rich geological, compositional, and atmospheric datasets, New Horizons also demonstrated that Pluto has been surprisingly geologically and climatologically active throughout 4+ Gyr, and that it exhibits a surprisingly complex range of phenomenology and geologic expression that rivals Mars in its richness. Dr. Stern described the mission's objectives the capabilities of the payload, the flybys of Pluto and KBO Arrokoth, and some of the major scientific discoveries made about in these flybys. He closed by outlining the future extended mission of New Horizons. The talk was followed by an extended Q&A section, where the audience had the opportunity to ask all of their most burning questions about Pluto, New Horizons, and the experience of being PI of a NASA mission. All in all, we couldn't have asked for a better return to in-person Special Public Talks!


# TSI IN THE MEDIA

'Study provides new insights into seasons on a planet outside our solar system', ANI News , 23 Jan 2022 [Lisa Dang]

'Hot Jupiter Exoplanet Provides New Insights Into Seasons on a Planet Outside Our Solar System', SciTech Daily , 30 Jan 2022 [Lisa Dang, Nicolas Cowan]

'February 11: International Day of Women and Girls in Science', McGill Reporter , 10 Feb 2022 [Victoria Kaspi]

'"La science québécoise au féminin" : paroles de chercheuses', TV5 Monde , 11 Feb 2022 [Victoria Kaspi]

'HERA Telescope: Early Findings Promise Deeper Understanding of the Cosmic Dawn', SciTech Daily , 12 Feb 2022 [Adrian Liu]

'James Webb Space Telescope Locked Onto Guide Star for High Accuracy Mirror Alignment', SciTech Daily , 17 Feb 2022 [Rene Doyon ]

'Eve Lee Awarded 2022 Annie Jump Cannon Award', AAS Newsroom , 24 Feb 2022 [Eve Lee]

'INSTEAD OF A BIG BANG, THERE COULD HAVE BEEN… A BIG BOUNCE?', SyFy Wire , 24 Feb 2022 [Robert Brandenberger]

'Mysterious Cosmic Flashes Pinpointed to a Surprising Location in Space – "Closest Ever"', SciTech Daily , 25 Feb 2022 [Victoria Kaspi]

'Four Years On, New Experiment Sees No Sign of 'Cosmic Dawn'', Quanta Magazine , 28 Feb 2022 [Cynthia Chiang]

'Mysterious Source of Fast Radio Bursts – "We Could Not Believe It"', SciTech Daily , 01 Mar 2022 [Victoria Kaspi]

'New Result Casts Doubt on 'Cosmic Dawn' Claim', Scientific American , 03 Mar 2022 [Cynthia Chiang]

'Astronomers may not have found a sign of the universe's first stars after all', Science News , 04 Mar 2022 [Cynthia Chiang]

'4 Years On, a New Experiment Sees No Sign of 'Cosmic Dawn'', Wired , 14 Mar 2022 [Cynthia Chiang]

'CHIME Outrigger telescopes boost search for fast radio bursts', McGill Newsroom , 30 Mar 2022 [Victoria Kaspi, Patrick Boyle]

'Astronomers reveal first image of the black hole at the heart of our galaxy', McGill Newsroom , 12 May 2022 [Daryl Haggard]

'Le trou noir central de la Voie lactée enfin dévoilé', La Presse , 13 May 2022 [Daryl Haggard]

'First Direct Visual Evidence That the Object in the Center of the Milky Way Is Indeed a Black Hole', SciTech Daily , 17 May 2022 [Daryl Haggard]

'"Boom, Boom, Boom" – MIT Astronomers Detect a Strange "Heartbeat" Billions of Light-Years From Earth', SciTech Daily , 13 Jul 2022 [Victoria Kaspi, Matt Dobbs]

'Astronomers detect a radio "heartbeat" billions of light-years from Earth', McGill Reporter , 18 Jul 2022 [Aaron Pearlman]

'Water World: Astronomers Discover an Extrasolar World That May Be Entirely Covered in a Deep Ocean', SciTech Daily , 27 Aug 2022 [Rene Doyon, Nicolas Cowan]

'The RSC Presents the Class of 2022', RSC Press Release , 06 Sep 2022 [Nicolas Cowan]

'Three McGill professors receive Royal Society of Canada medals', McGill Reporter , 13 Sep 2022 [Daryl Haggard]

'Claudia Mitchell, Victoria Kaspi honoured by the World Cultural Council', McGill Reporter , 20 Sep 2022 [Victoria Kaspi]

'Canadian Hydrogen Intensity Mapping Experiment (CHIME) team wins NSERC's Brockhouse Canada Prize for Interdisciplinary Research in Science and Engineering', NSERC Media , 15 Oct 2022 [Victoria Kaspi]

'Ultra-Hot "Super-Earth" Exoplanet 65 Light-Years Away Could Have No Atmosphere', SciTech Daily , 18 Oct 2022 [Nicolas Cowan]

'Discovery Could Dramatically Speed Up the Search for Extraterrestrial Life', SciTech Daily , 24 Oct 2022 [Nicolas Cowan]

'Natalya Gomez earns International Union of Geodesy and Geophysics Early Career Scientist Award', IUGG Media , 07 Nov 2022 [Natalya Gomez]

'McGill celebrates its Highly Cited Researchers', Meaghan Thurston, Associate Director, Research Communications , 22 Nov 2022 [Victoria Kaspi]

'James Webb Space Telescope Reveals Oldest Star Clusters in the Universe', SciTech Daily , 28 Nov 2022 [Rene Doyon]

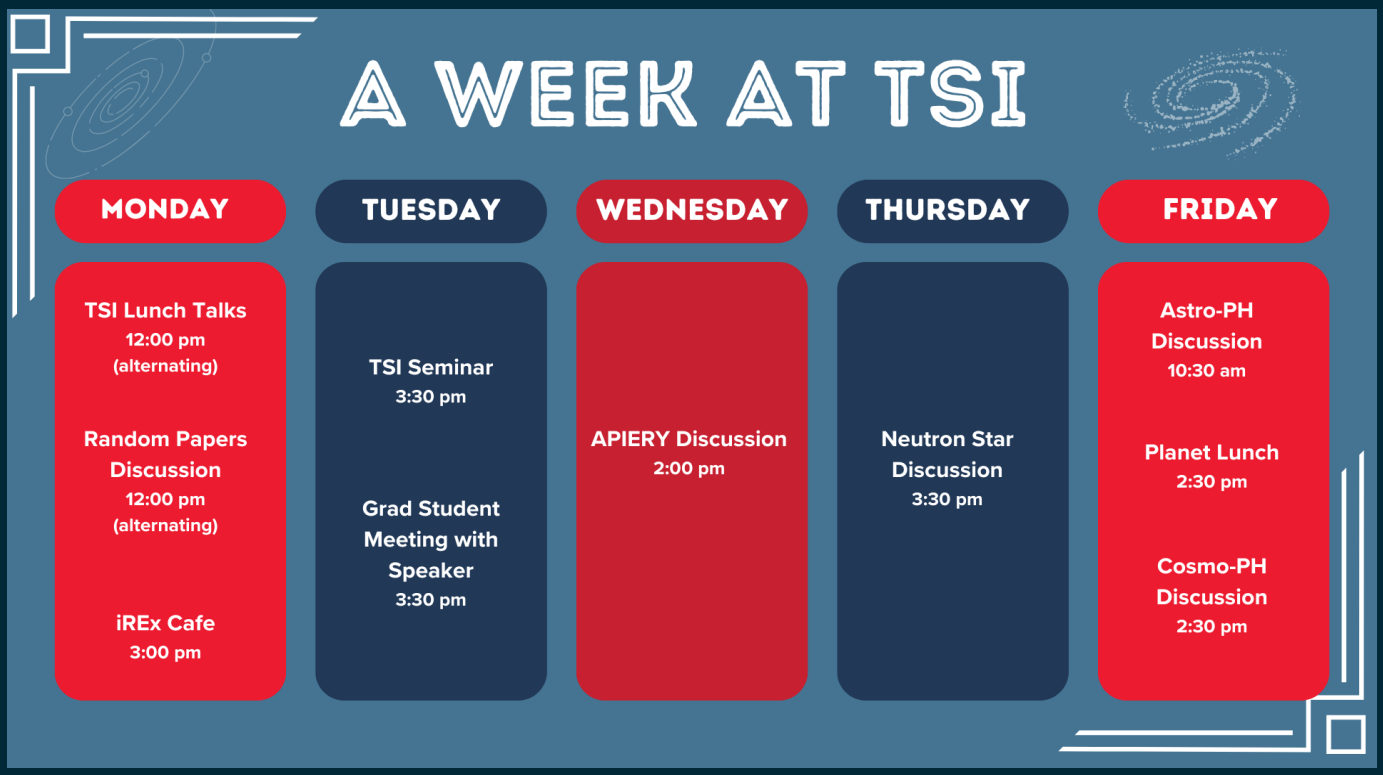
'Charles Gale and Daryl Haggard honoured by the Canadian Association of Physicists', McGill Reporter , 22 Dec 2022 [Darryl Haggard]

# 04
# INREACH

Fostering cross-fertilization of ideas, interdisciplinary interactions, and collaborations among Institute members is one of the main missions of TSI. 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 social events, there's never a dull moment at TSI!

The ongoing COVID-19 pandemic meant that many of our activities started off the year online. However, as restrictions were loosened in the summer, we were able to bring people back to campus and rekindle the homey vibe of the TSI house. Our discussion groups and journal clubs continued to meet, moving from a virtual format to a hybrid format as the Fall semester began. In October 2022 we held our very first in-person Jamboree in 2 years, hosting TSI members in the Ballroom of Thomson hosue to celebrate that we were able to gather again.

We were thrilled to also be able to host our social events in person as of Summer 2022, starting with the Summer Solstice Picnic in Parc Jeanne Mance. TSI provided the food and over 60 TSI members brought their blankets, friends, and games (including a volleyball net!) for an evening of relaxing summer fun! In the Fall, TSI's Halloween Party took place in person for the first time ever, filling the TSI house with students, postdocs, and faculty showing off their most creative costumes. The Fall term also saw the return of our Winter Solstice Party, complete with festive snacks, holiday card-making, and our traditional festive sweater contest!




MSI HALLOWEEN PARTY
Oct. 31, 5:30 pm | MSI Lounge
Pizza, drinks, costume contest, and more!
Please RSVP (link in email)
MSI

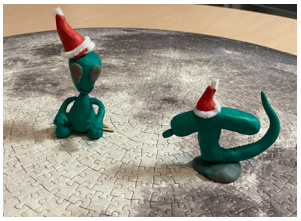

WELCOME BACK
PIZZA PARTY
SEP. 15, 2022 | 5PM-7PM
MSI CONF. ROOM & LOUNGE
Join us for welcome back to MSI pizza party! Meet your fellow MSI students, postdocs, and profs. MSI will provide pizza & drinks.
Please RSVP (see email for link)
MSI


MSI
SUMMER
SOLSTICE
PARTY
Join us in Parc Jeanne Mance! MSI will provide food & non-alcholic beverages.
RSVP required!
28 JUNE 6PM-8PM


TSI Winter Solstice Party 2022


TSI
HAPPY HOLIDAYS!


Contests!
Categories
Sweater
Card




PHYSICS OUTREACH, EDI, & ASTROMCGILL PRESENT...
MSI
WELCOME PICNIC
WHEN: MON. SEPT 12TH @ 5:00 PM
ARE YOU A MCGILL PHYSICS/MSI STUDENT INTERESTED IN GETTING INVOLVED WITH OUTREACH OR EDI?
COME CHAT & LEARN ABOUT PHYSICS AND ASTRONOMY OUTREACH AT MCGILL, AND OTHER EDI EFFORTS!
PIZZA & OUTREACH & EDI
HACKATHON

# SEMINARS

TSI hosts weekly seminars featuring speakers from across North America and beyond. TSI seminars are intended to be accessible to scientists from the entire breadth of backgrounds at TSI, including physics, planetary science, geology, atmospheric science, and astrobiology. As COVID-19 restrictions loosened in mid-2022, our seminars moved to a hybrid format, with attendance being possible both in person and online. Our semianr series is made possible by a generous gift from the Trottier Family Foundation and funding from the Centre de recherche en astrophysique du Québec (CRAQ).

## Winter/Spring 2022

**11 Jan** — **Charles Cockell** *(University of Edinburgh)*
'Space microbiology: microbial interactions in extremes and their uses'

**18 Jan** — Emily Kuhn (Yale)
'Drone Calibration for 21cm Experiments'

**25 Jan** — Melodie Kao (UC Santa Cruz)
'Brown Dwarf Radio Emission: A Window into Substellar Magnetospheres'

**01 Feb** — Nahee Park (Queen's University)
'Searching for extreme hadronic accelerators in our Universe with multi-messenger observations'

**08 Feb** — Joey Rodriguez (Michigan State University)
'Understanding Planetary Evolution with TESS'

**08 Feb** — Neil Turok (University of Edinburgh)
'Gravitational entropy and the flatness, homogeneity and isotropy puzzles'

**15 Feb** — McKinley Brumback (Caltech)
'A broad-band X-ray view of accretion disks around neutron stars'

**22 Feb** — Erin May (Johns Hopkins Applied Physics Lab)
'Spitzer's Exoplanet Legacy: Population Trends from Phase Curve Observations'

**08 Mar** — Andrina Nicola (Princeton University)
'Cosmological probe combination for current and future surveys'

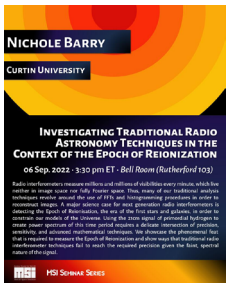
**22 Mar** — Carl Fields (LANL)
'Next-Generation Simulations of The Remarkable Deaths of Massive Stars'

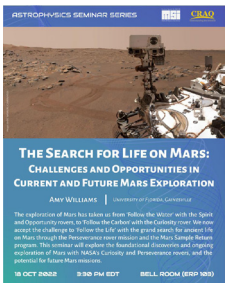
**29 Mar** — Hongwan Liu (NYU)
'A Stimulating Explanation of the Extragalactic Radio Excess'

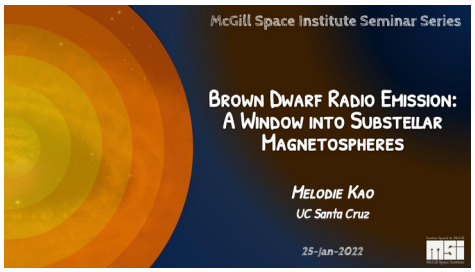
**05 Apr** — Maura McLaughlin (West Virginia University)
'Pulsar Timing Arrays See Red: Entering the Era of Low-Frequency Gravitational Wave Detection'

**12 Apr** — J. Xavier Prochaska (UC Santa Cruz)
'Probing the Universe with Fast Radio Bursts

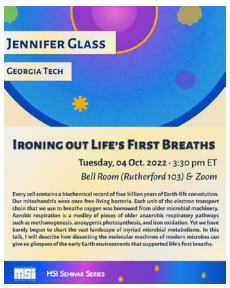
**19 Apr** — Caitlin Casey (UT Austin)
'The Rarest Galaxies in the first Two Billion Years'

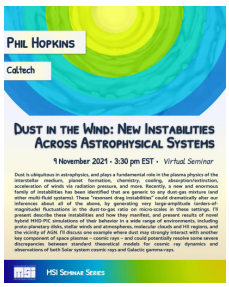


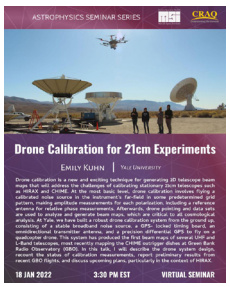








## Summer 2022

**19 Jul** Aaron Tohuvavohu (University of Toronto)
'Immediate observational access to the post-merger environment of a neutron star collision'

**25 Jul** Ruby Byrne (Caltech)
'Precision Calibration for 21 cm Cosmology'

**26 Jul** Barak Zackay (Weizmann Institute)
'An algebraic approach for recovering an unknown timing solution from a list of TOAs'

**26 Jul** Alexandra Mannings (UC Santa Cruz)
'Investigating Local Environments of Fast Radio Bursts'

## Fall 2022

**06 Sep** Nichole Barry (Curtin University)
'Investigating Traditional Radio Astronomy Techniques in the Context of the Epoch of Reionization'

**13 Sep** Jonathan Tan (Chalmers University of Technology & Univ Virginia)
'To the Frontiers of Cosmic Origins - From First Black Holes to Latest Planets'

**20 Sep** Urmila Chadayammuri (CfA (Harvard & Smithsonian))
'X-ray Population Studies with eROSITA - from supermassive black holes to the circumgalactic medium'

**27 Sep** Aaron Boley (UBC)
'Challenges to space sustainability: Space weapons'

**04 Oct** Jennifer Glass (Georgia Tech)
'Ironing out Life's First Breaths'

**18 Oct** Amy Williams (University of Florida Gainesville)
'The Search for Life on Mars: Challenges and Opportunities in Current and Future Mars Exploration'

**25 Oct** Nicholas Huang (Berkeley)
'Illuminating the Young Universe Through mm-wave Observations and Beyond'

**01 Nov** Rebecca Leane (SLAC/Stanford KIPAC)
'Dark Matter Searches with Celestial Bodies'

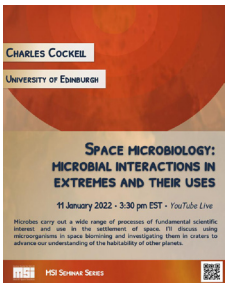
**08 Nov** Malena Rice (MIT / Yale (Fall 2023))
'Insights from the Orbital Architectures of Planetary Systems'

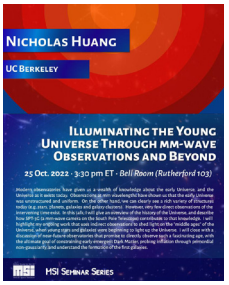
**15 Nov** Daniel Jacobs (Arizona State University)
'Recent developments in instruments for high redshift 21cm and exoplanets'

**22 Nov** Eleanor Armstrong (Stockholm University (Sweden))
'Counting stars: who's work in space science counts according to science communication'

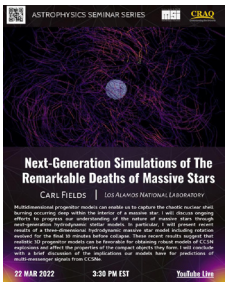
**29 Nov** Christene Lynch (University of North Carolina, Asheville)
'The MWA Long Baseline Epoch of Reionsation Survey: Improvements in the MWA EoR0 field'

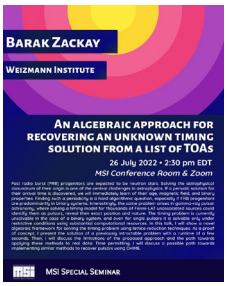
**13 Dec** Eric Koch (CfA)
'The atomic interstellar medium's role in the star formation lifecycle: a sharpened view of nearby galaxies from LGLBS and PHANGS-JWST'

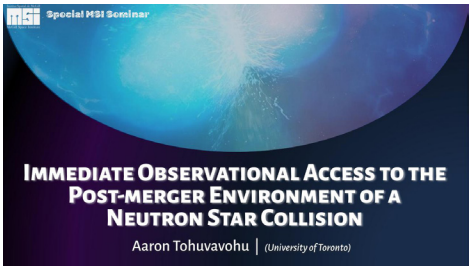


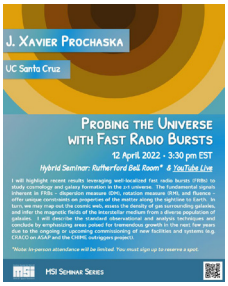



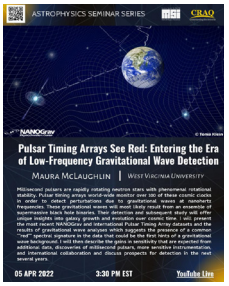


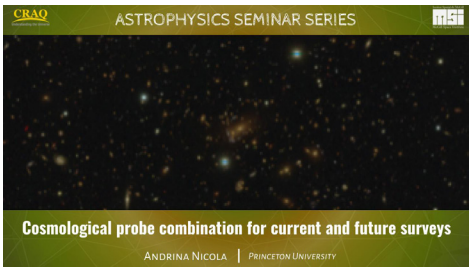


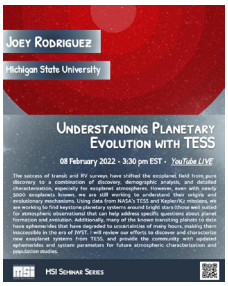



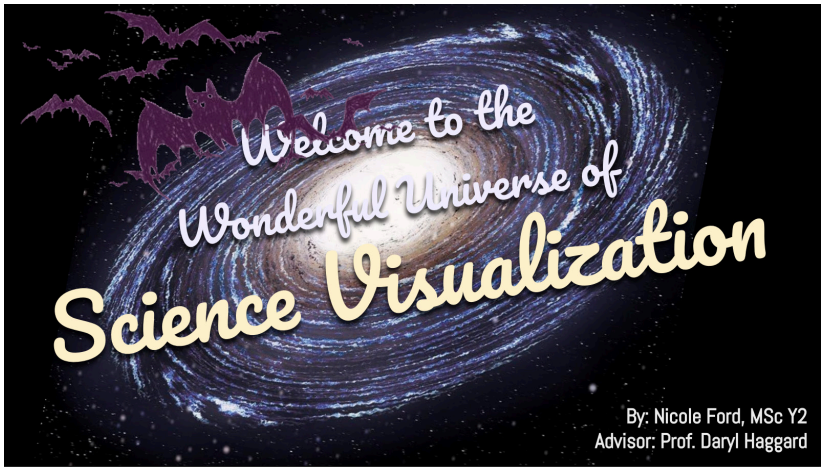




# TSI LUNCH TALKS


The Monday Lunch Talk Series has been a mainstay of TSI's inreach programs since the very beginning, providing a forum for TSI grad students, postdoctoral fellows, and faculty members to give short presentations over lunch and then engage in an extended, informal discussion. Lunch talks are held every other Monday during the Fall and Winter terms, and regularly draw anywehere from 25 to 45 participants. Any TSI member can give a lunch talk and they also serve as a great opportunity for new students and postdocs to introduce themselves to TSI. Like most of our events, Lunch Talks returned to an in-person format (with the option to join remotely) in Fall 2022, and our students and postdocs were thrilled to have them back!

Lunch Talks aim to provide an environment for speakers and attendees alike to explore topics beyond their own research. As such, both the format and content of lunch talks tend to be flexible. Lunch Talks have traditionally welcomed any and all format of talks, including blackboard talks, interactive workshops, more traditional short research talks; the only "rule" to be light on prepared material and leave plenty of space for discussion! In terms of content, anything goes as long as it's somewhat under the umbrella of space, space-related topics, or any of the other work we do at TSI, including outreach, education, and EDI. Speakers are welcome to practice a conference talk, tell us about a proposal, brainstorm a new idea, or talk about an interesting side-project or interest.


The return to in-person lunches brought with it a more adventurous edge, with most presenters opting for interactive workshops and blackboard talks. TSI graduate students got particularly creative; grad student Nicole Ford ran an interactive workshop bringing together art and research, where attendees had the opportunity to practice how to make artistic representations of the phenomena they study, some of which can be seen below. Grad student Nick Vieira also took advantage of the freedom to run a session on accessible representation of astronomical data, including tacticle models and sonification of data. Similarly, we also had a workshop on inclusive science communication, a blackboard talk on the peculiarities of white dwarfs, a first-hand account of the process of submitting JWST proposals, and a talk on blazar constraints on neutrino-dark matter scattering.




We're thrilled to have TSI Lunch Talks back on our roster, and look forward to the the creative topics that TSI memebrs will propose for future iterations!

*Left (from top): our new TSI Lunch Talk avatar, created by the talented Dr. Saniya Heeba; slides for lunch talks; examples of the visualizations created by TSI memebrs during Nicole Ford's lunch talk.*

# JOURNAL CLUBS

TSI members organise a variety of journal clubs and discussion groups that span across the various disciplines represented at TSI. From general discussions like astro-ph and Random Papers, to more niche groups like Neutron Star Discussion, there's something for

## Astro-ph Discussion

Astro-ph is a weekly journal discussion that takes place every Friday morning at TSI 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 TSI 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.

## ML in Astro Journal Club

The Machine Learning in Astrophysics Journal Club joined the roster of weekly events in 2021. It was co-founded by graduate students at TSI and Universite de Montreal and takes place every other week. Discussions are generally led by graduate students and focus on, as the name implies, the growing variety of applications of machine learning in astrophysics. So far, the group has had discussions about ML applications in pulsars, exoplanets, and cosmology.

## Neutron Star Discussion

NSD is a weekly journal club around neutron stars, a common thread that unites multiple research groups at TSI. They are a possible source of at least some Fast Radio Bursts being detected by CHIME (Prof. Kaspi & Prof. Dobbs); the discovery of a neutron star merger by LIGO has opened up a new way of studying these exotic objects (Prof. Haggard), 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).

## Planet Lunch

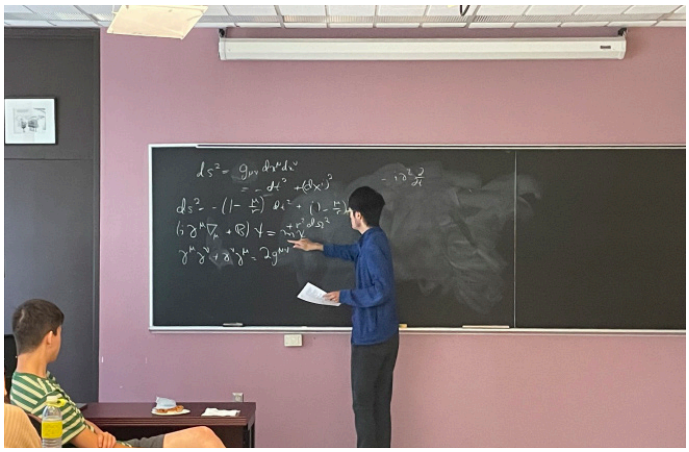
Planet Lunch brings together researchers from the Earth & Planetary Sciences, Atmospheric& Oceanic Sciences, and Physics for a weekly lunch discussion. The goal is to apply geology and planetary atmospheres expertise as studied in our Solar System to exoplanets, to achieve a better understanding of what we are learning from the much less detailed observational data on exoplanets. Experience derived from Solar System studies also guides the development of future astronomical facilities to study exoplanets. Each term, the group chooses a theme related to planetary science and each week someone leads a discussion about a paper or a topic related to that theme.

## Random Papers Discussion

The goal of Random Papers is to gain a broad view of current astrophysics research. Each week, a script chooses 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 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?

# TSI UNDERGRADUATE SUMMER RESEARCHER PROGRAM

Every summer since its inception, TSI has hosted an undergraduate summer research students from McGill and universities across the world. An integral part of the summer research experience at TSI is the TSI Summer Undergraduate Researcher Program, which consists of weekly professional development discussions and an end-of-the-summer Undergraduate Research Showcase. Due to the success of the program and the impact it makes on students, TSI was asked to expand the program to the entire Department of Physics in 2019, and we've hosted a joint summer program ever since. The program is open to all undergraduates conducting summer research with TSI-affiliated or Physics-affiliated professors. This year's edition of the program hosted over 70 undergraduate summer researchers, of which approximately 40 were working with TSI researchers. As activities slowly returned to being in person, this year's edition of the program was offered in a hybrid format. We were once again able to offer lunch during the weekly sessions, but we also offered a Zoom link to accommodate students doing research remotely.



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

## Professional Development Discussions & Workshops

A unique feature of the TSI summer undergraduate research program is a weekly discussion & workshop series. The format of these weekly meetings is a facilitated discussion, organized by TSI Program Admin Carolina Cruz-Vinaccia and Physics Undergraduate Advisor Kim Metera, in collaboration with TSI and Physics postdocs. The goal of these weekly meetings is twofold: 1) to provide guidance and mentorship for students at the earliest stage of their research careers: and 2) to foster a sense of community amongst the undergraduate summer researchers, allowing for interactions with peers outside their immediate research groups.

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 equity and inclusion in STEM. This year's program emphasized science communication, both to other scientists and to the public. Students had multiple opportunities to practice their oral communication skills, including 3 minute talks about their research, workshops on distilling the essence of their research to non-scientists, and 5-minute scientific showcasing the results of their summer research project. They

> ***"The most valuable part of the program was bringing together students who are conducting diverse research across the department. I got to know people that I otherwise wouldn't have interacted with, and speaking to people doing completely different things is very helpful when trying to orient our own interests."***


were also able to hone their writing skills through workshops on scientific writing, proposal writing, and drafting of CVs and cover letters.

After two years of virtual sessions, this year's sessions were able to return to an in-person format. Our undergraduates appreciated the opporutnity to interact with their peers face-to-face, and even used the Slack channel to organize social outings amongst themselves. Feedback gathered at the end of the summer overwhelmingly showed that the summer undergradutes appreciated the community-building aspect of the program, and felt like they had been able build stronger netwroks with their peers and with the postdocs and grad students who volunteered.

## Summer Undergraduate Research Showcase

We cap off the Summer Program with a Research Showcase, where undergraduate summer researchers present the results of their project to the entire TSI and Physics Department. This year's showcase took place in person over the course of an entire afternoon, though a Zoom option was available for those who wanted to present or attend remotely. There were four blocks of presentations, where a total of 30 undergraduates gave 5-min talks presenting their research. The audience was enthusiastic and interactive, asking more questions than we had time for! The showcase was followed by an outdoor reception, where presenters and audience members alike were able to celebrate a summer of hard work.

The undergraduate research projects covered a wide range of topics that reflected the diverse and interdisciplinary nature of the TSI. The presentations were evaluated by a panel of postdoc and graduate student judges, whose job was made difficult by the impressive quality of the presentations. Eight students received recognitions (including 5 TSI summer students): five students received Outstanding Presentation awards and an additional 3 received honourable mentions!

**Outstanding Presentations**

Michael Hetu
Yuliya Shpunarska
Mackenzie Pereira
Maya Goss
Philip Richard

**Honourable Mentions**

Sandhya Rottoo
Rawan Karam
Vincent Savignac

# EQUITY, DIVERSITY & INCLUSION

TSI is committed to equity, diversity, and inclusion (EDI) 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. We aim to build EDI into our activities as we develop them, taking advantage of the fact that we are still a young research institute. So far, we have focused on creating space for discussion of EDI and workplace climate issues, primarily through our weekly EDI discussion group (see below). We have also prioritized identifying and addressing areas of underrepresentation in the immediate TSI community.

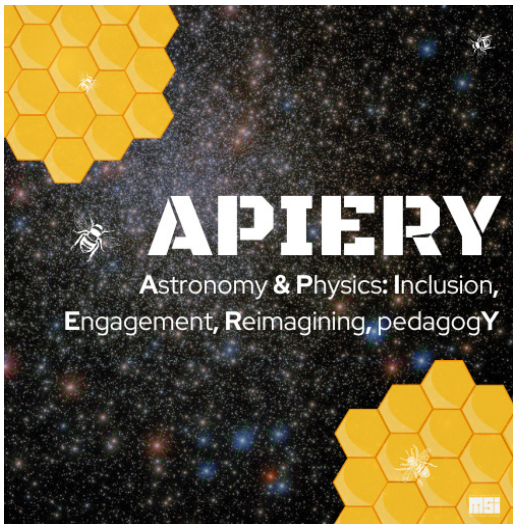
TSI collaborates on EDI related issues with similar groups both within and outside McGill. TSI works closely with the EDI Committee in the Physics Department and collaborates with the EDI Committee in Earth & Planetary Sciences. As of 2020, TSI has a seat on the Faculty of Science's Equity and Climate Committee (SECC), currently occupied by the MSI Coordinator. We also collaborate with the newly formed EDI Committee of the Center for research in astrophysics of Quebec (CRAQ).

The work we have put into our EDI efforts hasn't gone unnoticed. In May, our Coordinator, Carolina Cruz-Vinaccia, received McGIll's Equity and Community Building Award (Administrative and Support Staff category) for her work advancing equity and inclusion both for TSI and the McGill Physics community.

## EDI DIscussion Group: APIERY Discussion

APIERY Discussion (Astronomy/Physics Inclusion, Engagement, Reimagining pedagogY) is a weekly discussion group run by the TSI Program Admin that focuses on science engagement, education, and pedagogy, in order to make our astronomy and physics spaces and practice more inclusive. It is the successor the EPOD Discussion, which ran from 2016 to 2022. APIERY is open everybody at TSI and any of our member departments, regardless of position within the university or level of knowledge. While Astronomy and Physics are in the title, discussions also draw upon and are relevant to other areas of science education. Topic selection is a collective effort; at the beginning of each term, we run a brainstorming session where everyone is encouraged to suggest topics. TSI members are encouraged to suggest topics and lead the discussion if they so choose!

APIERY runs primarily like a journal club; the discussion is based on an academic paper (though other sources like blogs, podcasts, and YouTube videos may also be used.), but the paper is mainly a jumping-off point to discuss a broader topic. We also run APIERY Hack Sessions, where we agree on a collaborative project related to a topic we've previously discussed. Hack sessions are meant to help APIERY participants use the knowledge they've gained to produce something concrete and actionable, even if it's small.




McGill's EDI champions feted in style – and in person

*Thompson House hosts first in-person celebration of annual Award for Equity & Community Building in two years*

By Neale McDevitt, Editor, McGill Reporter

MAY 19, 2022

Comment on this article

A group photo of all the winners of a 2022 Award for Equity & Community Building — Andrea Clegg

## Identifying and Addressing Areas of Underrepresentation

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. We have made a particular effort to address under-representation at the post-doctoral level, implementing best practices during the application and evaluation process. The changes we implemented yielded results; for the past two years, over 50% of our incoming TSI postdoctoral fellows have been women. For the 2023 cycle, we are looking at how to do the same for racial diversity, particularly to address the lack of Black and Indigenous postdocs. There is still more work to be done and we are committed to continuing our efforts and ensuring that the environment we are recruiting into is inclusive.

## Building Relationships

Fostering equity requires building relationships with equity-oriented organizations within and outside McGill , particularly with those that serve marginalized groups in STEM. In Fall 2022, TSI connected with McGill's Branches Pick Your Path program, a mentorship program that links Black and Indigenous CEGEP students with McGill students who act as mentors. We have begun planning workshops for the mentors and mentees from the Indigenous stream of PYP, which will be deployed in 2023. We hope to offer similar programming to the Black students' stream of Pick Your Path in 2023. Similarly, we began collaborating n with Dell Technologies's Girls Who Game program and the Physics Department in early 2022 to develop Science in Space (page xx), a program aimed at creating inclusive spaces for girls and nonbinary students within STEM.

## Embedding EDI into TSI Outreach

One of the pillars of TSI's approach to EDI is to build it into our activities as we develop them. Starting in Fall 2022, we have started employing the principles of Inclusive Science Communication when developing new outreach activities, with a view to making our programming more inclusive. This has required being intentional about the audience we are trying to reach, collaborating with participants on assessing and adapting programs to fit their needs, and being mindful of the composition of our outreach team. We hope to be able to provide training for oinclusive science engagement to students inetrested in pursuing outreach and science communication, therefore expanding their skillsets and contributing to their broader education.

### A Glimpse into APIERY Discussion Topics: 2022

- 'Non-hierarchical education'
- 'Theories of change for higher education'
- ' Sci-fi & its potential for imagining radically different futures'
- ' Communities of practice in Physics/Astronomy Education'
- 'The influence of COVID-19 and remote learning's on social learning processes'
- 'Indigenous sovereignty and astronomy'
- 'Critical Race Theory & Feminist Standpoint Theory in Physics education'
- 'Setting the tone: clarifying concepts'
- 'Stereotype Threat and STEM'
- Addressing inequalities in the classroom
- 'Teaching About Racial Equity in Introductory Physics Courses'
- 'The effects of remote learning during COVID-19'
- Guest speaker: 'Settler Science and the Ethics of Contact'

SCIENCE IN SPACE

# 05 PEOPLE

## Awards

### Faculty Members

**Nicolas Cowan**
*Royal Society of Canada College of New Scholars*

**Natalya Gomez**
*Early Career Scientist Award from the International Union for Geodesy and Geophysics (IUGG)*

**Daryl Haggard**
*2022 CAP Herzberg Medal*
*Rutherford Memorial Medal in Physics, Royal Society of Canada*

**Vicky Kaspi**
*2022 Albert Einstein World Award of Science*

**Eve J. Lee**
*Annie Jump Cannon Award (American Astronomical Society*

### Postdoctoral Researchers

**Kristen Dage**
*Association of Postdoc Fellows Mentorship Award*

### Graduate Students

**Mohan Agrawal**
*EDI Scholarship - McGill Phyiscs Department*

**Bridget Andersen**
*FRQNT Doctoral Scholarship*

**Srobona Basak**
*MITACS Globalink Research Award*

**Matias Castro Tapias**
*McFee Scholarship - Department of Physics*

**Alice Curtin**
*Vanier Canada Graduate Scholarship*

**Hannah Fronenberg**
*FRQNT Doctoral Research Scholarship B2X*
*Mitacs Globalink Research Award*

**Amalia Karalis**
*NSERC CGS-M Scholarship*

**Mahesh Herath**
*Robert Wares Fellowship - McGill Earth & Planetary Sciences*

**Ketan Sand**
*Murata Family Scholarship - McGill Faculty of Science*

**Hugo Scherer**
*FRQNT Masters Scholarship*

**Vishwangi Shah**
*Kharusi Family International Science Fellowship - McGill Faculty of Science*

**Jared Splinter**
*John F. Prochnau Fellowship - McGill Earth & Planetary Sciences*

### Staff

**Carolina Cruz-Vinaccia**
*Equity & Community Building Award - McGill University*

# TSI DIRECTORY

## 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
Ken Ragan
Katelin Schutz
Jonathan Sievers
Tracy Webb
Lyle Whyte

## Associate Members

Oscar Hernandez
Richard Léveillé

## Staff

Carolina Cruz-Vinaccia

## Postdoctoral Researchers

Gonzalo Alonso-Alvarez
Arnab Chakraborty
Yayaati Chachan
Cherie Day
Kristen Dage
Adélie Gorce
Saniya Heeba
Mona Jalilvand
Ronniy Joseph
Vigneshwaran Krishnamurthy
Adam Lanman
Ryan McKinven
Jordan Mirocha
Raul Monsalve
Joshua Montgomery
Thomas Navarro
Giang Nguyen
Stephan O'Brien
Aaron Pearlman
Masoud Rafiei-Ravandi
Peter Sims
Amy Steele
Chia Min Tan
Bailey Tetarenko
Dallas Wulf
Maryam Yousefi
Fernando Zago

## Graduate Students

Michel Adamic
Mohan Agrawal
Soud Al Karusi
Avery Albert
Bridget Andersen
Srobona Basak
Lea Baumser
Mohit Bhardwaj
Vadim Bidula
Matteo Blamart
Olivia Blenner-Hasset
Louis-Jacques Bourdages
Hope Boyce
Nirmalya Brahma
Margaret Bruna
Christian Capanelli
Matias Castro Tapia
Rebecca Ceppas de Castro
Hoi-Man Kelvin Chan
Paul Chouha
Vincent Comeau
Alice Curtin
Caitlin Mackenzie Dewar
Amanda Di Nitto
Taylor Dibblee-Barkman
Aline Favero
Kelly Ann Foran
Nicole Ford
Hannah Fronenberg
Rafael Fuentes
Guillermo Gambini
Kit Gerodias
Erin Gibbons
Noah Goldman
Simon Guichandut
Aryana Haghjoo
Timothy Hallatt
Ian Hendricksen
Mahesh Herath
Lawrence Herman
Michael Jafs
Hao Jiao
Alexander Josephy
Zarif Kader
Amalia Karalis
Aditya Krishna Karigiri Madhusudhan
Zoe Kearney
Melisa Kozey
Samuel Laliberte
Benoit Laurent
Anan Lu
Matthew Lundy
Catherin Maggiori
Keza (Kevin) Marimbu
Lisa McBride
Francis McGee
Samuel McNichol
Meliss Mendes Silva
Marcus Merryfield
Keavin Moore
Karishma Moorthy
Brady O'Connor
Michael Pagano
Xinyu Pan
Robert Pascua
Matteo Puel
Syed Nayyer Raza
Jeremy Rothman
Maclean Rouble
Jean-Samuel Roux
Ketan Sand
Hugo Schérer
Vishwangi Shah
Jared Splinter
Nicolas Vieira
Jeannette Wan
Huiyi (Cheryl) Wang
Samantha Wong
Qing Hao Xu
Pamela Yaninska

## Undergraduate Students

Sara Babic
Hugo Joseph Baraër
Christopher Barbarie
Jöelle Bégin
Guilherme Caumo
Simon Chen
Benjamin Cheung
Maya Goss
Rawan Karam
Magnus L'argent
Marc-Olivier Lalonde
Arianna Lasinski
Ningyuan Li
Justin Brett Lipper
Wilfred Mason
Camryn Mullin
Varun Muralidharan
Sneha Nair
Marlon Josue Rivera Valladares
Sandhya Rottoo
Harper Clay Sewalls
Avinash Sookram
Jianing (Jenny) Su
Yifan Sun
Phillip Todd
Kyle Wong
Nicole Xu
Natalie Hardin
Maya Elizabeth Goss
Philip Richard
Vincent Savignac

# TSI FELLOWSHIPS

Trottier Space Institute Fellowships are made possible by a generous donation from the Trottier Family Foundation to support TSI postdoctoral researchers and graduate students.

## TSI Postdoctoral Fellows

TSI Postdoctoral Fellowships are awarded by a committee of faculty members who span different fields of TSI and recognize excellence in research.

**Yayaati Chaachan** ▪ *Physics* ▪ *Prof. Eve Lee's Group*

Dr. Chaachan has been a TSI fellow and CITA National Fellow since Fall 2022. He studies the processes that control the observed compositions of planetary atmospheres, how planets are assembled, and imprints of protoplanetary disk evolution and formation processes on planet demographics, using observational, analytical, and numerical methods

**Ronniy Joseph** ▪ *Physics* ▪ *Prof. Jon Sievers's Group*

Dr. Joseph joined Prof. Slevers's group as a TSI Postdoctoral Fellow in Fall 2021. He works on the detection of faint ancient radio signals from the most distant parts of the Universe to understand formation of very first stars and the Universe itself.

**Arnab Chakraborty** ▪ *Physics* ▪ *Prof. Matt Dobbs's Group*

Dr. Chakraborty has been an MSI postdoctoral fellow since Fall 2021. He works on observational cosmology and trying to understand the distribution of baryons at large scales using the redshifted 21-cm signal of atomic hydrogen. He is also interested in radio instrumentation and data analysis of CHIME and the upcoming CHORD telescope.

**Aaron Pearlman** ▪ *Physics* ▪ *Prof.Vicky Kaspi's Group*

Dr. Pearlman has been a TSI postdoctoral fellow in Prof. Vicky Kaspi's group since Fall 2020. 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.

**Kristen Dage** ▪ *Physics* ▪ *Prof. Daryl Haggard's Groups*

Dr. Dage has been a TSI postdoctoral fellow since Fall 2020. She studies 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 and the nature of the clusters that host them.

**Peter Sims** ▪ *Physics* ▪ *ProfJon Sievers's Group*

Dr. Sims has been an MSI postdoctoral fellow since Fall 2020. He works on 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, and the extraction of astrophysical and cosmological information encoded in observations of said periods.

**Cherie Day** ▪ *Physics* ▪ *Prof. Cynthia Chiang's Group*

Dr. Day has been a TSI postdoctoral fellow since Winter 2022. She works with Prof. Cynthia Chiang on instrumentation for experimental cosmology.

**Amy Steele** ▪ *Physics* ▪ *ProfJon Sievers's Group*

Dr. Steele has been an MSI Postdoctoral Fellow since Summer 2021. She studies circumstellar gas and dust, with a focus on using dead planetary systems to probe the composition of exoplanets.

**Saniya Heeba** ▪ *Physics* ▪ *Prof. Katelin Schutz's Group*

Dr. Saniya Heeba has been an MSI Postdoctoral Fellow since Fall 2021. She studies dark matter at the intersection of particle physics and cosmology. Broadly, that includes how dark matter is produced in the early universe, how it evolves, and how it can be probed using terrestrial and cosmological search strategies.

**Bailey Tetarenko** ▪ *Physics* ▪ *Prof. Daryl Haggard's Group*

Dr. Tetarenko has been a TSI Postdoctoral Fellow since Fall 2022. She focuses on the study of the physical processes governing astrophysical accretion discs in compact binary systems in our Galaxy.

# TSI Graduate Fellows (Incoming)

Recognizing the high calibre of our graduate students; every new MSc or PhD student supervised by a TSI faculty member receives a fellowship and the title of TSI Graduate Fellow. As a result, all TSI graduate students receive a portion of their funding from the Trottier Family Foundation's gift. Our incoming 2022 TSI Graduate Fellows are featured below

**Michel Adamic**
*Supervisor:* Matt Dobbs
Department of Physics

**Srobona Basak**
*Supervisor:* Jim Cline
Department of Physics

**Matteo Blamart**
*Supervisor:* Robert Brandenberger
Department of Physics

**Christian Capanelli**
*Supervisor:* Katelin Schutz
Department of Physics

**Matias Castro Tapias**
*Supervisor:* Andrew Cumming
Department of Physics

**Rebecca Cepas de Castro**
*Supervisor:* Adrian Liu
Department of Physics

**Caitlin Dewar**
*Supervisor:* Jim Cline
Department of Physics

**Michael Jafs**
*Supervisor:* Jim Cline & Jon Sievers
Department of Physics

**Amalia Karalis**
*Supervisor:* Eve Lee
Department of Physics

**Aditya Karigiri**
*Supervisor:* Eve Lee
Department of Physics

**Melisa Kozey**
*Supervisor:* Lyle Whyte
Department of Natural Resource Sciences

**Nayyer Raza**
*Supervisor:* Daryl Haggard
Department of Physics

**Hugo Scherer**
*Supervisor:* Katelin Schutz
Department of Physics

**Samatha Wong**
*Supervisor:* Ken Ragan
Department of Physics

**Not pictured:**

- Kelvin Chan (Physics)
- Taylor Diblee-Barkman (Physics)
- Kevin Marimbu (Physics)
- Francis McGee (Physics)

# TSI SUMMER UNDERGRADUATE RESEARCH AWARDS

TSI Summer Undergraduate Research Awards (TSI SURAs), established in 2021, fund excellent undergraduate students interested in pursuing research with TSI faculty members. The program's acts as a financial complement to our existing Summer Undergraduate Research Program and aims to make more opportunities for summer research accessible, existing alongside other McGill summer undergraduate fellowship programs (NSERC USRA & McGill SURA). TSI Summer Undergraduate Research Awards are valued at $3500, which is supplemented by the supervisor's funds to provide a stipend of approximately $7000 for the whole summer. Applications are open to students pursuing an undergraduate degree in relevant fields at any Canadian university, at any point in their programs. In recognition of the growing importance of having access to research opportunities, we actively encourage applications from students in the early stages of their program.

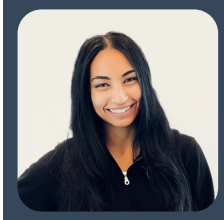
The evaluation process was designed with TSI's commitment to equity, diversity, and inclusion in mind. Applications are evaluated by the TSI Summer Undergraduate Award Committee, which is composed of postdoctoral researchers and the TSI Program Admin (see page xx). The evaluation rubric developed by the committee was made publicly available on our website during the application process, to ensure that applicants were aware of the evaluation criteria. During the deliberation process, the committee took care to ensure that there was a diversity of interests, research fields, and background represented on the short list of candidates.

In this second year of the program, we received over 100 applicants from universities across Canada. The quality of the applicant pool was impressive, making the committee's job quite difficult! In the end we awarded 6 TSI SURAs, all of which were accepted. The 2022 cohort of awardees spans the breadth of research areas at TSI, with students working on everything from black holes to building instrumentation to microbial assays. You can learn more about our seond cohort and their experiences with the program, in their own words, below.

**Christopher Barbarie** ▪ *McGill University* ▪ *Prof. Cynthia Chiang*

**Project:** *"Drone Based Calibration for the ALBA-TROSS Experiment"*
I had the opportunity to source and purchase components for a hexacopter. I then built the drone and had got to test it out in the field at the Uapishka field station. The part I liked most was having the opportunity to do field work!

**Rawan Karam** ▪ *McGill University* ▪ *Prof. Daryl Haggard*



**Project:** *"Monitoring Observations of SMC X-1's Excursions"*
Supervised by Professor Daryl Haggard and Dr Kristen Dage, we investigated the unusual geometry behind SMC X-1's accretion disk. We fit over 30 NASA/NICER X-ray observations of SMC X-1 using XSPEC, spanning different states of the system! As part of the MOOSE collaboration, I have had the opportunity to collaborate with astronomers from all over the world and build meaningful connections. This is something I would not have been able to do so early on, without the TSI fellowship!

**Not Pictured:**

**Nicole Xu** ▪ *McGill University* ▪ *Prof. Tracy Webb*

**Arianna Lasinski** ▪ *University of Toronto* ▪ *Prof. Jon Sievers*

**Kyle Wong ▪ University of Toronto ▪ Prof.Adrian Liu**

**Project:** *"Improving the data pipeline for the HERA radio telescope",*
I attempted to improve the statistical estimator used in the processing of data measured by the HERA radio telescope. The end result of the data analysis is a statistical characterisation of hydrogen found in the intergalactic medium during the epoch of reionization in the early universe. n addition to learning plenty about physics, astronomy, and statistics, I was able to interact with researchers even in non-academic settings, which allowed me to get a better idea of the way they think.

**Wilfred Mason** ▪ *McGill University* ▪ *Prof. Lyle Whyte*


*Project: "Automation of a microfluidic biosignature detection device"*
The goal was to automate a microbial, life-detection system ( MAMA) developed by Whyte Lab students. The automation platform consisted of a robotic assembly which collected a sample from an ice drill, a heating system to melt the sample, a fluidics circuit to distribute the sample, and an imaging module which used computer vision to detect color changes occurring in the wells of the MAMA. The automated detection platform (excluding the imaging system) was successfully deployed on an expedition to the Canadian High Arctic in July 2022. My favourite part was the opportunity to talk to students from different backgrounds from my own, to share ideas and collaborate on a multi-disciplinary project.

# TSI BOARD & COMMITTEES

## TSI Board 2022

### 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 ▪ *TSI Director; Professor, Physics*

Ken Ragan ▪ *TSI Associate Director ; Professor, Physics*

Matt Dobbs ▪ *Professor, Physics*

Robert Brandenberger ▪ *Professor, Physics*

Nagissa Mahmoudi ▪ *Assistant Professor. Earth & Planetary Sciences*

Catherine Maggiori ▪ *PhD Student, Natural Resource Science*

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Adrian Liu [Chair] ▪ *Assistant Professor, Physics*

Robert Brandenberger ▪ *Professor, Physics*

Nagissa Mahmoudi ▪ *Assistant Professor, Earth & Planetary Sciences*

Ken Ragan ▪ *Professor, Physics*

Jonathan Sievers ▪ *Associate Professor, Physics*

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Miguel Angel Fernandez ▪ *Postdoctoral Fellow, NRS*

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Amy Steele ▪ *Postdoctoral Fellow, Physics*

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## Undergraduate Summer Awards Committee

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## Outreach Steering Committee

Daryl Haggard ▪ *Associate Professor, Physics*

Nicole Ford ▪ *MSc Student, Physics*

Hannah Fronenberg ▪ *PhD Student, Physics*

Simon Guichandut ▪ *PhD Student, Physics*

Carolina Cruz-Vinaccia ▪ *TSI Program Administrator*

# 06
# IMPACT

## FACILITIES USED BY TSI 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

**Narval supercomputer**
*(Haggard)*
Owned and administered by Compute Canada and Calcul Quebec

### Ground-based Telescopes

**Anglo-Australian Telescope**
*(Webb)*

**Atacama Large Millimeter Array**
*(Haggard, Webb)*

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

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

**CHORD The Canadian Hydrogen Observatory and Radio transient Detector**
*(Chiang, Dobbs, Kaspi, Liu, Sievers)*

**Event Horizon Telescope Array**
*(Haggard)*

**European Southern Observatory: La Silla 3.6 m Telescope**
*(Cowan)*

**Gemini Observatory**
*(Cowan, Haggard, Webb)*

**Green Bank Telescope, Radio wavelengths**
*(Kaspi)*

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

**The Hydrogen Epoch of Reionization Array (HERA)**
*(Liu, Sievers)*

**James Clerk Maxwell Telescope**
*(Haggard)*

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

**Large Millimeter Telescope Alfonso Serrano**
*(Webb)*

**Observatoire du Mont-Mégantic**
*(Cowan)*

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

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

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

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

**W.M. Keck Observatory**
*(Haggard, Webb)*

**VERITAS Gamma-ray Observatory**
*(Hanna, Ragan)*

## Space-based Telescopes

**NASA/James Webb Space Telescope**
*(Cowan, Haggard)*

**NASA/Hubble Space Telescope**
*(Cowan, Haggard, Lee, Webb)*

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

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

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

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

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

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

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

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

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

# FACULTY COLLABORATIONS

**Ariel - ESA's M4 mission ▪ *[Cowan]***
**Other participating countries:** UK | France | Italy | Poland | Belgium | Spain | the Netherlands | Austria | Denmark | Ireland | Norway | Sweden | Czech Republic | Hungary | Portugal | Germany | Estonia

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

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

**CSA's 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 ▪ *(Dobbs, Kaspi)***
**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

**CHORD The Canadian Hydrogen Observatory and Radio transient Detector ▪ *(Chiang, Dobbs, Kaspi, Liu, Sievers)***
**Other participating institutions:** University of British Columbia | University of Calgary | Italian National Institute for Astrophysics (INAF) | MIT | NRC Dominion Radio Astrophysical Observatory | Queen's University | Royal Military College of Canada | University of Toronto | Perimeter Institute | West Virginia university |

**CSA's 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

**Event Horizon Telescope (EHT) 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

**Next Generation EHT Collaboration ▪ *(Haggard)***
**Other participating institutions:** Center for Astrophysics | Harvard & Smithsonian | Black Hole Initiative | MIT Haystack Observatory | National Astronomical Observatory of Japan | California Institute of Technology | Perimeter Institute for Theoretical Physics | University of Waterloo | Waterloo Centre for Astrophysics | Niels Bohr International Academy | Instituto Superior Técnico Portugal | University of Oxford | University of Cape Town | Universität Würzburg | Goethe Universität | Max-Planck-Institut für Radioastronomie | Harvard University | Instituto de Astrofísica de Andalucía-CSIC | Purdue University | University of Amsterdam | Gravitation and Astroparticle Physics Amsterdam (GRAPPA) Institute | Yale University | Princeton University | University College London | Princeton Gravity Initiative | University of Bonn | The University of Western Australia | Lebedev Physical Institute of the Russian Academy of Sciences | Moscow Institute of Physics and Technology | INAF-Istituto di Radioastronomia | University of Cambridge | Utrecht University | Universidad de Concepción | CSIRO Astronomy and Space Science | Observatorio Astronómico Nacional | Radboud University | Stanford University

**GBNCC: 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

**HERA - The Hydrogen Epoch of Reionization Array ▪ *(Liu, Sievers)***
**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 | Raman Research Institute | 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

**Laser Interferometer Space Antenna (LISA) Consortium (ESA L3 mission) ▪ *(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

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

**NASA's Survey and Time-domain Astrophysical Research eXplorer (STAR-X) ▪ *(Haggard)***
**Other participating institutions:** Howard University | Johns Hopkins | Max Planck Institute for extraterrestrial Physics | MIT Kavli Institute for Astrophysics and Space Research | NASA Goddard Space Flight Center | National Institute for Astrophysics - Astrophysics and Space Science Observatory of Bologna | Northwestern University | Pennsylvania State University | Space Science Data Center - Agenzia Spaziale Italiana | University of Bologna | University of California Berkeley | University of California Santa Cruz | University of Colorado Boulder | University of Crete | University of Maryland Baltimore County | University of Toronto | University of Utah | Wayne State University

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

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

**PALFA Pulsar Arecibo L-Band Feed Array survey ▪ *(Kaspi)***
**Other participating institutions:** Albert Einstein Institute | ASTRON | Columbia University | Cornell University | Franklin and Marshall College | Jodrell Bank Center for Astrophysics | Lafayette College |Max-Planck-Institut für Radioastronomie | National Radio Astronomy Observatory | National Radio Astronomy Observatory | Naval Research Laboratory | University of British Columbia | University of East Anglia| University of New Mexico | University of Texas at Brownsville | University of Wisconsin - Milwaukee | West Virginia University

**POLARBEAR ▪ *(Dobbs)***
**Other participating institutions:** Cardiff University | Imperial College | KEK, High Energy Accelerator Research Organization | Lawrence Berkeley National Lab | Paris Diderot University | University of California, Berkeley | University of California, San Diego | University of Colorado, 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 ▪ *(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-Institut 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, Urbana-Champaign

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

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

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