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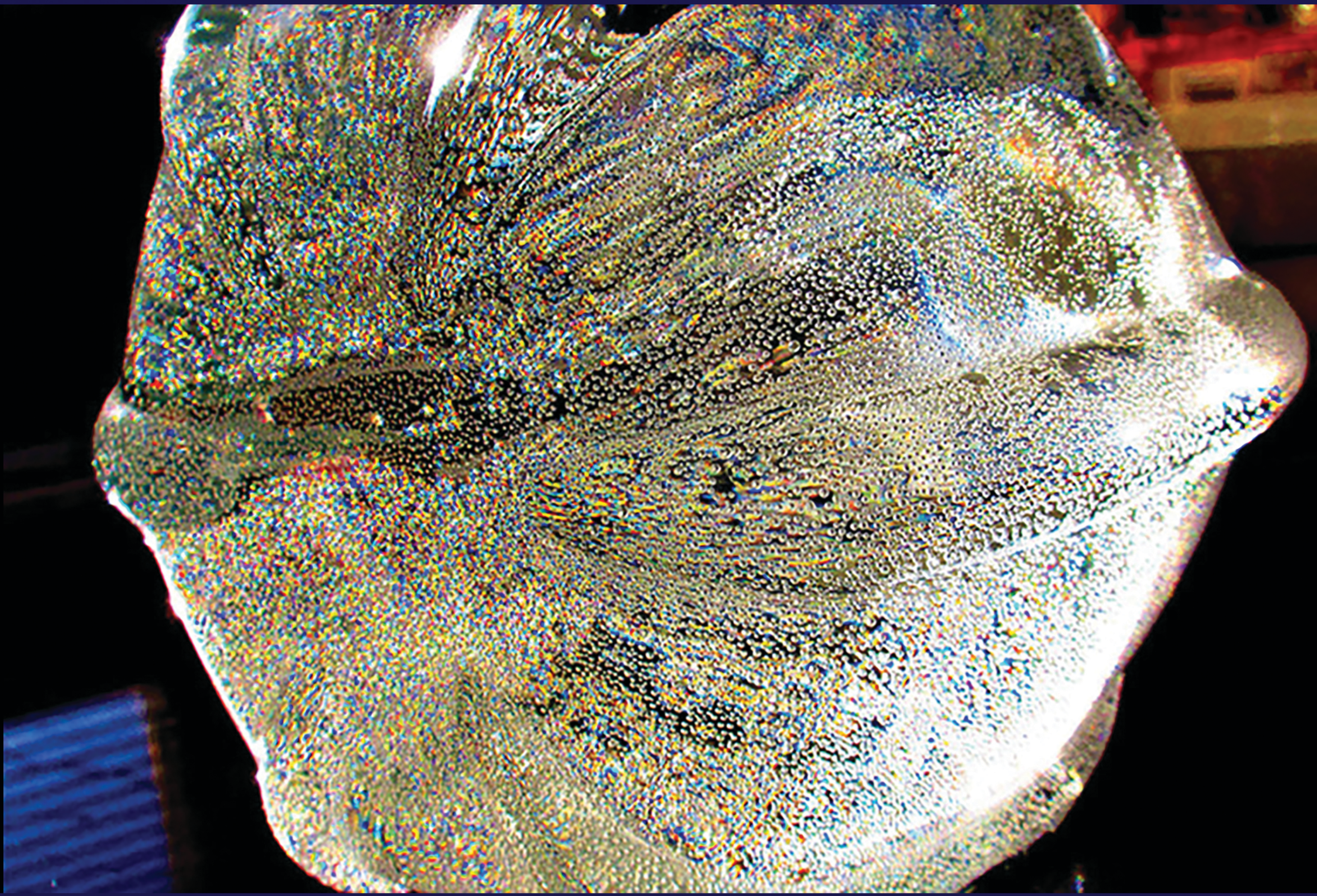
Physics in Canada
La Physique au Canada



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Featuring / En vedette :

Feature articles, 2024 Recognitions/Student Prizes, 2023 PhDs awarded, Conference Reports and EPhO

Articles de fond, 2024 Reconnaissances/Prix étudiant(e)s, 2023 Doctorats décernés, Rapports de conférences et EPhO

Canadian Association of Physicists / Association canadienne des physiciens et physiciennes

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FRONT COVER IMAGE / IMAGE DE COUVERTURE

Rainbow in a Jar

This photograph displays a jar of water under the sun. The container was first filled with cold tap water as it allows more gas to dissolve. The container is then left at room temperature for a day, allowing the water to warm up and release gas, creating what we see as bubbles. Sunlight is a mixture of light with different wavelengths, and as light travels through various mediums of different refractive indices, the rays bend. The angle of bending varies for different wavelengths of light creating the rainbow colours. The sun rays first refracted into the glass, then into the water, the air in the bubbles, back into the water, the glass, out into the air, and lastly to the camera. This image captures a complex case of refraction and showcases the beauty of natural light.

by **Gracie Zhang**
Victoria Park Collegiate Institute, Toronto, ON
2019 Art of Physics Competition
1st Place - High School/CEGEP Individual Category

Arc-en-ciel dans un bocal

Cette photographie montre un bocal rempli d'eau sous le soleil. Le réservoir a d'abord été rempli d'eau froide du robinet, car celle-ci permet de dissoudre davantage de gaz. Le réservoir a ensuite été laissé à température ambiante pendant une journée, afin que l'eau se réchauffe et libère du gaz, créant ainsi ce que nous voyons comme des bulles. La lumière du soleil est un mélange de lumière de différentes longueurs d'onde, et lorsque la lumière traverse différents milieux ayant des indices de réfraction différents, les rayons se courbent. L'angle de courbure varie en fonction des différentes longueurs d'onde de la lumière, créant ainsi les couleurs de l'arc-en-ciel. Les rayons du soleil sont d'abord réfractés dans le verre, puis dans l'eau, dans l'air contenu dans les bulles, puis de nouveau dans l'eau, dans le verre, dans l'air et enfin vers l'appareil photo. Cette image capture un cas complexe de réfraction et met en valeur la beauté de la lumière naturelle.

par **Gracie Zhang**
Victoria Park Collegiate Institute, Toronto, ON
Concours de l'Art de la physique 2019
Première prix - Catégorie individuelle des écoles secondaires et des cégeps

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Canadian Association of Physicists (CAP)
Association canadienne des physiciens et physiciennes (ACP)

The Canadian Association of Physicists was founded in 1945 as a non-profit association representing the interests of Canadian physicists. The CAP is a broadly-based national network of physicists working in Canadian educational, industrial, and research settings. We are a strong and effective advocacy group for support of, and excellence in, physics research and education. We represent the voice of Canadian physicists to government, granting agencies, and many international scientific societies. We are an enthusiastic sponsor of events and activities promoting Canadian physics and physicists, including the CAP's annual congress and national physics journal. We are proud to offer and continually enhance our web site as a key resource for individuals pursuing careers in physics and physics education. Details of the many activities of the Association can be found at http://www.cap.ca. Membership application forms are also available in the membership section of that website.

L'Association canadienne des physiciens et physiciennes a été fondée en 1946 comme une association à but non-lucratif représentant les intérêts des physicien(ne)s canadien(ne)s. L'ACP est un vaste regroupement de physiciens et de physiciennes oeuvrant dans les milieux canadiens de l'éducation, de l'industrie et de la recherche. Nous constituons un groupe de pression solide et efficace, ayant pour objectif le soutien de la recherche et de l'éducation en physique, et leur excellence. Nous sommes le porte-parole des physicien(ne)s canadien(ne)s auprès du gouvernement, des organismes subventionnaires et auprès de plusieurs sociétés scientifiques internationales. Nous nous faisons le promoteur enthousiaste d'événements et d'activités mettant à l'avant-scène la physique et les physicien(ne)s canadien(ne)s, en particulier le congrès annuel et la revue de l'Association. Nous sommes fiers d'offrir et de développer continuellement notre site Web pour en faire une ressource clé pour ceux qui poursuivent leur carrière en physique et dans l'enseignement de la physique. Vous pouvez trouver les renseignements concernant les nombreuses activités de l'ACP à http://www.cap.ca. Les formulaires d'adhésion sont aussi disponibles dans la rubrique « Adhésion » sur ce site.

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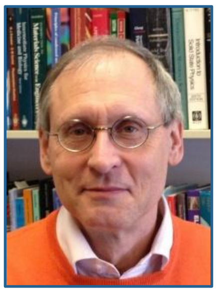
The Editorial Board welcomes articles from readers suitable for, and understandable to, any practising or student physicist. Review papers and contributions of general interest of up to four journal pages in length are particularly welcome. Suggestions for theme topics and guest editors are also welcome and should be sent to the Editor-in-Chief, Béla Joós, at bjoos@uottawa.ca.

Le comité de rédaction invite les lecteurs à soumettre des articles qui intéresseraient et seraient compris par tout physicien, ou physicienne, et étudiant ou étudiante en physique. Les articles de synthèse d'une longueur d'au plus quatre pages de revue sont en particular bienvenus. Des suggestions de sujets pour des revues à thème sont aussi bienvenues et peuvent être envoyées à la Redacteur-en-chef, Béla Joós, à bjoos@uottawa.ca.

CANADIAN UNIVERSITIES FACE A FINANCIAL STORM AND CHALLENGING TIMES

Béla Joós, Editor-in-Chief, *Physics in Canada*



Universities and colleges provide higher education, the path to economic productivity and innovation, not to mention an educated class necessary to maintain a functioning democracy, but these institutions of higher learning are under threat in Canada due to underfunding. The situation in each province is a little different, but the trends are national and particularly acute in Ontario, location of my institution. In 2019, Ontario enacted a 10% tuition fee reduction and a freeze for subsequent years. With inflation, this amounts now to a yearly cut of close to 30% to the revenues generated by tuition fees [1]. This has forced institutions to look for funding elsewhere.

Canadian universities have been quite resourceful in accomplishing this [1,2]. One strategy, whose importance grew dramatically over the last few years, was to increase revenues from the tuition fees of international students, which over a few years increased several fold, in some institutions even at the MSc level. Five years ago we could afford to support international MSc students from our grants by paying a top up to cover the difference between domestic and international fees. Now that the international fees are about four times larger than the domestic fees this is no longer realistic. Universities created professional and general course-based MSc programs targetting international students who had the means. These students saw this as a way to gain permanent residency. Not only were they adding a Canadian degree to their cv, but the visa came with a three year work permit post-graduation, which nearly guaranteed permanent residency.

The reliance on international tuition fees accelerated over the last few years along with Canada's aggressive immigration program, which involved not only international student visas but a Temporary Foreign Worker (TFW) program which grew rapidly and made it easy for employers to recruit TFWs, whether or not Canadian or permanent residents were available. If we step nowadays into a franchised food chain restaurant we will likely be served by a TFW. The private sector took advantage of the ease of access to the program to recruit massively abroad. Colleges embraced the strategy even more aggressively than universities. They teamed up with private sector partners to create programs which maximized revenues from international students, often with minimal costs. The massive influx of international students and workers created a housing crisis, which by many accounts was largely an Ontario College problem [3]. This led to a dramatic day of reckoning. Suddenly both programs were considered to have gotten out of hand. The intentions were good. Canada does need a large immigration program to sustain its growth, with its many opportunities and resources and low birth rate. But the execution and oversight of the massive immigration program were poor. The dramatic reduction in international student visas (a 35% cut in 2024, and a further 10% cut in 2025 and again in 2026 [3]) has led to a national financial crisis in universities [3,4]. In Ontario alone, the Council of Ontario Universities expects its members to experience a combined loss of $300M this fiscal year and $600M in the upcoming fiscal year according to its president, Steve Orsini [4].

The reaction sent shockwaves through the international community and statements from the government were interpreted to mean that Canada was no longer welcoming international students. Applications for admission are expected to decrease. Colleges in Ontario have announced massive cuts in programs. They expect a 70% drop in enrolment. There was abuse of the system in any case. A simple indicator was the percentage of accepted applicants who never showed up to register in their program, estimated to be a quarter [5]. Universities on the other hand are trying to cope with large deficits but have not so far announced major cuts. Universities cannot cut programs as easily as colleges [3], but the situation is evolving rapidly. McGill University in Montreal is facing its own challenges following the province's new tuition fee policies and has recently announced major cuts [6]. Quotas of study visas are now allocated to provinces who then distribute them to colleges and universities as Provincial Attestation Letters (PAL). These in turn allocate them internally according to their priorities. To apply for a visa, an applicant to a university program needs now a PAL. Physics graduate programs rely on international graduate students to ensure our research programs progress well. Our undergraduate physics and related programs do not graduate enough eligible or interested students to fill all available graduate research positions. These PALs are therefore important to our graduate programs. Those graduates provide valuable skills to the Canadian economy. We worried a few months ago whether we would get enough PALs or even enough applicants in view of the political climate. It seems that there will be enough PALs to give in 2025, but with Canada's public relations problem, it is not clear how many applications will be submitted to Canadian institutions. In addition, one of the incentives to come and study in Canada was the guarantee of a 3-year work permit after graduation. The federal government has narrowed the number of programs whose graduates receive these work permits (in particular, in colleges), removing a major incentive to come to study in Canada [3,7].

What does the future hold for universities? In the short term, deficits will persist. Upcoming cuts in international student visas of 10% per year for colleges and universities in 2025 and 2026 will not help. There is no immediate solution to the deficit problem. Colleges have made deep cuts to their programs, but a lot of the recent growth was artificial. Universities are trimming their budgets at the expense of the quality of education. The most valuable programs to society in colleges and universities are costly. Technical programs often require expensive equipment and can only be delivered to small cohorts. Definitely, not all training can be carried out in large auditoriums. Science and Engineering require laboratory training. Administrators in colleges and universities may have to prioritize low cost programs [3]. Universities with strong research programs will actively try to protect them because they are supported by significant grants, mainly federal, and they are the foundations of their prestige and international ranking, but they will have to do it in an administrative environment that is divided in its priorities.

Underfunding is a chronic problem which is becoming more acute [1,3]. There isn't the political will to increase funding in the higher education sector. Electors like low tuition fees. Elected officials respond to political pressure but there is little grassroot pressure to increase university funding, as evidenced by the near absence of this issue in election campaign rhetorics. Inadequate funding will have a long term impact on the quality and type of education Canadian youths will receive. We have achieved a high degree of excellence in Canada as measured simply by the recent number of Nobel prizes awarded to Canadians, in particular in physics. But some in the electorate do not see university research as critical in ensuring economic growth. Universities and colleges face headwinds and have to fight back in order to be once again part of the priorities of our society and governments.

The future of higher education will remain bleak until our governments and the people realize that our prosperity relies on proper funding of higher education [1,3]. We must provide economic arguments. Start-ups happen here and international firms locate here because we graduate students who have mastered leading-edge techniques of science and technology. Our most valuable assets are our graduates. As the dust settles on the international student visa crisis and the TFW program, it may be time to remember the economic benefits of foreign students receiving postgraduate degrees in our universities. Their contributions have been overshadowed by the questionable activities occurring in many colleges [8]. Parents send their children to colleges and universities to have a better life, and they should value the quality of the education they receive. We should make those parents understand that they elect governments. It is their responsibility to ensure that our governments provide enough financial resources to ensure that our universities remain world-class. Funding comes as a mix of provincial grants, federal grants, tuition fees, and increasingly philanthropic donations. The freezing of domestic tuition fees in Ontario since 2019 has been very damaging to Ontario institutions of higher learning, as they are not compensated by increased provincial grants. Colleges are speaking up [9], but they lost credibility by monetizing the easy availability of international student visas. Universities will need to speak louder.

Countries such as Germany have found that it makes good economic sense to have FREE tuition at universities, along with high standards for admission. We should make sure that our representatives understand the economic consequences of their inaction.

This is a rapidly evolving story. We can only hope that the turmoil will make our country realize what is at stake and make the right decisions to ensure a prosperous future for Canada.

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Editor-in Chief, *Physics in Canada*

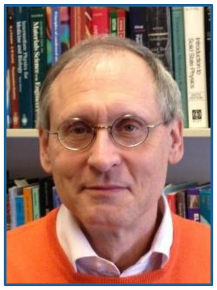
Béla Joós is a Professor of Physics at the University of Ottawa. He has been a member of the Editorial Board of *Physics in Canada* since January 1985 and took over as Editor in June 2006.

REFERENCES

1. Dan Breznitz, “We don’t need no education: How Canada’s broken university system holds us back”, The Globe and Mail, October 4 (2024).
2. Statistics Canada. Table 27-10-0363-01 Sources of funds for expenditures on research and development (R&D) in the higher education sector. October 22 (2024). **DOI:** https://doi.org/10.25318/2710036301-eng
3. Jayme Poisson and Alex Usher, “The crisis facing Canada’s colleges and universities – Transcript”, CBC Front Burner Transcript, December 3 (2024).
4. Global News, La Presse, “Universities face “across the board” cuts one year after federal study permits reduction”, January 21 (2025).
5. Youjin Choi and Feng Hou, “Characteristics of postsecondary international students who did not enrol in publicly funded postsecondary education programs”, Statistics Canada, November (2023). **DOI:** https://doi.org/10.25318/36280001202301100001-eng
6. “McGill University planning to cut budget by $45M, slash up to 500 jobs”, CBC News February 10 (2025). https://www.cbc.ca/news/canada/montreal/mcgill-45-million-budget-cut-1.7455165
7. Joe Friesen, “International student visa applications in Ontario will drop in 2025, province says”, The Globe and Mail, February 7 (2025).
8. Christopher Worswick, “We should consider the economic benefits of foreign students again to counter the effects of U.S. tariffs”, The Globe and Mail, February 25 (2025).
9. Joe Friesen, “As election nears, Ontario colleges sound alarm on financial impact of foreign - student shorfall”, The Globe and Mail, January 23 (2025).

Les universités canadiennes sont confrontées à une tempête financière et à une période difficile

Béla Joós, rédacteur en chef, *La Physique au Canada*



Les universités et les collèges dispensent un enseignement supérieur, voie vers la productivité économique et l'innovation, sans parler d'une classe éduquée nécessaire au maintien d'une démocratie fonctionnelle, mais ces établissements d'enseignement supérieur sont menacés au Canada en raison de leur sous-financement. La situation est légèrement différente d'une province à l'autre, mais les tendances sont nationales et particulièrement aiguës en Ontario, où se trouve mon établissement. L'Ontario a adopté en 2019 une réduction de 10 % des frais de scolarité et un gel pour les années suivantes. Compte tenu de l'inflation, cela équivaut maintenant à une réduction annuelle de près de 30 % des revenus générés par les frais de scolarité [1]. Cette situation a contraint les établissements à chercher des financements ailleurs.

Les universités canadiennes ont fait preuve de beaucoup d'ingéniosité pour y parvenir [1,2]. Une stratégie, dont l'importance s'est considérablement accrue au cours des dernières années, a consisté à augmenter les revenus provenant des frais de scolarité des étudiants internationaux, qui ont été augmentés de plusieurs fois en l'espace de quelques années, dans certains établissements, même au niveau de la maîtrise. Il y a cinq ans, nous pouvions nous permettre de soutenir les étudiants internationaux en maîtrise à l'aide de nos subventions en versant un complément pour couvrir la différence entre les frais nationaux et internationaux. Aujourd'hui, ce n'est plus réaliste car les frais internationaux sont environ quatre fois plus élevés que les frais nationaux,. Les universités ont créé des programmes de maîtrise en sciences professionnelles et générales ciblant les étudiants internationaux qui en avaient les moyens. Ces étudiants y voyaient un moyen d'obtenir la résidence permanente. Non seulement ils ajoutaient un diplôme canadien à leur CV, mais le visa était assorti d'un permis de travail de trois ans après l'obtention du diplôme, ce qui garantissait presque la résidence permanente.

La dépendance sur les frais de scolarité internationaux s'est accélérée au cours des dernières années, parallèlement au programme d'immigration agressif du Canada, qui comprenait non seulement des visas d'étudiants internationaux, mais aussi un programme de travailleurs étrangers temporaires (TET) qui s'est développé rapidement et a permis aux employeurs de recruter facilement des TET, que des résidents canadiens ou permanents soient disponibles ou non. Aujourd'hui, si nous entrons dans un restaurant d'une chaîne alimentaire franchisée, nous serons probablement servis par un TET. Le secteur

Le contenu de ce journal, y compris les opinions exprimées ci-dessus, ne représente pas nécessairement les opinions ou les politiques de l'Association canadienne des physiciens et physiciennes.

Les commentaires des lecteurs sur cet éditorial sont les bienvenus.

privé a profité de la facilité d'accès au programme pour recruter massivement à l'étranger. Les collèges ont adopté cette stratégie de manière encore plus agressive que les universités. Ils se sont associés à des partenaires du secteur privé pour créer des programmes qui maximisaient les revenus provenant des étudiants étrangers, souvent avec des coûts minimes. L'afflux massif d'étudiants et de travailleurs étrangers a provoqué une crise du logement qui, de l'avis général, était en grande partie un problème des collèges de l'Ontario [3]. Cette situation a donné lieu à un jour de bilan dramatique. Soudain, les deux programmes ont été considérés comme hors de contrôle. Les intentions étaient bonnes. Le Canada a besoin d'un vaste programme d'immigration pour soutenir sa croissance, compte tenu de ses nombreuses opportunités et ressources et de son faible taux de natalité. Mais l'exécution et la supervision de ce programme d'immigration massif ont été médiocres. La réduction considérable du nombre de visas pour les étudiants étrangers (35 % en 2024, puis 10 % en 2025 et à nouveau un autre 10% en 2026 [3]) a entraîné une crise financière nationale dans les universités [3,4]. Rien qu'en Ontario, le Conseil des universités de l'Ontario s'attend à ce que ses membres subissent une perte combinée de 300 millions de dollars pour l'exercice en cours et de 600 millions de dollars pour l'exercice à venir, selon son président, Steve Orsini [4].

Cette réaction a provoqué une onde de choc au sein de la communauté internationale et les déclarations du gouvernement ont été interprétées comme signifiant que le Canada n'accueillait plus d'étudiants étrangers. Les demandes d'admission devraient diminuer. Les collèges de l'Ontario ont annoncé des réductions massives de leurs programmes. Ils s'attendent à une baisse de 70 % des inscriptions. En tout état de cause, il y a eu des abus. Un indicateur simple est le pourcentage de candidats acceptés qui ne se sont jamais présentés pour s'inscrire à leur programme, estimé à un quart [5]. Les universités, quant à elles, tentent de faire face à d'importants déficits, mais n'ont pas encore annoncé de réductions majeures. Les universités ne peuvent pas supprimer des programmes aussi facilement que les collèges [3], mais la situation évolue rapidement. L'université McGill de Montréal est confrontée à ses propres défis suite aux nouvelles politiques de frais de scolarité de la province et a récemment annoncé des coupures importantes [6]. Les quotas de visas d'études sont désormais attribués aux provinces, qui les distribuent ensuite aux collèges et aux universités sous la forme de lettres d'attestation provinciales (LAP). Celles-ci les attribuent à leur tour à l'interne d'après leurs priorités. Pour demander un visa, un candidat à un programme universitaire a désormais besoin d'une LAP. Les programmes d'études supérieures en physique s'appuient sur des étudiants étrangers pour assurer la bonne marche de nos programmes de recherche. Nos programmes de physique de premier cycle et nos programmes connexes ne diplôment pas suffisamment d'étudiants admissibles ou intéressés pour combler tous les postes de recherche de deuxième cycle disponibles. Ces LAP sont donc importants pour nos programmes d'études supérieures et pour fournir la personnel hautement qualifié dont notre économie a besoin. Nous nous inquiétions il y a quelques mois si nous aurions assez de LAP à cause du climat politique. Il semblerait maintenant que nous en aurons assez pour 2025. A cause des problèmes de relation publique du Canada à l'étranger, il n'est pas clair combien étudiants étrangers vont soumettre des demandes d'admission de l'étranger. De plus, un des incitatifs pour venir étudier au Canada était la garantie d'un permis de travail de trois ans après la graduation. Le gouvernement fédéral a réduit la nombre de programmes qui qualifient pour ces permis, touchant en particulier les collèges. Ce qui enlève un incitatif majeur pour venir étudier au Canada [3,7].

Que réserve l'avenir aux universités ? À court terme, les déficits persisteront. Les réductions de 10 % par an des visas d'étudiants étrangers pour les collèges et universités en 2025 et 2026 n'arrangeront pas les choses. Il n'y a pas de solution immédiate au problème du déficit. Les collèges ont procédé à des coupes sévères dans leurs programmes, mais une grande partie de la croissance récente était artificielle. Les universités réduisent leur budget au détriment de la qualité de l'enseignement. Les programmes les plus utiles à la société dans les collèges et les universités sont coûteux. Les programmes techniques nécessitent souvent des équipements dispendieux et ne peuvent être dispensés qu'à de petites cohortes. Il est clair que toutes les formations ne peuvent pas être offertes dans de grands auditoriums. Les sciences et l'ingénierie nécessitent une formation en laboratoire. Les administrateurs des collèges et des universités peuvent être amenés à privilégier des programmes peu coûteux [3]. Les universités dotées de solides programmes de recherche s'efforceront activement de les protéger parce qu'ils sont soutenus par d'importantes subventions, principalement fédérales, et parce qu'ils sont à la base de leur prestige et de leur classement international, mais elles devront le faire dans un environnement administratif qui est divisé dans ses priorités.

Le sous-financement est un problème chronique qui ne cesse de s'aggraver [1,3]. Il n'y a pas de volonté politique d'augmenter le financement du secteur de l'enseignement supérieur. Les électeurs aiment les frais de scolarité peu élevés. Les élus réagissent à la pression politique, mais il n'y a guère de pression populaire pour augmenter le financement des universités, comme le montre la quasi-absence de cette question dans la rhétorique des campagnes électorales. Un financement insuffisant aura un impact à long terme sur la qualité et le type d'éducation que recevront les jeunes Canadiens. Nous avons atteint un haut niveau d'excellence au Canada, comme en témoigne le nombre récent de prix Nobel décernés à des Canadiens, notamment en physique. Cependant, certains électeurs ne considèrent pas la recherche universitaire comme un élément essentiel de la croissance économique. Les universités et les collèges sont confrontés à des vents contraires et doivent se battre pour faire à nouveau partie des priorités de notre société et de nos gouvernements.

L'avenir de l'enseignement supérieur restera sombre tant que nos gouvernements et nos concitoyens n'auront pas compris que notre prospérité dépend d'un financement adéquat de l'enseignement supérieur [1,3]. Nous devons fournir des arguments économiques. Si des start-ups voient le jour ici et si des entreprises internationales s'y installent, c'est parce que nos diplômés maîtrisent les techniques de pointe de la science et de la technologie. Nos actifs les plus précieux sont nos diplômés, en particulier ceux de l’enseignement supérieur. Alors que la crise des visas pour les étudiants étrangers et le programme TET se calment, il est peut-être temps de se rappeler les avantages économiques des étudiants étrangers qui obtiennent des diplômes de troisième cycle dans nos universités. Leurs contributions ont été éclipsées par les activités douteuses qui se déroulent dans de nombreux collèges [8]. Les parents envoient leurs enfants dans des établissements d'enseignement supérieur et des universités pour qu'ils aient une vie meilleure, et ils devraient apprécier la qualité de l'enseignement qu'ils reçoivent. Nous devons faire comprendre à ces parents qu'ils élisent les gouvernements. Il est de leur responsabilité de veiller à ce que nos gouvernements fournissent suffisamment de ressources financières pour que nos universités restent de classe mondiale. Le financement provient d'un mélange de subventions provinciales, de subventions fédérales, de frais de scolarité et, de plus en plus, de dons philanthropiques. Le gel des frais de scolarité en Ontario depuis 2019 a été très préjudiciable aux établissements d'enseignement supérieur de la province, car il n'est pas compensé par une augmentation des subventions provinciales. Les collèges se font entendre [9], mais ils ont perdu leur crédibilité en monnayant la facilité d'obtention des visas d'étudiants internationaux. Les universités devront parler plus fort.

Des pays comme l'Allemagne ont constaté qu'il était économiquement judicieux d'offrir des frais de scolarité GRATUITS dans les universités, tout en appliquant des normes d'admission élevées. Nous devons nous assurer que nos représentants comprennent les conséquences économiques de leur inaction.

Cette histoire évolue rapidement. Nous ne pouvons qu'espérer que l'agitation fera prendre conscience à notre pays de ce qui est en jeu et qu'il prendra les bonnes décisions pour assurer un avenir prospère au Canada.

Béla Joós, Université d'Ottawa
Rédacteur en chef, *La Physique au Canada*

Béla Joós est professeur de physique à l'Université d'Ottawa. Il est membre du comité de rédaction de La Physique au Canada depuis janvier 1985 et en est le rédacteur en chef depuis juin 2006.

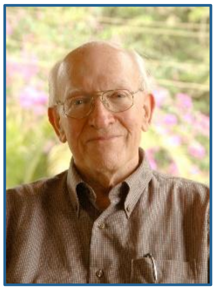
RÉFÉRENCES

1. Dan Breznitz, "We don't need no education: How Canada's broken university system holds us back", The Globe and Mail, October 4 (2024).
2. Statistics Canada. Table 27-10-0363-01 Sources of funds for expenditures on research and development (R&D) in the higher education sector. October 22 (2024). **DOI:** https://doi.org/10.25318/2710036301-eng
3. Jayme Poisson and Alex Usher, "The crisis facing Canada's colleges and universities – Transcript", CBC Front Burner Transcript, December 3 (2024).
4. Global News, La Presse, "Universities face "across the board" cuts one year after federal study permits reduction", January 21 (2025).
5. Youjin Choi and Feng Hou, "Characteristics of postsecondary international students who did not enrol in publicly funded postsecondary education programs", Statistics Canada, November (2023). **DOI:** https://doi.org/10.25318/36280001202301100001-eng
6. "McGill University planning to cut budget by $45M, slash up to 500 jobs", CBC News February 10 (2025). https://www.cbc.ca/news/canada/montreal/mcgill-45-million-budget-cut-1.7455165
7. Joe Friesen, "International student visa applications in Ontario will drop in 2025, province says", The Globe and Mail, February 7 (2025).
8. Christopher Worswick, "We should consider the economic benefits of foreign students again to

counter the effects of U.S. tariffs", The Globe and Mail, February 25 (2025).
9. Joe Friesen, "As election nears, Ontario colleges sound alarm on financial impact of foreign -student shorfall", The Globe and Mail, January 23 (2025).

NOTE: Le genre masculin n'a été utilisé que pour alleger le texte.

John Eric Crawford (1933-2020)



John Eric Crawford, Professor Emeritus in Physics, McGill University died at home on Saturday, September 19, 2020, after a period of challenging illnesses. John was born in Montreal, the only son of Myrtle McMillan and Robert Eric Crawford. He attended the University Schools of Toronto high school, graduated with both a B.A. and M.A. from the University of Toronto in Mathematics and Physics, and achieved a Ph.D. from McGill University. He designed and described a linear accelerator for his Ph.D. thesis under the supervision of Murray Telford. This accelerator was built and installed at the Royal Victoria Hospital in Montreal in 1962.

John touched the lives of a great many students and colleagues in the physics department at McGill University and other research facilities around North America and Europe. He was a gentle, quiet man, and possessed an insatiable curiosity for life, learning, and teaching others. He took great satisfaction in fixing things; no item was ever thrown away unless there was a full understanding of why repair was not possible. This same curiosity and vigour carried into all aspects of his life. He took particular pleasure in sailing, camping, extensive travel, photography, astronomy, all-things-music, and above all downhill skiing, which he was able to enjoy well into his eighties.

For many years Professor John Crawford was recognized as an inspiring, imaginative lecturer in physics at McGill University. His exceptional talents were given formal recognition by the Faculty of Science with The Leo Yaffe Award for Excellence in Teaching in 1983, the second year the award was given. John's remarkable insights and clarity of expression have inspired physics students at all levels, from "Planets, Stars and Galaxies", an introductory course that he pioneered, to graduate level courses in Nuclear Physics, Experimental Methods in Subatomic Physics and Electromagnetic Theory. Whether in small or very large courses, in academic classroom or laboratory, John consistently received outstanding evaluations from his students. He imparted an enthusiasm and love of science that delighted his students and his colleagues. At McGill, John was among the first to exploit the latest multimedia technology in his teaching. Whether he used these new methods or the traditional chalk and blackboard, John never failed to challenge the gifted student while simultaneously provoking the interest and enthusiasm of the average student.

Although a teacher of rare ability, John was equally accomplished as a researcher in nuclear physics. John devoted his long research career to nuclear spectroscopy. His early work, with colleagues and students, was accomplished at the Foster Radiation Laboratory (FRL), McGill University. The central theme of his research was the study of nuclei far from stability. In early years, the main research tool of the FRL was its 100 MeV proton synchrocyclotron, which was used to produce neutron-deficient nuclides mainly through (p, xn) or (p, pxn) reactions. Prior to 1980, most of this work was on beta-gamma spectroscopic studies to investigate such topics as reaction cross-sections, nuclear level schemes, or beta decay lifetimes. During this period, he developed a new line of research which involved a complete departure from previous techniques: laser spectroscopic studies yielding information on nuclear charge-radii and moments. His contribution was recognized in the international community, and with his collaborators, he continued this line of research at CERN, in Geneva, and in a vigorous in-house program at the FRL. At McGill University he used laser techniques to study fundamental nuclear properties - radii, spins, and moments. The techniques were borrowed from atomic physics. He collaborated with members of a number of European laboratories in the COMPLIS experiment at the ISOLDE on-line isotope separator at CERN Geneva. Later, he also collaborated with members of the University of Manitoba and Argonne National Laboratory in the Canadian Penning Trap project, which makes extremely precise measurements of nuclear mass. At his McGill home base, he helped build a fully equipped laser spectroscopy lab and used it mainly to do spectroscopy on ions confined in radiofrequency quadrupole traps. He also pursued his active research through a collaboration with TRIUMF, Texas A&M University and RIKEN for developing and exploiting collinear laser spectroscopy experiments at ISAC, a facility for which he, together with Bob Moore, Johnathan Lee and John D'Auria, was considered as one of the founding members. Until his passing away he was actively involved in experiments at TRIUMF, participating in group meetings, on-line beam times, offline data analysis and simulations.

John was highly appreciated by all his colleagues including the younger ones. He was a friendly and infinite resource person. We are missing him.

JEAN BARRETTE, McGill University

CHARLOTTE FROESE FISCHER (1929-2024)[1]

Charlotte Froese Fischer, a Guest Researcher at the National Institute of Standards and Technology (USA) and Affiliate Professor at the University of British Columbia (Canada), passed away on February 8th, 2024.

Charlotte Froese Fischer was born on September 21, 1929 in the Ignatyevo Mennonite Settlement of Nikolayevka in the Donetsk region of Ukraine. Within a few months, her village was displaced, and her family emigrated to Germany as refugees before continuing to Canada to settle down, ultimately in the province of British Columbia.

Charlotte studied mathematics, applied mathematics, and chemistry at the University of British Columbia (UBC). She already published her first paper on calculated diffraction patterns of dielectronic rods at centimetric wavelengths in 1954. Her career took a turn towards atomic physics when she was accepted for a Ph.D. program at Cambridge University under the supervision of Douglas R. Hartree. In 1957 Charlotte defended her thesis on solving the Hartree-Fock (HF) equations with computers. Since then, she has been widely recognized as the world-leading researcher on atomic structure calculations.

Over the next ten years, Charlotte worked as a professor in the Department of Mathematics at UBC, visiting various institutions during summers. In 1964, she became the first woman to be awarded an Alfred P. Sloan Foundation Research Fellowship. Charlotte married Patrick C. Fischer, a fellow mathematician and computer scientist, in 1967, and together they moved to the University of Waterloo, then Penn State University, and finally Vanderbilt University, where she was primarily appointed in computer science. However, her major research has always been in the development of powerful numerical methods related to atomic structure calculations. Even after formal retirement, Charlotte never stopped working in this field. For the past 20 years, she was a Guest Researcher at the Atomic Spectroscopy Group at NIST, with a five-year break when she moved back to Canada as an Affiliate Professor at UBC.

Charlotte published more than 300 papers that formed a true foundation for modern computational atomic physics of multi-electron atoms and ions. It is impossible to overestimate her contributions to the development of multi-configuration Hartree-Fock and Dirac-Hartree-Fock methods in atomic structure. Her classic books "The Hartree-Fock Method for Atoms" and "Computational Atomic Structure: An MCHF Approach" (with T. Brage and P. Jönsson) have become the most important textbooks on this topic.

[1] Adapted from a tribute published in the TAMOC Newsletter https://sites.google.com/site/tamocphysics/home

In 1990, Charlotte was elected a Fellow of the American Physical Society "For developing the numerical approach to the Hartree-Fock method for atoms; for providing benchmark oscillator strengths; for discovery of the calcium negative ion" [1].

She was also elected a member of the Royal Physiographic Society in Lund and a foreign member of the Lithuanian Academy of Sciences. In 2015, she was awarded an Honorary Doctorate from Malmö University, Sweden. The University of Western Ontario bestowed that honor in 2018.

Charlotte was a talented and generous unifier and promotor of all postdoctoral researchers she supervised over the years, as demonstrated by the expanding international Collaboration on Computational Atomic Structure (ComPAS) (https://compas.github.io) that quickly became her academic family. In her role as the natural leader of the collaboration, she has been the inspiration of many young scientists.

Charlotte was a generous supporter of charitable causes related to education, nature, women, and development. After Patrick's death, she endowed the Patrick C. Fischer chair in theoretical computer science at the University of Michigan. At University of Toronto, she established a graduate scholarship in honor of Beatrice "Trixie" Worsley, Canada's first computer scientist. She supported UBC with a student mobility award, recognizing the importance of the scholarship that took her to Cambridge, and created a graduate award to further computational physics at the University of Ottawa. Patrick and Charlotte also created a scholarship fund at Vanderbilt.

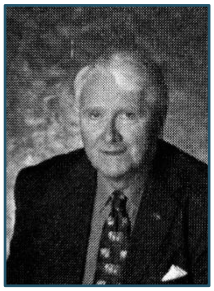
Charlotte Froese Fischer is dearly missed by all who knew her.

KLAUS BARTSCHAT (Department of Physics and Astronomy, Drake University), **CAROLYN FISCHER** (The World Bank, Washington D.C.), **MICHEL R. GODEFROID** (Spectroscopy, Quantum Chemistry and Atmospheric Remote Sensing, Université libre de Bruxelles), **PER JÖNSSON** (Department of Materials Science and Applied Mathematics, Malmö University) and **YURI RALCHENKO** (NIST).

REFERENCES

1. https://www.aps.org/funding-recognition/aps-fellowship?award_fellowship%5Bquery%5D=Charlotte%20Froese%20Fischer

JASPER MCKEE (1930-2024)



Jasper passed away peacefully at Ulster Hospital Belfast. He will be deeply missed by his son Conor (Katrina); daughter Siobhan (Russell); grandchildren Christa, Colton (Megan) and Jade; great grandchildren Liam, Royce and Jasper. He will also be missed by extended family members, many great friends, students and colleagues that he inspired, touched and encouraged along the way.

Dr. J.S.C (Jasper) McKee was educated at Campbell College and the Queen's University of Belfast, where he obtained his B.Sc. in Physics (1952) and Ph.D. in Theoretical Physics (1956). An assistant lectureship at Queen's was followed by seventeen years at Birmingham University in England where he became a Senior Lecturer in physics and held a DSc, prior to taking up his position as Professor of Physics and Director of the Accelerator Laboratory at the University of Manitoba (U of M) in Winnipeg, Canada in 1974. As a Fullbright Scholar, he spent two stints as a visiting Professor to the University of California, Berkeley in the late sixties. For twenty years Jasper also served as a weekly science correspondent for the Canadian Broadcasting Corporation. Since 1996, he was Professor Emeritus in the Department of Physics and Astronomy at U of M. He also served as an appointed Member of the National Advisory Board on Science and Technology of Canada and was a member of the Board of Directors of Atomic Energy of Canada.

Jasper often referred to himself as a 'peripatetic physicist'. The word 'peripatetic' arises from the career of Aristotle in the Lyceum in Ancient Athens, and his association with the 'peripatetic school', an informal institution whose members conducted philosophical and scientific inquiries. Jasper conducted teaching and research at universities in four countries on two continents. He published over 240 scientific papers and five books and edited volumes of conference proceedings. A collection of his papers are held at the U of M Archives and Special Collections.

Jasper was everything a University Professor should be. An engaging, brilliant conversationalist, public speaker, and enthusiastic teacher, always open to innovative ideas and with a gift for soliciting the best from younger staff and students. His optimistic, cheerful disposition and wit made him a pleasure to be with. At the University Club everyone regularly pulled up extra chairs to join the table where everyone was laughing, the "*McKee*" table. Eventually a larger table seating twelve was needed – the so-called "*Come and Go*" table was established (because people arrived and left for lunch at arbitrary times). As an indication of the positive influence Jasper had towards others, Jasper was awarded the McNeil Medal of the Royal Society of Canada (1995) for the communication of science to both students and lay public in Canada.

Dad (Jasper) was a dedicated father and husband who enjoyed family gatherings, parties and any occasion. He often invited his student's home at Christmas or on other occasions to join family parties; always treating Mum's (Christine's) delicious homemade marvels. A generous host, Jasper was attentive and entertaining, rarely seen without a wee dram or telling a tall tale. He diligently replenished the empty glass of any guest and his famous ‘paradise punch’ was a legendary ice breaker.

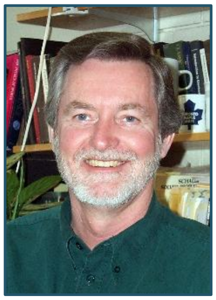
Jasper served as President of the Canadian Association of Physicists (CAP) in 1986-1987, was awarded the 1998 CAP Kirkby Medal, received his P.Phys. in Canada in 2000 and was also a fellow of the Institute of Physics (UK). He was the Editor of the CAP's journal *Physics in Canada* from 1990-2006.

Jasper served as the President of the Canadian Club of Winnipeg. He was also a liberal candidate in the 1988 and 1990 provincial general elections. An enthusiastic and gregarious member of the Westminster United Church, he frequently attended church services whenever his busy schedule allowed. His community service was recognized by an Outreach Award from the U of M (1986) and a Queen Elizabeth II Golden Jubilee Medal (2002).

Jasper will be sorely missed but will remain forever in our hearts.

Siobhan Russell

ERNEST LESLIE MCFARLAND (1946-2024)



The Canadian physics community has lost a very dear member. Ernie McFarland, retired professor and former Associate Chair in the Department of Physics at the University of Guelph, passed away suddenly on December 16, 2024. He is survived by his loving wife, Mary, two sons Grant and Steve, as well as stepson Dan, stepdaughter Lianna, and step-granddaughters Lotte and Margo.

Ernie first joined the department in 1974 as a lecturer and he soon became an integral member of the team. Although Ernie did not have a doctoral degree, his position was converted to tenure-track in 1985, and he became a tenured faculty member with a focus on physics education in 1988. This was a controversial move at the time, but it paved the way for the physics department at the University of Guelph to become recognized nationally for its commitment to excellence in pedagogy – a reputation maintained to this day.

In the words of a colleague at another institution: “Ernie was a vessel of energy, creativity and compassion, and few could match his captivating ability as a teacher and mentor”. He truly marveled at the wonders of the natural world and always infused his lectures with a joyful playfulness. He loved to start a session with a demonstration related to the subject matter of the day, asking students to predict what would happen and then collectively observing the result. Sometimes these demonstrations involved nothing more than a coffee mug on a string, but regardless of how simple or elaborate the setup, they were always designed to get students’ attention and cause them to wonder why. You never knew what was in his pockets when he arrived, but you could be sure it would be intriguing.

Ernie won many awards for his outstanding skills in the lecture hall, locally as well as at the provincial and national levels. Most notably, Ernie was named a 3M National Teaching Fellow in 1987 and received the CAP Medal for Excellence in Undergraduate Teaching in 1997. He played a key role in the founding of the Ontario Association of Physics Teachers in 1979, with the first OAPT conference held at the University of Guelph that summer. Ernie served as the editor of the Demonstration Corner column for the OAPT newsletter for 25 years (The Demonstration Corner Archives). He was awarded an honorary lifetime membership in 1987.

Writing textbooks and journal articles, Ernie had a passion for sharing his approach to physics teaching with colleagues in secondary and post-secondary education, giving many conference presentations and colloquia as well. He was truly honored to deliver the Herzberg Memorial Public Lecture at the 2006 CAP Congress at Brock University. Ernie also loved to wow junior scientists in elementary schools around the province, bringing the Physics Road Show to hundreds of students every year with physics department staff member Tom Kehn. They also appeared on the morning show on CTV with these engaging demonstrations – Ernie and Tom were a fabulous team.

With his longstanding reputation as a pioneer in physics education in Canada, Ernie was asked to share his expertise in a number of ways: he was a member of the CAP Teaching Medal selection committee for many years, as well as the Canadian National IUPAP Liaison Committee and the International Commission on Physics Education.

Ernie carried his child-like wonder and playful approach to life long learning into retirement, enjoying his chats with physics colleagues about the current antics of the department's outreach team until the end. We have lost a generous former colleague, a caring educator, a thoughtful mentor, and a true friend. In the words of one department alumnus: "He was one of the greats. … His legacy will live on in his many students."

In his memory, Ernie's family has asked for donations to either of two organizations that held a special place in his heart: the OAPT (Ontario Association of Physics Teachers - Donate) and Royal City Science, a non-profit organization in Guelph that continues his legacy of community-based science programming for people of all ages and backgrounds.

JOANNE O'MEARA, Professor of Physics, University of Guelph

L'UNIVERSITÉ DE MONTRÉAL (UDEM) CÉLÈBRE SON CENTENAIRE (1920-2020)

RÉSUMÉ: Le Département de physique de l'Université de Montréal (UdeM) célébrait en 2021 le centième anniversaire de sa fondation et profitait de cette occasion pour rappeler que nous appartenons tous à une communauté de gens passionnés, fière de son passé et résolument orientée vers la postérité.

(Note : Dans le présent document, le genre masculin est utilisé dans le seul but d'alléger le texte; il inclut les deux genres).

Par MATTHIEU P. LAVALLÉE, physicien-ingénieur nucléaire-auteur (Physique '75)
Membre du Comité centenaire, Département de physique, UdeM
<lavallee@lps.umontreal.ca>, http://histoire.phys.umontreal.ca/

100 ANS DE PHYSIQUE À L'UDEM

« Le Département de Physique rayonne par les gens qui le constituent, ses étudiants, les gens qui y travaillent ainsi que ceux qui y passent et qui poursuivent leurs carrières ailleurs. »

Nicole St-Louis, Directrice du Département de physique de l'UdeM
Lors du lancement des festivités du centenaire — campus MIL (20-10-2021)

Fondé en 1920, le Département de physique de l'Université de Montréal (UdeM) a célébré en 2021, avec un an de retard à cause de la pandémie de COVID-19, son premier siècle d'existence. Le comité organisateur, formé de dix-neuf représentants, placé sous la direction du professeur **Jean-François Arguin**, appuyé par le directeur sortant, **Richard Leonelli**, et plusieurs membres actifs, retraités et étudiants de la grande famille du Département de physique ainsi que de la Division de la gestion de documents et des archives de l'UdeM, avait élaboré un programme exceptionnel pour commémorer cette année historique.

Les festivités du centenaire furent lancées virtuellement le 16 juin 2021 à 17 h 30 (par vidéoconférence) et inclurent :

- les discours de bienvenue du Doyen de la Faculté des arts et des sciences (FAS), **Frédéric Bouchard** et de **Nicole St-Louis**, nouvelle Directrice du Département de physique;

- la présentation du site Web du centenaire intégrant trente-quatre capsules historiques. Voir : http://histoire.phys.umontreal.ca ;
- la sélection du jury des trois meilleurs films de l'histoire du **C**oncours **A**nnuel de **COU**rts-**M**étrages **A**mateurs **D**es **É**tudiants en **P**hysique de l'**U**niversité ***De*** **M**ontréal (Cacoumadepudem) ;
- ainsi qu'un exercice de réseautage sur la plateforme Web Gather Town.

Puis, le 20 octobre 2021, les festivités organisées sous le thème « 100 ans de physique » se poursuivirent, en présentiel cette fois, avec :

- la projection d'une capsule de l'historien Laurent Turcot, intitulée *Bombe nucléaire à Montréal durant la guerre*, concernant le laboratoire nucléaire secret de Montréal aménagé dans le pavillon principal de l'UdeM (aujourd'hui, le pavillon Roger-Gaudry) lors de la Seconde Guerre mondiale ;
- un panel de discussion sur les circonstances et faits saillants entourant l'établissement de ce célèbre laboratoire qui a conduit à l'émergence d'un premier groupe de professeurs-chercheurs en physique.

S'ensuivit :

- le dévoilement d'un mur interactif présentant une rétrospective des moments forts de l'histoire du Département de physique ;
- le concours d'affiches sur la recherche étudiante au Département de physique sous la responsabilité de Ahmad Hamdan, professeur adjoint de Physique des plasmas. Les gagnants furent :
  - Catégorie doctorat : 1er prix: Bruna Pascual Dias, Dominique Godin et Olivier Denis; 2^{e} prix: Alexandre Champagne-Ruel; 3e prix: Antoine Herrmann
  - Catégorie maitrise : 1er prix: Myriam Prasow-Émond ; 2e prix: Julien Leissner-Martin ; 3^{e} prix ex aequo: Selin Tuquet ;
  - Catégorie baccalauréat : Rose Lefebvre
- des visites guidées du campus MIL ;
- l'inauguration d'une exposition de documents historiques à la bibliothèque du MIL ;
- la remise d'un prix à Érika Loranger, gagnante du Quiz sur l'histoire du Département de physique; Voir http://histoire.phys.umontreal.ca/centenaire/quizz.pdf
- la projection d'un film historique intitulé *Bombe A à Montréal* de Pierre Buron présentant notamment le témoignage de l'éminent scientifique français Bertrand Goldsmith sur le rôle des savants internationaux qui ont travaillé dans le célèbre laboratoire nucléaire secret de Montréal de 1942 à 1946 ;

- et finalement le lancement du livre intitulé *Projet Manhattan : Montréal au cœur de la participation du Canada à la bombe atomique américaine* écrit par MM. Antoine Théorêt et Matthieu P. Lavallée, deux diplômés de la Faculté des arts et des sciences de l'UdeM. Cet ouvrage raconte l'invraisemblable et fascinante aventure atomique du Collège de France (Paris) à l'UdeM en passant par l'Université de Cambridge affiliée à celles de Chicago et de Columbia, et à Caltech. Il est dédié au Département de physique de l'Université de Montréal et a été publié à l'occasion du centenaire de sa fondation. Voir: https://www.librairie.umontreal.ca/product.aspx?sold=1&id=413171

Le résumé des événements du centenaire du Département de physique de l'UdeM est disponible à l'adresse suivante : http://histoire.phys.umontreal.ca/centenaire/histoire/festivites-du-centenaire

Tous les participants à ces festivités ont été ravis de découvrir l'histoire du Département de physique de l'UdeM, de connaître les recherches qui y sont effectuées et d'entrevoir les perspectives de la science physique de demain. En regardant un siècle en arrière, nous réalisons combien le rythme de la recherche scientifique s'est accéléré, combien il est désormais effréné et combien nos conditions de vie se sont améliorées grâce au progrès de la science. Dans ce monde qui bouge, nous aurons été des témoins privilégiés de notre temps et nous espérons que cette émotion transporte et incite la nouvelle génération de physiciens et de physiciennes, d'élèves, de scientifiques, de chercheurs et chercheuses à poursuivre la conquête du savoir en demeurant curieux, rigoureux et surtout… persévérants.

LES PIONNIERS DE MONTRÉAL ET LE DÉBUT DE LA « BIG SCIENCE »

> *« Le département, c'est l'œuvre de pionniers qui sont partis de rien en 1920 pour arriver à un département d'envergure internationale, c'est assez extraordinaire ! »*
>
> Matthieu P. Lavallée (Physique '75),
> UdeM Nouvelles (Octobre 2021)

Après des études classiques à Montréal, **Joseph-Ernest Gendreau** (1879-1949) entreprit des études supérieures en Europe et notamment à Paris où il étudia la physique (en particulier la radioactivité), la chimie, la médecine et la radiologie. De retour au pays, il fut, en 1920, un des membres fondateurs de la Faculté des sciences (aujourd'hui Faculté des arts et des sciences) de l'UdeM. Il occupa la première chaire de physique et enseigna la science des radiations aux futurs médecins. En 1937, il fut l'un des délégués nommés par le premier ministre canadien William Lyon Mackenzie King pour représenter le Canada à l'Exposition universelle de Paris, laquelle était consacrée aux « Arts et techniques dans la vie moderne » avec l'objectif de mieux faire connaitre les bienfaits des retombées de la science dans le grand public. Il en revint émerveillé et marqué par les multiples expériences qui y furent menées et conduites par des « démonstrateurs », dont celle du générateur électrostatique de Van der Graaff. Deux ans plus tard, en 1939, il convainquit le jeune Pierre Demers, alors étudiant à l'École normale supérieure de Paris, de poursuivre ses études en physique atomique. Demers se joignit à l'équipe de Frédéric Joliot-Curie (prix Nobel de chimie en 1935 avec sa conjointe Irène Joliot-Curie), contribua avec l'Américain Sherwood K. Haynes à l'installation du premier cyclotron français au Collège de France –

dont les plans avaient été fournies par le célèbre physicien américain (prix Nobel de physique en 1939) Ernest Orlando Lawrence de Caltech – et entreprit des recherches sur les neutrons au Laboratoire de synthèse atomique d'Ivry-sur-Seine. En juin 1940, l'invasion de la France par l'armée allemande au début de la Seconde Guerre mondiale l'obligea à revenir au Canada.

En 1942, à l'occasion du 300^{e} anniversaire de la fondation de Montréal, le Département de physique de l'UdeM prit un important virage lorsque l'UdeM déménagea dans un nouveau bâtiment principal construit sur le mont Royal (aujourd'hui le pavillon Roger-Gaudry). Dans une aile inoccupée, avec l'aide du gouvernement britannique, le Conseil national de recherches du Canada y installa une prestigieuse équipe de chercheurs européens venues du Laboratoire Cavendish de l'Université de Cambridge, rendu célèbre par le père de la physique nucléaire Ernest Rutherford après ses travaux sur la radioactivité à l'Université McGill entre 1898-1907. Ce laboratoire nucléaire secret, connu sous le nom de Laboratoire de Montréal, fut le premier centre de recherche international au monde et le seul en dehors des États-Unis à participer au Projet Manhattan devant conduire au développement de la bombe atomique américaine. Au total, 580 personnes y travaillèrent de 1942 à 1946 dans le plus grand secret, dont d'éminents savants de diverses nationalités. Après la Seconde Guerre mondiale, le laboratoire fut démobilisé et l'UdeM procéda à la réorganisation de son Institut de physique. La direction du nouveau Département de physique fut confiée à **Marcel Rouault**, un professeur-chercheur français spécialiste de la diffusion des gaz. En janvier 1947, **Pierre Demers** commença sa carrière en tant que professeur dans ce Département. En 1956, **Paul Lorrain** se joignit à l'équipe et devint directeur l'année suivante.

L'arrivée de **René J.-A. Lévesque** en 1960 donna une impulsion à la physique moderne. Il occupa les postes de directeur du Département de physique en 1969, de doyen de la Faculté des arts et sciences de l'UdeM en 1975 puis de vice-recteur à la recherche en 1978. L'astrophysique fit son entrée à ce moment dans le Département avec la venue du théoricien **Serge Lapointe**, puis celle **d'Hubert Reeves,** notre plus illustre représentant sur la scène internationale. Entre 1957 et 1966, le nombre de chercheurs titulaires d'un doctorat de physique fit un bond spectaculaire, passant de 3 à 27. En 1968, l'UdeM intégra à son campus universitaire un laboratoire de physique nucléaire (aujourd'hui le pavillon René-J.-A.-Lévesque) comprenant un accélérateur de particules (Tandem EN1), témoin de l'effervescence de la recherche nucléaire à l'échelle mondiale à cette époque.

En 1963, **Gilles Cloutier** devint professeur titulaire au Département de physique puis directeur des recherches à Hydro-Québec en 1971 où il joua un rôle majeur dans la mise sur pied du projet pancanadien Tokamak de Varennes considéré comme le plus important projet de recherche en physique réalisé au Canada à cette époque. En 1985, il devint recteur de l'UdeM après avoir été le président de l'Alberta Research Council de 1978 à 1983. En 1998, il fut nommé président adjoint du Conseil consultatif des sciences et de la technologie d'Industrie Canada par le premier ministre canadien Jean Chrétien.

En 1966, le Département fit l'acquisition d'un accélérateur de particules et recruta une dizaine de professeurs-chercheurs en science nucléaire dont **Paul Taras**, spécialiste de la spectroscopie nucléaire. En 1969, **Pierre Depommier**, spécialiste des particules fondamentales et leurs interactions, prit la direction du nouveau laboratoire de physique nucléaire de l'UdeM. En 1978, l'Observatoire du Mont-

Mégantic vit le jour sous l'initiative de **Gilles Beaudet** et de **Georges Michaud** ouvrant la porte à une expertise canadienne en observation infrarouge (astronomie observationnelle), laquelle fut mise en valeur par **René Doyon** dans plusieurs projets d'instruments spécialisés.

Jean-Robert Derome, nommé directeur du Département en 1988, développa de nouveaux groupes de recherche, dont celui de la physique des plasmas, de la cosmologie et celui de la physique de la matière condensée. Les dernières décennies furent aussi témoins de nombreuses découvertes auxquelles des membres des communautés diplômées, scientifiques et enseignantes de l'UdeM participèrent, notamment celles sur la matière sombre de l'Univers, sur les exoplanètes, la physique des particules et sur le boson de Higgs sans oublier celles sur la cryptographie quantique par **Gilles Brassard** et qui a conduit à la description pionnière d'un protocole de téléportation quantique (réalisé grâce à l'intrication quantique). Des disciplines « plus jeunes » sont aussi arrivées dans le monde de la physique telles que la physique solaire, les étoiles massives, la biophysique, la physique médicale, le vieillissement des matériaux ainsi que des outils innovants tels que les calculs de haute performance.

UN DÉPARTEMENT TOURNÉ VERS L'AVENIR

Aujourd'hui, **Nicole St-Louis** admet qu'il existe « deux secteurs d'activités où Montréal excelle et qui ont le potentiel de changer la donne avec des outils extrêmement puissants : les sciences de l'information quantique et l'intelligence artificielle. Ce qui nous permettra d'exploiter des données qu'on n'aurait jamais pu traiter avec nos cerveaux humains. »

Aujourd'hui, le Département poursuit sa mission fondamentale de former du personnel hautement qualifié pour les entreprises canadiennes, les services de santé, les institutions de recherches gouvernementales, l'enseignement postsecondaire, etc. Signe des temps, la présence des femmes en physique s'est accélérée : vingt et une ont obtenu un diplôme de premier cycle au cours des cinquante premières années du Département de physique et autant entre… 2017 et 2019 ! Pour en nommer que quelques-unes à la carrière particulièrement illustre: Chantal Mallen, Martine Simard-Normandin, Ève Christian, Corinne Le Quéré, Roxanne Guénette, Suzanna Randall, etc.

L'UdeM est plus que jamais une figure emblématique de l'expertise scientifique au Québec et au Canada. Ses réalisations passées laissent une empreinte indélébile et inspirante pour nous tous. Il faut maintenant se tourner vers l'avenir en réaffirmant la nature coopérative, universelle et généreuse de la Science.

La clôture du centième anniversaire du Département de physique de l'Université de Montréal fut célébré le 6 octobre 2022 sous le thème de la « Grande Unification ». Pour en savoir plus :

https://interaction.physique.umontreal.ca/la-grande-unification-2022/

Vive la physique à l'UdeM !

Photo 1: Pavillon principal de Université de Montréal (UdeM), maintenant le pavillon Roger-Gaudry, 25 juillet 1948. (Crédit: Archives de l'UdeM, D00361FP01973).

Photo 2: (À gauche) Personnel du Département de physique de l'UdeM, automne 1960. En première rangée (#7), vous reconnaîtrez, entre autres, Hubert Reeves alors membre du corps professoral. (Crédit: Archives de l'UdeM – 0233/P0233_c06353-5). (À droite) Identification du personnel du Département de physique de l'UdeM, automne 1960. (Crédit: Archives de UdeM + collaboration de Claude Cardinal et de Jacques L'Heureux).

Photo 3: Campus principal de l'Université de Montréal sur le mont Royal - 2021. (Crédit: Archives de l'UdeM).

Photo 4: Nouveau campus MIL - Complexe des sciences de l’Université de Montréal, avril 2022. (Crédit: Matthieu P. Lavallée).

Photo 5: De gauche à droite: Nicole St-Louis, directrice du Département de physique de l'UdeM, Matthieu P. Lavallée, membre du comité organisateur, Jean-François Arguin, président du comité organisateur. (Crédit: UdeM)

Photo 6: La capsule temporelle : Les membres organisateurs demeurent convaincus qu'en 2120 les souhaits déposés le 6/10/2022 lors de la clôture des festivités du centenaire sauront révéler les « saveurs » exquises, uniques et complexes du Département de physique de l'UdeM d'aujourd'hui. (Crédit: UdeM)

WHY DOES THE FOUNDATION OF ARTIFICIAL INTELLIGENCE DESERVE A NOBEL PRIZE IN PHYSICS?

SUMMARY: The 2024 Nobel Prize in Physics was awarded to John Hopfield (Princeton University) and Geoffrey Hinton (University of Toronto) "for foundational discoveries and inventions that enable machine learning with artificial neural networks" [1, 2]. Even though their fundamental works contributed significantly to the development of today's artificial intelligence, the community questioned whether a recognition with a Physics Nobel Prize falls in the appropriate discipline. However, the development of the fundamental artificial neural network models introduced by Hopfield and Hinton was inspired by spin glasses and is thus based on principles from many-body physics.

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This year's Nobel Prize in Physics caused puzzling debates in the community. The prize was awarded to John Hopfield (Princeton University) and Geoffrey Hinton (University of Toronto) "for foundational discoveries and inventions that enable machine learning with artificial neural networks" [1, 2]. While there is no doubt that a Nobel Prize is well deserved by the two researchers whose pioneering works laid the foundation for technologies that now shape our everyday life, many were confused about why it is Physics that lays claim on these fundamental developments. However, taking a closer look at the research behind the awards sheds some light into the discussion.

HOPFIELD'S CONTRIBUTION: HOPFIELD NETWORKS

Both Nobel laureates developed very fundamental network structures that revolutionized the field of machine learning with artificial neural networks [2]. John Hopfield's major contribution was the introduction of Hopfield networks [3]. These consist of a set of neurons, which are binary units, interacting via symmetrically weighted, bidirectional all-to-all connections, as illustrated in Figure 1. The weights of these connections are *learned* when the network evolves to minimize a chosen energy function for a given input. The energy function E_{HN} defined over a Hopfield network is given by

$$E_{\mathrm{HN}} = -\frac{1}{2}\sum_{i,j} w_{i,j} s_i s_j,$$

where $w_{i,j} = w_{j,i}$ is the connecting weight between neurons i and j with $w_{i,i} = 0$. The state of neuron i is denoted by $s_i \in \{-1, 1\}$, where the index i runs over all N neurons in the network. By optimizing the connection weights $w_{i,j}$ for a given input state $\boldsymbol{s}$, Hopfield networks can recover patterns from noisy inputs, making them powerful candidates to deal with incomplete data [3]. The chosen setup of a fully connected network of binary units resembles a spin glass in condensed matter physics, specifically a Sherrington-Kirkpatrick model [4] and the energy function takes the familiar form of an Ising model, revealing the field and experience that inspired Hopfield's work.

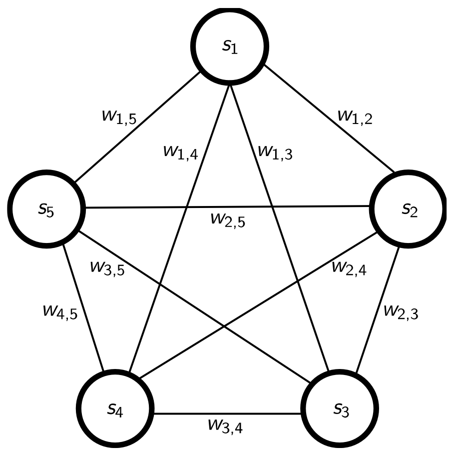

Figure 1. Hopfield network with $N = 5$ neurons s_i and connecting weights $w_{i,j} = w_{j,i}$.

HINTON'S CONTRIBUTION: RESTRICTED BOLTZMANN MACHINES

Similarly, Geoffrey Hinton introduced another fundamental network architecture, the restricted Boltzmann machine, a special case of the general Boltzmann machine [5], that finds applications in tasks like data generation [6] or classification [7]. Restricted Boltzmann machines consist of two layers of binary neurons, one interpretable *visible* layer and one *hidden* layer that characterizes the network's expressive power and enables efficient network training and data generation [6, 8]. While there are weighted bidirectional and symmetric all-to-all connections between neurons from different layers, no intralayer connections are allowed in the restricted Boltzmann machine, as illustrated in Figure 2. Based on this setup, an energy is defined for the overall network which is minimized by optimizing the connection weights during the network training process. This energy term E_{RBM} is defined similarly to the energy in Hopfield networks, but takes the restricted connectivity into account,

$$E_{\text{RBM}} = -\sum_{i,j} v_i w_{i,j} h_j - \sum_i a_i v_i - \sum_j b_j h_j \,.$$

Here, $v_i \in \{0,1\}$ denotes the state of each visible neuron and, accordingly, $h_j \in \{0,1\}$ denotes the state of each hidden neuron, where the indices i and j run over all N_{v} visible and N_{h} hidden neurons, respectively. The parameters $w_{i,j}$ denote the connecting weights and a_i and b_j denote a bias factor for the visible and hidden neurons, respectively, which are also optimized during the network training process. Just like the Hopfield network, the restricted Boltzmann machine describes the Sherrington-Kirkpatrick model [4] as a spin glass in an external field. Furthermore, from the network energy E_{RBM}, a Boltzmann distribution $P(\boldsymbol{v},\boldsymbol{h})=\frac{1}{Z}\exp[-E_{\mathrm{RBM}}]$, with partition function Z as normalization constant, can be defined over all possible states of the neuron ensemble. By drawing samples of visible neuron configurations from the distribution encoded in the trained network, interpretable data can be generated. The specific network architecture of the restricted Boltzmann machine provides an efficient algorithm for sample generation. This ability led to novel achievements in tasks like image or text generation [6, 8].

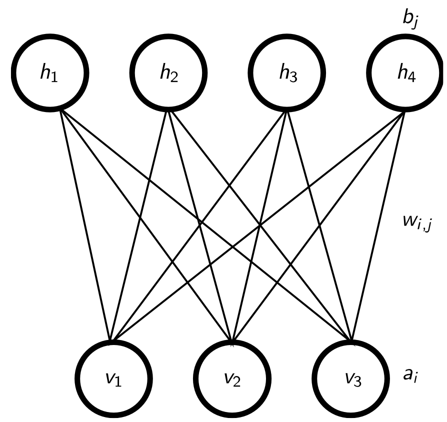

Figure 2. Restricted Boltzmann machine with $N_{\mathrm{v}}=3$ visible and $N_{\mathrm{h}}=4$ hidden neurons v_i and h_j, connecting weights $w_{i,j}$, and visible and hidden biases a_i and b_j, respectively.

Just like Hopfield networks, the introduction of the restricted Boltzmann machine as a fundamental artificial neural network architecture demonstrates the importance that physical models play in the field of machine learning and artificial intelligence. These developments show how the detailed understanding of spin glass models and the physical phenomena observed in those find applications far beyond many-body systems and directly affect commonly used technologies. The fact that physical principles have big impacts on computational algorithms clearly showcases how intertwined different research disciplines are and emphasizes the importance of collaborations to combine knowledge and approaches across specialized topics.

Nowadays, Hopfield networks and restricted Boltzmann machines are outdated and have been replaced by advanced, more powerful artificial neural network architectures [9]. Those include recurrent neural networks, or transformer models whose immense strength is demonstrated in recent groundbreaking artificial intelligences like ChatGPT [10]. However, all these impressive advances are built on the foundation of Hopfield networks and restricted Boltzmann machines. The introduction of those models in the 1980s pointed out that artificial neural networks are more powerful than experienced before and with this ended a decay period known as the *AI winter*. Together with the introduction of efficient learning algorithms for the restricted Boltzmann machine by Geoffrey Hinton and co-workers in the mid 2000s [11], they motivated the enhancements that led to today's state-of-the-art artificial neural network architectures.

While physics has significantly inspired the fundamental developments of today's artificial neural networks, at the same time artificial neural networks play an important role in the developments in state-of-the-art classical and quantum physics [12, 13]. Besides optimizing data evaluation, suggesting efficient experimental setups, or automatizing the tuning of experimental devices, artificial neural networks can be used for phase transition detection, to model quantum many-body systems, and more. Especially in the field of numerically simulating dynamics and ground states of quantum many-body systems, restricted Boltzmann machines have been the driving force that initiated the field [14, 15, 16, 17]. Early works used restricted Boltzmann machines as a general wavefunction ansatz and showed that such a general approach can accurately and efficiently model even higher-dimensional qubit systems.

CONCLUSIONS

Overall, there is a strong bidirectional connection between artificial neural networks and physics where one takes advantage of the other. While today's artificial neural networks play a significant role not only in our everyday life but also in various fields of classical and quantum physics, we would not have reached this stage without many-body physics that inspired the fundamental developments of artificial neural networks. With this, the 2024 Nobel Prize in Physics has surely been awarded in the right discipline. In the end, physics has not laid claim on those fundamental developments with this Nobel Prize, it has rather always been the understanding and phenomena of physical models that made those developments possible.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Press release. NobelPrize.org., Nobel Prize Outreach AB 2024, 2024.

[2] Advanced information. NobelPrize.org, Nobel Prize Outreach AB 2024, 2024.

[3] J. Hopfield, "Neural networks and physical systems with emergent collective computational abilities," Proc Natl Acad Sci USA **79(8)**, pp. 2554-2558, 1982.

[4] D. Sherrington and S. Kirkpatrick, "Solvable Model of a Spin-Glass," Phys Rev Lett **35**, p. 1792, 1975.

[5] G. Hinton, "Boltzmann machine," Scholarpedia **2(5)**, p. 1668, 2007.

[6] P. Smolensky, "Chapter 6: Information Processing in Dynamical Systems: Foundations of Harmony Theory," in Parallel Distributed Processing: Explorations in the Microstructure of Cognition, Volume 1: Foundations, MIT Press, 1986.

[7] H. Larochelle and Y. Bengio, "Classification using discriminative restricted Boltzmann machines," Proceedings of the 25th international conference on Machine Learning - ICML '08, p. 536, 2008.

[8] G. Hinton, "Training products of experts by minimizing contrastive divergence," Neural Computation **14(8)**, pp. 1711-1800, 2002.

[9] I. Goodfellow, Y. Bengio and A. Courville, Deep Learning, MIT Press, 2016.

[10] OpenAI, ChatGPT, 2023.

[11] G. Hinton, "A Practical Guide to Training Restricted Boltzmann Machines," UTML TR **2010**, p. 003, 2010.

[12] A. Dawid, J. Arnold, B. Requena, A. Gresch, M. Plodzien, K. Donatella, K. Nicoli, P. Stornati, R. Koch, M. Büttner, R. Okula, G. Munoz-Gil, R. Vargas-Hernandez, A. Cervera-Lierta, J. Carrasquilla, V. Dunjko, M. Gabrie, P. Huembeli, E. van Nieuwenburg, F. Vicentini, L. Wang, S. Wetzel, G. Carleo, E. Greplova, R. Krems, F. Marquardt, M. Tomza, M. Lewenstein, A. Dauphin, "Modern applications of machine learning in quantum sciences," arXiv:2204.04198 [quant-ph], 2022.

[13] G. Carleo, I. Cirac, K. Cranmer, L. Daudet, M. Schuld, N. Tishby, L. Vogt-Maranto and L. Zdeborová, "Machine learning and the physical sciences," Rev Mod Phys **91**, p. 045002, 2019.

[14] G. Carleo and M. Troyer, "Solving the quantum many-body problem with artificial neural networks," Science **355(6325)**, pp. 602-606, 2017.

[15] G. Torlai and R. Melko, "Learning thermodynamics with Boltzmann machines," Phys Rev B **94**, p. 165134, 2016.

[16] G. Torlai, G. Mazzola, J. Carrasquilla, M. Troyer, R. Melko and G. Carleo, "Neural-network quantum state tomography," Nature Physics **14**, pp. 447-450, 2018.

[17] R. Melko, G. Carleo, J. Carrasquilla and J. Cirac, "Restricted Boltzmann machines in quantum physics," Nature Physics **15**, pp. 887-892, 2019.

CHARLOTTE FROESE FISCHER (1929–2024): HER LIFE IN AND CONTRIBUTIONS TO SCIENCE

SUMMARY: Charlotte Froese Fischer's scientific career spanned eight decades that dominated the field of computational atomic physics, radiative processes, and electron-atom collisions.

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Professor Charlotte Froese Fischer might be best known as a pioneer in computational atomic physics, developing methods and methodologies to represent a wide range of atomic properties. Her early work covered electron correlation in atomic systems, but later she extended this to a wide range of topics involving complex interactions with radiation and collision phenomena. The following article first outlines her early scientific career and then enlarges on her many collaborations and her monumental influence on the field.

Charlotte began her education in Vancouver, Canada. She attended the University of British Columbia (UBC) there for her BA degree in Mathematics and Chemistry in 1952 and her MA in Applied Mathematics in 1954. She moved to Cambridge, England, for her Ph.D., supervised by Douglas Hartree, and naturally her paper with him [1] concerned the solution of the Hartree-Fock (HF) equations for states of Ne^{3+} and Ne^{4+}. On her return to UBC in 1957 as a professor in the Department of

Mathematics, she pursued her HF calculations of other complex ions. But in keeping with her mathematical background, she also studied mathematical aspects of these nonlinear integro-differential equations, including their convergence to self-consistency. In 1964, in recognition of her achievements, Charlotte was the first woman to be awarded an Alfred P. Sloan Fellowship.

While at UBC, she had access to a large-scale computer. It was clear that the HF equations had limitations for accuracy, so she developed extensions to the theory to incorporate many configurations. This multi-configuration Hartree-Fock (MCHF) approach [2,3] proved very powerful and thereby results of much greater accuracy were achieved [4,5]. Charlotte introduced the idea of relaxing the radial orbital orthogonality constraints to capture electron correlation more efficiently [3,6]. The standard Racah-Fano algebra for the angular integration of the Hamiltonian had to be extended [7] and the angular codes were adapted accordingly [8]. With increasing computing power, she and her collaborators were able to undertake sequences of calculations which showed the convergence of results as more terms were systematically introduced into the MCHF wave functions [9,10]. This gave much greater confidence in the accuracy of the largest calculations. She was never happy to extrapolate her results to a supposed "best" value, but there was really no need to do that – everyone trusted her results, and with good reason.

In the 1990's Charlotte made major contributions to the understanding of correlation in negative ions [11], including being the first to predict a positive electron affinity for calcium [12] (a discovery that led to her becoming a Fellow of the American Physical Society). The work on negative ions also included important contributions to the prediction and understanding of transitions between bound or semibound states of negative ions [13], a topic still of great importance for example in sympathetic cooling [14]. About the same time, an increased interest in hyperfine structure effects and isotope shifts led to new predictions and exotic discoveries in astrophysics, for example long-lived states decaying only with hyperfine-induced transitions [15,16] and *F*-dependent lifetimes [17]. Similar methods also explained and predicted transitions induced by an external magnetic field [18,19]. During this time, she also engaged in the forefront of computing intercombination lines [20] and *J*-dependent lifetimes [21,22].

Relativistic corrections need to be included at some stage to achieve reliable results with increasing nuclear charge. Charlotte first developed the MCHF + BP method that introduces relativistic corrections in the Breit-Pauli (BP) approximation using the configuration-interaction (CI) approach to improve atomic wave functions [23,24]. In that context, a Davidson program was built [25] to find a few selected extreme eigenpairs of a large, sparse, real, symmetric matrix. This efficient algorithm and code remain a cornerstone of the most recent atomic structure packages for solving the eigenvalue problem targeting the physical atomic energy levels of interest.

In parallel with this, Charlotte and co-workers continued pushing the limits for accuracies in the treatment of correlation [26]. In some cases, this gave results approaching the spectroscopic accuracy of experiments [27], thereby opening the way to tests of quantum electrodynamic (QED) effects in rather complex atomic systems [28]. All this led to a close synergism both with computational science and technology when developing new methods, but also with experimental physics, fusion research and astrophysics.

Early on, Charlotte engaged herself in parallel computing. In 1992 she presented a paper on a hypercube conversion of serial codes for calculations of atomic structure [29]. A few years later, she and her post-docs presented a Parallel Virtual Machine (PVM) implementation of the MCHF package [30]. These works set the standard, and from this time onwards all her codes were adapted for parallel computing on supercomputers. Dynamic memory allocation, sparse-matrix methods, combined with Gaigalas' angular library [31,32] were implemented in the atomic-structure package ATSP2K [33] to allow large-scale calculations of atomic energy levels, transition rates of all types, isotope shifts, hyperfine constants, and Land\'e factors. For transition probabilities, the individual orbital optimization of wave functions for the initial and final states produces the most accurate wave functions for given expansions but complicates the calculation of the transition matrix elements since the two sets of orbitals will be nonorthogonal. A biorthonormal transformation of the orbitals, with a counter-transformation of the MCHF/CI eigenvectors that leave the total wave functions invariant was implemented to solve this issue [34].

When the MCHF + BP approach alone could not provide the results she wanted, (for instance when the Breit-Pauli approximation becomes inadequate to describe both correlation and relativity), Charlotte was happy to embrace other codes and methods to meet her needs [26]. In particular, she led the team developing Ian Grant's fully relativistic GRASP code [35,36]. That team continues to work together [37,38] through the international Computational Atomic Structures (CompAS) network (see Fig. 1 for a photo of the group at the 2016 Malmö meeting). The latest release of the code, GRASP2018, with Charlotte as the main author [39], has the same broad coverage of properties as ATSP2K. In addition, it comes with a detailed manual [40], allowing a broad range of researchers to compute atomic data of importance in various fields such as astrophysics, nuclear physics, and medicine. Examples of applications, to mention a few, include computation of atomic data needed for the extraction of nuclear radii from laser measurements on isotope separators [41,42], along with transition and energy data for astrophysical element abundance determinations [43-46]. It is not an overstatement to say that the code is a very important working horse in many fields.

Along with her calculations, Charlotte was very committed to making her computer programs available and was one of the first subject editors of the journal *Computer Physics Communications*. This ensured that those who developed such programs were given due acknowledgement of their work. She contributed her own codes and worked with other authors to enhance their codes to make them even more applicable than the authors had originally intended.

In addition to her remarkable work on electronic structure discussed above, it was unavoidable for Charlotte to move beyond pure atomic structure and include the treatment of continuum states --- first with auto-ionization [47,48] and photo-ionization [49,50] and later with collisions. This also led to further development of the spline Galerkin method [51], both for continuum processes and bound states. Charlotte's work with the late Oleg Zatsarinny had a tremendous impact on the calculation of electron collisions, especially from complex targets. A very important paper to introduce what later

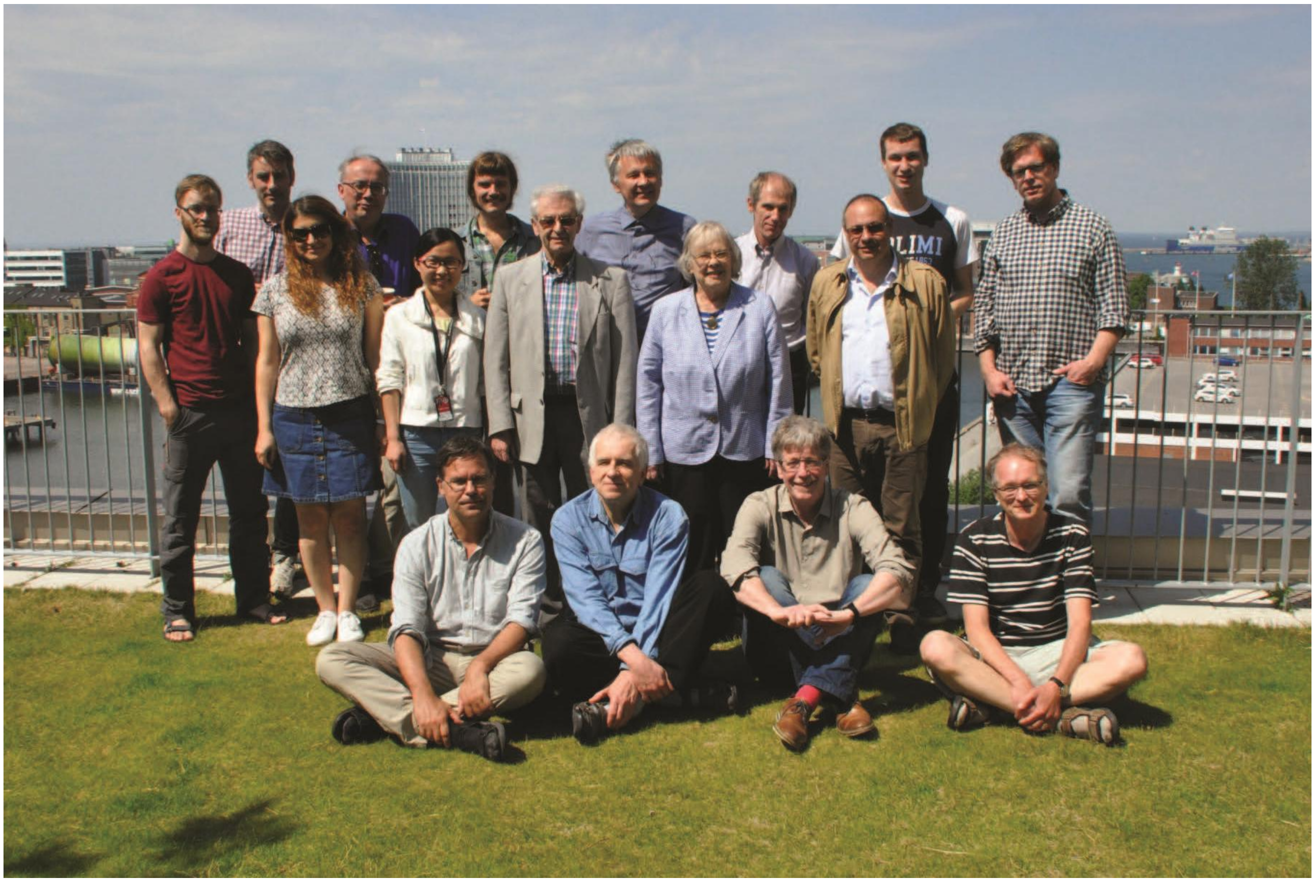

Figure 1. Group picture taken at the Malmö CompAS meeting, June 2016. Charlotte is standing in the middle row, second from the right.

became known as the B-spline R-matrix (BSR) method was the one on photo-ionisation of lithium [52]. Recall that photo-ionisation is essentially electron scattering from the residual ion; *i.e.*, one needs to solve that problem and generate matrix elements with the initial bound state. Charlotte had generously invited Oleg to Vanderbilt University after science in the Ukraine became difficult, and she also shared her B-spline library with Oleg to adapt for his purposes. This ultimately resulted in Oleg's most important contribution to science, namely the publication of his computer code in CPC [53]. Charlotte and Oleg kept working together as an excellent team for many years, with her mostly being interested in numerical methods and their application to structure physics, while Oleg's emphasis was on electron collisions. Being a general close-coupling code, BSR can be run in complete bound-state mode (for a comparison with MCHF, see [54]), for photo-ionisation as a bound-continuum process, and for electron collisions. To get an impression of what can be done with BSR, see the Topical Review [55]. The extension from a non-relativistic and semi-relativistic (Breit-Pauli) to a full-relativistic (Dirac-Breit) version, once again, critically depended on Charlotte's collaboration [56]. The importance of BSR is seen in its prominent status as a contributing software to fill many databases, including LXCat [57].

Without Charlotte's inviting Oleg, this work would most likely never have reached the current status. In 2021 Charlotte published a review of these developments [58].

A somewhat different aspect of Charlotte's influence flowed from a panel discussion on uncertainty quantification held as part of the 2010 ICAMDATA meeting in Vilnius, Lithuania. The participants were Charlotte Froese Fischer and Igor Bray, with Gordon Drake as moderator. The purpose of the discussion was to ascertain the degree of support from the theoretical atomic physics community for a new policy to require uncertainty estimates for computations of atomic properties. Charlotte's support played a key role in establishing the new policy, and it is now widely regarded as the standard for publications in the field.

Her books [3,59] have been very influential for new generations of atomic physicists. An important autobiographical article entitled "Reminiscences at the end of the Century" [60] appeared in a special issue of *Molecular Physics* that commemorated Charlotte's scientific achievements and celebrated her 70th birthday. Further details can be found in the review article [61] that appeared on the occasion of her 90th birthday.

Charlotte's legacy is, of course, the quality of her work, but it also includes the supportive way she worked with colleagues and students alike. She will remain an exemplary educator and a role model for us all.

REFERENCES

1. C. Froese and D.R. Hartree, "Wave functions for the normal states of Ne^{+3} and Ne^{+4}", Mathematical Proceedings of the Cambridge Philosophical Society **53**, 663 (1957).
2. C. Froese Fischer, "A multi-configuration Hartree-Fock program", Comput. Phys. Commun. **1**, 151 (1969).
3. C. Froese Fischer, *The Hartree-Fock Method for Atoms, A numerical approach*, John Wiley and Sons, New York, 1977.
4. P. Jönsson, A. Ynnerman, C. Froese Fischer, M. Godefroid, and J. Olsen, "Large-scale MCHF and CI calculations of transition probabilities and hyperfine structures in the sodium resonance transition", Phys. Rev. A **53**, 4021 (1996).
5. M. Godefroid, C. Froese Fischer, and P. Jönsson, "Nonrelativistic variational calculations of atomic properties in Li-like ions: Li I to O VI", J. Phys. B: At. Mol. Opt. Phys. **34**, 1079 (2001).
6. C. Froese Fischer and J.E. Hansen, "Theoretical oscillator strengths for the resonance transitions in the Zn I isoelectronic sequence", Phys. Rev. A **17**, 1956 (1978).
7. A. Hibbert, C. Froese Fischer, and M. Godefroid, "Non-orthogonal orbitals in MCHF or configuration interaction wave functions", Comput. Phys. Commun. **51**, 285 (1988).
8. A. Hibbert and C. Froese Fischer, "A general program for computing angular integrals of the non-relativistic Hamiltonian with non-orthogonal orbitals", Comput. Phys. Commun. **64**, 417 (1991).
9. M. Tong, P. Jönsson, and C. Froese Fischer, "Convergence studies of atomic properties from variational methods: total energy, ionization energy, specific mass shift and hyperfine parameters for Li", Physica Scripta **48**, 446 (1993).

10. T. Brage, C. Froese Fischer, and P. Jönsson, “Effects of core-valence and core-core correlation on the line strength of the resonance lines in Li I and Na I”, Phys. Rev. A **49**, 2181 (1994).
11. C. Froese Fischer, “Correlation in negative ions”, Physica Scripta **40**, 25 (1989).
12. C. Froese Fischer, J. Jolanta, and S. Vosko, “Ground states of Ca^- and Sc^- from two theoretical points of view”, Phys. Rev. Lett. **59**, 2263 (1987).
13. G. Miecznik, T. Brage, and C. Froese Fischer, “Autoionization studies of the 1s2s2p $^4P_{5=2}$ levels in He^-, Li I, and Be II”, Phys. Rev. A **47**, 3718 (1993).
14. R. Tang, R. Si, Z. Fei, X. Fu, Y. Lu, T. Brage, H. Liu, C. Chen, and C. Ning, “Candidate for Laser Cooling of a Negative Ion: High-Resolution Photoelectron Imaging of Th^-“, Phys. Rev. Lett. **123**, 203002 (2019).
15. T. Brage, P. Judge, A. Aboussaïd, M. Godefroid, P. Jönsson, A. Ynnerman, C. Froese Fischer, and D. Leckrone, “Hyperfine induced transitions as diagnostics of isotopic composition and densities of low-density plasmas”, Astrophysical Journal **500**, 507 (1998).
16. T. Brage, P.G. Judge, and C.R. Proffitt, “Determination of hyperfine-induced transition rates from observations of a planetary nebula”, Phys. Rev. Lett. **89**, 281101 (2002).
17. K. Yao, M. Andersson, T. Brage, R. Hutton, P. Jönsson, and Y. Zou, “M_F -dependent lifetimes due to hyperfine induced interference effects”, Phys. Rev. Lett. **97**, 183001 (2006), Erratum: Phys. Rev. Lett. **98**, 269903 (2007).
18. J. Li, J. Grumer, W. Li, M. Andersson, T. Brage, R. Hutton, P. Jönsson, Y. Yang, and Y. Zou, “Theoretical investigation of magnetic-field-induced $2p^5\,3s^3\,P_{0,2} - 2p^6\,{}^1S_0$ transitions in Ne-like ions without nuclear spin”, Phys. Rev. A **88**, 013416 (2013).
19. W. Li *et al.*, “A novel method to determine magnetic fields in low-density plasma facilitated through accidental degeneracy of quantum states in Fe^{9+}”, The Astrophysical Journal **807**, 69 (2015).
20. A. Ynnerman and C. Froese Fischer, “Multiconfigurational-Dirac-Fock calculation of the $2s^2\,{}^1S_0 - 2s2p\,{}^3P_1$ spin-forbidden transition for the Be-like isoelectronic sequence”, Phys. Rev. A **51**, 2020 (1995).
21. M. Godefroid and C. Froese Fischer, “Relativistic and correlation effects on the lifetimes of 3s4p $^3P_0$ J Levels in Mg-like Sulphur and Chlorine”, Physica Scripta **31**, 237 (1985).
22. T. Brage and A. Hibbert, “Plunging configurations and J-dependent lifetimes in Mg-like ions”, J. Phys. B: At. Mol. Opt. Phys. **22**, 713 (1989).
23. C. Froese Fischer, “The MCHF atomic-structure package”, Comput. Phys. Commun. **64**, 369 (1991).
24. A. Hibbert, R. Glass, and C. Froese Fischer, “A general program for computing angular integrals of the Breit-Pauli Hamiltonian”, Comput. Phys. Commun. **64**, 455 (1991).
25. A. Stathopoulos and C. Froese Fischer, “A Davidson program for finding a few selected extreme eigenpairs of a large, sparse, real, symmetric matrix”, Comput. Phys. Commun. **79**, 268 (1994).
26. Z. Cai, V.M. Umar, and C. Froese Fischer, “Large-scale relativistic correlation calculations: Levels of Pr^{+3}“, Phys. Rev. Lett. **68**, 297 (1992).
27. J. Grumer, R. Zhao, T. Brage, W. Li, S. Huldt, R. Hutton, and Y. Zou, “Coronal lines and the importance of deep-core–valence correlation in Ag-like ions”, Phys. Rev. A **89**, 062511 (2014).
28. R. Si, X.L. Guo, T. Brage, C.Y. Chen, R. Hutton, and C. Froese Fischer, “Breit and QED effects on the $3d^9\,{}^2D_{3/2} \rightarrow {}^2D_{5/2}$ transition energy in Co-like ions”, Phys. Rev. A **98**, 012504 (2018).

29. M. Bentley and C. Froese Fischer, “Hypercube conversion of serial codes for atomic structure calculations”, Parallel Computing **18**, 1023 (1992).
30. A. Stathopoulos, A.B. Ynnerman, and C. Froese Fischer, “A PVM Implementation of the MCHF Atomic Structure Package”, The International Journal of Supercomputer Applications and High Performance Computing **10**, 41 (1996).
31. G. Gaigalas, Z. Rudzikas, and C. Froese Fischer, “An efficient approach for spin-angular integrations in atomic structure calculations”, J. Phys. B: At. Mol. Opt. Phys. **30**, 3747 (1997).
32. G. Gaigalas, “Integration over spin-angular variables in atomic physics”, Lithuanian Journal of Physics **39**, 79 (1999), arXiv:physics/0405078.
33. C. Froese Fischer, G. Tachiev, G. Gaigalas, and M. Godefroid, “An MCHF atomic-structure package for large-scale calculations”, Comput. Phys. Commun. **176**, 559 (2007).
34. J. Olsen, M. Godefroid, P. Jönsson, P.Å. Malmqvist, and C. Froese Fischer, “Transition probability calculations for atoms using non-orthogonal orbitals”, Phys. Rev. E **52**, 4499 (1995).
35. F. Parpia, C. Froese Fischer, and I. Grant, “GRASP92: A package for large-scale relativistic atomic structure calculations”, Comput. Phys. Commun. **94**, 249 (1996).
36. P. Jönsson, G. Gaigalas, J. Bieroń, C. Froese Fischer, and I. Grant, “New version: Grasp2K relativistic atomic structure package”, Comput. Phys. Commun. **184**, 2197 (2013).
37. C. Froese Fischer, M. Godefroid, T. Brage, P. Jönsson, and G. Gaigalas, “Advanced multiconfiguration methods for complex atoms: I. Energies and wave functions”, J. Phys. B: At. Mol. Opt. Phys. **49**, 182004 (2016).
38. P. Jönsson M. Godefroid, G. Gaigalas, J. Ekman, J. Grumer, W. Li, J. Li, T. Brage, I.P. Grant, J. Bieroń, and C. Froese Fischer, ”An Introduction to Relativistic Theory as Implemented in GRASP”, Atoms **11**, 7 (2023).
39. C. Froese Fischer, G. Gaigalas, P. Jönsson, and J. Bieroń, “GRASP2018 A Fortran 95 version of the General Relativistic Atomic Structure Package”, Comput. Phys. Commun. **237**, 184 (2019).
40. P. Jönsson, G. Gaigalas, C. Froese Fischer, J. Bieroń, I.P. Grant, T. Brage, J. Ekman, M. Godefroid, J. Grumer, J. Li, and W. Li, “GRASP Manual for Users”, Atoms **11** (2023).
41. D.T. Yordanov *et al.*, “Structural trends in atomic nuclei from laser spectroscopy of tin”, Communications Physics **3**, 107 (2020).
42. A. Barzakh *et al.*, “Large shape staggering in neutron-deficient Bi isotopes”, Phys. Rev. Lett. **127**, 192501 (2021).
43. P. Jönsson, G. Gaigalas, P. Rynkun, L. Radžiūtė, J. Ekman, S. Gustafsson, H. Hartman, K. Wang, M. Godefroid, C. Froese Fischer, I. Grant, T. Brage, and G. Del Zanna, “Multiconfiguration Dirac-Hartree-Fock Calculations with Spectroscopic Accuracy: Applications to Astrophysics”, Atoms **5**, 16 (2017).
44. W. Li, A.M. Amarsi, A. Papoulia, J. Ekman, and P. Jönsson, “Extended theoretical transition data in C I – IV”, Monthly Notices of the Royal Astronomical Society **502**, 3780 (2021).
45. J.Q. Li, C.Y. Zhang, G. Del Zanna, P. Jönsson, M. Godefroid, G. Gaigalas, P. Rynkun, L Radžiūtė, K. Wang, R. Si, and C.Y. Chen, “Large-scale Multiconfiguration Dirac–Hartree–Fock Calculations for Astrophysics: C-like Ions from O III to Mg VII”, The Astrophysical Journal Supplement Series **260**, 50 (2022).
46. L. Kitovienė, G. Gaigalas, P. Rynkun, N. Domoto, M. Tanaka, and D. Kato, “Theoretical study of Th III energy levels and transitions for applications to kilonova spectra”, Monthly Notices of the Royal Astronomical Society **538**, 92 (2025).

47. C. Froese Fischer and T. Brage, "A program for computing autoionization properties", Comput. Phys. Commun. **74**, 381 (1993).
48. T. Brage and C. Froese Fischer, "Autodetachment of negative ions", Phys. Rev. A **44**, 72 (1991).
49. C. Froese Fischer and J. E. Hansen, "Photodetachment cross section for Ca^- ", Phys. Rev. A **44**, 1559 (1991).
50. T. Brage, C. Froese Fischer, and G. Miecznik, "Nonvariational, spline-galerkin calculations of resonance positions and widths, and photodetachment and photoionization cross sections for H^- and He", J. Phys. B: At. Mol. Opt. Phys. **25**, 5289 (1992).
51. C. Froese Fischer and M. Idrees, "Spline algorithms for continuum functions", Computer in Physics **3**, 53 (1989).
52. O. Zatsarinny and C. Froese Fischer, "The use of basis splines and non-orthogonal orbitals in R-matrix calculations: application to Li photoionization", J. Phys. B: At. Mol. Opt. Phys. **33**, 313 (2000).
53. O. Zatsarinny, "BSR: B-spline atomic R-matrix codes", Comput. Phys. Commun. **174**, 273 (2006).
54. O. Zatsarinny and C. Froese Fischer, "Atomic structure calculations using MCHF and BSR", Comput. Phys. Commun. **180**, 2041 (2009).
55. O. Zatsarinny and K. Bartschat, "The B-spline R-matrix method for atomic processes: application to atomic structure, electron collisions and photoionization", J. Phys. B: At. Mol. Opt. Phys. **46**, 112001 (2013).
56. C. Froese Fischer and O. Zatsarinny, "A B-spline Galerkin method for the Dirac equation", Comput. Phys. Commun. **180**, 879 (2009).
57. L.C. Pitchford *et al.*, "LXCat: an open-access, web-based platform for data needed for modeling low temperature plasmas", Plasma Processes and Polymers **14**, 1600098 (2017).
58. C. Froese Fischer, "Towards B-Spline Atomic Structure Calculations", Atoms **9** (2021).
59. C. Froese Fischer, T. Brage, and P. Jönsson, *Computational Atomic Structure - An MCHF Approach*, Institute of Physics Publishing, Bristol, 1997.
60. C. Froese Fischer, "Reminiscences at the end of the Century", Mol. Phys. **98**, 1043 (2000).
61. A. Hibbert, "Charlotte Froese Fischer: Her Work and Her Impact", Atoms **7**, 107 (2019).

EXPLORING AMBIENT RADIO FREQUENCY EMISSIONS

SUMMARY: Radio astronomy observatories, such as the Dominion Radio Astrophysical Observatory (DRAO) in British Columbia, reside in 'radio quiet zones'. We explore how necessary such zones are by studying the radio frequency emission in our environment.


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Modern technology has led to radio frequency (RF) emission being virtually everywhere. The increasing reliance on services like cellular data, Wi-Fi, and Bluetooth, as well as the prevalence of older technologies such as microwaves, has led to inescapable daily RF exposure. The number of emitting devices is only growing as more and more uses of the wide range radio spectrum are discovered. The allocation of RF bandwidth for these different services is recommended by the International Telecommunication Union in the International Mobile Telecommunication (IMT) requirements and is determined at a national level where some frequency bands are reserved for astronomy and space physics research. The limited capacity of the radio band affects the expansion of current services and the development of new technology. Thus, there is always pressures to exploit frequencies currently protected for research.

The prevalence of RF emission has led to extensive investigation into its effects and potential uses. There are concerns around adverse health problems due to radiation exposure — although it is non-ionizing, RF radiation still may cause biological harm and government standards have been developed for exposure limits [1, and references therein]. Furthermore, as RF band crowding becomes more common, understanding possible unintentional interference becomes important. For example, band crowding can lead to compromised private communication, disrupted medical tests, or interrupted services [2].

RF interference (RFI) can be quite problematic in radio astronomy since it may lead to spurious observations and noise in the data. Protective measures for observatories include designated 'radio-quiet zones' and containing on-site instruments such as printers and hard drives in Faraday cages to limit artificial emission [3]. The Dominion Radio Astrophysical Observatory (DRAO) of the National Research Council of Canada (NRC; Figure 1) is in such a radio-quiet zone near Penticton, British Columbia. The DRAO contains the Synthesis Telescope and the 26-metre John A. Galt Telescope, which both operate at frequencies between 0.4 and 2 GHz. It also has a solar radio flux monitoring facility to provide space weather data for both research and commercial purposes. The site also hosts the Canadian Hydrogen Intensity Mapping Experiment, a novel, stationary radio telescope to map hydrogen in 3-D across most of the observable Universe. One of the main purposes of the DRAO, which it is internationally known for, is to design and develop radio instrumentation. DRAO monitors the RFI on site through a non-directional antenna but, as of 2024, there is no consistent recording outside of the CHIME band and a dedicated RFI monitoring system is still in progress [4].

Figure 1. The Dominion Radio Astrophysical Observatory near Penticton, British Columbia. Image credit National Research Council.

Other observatories, such as the National Radio Astronomy Observatory (NRAO) in the United States, undertake the same precautions. A National Radio Quiet Zone in West Virginia was established around the site of the Green Bank Telescope, while the Jansky Very Large Array in New Mexico gains most of its protection from being geographically remote. The Atacama Large Millimeter/submillimeter Array, operated in part by the NRAO along with the European Southern Observatory and the National Astronomical Observatory of Japan, benefits both from a regulated protective zone and from its location at 5000 m altitude in the Atacama Desert of Chile. Despite any choice of site or of radio-quiet zones, these observatories still have to continuously monitor and mitigate human-made interference [e.g. 5,6].

Currently, most measures only include terrestrial-based sources of interference, however satellites are a new, and growing, source of risk for radio observatories [e.g. 6,7]. Astronomers at the future site of the next-generation Square Kilometre Array in Australia have already detected intended and unintended emission from telecommunications satellites [8].

For this study, we examined the strength and distribution of terrestrial-based RF emission in and around Calgary, Alberta, and at the DRAO to characterize the RF emission distribution. While the RF environment has changed since we conducted this study in 2018, as a consequence of increased satellite activity and other forms of emission, we present these results as documentation of the past environment with the aim to redo the measurement. We aim to present a more general look at RFI as, often, observatories do not publicize their RFI measurements, or they are published in observatory-specific technical reports. In Section 2, we outline the experimental design, including the frequency bands and locations of the measurements, and the equipment used. In Section 3, we show the observational results (3.1-3.3) and discuss the strongest emission seen (3.4). In Section 4, we summarize the paper.

EXPERIMENTAL DESIGN

At a combination of public and private, outdoor and indoor, and busy and quiet areas, we measured the radio spectrum in five frequency bands commonly used in communications and research. We took observations between March and June 2018 and determined the average spectra over two-minute intervals. Most measurements, aside from those at Mount Yamnuska, Nose Hill, and the apartment were taken during business hours. The apartment measurements were taken on a weekday evening, and the mountain and hill measurements on a Sunday during daytime. We aimed for these times to reflect the environment of everyday life.

BANDS OF INTEREST

We chose two bands covering the cell phone ranges (824-960 MHz, 1710-2170 MHz) and an unlicensed 'industrial, science, and medical devices' (ISM) band (2400-2500 MHz; as in [9]). As radio astronomers, we also chose two radio astronomy bands (406-410 MHz, 1405-1435 MHz). These two frequency bands are the ones observed by the Synthesis Telescope at the DRAO [10].

LOCATIONS

We chose several different locations around Calgary and Kananaskis, Alberta, (Figure 2) to investigate the variety of RF environments we could encounter in day-to-day life. At the University of Calgary, we chose four locations: MacEwan Hall, a public student hub (labeled as *Hub* in the figures); the Taylor Institute for Teaching and Learning, a moderately used, technologically advanced building (*Inst*); a semi-isolated basement lab (*Lab*); the outdoor quad in between the Administration and MacKimmie buildings, which is a well-frequented area with close proximity to four cell phone towers (*Quad*). We took three measurements elsewhere in the city: Nose Hill Park, a large, open, urban area (*Park*); an apartment downtown (*Apt*); a street in the Varsity neighbourhood (*Nbhd*). Additionally, we measured at three locations outside the city: a rural area off Highway 1A near Cochrane (*Rural*); on the front, prairie-facing side of Mount Yamnuska (*Mtn f*); on the backside of Mount Yamnuska (*Mtn b*). We also performed the same measurements at the DRAO (*DRAO*), which is a designated radio-quiet zone.

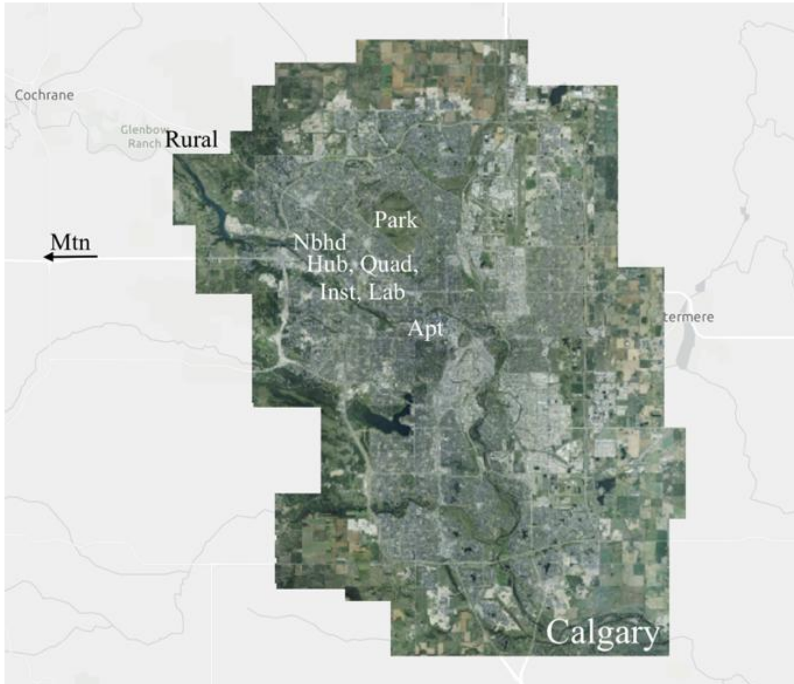

Figure 2. Locations in and around Calgary, Alberta, where we took ambient RF emission measurements. Each is labeled with its abbreviation used in the paper. Image credit City of Calgary, Esri Canada, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NRCan, Parks Canada.

EQUIPMENT AND PROCEDURE

We used a Keysight N9340B handheld RF spectrum analyzer [11] for measurements. With a range of 100 kHz to 3 GHz, narrow resolution bandwidths, and a preamplifier, this was an ideal choice for a portable, accurate device that could measure potentially weak signals.

We attached to the spectrum analyzer an Aaronia OmniLOG 90200 [12], which is a small radial isotropic broadband antenna. This antenna is ideal for our experiment as it has equal gain in all radial directions, allowing us to measure ambient RF signals without worrying about the source direction. Since the number of, and distance to, all RF-emitting devices was not determined, the ambient RF signals measured represent uncontrolled exposure situations.

We used the spectrum analyzer in 'Spectrogram' mode, which measures the average power continuously over time. Using this mode, we can determine the continuity and strength of signals, and determine the average and peak power one would encounter at each location. We adjusted the input attenuation depending on the signal strength of each location, increasing the attenuation for locations with strong emission. The attenuation level, if set to 10 or 20 dBm, results in an increase in the noise floor of the same value (as will be seen in the emission figures). We measured the noise for the instrument in each frequency band with a terminated input.

RF EMISSION OBSERVATIONS

Below we present the average spectral distributions for our five bands of interest in the locations identified above. This section begins with the radio astronomy bands, followed by the cell phone bands, and then finally the unlicensed band. We present relative comparisons of the distributions. In addition to the average spectral distributions, we also recorded the maximum power intensities at the various locations in the different bands. We present the top five power intensities, and compare them to Health Canada exposure limits in the final subsection.

RADIO ASTRONOMY BANDS (406-410 MHZ, 1405-1435 MHZ)

Figure 3 displays the average power of signals in the 406-410 MHz band. There were four specific signals prominent between 409-410 MHz. Notably, a 409.9 MHz signal was strong around campus (*Quad*, -85 dBm, *Hub*, -89 dBm), as well as in suburban Calgary (*Nbhd*, -79 dBm). A 409.1 MHz signal was prominent in the suburban and rural areas as well. The designated use for the band contains fixed and mobile radio use as well as radio astronomy continuum observations, where 'fixed' and 'mobile' are terms describing any radio-communication device between fixed or mobile stations, respectively [13]. Use in the 409-410 MHz sub-band contains public and private radio dispatch systems [14]. For example, signals seen on campus may come from campus security, grounds

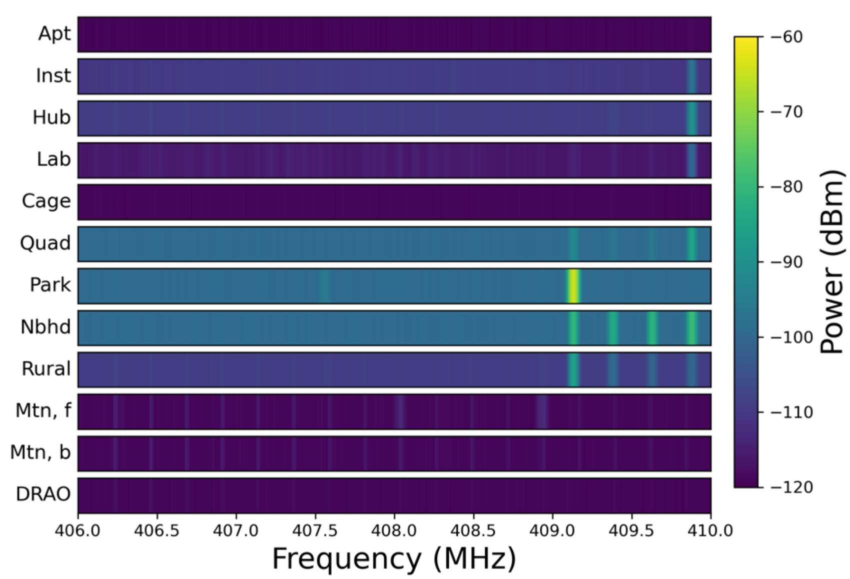

Figure 3. The power (dBm) measured at each location for the 406-410 MHz radio astronomy band. This band is also used for fixed and mobile use and tends to be used by public and private dispatch services. The measured noise levels at this frequency with the respective attention are: -119 dBm (*Apt, Lab, Cage, Mtn f, Mtn b, DRAO*); -109 dBm (*Inst, Hub, Rural*); -99 dBm (*Quad, Park, Nbhd*).

maintenance, or parking radios. The exact sources of the RF signals were not determined since these facilities do not wish to disclose their frequency of use and compromise their radios. Less public, or isolated, places (*Mtn b* and *DRAO*) showed no emission.

In the 1405-1435 MHz range, shown in Figure 4, there is a lack of signal across most bands. This is an expected result since, aside from radio astronomy use, the range 1400-1427 MHz has designation for passive earth exploration (via satellite) and space research, and thus no emissions are allowed at these frequencies [13]. This protected band is essential for mapping the small- and large-scale structure of the Galaxy since it corresponds to the 1420 MHz hyperfine transition line of neutral hydrogen, abundant in interstellar space [15]. There is a fixed and mobile devices band that begins at 1429 MHz, which may explain the faint emission seen in otherwise quiet areas (*Mtn f, Mtn b,* and *DRAO*) at 1433 MHz.

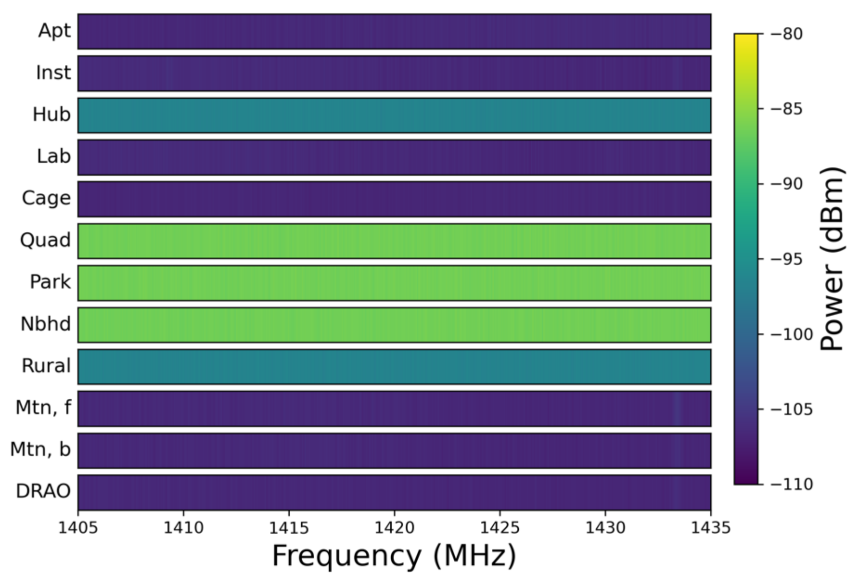

Figure 4. The power (dBm) measured at each location for the 1405-1435 MHz radio astronomy band. Note that the power scale is much lower in this figure compared to the others, and these measurements likely consist primarily of noise. The measured noise levels at this frequency with the respective attention are: -107 dBm (*Apt*, *Inst*, *Lab*, *Cage*, *Mtn f*, *Mtn b*, *DRAO*); -97 dBm (*Hub*, *Rural*); -86 dBm (*Quad*, *Park*, *Nbhd*).

CELL PHONE BANDS (824-960 MHZ, 1710-2170 MHZ)

In the lower-frequency cell phone band (Figure 5), campus quad (*Quad*) shows the strongest signals at - 7 dBm, owing to the placement of four cell phone towers nearby. The Taylor Institute (*Inst*) shows emission across the entire band, unlike other locations, likely due to the prominence of licensed and amateur digital devices used to make it an interactive learning space. In remote locations, there is strong emission on the prairie exposed front side of Mount Yamnuska (*Mtn f*, -67 dBm), while the mountain sheltered landscapes have largely attenuated signals (*Mtn b*, -90 dBm, and *DRAO*, -94 dBm). The strong signals seen at many locations fall within the 869-894 MHz band allocated for cellular mobile use in the IMT system [16]. Cellular mobile systems also use the range 824-849 MHz, while trunked mobile radio systems, which control user traffic by automatically designating users to certain channels, radiolocation devices and amateur radio services fill the rest of this explored range [16].

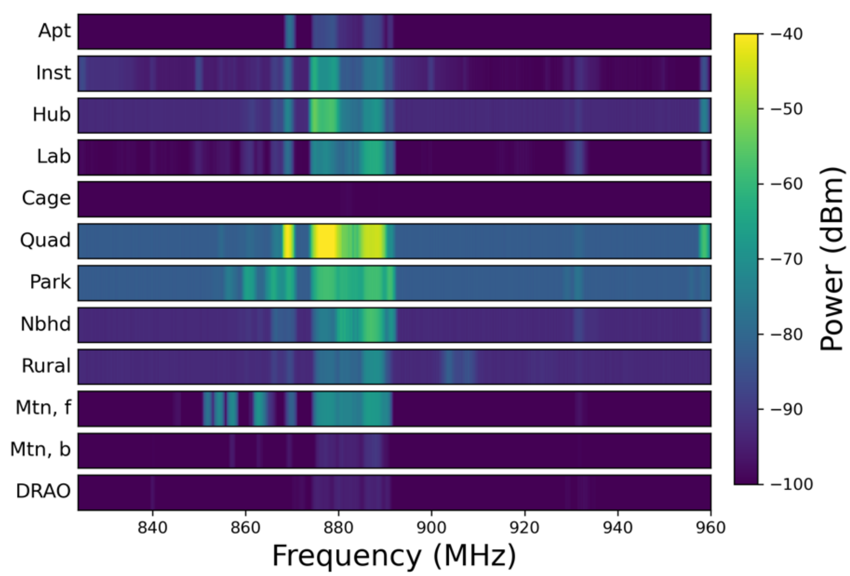

Figure 5. The power (dBm) measured at each location for the 824-960 MHz band. Mobile phones, amateur radio or radiolocation devices are some examples of other uses for this band. The measured noise levels at this frequency with the respective attention are: -103 dBm (*Apt*, *Lab*, *Cage*, *Mtn f*, *Mtn b*, *DRAO*); -93 dBm (*Inst*, *Hub*, *Nbhd*, *Rural*); -83 dBm (*Quad*, *Park*).

The higher-frequency cell phone band (Figure 6) also contains smaller sub-bands of fixed and mobile communication services. As illustrated in the figure, most devices around Calgary use the IMT-designated 1710-1755 MHz, 1850-2000 MHz, and 2110-2810 MHz bands [13, 17]. Similar to the lower cell phone range explored, the campus quad (Quad) displayed the strongest signals at -45 dBm. MacEwan Hall (*Hub*), Nose Hill Park (*Park*), and a neighbourhood street (*Nbhd*) also had quite strong peak strength between -45 and -60 dBm, while areas sheltered by the environment such as the apartment (*Apt*) and the front of Mount Yamnuska (*Mtn f*) showed weaker emission peaking near - 73 dBm.

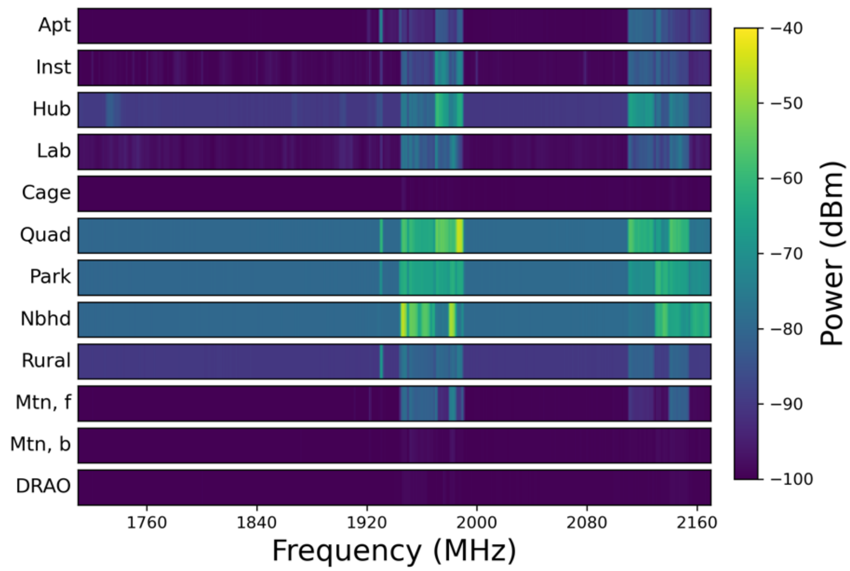

Figure 6. The power (dBm) measured at each location for the 1710-2170 MHz band. Emission in this band is mostly restricted to the specific frequencies that mobile phones use. The measured noise levels at this frequency with the respective attention are: -100 dBm (*Apt*, *Inst*, *Lab*, *Cage*, *Mtn f*, *Mtn b*, *DRAO*); -91 dBm (*Hub*, *Rural*); -80 dBm (*Quad*, *Park*, *Nbhd*).

In both bands, indoor spaces typically show decreased signal strength, likely due to attenuation from building materials such as concrete [18]. The architecture strongly influences the amount of RF emission seen. In outdoor spaces, the line of sight to emitting cell phone towers is a large factor in the strength of signal as they are consistently emitting at high power, and the power density decreases with the inverse square of distance [19, 20]. Consequently, the campus quad (Quad), a suburban neighbourhood (*Nbhd*), and the front side of Mount Yamnuska (*Mtn f*) are prime locations for strong, consistent signals. In certain outdoor (*Rural* and *Mtn f*) settings, the peak signals were over -20 dBm lower than the open area of the Quad. In other outdoor, more remote locations (*DRAO* and *Mtn b*), the signals peaked only 2-10 dBm above the noise. Here, natural barriers or large distances from emitting sources help provide large reductions in signal strength. Emissions are still faintly seen in the radio-quiet zone, demonstrating that protective measures are not strictly sufficient and astrophysical observations may easily be contaminated.

UNLICENSED ISM DEVICES BAND (2400-2500 MHZ)

Figure 7 shows the spectra for ISM devices. Signals were only prominently seen in MacEwan Hall (*Hub*, -80 dBm) and the Taylor Institute (*Inst*, -88 dBm), and possibly seen in the apartment (*Apt*) and the lab (*Lab*). Many devices that use this band emit intermittently. The measured spectra can show variation and are dependent on the surroundings at the exact time of measurement. However, Kwan and Fapojuwo [9] note that despite intermittent signals, they find overall radio emissions are not significantly different between peak and off-peak hours in the cell phone and ISM devices bands. The ISM Devices band is also used for fixed, mobile and radiolocation devices [13]. However, its unlicensed nature means that Wi-Fi, Bluetooth, cordless phones, microwaves, and many other non-cellular devices exploit this band. This is a consequence of the limited spectrum and cost of the licensed spectrum which has driven companies towards network services, such as Wi-Fi, in this band and others [21].

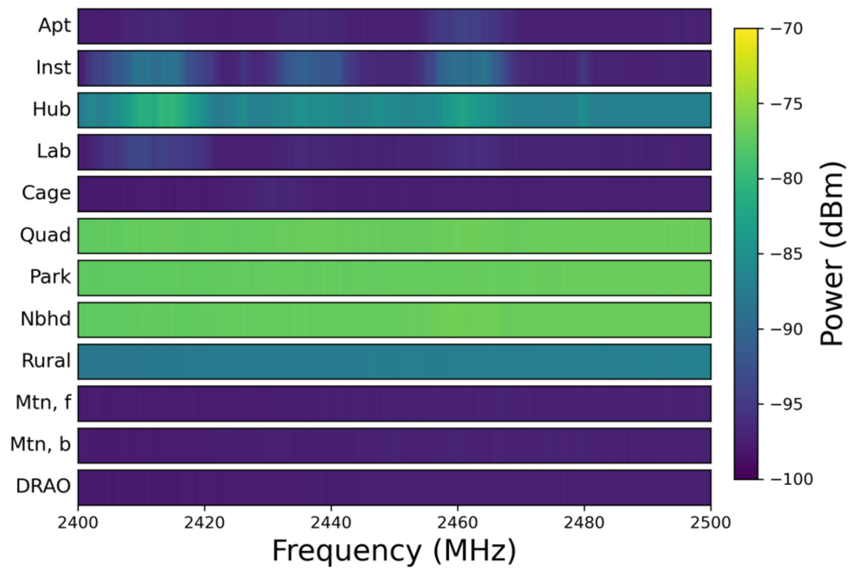

Figure 7. The power (dBm) measured at each location for the 2400-2500 MHz band. This contains industrial, science, and medical devices. The measured noise levels at this frequency with the respective attention are: -97 dBm (*Apt*, *Inst*, *Lab*, *Cage*, *Mtn f*, *Mtn b*, *DRAO*); -87 dBm (*Hub*, *Rural*); - 7 dBm (*Quad*, *Park*, *Nbhd*).

POWER INTENSITY

In Table 1 we present the power intensities for the five strongest signals we observed, all of which are in the cell phone bands, and compare these powers to the exposure limits published by Health Canada. To calculate the power intensity, S [W m^{-2}], we use

$$S = \frac{10^{P/10}}{1000}\frac{4\pi}{\lambda^2 G} ,$$

where P is the measured power [dBm], λ is the wavelength of interest [m], and G is the gain of the antenna. The gain of the antenna is found by calculating

$$G = 10^{\frac{g}{10}} ,$$

where g is the gain in dBi (decibel in relation to an isotropic antenna), which is provided by the manufacturer for all frequencies in the antenna's range. This calculation is relating the received power from the effective aperture of the antenna and assumes the antenna is receiving the maximum power from the incoming radiation.

TABLE 1

Power intensity [in W m^{-2}] of the five strongest signals we measured. The signals were averaged across a 2-minute observation. Health Canada exposure limits are shown for the relevant frequency.

Location	Frequency (MHz)	Avg. Power (dBm)	Std. Dev. (dBm)	Avg. Power (10^{-6} W m^{-2})	Health Canada Limit (W m^{-2})
Quad	876	-37.76	3.16	17.3	2.69
Quad	1986	-45.02	2.95	12.5	4.70
Nbhd	1945	-45.72	1.51	9.4	4.63
Hub	1971	-59.33	5.09	0.4	4.67
Inst	1970	-59.54	3.19	0.5	4.67

Exposure limits are determined by Health Canada from numerous studies investigating the effects of RF exposure on the human body [1]. The exposure limit is determined as the lowest strength of field for which there has been an identified health concern, with a margin for safety. The calculated limits for a 6-minute exposure, in power density S_{RL} [W m^{-2}], for the 300 MHz to 6 GHz range can be expressed by

$$S_{RL} = 0.02619 f^{0.6834} \quad ,$$

where f is the frequency of interest, in units of MHz [1].

The strongest power density we measured is more than a million times lower than the exposure limit. Similarly, Kwan and Fapojuwo [9] also found the strongest consistent signal to be in an open area near a cell phone tower with a power density of 4×10^{-5} W m^{-2}. While this is comparable to our strongest signal (Table 1), they are both still much smaller than the recommended safe limit.

For comparison, one of the strongest extragalactic radio signals, the supernova remnant Cassiopeia A, was 2.7×10^{-23} W m^{-2} Hz^{-1} at 1 GHz in 1980 and has been decreasing in strength over time [22]. Many other radio sources are on the order of 10^{-25} to 10^{-24} W m^{-2} Hz^{-1} [23]. The units include Hz^{-1}, indicating the detector bandwidth must be taken into consideration. For example, if a detector has a 1 GHz bandwidth, the power density would then be around 10^{-14} W m^{-2}. Clearly, astronomical signals are much weaker than anthropogenic signals, justifying the protective measures and radio-quiet zones in place at radio observatories.

CONCLUSIONS

The radio window of our atmosphere is partitioned and allocated for use, including cellphone communication, satellite television, and research in space and astronomy. As radio astronomers, we were curious about the RF intensity present in our daily lives, and how RF intensities generated by industries compared to the signals we study from outer space.

We presented the average spectral distribution and maximum power intensities for five RF bands covering well-used portions of the radio spectrum in several different environments. The spectral distributions found were variable and environment dependent. What we found particularly interesting was that many cell phone bands had signals that were stronger in outdoor, public locations than in indoor environments. By contrast, signals in the unlicensed ‘industrial, science and medical devices’ band we investigated were stronger in indoor public places rather than outdoors. Finally, in the radio astronomy bands we explored, it was clear that radio-quiet zones at astronomical observatories are essential in efforts to reduce radio frequency interference, especially since portions of the radio spectrum allocated for radio astronomy are also used by various private services.

At radio observatories, there is continuous monitoring and mitigation of RFI. Current efforts are being directed towards the risk of satellite-produced interference — technology that is changing the feasibility of ground-based astronomy. How, then, are these satellites changing the radio exposure of our everyday environments?

ACKNOWLEDGEMENTS

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REFERENCES

1. Consumer and Clinical Radiation Protection Bureau, Industry Canada, “Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3kHz to 300GHz” [Online], Safety Code 6, https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/consult/_2014/safety_code_6-code_securite_6/final-finale-eng.pdf (2015).
2. United States Federal Communications Commission, “RF Safety FAQ” [Online] https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q18 (accessed Oct 2024).
3. W. van Driel, “Radio quiet, please! – protecting radio astronomy from interference”, Proceedings of the International Astronomical Union **5**, 457-464 (2009).
4. A. Hill, A. Gray, private communication.

5. D. Mertely, R. Ridgeway, C. Patscheck, E. Reynolds, K. Shores, N. Thomas, R. Tapia, “VLA Site Spectrum Survey: 2-18 GHz Results” (EVLA Memo 54) [Online], https://library.nrao.edu/public/memos/evla/legacy/evlamemo54.pdf (2003).
6. G. Siringo and S. Dougherty, “ALMA Spectrum and Radio Frequency Interference” (ALMA White Paper) [Online], https://library.nrao.edu/public/memos/rfi/RFI_152.pdf (2023).
7. C. De Pree, W. Armentrout, T. Beasley, U. Rao, F. Schwab, S. Wasik, “Coordinated GBT-Starlink Tests (April-July 2023)” (NRAO RFI MEMO Series No. 154) [Online] https://library.nrao.edu/public/memos/rfi/RFI_154.pdf (2023).
8. D. Grigg, S.J. Tingay, M. Sokolowski, R.B. Wyath, B. Indermuehle, S. Prabu, “Detection of intended and unintended emissions from Starlink satellites in the SKA-Low frequency range, at the SKA-Low site, with an SKA-Low station analogue”, Astronomy & Astrophysics **678**, L6 (2023).
9. J.C. Kwan, and A.O. Fapojuwo, “Measurement and Analysis of Available Ambient Radio Frequency Energy for Wireless Energy Harvesting”, 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall), 1-6 (2016).
10. T.L. Landecker, *et al.*, “The Synthesis Telescope at the Dominion Radio Astrophysical Observatory”, Astron. Astrophys. Suppl. Ser. **145**, 509-524 (2000).
11. Keysight Technologies, “N9340B Handheld Spectrum Analyzer (HSA) 3 GHz - Technical Overview” [Online], https://literature.cdn.keysight.com/litweb/pdf/59897847EN.pdf?id=1398700 (2016).
12. Kaltman Creations LLC, “Radial Isotropic Broadband Antenna OmniLOG® 90200” [Online], https://aaroniausa.com/wp-content/uploads/2015/10/OmniLOG_90200.pdf (2013).
13. Industry Canada, “Canadian Table of Frequency Allocations” [Online], http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10759.html (2018).
14. Industry Canada, “SP 450 MHz — Spectrum Utilization Policy for the Frequency Bands 450-451 MHz and 455-456 MHz and also Part of the 150 MHz Band Used in Support of Broadcasting Operations and the Frequency Band 409-410 MHz and 420-421 MHz Used by the Mobile Radio Service” [Online], http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01053.html (1986).
15. J.M Dickey, and F.J. Lockman, “HI in the Galaxy”, Annu. Rev. Astron. Astrophys. **28**, 215261 (1990).
16. Industry Canada, “Policy and Technical Framework, Mobile Broadband Services (MBS) — 700 MHz Band, Broadband Radio Service (BRS) — 2500 MHz Band” [Online], http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10124.html(2012).
17. Industry Canada, “Consultation on the Spectrum for Advanced Wireless Services and Review of the Mobile Spectrum Cap Policy” [Online], http://www.ic.gc.ca/eic/site/smtgst.nsf/eng/sf08093.html (2019).
18. C.D. Taylor, S.J. Gutierrez, S.L. Langdon, K.L. Murphy, and W.A. Walton III, “Measurement of RF Propagation into Concrete Structures over the Frequency Range 100 MHz to 3 GHz”, Wireless Personal Communications, The Springer International Series in Engineering and Computer Science (Communications and Information Theory) **377**, 131-144 (1997).
19. S.H.S. Al-Bazzaz, “Theoretical Estimation of Power Density Levels Around Mobile Telephone Base Stations”, Journal of Science and Technology **13**(2), 3-16 (2008).
20. Federal Communications Commission, “Human Exposure to Radio Frequency Fields: Guidelines for Cellular Antenna Sites” [Online], https://www.fcc.gov/consumers/guides/humanexposure-radio-frequency-fields-guidelines-cellular-and-pcs-sites (2018).

21. Industry Canada, “Commercial Mobile Spectrum Outlook” [Online], http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09444.html (2013).
22. J.W.M Baars, R. Genzel, I.I.K Pauliny-Toth, A. Witzel, “The Absolute Spectrum of Cas A; An Accurate Flux Density Scale and a Set of Secondary Calibrators”, Astronomy & Astrophysics **61**, 99-106 (1997).
23. R.A. Laing, J.M. Riley, and M.S. Longair, “Bright Radio Sources at 178 MHz: Flux Densities, Optical Identifications and the Cosmological Evolution of Powerful Radio Galaxies”, Mon. Not. R. Astr. Soc. **204**, 151-187 (1983).

FROM UNDERREPRESENTED TO UNSTOPPABLE: BUILDING INCLUSIVE STEM COMMUNITIES

SUMMARY: The CISE Atlantic Team is committed to building and enhancing inclusive STEM education, research and workplace ecosystems in Atlantic Canada (https://ciseatlantic.ca/).

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The Chairs for Inclusion in Science and Engineering (CISE) is a Natural Sciences and Engineering Research Council of Canada (NSERC) program that supports a team of researchers to advance a culture of inclusion in science, technology, engineering and mathematics (STEM) by undertaking initiatives to enhance equity, diversity and inclusion and to reduce barriers faced by underrepresented populations. The CISE program evolved from NSERC's current Chairs for Women in Science and Engineering (CWSE) program. The inaugural CISE chairholders are from Atlantic Canada and were announced in September 2023: Dr. Svetlana Barkanova (**SB**, Physics Program, School of Science and the Environment, Grenfell Campus, Memorial University of Newfoundland), Dr. Kevin Hewitt (**KH,** Department of Physics and Atmospheric Science, Dalhousie University) and Dr. Stephanie MacQuarrie (**SM**, Department of Chemistry, Cape Breton University). Japna Sidhu-Brar (**JSB**, Program Manager) and Kathryn White (**KW**, Project Coordinator) have joined the team. I first interacted with the CISE Atlantic Team in March 2024 on their "Physics in the Rural Classroom" initiative. I am also well aware of the Chairs' previous work to advance equity, diversity and inclusion in STEM and specifically Drs. Barkanova and Hewitt within the CAP and across our national physics community. This is important work that I believe needs to be highlighted, shared and supported.

To celebrate the first year of the CISE program, I interviewed the inaugural CISE Atlantic team members. I sent each team member a list of questions related to the program objectives, challenges, activities and outcomes. Their responses below are unedited to maintain their authentic voices. The responses presented here represent a subset of the total responses. The full interview will be linked to the *Physics in Canada* website.

WHAT ARE SOME OF THE KEY OBJECTIVES FOR THE CHAIRS FOR INCLUSION IN SCIENCE AND ENGINEERING (CISE) PROGRAM?

JSB: The main objectives of CISE-Atlantic are threefold, with programs and initiatives typically falling within:

1. Recruitment into, retention within and talent development for Equity-Deserving Groups in Science, Technology, Engineering and Mathematics from K-16 and into employment.
2. Catalyzing policy and systemic change to dismantle barriers to opportunity through connection-building.
3. Development of quality measurements, output, literature and resources to advance success in STEM through learning, collaboration and research.

Our programs and initiatives are all rooted in a social justice and equity ethic framework, i.e., a framework that recognizes a principled concern for reducing racial and other social inequities through and within STEM [1]. Our work is further guided by a multiple paradigm approach across a K-16 model of education, examining pipeline, pathway and ecosystem approaches to inclusion in STEM by supporting students' transition from high school to college, technical training, or other options for post-secondary learning. In this way, we strive for a diversity of programming that accounts for a diversity of needs, including rural and remote accessibility considerations.

Our work includes analyzing evaluation practices and developing promising measurement tools to gauge impact and effectiveness of all programs and initiatives. Ultimately, this work cannot be done individualistically or within silos. Hence, our program is underpinned by synergistic and meaningful collaborations and partnership-building.

WHY DID YOU DECIDE TO TAKE ON THIS ROLE?

SM: I joined CISE-Atlantic to work with a dedicated team advancing inclusion in STEM through systemic change, equity-driven programs, and meaningful collaborations. Contributing regionally and nationally to initiatives that connect equity-deserving groups with STEM opportunities resonated with me. As a white, neurotypical cisgender woman, I recognize my privilege but also the challenges of growing up in a rural area with limited STEM access. With this team, we're creating accessible pathways to STEM education and careers. Our program applies research, policy, and community engagement to dismantle barriers and drive measurable change.

JSB: The simple answer is that I like to help people and my community - whether that is a community of women, scientists, fellow workers, trade unionists, Black, Indigenous and Peoples of Colour etc. As a STEM educator (and astronomer), I am motivated by a desire to learn and share knowledge, to create spaces of mutual growth and understanding. As the CISE-Atlantic Program Manager, I am able to leverage my skills and experience as our team works collaboratively with many partners towards restorative and transformative spaces for equity-deserving groups in STEM. I believe that this is what we, as humans, owe to one another - the right to a life of dignity and authenticity.

KH: I decided to take on this role to learn from others that have created successful programs serving underserved communities in STEM, and to share the lessons learned from my own experience of creating long-lasting and successful organizations such as the Imhotep's Legacy Academy. When one enters conversations with humility, a great deal of good can emerge. "Certainty is the enemy of unity." Certainty in the context of Physics is an expectation, certainty in the face of the complexity of human behavior – the mission in which we are engaged - is a recipe for disaster. So, I engage in these conversations with the knowledge that the context will inevitably differ and we must listen meaningfully to uncover that nugget, or gold mine, of information that can apply to our own initiatives, enhancing its chances of success. I am intrigued by what we could do collectively - with the expectation that the whole is greater than the sum of its parts.

KW: I work with CISE Atlantic because I am passionate about knowledge mobilization, science promotion and community outreach. Our work reduces barriers to STEM for equity-deserving groups across Atlantic Canada. I previously worked as an Indigenous community liaison, helping link research projects with local Indigenous community priorities and ways of knowing. Knowledge mobilization, as defined by SSHRC, is a term used to describe a wide range of research activities, including knowledge synthesis, dissemination, transfer, exchange, and co-creation by researchers and knowledge users [2]. As liaison, I saw a lot of hesitancy from Indigenous communities towards STEM, communities often felt unreflected in the scientific community. Our team works to combat these inequities by ensuring that STEM topics are accessible and inclusive for all. By exposing equity-deserving communities from across Atlantic Canada to diverse STEM role models and perspectives, we are actively promoting pathways to STEM education and employment for all.

SB: While living in Latvia had its challenges, it was not until I moved to Canada that I was introduced to biases like "women are not good at math." I was asked if I was a mail-order bride, so I joked that I was a mail-order physicist! It broke my heart to see female students struggling with imposter syndrome. While tutoring female Indigenous students at the University of Manitoba, a physics textbook reference confused us all, assuming we all had the same experiences as the author. Fortunately, textbooks have improved, like "ASTRO" (2020) by Ghose, Milosevic-Zdjelar, Read and Reid, which intentionally includes multicultural examples. A newcomer to Canada, I was fortunate to find support systems, but would I stay in physics if I had landed in a less diverse and supportive community? I am not sure. Now, with funding from NSERC and Cenovus, we can change these environments so that they are more inclusive!

WHAT ARE SOME OF THE CHALLENGES THAT YOU SEE NEED TO BE ADDRESSED TO ENHANCE INCLUSION IN SCIENCE/PHYSICS?

JSB: Enhancing inclusion in science, and physics in particular, means understanding and acknowledging the inherent structures of power within academia and education, and how that has impacted the nature and quality of research that is pursued. What kinds of research are celebrated, and which ones are ignored? As scientists, we should counter the notion or assumption that the physical sciences are simply "objective" endeavours, that the consequences of discovery can be ignored for this so-called "pursuit of truth" or that the act of discovery can be divorced from its ultimate impact on ourselves, our neighbours, our global communities. Scientific endeavours are inherently human, susceptible to human biases and the legacy of inequity, exclusion and exploitation within the wider society. There is work being done towards cultivating this kind of lens within science and Physics - we have come far but we still have a long way to go, together.

KH: Inclusion is an outcome, exemplified by a sense of Belonging, created when systemic barriers are identified and removed through the process of equity. I've often heard sentiments like "Oh, well we have a person of color on this committee or that, so we've solved the problem." While there is a correlation between inclusive outcomes and diversity, there is more to unpack. If we do not remove systemic barriers, existing exclusionary practices continue to be perpetuated, including by those from equity-deserving groups themselves. This is unsurprising as we have not reckoned with the system itself that measures success as adherence to the dominant group mindset or behavior. We have to guard against complacency in our work in transformative justice.

Removing systemic barriers needs meaningful input from those who are subject to the system - the students, and especially those who leave Physics. Surveys need to focus on these individuals and explore their motivations. If, for example, they do not see the connection between Physics and their own social justice principles, how can the Physics community reach out and acknowledge those motivating factors? Deeply consider what role Physics plays in response to social injustice faced by their communities. In my own research, I combine Physics with Black and African Diaspora Studies, pursuing interdisciplinary work that addresses Black women's health. When we make the connections clear between Physics, community and social justice, we may be able to draw those students to Physics, highlighting it as a field that can be rooted in humanity.

WHAT ACTIVITIES AND/OR INITIATIVES ARE YOU WORKING ON (UNDER DEVELOPMENT OR UNDERWAY) IN ATLANTIC CANADA?

KW: One program we're working on is the Physics in the Rural Classroom (PiRC) pilot program (2024-2026). This program addresses the challenge of delivering quality physics education in rural Atlantic Canadian schools. Designed for educators teaching Grades 7-12, PiRC aims to enhance physics instruction through online curriculum-aligned workshops and career exploration sessions. Collaborating with teachers and STEM professionals, the program provides equitable access to physics content while exposing learners to diverse career pathways and inspiring role models, particularly from equity-deserving groups.

The pilot will deliver 64 interactive workshops annually, targeting physics curriculum objectives and supporting educators in schools lacking specialized physics teachers or resources. Educators gain access to tailored professional learning opportunities and an expanding network of peers. STEM volunteers contribute by delivering virtual talks, which are developed with comprehensive training in science communication and cultural inclusivity, ensuring engaging and meaningful student interactions.

Key outcomes include increased educator confidence in teaching physics, greater student interest in physics careers, and strengthened ties between STEM professionals and rural communities. With its scalable model and sustainability-focused partnerships, PiRC aims to create lasting impacts on physics education in Atlantic Canada and beyond.

KH: We are also in the process of launching the three-year Bringing STEM to Life: Work-Integrated Learning Program in Physics - Nova Scotia Pilot Program 2025! A free four-week summer hybrid program that bridges work experience, mentorship, and high school Physics credit achievement, it is designed to support Black and African Nova Scotian High School learners as they decide whether to pursue careers in Science, Technology, Engineering, Math (STEM). The Program's basis is the successful Work-Integrated Learning Program established by Lisa Cole, Director of Programming of York University's k2i Academy. W-IL Physics is a collaboration between k2i Academy, the McDonald Institute, the Africentric Math cohort (AMC) program and Imhotep's Legacy Academy (ILA).

20 high school learners from participating schools will be hired by Dalhousie University as Lab Assistants. Learners will work on STEM research projects based on local research and the United Nations' Sustainable Development Goals. Hands-on STEM activities will facilitate the learners' understanding of Physics concepts and the development of their research projects. Activities will be designed and delivered by a team of Undergraduate Mentors, who will work closely with Dalhousie Faculty Members and a High School Physics teacher to ensure provincial curriculum alignment and achievement of a Physics credit.

The three-year period is a critical timeframe in which to evaluate and improve practice, assessing the significance of work-integrated learning opportunities in STEM at an academic juncture where many learners avoid a critical subject (Physics) that would take them along STEM pathways. We will be looking to maintain W-IL in Physics within the Nova Scotia education system and expand its reach, including by integrating Summer Internship pathways. Leveraging connections to regional and National networks, there can be crossover work with BESTSTEM, a national network of out-of-school-time programs, supporting Black, Indigenous, and LatinX learners.

WHAT DO YOU HOPE TO ACHIEVE DURING YOUR TENURE AS CHAIRS?

SM: As one of the three NSERC CISE Atlantic Chairs, one of my biggest priorities is making sure rural and underrepresented students see STEM as a place where they belong. That means building and expanding programs that don't just introduce students to science and technology but actually keep them engaged and supported along the way. For too long, we've asked students to overcome barriers that shouldn't exist in the first place. Our team is focusing on fixing the system, not the students, and that means addressing the structural challenges that keep underrepresented groups from accessing STEM. Through policy and institutional change, we are working with educators and policymakers to embed equity and diversity into STEM education policies. We are also working to ensure that outreach, mentorship, and community engagement is recognized and valued in the academic tenure and promotion process. We know impact comes not just from reaching large numbers of students but from meaningful, sustained engagement, ensuring youth, partners, and collaborators all feel supported and inspired in STEM. By working as a team, we will create a stronger, more inclusive STEM ecosystem in Atlantic Canada, one where opportunities aren't determined by geography, background, or circumstance.

SB: As a woman and an immigrant, I learned that diversity does not guarantee inclusion, but I found a support network in the CAP community. Now, one of my goals is to contribute to the development of the national and international networks, and to involve academia and industry groups to expand “Physics in Rural Classroom” nationwide. Achieving equity and inclusion in physics remains a long-term challenge [4], but data collection such as CanPhysCounts [5] and grassroots initiatives help drive systematic change. The Chairs for Women in Science and Engineering (CWSE) have led transformative work for over three decades [6], and we are working with the National Network on new initiatives in the Northwest Territories and Nunavut, to truly make a lasting impact cost-to-cost-to-coast. Another key network I rely on is my own research community, organized around the Canadian Institute of Nuclear Physics, the Institute of Particle Physics, the McDonald Institute, TRIUMF and SNOLAB, many of which are partnering with us on outreach initiatives. As equity, diversity and inclusion become central to the long-term planning in subatomic physics [BD9], my dream is to help build the “Network of Networks” in Canada to work for inclusion in STEM at the national level.

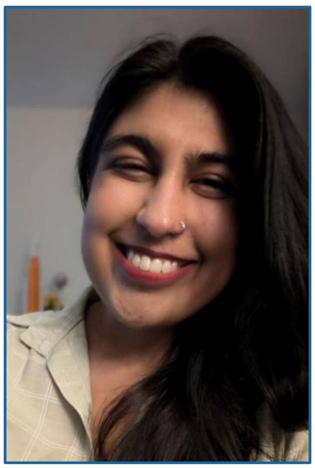
KH: During the women’s movement in the 60s and 70s, Women of Colour were left behind, giving rise to the need to recognize intersectionality, as coined by Kimberlé Crenshaw. If you look at the proportion of Women in STEM in leadership roles in Canada, it remains white dominated. It is clear, institutional STEM leadership needs to pay more attention to ensuring the success of Women of Colour in STEM. If you’re reading this and are in a position to elevate, celebrate or even step aside for a Woman of Colour in STEM, do it.

CISE Atlantic recognizes we must also collectively address the severe underrepresentation of Blacks in STEM in Canada. Only 1% of respondents to the aforementioned CanPhysCounts Survey self-identified as Black and stated possessing or pursuing degrees in Physics in Canada. In this era of nationalistic fervor where the movement of people and goods face ever increasing barriers, Canada's success will be determined by its ability to engage those at home, including the future 15% of the population under fifteen who self-identify as Black. We can't afford to leave them behind because with a more diverse STEM workforce, inclusive of Black Canadians, our innovation and discovery goals are that much closer and brighter.

Finally, having been the lonely only Black Physics professor in Canada for a large part of my career, I would like to highlight and address the isolation felt by Blacks in Physics. Looking at the success of Imhotep’s Legacy Academy during its 22-year existence, we can see how the creation of programs to serve the diverse needs of the Black learner could lead to amazing outcomes when one focuses on the system. I would like to translate some of that hard earned success to other marginalized communities, always applying the principle of “nothing about us without us.”

INFORMATION ON CISE-ATLANTIC TEAM MEMBERS

KW: Kathryn is a young Indigenous woman passionate about community engagement. Growing up and living in rural Newfoundland, she understands the diverse needs of rural and remote communities throughout Atlantic Canada. Kathryn is the Project Coordinator for CISE Atlantic at Grenfell Campus in Corner Brook, Newfoundland and Labrador. She completed her B.Sc. (Hons) in Geography and Biology at Memorial University (2020) and has a Certificate in Public Policy. Keen to understand the diverse and varied needs of organizations, teams, and individuals, Kathryn is completing her Master of Management at Grenfell Campus. Deeply involved in her community, she serves on the Board of Directors for the Elmastukwek Mawio'mi and is the Commanding Officer of the 511 Humber Royal Canadian Air Cadet Squadron. During the sunnier months of the year, Kathryn also works as a flight instructor within the Air Cadet Gliding Program. Since 2017 she's helped instruct and mentor over 100 young aviators from across Canada to earn their Transport Canada Glider Pilot licence.



JSB: Japna Sidhu-Brar (she/her/elle) is the Program Manager for CISE-Atlantic, whose activism and 10 years as a science communicator underpin her ongoing commitments to eradicating barriers to inclusion in STEM. Japna graduated from Mount Allison University in 2014, majoring in Physics and minoring in Astronomy, Mathematics and Philosophy. She has training in matters related to Human Rights, EDIA, and Anti-Oppressive Practice, growing out of her time with Unifor, the largest private sector union in Canada, in her roles as a Union Representative at Local and Regional Levels, the Atlantic Racial Justice Liaison, and a Discussion Leader. Additionally, Japna has a leadership certificate in Equity, Diversity and Inclusion from Dalhousie University's Faculty of Open Learning and Career Development. She has served as a Board member for Our Times Magazine and currently sits on the Board of Directors for Youth Science Canada. She is a part-time Organizer for the Public Service Alliance of Canada, and plays a Bugbear named Shump in a Dungeons and Dragons campaign.

SM: Dr. MacQuarrie is the Dean of Science and Technology and Full Professor of Organic Chemistry at Cape Breton University and NSERC Chair for Inclusion in Science and Engineering. Originating from Nova Scotia, she obtained her B.Sc. from Mount Allison University in 1996 starting her research career with Dr. Langler studying thiols. She continued to pursue chemistry in graduate school at Virginia Polytechnic Institute and State University where she earned her Ph.D. in organic chemistry practicing asymmetric synthesis. In Dr. Crudden's group at Queen's University during her post-doc, she had the opportunity to step outside of organic and into materials and metals. Now at CBU, Stephanie's research includes finding high value applications for waste streams, reducing the total carbon footprint of advanced materials and the development of functional materials for electronics, catalysis and absorption. With her partner she has raised three awesome kids in Cape Breton and they enjoy hosting visitors on North America's #1 Island!

KH: Dr. Hewitt is a full Professor in the Department of Physics & Atmospheric Science at Dalhousie University, inaugural Associate Dean of Equity and Inclusion for Dalhousie's Faculty of Science, and Natural Sciences and Engineering Research Council of Canada Atlantic-region co-chair for Inclusion in Science & Engineering. In his Bionanophotonics lab, he's developing novel nanoparticle probes for bioimaging and treatment, optical imaging approaches combining Holography and Raman Spectroscopy, and a prototype medical diagnostic tool for liver transplantation and uterine fibroids applications. Completing his B.Sc. in Physics & Biology at the University of Toronto (1992), he received the UofT Physics prize. At Dalhousie he unified his deep and abiding interests in science and community engagement by co-founding (in 2003) the award-winning Imhotep's Legacy Academy, a STEM outreach program for Black students from junior high to university and established in 2021 the Canadian Black Scientists Network Youth regional science fair. He's featured in Cool Black North, a film which explores the unique and vibrant Canadian Black Community and was a guest on CBC Ideas. He's been recognized with the top awards for science promotion in the province (Nova Scotia Discovery Centre Science Champion, 2018) and country (NSERC Award for Science promotion, 2021). His community engagement has been recognized with Nova Scotia's Queen Elizabeth II's Platinum Jubilee medal (2023) and Youth Community Service Award in British Columbia (1999). National awards for professional excellence (Harry Jerome Award for Professional Excellence, 2014), service to students at Dalhousie (Rosemary Gill award, 2021) and international leadership (2025 Robert Holland Jr. Award for Excellence in Research and Leadership) round out the breadth and depth of his contributions.

SB: Dr. Svetlana Barkanova is a professor of physics at Grenfell Campus, MUN. She began her career at the Nuclear Research Center in Latvia in 1994, moved to Canada in 1998 to expand her expertise, and earned a Ph.D. in Theoretical Subatomic Physics from the University of Manitoba in 2004. An internationally-recognized researcher, Dr. Barkanova seeks to uncover the fundamental building blocks of the universe and their interactions, with emphasis on hadron structure and multi-loop calculations for precision experiments. Throughout her career, Dr. Barkanova has been committed to improving diversity, equity, and inclusion in research and education, and developed a wide coast-to-coast-to-coast professional network. She has served on Boards such as WISE NL and Science Atlantic, held leadership roles within the CAP, including chairing the Division of Theoretical Physics and the Division for Gender Equity in Physics, organized national and international conferences, and contributed her expertise to grant and prize selection committees. An award-winning teacher and dynamic public speaker, she is passionate about science outreach and enjoys sharing her love for physics with audiences of all ages.

CONCLUSION

The CISE Atlantic Team is now more than one year into a 5-year funded program. Their individual perspectives on and passion for equity, diversity and inclusion are certainly front and center in this interview. Their ongoing initiatives and the early outcomes are fantastic, and I believe are positioned to advance inclusion in STEM in Atlantic Canada and nationally. More information on the CISE Atlantic initiatives and how you can get involved can be found on their website (https://ciseatlantic.ca/). The national CISE program is ongoing, next accepting team applications from the province of Quebec, for a start date of September 1, 2025.

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REFERENCES

1. E.O. McGee, D. Naphan-Kingery, M.L. Miles, and O. Joseph, How Black Engineering and Computing Faculty Exercise an Equity Ethic to Racially Fortify and Enrich Black Students, J. High. Educ., **93(5)**, 702–734 (2022). https://doi.org/10.1080/00221546.2022.2031704
2. SSHRC (2023, November 24). Guidelines for Effective Knowledge Mobilization. https://www.sshrc-crsh.gc.ca/funding-financement/policies-politiques/knowledge_mobilisation-mobilisation_des_connaissances-eng.aspx
3. E.O. McGee, *Brown, Bruised: How Racialized STEM Education Stifles Innovation* (Harvard Education Press, Cambridge MA, 2020).
4. S. Barkanova, G. Grinyer, J. Mammei, C. Sealfon, A. Smolina, “Striving for Equity in Canadian Physics”, ICWIP 2023.
5. E. Hennessey, A. Smolina, S. Hennessey, A. Tassone, A. Jay, S. Ghose, K. Hewitt, Canadian Physics Counts: An exploration of the diverse identities of physics students and professionals in Canada, https://arxiv.org/abs/2403.04679 (2024).
6. C. D'Amours, H. Young, C. Mavriplis, *The Chairs for Women in Science and Engineering Program - Thirty Years of Action Across Canada, from 1989 to 2021* (Springer, New York NY, 2024).

Student Competitions 2024 Compétitions étudiantes

The CAP would like to thank and congratulate everyone who participated in this year's Best Student Presentation Competition, including 168 student competitors and the 49-member judging team and to thank everyone who attended the talks and visited the posters. Your support and participation was vital to the success of the event.

As always, this year was met with a series of fantastic poster and oral presentations and all presenters should be proud of their hard-work and accomplishments!

L'ACP tient à remercier et à féliciter tous ceux qui ont participé au concours du meilleur présentation d'étudiant de cette année, y compris les 168 étudiants concurrents et les 49 membres de l'équipe de juges, et à remercier tous ceux qui ont assisté aux présentations et visité les affiches. Votre soutien et votre participation ont été essentiels à la réussite de l'événement.

Comme toujours, cette année a été marquée par une série de présentations orales et d'affiches fantastiques et tous les présentateurs peuvent être fiers de leur travail et de leurs réalisations !

CAP Overall Student Poster Awards

PLACEMENT	NAME/AFFILIATION
First	Jennika McIntosh, University of Guelph
Second (tie)	Casee Griffith, Western University
Second (tie)	Sydney Wilson, Western University
Honourable Mentions	(in alphabetical order) Audren Dorval (Université de Montréal), Abo-bakr Emara (Carleton University) and Irfan Javed (University of New Brunswick)

CAP Overall Student Oral Presentation Awards

PLACEMENT	NAME/AFFILIATION
First	Nathan Drouillard, University of Windsor
Second	Lauren Dutcher, McMaster University
Third	Robin Coleman, University of Guelph
Honourable Mentions	(in alphabetical order) Dean Eaton (University of Waterloo), Zhihua Han (Simon Fraser University), Farah Kamar (Western University), Juliette Letellier-Bao (École Polytechnique de Montréal) and Evan Vienneau (University of Alberta)

CAP DIVISION STUDENT POSTER AWARDS

DIVISION OF ATOMIC, MOLECULAR AND OPTICAL PHYSICS CANADA	
PLACEMENT	**NAME/AFFILIATION**
First	Casee Griffith, Western University
Second	Darij Starko, York University

DIVISION OF GENDER EQUITY IN PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Jennika McIntosh, University of Guelph

DIVISION OF NUCLEAR PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Jennika McIntosh, University of Guelph

DIVISION OF PHYSICS IN MEDICINE AND BIOLOGY	
PLACEMENT	**NAME/AFFILIATION**
First	Sydney Wilson, Western University
Second	Leah Devos, University of Toronto
Third	Kadia Malik, University of Windsor

DIVISION OF THEORETICAL PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Irfan Javed, University of New Brunswick, Fredericton

PARTICLE PHYSICS DIVISION	
PLACEMENT	**NAME/AFFILIATION**
First	Audren Dorval, Université de Montréal

CAP DIVISION STUDENT ORAL PRESENTATION AWARDS

DIVISIONS OF APPLIED PHYSICS AND INSTRUMENTATION, PHYSICS EDUCATION, AND PLASMA PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Emily Tracey, Western University
Second	Melissa Baiocchi, Queen's University

DIVISION OF ATOMIC, MOLECULAR AND OPTICAL PHYSICS, CANADA	
PLACEMENT	**NAME/AFFILIATION**
First	Nathan Drouillard, University of Windsor
Second	Evan Petrimoulx, University of Windsor
Third (tie)	Sage Buchanan, Western University
Third (tie)	Robert Gerstner, Western University

DIVISION OF CONDENSED MATTER AND MATERIALS PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Lauren Dutcher, McMaster University
Second	Connor Wilson, Brock University

DIVISION OF NUCLEAR PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Robin Coleman, University of Guelph
Second	Paul Deguire, University of Guelph
Third	Thomas Hepworth, University of Winnipeg

DIVISION OF PHYSICS EDUCATION	
PLACEMENT	**NAME/AFFILIATION**
First	Victoria Arbour, University of Guelph

DIVISION OF PHYSICS IN MEDICINE AND BIOLOGY	
PLACEMENT	**NAME/AFFILIATION**
First	Farah Kamar, Western University
Second	Nicholas Palmersley, University of Manitoba
Third (tie)	Sylvia Luyben, University of Guelph
Third (tie)	Nitara Fernando, Western University

DIVISION OF PLASMA PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Juliette Letellier-Bao, École Polytechnique de Montréal
Second	Sean Watson, École Polytechnique de Montréal

DIVISION OF QUANTUM INFORMATION	
PLACEMENT	**NAME/AFFILIATION**
First	Zhihua Han, Simon Fraser University

DIVISION OF THEORETICAL PHYSICS	
PLACEMENT	**NAME/AFFILIATION**
First	Dean Eaton, University of Waterloo
Second	Muhammad Muzammil, University of New Brunswick, Fredericton
Third	Jonathan Barenboim, Simon Fraser University

PARTICLE PHYSICS DIVISION	
PLACEMENT	**NAME/AFFILIATION**
First	Evan Vienneau, University of Alberta
Second	Emma Ellingwood, Queen's University
Third	Nicholas Swindinsky, Queen's University

HYDROGEN DETECTION IN SURFACE ANALYSIS: BEST PRACTICES AND STANDARDS

SUMMARY: The quantitative nature of elastic recoil detection analysis (ERDA) complements the superior depth resolution of secondary ion mass spectroscopy (SIMS) for hydrogen detection and depth profiling. Unlike SIMS, ERDA achieves direct quantification of elemental concentrations without reliance on standards based on the fundamental principles of Rutherford scattering cross sections.

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CASEE GRIFFITH RECEIVED 2ND PLACE IN THE 2024 CAP BEST OVERALL STUDENT POSTER PRESENTATION

Many alternative energy technologies involve hydrogen generation, transport and storage [1]. Understanding hydrogen-related processes is challenging, as hydrogen's physical properties make it inherently difficult to detect and quantify. There are two groups of ion beam analysis (IBA) methods that allow us to detect hydrogen: (1) high energy elastic or nuclear reaction techniques and (2) secondary-ion mass spectrometry-based techniques. Both produce information about the compositional changes as a function of depth in materials.

ELASTIC RECOIL DETECTION ANALYSIS (ERDA)

ERDA is an accelerator-based IBA method [2]. 2025 will mark the 50th anniversary of ERDA, a technique developed in Canada. ERDA was invented by two groups from the Laboratoire de Physique Nucléaire at Université de Montréal, and the INRS-Énergie in Varennes, Québec [3]. Since that publication, ERDA has proven to be extremely useful for depth profiling of hydrogen and its isotopes in the near-surface region of materials. The high energy accelerator-based method operates by using a MeV-energy ion beam to eject ions from a sample, detecting the recoiled ions to produce a depth profile (Figure 1(a)). Typical ERDA setups either include a stopping foil to filter the projected ions to a solid-state detector or a time-of-flight (TOF) detection system without the stopping foil. Absolute hydrogen quantification is attainable because ERDA is governed by Rutherford cross-sections for

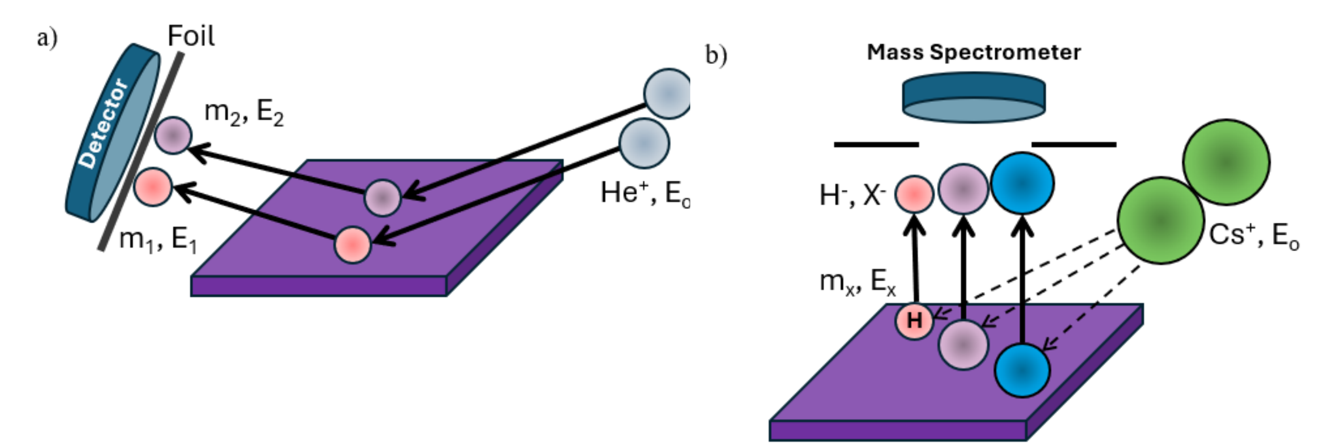

Figure 1. (a) Schematic diagram of ERDA processes. The incident ion (He^+) interacts with the sample and recoils target H^- ions to the detector. The detector measures the energy of the recoiled ions, and the foil filters out incident and other lower in energy ions interfering with the H^- signal, including forward scattered He. E_o is the known incident energy, whereas E_1 represents the detected energy of the recoiled ions. Using E_0 and E_1, a depth profile is constructed; (b) Schematic diagram of D-SIMS processes. The primary ions (Cs^+) sputter the atoms in the impact zone, generating neutral, negative, and positive ions. These secondary ions are separated by a mass spectrometer using the mass-to-charge ratio (m/z). The secondary ions are measured, and the time evolution of the local concentration vs. sputtering time is obtained. To produce a depth profile, additional calculations to convert sputtering time to depth is necessary.

particle scattering (independent of ionization probability), therefore the amount of recoiled hydrogen atoms detected are proportional to that in the sample.

DYNAMIC SECONDARY ION MASS SPECTROMETRY (D-SIMS)

The second group of IBA methods is mass spectrometric techniques including D-SIMS, which can use an accelerator or a keV-energy ion source but at a much lower energy than ERDA. D-SIMS detects hydrogen by analyzing secondary ions sputtered from a surface using an incident beam (Figure 1(b)). Typical setups utilize primary ions of the keV energy range, such as O^+ or Cs^+, to enhance secondary ion yield and achieve precise depth profiling. In SIMS, the incident ion beam sputters the material surface layer by layer, ejecting atoms, molecules, and ions. The secondary ions are detected; and therefore quantification is strongly dependent on the ionization process, which also depends on the composition (matrix effects). While instantaneous intensities can be measured using methods like TOF, one can also plot the temporal evolution of the local concentration to obtain a time profile. The time profile can be converted into a depth profile with the assistance of a profilometry calibration [4].

CALIBRATION STANDARDS

The D-SIMS and ERDA are not without limitations, yet using the techniques together can overcome these challenges. For D-SIMS, quantification is not easily attainable as only a fraction of the atoms sputtered are ionized. Therefore, the counts measured are not proportional to the sample and a calibration standard of the same composition is needed to account for the ionization probabilities. For ERDA, the sensitivity is not sufficient for ultra-low concentration samples, and it has limited mass resolution for isotopic analysis. Therefore, a goal of this study was to produce ultra-thin film hydrogen calibration standards and depth profile them using D-SIMS and ERDA. D-SIMS offers superior depth resolution and chemical specificity whereas ERDA provides accurate hydrogen quantification. Using the techniques in tandem, each one can make up for the limitations of the other and together provide a complete understanding of hydrogen distribution in a material.

METHODOLOGY AND DISCUSSION

FORMING TITANIUM HYDRIDE

To fabricate hydrogen thin-film hydrogen calibration standards, Si (001) wafers were etched in HF and coated with titanium by magnetron sputter deposition to the thicknesses of 20, 50 and 100 nm. Titanium was chosen because titanium hydride phases are well known, and Ti films have strong adhesion and thickness uniformity on Si.

TiH_x formation was achieved via two methods: (1) gas phase annealing (450°C, 1 hour in a forming gas flow (95% N_2, 5% H_2)) [5]; and (2) galvanostatic polarization (20 minutes at -6 mA/cm^2). In a three-compartment electrochemical cell, the Ti/Si (001) sample was submerged in an electrolyte solution of 0.05 M H_2SO_4 with Ag/AgCl as a reference electrode and Pt as a counter electrode. Cyclic voltammetry (CV) was conducted between -3 V and +3 V. Based on the CV, the optimal current density was determined to be -6 mA/cm^2; more details are given here [6].

MEASURING ERDA SPECTRA

The goal of ERDA is often to measure absolute hydrogen concentration in an unknown sample. When collecting ERDA spectra, the area under the peak (integrated area *IA*) represents the measured yield, or the number of detected recoiled particles (Eq. 1) [7].

$$IA = \Omega Q N_H \sigma(E) \frac{1}{\sin \alpha} \tag{1}$$

This yield is directly related to the areal atomic density (N_H) of the target H atoms. The ion beam fluence (Q) reflects the total number of ions striking the target, while $\sigma(E)$, the energy-dependent cross-section, describes the likelihood of scattering events at a given ion energy. The term $\sin \alpha$ is an angular-dependent geometric correction factor. Quantifying the yield of hydrogen from ERDA spectra enables accurate determination of the hydrogen areal atomic density, linking experimental measurements to the underlying material properties.

BEST PRACTICES FOR ERDA

The TiH_x samples were analyzed using a 2.8 MeV ^4He beam in a conventional ERDA setup with an incident angle of 75°, recoil angle of 30° and a 12.3 µm Al-coated mylar range foil in front of the detector in IBM geometry (incident ion beam and detector in the same scattering plane) [8]. Charge collection was monitored by an intermittent Faraday cup that intercepts the beam in front of the target with a duty cycle of 75%. Kapton® was utilized as a primary standard.

Representative ERDA spectra for Kapton® and TiH_x/Si (001) samples are compared in Figure 2. A Si (001) wafer exposed to air for a short period of time was analyzed to estimate possible surface hydrocarbon contamination. The Stopping Range of Ions in Matter (SIMNRA) program was utilized for fitting ERDA spectra, and the near-surface profile of hydrogen distribution was accurately generated [8]. Exhibiting different characteristics, the TiH_x /Si (001) hydrogen spectrum has a narrow peak, whereas the Kapton spectrum has a lower flattened signal that gradually tapers off. The difference in the shapes is due to the stopping power of the material; TiH_x has a much higher stopping power than Kapton. Furthermore, the intensity of the TiH_x peak can be attributed to a higher density of hydrogen present.

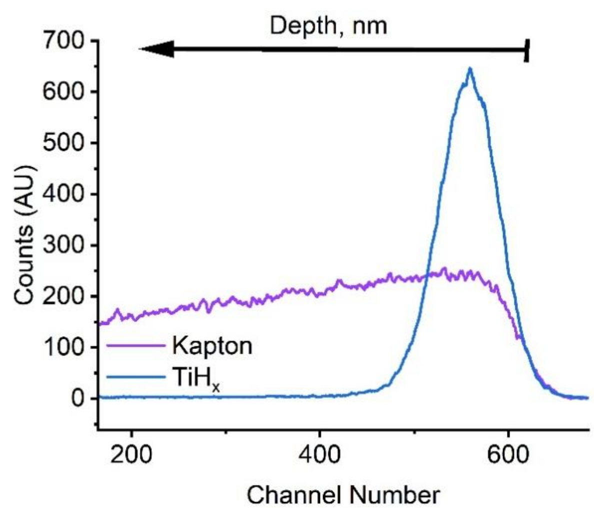

Figure 2. Representative elastic recoil detection spectra for polyoxydiphenylene pyromellitimide (Kapton®) and a 100 nm TiH_x/Si (001) prepared via gas phase annealing.

The TiH_x thin films were analyzed further to assess their efficacy as hydrogen calibration standards. Parameters such as lateral homogeneity, stability over time, and stoichiometries were assessed. To confirm the lateral homogeneity of the hydrogen profile, ERDA measurements were performed on multiple spots of the same sample, separated by at least 1-2 mm. The typical spot-to-spot H peak variation was approximately 2% (calculated from integrated H counts), suggesting a uniform distribution of hydrogen. Additionally, the TiH_x samples were found to be relatively stable over time. Multiple uncertainties are significant for hydrogen quantification (see summary in Table 1). Over a 6-month period, the average integrated H counts for a 100 nm TiH_x sample are ~27 500 and stayed within 3.8% total uncertainty that is associated with ERDA analysis. All measurements fell within ERDA uncertainties, suggesting stability over time when stored under ambient conditions. Finally, the

TABLE 1

All relevant uncertainties that were considered when calculating the relative uncertainty of the integrated counts measured during ERDA.

Quantity	Description	Relative uncertainty (%)
δIA_H	Uncertainty of integrated area, Poisson statistics	0.6
$\delta\phi$	Uncertainty of recoil angle	0.5
$\delta\alpha$	Uncertainty of sample angle	0.5
δIA_{H_Kapton}	Uncertainty of integrated area, Kapton standard	1.0
δN_{H12}	Spot-to-spot H peak variation	2.0
δI	Ion-beam current integration uncertainty	3.0
Total		3.8

thickness of each layer was calculated with exact stoichiometries determined using SIMNRA. The most prevalent stoichiometries for the annealed samples were $TiH_{1.5}$ and TiH_2, whereas the polarized samples predominantly formed $TiH_{1.7}$.

MEASURING SIMS SPECTRA

Measuring secondary ion intensity (Eq.2) for a particular sample is the quantification principle of D-SIMS. The intensity of secondary ions can be expressed by the following:

$$I^T_{X+} = j_p \times A \times Y^T_{X+} \times f \times C^T_{X+} \quad (2)$$

where I^T_{X+} is the measured ion current of X^+ in the matrix T, j_p is the primary ion current density, A is the area of analysis, Y^T_{X+} is the secondary ion yield in the matrix T, f is the instrumental transmission factor for X, and C^T_{X+} is the atomic concentration of X in the matrix T. Secondary ion yield is dependent on the ionization probability, which is strongly influenced by the matrix (chemical environment).

BEST PRACTICES FOR SIMS

D-SIMS was conducted on the TiH_x/Si (001) samples to obtain an elemental depth profile. The samples were analyzed using the Cameca IMS-3f SIMS instrument with the Cs^+ primary beam (40 nA) and secondary ions were detected as negative species. Each analysis area was sputtered in a square of $250 \times 250\ \mu m^2$, with the data collected in a 60-µm diameter area in the middle of the sputtered crater to avoid edge effects. Sputtering time was converted to depth (nm) using profilometry, determining the depth of the crater to be 177 nm. This resulted in a conversion factor of 0.133 nm/s, which is shown on the abscissa of a representative TiH_x/Si (001) D-SIMS spectrum (Figure 3). Note that the Ti signal is higher than the H signal by nearly two orders of magnitude. The ratio between the two signals is not only determined by the difference in concentration of Ti and H in the hydride, but also by the difference in ionization probabilities. Ti, TiH and O signal are persistent at the depth of Si substrate, due to ion intermixing (forward recoils of Ti and O from the top layer), as well as an increase in surface roughness during sputtering processes.

D-SIMS for the TiH_x/Si (001) samples reveal that the hydride is ~60-75 nm thick, as the TiH_x signal decreases in this range, and the Si signal increases. This is expected, as the hydride has a larger volume than the 50 nm of Ti that was deposited on Si (001). Next, there is a large increase of hydrogen on the surface, revealing possible hydrocarbon contamination. TiH^- was also detected as a secondary negative ion to quantify H, as it provides a unique signal related to the TiH_x layer (not affected by H in the vacuum). TiH^- signal drops by an order of magnitude at 80 nm and further goes to 0, indicating no significant H present in the Si substrate. Note that the H (m = 1) signal remains high due to a possible interfering signal from the H-containing species in the vacuum. The interface depth profile shows a complex picture with some layers that can be significant, e.g. SiO_2, visible as a plateau from 60 to 80 nm, and can be related to thin silicon oxide layer that was on the surface prior to Ti metal deposition, while other elements can be due to the ion mixing, e.g. Ti and H can present at the interface due to forward scattering from the layer above.

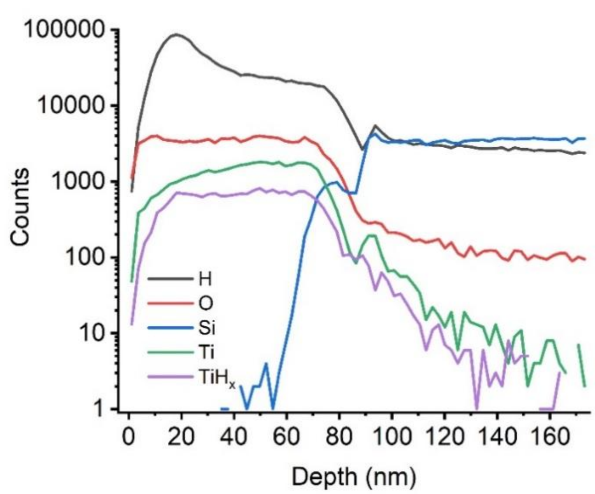

Figure 3. SIMS depth profile for 50 nm TiH_x/Si (001), that was prepared via gas phase annealing, for masses (m = 1(H), m = 16(O), m = 28(Si), m = 48(Ti), and m = 49(TiH)).

SUMMARY

The combination of D-SIMS and ERDA is significant for advancing accurate hydrogen detection in materials science. D-SIMS may be a strong competitor of ERDA due to its superior depth resolution and chemical specificity, but quantification of the results requires the application of ERDA as a complementary technique. This paper reviews a candidate TiH_x/Si (001) standard for hydrogen analysis. It was found to have a uniform hydrogen distribution, long-term stability, and well-defined stoichiometries. The ERDA spectra of the calibration standards provided the quantification of hydrogen's areal atomic density, whereas the D-SIMS spectra provided detailed depth profiles of hydrogen and other associated elements. The information obtained highlights the complementary strengths of ERDA and D-SIMS for comprehensive hydrogen analysis.

ACKNOWLEDGEMENTS

We gratefully acknowledge Jack Hendriks for his valuable help with elastic recoil detection analysis and Rutherford backscattering spectrometry at the Tandetron Accelerator Facility. We would like to thank Dr. Jonas Hedberg (SSW) for dynamic SIMS measurements and Todd Simpson at the Western Nanofabrication Facility for their assistance with Ti thin film sample preparation. Funding was provided by NSERC/CRSNG Discovery Grant RGPIN-2020-06679 and RGPIN-2023-05794.

REFERENCES

1. J.L. White, A.J. Rowberg, L.F. Wan, S. Kang, T. Ogitsu, R.D. Kolasinski, J.A. Whaley, A.A. Baker, J.R. Lee, Y.-S. Liu, "Identifying the role of dynamic surface hydroxides in the dehydrogenation of Ti-doped $NaAlH_4$", ACS Applied Materials & Interfaces **11**, 4930-4941 (2019).
2. A. Romanenko, L.V. Goncharova, "Elastic recoil detection studies of near-surface hydrogen in cavity-grade niobium", Superconductor Science and Technology **24**, 105017 (2011).
3. J. L'Ecuyer, C. Brassard, C. Cardinal, J. Chabbal, L. Deschenes, J. Labrie, B. Terreault, J. Martel, R. St.-Jacques, "An accurate and sensitive method for the determination of the depth distribution of light elements in heavy materials", Journal of Applied Physics **47**, 381-382 (1976).
4. B. Paudel, J.A. Dhas, Y. Zhou, M.-J. Choi, D.J. Senor, C.-H. Chang, Y. Du, Z. Zhu, "ToF-SIMS in material research: A view from nanoscale hydrogen detection", Materials Today, (2024).
5. K. Horn, W. Lanford, "Measurement of the off-resonance cross section of the 6.4 MeV ^{1}H (^{15}N, αγ) ^{12}C nuclear reaction", Nuclear Instruments and Methods in Physics B **34**, 1-8 (1988).
6. C. Griffith, J.J. Noël, L.V. Goncharova, "Hydrogen thin film standards for high-resolutions depth profiling", International Journal of Hydrogen Energy, in preparation (2024).
7. Y. Wang, "Hydrogen standards in elastic recoil detection analysis", Nuclear Instruments and Methods in Physics B **219**, 115-124 (2004).
8. M. Mayer, SIMNRA user's guide, Max-Planck-Institut fur Plasmaphysik, Garching, Germany, 1997.

HIGHLY TUNABLE BROADBAND STIMULATED RAMAN SPECTROSCOPY

SUMMARY: We employ Kerr-instability amplification for broadband stimulated Raman spectroscopy, resulting in a tunable probe from -6000 to 0 cm^{-1} that we use to measure 1-decanol. Our approach provides a broader and more tunable alternative to optical parametric amplifiers.

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Department of Physics, University of Windsor, Windsor ON N9B 3P4 CANADA

NATHAN DROUILLARD RECEIVED 1ST PLACE IN THE 2024 CAP BEST OVERALL STUDENT ORAL PRESENTATION

Molecular vibrations occur on the femtosecond (1 fs = 1 x 10^{-15} s) timescale. As a result, it can be advantageous to use ultrafast light sources for vibrational spectroscopy. In most cases, the vibrational structure of a molecule can be accessed via its Raman active modes. Femtosecond stimulated Raman spectroscopy (FSRS) is a popular technique for measuring Raman spectra on the femtosecond timescale, providing numerous improvements upon traditional spontaneous Raman spectroscopy [1]. One advantage of using ultrashort pulses is that they have inherently broad spectra. In FSRS, the spectral region of detection is dictated by the bandwidth of the Raman probe spectrum. As such, recent advancements in FSRS have been aimed at improving the bandwidth and tunability of the Raman probe spectrum [1].

The earliest method for generating the Raman probe spectrum was supercontinuum generation (SC). Our method directly amplifies a supercontinuum spectrum to provide higher intensities than possible from simply SC. A more intense Raman probe pulse leads to more stimulated Raman scattering and therefore a greater signal. Later, it became common to use optical parametric amplifiers, but these are limited to bandwidths of around 1200 cm^{-1} due to gain narrowing. More recently, non-degenerate four-wave mixing has been used to create a more tunable and broadband source via multiple beamlets each spanning 1600 cm^{-1}, with a total spectral range of 4000 cm^{-1} [2]. In comparison, our method generates a spectrum from a single beam that spans 6000 cm^{-1}.

Using Kerr-instability amplification (KIA), we first generate a supercontinuum spectrum in sapphire. We then mix the supercontinuum with an intense pump beam in a piece of MgO to directly amplify the supercontinuum by 2-3 orders of magnitude [3-5]. The amplified spectrum is readily tuned via the relative temporal delay of the pump and the so-called (supercontinuum) seed. The amplified spectrum is used as the Raman probe spectrum for our stimulated Raman experiment, resulting in a broad and highly tunable spectrum. We use our novel method to measure the stimulated Raman loss spectrum of 1-decanol by using an anti-Stokes probe pulse. This article is an overview of our recent work on KIA and using KIA as a source for spectroscopy [3-6].

SETUP

Figure 1 outlines our experimental setup. We split the output of our Ti:Sapphire laser into three main arms serving as the KIA pump, KIA seed, and Raman pump. The KIA component of the experiment is indicated by the shaded region. The amplified supercontinuum spectrum, shown by the yellow-green beam, is used as the Raman probe. The Raman pump is modulated by a chopper that is synchronized with the laser and the spectrometer. The Raman pump and probe overlap in a 4 cm cuvette to generate the stimulated Raman response. We measure the stimulated Raman loss spectrum with an Ocean Optics Flame-S spectrometer.

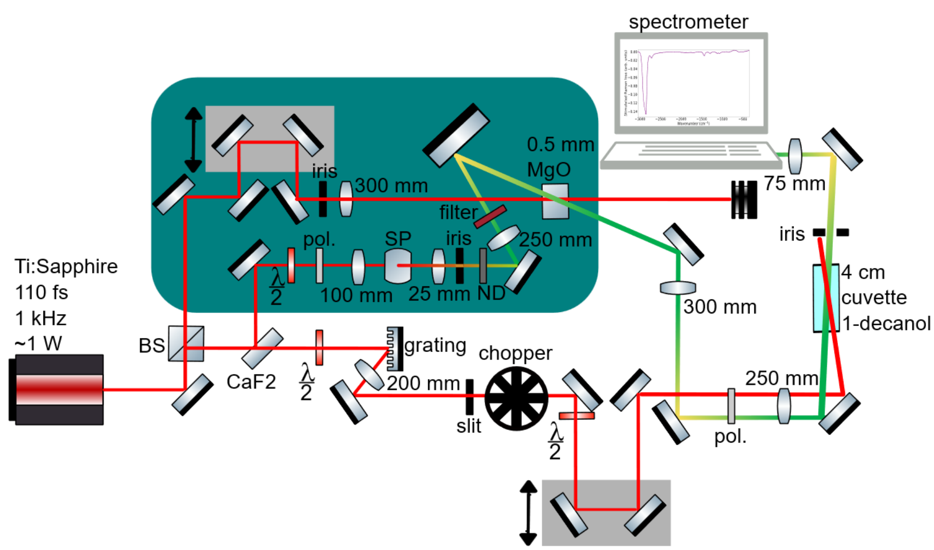

Figure 1. Experimental setup. The shaded region is the setup for KIA, which produces the Raman probe. The Raman pump pulse is created by limiting the laser spectrum via a grating and a slit. We measure the stimulated Raman loss spectrum with an Ocean Optics Flame-S spectrometer. Note: a version of this figure is featured in [4].

RESULTS

Figure 2 illustrates how KIA amplifies the supercontinuum spectrum that is first generated in sapphire. While the un-amplified supercontinuum spectrum is intense enough near the pump wavelength, this intensity drops off quickly in the visible. By amplifying the spectrum using KIA, we have sufficient

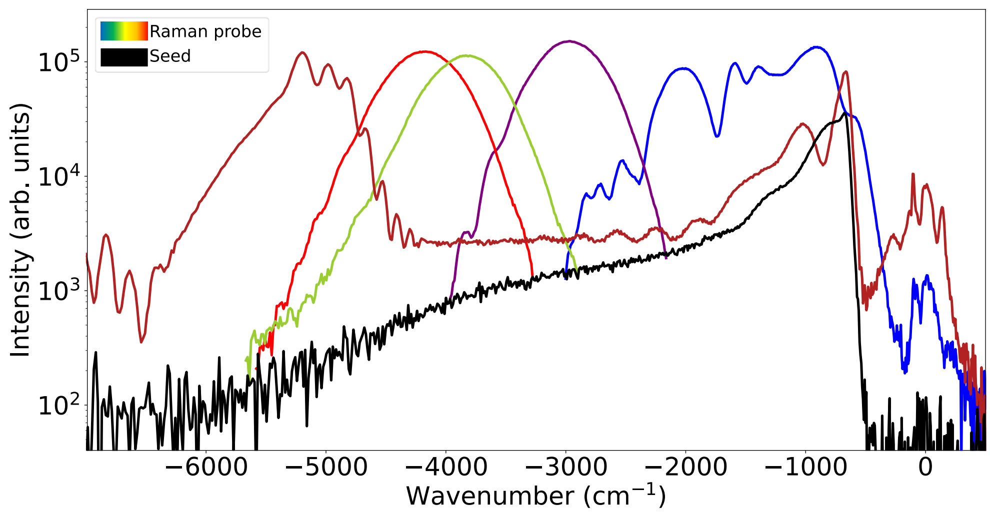

Figure 2. The black line shows the supercontinuum spectrum generated by sapphire. The various coloured lines indicate the amplified spectrum from KIA, the Raman probe spectrum, at different temporal delays between the KIA pump and seed.

Raman probe intensity from -6000 cm^{-1} to 0 cm^{-1}. While adjusting the delay between the KIA pump and seed can optimize amplification at a given wavelength, shown by the coloured lines, there is sufficient intensity to generate the complete Raman loss spectrum even if the delay is tuned to optimize -6000 cm^{-1}. The -594 cm^{-1} (750 nm) cutoff filter attenuates the seed spectrum prior to amplification, but without the filter, KIA can amplify to 2800 cm^{-1} on the Stokes side of the pump. We have chosen to use a filter to optimize amplification on the anti-Stokes side. We choose to operate in the anti-Stokes regime because the main peak shown in Figure 3 is at the limit of our spectrometer if detected on the Stokes side with a wavelength of approximately 1000 nm.

Figure 3 shows the stimulated Raman loss spectrum of 1-decanol. We measure Raman loss rather than Raman gain simply because we operate in the anti-Stokes regime. The main figure highlights the strongest peak near -2900 cm^{-1}, which corresponds to the CH_2 and CH_3 stretching modes, along with an overtone mode at -2858 cm^{-1} which is the exact value of the peak tip. Therefore, it is likely that we are exciting the molecule to the second excited state and driving the methyl stretching modes. The shoulder feature on the main peak at -2720 cm^{-1} indicates a combination mode. Zooming in on the same figure, the inset shows additional weaker Raman modes ranging from -1500 cm^{-1} to -1000 cm^{-1}. In order from left to right, we observe: -1440 cm^{-1} (CH_2 scissoring), -1296 cm^{-1} (CH_2 wagging), -1116 cm^{-1} (likely CH_3 rocking), and -1068 cm^{-1} which could be the CC stretching, CO stretching, or CH_2 rocking mode [7].

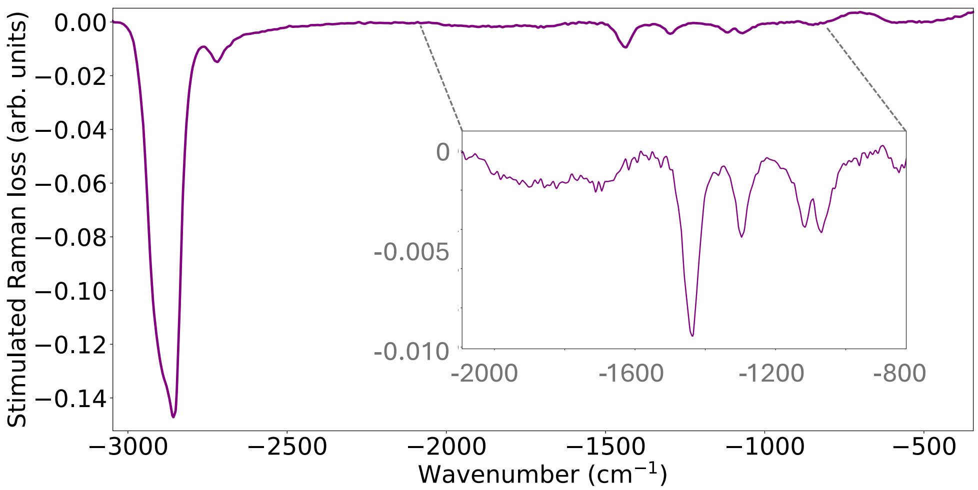

Figure 3. Stimulated Raman loss spectrum of 1-decanol. Shown are the overtone mode at -2858 cm^{-1}, the CH_2 and CH_3 stretching modes ranging from 2880 to 2957 cm^{-1}, and the combination mode at - 2720 cm^{-1}. The inset shows that by zooming-in near -1500 cm^{-1}, we can resolve additional known Raman modes at lower energies [7].

CONCLUSION

Our work aligns with recent advancements in the field of broadband stimulated Raman spectroscopy and introduces a novel technique for generating a broad and tunable Raman probe spectrum. By using Kerr-instability amplification to generate the probe spectrum, we can tune the bandwidth by over 6000 cm^{-1}, demonstrating a broader and more tunable alternative to OPAs. We use our technique to measure the stimulated Raman loss spectrum of 1-decanol.

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REFERENCES

1. D.R. Dietze and R.A. Mathies, “Femtosecond Stimulated Raman Spectroscopy”, ChemPhysChem **17**, 1224-1251 (2016).
2. L. Zhu, W. Liu, and C. Fang, “A versatile femtosecond stimulated Raman spectroscopy setup with tunable pulses in the visible to near infrared”, Appl. Phys. Lett. **105**, 041106 (2014).
3. S. Ghosh, N.G. Drouillard and T.J. Hammond, “Single-stage few-cycle pulse amplification,” Phys. Rev. A **109**, 013511 (2024).
4. S. Ghosh, N.G. Drouillard, and T.J. Hammond, “Supercontinuum amplification by Kerr instability,” Phys. Rev. A **109**, 043508 (2024).
5. N.G. Drouillard, T.J. Hammond, “Phase dependence of Kerr-based parametric amplification,” Phys. Rev. A **110**, 023517 (2024).
6. N.G. Drouillard and T.J. Hammond, “Novel and simple method for broadband stimulated Raman spectroscopy", *arXiv preprint* arXiv:2409.19080 (2024).
7. J. Kiefer, S. Wagenfeld, and D. Kerlé, “Chain length effects on the vibrational structure and molecular interactions in the liquid normal alkyl alcohols”, SAA **189**, 57-65 (2018).

REPORT ON CANADA'S PARTICIPATION IN THE 8TH EUROPEAN PHYSICS OLYMPIAD IN KUTAISI, GEORGIA

By **LIOR SILBERMAN** (University of British Columbia) < lior@math.ubc.ca >

This year the Canadian Physics Team competed in the European Physics Olympiad (EuPhO), which took place July 15 to July 19, 2024 in Kutaisi, Georgia. This was a new experience for us, EuPhO having a different style and format from the International Physics Olympiad (IPhO) where we usually compete (this year's IPhO was held in Isfahan, Iran).

The Georgian organizers did a commendable job, especially with the challenge of having about double the usual number of participating countries. The EuPhO Academic Committee created excellent problems, which challenged the best high school physics students in the world, developed their interest in aspects of physics usually not taught in schools, and taught them some new skills.

The experimental problem explored the use of piezoelectric crystals to measure mechanical properties of other objects. The students determined the piezoelectric properties of a crystal and then used it to study the deformation of an elastic ball that was dropped on the crystal. The problem required students to make creative uses of the given experimental components, to design appropriate circuits to get precise measurements (for example to deal with the capacitance of the multimeter), and to handle the measured data. The combination tested the experimental skills of the students very well.

In the first theoretical problem students analyzed the impulse as a sliding puck collides with a concave semicircular fence and eventually rebounds from it (a phenomenon that may be familiar to Canadians). The second theoretical problem led students through calculating the relativistic Doppler effect for signals of subluminal speed. In the third problem the students analyzed the Fabry-Pérot interferometer. The problems were difficult, with a best overall score of 86%.

We would like to deeply thank our sponsors: UBC, the Trottier Family Foundation, former Team Canada member (1998, 1999) and medalist Sonny Chan, TRIUMF (Canada's particle accelerator), the University of Toronto Schools, and the UBC Physics and Astronomy Department. Their generosity allowed us to organize an 8-day National Olympiad finals and training camp in Vancouver for 17 top students and to send the team to Georgia: all the students' travel and accommodation expenses for the finals and the Pho were covered by the Canadian Physics Olympiad.

Figure 1. Our team with medals after the closing ceremony. From left: Zhou Long, Harry Gong, Zander Li, Tristan Yan-Klassen, Athanasios Mavrakanas, Lior Silberman.

Training camp participants were selected from the top 20 scores in the 2024 Canadian Association of Physicists High School/Cégep Prize Exam. Team Canada members, selected at the end of the camp, were:

- Zander Li from Laurel Heights Secondary School, ON, student of teacher David Vrolyk
- Harry Gong from St. George's School, BC, student of teacher Nathan Moens
- Zhou Long from Access Academy, AB, student of teacher Kevin Sunie
- Tristan Lee Yan-Klassen from Eric Hamber Secondary, BC, student of teacher Mark Lam
- Athanasios Mavrakanas from Marianopolis College, QB, student of teacher Baharak Fatholahzadeh

The team leader was Dr. Lior Silberman, professor of mathematics at UBC and past IPhO contestant (1994 Israeli team).

The competition was held at Kutaisi University, a university founded in 2020 in the city of Kutaisi, Georgia. The opening and closing ceremonies featured formal speeches by (among others) the Georgian Minister for Education and the EuPhO President, as well as artistic demonstrations of traditional Georgian culture including both dancing and singing. The compressed EuPhO schedule afforded less time for cultural exploration than an IPhO but there was time for some excursions to nearby historical monuments.

Fifty-four teams participated in this year's Olympiad. Our students did very well considering their short training (as compared to the countries with many gold medalists, which train their team for 1 to 2 years). Zander Li won a gold medal, finishing 21st of 186 competitors. Harry Gong and Tristan Yan-Klassen won bronze medals, and Zhou Long and Athanasios Mavrakanas won honourable mentions.

INTERNATIONAL HIGH SCHOOL TEACHER PROGRAMME AT CERN: REFLECTIONS ON MY EXPERIENCE

By **AMANDA CRAIG** (Gonzaga High School, Newfoundland and Labrador English School District) <amandacraig@nlschools.ca>

SUMMARY: Read about a high school teacher's unforgettable two weeks at CERN, witnessing firsthand the power of international collaboration in scientific discovery. This reflection shares how the experience is inspiring new ways to motivate students and cultivate a lifelong love for learning and problem-solving.

CERN, Conseil Européen pour la Recherche Nucléaire, was created in 1952 [1] and its design is an example of how humanity can work together to solve complex problems. CERN's mission is multi-faceted and includes discovery, innovation, collaboration and education. They provide particle accelerator facilities so that physicists can perform world-class research in fundamental particle physics. Their aim is to be environmentally responsible and sustainable as they expand humanity's understanding of what the universe is made of and how it works. CERN ensures collaboration on purely scientific research and shares the results of experimental and theoretical work with the public. People from all around the world are united for the benefit of humanity as they push the boundaries of science and technology unconstrained by geographical borders; international collaboration is the driving force behind all research, innovation and discoveries. Lastly, CERN hopes to engage everyone in the values of scientific research and train the next generation of engineers, physicists and technicians [2].

In July of 2024, I attended the International High School Teacher (HST) Programme in Geneva, Switzerland at the Large Hadron Collider (LHC) at CERN, and became a student again for two weeks [3]. It was one of the most rewarding experiences of my life, both personally and professionally. I attended world class lectures, visited cutting edge facilities, participated in workshops and developed a network of international colleagues. I met some of the most talented engineers and physicists that this world has produced. It was humbling to witness the greatness that humanity can accomplish when we all work together! It is now my duty, as an alumna of HST 2024, to spread their message and ignite scientific wonder in my science and physics classes.

Figure 1. Amanda Craig and Daša Červeňová creating a cloud chamber at a Science Gateway workshop. Science Gateway is CERN's new education and outreach center.

Science in general has tried to answer fundamental questions throughout history, and the work at the LHC is no different. Physicists want to know where we come from, what we are made of and where we are going. By looking at the smallest, fundamental particles, we can look back in time to get information just a few moments after the Big Bang. What is special about this type of fundamental research, however, is that no one can anticipate the spin off benefits that can result. The knowledge gained at the LHC over the years has led to the invention of the world wide web [4], touch screens [5], and medical applications such as cutting-edge cancer treatment [6].

Our current understanding of the universe is incomplete [7]. We need more information about the Higgs boson so we can measure its properties. While we have found the particles predicted by the standard model, this does not offer a unified description of all the fundamental forces because it cannot describe gravity. Current observations have shown that visible matter only accounts for 5% of the mass-energy in the universe [8]. We still do not know what the remaining 95% of the universe is made of. The search is on to find dark matter and dark energy [9, 10]. Also, we do not know why we have not been able to find antimatter in our universe [11, 12]. This is exciting for students, teachers and physicists the world over.

At CERN, the best and brightest particle physicists and engineers tackle the impossible. Currently more than 17 000 people from over 100 nationalities work together to question the boundaries of human knowledge [13]. The information that results is free and available to everyone. In this technological age of greed and consumerism, CERN stands firm in its belief that knowledge should be shared and not used for personal gain. The takeaway messages that I want to bring to my students are ones of

Figure 2. (left) Amanda Craig outside of the ATLAS control room. ATLAS is the largest detector ever constructed for a particle collider and is used as a general purpose particle physics experiment. (right) A ”mini-CMS” particle detector created using Lego.

creativity and ambition. The common thread amongst people working at the LHC is a mindset of lifelong learning. Impossible is only a mindset and with the right people working together, amazing solutions can be found for the most difficult problems. To overcome the monumental problems facing our world, one must not only have the knowledge but also be adaptable and creative in their approach.

My experience as a participant in HST 2024 has not only deepened my understanding of fundamental physics but has fundamentally reshaped my pedagogical approach. Inspired by CERN's collaborative spirit and relentless pursuit of knowledge, I am committed to evolving my teaching practices to better prepare students for the complexities of the 21st century. My key educational goals include:

1. **Fostering Scientific Literacy and Inquiry-Based Learning:** When completing my masters studies, I focused on the educational leaders' perspectives of scientific literacy and much has changed since then. I plan to update my course notes to include relevant examples in particle physics to generate interest and introduce content beyond our provincial curriculum. I want to make science relevant and exciting for students using an inquiry-based approach and design lessons that challenge students to ask “How do we know?” rather than “What do we know?”[14]. Using real world data I can adapt questions and investigations, moving away from rote memorization towards genuine scientific exploration.
2. **Enhancing Critical Thinking and Problem-Solving Skills:** I hope to motivate students and activate their knowledge using a more active and hands-on approach by incorporating teaching

resources from both the Perimeter Institute (PI) and CERN. The challenges faced at CERN, such as the search for dark matter or the mysteries of antimatter, exemplify complex, open-ended problems. I want to use authentic learning experiences to equip students with skills vital for their future studies as well as the evolving world of work. Using inquiry-based, problem-based or project-based approaches students are encouraged to think critically, collaborate, and iterate solutions, echoing the iterative process of scientific research at the LHC.

3. **Integrating Artificial Intelligence:** Each day we try to create independent learners to solve our world's problems, we see greatness in students when they don't see it in themselves, and we help students find their way on their own learning journey. The trick is to not lower your standards, to expect greatness and always strive for better. This message rings out loud and clear at the LHC. Their work is highly data-driven and increasingly reliant on computational tools, including machine learning and AI. Recognizing the growing importance of digital literacy and AI fluency, I will introduce my students to how AI is used in particle physics and how students can use AI to help them on their own learning journey. I hope to foster an understanding of AI's capabilities, ethical considerations, and its role as a powerful tool for scientific discovery and problem solving.
4. **Incorporating Global Collaboration and Networking:** CERN stands as a beacon of international cooperation, a model that directly informs my commitment to fostering a global learning community. As a member of HST 2024, I now have a network of international teacher friends to work with in order to improve my own craft and this is one of the greatest gifts of all. I joined the Math Science Special Interest Council and wrote an article for their newsletter about my experiences during HST 2024. In October, I helped coordinate professional learning sessions in St. John's and Corner Brook delivered by the Perimeter Institute which helped connect more teachers to the PI Teachers' Network. I delivered a lunch and learn session at Gonzaga High School with their STEM club all about the work at the LHC. In the near future, I hope to hold in-person and virtual events for teachers and students to share my experiences. Using my new network of international teacher friends, I hope to explore virtual collaborative projects between my students and their peers abroad, providing authentic experiences of global teamwork. My ongoing and planned outreach initiatives are designed to extend this collaborative spirit to other educators, sharing resources and best practices for physics education across Canada.

Although physics is my passion, teaching extends beyond all our subject areas. Teaching is about fostering and nurturing the passions of others. My goal is to empower students to be curious, critical, adaptable, and collaborative learners, equipped with the skills and mindset to tackle the complex challenges of their future, much like the inspiring scientists and engineers at CERN. We all have much to give to this world and, therefore, much to share with each other. I have been so lucky to be surrounded by such supportive teachers, professors, colleagues, students, parents, family and friends on my own physics journey.

Many groups and organizations have worked together to send me to HST 2024, and to them all I owe a great deal of gratitude. Thank you to Dr. Stephanie Curnoe and the entire nominating committee of colleagues and former students for putting my name forward for the CAP Award for Excellence in Teaching High School/CEGEP Physics. It has been a humbling and rewarding experience to be recognized and has opened doors to other opportunities. Thank you to the Canadian Association of Physicists, the CAP Foundation, TRIUMF, Perimeter Institute, SNOLAB, and Canadian Light Source for sponsoring the teaching award and research experiences and for encouraging and promoting physics education in high school. Lastly, thank you to the Perimeter Institute and the Institute for Particle Physics who provided supplemental sponsorship for my trip to CERN.

Amanda Craig is a physics teacher at Gonzaga High School, St. John's (on leave 2024-2025). She can be reached at amandacraig@nlschools.ca. For a detailed presentation about Amanda's experiences at HST 2024 please see the following online presentation. For more information about CERN or to avail of their free teaching resources please visit https://home.cern/.

REFERENCES

[1] *CERN History.* https://home.cern/about/who-we-are/our-history.

[2] *CERN Mission.* https://home.cern/about/who-we-are/our-mission.

[3] *CERN International High School Teacher Programme*. https://teacher-programmes.web.cern.ch/international-high-school-teacher-programme.

[4] Wikipedia. (n.d.). *World Wide Web*. Retrieved May 13, 2025, from https://en.wikipedia.org/wiki/World_Wide_Web; https://home.cern/science/computing/birth-web.

[5] The first capacitative touch screens at CERN. Retrieved May 13, 2025, from https://cerncourier.com/a/the-first-capacitative-touch-screens-at-cern/.

[6] U. Amaldi and A. Jorant, Medical Applications at CERN and the ENLIGHT Network, PMC Physics in Medicine, **6(1)**, 010101 (2016). https://kt.cern/applications/healthcare.

[7] https://home.cern/about/what-we-do/fundamental-research.

[8] Planck Collaboration, Planck 2018 results VI. Cosmological parameters, Astronomy & Astrophysics, **641**, A6 (2018). https://doi:10.1051/0004-6361/201833910.

[9] DES Collaboration, Dark Energy Survey Year 3 results: Cosmological constraints from galaxy clustering and galaxy-galaxy lensing with photometric redshift uncertainties, Physical Review D, **109(2)**, 023513 (2024). https://doi.org/10.1103/PhysRevD.109.023513.

[10] M. Filzinger, *et al.*, Ultralight Dark Matter Search with Space-Time Separated Atomic Clocks and Cavities, Physical Review Letters, **134(3)**, 031001 (2025). https://doi.org/10.1103/PhysRevLett.134.031001.

[11] E.K. Anderson, *et al.*, Observation of the effect of gravity on the motion of antimatter, Nature, **621**, 716–722 (2023). https://doi.org/10.1038/s41586-023-06527-1.

[12] STAR Collaboration, Observation of the heaviest antimatter hypernucleus, Nature, **632**, 1026-1031 (2024). https://doi.org/10.1038/s41586-024-07823-0.

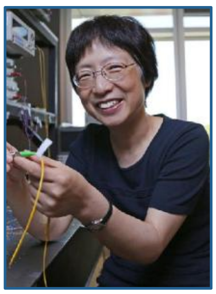
[13] *CERN People*. Retrieved May 13 2025, from https://home.cern/about/who-we-are/our-people.

[14] National Research Council, *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*, The National Academies Press (2012).

2024 CAP Medal Recipients / Lauréats des médailles de l'ACP de 2024

The CAP is very pleased to recognize its 2024 medal recipients. Please visit the CAP website for the list of medal recipients with a link to the detailed citations and any remarks submitted by the recipient following the receipt of the award.

L'ACP est très heureuse de reconnaître ses récipiendaires de médailles 2024. Veuillez consulter le site web de l'ACP pour obtenir la liste des récipiendaires de médailles, ainsi qu'un lien vers les citations détaillées et les remarques à la suite de la réception de la récompense.



CAP Medal for Lifetime Achievement in Physics / Médaille de l'ACP pour contributions exceptionnelles à la physique

Xiaoyi Bao, University of Ottawa, in recognition of broad and profound contributions to the optical fibre field; from laying the physical principles for new optical measurement techniques, to developing applications with important impact for Canadian infrastructure and telecommunications.

CAP Herzberg Medal / Médaille de l'ACP Herzberg

Julie Hlavacek-Larrondo, Université de Montréal, in recognition of her leadership role in the study of super-massive black-holes in galactic clusters, and the innovative use of artificial intelligence (AI) in the analysis of massive quantities of astrophysical data.

CAP-CRM Prize in Theoretical and Mathematical Physics / Le Prix ACP-CRM de physique théorique et mathématique

Bianca Dittrich, Perimeter Institute for Theoretical Physics, in recognition of her important contributions to our understanding of the problem of observables in quantum gravity, and for her advancement of spin foam approaches to quantum gravity.

CAP-DCMMP Brockhouse Medal / Médaille de l'ACP-DPMCM Brockhouse

Marcel Franz, University of British Columbia, in recognition of his work on topological, superconducting and low-dimensional materials as well as the theoretical advances in the physics of Majorana fermions under strong interactions.

CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics / Médaille Vogt de l'ACP-TRIUMF pour contributions en physique subatomique

Douglas Andrew Bryman, **University of British Columbia**, in recognition of his remarkable contributions to particle physics through his work and leadership on a broad range of experiments testing fundamental phenomena at the precision frontier.

CAP Medal for Excellence in Teaching Undergraduate Physics / Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle

Nikolas Provatas, McGill University, in recognition of his ongoing commitment to excellence in undergraduate course instruction, mentorship of undergraduate research, involvement in physics education research, and outreach activities.

2024 CAP Fellows / Les Fellows de L'ACP de 2024

The CAP is pleased to announce the 2024 CAP Fellows (FCAP). The CAP Fellowship Program recognizes CAP members who have made important contributions in physics research, in physics teaching, in the advancement of technology, or in service to physics in Canada.

L'ACP est heureuse d'annoncer les 2024 Fellows de l'ACP (FCAP). Le programme de bourses de l'ACP reconnaît les membres de l'ACP qui ont apporté une contribution importante à la recherche en physique, à l'enseignement de la physique, à l'avancement de la technologie ou au service de la physique au Canada.

Corina Andreoiu, Simon Fraser University, in recognition of her influential contributions to subatomic physics, particularly in advancing the understanding of collective behavior and shape co-existence in nuclei, and for dedication to the Canadian physics community through tireless service to the CAP, the Canadian Institute of Nuclear Physics, and TRIUMF.

Xiaoyi Bao, University of Ottawa, in recognition of of her ground-breaking work in the field of fiber optics and photonics; and in recognition of inspiring mentorship which has empowered a diverse group, notably women, to secure faculty positions, establish companies, and assume executive positions.

Robert Brandenberger, McGill University, in recognition of his coupling of ground-breaking developments in theoretical cosmology with recent dramatic advances in observational astronomy of the early universe; and an outstanding record of mentorship and training.

M**elanie C.W. Campbell, University of Waterloo,** in recognition of her outstanding research contributions to visual optics and novel ocular imaging; and for advocacy for women in physics and for service to the Canadian physics community, in particular as President of the CAP.

Marie D'Iorio, University of Ottawa, in recognition of her research contributions to semiconductor quantum structures and organic electronics; and for contributions to applied and private sector physics through major roles as Director-General of NRC's Institute for Microstructural Sciences and as the Executive Director of the National Institute for Nanotechnology (NINT).

Cecile Fradin, McMaster University, in recognition of her influential contributions to experimental biophysics, particularly with optical probes of dynamics within the crowded medium of cells, and for excellence in the education and mentorship of junior scientists at all levels.

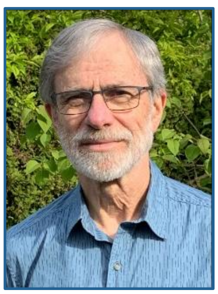
Gwen Grinyer, University of Regina, in recognition of her outstanding research contributions of ultra-high precision measurements to test the Standard Model description of electroweak interactions and designing of state-of-the-art instrumentation to study the structure of rare isotopes; and for championing equity, diversity and inclusion, and challenging the barriers faced by women and 2SLGBTQ+ people in STEM.

Eric Hessels, York University, in recognition of their advancements in the state of the art for high precision atomic physics measurements and establishment of tests of fundamental physics; and for an outstanding record of mentorship and training.

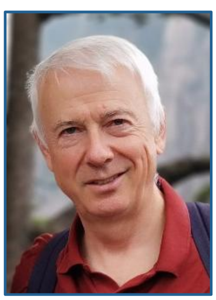
Rituparna Kanungo, Saint Mary, in recognition of her contributions to experimental subatomic physics and groundbreaking discoveries in rare isotopes and nuclear shells; and for leadership of international collaborations in Japan, Germany, and Canada's TRIUMF, and service to national and international organizations.

Karen Kavanagh, Simon Fraser University, in recognition of her contributions to the formation and characterization of novel electronic materials and interfaces and for techniques applied to the nanofabrication of metallic nanohole arrays whose polarization properties help secure Canadian banknotes against counterfeiting; and for service to the Canadian physics community and a dedication to outreach.

Christine Kraus, SNOLAB, in recognition of her contributions to Canadian physics through service to the Canadian Association of Physicists in various organization and administrative roles, often with a focus on equity, diversity and inclusion; and for major research contributions to the SNO and SNO+ experiments, increasing the impact of Canadian physics research.



Gabor Kunstatter, University of Winnipeg, in recognition of his outstanding service to the Canadian physics community and leadership in the CAP, and for influential contributions to theoretical physics in the areas of quantum field theory, black holes and quantum gravity.



Robert Mann, University of Waterloo, in recognition of his outstanding research contributions in theoretical physics and excellence in teaching; and for dedicated service to the Canadian physics community, in particular as President of the CAP.

Michael R. Morrow, Memorial University of Newfoundland, in recognition of his extensive service to the Canadian physics community, including science outreach and serving as the CAP President; and in recognition of research using nuclear magnetic resonance to study molecules in model membranes and bilayers.

Robert Myers, Perimeter Institute for Theoretical Physics, in recognition of his ground-breaking research in quantum field theory and quantum gravity; and for service to the Canadian theoretical physics community, especially through contributions to the founding of the Perimeter Institute.

Manu Paranjape, Université de Montréal, in recognition of his service to the CAP and the Canadian theoretical physics community, including the organization of the Theory CANADA series of conferences; and for the extraordinary breadth, creativity, and originality of his research resulting in exceptional contributions to the field of theoretical physics.

William Richard Peltier, University of Toronto, in recognition of his key contributions to understanding the physics of the Earth, including glacial isostatic adjustment, mantle convection, fluid dynamics of the atmosphere and oceans, and global climate variability; and for an outstanding record of mentorship and training.

Federico Rosei, INRS-Energie et Matériaux, in recognition of his remarkable achievements in materials physics, particularly multiferroic materials and quantum dots, coupled with outstanding mentorship of trainees, and for international leadership which promotes the excellence of Canadian physics on a global scale.

Wendy Taylor, York University, in recognition of her outstanding contributions to particle physics including leading collider searches for magnetic monopoles, B-meson oscillations, and CP violation; and for notable service to the physics community, engaging in physics outreach, and tirelessly promoting equity, diversity, and inclusion in physics.

2024 HIGH SCHOOL / CÉGEP PHYSICS TEACHING AWARDS / PRIX DE L'ACP EN ENSEIGNEMENT DE LA PHYSIQUE AU SECONDAIRE ET AU COLLÉGIAL 2024

The Canadian Association of Physicists joins members of our community in congratulating the winners of the 2024 High School/CEGEP Teacher Awards. This year, we decided to give two awards in the British Columbia-Yukon region to be able to recognize two excellent teachers.

L'Association canadienne des physiciens et physiciennes se joint aux membres de notre communauté pour féliciter les lauréats des prix 2024 pour les enseignants des écoles secondaires et des cégeps. Cette année, nous avons décidé de décerner deux prix dans la région de la Colombie-Britannique et du Yukon afin de récompenser deux enseignants exceptionnels.

British Columbia and Yukon / *Colombie-Britannique et Yukon*

MARK LAM, Eric Hamber Secondary School, Vancouver, BC, in recognition of his passion and dedication to teaching physics, particularly his dedication to ensuring students have a depth of physics understanding and his support of students embarking on, and succeeding in, physics-related competitions. Additionally, his support of other physics teachers, including both in-service teachers through the materials posted on his website and pre-service teachers through his mentorship during their school placements, make him an asset to the physics teaching community.

British Columbia and Yukon / *Colombie-Britannique et Yukon*

MATT TRASK, Rockridge Secondary School, West Vancouver, BC, in recognition of his passion and dedication to teaching physics, particularly his embedded use of technology and the development of a STEM program in which students grow their understanding, competence, and autonomy. Matt's classroom approach of learning with students is revered by students and colleagues alike. Additionally, his leadership in fair and competency-based assessment practices make him a deserving recipient of this award.

Ontario

TASHA RICHARDSON, Ontario Science Centre Science School, in recognition of her passion and dedication in teaching physics, particularly her use of physics education research and hands-on experiments that connect students' observations to the underlying physics concepts and theories. Additionally, Tasha's mentoring support of pre-service teachers and her efforts in producing teaching resources about equity, diversity, and inclusion in STEM also make her a deserving recipient of this award.

Atlantic / *Atlantique*

LINDSAY JANES, Center for Distance Learning and Innovation, in recognition of her passion and dedication in teaching physics, particularly through her use of universal design for learning and deep learning principles. Lindsay's extra-curricular support for her students is far-reaching and has included many STEM-related competitions and opportunities for students to create and connect beyond the classroom. Her dedication to developing students' conceptual understanding and to ensuring that distance learning students are receiving accessible, rich, and engaging physics education is truly admirable. Within the teaching community, Lindsay is a known mentor to others in both physics and assessment, as she has shared her un-grading experiences and resources with others province-wide.

Unfortunately, there were no nominations received for the Prairies-Northwest Territories or Quebec-Nunavut regions for the 2024 awards. Please consider nominating high school or CEGEP when the call for nominations is launched in the spring. Your nominations are vital to ensure that we recognize and honour deserving educators.

Malheureusement, aucune candidature n'a été reçue pour les régions de Prairies et Territoires du Nord-Ouest et du Québec-Nunavut pour les prix 2024. Veuillez proposer la candidature d'enseignant(e)s de secondaire ou de collégial lorsque l'appel à candidatures sera lancé au printemps. Vos candidatures sont essentielles pour que nous puissions reconnaître et honorer les éducateurs / éducatrices méritants.

Congratulations / Félicitations!

2024 Student Prize Winners / Gagnants des Prix pour les étudiant(e)s 2024

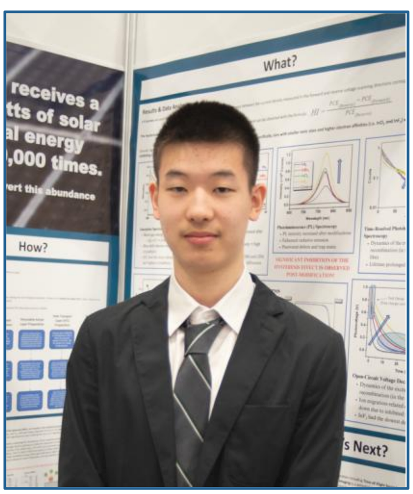
2024 CAP High School-Cégep Prize Exam National Winners / L'examen du secondaire ou collégial de l'ACP – Gagnants à l'échelle nationale 2024

First prize/Premier prix	**Zander Li**	**Laurel Heights Secondary School, ON**
Second prize/Deuxième prix	**Tristan Yan-Klassen**	**Eric Hamber Secondary School, BC**
Third prize/Troisième prix	**Frank Zehao Liu**	**University Hill Secondary, BC**

2024 Canada-Wide Science Fair Prizes / 2024 Prix expo-sciences pan canadienne

The 2024 Canada-Wide Science Fair was in Ottawa ON from May 26-31. This year the CAP sponsored one prize in the Senior category.

Senior CAP Physics Prize – Victor Xu, Toronto, ON



Project: Hysteresis Inhibition for Performance Improvement via Halide Engineering in Perovskite Solar Cells

Abstract: Perovskite solar cells are novel semiconductors with impressive efficiency and potential. However, they face challenges of unstable power output and rapid degradation, leading to long-term stability issues that hinder their commercial viability. To solve this issue, I created a strategy that incorporates various chemical additives during the fabrication process of this device. My results not only indicate a significant improvement in stability post-modification, but also enhanced fundamental properties of the solar cell. This highlights my project's importance in advancing renewable energy for a sustainable future.

2024 CAP-CAPF SCHOLARSHIP RECIPIENTS / BÉNÉFICIAIRES DE BOURSES D'ÉTUDES DE L'ACP-FAPC 2024

The CAP is pleased to announce the recipients of the 2024 CAP-CAPF student scholarships, made possible through the generous donations to the CAP Foundation. Please visit the CAP website for the list of scholarship recipients with a link to the detailed citations and any remarks submitted by the recipient following the receipt of the award.

L'ACP est heureuse d'annoncer les récipiendaires des bourses étudiantes de l'ACP-FACP pour 2024, rendues possibles grâce aux généreux dons à la Fondation de l'ACP. Veuillez consulter le site web de l'ACP pour obtenir la liste des récipiendaires des bourses d'études, ainsi qu'un lien vers les citations détaillées et les remarques à la suite de la réception de la récompense.

The 2024 Allan Carswell Physics Educator Scholarships / Les Bourses Allan Carswell d'enseignant en physique 2024

Ben Giers, Mount Royal University, in recognition of his excellent academic record as well as his engagement in education research. Additionally, he has taken on a formal peer tutoring role, demonstrating his ability to effectively convey physics concepts to others. Ben's undergraduate research projects have "deepened [his] appreciation for the beauty and complexity" of physics, "fueling [his] desire to share this enthusiasm with future generations".

Dennis Thai, University of Alberta, in recognition of his excellent academic record as well as his work in undergraduate physics research. Additionally, he has demonstrated exceptional communication skills, being recognised as a passionate and engaging speaker when discussing and explaining physics within his research group. Dennis' dedication to building his knowledge of physics and research on his way to becoming an educator will allow him to "foster the curiosity of [his] future students by discussing or providing guidance towards more advanced and current topics in physics".

The 2024 Boris P. Stoicheff Memorial Graduate Scholarship / La Bourse commémorative pour étudiants de cycles supérieurs Boris P. Stoicheff 2024

Everett Patterson, University of Waterloo, in recognition of creative insights into the application of relativistic quantum information to determine the temperature of black holes.

Meet Your 2024-25 Executive

President / Président

Martin Williams is a tenured faculty member in the department of physics at the University of Guelph and serves as the university's director of Teaching and Learning. Martin's teaching has been recognized through several awards including the CAP Medal for Excellence in Teaching Undergraduate Physics and the University of Guelph's Distinguished Professor Award for Excellence in Teaching. Martin obtained his Ph.D. degree in Experimental Condensed Matter Physics from Imperial College, University of London, UK. Martin has an active research programme with current interests in the Scholarship of Teaching and Learning. Before arriving at Guelph, he worked as a postdoctoral fellow at Imperial College and University College London. He is a chartered Physicist and member of the Institute of Physics UK and a past Chair of the Division of Physics Education of the Canadian Association of Physicists.

Vice-President / Vice-président

Pierre Bénard's educational background includes a Ph.D. and undergraduate studies completed at the Universite de Sherbrooke, as well as a Master's degree from the University of Toronto. He has focused his research and scholarly endeavors primarily on condensed matter theory, particularly in the area of high-temperature superconductivity. However, Pierre's interests have expanded to encompass applied physics, specifically working on materials and technologies relevant to the energy transition. From 2017 to 2023, Pierre served as the director of the Hydrogen Research Institute at the Universite du Quebec a Trois-Rivieres, where he made significant contributions to the field. During his tenure, he successfully established a collaborative research unit with colleagues at INRS EMT in Varennes, concentrating on materials for the new energy transition. Furthermore, he played a key role in the creation of an innovation zone focused on technologies essential to the energy transition. Pierre's dedication extends beyond his research and academic pursuits. He aims to address the future and role of physics in Canadian society while considering the regional context and the challenges faced by smaller universities. With his comprehensive understanding of the discipline, Pierre seeks to bring valuable perspectives to the development of the Canadian Association of Physicists and advocate for the interests of physics within the broader scientific community.

Vice-President Elect / Vice-présidente élue

Wendy Taylor is a Professor of Physics at York University. After she completed her PhD in physics at the University of Toronto in 1999, she was a Stony Brook University (NY) postdoctoral fellow based at Fermilab (IL). She then joined the faculty at York University in 2004, where she held a Tier 2 Canada Research Chair in Experimental Particle Physics for 10 years. Her research is currently focused on the search for the hypothetical magnetic monopole using the ATLAS detector at the CERN Large Hadron Collider in Geneva, Switzerland. Wendy's past leadership roles include President of the Board of Trustees of the Institute of Particle Physics (2023-24), executive membership of the TRIUMF Board of Management (2018-21), Chair of the CAP Particle Physics Division (2007-08), and Chair of the CAP Committee to Encourage Women in Physics (1997-99). She has also served on international, federal, and provincial review panels and award selection committees. Wendy engages with the media and with the public on particle physics topics. Throughout her career, Wendy has advocated for equity, diversity, and inclusion in physics.

Past President / Président sortant

William (Bill) Whelan is a Professor of Physics at the University of Prince Edward Island. He completed a PhD in Medical Physics at McMaster University in 1996 and joined the faculty at the Toronto Metropolitan University that same year. After 12 years on faculty at TMU, he joined the University of Prince Edward Island in 2008 as a Tier 2 Canada Research Chair in Biomedical Optics. His research is focused on the design and development of biomedical sensors, based on Raman, optoacoustic, and near-infrared spectroscopy. He was Chair of the Department of Physics (2015-2021) and Chair of the Faculty of Science Research Committee. Bill has served on grant review panels for NSERC (Physics EG1505), the Canadian Cancer Society Research Institute (Innovation/I2I Programs) and CIHR (Medical Physics and Imaging). Bill's participation in the CAP includes serving as Chair of the Division of Medical and Biological Physics (2001-03), Director of Communications (2006-09) and Chair of the CAP- NSERC Physics Liaison Committee (2014-17). He was also a member of the National Board of Directors of the Canadian Cancer Society (2010-12). Bill is actively involved in science outreach, including chairing the PEI Science Fair for 10 years and co-chairing the Canada-Wide Science Fair in 2012.

Secretary-Treasurer / Sécretaire-Trésorier

Christine Kraus is a SNOLAB research scientist, with adjunct positions at Laurentian University and Queen's University. Her research field is particle astrophysics. In 2004 she received her Ph.D. from the Johannes Gutenberg University in Mainz, Germany for the final analysis of the Mainz Neutrino Mass experiment. From there she moved to Canada to pursue a postdoctoral fellowship on the famous SNO experiment at Queen's University. Since 2010, when she moved to Sudbury as a Canada Research Chair, her main focus is the SNO+ experiment, which is now taking data. Prof. Kraus is a past advisory council member as well as a past PPD chair.

Executive Director / Directrice exécutive

Francine Ford, Canadian Association of Physicists

President / Président
MARTIN WILLIAMS, University of Guelph

Past President / Président sortant
BILL WHELAN, P.Phys., University of PEI

Vice-President / Vice-président
PIERRE BÉNARD, Université du Quebec à Trois-Rivières

Vice-President Elect / Vice-présidente élue
WENDY TAYLOR, York University

Secretary-Treasurer / Secrétaire-trésorier
CHRISTINE KRAUS, Laurentian University

Executive Director / Directrice exécutive
FRANCINE FORD, CAP/ACP

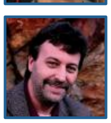
Director – Academic Affairs / Directrice – Affaires académiques
CHITRA RANGAN, University of Windsor

Director (Interim) – Communications / Directrice (intermédiare) – Communications
BARBARA FRISKEN, Simon Fraser University

Director – International Affairs / Directeur – Affaires internationales
OLIVER STELZER-CHILTON, TRIUMF

Director – Member and Affiliate Services / Directeur – Services aux members et affiliés
DAVID TESSIER, Wester University

Director – Private Sector Relations / Directeur – Relations avec le secteur privé
IAN D'SOUZA, P.Phys., Honeywell Aerospace



Director – Professional Affairs / Directeur – Affaires professionnelles
DANIEL CLUFF, P.Phys., CanMind Associates

Director – Science Policy / Directeur – Politique scientifique
JAMES FRASER, Queen's University

Director – Student Affairs / Directeur – Affaires étudiantes
BEN NEWLING, P.Phys., University of New Brunswick

CAP Foundation – 2024 Member Update and Impact Summary

Manu Paranjape, President, Canadian Association of Physicists Foundation

SUMMARY

The last update on the activities of the CAP Foundation (CAPF) in *Physics in Canada* was in 2016—now nine years ago. It is time to provide members with a refreshed overview. As a charitable organization, CAPF is dedicated to raising funds to support education and student activities within the Canadian Association of Physicists (CAP). Over the past year, we have focused on four key administrative objectives: Leadership Renewal, Board Membership Update, Ratification of Terms of Reference (2024), and Update Investment Policy Statement (IPS) (2024).

What is the CAP Foundation

The **Canadian Association of Physicists Foundation (CAPF)** is the charitable arm of the CAP, dedicated to advancing physics education in Canada. Our mission is to support students, educators, and the broader physics community through sustainable funding, outreach programs, and strategic partnerships.

This update provides members with an overview of how your donations – both big and small – are making a difference. It is not a formal activity report, but rather an **information package** to highlight the **impact of your support**, recent developments, and the Foundation's goals for the future.

Why Your Support Matters

Thanks to a combination of individual contributions and major endowments from partner foundations, the CAPF funds a wide range of programs – from national physics exams and travel grants for physics students to scholarships and public lectures. Member donations are critical for sustaining our core programs, especially those aimed at high school outreach and undergraduate engagement.

Whether you give $10 or $1,000, every tax-deductible donation helps inspire and support the next generation of physicists in Canda.

Donate today: https://cap.ca/capf/donate/.

BOARD OF DIRECTORS JUNE 2024 – JUNE 2025

(bios of the Board of Directors can be found on the CAPF website at http://www.cap.ca/capf)

Manu Paranjape, Université de Montréal (Chair)	Ken Iliadis, MEA Forensic (Vice-Chair)	Gordon Drake, University of Windsor (Treasurer)
Ian D'Souza, Honeywell Aerospace	LeeAnn Janissen, LeeAnn Janissen Ceramic Art	Kyla Smith, Oxford University
Ann McMillan, Retired	Michael Morrow, Memorial University of Newfoundland	Francine Ford, CAP (Executive Manager)

RECENT CAPF ACTIVITIES

ENDOWED

CAP Lecture Tour: Funding from a generous donor in 2022 ensures that the CAP Lecture Tour continues in perpetuity, offering around 15 lectures annually for undergraduate physics students across Canadian universities. The program particularly benefits smaller departments where access to high-profile speakers is limited. Departments nominate preferred speakers, and students ultimately select the lecturers. As part of the endowment agreement, at least one lecture will now be aimed at high school students. Under the leadership of National Coordinator Gwen Grinyer (University of Regina) and CAP Vice President Pierre Benard (Université du Québec à Trois Rivières), the tour has transitioned from virtual (pandemic years) to hybrid and, in 2025, will return to fully in person with an anticipated 12 lecturers delivering 20 talks.

Stoicheff Scholarship: Generous donations allowed us to establish an endowment to fund a $3,000 biennial award. This scholarship is administered by the CAPF in even years and the Optica Foundation (formerly the OSA Foundation) in odd years. Further information on this scholarship can be found on the Stoicheff Scholarship web page. Since 2016, it has been awarded to:

2016: Christopher Pugh (Waterloo)

2018: Aimee Gunther (Waterloo)

2020: Matthew Robbins (Waterloo)

2022: Kate Fenwick (Ottawa)

2024: Everett Patterson (Waterloo)

Svensson Memorial Scholarship: This $3,000 biennial award, created in 2019, recognizes graduate students for research excellence and service to the physics community. It is awarded by the CAP in odd years. **This scholarship is not yet endowed and will end once the original donation is exhausted should funds not be secured before then.** Further information on this scholarship can be found on the Svensson Scholarship webpage. Recipients to date:

2021: Robin Hayes (TRIUMF/UBC)

2023: Janani Balasubramanian (Ontario Tech)

Carswell Graduate Scholarships: Endowed in 2019 by the Allan Carswell Family Foundation, this scholarship (two $5,000 scholarships awarded annually) supports physics graduates pursuing a teaching degree. Further information on these scholarships can be found on the Carswell Scholarships webpage. Recipients to date:

2020: Samantha Scarfe (Ottawa), Joshua Mogyoros (Toronto)

2021: Jay Florica (Guelph), Michelle Sullivan (Alberta)

2022: Eli Sollid (Calgary), Eloise Faehndrich (UBC)

2023: Elijah Adams (Calgary), Kara Deane (UBC)

2024: Ben Giers (Mount Royal), Dennis Thai (Alberta)

SPONSORED

High School / Cégep Teaching Awards: These five regional annual awards include two years of free CAP membership and a grant for professional development or classroom resources. The grants are funded by TRIUMF, Perimeter Institute, CAP and, until 2021, Engineers & Geoscientists BC. One award recipient is given the opportunity to receive a special award to attend a CERN High School Workshop the following summer, sponsored by Perimeter Institute and the Institute of Particle Physics (IPP). The remaining award recipients are offered the opportunity to participate in a Research Experience at any of TRIUMF, Perimeter Institute, Canadian Light Source, or SNOLAB. Regional winners since these awards were established can be found on this section of the CAP's Recognitions website.

FUNDED SOLELY THROUGH MEMBER DONATIONS

Lloyd G. Elliott University Prize Exam: A national competition for undergraduate physics students, funded by CAPF member donations. Prizes: $500 (1st place), $300 (2nd place), $200 (3rd place). The list of winners can be found on the Undergraduate Prize Exam webpage.

Canada-Wide Science Fair (CWSF): The CAPF sponsors one or more physics prizes at the CWSF to engage students in STEM and showcase the value of physics education. The CAP holds the distinction of being one of only two organizations that have sponsored at least one prize at the CWSF since its inception. During years when sufficient member donations are received, the CAPF expands its sponsorship from just the Senior level to also include the Intermediate and/or Junior levels. Previous winners can be found on the CAP's CWSF webpage.

High School Prize Exam: This annual competition offers national prizes and, when donations allow, provincially-based awards. The top national-level students are invited by Dr. Andrzej Kotlicki, the Olympiad Coordinator to travel to UBC and train for a possible spot on the International Physics Olympiad Canadian team. Suspended during the pandemic (2020-2022), it was reinstated in 2023 and will continue in 2025.

Conference Support: When funding permits, the CAPF sponsors travel support for student attendees at the Canadian Undergraduate Physics Conference (CUPC) and the Canadian Conference for Women and Gender Minorities in Physics (CCUW*iP) (virtual during the pandemic) and has supported student travel to the Canada-America-Mexico Graduate Student Conference four times since 2016.

MOVING FORWARD

Infographic & New Donation Drive: CAPF is working on new promotional materials to engage members in funding initiatives.

STRATEGIC ACTIVITIES TIMELINE

2016: Launched the "Ignite the Spark" campaign, successfully raising member donations to match the Carswell Family Foundation's $50,000 contribution.

2017: Kyla Smith joined as the first student Board member, co-developing the "Spot the Physicists" campaign and producing five career profile videos (careers.cap.ca/careers.html).

2018: Identified as a strategic initiative and established the following year, the Svensson Memorial Scholarship was created.

2019: Carswell Family Foundation donated $250,000 to endow the Carswell Physics Educator Scholarship Program ($5,000 per award, two awards per year).

2020-2021: Programs adapted for online delivery due to the pandemic. Board members included Kyla Smith, Gabor Kunstatter, Mike Morrow, Mike Roney (Chair), LeeAnn Janissen, Anastasia Ziprick, Gordon Drake, Ian D'Souza and Stephen Pistorius.

2022-2024: Successfully secured an endowment of $300,000 for the CAP Lecture Tour, ensuring its long-term sustainability. Manu Paranjape was appointed to the Board to replace Mike Roney and was subsequently elected Chair of the CAP Foundation. We extend our gratitude to Mike Roney for his long-term service on the CAPF Board. The Investment Policy Statement and Board Terms of Reference were formally updated and ratified, reinforcing governance and financial oversight. Stephen Pistorius and Anastasia Ziprick completed their terms, and we extend our gratitude for their service. They have been succeeded by Ann McMillan and Ken Iliadis, who bring fresh perspectives and expertise to the Board.

PhD Physics Degrees Awarded in Canadian Universities / Doctorats en physique décernés par les universités canadiennes

January 1 2023 to December 31 2023 / 1er Janvier 2023 au 31 Décembre 2023

CONCORDIA UNIVERSITY

HUCK, J., “The Cerebral Venous Network: deoxyhemoglobin as contrast, bias and quantitative biomarker in magnetic resonance imaging”, (C. Gauthier), June 2023, postdoctoral fellow at Universite de Sherbrooke, Sherbrooke, QC, Canada.

RAZAVIPOUR, F. “Metabolic and Blood Flow Properties of Functional Brain Networks using Human Multimodal Neuroimaging” (C. Grova, C. Gauthier), June 2023.

McGILL UNIVERSITY

AHMED, W., "Search for a bosonic decay of a charged Higgs at the LHC with the ATLAS detector", (R. Steele), Winter 2023.

AL KHARUSI, S., "Development of a water Cherenkov muon veto for the nEXO neutrinoless double beta decay experiment", (T. Brunner, D. Haggard), Fall 2023.

BHARDWAJ, M., "Deciphering the Origins of FRBs Using Local Universe CHIME/FRB Discoveries", (V. Kaspi), Winter 2023.

BOYCE, H., "Observational probes of supermassive black hole environments: from the event horizon to the sphere of influence", (Haggard), Fall 2022.

BURNS, D., "Timescale coupling phenomena with hydrodynamics phase field crystal models: The atomic scale shuffle", (N. Provatas, M. Grant), Fall 2023.

CHURCHILL, J., "Electromagnetic radiation from various stages of relativistic heavy-ion collisions", (C. Gale), Fall 2022.

COWIE, M., "Charge re-organization timescales and loss tangents at semiconductor surfaces measured by nc-AFM", (P. Grutter), Summer 2023.
ENGSTRÖM, L., "Combining spin-orbit coupling and multi-orbital interactions: a recipe for novel magnetism and superconductivity", (T. Pereg-Barnea, W. Witczak-Krempa), Summer 2023.

FRICK, M., "Improvements to the thermodynamic and kinetic consistency of the Phase Field Crystal model", (N. Provatas), Winter 2023.

FUENTES, R., "Hydrodynamics of convection with composition gradients: Salty water and Jupiter", (A. Cumming), Fall 2022.

GAMBINI, G., "A dark matter candidate in the context of physics beyond the standard model", (J. Cline), Fall 2022.

HEFFERNAN, M., "Quantification of the Quark-Gluon Plasma with statistical learning", (C. Gale), Fall 2022.

JREIDINI, P., "Novel developments in phase-field crystal modeling for the solidification of complex materials", (N. Provatas), Fall 2022.

JUTRAS-DUBÉ, L., "Geometric models of embryonic pattern formation and of genetic oscillator synchronization", (P. Francois), Fall 2022.

LI, Y., "Holographic conformal field theories and their flat-space structures", (S. Caron-Huot), Summer 2023.

LI, Z., "Search for a fermiophobic charged Higgs boson in proton-proton collisions with the ATLAS detector", (F. Corriveau, A. Warburton), Fall 2023.

LIU, Z., "Spatial organization and dynamics of multiple DNA molecules confined in a nanofluidic cavity", (W. Reisner), Winter 2023.

MATTE, D., "Ultrafast electron cold field emission from a tungsten nanotip by single cycle THz pulse", (D. Cooke), Fall 2022.

MCGOWAN, J., "Measurement of the electroweak production of a Photon and a W Boson in association with two jets using the ATLAS Detector", (B. Vachon), Fall 2023.

MENDES SILVA, M., "Nuclear equations of state, superfluidity models and cold neutron star observations", (C.Gale, A. Cumming), Summer 2023.

MODARRESI-YAZDI, R., "Comparative studies of jet quenching in relativistic heavy ion collisions", (C. Gale), Summer 2023.

MURRAY, K., "Design and commissioning of a multi-reflection time-of-flight mass-spectrometer for Barium tagging with nEXO", (T. Brunner), Winter 2023.

NASERI, H., "The use of radiomics and natural language processing to detect pain in the simulation-CT images of patients undergoing radiotherapy for bone metastasis", (J. Kildea), Winter 2023.

PAGANO, M., "From mitigating systematics to theoretical interpretation of the 21cm signal during the epoch of reionization", (A. Liu), Winter 2023.

PROULX-GIRALDEAU, F., "Guided by evolution: biophysical mechanisms of homeostasis, control and adaptation in cells", (P. Francois), Winter 2023.

PUEL, M., "Topics beyond the standard cosmological model", (J. Cline), Fall 2023.

SAHA, S., "Search for a new light particle produced in association with a top quark pair with the ATLAS Detector", (S. Robertson), Fall 2022.

SOLYOM, A., "Spin-orbit torque control of nanomagnetic devices probed by nitrogen-vacancy centres in diamond", (L. Childress, J. Childress), Summer 2023.

WAKELING, H., "A measurement of the denominators of R(D(*)) with 189 inverse femtobarns of Belle II data", (S. Robertson), Winter 2023.

ZAHRAEE, Z., "Analytical Bootstrap of Conformal Field Theory", (S. Caron-Huot), Fall 2023.

ZENG, L., "Organization, Mixing, and Demixing of Semiflexible Polymer Chains in Nanochannels Under Nonequilibrium Compression", (W. Reisner), Fall 2023.

McMASTER UNIVERSITY

SHARMA, S., "Study of unconventional superconductors and breathing pyrochlore magnets", (G. Luke), November 2023, Postdoctoral Fellow at the University of Minnesota, USA.

SMITH, E., "The Dipole-Octupole Quantum Spin Ice Candidate $Ce_2Zr_2O_7$", (B. Gaulin), November 2023, Postdoctoral Fellow at ETH, Zurich, Switzerland.

QUEEN'S UNIVERSITY

ABOELHASSAN, S., "On Maximal Extensions of the Vaidya Metric", (K. Lake), April 2023, Assistant Professor of Mathematics at University of Prince Edward Island, Charlottetown, Prince Edward Island, Canada.

ALLEN, T., "Shedding Light on Laser-Metal Interactions: *In situ* Monitoring with Inline Coherent Imaging and Integrating Sphere Radiometry", (J. Fraser), November 2023, Optical Scientist at Light Machinery, Nepean, ON, Canada.

FASCIONE, E., "Searching for Electron-Interacting Dark Matter with the Super Cryogenic Dark Matter Search", (W. Rau), August 2023, Postdoctoral Fellow at the University of Heidelberg, Heidelberg, Germany.

FRIEDLANDER, A., "Black Holes to Dark Matter and Back Again", (A. Vincent), July 2023, Geomatics Data Analyst and Developer at Ministry of the Environment, Conservation and Parks, Toronto, Ontario, Canada.

GERMOND, R., "Techniques and Challenges in Low-Mass Dark Matter Searches Using CDMS Style Detectors", (W. Rau), February 2023Postdoctoral fellow at Institute for Quantum Computing (IQC) of the University of Waterloo, Waterloo, Ontario, Canada.

LEBEDEV, D., "General Expressions for Measurable Geometric and Kinematic Quantities in Curved Spacetime", (K. Lake), August 2023, Term Adjunct at Queen's University, Kingston ON, Canada.

POUSHIMIN, R., "From Surface Plasmon Resonance to Hot Electron Emission: Pioneering Next-Generation of Enhanced Photodetection", (J.-M. Nunzi), September 2023, Optical Engineer at VIAVI Solutions, Ottawa, ON, Canada.

SEMENEC, I., "The Geoneutrino Signal in the SNO+ Experiment", (M. Chen), November 2023.

SIMMONS, J., "Using Quadrature and Collocation Methods to Calculate Spectra of Polyatomic Molecules with General Potential Energy Surfaces", (T. Carrington), April 2023.

TAM, B., "Enabling Neutrinoless Double Beta Decay in the SNO+ Experiment Through the Deployment and Study of Liquid Scintillator", (M. Chen), August 2023, Newton Fellow (postdoc) at University of Oxford, Oxford, UK.

WANG, D., "Light Emission and Charge Transport in Reverse-biased Polymer Junctions", (J. Gao), September 2023, Senior Process Engineer at Advanced Micro-Fabrication Equipment Inc., Shanghai, China.

WINDELER, M., "High-Average-Power Optical Parametric Chirped Pulse Amplification Development for the Linac Coherent Light Source II", (J. Fraser), November 2023, Educator, Halifax, NS, Canada.

SIMON FRASER UNIVERSITY

BLABER, S., "Energetically Efficient Control of Stochastic Thermodynamic Systems", (D. Sivak), June 2023, Postdoctoral Fellow with Professor Joerg Rottler at the University of British Columbia, Vancouver, British Columbia, Canada.

JAGER, B., "Precision Measurements of Higgs Boson Production in Decays to W Bosons using Machine Learning with the ATLAS Experiment", (B. Stelzer), June 2023.

LEE, J., "Exploring the magnetism of the 4f-based intermetallic compounds on geometrically frustrated lattices", (E. Mun), October 2023, manager at A.TECH Software Company in Ulsan, South Korea.

MANDAL, S., "Superconductivity of triple-point fermions", (I. Herbut), June 2023, Postdoctoral Researcher with Professor Matthias Scheurer at the Department of Physics, University of Stuttgart in Baden-Wurtenberg, Germany.

NARAYANAN, S., "Chiral Symmetry Breaking in the Fractional Quantum Hall Effect in Graphene", (M. Kennett), October 2023.

SIDHU, S., "Improving the statistical sensitivity reach, of the TUCAN neutron electric dipole moment experiment", (J. Sonier, R. Picker).

TORONTO METROPOLITAN UNIVERSITY

BASHARAT, F., "Low-dose, X-ray-based Imaging of Lung Function", (J. Tanguay), June 2023, Medical Physics Resident at Cancer Centre of Southeastern Ontario, Kingston, Ontario, Canada.

D'SOUZA, M., "Advancements in Water Calorimetry Design and Techniques, and Applications to Modern Radiotherapy", (A. Sarfehnia, C. Kumaradas), October 2023, Medical Physics Resident at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.

HORNSBY, T., "Ultrasound Activation of Nanodrug Carriers Functionalized with Anticancer Drugs: Modelling and Measurements", (J. Tavakkoli), October 2023, Radiation Oncology Physics Resident at McGill University (St. Peter's Health Partners), Montreal, Quebec, Canada.

MONJAZEBI, D., "Phase Aberration Estimation in Synthetic Transmit Aperture Ultrasound Imaging and Its Application to Estimating Sound Speed", (Y. Xu), June 2023, Data Scientist at Shopify, Toronto, Ontario, Canada.

QUIROUETTE, C., "Impact of the discrete, stochastic nature of cell-virus interactions on the likelihood of infection establishment, interpretations of experimental infectivity measurements, and parameter estimation from such measurements", (C. Beauchemin), June 2023, Research Scientist at Wyatt AI, Montreal, Quebec, Canada.

ZALLOUM, I., "On the fine-tuning of the size and resonance frequency of microfluidically-generated monodisperse microbubbles", (R. Karshafian, S. Tsai), June 2023.

UNIVERSITÉ DE MONTRÉAL

BÉDARD, A., « Caractérisation et modélisation de l'évolution spectrale des étoiles naines blanches chaudes », (P. Bergeron, P. Brassard), March 2023, postdoctoral fellow at the University of Warwick, Coventry, UK.

BOUCHER, A., « Caractérisation de l'atmosphères des exoplanètes par spectroscopie de transit à haute dispersion avec SPIRou », (D. Lafrenière), March 2023, Scientist (physics) at Environment and Climate Change Canada, Dorval, Qc, Canada.

BROUSSEAU-COUTURE, V., « Étude de la dépendance en température de la structure électronique à l'aide de la théorie de la fonctionnelle de la densité : effets non adiabatiques, dilatation du point zéro, couplage spin-orbite et application aux transitions de phase topologiques », (M. Côté), March 2023, Scientist, physical sciences - research Air quality policy-issue response section at Canadian Meteorological Center Environment and Climate Change Canada, Dorval, Québec, Canada.

CACOT, L., « Couplage d'une décharge à barrière diélectrique avec un aérosol pour le dépôt de couches minces (multi)fonctionnelles : rôle de l'injection pulsée de précurseurs », (L. Stafford, N. Naudé), March 2023, Coordonnatrice principale, Bureau Recherche Développement Valorisation (BRDV) - Direction générale et administration à l'Université de Montréal, Montréal, Québec, Canada.

DARVEAU-BERNIER, A., « Caractérisation d'atmosphères d'exoplanètes à haute résolution à l'aide de l'instrument SPIRou et développement de méthodes d'extraction spectrophotométriques pour le télescope spatial James Webb », (R. Doyon, D. Lafrenière), May 2023, Scientist (physics) at Environment and Climate Change Canada, Montréal, QC, Canada.

DUCHAINE, J., « Modélisation Monte Carlo du CyberKnife M6 et ses applications à la dosimétrie de petits champs de radiothérapie », H. Bouchard March 2023, Project Analyst at Quick Release, Coventry, Warwickshire, UK.

HARDY, F., « Observations, modélisation, évolution et origines des naines blanches magnétiques », (P. Dufour), March 2023, Scientifique de données au Centre de recherche du CHUM, Montréal, QC, Canada.

PAPADATOS, C., "Advances in Calibration and Tracking Techniques for Pixelated Si Timepix3 Detectors", (C. Leroy), September 2023, Professeur de physique au CEGEP Vanier, Montréal, Qc. Canada.

RAHMAN, MD. M., "Modeling and numerical study of the diffusion of point defects in α−iron", (N. Mousseau), June 2023, postdoctoral fellow at Polytechnique Montréal, Montréal, Québec, Canada.

REMY, C., « Contrôle en temps réel de la précision du suivi indirect de tumeurs mobiles en radiothérapie », (H. Bouchard), March 2023, Systems designer/ ingénieure systèmes à Zimmer Biomet, Montréal, QC, Canada.

UNIVERSITÉ DE SHERBROOKE

ABBASI ESKANDARI, M., "Magnetic properties of oxide heterostructures for magnetic cooling systems and spintronics", (P. Fournier), Mai 2023, Postdoctoral Researcher at McGill Université, Montreal, Québec, Canada.

DÉSOPPI, L., « Groupe de renormalisation fonctionnel pour systèmes fermioniques unidimensionnels sur réseau appliqué au modèle de Fermi-Hubbard étendu », (C. Bourbonnais), Décembre 2023, Chercheur posdoctoral, Université de Sherbrooke, Sherbrooke, Québec, Canada.

GAUVIN-NDIAYE, C.-A., « L'approche autocohérente à deux particules: cuprates dopés en électrons et améliorations de la méthode », (A.-M. Tremblay), Novembre 2023, Leader de l'équipe théorique, Nord Quantique, Sherbrooke, QC, Canada.

KRIEKOUKI, I., « Approche industrielle aux boîtes quantiques dans des dispositifs de silicium sur isolant complètement déplété pour applications en information quantique », (M. Pioro-Ladrière), Décembre 2022.

LEFRANÇOIS, É., « Étude du transport thermique dans l'isolant magnétique α-RuCl3 : candidat de liquide de spins quantique Kitaev », (L. Taillefer), Juillet 2023, Coordonnateur de la formation, Institut Quantique, Université de Sherbrooke, Québec, Canada.

ROHRBACHER, C., « Dispositifs de spin sur plateforme silicium de 300 mm et intégration cryo-CMOS pour la mise à l'échelle des qubits de spin », (E. Dupont-Ferrier), Novembre 2023, Senior Experimental Quantum Physicist, Université de Sherbrooke, Sherbrooke, QC, Canada.

SHILLITO, R., "Simulation and optimisation of superconducting Qubit control and readout", A. Blais, Septembre 2023, Theoretical Physicist at Nord Quantique, Sherbrooke, Québec, Canada.

UNIVERSITÉ LAVAL

BÉLANGER, C., "Next generation of optimization and interactive planning algorithms for brachytherapy treatments", (L. Beaulieu), Décembre 2023, Software Engineer Algorithm Development, Elekta Brachy, Veenendaal, The Netherlands.

CHANTREL, P-E., « Amplification d'un signal à 10 µm par pompage optique du CO_2 utilisé comme milieu de gain », (B. Witzel, M. Piché), Octobre 2023, Software Developer, Toronto.

COLMENARES CALDERON, Y.N., "Exploring As-Se Based Chalcogenide Thin Films for the Fabrication of Micro-Optical Components", (Y.Messaddeq), Avril 2023, Postdoctoral fellow at ULaval at the Chemistry department.

DE TILLIEUX, L.P., « Développement d'une sonde de spectroscopie de réflectance diffuse résolue spatialement pour la caractérisation de tissus épithéliaux », (P. Marquet), Septembre 2023, Optronics expert, Nüvü Caméras Inc.

GAUTHIER, J-C., « Conversion de lumière dans l'infrarouge-moyen par amplification fibrée », (R. Vallée), Février 2023, Director - Operations, comm. & industry promo. at Optonique, Québec, Canada.

JOBIN, F., « Développement de lasers impulsionnels à fibre dopée au dysprosium », (R. Vallée, M. Bernier), Octobre 2023, Research scientist, ABB, Québec, Canada.

KASSIMI, Y., « Source infrarouge accordable de haute énergie pour le pompage optique d'un amplificateur CO_2 à 10 microns », (B. Witzel, M. Piché), Octobre 2023, Senior Functional Developer at Equisoft.

KROSHKO, A., « L'analyse de frontières stochastiques appliquée à la prédiction dosimétrique pour la planification de traitement en radiothérapie externe », (L. Archambault), Décembre 2023, Medical Physicist, Centre Intégré de santé et des services sociaux du Bas-Saint-Laurent, Rimouski, Quebec.

LEBEL-CORMIER, M-A., « Conception d'une nouvelle génération de calorimètres multi-point utilisant une fibre optique à réseaux de Bragg pour la dosimétrie en radiothérapie », (L. Beaulieu, M. Bernier), Décembre 2023, Medical Physicist, Centre Intégré de santé et des services sociaux du Bas-Saint-Laurent, Rimouski, Quebec.

PARADIS, P., « Développement de lasers impulsionnels tout-fibre pour la spectroscopie dans l'infrarouge moyen », (M. Bernier, R. Vallée), Juillet 2023, Postdoctoral researcher at LumIR Lasers, Québec, Canada.

PELCHAT-VOYER, S., « Optimisation de l'accélération directe d'électrons par une impulsion laser avec un déphasage de Gouy ajustable », (M. Piché), Mars 2023, Spécialiste en imagerie hyperspectrale et télédétection, Flyscan Systems Inc.

TAYAMA, G., "Development of aluminum-phosphate hybrid materials via sol-gel route for additive manufacturing of photonic materials", (T. Galstien, Y. Messaddeq), Octobre 2023, Postdoctoral fellow at ULaval in the Physics Department.

THO, D., « Suivi électromagnétique en curiethérapie à haut débit de dose: performance et rôle de la technologie », (L. Beaulieu), Février 2023, Postdoctoral fellow at MD Andersen Cancer Center, Houston, Texas.

UNIVERSITY OF ALBERTA

BIN AKBER ALI, A., "Searches for Magnetic Monopoles and Highly Ionising Particles at $\sqrt{s}$ = 13 TeV at the LHC with MoEDAL", (J. Pinfold, M. de Montigny), November 2023, Research Fellow for CNRS (French National Centre for Scientific Research), Singapore.

BOROWIECKI, R., "Improved spectral estimates of climate oscillations in the Quaternary and Neogene", (V. Kravchinsky, M. van der Baan), June 2023, Field Geophysicist, ConeTec Investigations Ltd., Edmonton, AB, Canada.

BRUULSEMA, C., "Theory and Application of Thomson Scattering to Particle Transport and Magnetic Field Measurements in Laser-Produced Plasmas", (W. Rozmus), June 2023, Postdoctoral fellow, National Ignition Facility, Lawrence Livermore National Laboratory, Livermore, CA, USA.

FAHLMAN, S., "You Must Construct Additional Hypermassive Neutron Stars", (R. Fernández Munoz), November 2023, Forecasting and Analytics Specialist, Capital Power, Edmonton, AB, Canada.

HANNESON, C., "Geothermal Exploration and Tectonic Studies in Southwestern Canada Using the Magnetotelluric Method", (M. Unsworth), November 2023, Geophysicist, SJ Geophysics, Vancouver, BC, Canada.

MODI, S., "Higgs Boson Production in Gluon Fusion through the Next-to-Next-to-Leading Power in Quark Mass", (A. Penin), November 2023, Visiting Assistant Professor, Stetson University, DeLand, Florida, USA.

OKWOLI, E., "Comparison and Prediction of High-Resolution Probe Screening Measurements on Rock Cores", (D. Potter), November 2023, Data Warehouse Analyst, Edmonton Public Library, Edmonton, AB, Canada.

SAFARABADI FARAHANI, S., "A Search for Dark Matter Interactions in the DEAP 3600 Detector Using Fiducial Masses Ranging from 1433 to 2966 kg", (A. Hallin), November 2023, Data Analyst, Zero Point Cryogenics, Edmonton, AB, Canada.

SARKAR, S., "Search for TeV-Scale Neutrino Dimuon Events with 10.7 Years of IceCube Data", (R. Moore), November 2023, Astronomical Software Developer, Dept. Physics, University of Alberta, Edmonton, AB Canada.

UNIVERSITY OF BRITISH COLUMBIA

BEVINGTON, C.W.J., "Development of advanced denoising and analysis algorithms for applications in hybrid PET/MRI brain imaging", (V. Sossi), November 2023, Postdoctoral Research Fellow at University of British Columbia, Vancouver, BC, Canada and Class IV Flight Instructor at Principal Air, Abbotsford, BC, Canada.

DVORAK, A., “Advances in Quantitative Magnetic Resonance Imaging of Myelin”, (S. Kolind), May 2023, Founder and CEO at InForm Imaging, Vancouver, BC, Canada.

FOMICHEV, S., "Electron-phonon coupling in insulators: beyond the Migdal limit", (M. Berciu), November 2023, Quantum Scientist at Xanadu Quantum Technologies Inc., Toronto, Ontario, Canada.

GARG, P., "Biophysics of Disease and Evolution: Molecules to Organisms", (S. Plotkin), May 2023, Research Programmer at Canada's Michael Smith Genome Sciences Centre, Vancouver, BC, Canada.

GYSBERS, P., "Radiative Capture and Decays in Ab Initio Nuclear Theory" (P. Navratil, R. Kruecken), May 2023, Research Associate at the Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI, USA.

HAENEL, R., “Collective modes of the superconducting condensate”, (M. Franz, D. Manske, M. Daghofer), November 2023, Quantum Software Engineer at Photonic Inc, Coquitlam, BC, Canada.

HUANG, Y., "Dynamics of transneptunian objects under the influence of a rogue planet", (B. Gladman), November 2023, Project Research Fellow at National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan.

MORRIS, S.R., "Magnetic resonance imaging to measure myelin: orientation dependence and application to spinal cord injury", (C. Laule), May 2023, Medical Physics resident in Radiation Oncology at NYU Langone Health, New York City, NY, USA.

NEWHOUSE, R., “Using displaced tracks to search for sterile neutrinos in the ATLAS detector”, (A. Lister), May 2023, Software Engineer at Amazon Web Services, Vancouver, BC, Canada.

PARADA TORRES, J., "Red giant stars as standard candles", (H. Richer), May 2023.

PINSONNEAULT-MAROTTE, T., "A Detection of Cosmological 21 cm Emission from CHIME in Cross-correlation with the eBOSS Lyman-α Forest", (G. Hinshaw), November 2023, Postdoctoral fellow, Stanford University/Kavli Institute for Particle Astrophysics and Cosmology (KIPAC).

RIPOCHE, P., "Studies of evolved stellar populations: from giants to remnants", (J. Heyl), November 2023.

SAITO, Y., "Development of statistical tools for studies of the rapid neutron capture process", (R. Kruecken), May 2023, Postdoctoral Fellow at the University of Notre Dame, IN, USA.

SHIN, H., "Study of 4+ and 3+ titanate oxide thin films grown by molecular beam epitaxy", (K. Zou), May 2023, Senior Materials Scientist at PsiQuantum, Palo Alto, CA, USA.

TUMMURU, T., "Topological superconductivity in twisted 2D structures", (M. Franz), May 2023, Scientist at Hitachi Energy, Zürich, Switzerland.

WADDELL, C., "Boundaries, Braneworlds, and Black Holes: Applications of the AdS/BCFT Correspondence", (M. Van Raamsdonk), November 2023, Postdoctoral Fellow at the Perimeter Institute, Waterloo, Ontario, Canada.

WANG, R., "Relaxation Dynamics in a Molecular Ultracold Plasma Control and Modeling", (E. Grant), November 2023, Postdoctoral Fellow at Quantum Valley Ideas Lab, Waterloo, ON, Canada.

YAN, X., "Towards Scalable Quantum Silicon Photonics with Spin Qubits", (J. Young), May 2023, Senior Photonic Engineer II at Xanadu Quantum Technologies, Toronto, ON, Canada.

UNIVERSITY OF CALGARY

ESTEKI, K., "Thermo-electro-optical properties of disordered nanowire networks", (C. Gomes da Rocha), November 2023.

FREDERICK, R., "Advances in Total Body Irradiation Treatment: Improving Standardization and Efficiency", (G. Pierce), November 2023, Medical Physicist at Alberta Health Services, Calgary, Alberta, Canada.

JI, J., "Novel approaches towards non-cryogenic quantum repeaters", (C. Simon), May 2023.

KARUVADE, S., "Power and Certifiability of Quantum Computing for Open Systems", (B. Sanders), February 2023.

MANN, T., "Development and Clinical Implementation of Applications for Guiding Linac-based Stereotactic Radiosurgery Planning", (K. Thind), November 2023.

MOHANDESI, A., "Characteristics of Topside Equatorial Ionospheric Irregularities: An Investigation Using Swarm Echo Measurements", (D. Knudsen), November 2023.

RANASINGHE, S., "Radio Study of Supernova Remnants: Understanding the Missing Supernova Remnant Problem", (D. Leahy), November 2023.

REITER, K., "Auroral Zone Geomagnetic Activity and Space Weather Implications", (J. Brown), November 2023.

SAXENA, G., "Manipulation of dynamical resources in quantum information theory", (G. Gour), May 2023.

SHANDILYA, P., "Optomechanical Spin-Photon Interface in Wide-Band Gap Materials", (P. Barclay), May 2023.

VAN ELBURG, D., "Three-Dimensional Transvaginal Ultrasound for Intracavitary and Interstitial Gynecologic High-Dose-Rate Brachytherapy", (T. Meyer), November 2023.

UNIVERSITY OF GUELPH

BIDAMAN, H., "Lifetime Analysis of 100Zr and Simulating the Detector Array for Energy Measurements of Neutrons (DAEMON)", (P. Garrett), June 2023, Detector Product Engineer at Redlen Technologies Inc, Saanichton, British Columbia, Canada.

BURACZYNSKI, M., "Impurities and Inhomogeneities in Neutron Matter", (A. Gezerlis), February 2023, Quantitative Analyst at Deloitte, Oakville, Ontario, Canada.

KASANDA, E., "A Novel Method of Sub-milimeter Range Verification for Hadron Therapy using a Tumour Marker", (C. Svensson), June 2023, Postdoctoral Fellow at University of Bern, Bern, Switzerland.

NASROLLAHZADEH, F., "Structuring Plant-Based Foods Using Less Refined Plant Proteins and High Moisture Extrusion", (M. Martinez, J. Dutcher), June 2023.

PALKANOGLOU, G., "Pairing in nuclear and cold atomic systems", (A. Gezerlis), October 2023, Postdoctoral Research Associate at TRIUMF, Vancouver, British Columbia, Canada.

RADICH, A., "^{124}Xe Angular Correlation Analysis and Development of the Detector Array for Energy Measurements Of Neutrons (DAEMON)", (P. Garrett), February 2023, Neutron Scientist at General Fusion, Cambridge, Ontario, Canada.

SALIMINASAB. M., "A Membrane Photosensor Related to Proteorhodopsin with Unique Motifs for Signal Transduction", (L. Brown), October 2023, Postdoctoral Fellow at University of Toronto, Ontario, Canada.

XIAO, P., "Towards Understanding Membrane Protein Folding and Stability", (V. Ladizhansky, L. Brown), October 2023, Postdoctoral Research Associate at Michigan State University, East Lansing, MI, United States.

UNIVERSITY OF OTTAWA / UNIVERSITÉ D’OTTAWA

COUTURE, N., "Enhancing time-resolved THz systems through the integration of optical fibers", (J.-M. Ménard), November 2023, Research Scientist, Ciena, Ottawa, ON, Canada.

DUBE, Z., "Photoelectron spectroscopy using a synthetically chiral laser pulse", (A. Staudte), May 2023, Senior Research Technician, King’s College London, UK.

GODFREY, A. "Blister Formation Using Ultrafast Laser Pulses", (P. Corkum), February 2023, Senior Optical System Designer, Ciena, Ottawa.

HOGAN, R., "Manipulating beam propagation in slow-light media", (R. Boyd), September 2023, Postdoctoral Fellow in the Liu Hui Group at Nanjing University in Nanjing, China.

LAFERRIERE, P., "Quantum Optical Properties of Nanowire Quantum Dots", (D. Dalacu), January 2023, Postdoctoral Fellow at Carleton University, Ottawa.

LEBLANC LATOUR, M., "Cellulose biomaterials for bone tissue engineering", (A. Pelling), January 2023, CEO and co-founder of Sugar Coated Technologies Inc.

LEMIEUX, S., "Applications of high-gain parametric down-conversion to metrology", (R. Boyd), March 2023, Defense Scientist in Electro-optic Surveillance and Reconnaissance at Defence Research and Development Canada.

MANALO, J., "Computational methods for designing semiconductor quantum dot devices", (P. Hawrylak), September 2023, Postdoctoral Fellow at University of Windsor.

SALEEM, Y., "Electronic and Optical Properties of 2D Materials", (P. Hawrylak), April 2023, Postdoctoral Fellow at TU Dortmund, Germany.

SIT, A., "The Physics of Spatially Twisted Nematic Liquid Crystals", (E. Karimi), October 2023, Research Associate, National Research Council, Ottawa.

TAVAKOLI, S.K., "Dynamical Complexity of Nonlinear Dynamical Systems with Multiple Delays", (A. Longtin), September 2023, Postdoctoral Fellow at the University of Ottawa.

WANG, H., "Stimulated Brillouin scattering in chalcogenide microfiber sensors and random fiber lasers", (X. Bao), February 2023, Associate Professor, North University of China.

UNIVERSITY OF SASKATCHEWAN

BAUER, R., "Probing Matter with Photons, Electrons and Neutrons: A Study of Water and Flax", (J. Tse, GS Chang), June 2024, Research Associate at Zentrum fur Wasserforschung Freiberg, Freiberg, Hamburg.

BRAUN, P., "Investing Local Interactions of Transition Metal Ions in Correlated Materials", (A. Moewes, R. Green), June 2023, Associate Scientist at Canadian Light Source, Saskatoon, SK, Canada.

deOLIVEIRA, T., "Heavy-Light and Doubly-Strange Diquark Spectrum from QCD Laplace Sum-Rules and Diagrammatic Renormalization Methods", (T. Steele), October 2023, physics instructor at a Canadian University.

ELCOCK, W., "Characterization of Ion Implanted Materials for Photonic Applications: Radiation Damage in Tellurium Dioxide and Silicon LEDs", (M. Bradley, GS Chang), June 2024, research analyst at Environmental Materials Science (EMS) Inc, Saskatoon SK, Canada.

MORENO, J., "Characterization of an Inductively-Coupled Plasma Immersion Ion Implanted System", (L. Couedel, M. Bradley), June 2023, Isotope Production Scientist for TMC2 Manufacturing Company, North Vancouver, BC, Canada.

TAVASSOLI, A., "Drift Instabilities, Anomalous Transport, and Heating in Low-temperature Plasmas", (A. Smolyakov), June 2023, Postdoctoral fellow at Australian National University, Canberra Australia.

ZHEN, P., "First Principles Studies of Structure-Carcinogenicity Relationship", (GS Chang), June 2024.

UNIVERSITY OF TORONTO

AUDETTE, A., "Physical Mechanisms Behind the Midlatitude Atmospheric Energy Transport Response to Imposed Arctic Sea Ice Loss.", (P.J. Kushner), November 2023, Postdoctoral Fellow at the University of California in Santa Cruz, U.S.A.

BAKER, D., "Understanding Pulsar Scintillation with the Power of Straight Lines.", (U.-L. Pen), March 2023, postdoctoral fellow at Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan.

BARRON, J.P.O., "New Probes of Hidden Sectors: From Colliders to Cosmology.", (D. Curtin), November 2023, Postdoctoral Fellow at Stony Brook University in Stony Brook, NY, USA.

BARTRAM, F.M., "Optical studies of topological magnetic materials.", (L. Yang), November 2023, Application Engineer, R&D department, at Zolix Analytical Instruments, Beijing, China.

BASSO, M., "Measurement of Associated Production of Higgs Bosons Decaying to Pairs of W Bosons with the ATLAS Detector at the Large Hadron Collider.", (R.S. Orr), June 2023, Postdoctoral Fellow with the ATLAS Group, Particle Physics Department, Physical Sciences Division, TRIUMF, Vancouver, BC, Canada.

BEDROYA, O., "Resource-Efficient Real-Time Polarization Compensation for MDI-QKD.", (H.K. Lo, L. Qian), June 2023, Quantitative Networking Engineer at Photonic Inc., Coquitlam, BC, Canada.

CABAJ, A., "Synthesizing Observations and Models to Improve Estimates of Snow on Arctic Sea Ice", (P.J. Kushner), November 2023, Postdoctoral Fellow, University of Toronto Mississauga, Geography, Mississauga, ON.

FENG, J.K.F., "Next Generation Ultrafast Electron Diffractometer", (R.J.D. Miller), June 2023.

GORDON, J.A.S., "Exploring Symmetry and Field-Induced Phenomena in Kitaev Materials", (H.-Y. Kee), June 2023, now an IT Specialist at Bank of Montreal (BMO), Toronto, ON, Canada.

HAN, Y.F., "Measurement of Electroweak $VVjj$ Production in Semileptonic Final States in pp Collisions at $\sqrt{s}$ = 13 TeV with the ATLAS Detector", (P. Savard), June 2023, Data Scientist, Rakuten, Tokyo, Japan.

JACKSON, S.G., "Toward a compact two-photon optical clock based on calcium", (A. Vutha), June 2023.

KETABCHI HAGHIGHAT, S., "Measurement of the cross section of the Higgs boson production in association with a Z boson and decaying into W $W*$", (P. Krieger), June 2023, Senior Data Scientist at MinervaAI, Toronto, ON, Canada.

KIRBY, D., "Mesoscopic models of cellular signaling reveal strategies for specificity in crosstalk signal pathways", (A. Zilman), June 2023, Senior Policy Analyst at Regina at Government of Saskatchewan, Regina, SK, Canada.

KISLIUK, D.P., "Searches for Lepton Flavour Violating Higgs Boson Decays with the ATLAS Detector", (R.S. Orr), November 2023.

LADAN, J., "Experiments on the formation of rippled icicles", (S.W. Morris), June 2023.

LI, K., "Quantifying the impacts of resolution-dependent model errors on tropospheric ozone simulation", (D.B.A. Jones), November 2023.

LIN, F.X., "Dispersion Measure Variations Predict Lensing in Pulsars", (U.-L. Pen), June 2023, Chief Data Scientist at Fanstories, Toronto, ON, Canada.

LINDQUIST, A.W., "Unconventional Superconductivity in Spin-Orbit Coupled Systems", (H.-Y. Kee), November 2023, NMR Scientist at Foqus Technologies Inc., Toronto, ON, Canada.

MA, Y., "Irreversible fluxes in double-diffusive systems and the origin of thermohaline staircase", (W.R. Peltier), March 2023, Postdoctoral Fellow at MIT, Cambridge, MA, U.S.A.

MACKAY, V., "Instrument Design and Analysis Techniques for Low-Redshift 21 cm Cosmology and Transient Detection with CHORD and CHIME", (K. Vanderlinde), November 2023, Postdoctoral Scholarship at MIT, Cambridge, MA, U.S.A.

MASSARELLI, G., "The properties of Dirac materials: Strain, magnetoelectrics and Krein-Hermiticity", (A. Paramekanti), June 2023, research scientist in the field of artificial intelligence, at a tech startup in USA.

MCGIBBON-GARDNER, S.M., "Models of Elite and Equipotent Dynamics in Cellular Reprogramming and Cancer Growth", (S. Goyal), November 2023.

MENG, H.Y., "Searching for beyond the Standard Model phenomena in dijet events with at least one lepton with the ATLAS detector", (W. Trischuk), November 2023.

OGHBAEY, S., "Fixed Target Sample Delivery for Serial Crystallography and Ultrafast Study of Bismuth by Electron Diffraction", (R.J.D. Miller), June 2023, Lecturer at the University of Toronto, Toronto, ON, Canada.

ROTHSCHILD, J., "The role of stochastic competitive processes on population diversity and dynamics in ecological communities", (A. Zilman), June 2023.

ROY, J., "Aspects of Resummation in Effective and Finite Temperature Field Theory", (M.E. Luke), November 2023, Postdoctoral Fellow, Duke University, Durham, NC, U.S.A.

SPOURDALAKIS, A.G.B., "Effective Field Theory and Machine Learning for Jet Physics", (M.E. Luke), March 2023, Research Associate at N.C.S.R. DEMOKRITOS Institute of Nuclear & Particle Physics Agia Paraskevi, Greece.

URIBE CASTANO, LJ., "Wide-field Polarimetric Second Harmonic Generation Microscopy for Histology Imaging", (V. Barzda), June 2023, Quantitative Analyst at Dynasty Power Inc., Calgary, AB, Canada.

VOLETI, S., "Hidden order and Spin liquids in Correlated d-orbital oxides", (A. Paramekanti), November 2023, Senior Data Scientist, MLSE (Maple Leaf Sports & Entertainment Partnership), Toronto, ON, Canada.

XU, P., "Probing atom on-site interactions in an optical lattice", (J.H. Thywissen), June 2023, Quantitative Strategist at Morgan Stanley, Toronto, ON, Canada.

YIP, L.S.K., "Control of Acoustic Waves by Locally Resonant Phononic Crystals", (S. John), November 2023, Lecturer at the Chinese University of Hong Kong, Hong Kong.

UNIVERSITY OF VICTORIA

ADEGUN, J., "Improvement of the efficiency and Beam Quality of the TRIUMF Charge State Booster", (D. Karlen, O. Kester), Postdoctoral Fellow at TRIUMF in the Beam Delivery Group, Vancouver, BC, Canada.

BI, J., "Dust Dynamics in Protoplanetary Disks: Fables of the Sun and the Wind in the Pre- and Post-Planet-Formation Eras", (R. Dong), Postdoctoral Fellow at AISAA, Taipei, Taiwan, Republic of China.

BIALEK, S., "Skyward AI: Advancing Astronomy with Intelligent Machines", (S. Fabbro, K. Venn), AI/ML Specialist at Oceans Network Canada, Victoria, BC, Canada.

BORUKHOVETSKAYA, A., "Tidal Evolution of Dwarf Spheroidal Satellites", (J. Navarro).

BROMMA, K., "Three dimensional spheroids and gold nanoparticles in combined cancer therapy", (D. Chithrani, W. Beckham), Medical Physics Resident at BC Cancer, Victoria, BC, Canada.

CERVANTES SMITH, M., "Development and Implications of ISOL Target-Materials with High-Carbon content for Short-Lived Radioactive Isotope Beam Production", (A. Gottberg, D. Karlen), now working at TRIUMF in Vancouver, BC, Canada.

ESPLEN, N., "Development of Enabling Technologies for Ultra-high Dose Rate and Spatially Fractionated Radiation Therapy", (M. Bazalova-Carter), now a Postdoctoral Fellow at MD Anderson Cancer Center, University of Texas, Houston, TX, USA.

FOROUGHI ABARI, S., "Searching for Dark Sectors with Proton Bremsstrahlung", (A. Ritz), Postdoctoral Fellow at Carleton University, Ottawa, ON, Canada.

MILLER, C., "Development of Tau Polarimetry for Measuring Beam Polarization in e^+e^- Colliders", (M. Roney), Postdoctoral Fellow at the University of Victoria, Victoria, BC, Canada as well as at Simon Fraser University, Burnaby, BC, Canada.

O'CONNELL, J., "Developing Lower Cost Radiotherapy Solutions for Low and Middle Income Countries", (M. Bazalova-Carter), Postdoctoral Fellow at Dana Farber Cancer Institute, Harvard Medical School, Boston MA, USA.

SHELBAYA, O., "Model Coupled Accelerator Tuning", (O. Kester, D. Karlen), now working at TRIUMF in the Beam Physics Group in Vancouver, BC, Canada.

THOMPSON, W., "Lights in Motion Observing Nearby Planets with Imaging, Wavefront Sensing, Orbital Detection, and Spectroscopy", (C. Marois, F. Herwig), Postdoctoral Fellow at the National Research Council of Canada, Herzberg Astronomy and Astrophysics, Victoria, BC, Canada.

WESTERN UNIVERSITY

GIMENEZ UMBERT, B., "New Aspects of Scattering Amplitudes, Higher-k Amplitudes, and Holographic Quark Gluon Plasmas", (A. Buchel), June 2023, STFC Research Fellow at the University of Southampton.

MAZAREI, M., "Modelling Cell Population Growth", (M. Karttunen), June 2023.

SOLTANI, S., "Computational Modeling of Melanin Aggregation", (M. Karttunen), June 2023.

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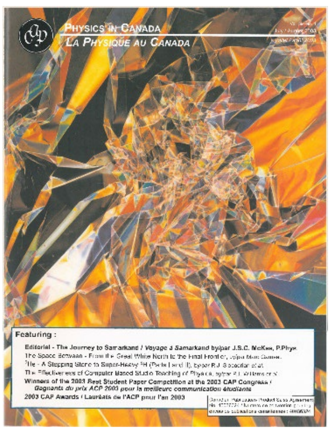
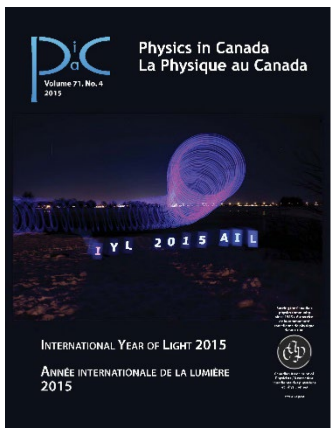
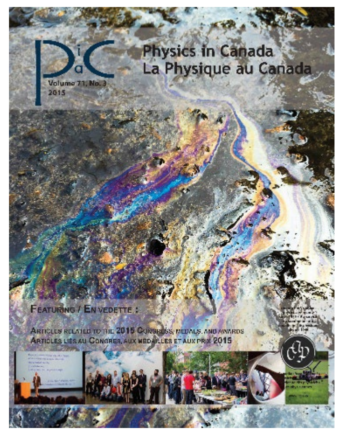
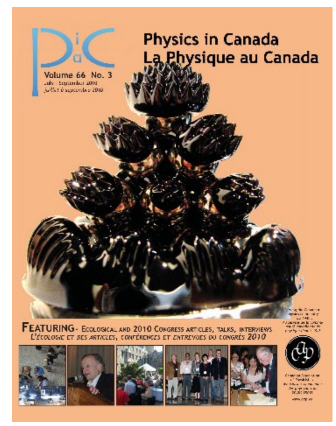
You are invited to submit photographs of beautiful or unusual physics phenomena that may be selected to appear on the cover of Physics in Canada. Please send an electronic copy of the photograph, with a short (200 words or less) description explaining the phenomena in terms suitable for, and understandable to, any practising or student physicist, to the Editor of Physics in Canada at pic-pac@cap.ca. Please note that all entries must be original artwork produced by the participant.









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Vous êtes invités à soumettre des photographies de phénomènes physiques magnifiques ou inhabituels qui pourraient être sélectionnées pour figurer sur la couverture de La Physique au Canada. Veuillez envoyer une copie électronique de la photographie, accompagnée d'une brève description (200 mots ou moins) expliquant le phénomène en des termes adaptés et compréhensibles pour tout physicien(ne) en exercice ou étudiant(e), au rédacteur en chef de La Physique au Canada à l'adresse suivante : pic-pac@cap.ca. Veuillez noter que toutes les contributions doivent être des œuvres d'art originales produites par le participant.

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Reciprocal Agreements - Group Insurance

Comment sommes-nous une communauté ?

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Mise en réseau - Conférences - Bourses
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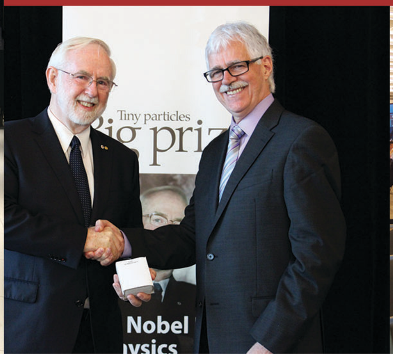

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