Physics in Canada
La Physique au Canada

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Serving the Canadian physics community since 1945 / Au service de la communauté canadienne de physique depuis 1945

Featuring / En vedette :

Articles related to the 2019 Congress, medals, and awards
Articles liés au Congrès, aux médailles et aux prix 2019

Canadian Association of Physicists / Association canadienne des physiciens et physiciennes

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La Physique au Canada
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Feature Articles / Articles de fond

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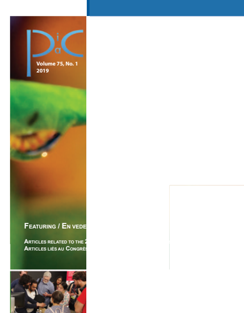

"Goutte d'eau: lentille optique naturelle" by Antony Hu, École Secondaire de la Cité des Jeunes Vaudreuil-Dorion, QB – Second Place (High School/CEGEP Individual Category), 2019 Art of Physics competition. See https://www.cap.ca/programs/art-physics-2/

The Local Organizing Committee delivered a memorable experience for all Congress delegates attending the 2019 CAP Congress in Burnaby, BC.

< Goutte d'eau : lentille optique naturelle > par Antony Hu, École Secondaire de la Cité des Jeunes Vaudreuil-Dorion, QB – Catégorie projet individuel au niveau secondaire ou cégep, 2e prix, Concours L'Art de la Physique 2019. Voir https://www.cap.ca/fr/activites/lart-de-physique/

Le Comité organisateur a fait du Congrès 2019 à Burnaby, Colombie britannique, une expérience mémorable pour tous les délégués.

Advertising rates and specifications (effective January 2019) as well as subscription and single issue order forms can be found on the CAP website (www.cap.ca - > Publications - > *Physics in Canada*).

Les tarifs et dimensions des publicités (en vigueur depuis janvier 2019) ainsi que les formulaires d'abonnement et de commande de numéros individuels se trouvent sur le site internet de l'ACP (www.cap.ca - > Publications - > La Physique au Canada).

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 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 physiciens canadiens face au gouvernement, aux organismes subventionnaires et à plusieurs sociétés scientifiques internationales. Nous nous faisons le promoteur enthousiaste d'événements et d'activités mettant à l'avant-scène la physique et les physiciens canadiens, 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 TRANSFORMATION OF *PHYSICS IN CANADA*

Although *Physics in Canada* has appeared in your mailbox less frequently during the last two years due to a number of production challenges beyond our direct control, we have nevertheless delivered to our subscribers and members two 2018 significant issues, the first commemorating *70 years of Neutron Scattering in Canada*, and the second on *Physics in Mining*. The current issue is a celebration of the accomplishments of our members in 2019. This will be followed by our second 2019 issue entitled *The History of the Future of TRIUMF*, an issue celebrating the first 50 years of TRIUMF and how it lay the foundations of its future. In 2020 we will offer an issue on *Science and the Public* exploring the challenges facing scientists in conveying their message to the general public and ensuring good science prevails, and a second one on EDI (Equity, Diversity, Inclusivity).

How should one interpret our reduced and greatly delayed output? As a reflection of how the CAP has been investing significant resources, including staff time, to introducing upgraded management systems to help us grow to meet the changing needs of our community.

An important role of CAP is to nurture a sense of community among Canadian physicists, especially with the progressive fragmentation of our field and the emergence of specialized associations soliciting our attention. Much of that role can be fulfilled by posting material on-line, but a direct engagement with the membership is also required to prod our members into action or provide timely information. *News Flashes* and *News Bulletins* will likely provide this, with links to more intensive material online.

Thus, a significant part of these upgrades has been aimed at improving the CAP's infrastructure that supports our Bulletins, News Flashes, e-mails, and website.

Now that the new website and the new management system have been implemented, and we are about to start issuing our Bulletins and Flashes using this new system, the Editorial Board and Communications Committee are partnering to determine the niche which Physics in Canada can and should fill in our communication strategy, and how best to structure the publication to do so. Here are some preliminary thoughts on the subject.

A magazine format such as *PiC* remains the best vehicle for commemorating major milestones or for in-depth discussions of subjects of importance to the community, such as EDI and evidence-based policies. However, the reading habits of our members have rapidly evolved over the last decade. One has simply to consider one's own daily routine and where we now get our information. We spend many hours a day reading off screens and exchanging thoughts via e-mails or social media posts. Even purely scientific material is increasingly explored from smartphones, tablets, following twitter accounts, and online versions of newsletters and journals produced by scientific organizations.

CAP's limited resources, within challenging financial times, necessarily affect the scope of what can be managed with respect to Physics in Canada. We are forced to prioritize what we should publish in print or in fully downloadable issues. Theme issues have been, in my opinion, our most valuable output. We should focus on these and produce two such issues per year. We should make *PiC* thematic, addressing important topical subjects or offering a broad discussion of interesting themes of relevance to our community. By offering something of a more permanent nature, with its archives, *PiC* will remain the ideal vehicle for presentation of comprehensive reviews, broader discussion of topics of interest, and matters of archival significance.

Béla Joós, Editor, *Physics in Canada*

Comments of readers on this Editorial are more than welcome.

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.

Bela Joós est professeur de physique a l'Université d'Ottawa. Il est membre du Comite de rédaction de la *Physique au Canada* depuis janvier 1985 et est devenu rédacteur en chef en juin 2006.

LA TRANSFORMATION DE *LA PHYSIQUE AU CANADA*

Bien que *La Physique au Canada* vous est parvenue moins souvent ces deux dernières années à cause de plusieurs défis de production au-delà de notre contrôle, nous avons néanmoins livré en 2018, à nos abonnés et à nos membres, deux numéros significatifs dont le premier commémore les *70 années de diffusion des neutrons au Canada* et, le second traite de *La Physique dans l'exploitation minière*. Le présent numéro célèbre les réalisations de nos membres en 2019. Le prochain numéro, le second de 2019, célèbrera les 50 premières années de TRIUMF et comment ses années ont préparé son avenir. En 2020, nous offrirons un numéro sur *La Science et le public*, qui exposera les défis que les scientifiques doivent relever pour porter leur message au grand public et assurer que la science saine l'emporte. Il y en aura un autre sur l'EDI (équité, diversité et inclusivité).

Comment faut-il comprendre notre production réduite et fort tardive? Comme une réflexion du grand investissement que l'ACP a fait en temps de son personnel et en équipement pour moderniser son système administratif dans le but de croître pour servir les besoins changeants de notre communauté.

Un rôle important de l'ACP est de susciter un esprit de corps chez les physiciens du Canada, étant donné surtout la fragmentation progressive de notre discipline et l'émergence d'associations spécialisées sollicitant notre attention. Ce rôle peut être exercé en bonne partie en publiant des documents en ligne, mais il faut en outre un engagement direct auprès des membres pour les inciter à agir ou leur fournir une information en temps utile. Nos *Flash-info et Bulletins* devraient atteindre cet objectif et renvoyer à des documents plus approfondis sur le Web. Ainsi une bonne partie des améliorations visaient à améliorer l'infrastructure de l'ACP qui soutient nos *Bulletins, Flash-info, courriel*, et notre site web.

Maintenant que le nouveau site web et le nouveau système d'administration ont été mises en œuvre et que l'ACP commencera à émettre les *Bulletins* et *Flash-info* utilisant le nouveau système, le Comité de rédaction et le Comité de communications vont travailler à déterminer le rôle que pourra et devra remplir *La Physique au Canada* (*PaC*) dans la stratégie de communication de l'ACP. Ils décideront aussi comment structurer *La PaC* pour réaliser ce rôle. Voici quelques idées sur la question.

Un format comme celui de la revue *PaC* demeure le meilleur moyen de commémorer des jalons importants ou de discuter de profonds sujets d'importance pour la collectivité, tels l'EDI et les politiques fondées sur des preuves scientifiques. Les habitudes de lecture de nos membres ont toutefois évolué rapidement au cours de la dernière décennie. Il suffit d'examiner notre propre routine quotidienne et les sources actuelles de notre information. Chaque jour nous passons des heures à lire à l'écran et à échanger des idées par courriel et médias sociaux. Nous examinons même de plus en plus des documents strictement scientifiques à l'aide de téléphones intelligents, de tablettes, sur les comptes Twitter, les versions en ligne de bulletins de nouvelles et de revues émanant d'organismes scientifiques.

Les maigres ressources de l'ACP en cette période financière difficile ajoutent des contraintes sur ce que *La Physique au Canada* peut réaliser. Cela oblige à établir un ordre de priorité dans ce qui devrait être publié sous forme d'imprimés ou en numéros téléchargeables en entier. À mon avis, les numéros à thème sont notre œuvre la plus précieuse. Nous devrions y mettre l'accent et produire deux tels numéros par année. Nous devrions faire de la *PaC* une revue thématique portant sur d'importants sujets d'actualité ou offrant une vaste discussion sur d'intéressants thèmes pertinents à notre collectivité. En offrant des éléments de nature plus permanente dans ses archives, la *PaC* sera idéale pour présenter un tableau complet ou élargi de sujets intéressants, et des questions de valeur archivistique.

Béla Joós, rédacteur en chef,
La Physique au Canada

Les commentaires des lecteurs sur cet éditorial sont toujours les bienvenus.

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

Gilles Fontaine (1948-2019)

Gilles Fontaine a fait ses études de premier cycle en physique à l'Université Laval (1969). Il a obtenu en 1974 son doctorat de l'Université de Rochester et il fut professeur titulaire au Département de physique de l'Université de Montréal depuis 1977. Il était également titulaire depuis 2000 de la Chaire de recherche du Canada en astrophysique stellaire.

M. Fontaine fut le récipiendaire de nombreux prix et distinctions, dont le prix Marie-Victorin en 1999, l'un des 14 Prix du Québec décernés annuellement par le gouvernement du Québec, le Prix Carlyle S. Beals en 2000 décerné par la Société canadienne d'astronomie (CASCA), ainsi que la Médaille de l'Association canadienne des physiciens et physiciennes (ACP) en 2016 pour contributions exceptionnelles à la physique, et en particulier pour ses travaux exceptionnels mondialement reconnus dans les études théoriques et d'observation sur les naines blanches et les derniers stades de l'évolution des étoiles, dont d'importants apports à l'équation d'état des naines blanches et les études sur les étoiles compactes pulsantes, ainsi que la découverte d'une nouvelle catégorie de sous-naines pulsantes. Il fut également élu en 1992 Membre de la Société royale du Canada.

Digne héritier de la tradition d'excellence dans le domaine de l'astrophysique au Canada, M. Fontaine s'est distingué sur la scène internationale pour la qualité exceptionnelle de ses travaux de recherche en astrophysique stellaire, particulièrement dans l'étude des phases finales de l'évolution stellaire (étoiles naines blanches et sous-naines), ces produits ultimes de l'évolution stellaire pour la grande majorité des étoiles. Il a non seulement jeté les bases d'une véritable théorie de l'évolution des naines blanches, mais il est aussi un des pionniers de leur utilisation comme cosmochronomètres indépendants des différentes composantes de notre galaxie. Il s'est également imposé comme chef de file dans le domaine de l'astérosismologie, cette méthode unique permettant de sonder la structure interne des étoiles par l'étude de leurs « tremblements d'étoile », en combinant à la fois observations et modélisation numérique. Auteur prolifique, M. Fontaine s'est aussi consacré de façon remarquable à la formation de scientifiques de grand calibre. Ayant bâti une équipe de recherche de renommée mondiale, M. Fontaine a pu attirer plusieurs étudiants étrangers pour les cycles d'études supérieures. Il a démontré de plus d'une façon être un enseignant hors pair et un excellent communicateur. Par ces actions, il a sans aucun doute suscité de nombreuses vocations scientifiques. Mentionnons finalement que l'astéroïde 2010 GF153, découvert

Gilles Fontaine received his undergraduate degree in physics at the Université Laval (1969). He obtained his Ph.D. from the University of Rochester in 1974 and was a tenured professor in the Department of Physics at the University de Montréal since 1977. He also held the Canada Research Chair in Stellar Astrophysics since 2000.

Dr. Fontaine has been the recipient of many awards and distinctions, including the 1999 Prix Marie-Victorin, one of the 14 Québec Prizes awarded annually by the Government of Québec, and the 2000 Carlyle S. Beals Award from the Canadian Astronomical Society (CASCA), as well as the 2016 Medal for Lifetime Achievement in Physics awarded by the Canadian Association of Physicists (CAP), for his pioneering, world-renowned work in theoretical and observational studies of white dwarf stars and the late stages of stellar evolution, including major contributions to the equation of state for white dwarfs and investigations of pulsating compact stars, as well as the discovery of a new class of subdwarf pulsators. He was also elected in 1992 Member of the Royal Astronomical Society of Canada.

A true follower of the tradition of excellence in the field of astrophysics in Canada, Dr. Fontaine has distinguished himself internationally for the exceptional quality of his research in stellar astrophysics, especially for his study on the final phases of stellar evolution (white dwarfs and subdwarfs, the final products of stellar evolution for most stars). Not only did he build the foundations for an actual theory on the evolution of white dwarfs, he is also one of the pioneers who first used them as cosmochronometers independent from the other components of our galaxy. He also became a true leader in the field of astroseismology, the unique method by which we can examine the internal structure of stars by studying their "starquakes", using observations and numerical modeling. As a prolific writer, Dr. Fontaine has also made a remarkable contribution by training great scientists. By creating a world renowned research team, Dr. Fontaine has encouraged numerous foreign students in pursuing postgraduate education. He has proven in different ways that he is an incredible teacher and a great communicator. With his actions, he has undoubtedly contributed to building scientific vocations. Lastly, it is worth mentioning that the asteroid 2010 GF153, discovered in April 2010 as part of a deep survey of NASA's Wide Field Infrared Explorer (WISE) telescope, is now known as (400811) Gillesfontaine.

en avril 2010 dans le cadre d'un sondage profond du télescope Wide Field Infrared Explorer (WISE) de la NASA, porte désormais le nom de (400811) Gillesfontaine.

Il fut un collègue exceptionnel et un ami cher pour tous ceux qui l'auront côtoyé.

Pierre Bergeron
Université de Montréal

He was an exceptional colleague and a dear friend to all who knew him.

Pierre Bergeron
Université de Montréal

Li-Hong Xu (1957–2019)

Dr. Li-Hong Xu, a prominent and devoted member of the Canadian Physics community, passed away on January 21, 2019 after a short battle with cancer. Li-Hong was born on May 2, 1957 in Suzhou in the People's Republic of China. In 1977, Li-Hong was among a small elite group who got into university where she graduated in physics with highest honours. She was one of only two from her class of 240 graduates chosen to remain in Suzhou University as an assistant professor.

Li-Hong came to the University of New Brunswick in Fredericton in 1988 as a Visiting Scholar. She earned her PhD in molecular spectroscopy in 1992 and continued at UNBF as a post-doctoral fellow in the Centres of Excellence in Molecular and Interfacial Dynamics. Li-Hong received her Diploma in University Teaching in the first cohort of graduates of the Centre for Enhanced Teaching and Learning.

She then joined Dr. J.T. Hougen as a research associate in the Molecular Physics Division of the National Institute of Standards and Technology. In 1995, Dr. Xu returned to New Brunswick and took up a faculty position at the UNB campus in Saint John where she set up a laboratory for high-resolution gas-phase laser spectroscopy of molecules of environmental and astrophysical importance. Her research lab attracted post-doctoral fellows and visiting researchers and students from Belgium, France, Russia, Iran, the Czech Republic, China and the US. A large number of undergraduate summer and work-study students were given a good start on their careers there.

Dr. Xu gained recognition internationally as a valued visitor and collaborator at centres such as NASA/Goddard, the NASA Jet Propulsion Lab, NIST Boulder, the Institute of Applied Physics in Nizhny Novgorod, the Max Planck Institute for Radio Astronomy and the University of Cologne. From 2002-2005, she was a member of the Canadian Institute for Photonic Innovations and was also a charter member of the Far-Infrared Beam Team at the Canadian Light Source synchrotron in Saskatoon. She served on the Editorial Board of the Journal of Molecular Spectroscopy and on International Advisory Committees for International Symposia and Conferences, receiving invitations for plenary presentations at the 21st HRMS meeting in 2010 in Poznan, Poland, and the 71st ISMS symposium in 2016 in Urbana, Illinois.

In Canada, Dr. Xu was a loyal P.Phys. member of the CAP, serving from 2003-2009 as Regional Councillor for NB/NL and from 2008-2010 as NB Coordinator for the CAP High School Prize Exam. She had a special interest in promoting women in science and from 2011-2014 served as Chair and Past Chair of the CAP Committee to Encourage Women in Physics (CEWIP), which also involved service on the Annual Congress organizing committees. Regionally, from 2009 on, she served on the Science Atlantic Physics and Astronomy Committee. She was on the Canadian national delegations to the International Conferences for Women in Physics in Korea in 2008, in South Africa in 2011, and in Waterloo in 2014 where she was Team Leader and the lead author of the paper, "Women in Physics in Canada". Notably, she was one of the promoters, organizers and invited speakers for the Canadian Conference for Undergraduate Women in Physics. Colleagues saw Li-Hong as "the spirit of CEWIP" and that's how many women in physics, in Canada and abroad, will remember her.

Li-Hong was a member of GSC29 (General Physics) for the 2004-05 NSERC grant competition, and Committee Chair for the subsequent two years. She served on the NSERC 2009-10 Steacie Fellowship Committee and the Physics Evaluation Group 1505 for the 2011-12 Discovery and RTI (Research Tools and Instruments) grants. In 2013 she was appointed Group Chair for Physics and held a seat on the NSERC Committee on Grants and Scholarships (COGS). In this role, she became a familiar figure at the 2014-2016 CAP Congresses with her annual plenary presentations on the granting picture for physics at NSERC.

In addition to her many external commitments, Dr. Xu maintained an exemplary role at UNB in teaching, service and outreach, notably for women and girls. She received her department's award for teaching excellence in 2013 and the faculty teaching award in 2015; she was one of the inaugural winners of the "Change One Thing" innovation challenge by the UNB Centre for Enhanced Teaching & Learning. In collaboration with the Saint John Free Public Library, Li-Hong instituted a "Physics Circle" where girls gathered weekly to explore interesting physics activities. She visited a number of local schools for physics shows, gave presentations for groups of Girl Guides, and participated in the Canadian Association for Girls in Science's local chapter. In conjunction with UNB open houses, regional science fairs and special events, she set up popular fun demonstrations for the visiting students and their parents to encourage and stimulate their interest in physics. She became Director of the Music Program of the Lorenzo Society seven years ago and will be remembered for her warm introductions (and also her welcoming bowl of chocolates) at the Saint John String Quartet noon-hour concerts. She organized student-led concerts and arranged for UNB students and staff to join forces with the Dalhousie Medicine New Brunswick medical students in the Heartbeat Choir and the Ceol ceilidh band, greatly enriching the cultural life at the university. She received a President's Distinguished Service Award in 2017.

From 2005-11, Li-Hong was co-president, then president, of the Chinese Cultural Association, and was the founding Director of the Saint John Chapter of the Asian Heritage Society NB from 2008-18, organizing events annually for Asian Heritage Month in May. She was a member of the SJ Community Arts Board from 2008-14, and of the Imperial Theatre Board from 2016-18. She was an honorary life member of the school district Senior String Orchestra, and a second violinist with the Altomare community orchestra. She danced with the Jasmine Performing Arts group and taught tai chi lessons at The Studio dance school.

In all of her professional, university, community and personal roles, Li-Hong was a tireless and effective role model. Despite her whirlwind of activities, Li-Hong never seemed to be rushed, and was a devoted mother to her children, Alex and Miranda. From her difficult start as a young woman, Li-Hong rose to positions of respect and importance and made profound contributions in a myriad of ways. She embodied the best of the multicultural character of Canada. Li-Hong's enthusiasm, boundless energy and engaging personality will be profoundly missed.

Extracted from an In Memorium prepared by Ronald M. Lees, Fredericton, NB, and Adriana Predoi-Cross, Lethbridge, AB

2019 Student Competitions / *Compétitions Étudiantes 2019*

(See extended abstracts of the winners on pages 8–27 plus photo on page 7 / *Voir les résumés des gagnants aux pages 8–27 et photographie a la page 7*)

The Canadian Association of Physicists has established these awards to recognize student members giving the best oral and poster research presentations at the annual CAP Congress. Up to three awards in each category, each consisting of a certificate of recognition and a cash prize, are made each year. in addition, a number of CAP Divisions offer prizes for the best student presentations at the divisional level. Eligibility, selection procedure, and selection criteria for the competitions are available through the Congress website each year.

L'Association canadienne des physiciens et physiciennes a créé ces prix afin de récompenser les membres étudiants auteurs des meilleures communications au congrès annuel. Elle décerne tous les ans un maximum de trois prix dans chaque catégorie, chacun consistant d'un certificat de mérite et d'une somme. De plus, plusieurs divisions offrent des prix pour leurs meilleures présentations étudiantes. Admissibilité, modalités et critères de sélection pour les prix sont sur le site web de l'ACP.

CAP Student Competition Prizes / *Prix de compétitions étudiantes de l'ACP*

Division prizes include a cash prize of $200 (1st), $100 (2nd), and $50 (3rd); CAP prizes are $400 (1st), $200 (2nd), and $100 (3rd) / *Les prix des divisions incluent une somme de 200 $ (1er), 100 $ (2e) et 50 $ (3e); les prix de l'ACP sont 400 $ (1er), 200 (2e), et 100 $ (3e).*

CAP Division Student Poster Awards

APPLIED PHYSICS AND INSTRUMENTATION, PHYSICS EDUCATION, PLASMA PHYSICS, AND THEORETICAL PHYSICS	
Placement	**Name / Affiliation**
First	Wrick Disgupta, TRIUMF
Second	Oliver Shelbaya & Spencer Kiy, TRIUMF

ATOMIC, MOLECULAR AND OPTICAL PHYSICS, CANADA	
Placement	**Name / Affiliation**
First	Denis Uhland, University of B.C.
Second	Jordan Fordyce, University of B.C.

CONDENSED MATTER AND MATERIAL PHYSICS	
Placement	**Name / Affiliation**
First	Avinash Kumar, Simon Fraser University

PHYSICS IN MEDICINE AND BIOLOGY	
Placement	**Name / Affiliation**
First	Jeremy Marvin, University of Windsor

BIOLOGICAL SOCIETY OF CANADA (BSC) STUDENT POSTER AWARD
Name / Affiliation
Jeremy Marvin, University of Windsor
Esther Lin, University of B.C.

WOMEN IN PHYSICS
Name / Affiliation
Jordan Fordyce, University of B.C.

CAP Overall Student Poster Awards

Placement	**Name / Affiliation**
First	Sourav Sarkar, University of Alberta
Second	Avinash Kumar, Simon Fraser University
Third	Jeremy Marvin, University of Windsor
Honourable Mentions	Wrick Dasgupta, TRIUMF Denis Uhland, University of B.C.

CAP Division Student Oral Presentation Awards

APPLIED PHYSICS AND INSTRUMENTATION, PLASMA PHYSICS	
Placement	**Name / Affiliation**
First	Marie Vidal, Queen's University
Second	Austin de St. Croix, TRIUMF & University of B.C.

ATOMIC, MOLECULAR AND OPTICAL PHYSICS, CANADA	
Placement	**Name / Affiliation**
First	Alicia Sit, University of Ottawa
Second	Erik Frieling, University of B.C.
Third	Sean Graham, Simon Fraser University

CONDENSED MATTER AND MATERIALS PHYSICS	
Placement	**Name / Affiliation**
First	Daniel Korchinski, University of B.C.
Second	Adam DeAbreu, Simon Fraser University
Third (tie)	Cristina Cordoba, Simon Fraser University
Third (tie)	Camille Chartrand, Simon Fraser University

PHYSICS IN MEDICINE AND BIOLOGY	
Placement	**Name / Affiliation**
First	Alaa Al-Shaer, Simon Fraser University
Second	Kyle Bromma, University of Victoria

NUCLEAR PHYSICS	
Placement	**Name / Affiliation**
First	Andrew MacLean, University of Guelph
Second	Fatima Garcia, Simon Fraser University
Third	Melanie Gascoine, Simon Fraser University
Honourable Mentions	Carlotta Porzio, TRIUMF & Università degli Studi di Milano Michael Gennari, TRIUMF

PARTICLE PHYSICS	
Placement	**Name / Affiliation**
First	Etienne Dreyer, Simon Fraser University
Second	Daniel Durnford, University of Alberta
Third	Clarke Hardy, Queen's University

THEORETICAL PHYSICS	
Placement	**Name / Affiliation**
First	Lindsay Forestell, University of B.C.
Second	Jack Davis, University of Waterloo

CAP Overall Student Oral Presentation Award

Placement	**Name / Affiliation**
First	Daniel Korchinski, University of B.C.
Second	Lindsay Forestell, University of B.C.
Third	Alaa Al-Shaer, Simon Fraser University
Honourable Mentions	Etienne Dreyer, Simon Fraser University Marie Vidal, Queen's University Alicia Sit, University of Ottawa Andrew MacLean, University of Guelph

The CAP 2019 best student presentation award winners gather for a photograph with the CAP Vice-President Elect, Manu Paranjape (2nd from left in front row) and CAP President, Shohini Ghose (far left in front row).

Thanks to the CAP competition sponsors / *Merci au commanditaire de la compétition de l'ACP:*

Micromachines and Institute for Quantum Computing

and to the CAP's National Coordinator, and all of the judges for their extraordinary efforts in organizing this event. Our thanks are also extended to all competitors.

The winners of the 2019 CAP Best Student Presentation Competition at the CAP Annual Congress, 2019 June 3-7 in Burnaby, BC, are listed on pages (6-7). The extended abstracts of those winners of the CAP prizes who submitted them for publication are reproduced below. Ed.

Universality of Spreading Processes with Spontaneous Activity

by Daniel J. Korchinski[1], Javier G. Orlandi, Seung-Woo Son, and Jörn Davidsen

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When one forwards a funny email or retweets a viral tweet, one participates in a spreading process unfolding on a social network. Spreading processes on networks are ubiquitous in both human and natural systems: power failures can cascade between electrical network substations, action potentials ripple through neural networks, radioisotope tracers traverse predation networks, and computer worms burrow through computer networks [1]. Even processes embedded in space, such as the percolation of a fluid through porous rock, is a type of spreading on a network.

Although it might be hard to imagine that such a disparate collection of processes might have any unifying structure governing their spread when the underlying systems are so distinct, a truly marvellous fact is that all of them exhibit a phase transition as the probability of transmission between nodes is increased. To use the language of epidemiology, when the probability of transmission is low outbreaks are almost always finite (see Fig. 1a and Fig. 1e "sub-critical"). However, when the reproduction number (i.e., the average number of new infections caused by an infected node) is one, it becomes possible for epidemics (outbreaks extensive with the system size) to occur (see Figs. 1b, 1d). Of course, being a well-behaved phase transition, the vicinity of this critical transmission probability is characterised by various scale-free phenomena governed by critical exponents that depend only on the dimensionality and topology of the underlying network, thereby defining a shared universality class [1].

Quite generically, the universality class for re-excitable nodes was understood to be that of directed percolation.

Summary

Spontaneous activation in spreading processes changes the universality class from directed percolation to undirected percolation.

Directed percolation is a broad universality class, encompassing the network spreading processes already mentioned, along with models of wildfires, catalytic chemical reactions, and Reggeon field theory (for a review, see [2]). It is characterised by local interactions and a transition from an active state to a unique absorbing state (see Fig. 1a). In the context of disease spreading, a unique absorbing state exists for the disease of small-pox: no humans are infected with the disease and it will never reappear. However, the requirement of a unique absorbing state is not strictly satisfied for many spreading processes.

For many spreading processes, random initiation drives recurring outbreaks which then lapse back into the "absorbing" quiescent state (see Fig. 1c). For instance, neurons cultured in the lab self-organize to a near-critical point, which we know from observing spontaneous scale-free neuronal avalanches. Initially, these were observed with directed percolation exponents [3]. However, the very fact that we see multiple avalanches indicates that these neurons cannot strictly belong to the universality class of directed percolation, and recent work has called the underlying universality class into question [4]. Even in the case of small-pox, one could envision an unenviable future in which it is released from research laboratories and the "absorbing" state is shown to be spongy. Therefore, directed percolation is only a good approximation for systems in which there is a good separation between the timescale of initiation of *ex nihilo* activity and the spreading and cessation of that activity.

To study what happens when spontaneous activity is considered, we have introduced a discrete-time model that has both a spreading parameter and a probability of spontaneous activation baked in [5]. In each time-step, each

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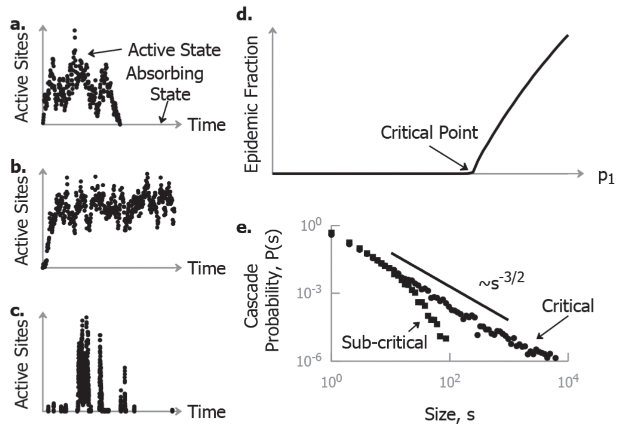

Fig. 1 The behaviour of the directed-percolation transition. **a.** The number of active sites starting from a single infected node below the critical point, exhibiting a fluctuating active phase that returns to a quiescent absorbing state. **b.** Above the critical point, a single infected node can lead to an eternal fluctuating steady state. **c.** Here, nodes are randomly reactivated, but a clear separation of time-scales continues to drive scale-free cascades, destroying the absorbing state. **d.** The fraction of nodes that belong to the largest cluster shows a clear phase transition as the spreading parameter p_1 is increased. **e.** The cascade distribution becomes scale-free at the critical point labelled in panel d.

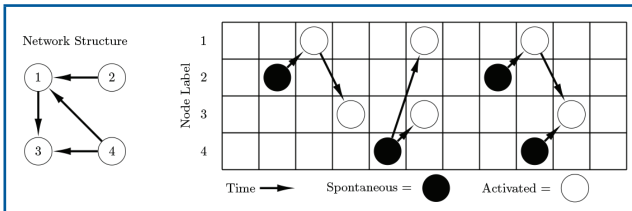

Fig. 2 An illustration of a spreading process on a simple network with spontaneous activation. (Left) A directed network consisting of four nodes and four edges. (Right) A sample time series of activations. Spontaneous activations can be identified as those nodes that activate without any of their parents being active in the preceding time-step. When assuming a separation of time-scales, the first two cascades might be falsely labelled a single cascade because they are contiguous. Knowledge of the network structure allows us to disentangle independent cascades. Additionally, when there is no separation of time-scales, initially-independent streams of activity can merge, leading to cascades with multiple roots, as occurs in the third cascade.

node i activates with a probability that depends only on the number of their parents $m_{i,t}$ (we consider networks with directed edges) that were active in the preceding time-step:

$$P_{i,t+1} = 1 - (1 - p_0)(1 - p_1)^{m_{i,t}} \quad (1)$$

In the case that the spontaneous activation parameter $p_0 = 0$, we have a simple branching process, which falls into the universality class of directed percolation, while for $p_1 = 0$, we simply have dynamical percolation, belonging to the distinct universality class of undirected (isotropic) percolation (for a comparison, see [6]). Finding a well-defined critical point for $p_0 > 0$ is challenging. In directed percolation, there are several measures that could be used to define the critical point: it could be identified with a unity reproduction number, or with a divergence in the susceptibility of the active fraction, or as the point at which epidemics appear. However, when $p_0 > 0$, it's not so clear which measure to use. Since cascades merge and over-lap, nodes can have more than one parent (see Fig. 2), meaning the reproduction number, σ, (defined by the mean number of active daughters to an active node) is not simply $\sigma = p_1 \times$ (average number of outgoing connections) as it is in directed percolation. Further, the susceptibility no longer diverges, but instead attains a maximum on a Widom line [7]. Even defining cascades in the presence of spontaneous activity is challenging, because initially-independent cascades can merge together (see Fig. 2). It is necessary to use the network structure to separate cascades that overlap in time but not in space. However, if one considers cascades defined by causal clusters, as has been proposed in the neuroscience context [8], epidemics can be readily defined and observed for sufficiently large p_1. We found that all three of these measures, the reproduction number equalling one, the Widom line, and the appearance of epidemics, all disagree when $p_0 > 0$ (see Fig. 3a).

To determine which of these phase-lines correctly generalized the directed-percolation critical point we conducted numerical and analytical investigations of cascade statistics on all three phase-lines. We found that only the critical line associated with the appearance of epidemics produced the expected scale-free behaviour in the cascade distribution [5]. Additionally, for simple network structures, that line can independently be derived by identifying the set of points that cause the correlation length or average cluster size to diverge. However, in our investigation we also found something quite surprising on the critical line: a cross-over between two distinct sets of critical exponents (see Fig. 3b). Small cascades obey statistics $P(s) \sim s^{-1.5}$ that would correspond to the universality class of mean-field directed percolation; however, large cascades obey statistics corresponding to undirected percolation, $P(s) \sim s^{-2.5}$.

Nonetheless, all outbreaks on the critical line exhibit the same universal scaling $p(s) \sim s^{-3/2}\, g(s/s_m)$ with $s_m \sim p_0^{-2/3}$, for a cross-over scaling function $g(x)$ (see Fig. 3c). The transition between these regimes is set by the scale at which the merging of cascades occurs (see Fig. 3d). For systems with a lower rate of spontaneous activation, encountering another cascade is unlikely, and so the directed percolation exponents survive to larger sizes. The eventual dominance of the undirected percolation exponents is guaranteed because the isotropic correlation length diverges on

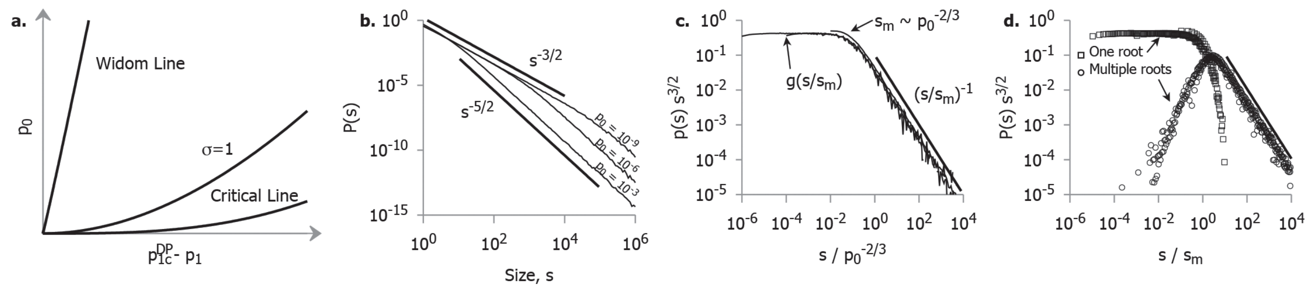

Fig. 3 Simulations of outbreaks on the critical line for a simple 10-regular network. **a.** The phase diagram for the spreading process with reactivation in the vicinity of the directed percolation critical point p_{1c}^{DP}. σ denotes the reproduction number (i.e., average number of daughters). **b.** The outbreak distribution on the critical line is asymptotically scale-free, and exhibits a transition in the scaling exponent. **c.** The data in **b**, rescaled to exhibit a universal curve collapse, with $p(s) \sim s^{-3/2}g(s/s_m)$. The curve collapse explicitly gives the functional form of the cross-over function $g(s/s_m)$, showing that $g(x << 1) \sim x^0$ and that $g(x >> 1) \sim x^{-1}$. **d.** The data of **c**, partitioned into outbreaks with and without merging of activity, reveals that the exponent transition at s_m is precisely when the merging of avalanches dominates.

the critical line, meaning that the anisotropy associated with the time-direction of the spreading process (i.e., the "directed" part of the associated percolation problem) must vanish. More simply, one cascade can merge with another one that was initiated either before or after it, restoring a time-symmetry that is not present in directed percolation, where activations always follow from their parent. This additional symmetry removes the absorbing state that defines directed percolation, lifting the universality class from directed to undirected percolation. We have tested the robustness of our findings on a variety of network topologies, including brain-connectome analogues, fat-tailed, and small-world networks, finding in each case numerical results that exhibit a transition between universality classes [5].

CONCLUSION

The universality class of directed percolation appears in myriad places, but only when one assumes a separation of time-scales between the initiation and propagation of activity. When those time-scales mix, the cooperation of initiation and spreading changes the underlying universality class to one of undirected percolation. Characteristics of directed percolation survive only on the smallest scales, with exponents related to undirected percolation dominating asymptotically. Our work provides a bridge between two fundamental universality classes of non-equilibrium statistical physics and implies that spreading processes with spontaneous activity are fundamentally distinct from ordinary spreading processes.

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Cosmological Constraints on Hidden Physics

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THE HUNT FOR NEW PHYSICS

The Standard Model (SM) of particle physics does a remarkable job of explaining the nongravitational forces of nature. These include the strong, weak, and electromagnetic forces, as well as all of the corresponding particles. These particles include quarks, leptons, and their force carriers: photons, gluons, W bosons and Z bosons. In 2012, the discovery of the Higgs boson at the Large Hadron Collider (LHC) completed the current model of particle physics, and brought all of our theoretical knowledge in line with our experimental observations [1,2].

This was a monumental success, but as successful as the SM is, it still has some weaknesses. For example, neutrinos, the neutral partners to the charged leptons (electrons, muons, and taus), should be massless. However, observations of solar and atmospheric neutrino oscillations between different flavours indicate that they do in fact have mass, in direct contradiction with the SM [3,4]. Further to this, we have measured the mass of many of the other particles, but we do not know *why* everything has the mass that they do (and in fact, some calculations indicate that the 'smallness' of the Higgs boson mass is a real problem in the Standard Model!). These are just a few examples of the need to search for new particles and new physics beyond the Standard Model.

We have a second 'Standard Model' of cosmology that has done the same thing for our understanding of the evolution of the Universe that the regular SM has done for particle physics. Called the ΛCDM model, we require a source of dark energy, (cold) dark matter, and regular matter. These make up the entire energy content of the universe, and together with general relativity explain how the Universe has evolved from the earliest times to produce the extraordinary galaxies and structures that we see today.

Once again, however, we have unresolved questions. What is the nature of dark matter? Is it a particle or something else? How does gravity, which works so well on cosmological scales, interact with the quantum field theories of particle physics? Where did the matter of the Universe actually come from? These are only a few of the questions that are being asked by todays scientific community. The search for these answers drives much of what we explore moving forward, both in theory and experimentally.

Summary

New physics may be hidden in a dark sector that minimally interacts with the Standard Model. We investigate one such dark sector, using cosmology to place stringent constraints.

DARK FORCES

We have been searching for the answers to these puzzling problems for some time now. While the LHC continues to push the frontiers on precision particle physics, everything we have seen since the discovery of the Higgs boson has been in line with what we would expect from the Standard Model, and does not (yet) hint at the new physics we wish to find. We have also dedicated entire search programs to the hunt for dark matter (typically WIMP-like dark matter, but many other programs have been started as well), with no results so far [5]. Because of this, we have begun to extend our search even further, to look for harder to find physics in more creative places. One such possibility is the search for dark sector forces, which would have minimal connections to the Standard Model. These forces would evade the conventional searches, but could possibly be constrained using the cosmological laboratory. An example of the interactions possible for such a dark force are shown in Fig. 1. The dark sector could be produced by some small interaction with the visible sector, evolve on its own, or decay and create regular particles that then interact with each other and produce a signal for us to detect.

Here we focus on a particular dark sector that consists of self-interacting dark gluons. This force behaves similarly to the strong force that we know and understand very well, with the particle behaviour shown in Fig. 2. At the largest energies, asymptotic freedom leads to free quarks and gluons and a well defined perturbative theory. However, as we move down in energy the coupling constant, α, actually increases to the point that free states are no longer possible, and confinement occurs. This gives us the particles we know and understand, such as hadrons (protons

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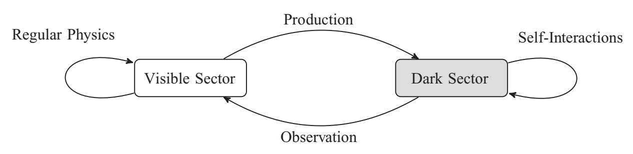

Fig. 1 Visualization of the connections possible between the visible and dark sectors.

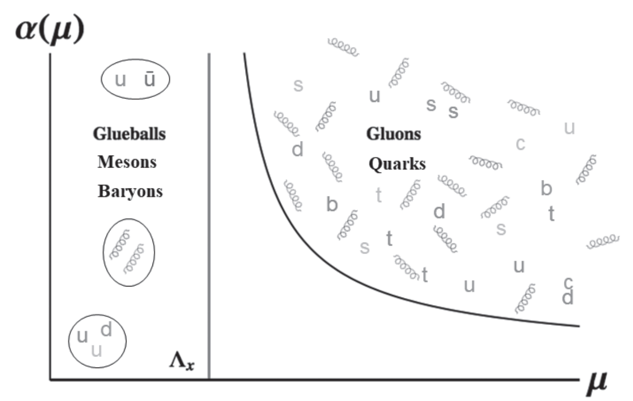

Fig. 2 Schematic depiction of confinement of particles in QCD. At high energies(μ) asymptotic freedom leads to free states of quarks and gluons, while low energies leads to bound states of the particles we are familiar with, the mesons and hadrons. The vertical axis depicts α, the coupling strength between fields in the theory.

and neutrons), and mesons (pions). It even predicts bounds states of pure glue, known as glueballs.

In our dark force, we do not include dark quarks, so the only bound state we expect is the glueball. This is what we focused on in our study. We asked and answered questions such as:

- Does it interact with itself?
  - They actually have unique self-interactions that are often termed ‘cannibalism’ due to the fact that three glueballs can collide and only two come out.
- What would its abundance be?
  - This is heavily dependent on the mass of the dark glueball and temperature of the dark sector. If the correct conditions are met, we can reproduce the dark matter abundance required by ΛCDM. This is shown in Fig. 3.
- Is there more than one type of glueball?
  - There is in fact an entire spectrum of glueball states. However, most of the interesting physics is tied up in the lightest state (where $J^{PC} = 0^{++}$), and so we can keep ourselves focused to only a small subset of the glueballs.

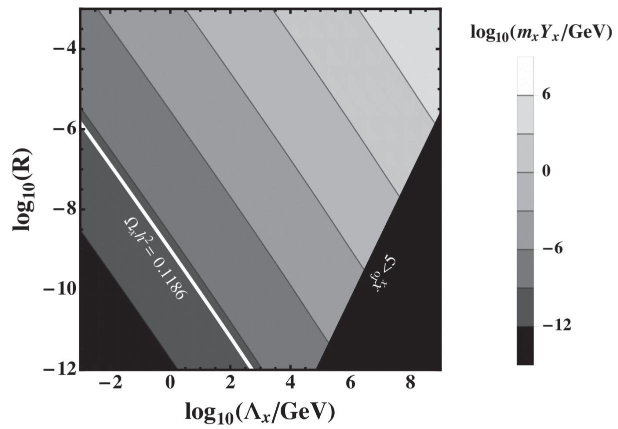

Fig. 3 Abundance of dark glueballs that can be produced in the early Universe as afunction of the mass of the glueballs (horizontal) and temperature of the hidden sector relative to the visible (vertical). Everything above the bold white line is ruled out by overproduction of dark matter.

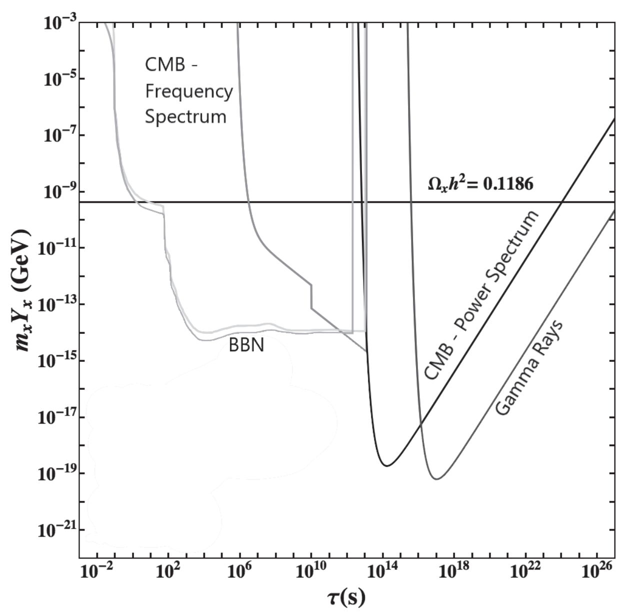

Fig. 4 Cosmological constraints that can be placed on dark glueballs. These span many orders of magnitude in the possible lifetime of the glueball, from seconds to the age of theUniverse. The vertical axis represents the net abundance of glueballs present before they began to decay: the horizontal black line specifically refers to a Universe in which the dark glueball makes up 100% of the measured total dark matter abundance. Any portion of the parameter space above a different constraint curve is ruled out. Over nearly every epoch, a different observation can be used to place constraints on the model.

- Can it interact with regular matter?
  - Yes! The amount of interaction is heavily regulated by various cosmological constraints, which we look at in more detail further on.

COSMOLOGICAL CONSTRAINTS

The final piece of the puzzle is how we can constrain such a dark force. The answer comes from our high precision cosmological observations. We can probe different epochs in the history of the universe using different observations, examples of which are shown in Fig. 4. For example, studies of the lightest elements seen today tell us about Big Bang Nucleosynthesis, which were the few moments responsible for producing the entirety of helium in the early Universe. Moving forward in time, we can actually see the 'last scattering surface' which is the last time the background light of the Universe interacted strongly with free electrons. This light is now what we know to be the Cosmic Microwave Background (CMB), which we have probed extensively with a multitude of experiments. As both of these epochs are very well understood in our current theoretical framework, any disturbance to these models (and subsequent observations) is highly constrained [6,7]. Thus, a new particle such as a dark glueball can only have small interactions (such as a feeble decay to photons or regular gluons). Even further, a glueball that has a lifetime around the age of the Universe would be expected to produce gamma ray signals today, which we could look for with our high energy telescopes. All of these together can be used to put strict limits on not only the possible mass of these dark glueballs, but also how strongly they may interact with the SM. Thus, we can use the cosmological laboratory to provide complementary constraints to those from dark matter and collider searches in our ever evolving hunt for clues to unravel the mysteries we have before us.

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Characterizing the Flexibility of the Body's Building Block: Collagen

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WHAT IS COLLAGEN?

Collagen is the fundamental building block of animals and is the most abundant protein in our bodies [1,2]. Its evolutionary origins trace back to the dawn of metazoan organisms, where it supported the coalescence of multicellular life forms [3,4].

Different types of collagen are localized to different tissues and can form various higher-order structures. The most abundant class are the fibril-forming collagens, which align in a staggered parallel fashion and give rise to long fibrillar nanostructures (Fig. 1A). The basic structural unit of this fibril is the 300-nm-long triple-helical collagen molecule. Assembled from three polypeptide chains in the inner compartments of a cell, the molecule is trafficked to the outside of our cells where it assembles into higher-order structures, such as the fibril. However, collagen molecules can also assemble into networks, as shown in Fig. 1B. These networks play an essential role in providing a filtration barrier to macromolecules around organs such as kidneys [5]. Whereas fibrils consist primarily of collagen type I molecules, collagen network structures are typically formed by collagen type IV molecules. In this short article, we report on the mechanical properties of these collagen molecules, comparing the fibril-forming collagen type I to the network-forming collagen type IV.

We have characterized the different collagen types by analyzing them at the molecular level. Collagen's distinct triple-helical structural feature is shared amongst all twenty-nine collagen types, where the triple helix arises due to the polypeptide chains having a unique amino acid composition that is a repeating unit of Gly-X-Y. Having this glycine every third residue is a structural requirement that confers compactness and hydrogen-bonding abilities to stabilize the triple helix [1]. A key feature that differentiates collagen type IV from fibrillar collagens lies in this repeating unit, where collagen type IV has missing glycine residues which lead to triple-helical interruptions within the molecule. A central question is how these interruptions contribute to the flexibility of collagen, and this is what we aimed to address in our studies.

Summary

This article investigates the structural impact of local sequence variations along the contour of collagen, by sampling AFM-based images and performing statistical analyses.

ATOMIC FORCE MICROSCOPY

We use atomic force microscopy (AFM) as our experimental tool to study the mechanical properties of collagen molecules. AFM is a type of scanning probe microscope that utilizes a sharp tip to image the nanoscale topological features of a surface. By using a laser detection system, the instrument can record the deflection of the tip as it scans across the surface to yield a height map of any features present. We start our sample preparation by depositing collagen molecules onto mica – an atomically flat surface commonly used for imaging biological samples. Once deposited, the molecules adhere to the surface [6]. When imaged with AFM, collagen molecules appear as elevated string-like features on the flat mica background (Fig. 1). The AFM images provide us with an ensemble of conformations adopted by the collagen molecules, and we can use these conformations to extract information related to their mechanical properties. But before this is possible, we need a quantitative way to gain access to their conformations.

A custom-built MATLAB code, SmarTrace, was developed to analyze AFM images of individual collagen molecules [6]. The code first extracts the backbone coordinates of each chain in an image. To do so, SmarTrace requires minimal user intervention – the selection of only a few points near each chain – and uses a correlation-based algorithm to best match the backbone of the chain. From these backbone contours, we implement polymer physics tools to determine molecular flexibility.

POLYMER THEORY

Once a set of collagen chains has been traced, the coordinates along the backbone and the tangent vectors along

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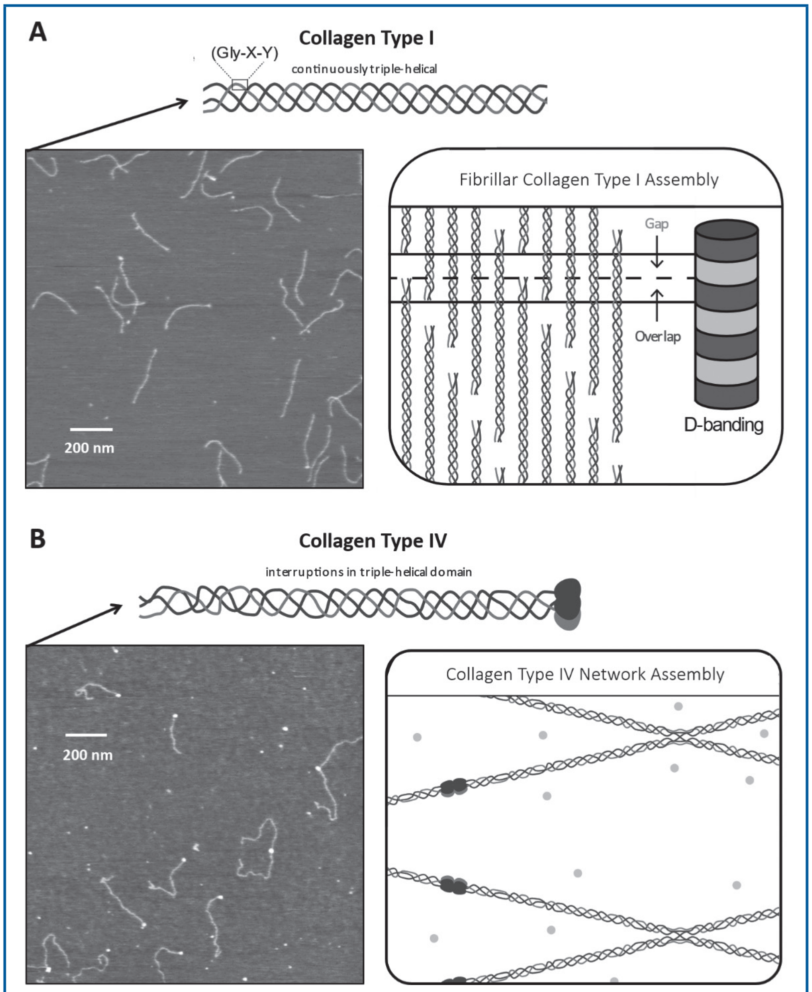

Fig. 1 **Atomic Force Microscopy (AFM) and supramolecular organizations of fibrillar and network-forming collagens.** AFM images of **(A)** collagen type I and **(B)** collagen type IV molecules deposited from 100 mM KCl, 1 mM HCl (pH ~ 3) with schematics of their corresponding molecular structures and supramolecular assembles placed above and to the right of the AFM images, respectively.

the chains are collected by the program. To relate these conformations to collagen's mechanical properties, we use the worm-like chain model, depicted schematically in Fig. 2A. The model describes a semi-flexible polymer, where short segments adopt straight conformations (the lowest-energy state) at zero temperature. In the presence of thermal fluctuations of energy, $k_B T$, the segments adopt smoothly curved conformations. The energy required to bend a segment of length Δs into an arc with angle θ between its ends is related to the polymer's persistence length, which we denote with the symbol p:

$$E_{bend} = \frac{p\theta^2}{2\Delta s} k_B T. \qquad (1)$$

The persistence length is best described. as the length along the contour over which the correlation of chain tangent vectors drops by a factor of e. Thus, persistence length characterizes the chain's flexibility, and is the mechanical property on which we focus.

We calculated the mean squared end-to-end distance $\langle R^2(\Delta s)\rangle$ and the mean dot product of the starting and ending unit tangent vectors $\langle \hat{t}(s).\,\hat{t}(s+\Delta s)\rangle$ for segments of length ΔS within the pool of traced chains. The mean squared end-to-end distances and tangent vector correlation data are fit with the predictions of the worm-like chain (WLC) model, described in Eqs. 2 and 3, to estimate persistence length (Fig. 2B).

$$\langle R^2(\Delta s)\rangle = 4p\Delta s\left[1-\frac{2p}{\Delta s}\left(1-e^{-\frac{\Delta s}{2p}}\right)\right] \qquad (2)$$

$$\langle \hat{t}(s)\cdot\hat{t}(s+\Delta s)\rangle = \langle \cos\theta(\Delta s)\rangle = e^{-\frac{\Delta s}{2p}} \qquad (3)$$

The plots in Fig. 2B show that collagen can be well-described by the WLC model.

The persistence length obtained for collagen type IV ($p \approx 41$ nm), reveals that it is significantly more flexible than fibrillar collagen type I ($p \approx 104$ nm). Could this enhanced flexibility be attributed to the presence of triple-helical interruptions? We decided to take a closer look at the amino acid sequence of collagen type IV and map out where these interruptions are along the contour of the molecule.

SEQUENCE-DEPENDENT ANALYSIS

To perform a sequence-dependent analysis, we need a sense of directionality to the chains so that we can align them at the same end. The collagen type IV molecules have a discernable "knob" at one end, which marks its C-terminal globular domain, and so we use it as a marker to trace chains starting at the edge of the knob. A schematic structure of collagen type IV is represented in Fig. 3B, where the boxes correspond to tripe-helical segments, and gaps to overlapping interruptions where all three chains possess a non-triple-helix-forming sequence. One can see that the chains have more interruptions at the end further from the knob. In addition, by inspecting the AFM images, we can see that the collagen IV molecules appear to be more flexible towards that end as well. To quantitatively show this, we devised an algorithm that performs a

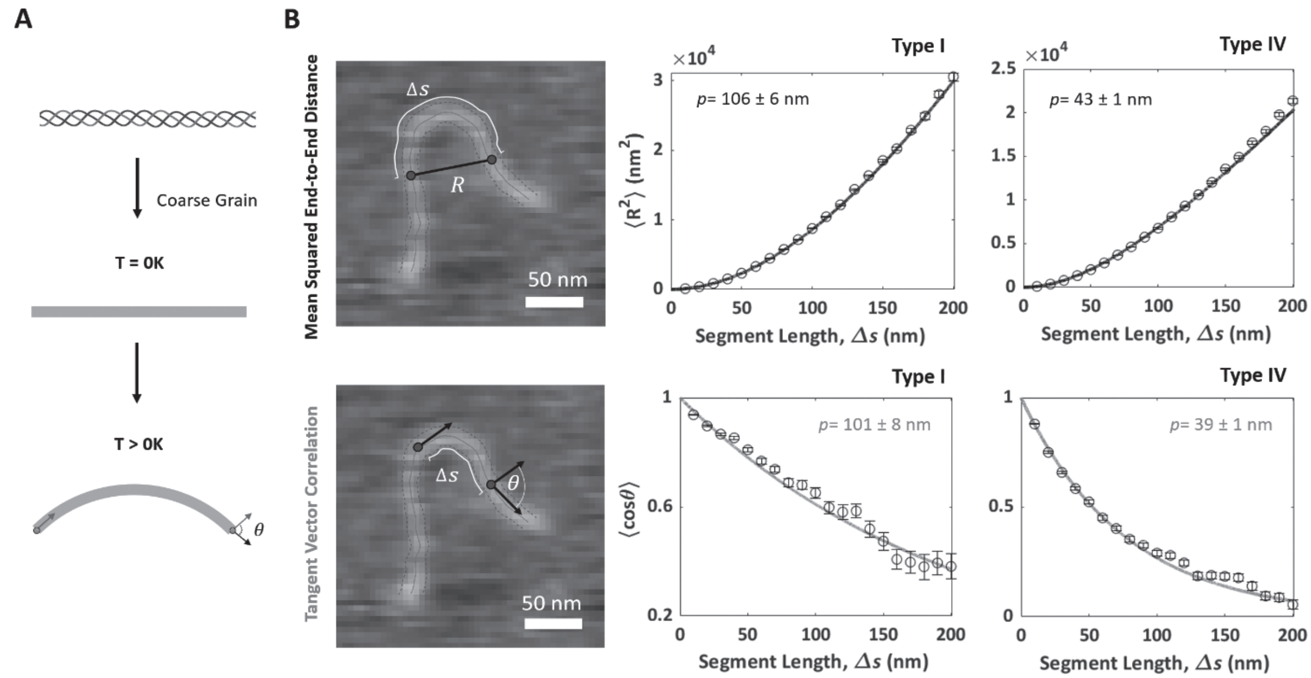

Fig. 2 **Homogeneous analysis of collagen to extract persistence length. A.** The Worm-Like Chain (WLC) model. **B.** The persistence lengths were obtained using $\langle R^2(\Delta s)\rangle$ (black; Eq. 2)) and $\langle \cos\theta(\Delta s)\rangle$ (gray; Eq. 3) analyses, as shown for the collagen data here. These data are fit well by the predictions of the worm-like chain model. The fibrillar collagen type I possess a persistence length of $p \approx 104$ nm [6] ($N = 100$ chains), while collagen type IV exhibits a substantially lower overall persistence length of $p \approx 41$ nm ($N = 280$ chains).

sequence-dependent analysis to determine how these local sequence variations affect flexibility. The algorithm works by calculating an effective persistence length at 1 nm increments along the contour of the chain, using a chain segment of fixed length $\Delta s = 30$ nm centered at each of these positions along the contour, s. Since the angular distribution for a worm-like chain segment is expected to be Gaussian with zero mean and variance equal to the ratio of its segment length Δs and persistence length p, an effective persistence length for the segment centred at position s can be calculated as

$$p^*(s) = \frac{\Delta s}{\sigma_\theta^2(s)}. \qquad (4)$$

As seen in Fig. 3A, the distributions of angles $\theta(\Delta s)$ extracted from our AFM images are well described by a Gaussian distribution with zero mean. Our collagen type IV effective persistence length profile is shown in Fig. 3B, where the profile has been aligned with the expected structure of collagen type IV. We can see that at the end far from the knob, the persistence length significantly drops, in agreement with our visual argument made earlier. This shows that an increase in interruptions is indeed correlated with an enhanced flexibility of the molecule. Also, where there are overlapping interruptions, boxed in black, the persistence length exhibits minima, further supporting the concept of interruptions providing enhanced flexibility to the structure. Lastly, we note that where there are longer stretches of triple-helical segments, we capture the persistence length found for fibrillar collagen type I, which are continuously triple-helical molecules [6].

CONCLUSION

Our results shed light onto the heterogeneity of the collagen type IV molecule and the effects of triple-helical interruptions on its flexibility. By performing statistical analysis, we can gain insight onto the structural consequences of interruptions – a feature that is incompletely understood and lacking a well-defined biological role. The differences seen in the flexibility of fibrillar and network-forming collagen may be manifest by the type of higher-order structures they assemble into, where collagen type I assembles into fibrils which are more rigid structures than the networks formed by collagen type IV.

ACKNOWLEDGEMENTS

This work was supported by a Discovery Grant from NSERC. We are grateful for the assistance provided by our collaborators, Sergey Budko and Billy G. Hudson from Vanderbilt University. We would like to give a special thanks to ChangMin Kim for assistance with AFM instrumentation.

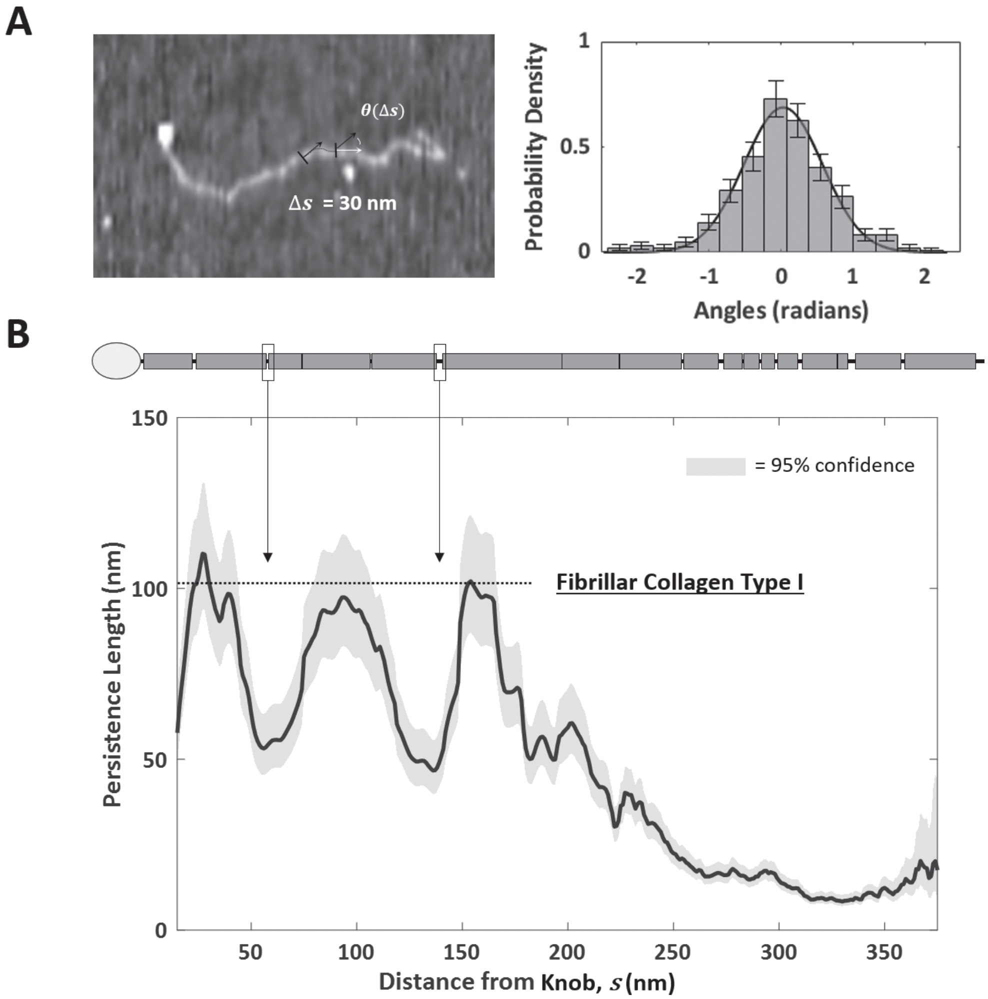

Fig. 3 **Position-dependent persistence length profile of collagen type IV. A.** For segments of length *Δs* each centered at a distance *s* along the backbone from the "knob" of each chain, the effective persistence length is determined by the variance of angular changes *θ*(*Δs*) among these segments (Eq. 4). **B.** Collagen type IV structural representation (box = triple-helical, gap = overlapping interruption) aligned with the persistence length profile, where the dashed line indicates the persistence length found for the continuously triple-helical fibrillar collagen type I [6], and the arrows correspond to key overlapping interruptions that locally increase flexibility.

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Search for Neutrino Trident Events in IceCube

by Sourav Sarkar[1] and Roger Moore

Standard Model (SM) of particle physics has been a great success with the discovery of the fundamental particles and their interactions via strong, weak and electromagnetic forces. However, neutrino oscillation experiment [1] observed that starting with one particular flavour of neutrino from source, it can be detected as a different flavour of neutrino in the detectors. This phenomena, known as neutrino oscillation, requires the neutrinos to have tiny nonzero masses which directly contradicts the prediction of massless neutrinos in SM. Many beyond standard model (BSM) theories (e.g., supersymmetry (SUSY), string theory) have been developed to incorporate such experimental anomalies and require presence of additional fundamental particles that have not been observed yet. One of the processes that can probe into the new physics (NP) is neutrino trident production (NTP) which is our point of interest in this article. NTP is a sub-dominant SM process which can also produce new intermediate particles and we can constrain the properties of these new particles by observing the final state particles. Several collider and neutrino beam experiments are looking for BSM particles, however, their search is limited by upper limits of the beam energy (~ 10TeV) and luminosity (i.e., rate of events). Detection of neutrinos at the IceCube neutrino obeservatory [2] relies on the natural sources of neutrinos (e.g., atmosphere, astrophysical sources) that can produce neutrinos with energy as high as ~ 10PeV. Therefore, search for NTP events in IceCube can have a potential advantage over any collider or beam experiments.

In this article we will briefly discuss the theoretical motivation of searching for NTP events in section 2. Section 3 summarizes the details of IceCube detector and the aspect of detecting NTP events and potential challenges in IceCube. And, finally in section 3, we conclude our discussion by summarizing the article.

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Summary

Neutrino trident production (NTP) is a standard model (SM) sub-dominant process that can be used as a powerful probe for the search of new physics. In this article, we explore the possibility of detecting NTP events at the IceCube neutrino observatory using atmospheric neutrinos.

Theoretical Motivation of Neutrino Trident Production

Neutrino is one of the SM fermions and they do not carry any charge. Therefore, neutrinos can interact only via weak interaction by exchanging charged W boson (charged current (CC) interaction) or neutral Z boson (neutral current (NC) interaction). Cross-section of sub-dominant process like NTP is several order of magnitude less than the cross-section of standard CC or NC neutrino interactions. However, dedicated study of NTP process can be used as powerful probe into the search for BSM physics. In NTP process, an incoming neutrino interacts with the coulomb field of a nucleus and creates three outgoing leptons (an outgoing neutrino and two charged leptons) and a recoiled nucleus as seen in Fig. 1. NTP processes can be both CC and NC depending on the exchange of type of weak bosons. However, weak bosons can also be replaced by additional BSM vector (scalar) bosons Z' (S') from $L_\mu - L_\tau$ model [3]. The presence of such additional BSM bosons can enhance the NTP event rate significantly. CHARM II [5], CCFR [6], and NuTeV [7] have observed NTP events in the past and based on their observed event rate, limits on the mass-coupling constant parametric space have been set which can be seen in Fig. 2 [4]. Among all the NTP processes, we are interested in only the channels that produce two outgoing muons ($\mu^\pm$) as the charged leptons. To investigate the feasibility of detecting NTP events in the higher energy regime, we calculate the SM cross section and simulate events of NTP processes that produce dimuons using equivalent photon approximation (EPA) with CalcHep [8]. From Fig. 3 [left], we notice that the CC contribution of the total cross-section increases with steeper slope at around ~ 4TeV incoming neutrino energy. Right side plot of Fig. 3 shows that W boson becomes on-mass shell (i.e., resonance at ~ 80GeV), which is responsible for increase in the cross-section. Therefore we expect to observe more NTP events as we go higher in energy of the incoming neutrinos and it is only possible with neutrino observatories (like IceCube) as they can detect high energy neutrinos which is beyond the reach of collider experiments.

1. Sourav Sarkar received 1st place in the CAP Best Student Poster Presentation competition at the 2019 CAP Congress at Simon Fraser University in Burnaby, BC.

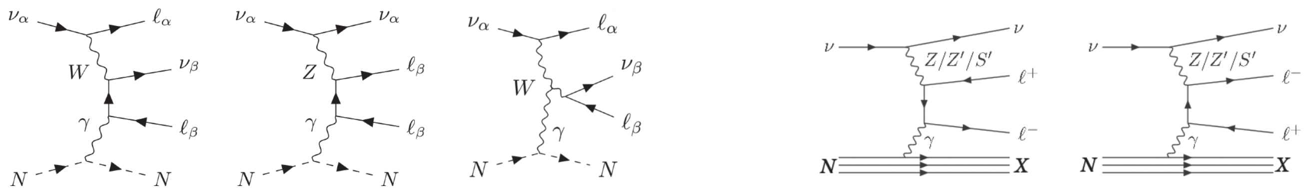

Fig. 1 [Left]: Feynman diagrams for SM NTP processes. N is the interacting nucleus and l is the charged lepton with flavours $\alpha, \beta = e, \mu, \tau$. [Right]: Feynman diagram replacing Z boson with BSM bosons Z' and S'.

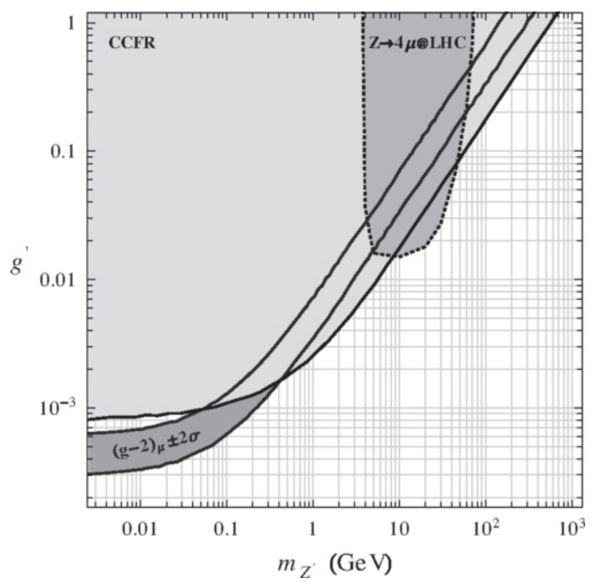

Fig. 2 Parameter space for Z' gauge boson. Shaded region above the lines is the excluded region.

SEARCH FOR NTP EVENTS IN ICECUBE DETECTOR

IceCube neutrino observatory, located at the geographic south pole uses a cubic kilometer of antarctic ice as its detector vol- ume. When a neutrino interacts in the ice, it deposits either a fraction or all of its energy which creates high energy charged particles in the medium. If these charged particles travel faster than the phase velocity of light in ice they emit photons via Cherenkov radiation. IceCube detector aims to detect the Cherenkov photons to get information about the primary inter- action by reconstructing energy, direction and flavour of incoming neutrinos. To detect these Cherenkov photons, 5160 digital optical modules (DOMs) consisting of photomultiplier tubes (PMTs) and related electronics are installed in the ice (shown in Fig. 4 [left]). These DOMs are instrumented on 86 strings at a depth from 1450 m to 2450 m from the surface at the south pole as shown in Fig. 4 [right]. The volume of the full detector is one cubic kilometer and in the middle of the detector, there is a densely spaced infill array of DOMs with higher quantum efficiency (QE) PMTs (i.e., better resolution) to probe into lower energy neutrino interactions. This densely spaced core of the detector is called DeepCore volume which is an order of magnitude smaller compared to the full detector volume. When a muon neutrino interacts in the detector via CC interaction, it produces a high energy muon that can travel a long distance through ice before losing its energy in the surrounding medium and decay. Cherenkov radiation detected from such muons look like elongated tracks in the detector (as shown in Fig. 5 [left]), so they are called 'track-like' event. For all other neutrino interactions (all flavour of NC interactions and electron- and tau-neutrino CC interaction) where secondary particles are other than a muon, they create electromagnetic and hadronic shower in ice where multiple charged particles produce Cherenkov radiation in all direction from the primary interaction vertex allowing the detector to see light isotropically (shown in Fig. 5 [right]) and these events are called 'cascade-like' events.

For the search of NTP events, we are only interested in di-muon production channels, i.e., we will be looking only into track-like events in IceCube. Moreover, there are two muons generated through NTP process simultaneously, so the goal of this research is to look for double-track events in IceCube. We rely on the abundant atmospheric neutrino sample (neutrinos that are created in the earth's atmosphere from the interaction of cosmic rays) for NTP event search. From the well established atmospheric neutrino flux, calculated NTP cross-section and efficiency of detecting track events in IceCube, we can estimate the expected NTP event rate for only SM contributions in both IceCube and DeepCore detector which is given in Table. 1.

Now that we have an expected NTP event rate, our immediate challenge is to build an efficient event reconstruction tool that can distinguish the difference between a single-track event (standard CC) and a double-track event (NTP). The ability of detecting double-track events depend on the detector resolution and separations between two tracks. If the separation is too small, light from those two tracks are not resolvable which can make the double-track and single-track events indistinguishable from each other. We are currently in the process of exploring and exploiting double track signature to develop reconstruction algorithm that can detect such event topology. In order to explore the properties of double track events, we have created toy Monte Carlo (MC) simulations of NTP events in IceCube detector, two sample events are shown in Fig. 6. We are also

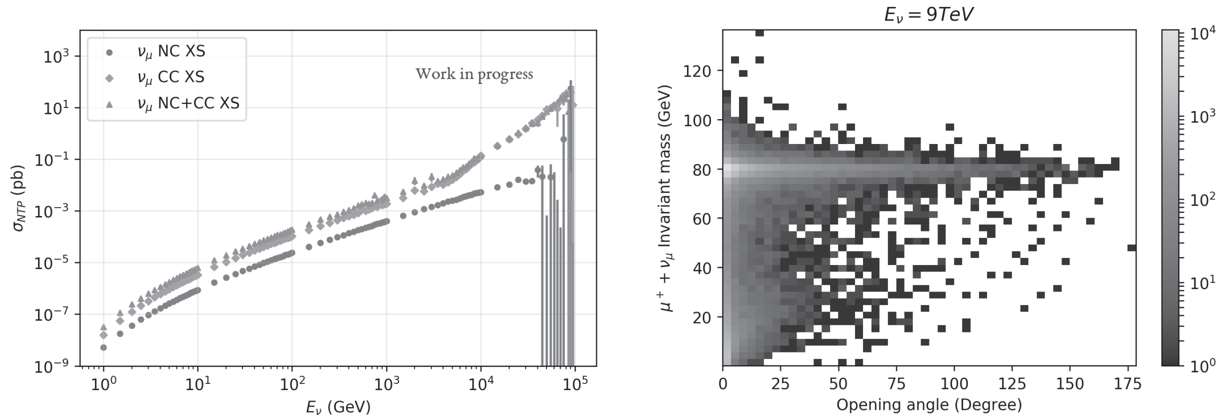

Fig. 3 [Left]: Total Cross-section of NTP channel of di-muon production. [Right]: Distribution of *W* boson invariant mass and opening angle between two outgoing muons. Peak at 80GeV shows the presence of on-mass shell *W* boson.

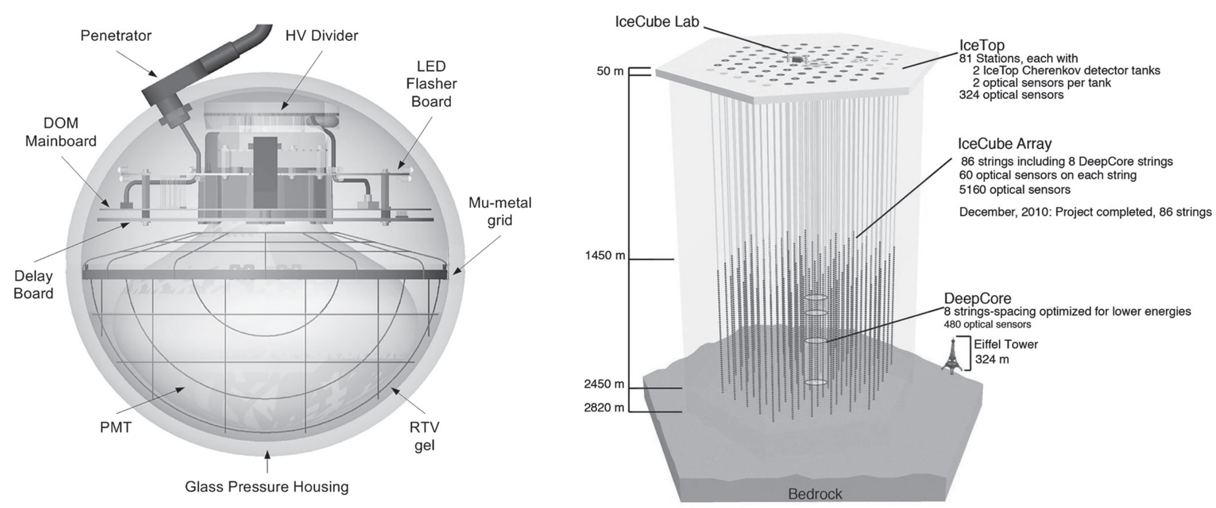

Fig. 4 [Left]: DOM with PMT placed in the bottom half. [Right]: Schematic of IceCube detector configuration.

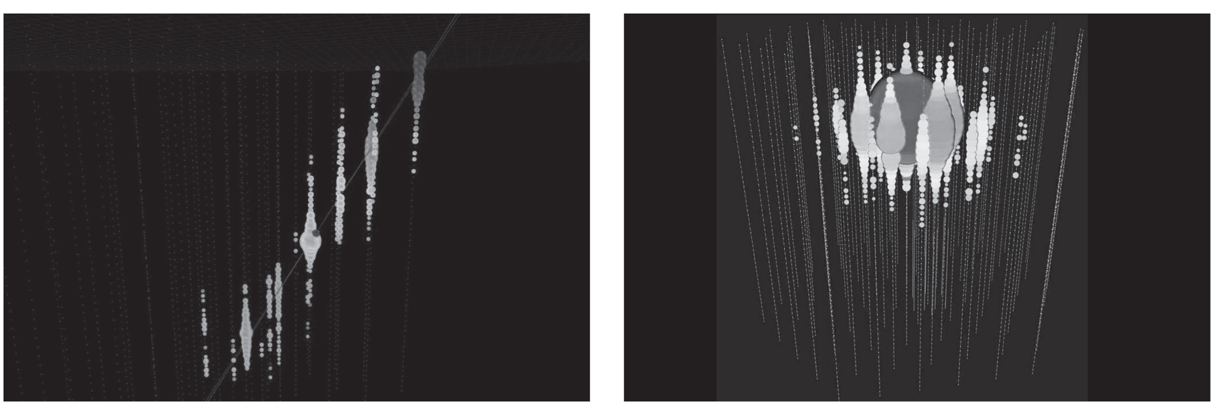

Fig. 5 Track-like (left) and cascade-like (right) event topology in IceCube.

TABLE 1

Estimated NTP and CC event rates from SM in IceCube [left] and DeepCore [right].

IceCube Volume	DeepCore Volume
Emergy range 100GeV – 5TeV	Emergy range 1GeV – 1TeV
~9.35 NTP events/year	~2.17 NTP events/year
~34, 975 standard CC events/year	~192, 060 standard CC events/year

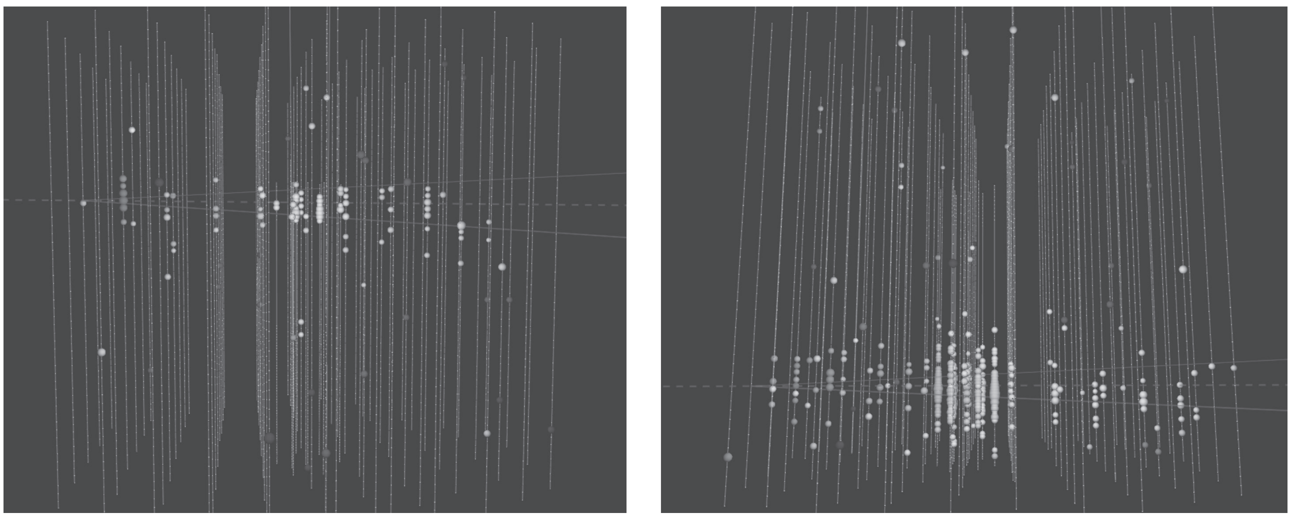

Fig. 6 Double track NTP event simulations in IceCube.

working on determining the limit of the track separation below which it is not possible to detect NTP signal events from standard CC background.

CONCLUSION

In summary, NTP process can be used as a powerful probe into the study of new physics. Collider and neutrino beam experiments are limited by energy of incoming neutrinos to detect significant number of trident events that can set a strong constraint on the BSM bosons search limit. In this work, we explore the possibility of detecting NTP events in IceCube with some advantage over standard collider and beam experiments. However, poor detector resolution and large background events are the challenging hurdles that we need to overcome to get more constraining BSM boson search limit by detecting double track NTP events.

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Shaping Arbitrary Energy Landscapes with Feedback

by Avinash Kumar[1] and John Bechhoefer

The interaction of light with matter at the nanoscale has been a topic of great importance over the past several decades. After pioneering work by Ashkin *et al*. [1], optical tweezers have been used to exert forces on small mesoscopic particles as well as to detect their fluctuations for physical [2,3], chemical [4,5], and biological applications [6-8]. Other forms of tweezers use forces based on optofluidics [9], plasmonics [10], and photophoresis [11].

In addition to passive traps that create potential wells to confine particles, there are traps that create *virtual potentials* that confine particles using active feedback based on position measurements of the trapped object. Such feedback traps need only create a force of controlled magnitude and direction and apply confinement based on feedback from position measurements. The feedback trap can be based on a variety of forces, including electrokinetics [12], magnetism [13], and thermophoresis [14]. Sometimes the goal is to apply a more complicated force field rather than just creating a trap [15]. Feedback traps based on optical tweezers [16] use forces from the underlying harmonic potential to achieve such goals. In this article, we explore the idea that using feedback based on the measured particle position, one can create essentially arbitrary potentials.

Typically, an optical tweezer uses a tightly focused Gaussian beam to trap microspheres. In our experiment, we trap 1.5 µm diameter silica beads. A particle in a trap can be modelled as a dielectric particle placed in an inhomogeneous electric field. Forces acting on the particle from the external field are categorised into scattering and gradient forces. *Scattering forces* arise from momentum transfer from photons to particle and push the particle along the direction of propagation of the light. *Gradient forces* arise from gradients in the electric field and act in the direction of increasing electric field. If the total gradient force exceeds the scattering force, a particle is trapped.

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Summary

A closed-loop feedback trap based on optical tweezers enables the shaping of arbitrary energy landscapes for colloidal particles.

Since an optical tweezer exerts a force to counteract fluctuations, it can be used to provide feedback forces on colloidal particles to probe and manipulate their dynamics with high resolution and bandwidth.

Here, we combine the technique of optical tweezers with feedback control to create virtual potentials by applying varying forces on a particle. The feedback protocolinvolves observation of the position of a freely diffusing particle, calculation of a force based on an imposed potential and application of that force (Fig. 1). Optical tweezers have previously used feedback to create position and force clamps [17-19]. In a force clamp, feedback is used to apply a constant force on the trapped particle. In a position clamp, the forces are varied to keep a particle at a desired position. In our version of feedback trap, we update force and position at rates of order 100 kHz to create a virtual energy landscape. It should be noted that these virtual potentials are discrete approximations of real potentials. In a real potential, forces are applied instantaneously as the position changes, but in a virtual potential, feedback forces are set once per feedback loop and are approximately constant throughout the loop. The performance of a feedback trap is limited by the amount of latency (delay) in the control system.

Our feedback optical tweezer is based on a homemade microscope. A water-immersion high-numerical-aperture microscope objective (60X, NA = 1.2) is used for trapping. A low-numerical-aperture microscope objective (20X, NA = 0.4) focuses the detection laser on the trapped particle to detect the fluctuations. The trap centre is shifted regularly to create a feedback force. This is done by an acoustooptic deflector which is imaged on the back focal plane of the trapping objective. Angular deviation of the deflector output is translated into a linear shift in the trapping plane. A quadrant photodiode detector is used to read the signals from the trapped particle. In order to precisely apply the feedback forces, the feedback timing should be accurate. We use a National Instruments FPGA-based data acquisition module (NI USB-7855R) that runs at a deterministic time step of 10 µs and can read and write signals simultaneously. The setup is described in more detail in Ref. [16].

1. Avinash Kumar received 2nd place in the CAP Best Student Poster Presentation competition at the 2019 CAP Congress at Simon Fraser University in Burnaby, BC.

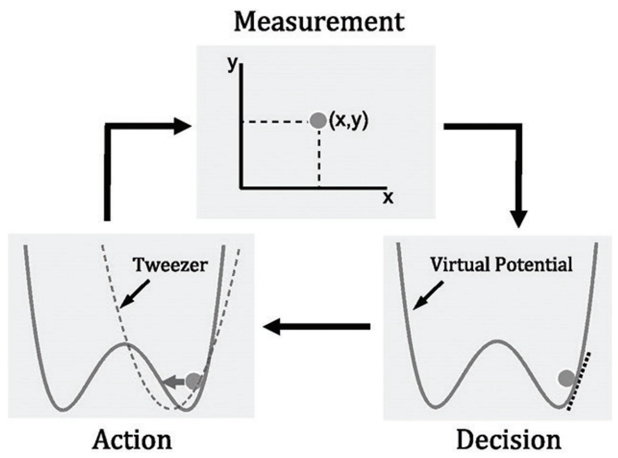

Fig. 1 One cycle of a feedback trap. *Measurement*: estimate the current position of the particle, *Decision*: calculate force based on the imposed potential (red), and *Action*: apply the force by shifting the harmonic well centre (blue).

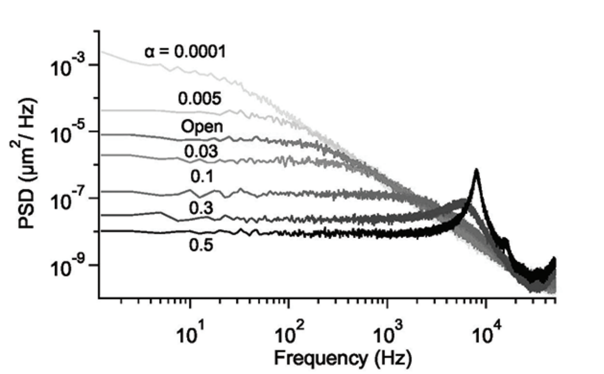

Fig. 2 Power spectral density for different feedback gains. The red plot corresponds to the "open loop" optical tweezer (no feedback). The other curves correspond to different feedback gains. Feedback can create both stiffer and weaker traps.

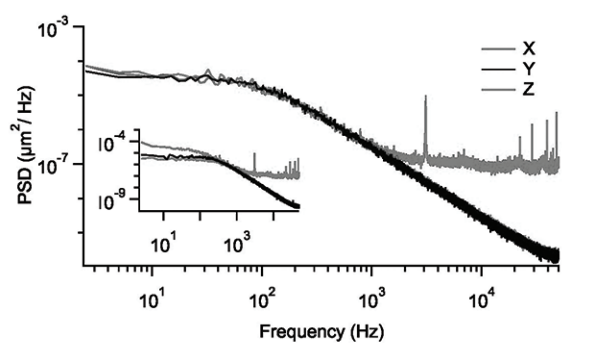

Fig. 3 Power spectral density in *x*, *y* and *z* directions. Inset: power spectrum density without feedback. With *x* and *y* feedback, all three dimensions show the same stiffness.

Using feedback, we create virtual harmonic wells of variable stiffness [16]. A similar instrument has been developed independently by Albay *et al*. [20]. The discrete dynamics of a particle in a virtual harmonic well is given as

$$x_{n+1} = x_n - \tilde{\alpha}\,(x_n - x_n^t) + \xi_n \tag{1a}$$

$$x_n^t = \bar{x}_n(1-G) \tag{1b}$$

$$\bar{x}_n = x_{n-2} + \zeta_n, \tag{1c}$$

where x_n is the particle's real position, $\bar{x}_n$ the observed positions, x_n^t the trap position at time t_n, ξ_n the integrated thermal noise, ζ_n the integrated measurement noise, and $G \equiv k_v/k_t$ is a dimensionless gain. Here, k_v is the stiffness of the virtual trap and k_t that of the real trap. The constant $\tilde{\alpha} = G[1 — \exp(\Delta t/t_r)]$ accounts for the relaxation in the trap during one cycle of the feedback loop, Δt. Here, $t_r = \gamma/k_t$ is the relaxation time, γ the viscous drag coefficient. We operate our trap in the limit $\Delta t << t_r$ where $\tilde{\alpha} \approx \alpha \equiv \Delta t/t_r$. The feedback delay time is $t_d = 20$ μs $= 2\Delta t$.

Figure 2 shows that we can change the effective stiffness of a virtual trap using feedback at constant laser power. We obtained a 30-fold gain in the stiffness of the trap compared to that of the underlying harmonic trap. Often changes in trap stiffness are created by varying the total laser intensity in the trap. In a feedback trap, a similar control is achieved by changing the feedback gain α. For large values of α, the particle dynamics deviates from potential motion, showing oscillations and even instability because of overcorrection [21]. We work with α values where the variance is minimum.

Another interesting feature of a feedback trap is its ability to *reduce* trap strength [16]. In an ordinary optical tweezer, the axial stiffness is weaker than the transverse stiffness. See the inset in Fig. 3. This asymmetry is an inherent feature of the electric-field gradient of a Gaussian beam. Figure 3 shows that the usual anisotropic trap can be made isotropic in all three dimensions using feedback. We used the feedback to reduce the trapping strength in the transverse directions so that it matches the axial stiffness. Isotropy is an important property, as it allows a force sensor to measure three-dimensional forces in a straightforward manner. In an anisotropic trap, one would have to allow for different bandwidths in different directions, which complicates the interpretation of force measurements.

To demonstrate the flexibility of our feedback trap, we create a variety of virtual potentials such as harmonic well, double-well and linear potentials (Fig. 4). In Ref. [16], we have shown a family of double-well potentials where the barrier height, well separation and the curvatures are controlled independently. Note that for a linear potential, the curvature at the centre is

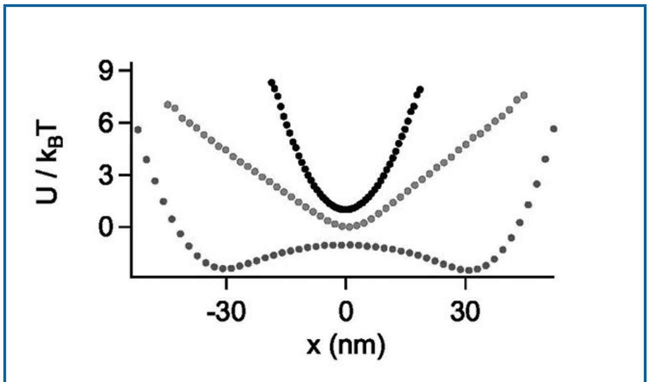

Fig. 4 A family of virtual potentials $U(x)$ showing harmonic (star), linear (triangle) and a double-well shapes (square). The potentials are reconstructed from the corresponding Boltzmann distribution of the position measurements. The three cases are offset by $k_B T$ to aid in visualization.

governed by the feedback time and the force exerted, F. The basin at the centre can be approximated by a harmonic well with $\alpha = \frac{F}{\gamma}\Delta t/\Delta x$, where Δx is the range over which the harmonic approximation holds.

Other methods such as time-shared optical tweezers and holographic tweezers can create such energy shapes. Nanometer-scale precision in displacements can be achieved with holographic tweezers [22], but the spatial scale of the potential minima will be diffraction limited. If the goal is simply to create a double-well potential, timeshared traps are useful. However, in such traps, the effective stiffness per well becomes smaller as well separation is reduced. Well separation and barrier height are coupled, too. Here, we can *independently* vary well separation, well curvature, and barrier height [16].

In Ref. [16], we reduced the length scale of these one dimensional double-well potentials to a well spacing of 10.6 nm with a barrier height of $0.16 k_B T$ [16]. These length scales are far below the diffraction limit and cannot be created with techniques such as multiplexed or holographic tweezers. The ability to create a double-well potential with low energy barrier but high well curvature is important, as it traps the particle in a well-defined volume of space while still allowing for fast transitions between macrostates.

Currently we are using our tweezer-based feedback trap to explore the *Mpemba effect* and its inverse. As described by the Tanzanian high-school student Erasto Mpemba in 1969, when two identical water samples are prepared initially at hot and warm temperatures and then quenched to a cold temperature, the hot system can cool (and freeze) faster than the warm one—a phenomenon now known as the Mpemba effect [23]. The cooling anomaly has been predicted theoretically in other systems such as nanotube resonators [24], spin glasses [25], and experimentally observed in clathrate hydrates [26]. Many explanations have been proposed, involving processes such as evaporation [27], convection [28], supercooling [29], dissolved gases [30], and hydrogen bonding [31]. These hypothetical mechanisms all have at least some experimental support, suggesting that multiple factors can lead to the anomalous cooling of the Mpemba effect. Indeed, the problem with traditional approaches is that there can be *too many* explanations, implying that they miss essential aspects of the phenomena.

Our approach to the Mpemba effect is based on a recent study by Lu and Raz [32], who argued that the Mpemba effect can be seen (and hence better understood) in a much simpler context (Brownian particle in a potential) and that the simplicity of such situations can clarify the mechanisms behind the effect. In preliminary work [33], we have explored cooling and heating in a tilted double-well potential with asymmetric domains. If the asymmetry is chosen to give a direct path between high- and low-temperature basins of attraction, we observe that an initial hot state cools to the bath temperature faster than an initially warm state [33].

In summary, we have created virtual harmonic wells and static double-well potentials with feedback. The form of such potentials can be arbitrary and are easily tunable. Virtual double-well potentials have been used previously to test the fundamental relationship between information and thermodynamics [34,35]. Experimental studies reveal that biological processes such as protein folding occurs at scales which can be described by the diffusive dynamics in a low-energy landscape [36]. The virtual potentials described here will be useful for such studies.

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2019 CAP Medal Recipients / Lauréats des médailles de l'ACP de 2019

The CAP is very pleased to recognize its 2019 medal recipients. Please visit the website below 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. An interview with Teaching medal recipient, Robert Mann, is included in this issue.

L'ACP est très heureuse de reconnaître ses récipiendaires de médailles 2019. Veuillez consulter le site web ci-dessous 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. Une intervue avec Robert Mann, récipiendaire de la médaille d'enseignement, est incluse dans ce numéro.

https://www.cap.ca/programs/medals-and-awards/medal-recipients-year/ (choisi "francais" dans la boîte bleu pour voir l'annonce en français)

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

Jaume Gomis
Perimeter Institute for Theoretical Physics

For his broad range of important contributions to string theory and strongly coupled gauge theories, including the pioneering use of non-local observables, the exact computation of physical quantities in quantum field theory, and the unravelling of the nonperturbative dynamics of gauge theories.

Pour ses apports importants à la théorie des cordes et aux théories de jauge fortement couplées, dont l'utilisation inédite d'observables non locales, le calcul exact de quantités physiques dans la théorie quantique des champs et la simplification de la dynamique non perturbative des théories de jauge.

CAP-COMP Peter Kirkby Memorial Medal for Outstanding Service to Canadian Physics / Médaille commémorative Peter Kirkby de l'ACP-OCPM pour services exceptionnels à la physique au Canada

Béla Joós
University of Ottawa

For his tireless service and selfless devotion to strengthening the Canadian physics community. His service in the executive of the Canadian Association of Physicists, and his central role in supporting, transforming, and rejuvenating Physics in Canada as a national physics magazine during more than 30 years on the editorial board and more than a decade as editor, embody the ideals of outstanding service to Canadian physics that the Kirkby medal celebrates.

Pour ses efforts infatigables et son dévouement afin de renforcer la collectivité canadienne de la physique. Ses services à la direction de l'Association canadienne des physiciens et physiciennes et son rôle de premier plan à appuyer, transformer et rajeunir La Physique au Canada, à titre de revue nationale de physique pendant plus de 30 ans au comité de rédaction et de dix ans à titre de rédacteur en chef, illustrent son idéal de service exceptionnel à La Physique au Canada, ce que salue la Médaille Kirkby.

CAP/DCMMP Brockhouse Medal / Médaille Brockhouse ACP-DPMCM

Graeme Luke
McMaster University

For his contributions in the field of superconductor research using muon-spin techniques, and his leading role in developing these techniques at TRIUMF, a signature of Canada's research excellence.

Pour ses contributions au domaine de la recherche sur les supraconducteurs au moyen de techniques de spin des muons, et pour son rôle de meneur dans le développement de ces techniques à TRIUMF, ce qui a consacré l'excellence du Canada en recherche.

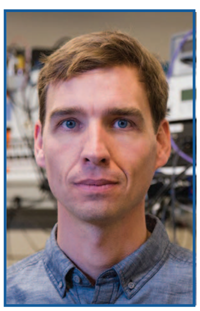
Medal for Excellence in Teaching Undergraduate Physics / Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle

Robert Mann
University of Waterloo

For his overall accomplishments in teaching, and the promotion of quality teaching both at his institution and through the CAP, which are exemplified by the instigation of an annual Teaching Retreat at the University of Waterloo and the implementation of the CAP's Award for Excellence in High School/CEGEP Physics Teaching.

Pour ses réalisations en enseignement et la promotion de la qualité de l'enseignement, tant au sein de son établissement qu'à l'ACP, ce qu'illustrent la création d'une réflexion annuelle sur l'enseignement à l'Université de Waterloo et l'instauration du Prix d'excellence en enseignement de la physique au secondaire/cégep de l'ACP.

CAP Herzberg Medal / Médaille Herzberg



Paul Barclay
University of Calgary

For his demonstrated leadership in nanophotonics and optomechanical devices that is building new bridges between pure and applied quantum science.

Pour son leadership manifeste en dispositifs nanophotoniques et optomécaniques qui servent à jeter de nouveaux ponts entre la science quantique pure et appliquée.

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

Douglas Bonn
University of British Columbia

For his accomplishments in quantum materials that have advanced our understanding of high-temperature superconductors.

Pour ses réalisations dans les matériaux quantiques qui ont fait progresser notre compréhension des supraconducteurs à haute temperature.

CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics / Médaille Vogt de l'ACP-TRIUMF pour contributions à la physique des particules subatomiques

Scott Oser
University of British Columbia / TRIUMF

For his contributions to the study of neutrino oscillations with the SNO and T2K experiments, and to experimental searches for dark matter with SuperCDMS. He has demonstrated excellence in hardware design and construction, data analysis, scientific interpretation of the results, organization, and leadership. The award is in recognition of the breadth of his scientific endeavours, demonstrable expertise, and high impact in each experiment.

Pour ses apports à l'étude des oscillations de neutrinos grâce aux expériences de l'Observatoire de neutrinos de Sudbury (ONS) et du T2K, et aux recherches expérimentales de matière noire avec le SuperCDMS. Scott Oser a fait preuve d'excellence en conception et fabrication de matériel, analyse de données, interprétation scientifique des résultats, organisation et leadership. Cette médaille vise à reconnaître ses diverses entreprises scientifiques, son expertise avérée et sa portée profonde dans chaque experience.

Lauréats des médailles de l'ACP de 2019

2019 Medals and Prizes - Interview with Robert Mann, Recipient of the CAP's 2019 Medal for Excellence in Teaching Undergraduate Physics, September 2019 (by Daria Ahrensmeier)

Interviewer: Hello, Robb. Congratulations on your teaching medal!

Robb Mann: Thank you.

Interviewer: Before we talk about your current teaching, I want to ask you about something interesting I learned about you this week. I heard that you taught high school.

Robb Mann: A long time ago, yes. I was a supply teacher. It wasn't full-time, but in the 1970s, I did this. I supply taught science at several high schools in Burlington and in Hamilton, Ontario.

Interviewer: And did you enjoy it?

Robb Mann: Mostly, yes. I was only a little bit older than the students themselves. And the ones that knew it (or rather figured it out) would push back. But I managed to hold my own. It was different in different schools. The best experiences were when the teachers had clearly laid out lesson plans that I would follow. And I actually like high school students. I mean, when I was teaching it wasn't too much earlier that I was one. But it did give me some insight as to how they think. And there was a huge spectrum of thought and attitude. Sometimes as a supply teacher, although I was mostly called in to do science, on occasion I had to be called in to do something else. The most awkward one was when I had to do a grade nine art class. That was really out of my comfort zone — basically I just maintained the class. But in the science classes, I actually did teach. I would not do just one-shot classes — sometimes I was in for four days in a row or even a week. I think that happened a few times.

Interviewer: You were a student at the time?

Robb Mann: I was an undergrad at the time. I began halfway through my undergrad years, and I did it all the way through to the end of my PhD. And then, I didn't do it anymore.

Interviewer: Speaking of art classes, another thing that I learned about you was that somebody said you had acting training.

Robb Mann: Yeah, I haven't done that for a while. But I did for about six years in a row, I acted in local community theater, yes. So, I played the Grinch in *Seussical*, and I was Mr. Darling in *Peter Pan*. And… yes, so I did some of that, that's right.

Interviewer: You must have enjoyed that, otherwise you wouldn't have done it.

Robb Mann: Certainly, at the beginning! I guess I'd say overall, I still enjoyed it. At the beginning, it was very novel. I hadn't done it before. After about six years of it, it had an element of repetitiveness. And I was going on sabbatical. After that sabbatical, I didn't return to it to the extent I've done it. I've been singing in choirs instead. Acting in a musical is considerably time-consuming. At first, it's a weekly commitment but two weeks before the show is on, you're basically in three hours every night in final rehearsals and it's very time-consuming. And that's partly why I didn't go back to it. I'm not saying I'll never do it again, but, you know, there are people a lot more talented than me that do it.

Interviewer: Did you take anything from your acting experience into teaching?

Robb Mann: Well, yeah, and probably vice versa. Pacing would be one aspect. In acting one of the key things that matters is timing and pacing. It translates a bit differently when you're in front of the class, but nevertheless it's still helpful. When you're acting, the director doesn't like dead space — that really bores an audience. The audience doesn't notice it, but as soon as a character says a line, the next character needs to come in with their line, unless of course there's some other thing that happens. But dead space — vacancy between lines — seems huge to an audience. And to some extent, I think that's true in a classroom. You've got to balance your speaking. On the one hand, students need time to reflect, so you want to put in the necessary pauses. But you don't want to go too slow or too monotonously. So I would say that pacing and timing are probably the main thing I have taken from acting into teaching. [Pauses] And fun and being a bit comedic and all that kind of thing, right? But I was doing that long before I was acting, I guess.

Interviewer: Is it a personality thing too?

Robb Mann: It is partly, yes. That's right. I mean, it's fun to be in front of an audience. That does not bother me.

Interviewer: That's probably helpful.

Robb Mann: It does help, yes.

Interviewer: Did you take anything away from the high school teaching, or did you change very much how you teach?

Robb Mann: Well, I mean, as the students get older, they're more mature … and in university, they want to be there. The main thing I take in either case is that when students ask questions, I always try and turn the question into something useful in the class instead of give the impression that's a stupid question. And often, students know more than they're able to say or to ask. This comes with experience, but I suppose partly in high school and certainly in early years of university teaching, they're not asking the actual question — they're asking what is often a good question but in a very obtuse way, or they don't quite know how to articulate it. So what I usually try and do is I say, "If I understand you right, I think you're trying to ask about X, Y or Z." And almost all the time, they say "Yeah, yeah, yeah, that's right!" So that part helps. It's also true, I suppose, of anybody, but with younger students, they don't know how to formulate their questions very well yet. They have the right intuition more than they have the right level of articulation. That's what I found. Of course, there are exceptions, but almost always you can turn a weak question into a good one or at least a reasonable question. That's one thing I got out of high school teaching.

I think one of the most important things is to try and help the students walk through the subject from their point of view, from where they are beginning.

Interviewer: In your talk, when you received the teaching medal, you talked about teaching young students as well as more experienced students, grad students, and up to faculty, things they have to learn. For somebody who didn't attend your talk, what would be the main message that you would want them to get?

Robb Mann: Well, I would say I think one of the most important things is to try and help the students walk through the subject from their point of view, from where they are beginning. And I would say when I've made mistakes and when I've seen other teachers make mistakes, they're either assuming too much prior knowledge or they're not assuming enough prior knowledge. Usually it's the former but sometimes it's the latter. And it does take a bit of energy, but with experience, you get used to it. Of course, schooling has changed a bit … I don't deal with children very much to the extent I have in the past, when I've taught Sunday school. But you know, when I teach an eight-year-old kid, I ask myself what did I know when I was eight? It's where you are coming from — ask the student what did you do recently, what are you doing lately? And then I calibrate my knowledge with them, or with the general public.

For example, I usually say, "You probably understand planetary motion to be like this," and I'll make movements with my hands or something. I try and find common ground with whoever I'm teaching and then I get them to branch out elsewhere. That's what I mean by starting from their viewpoint. I think certainly with individuals, that's the best way to do it. In a group of course, not everybody is at exactly the same place, though statistically most of the class is at the same place. And I guess the fact that I came through the Canadian system, the Ontario system, that also helps. So that would be the main thing. Begin with the science the person knows and help them move from there.

Interviewer: Another thing you mentioned was that you're training future scientists.

Robb Mann: Yeah.

Interviewer: Do you see everybody as a future scientist? Do you try to achieve that for students who, for example, are taking a service course?

Robb Mann: Well, to a certain extent, yes. I'm teaching engineers this fall, so they're not going to become scientists. But to a certain extent, I would hope a person taking one of the courses I've taught would understand something of what it is like to be a scientist, to think like a scientist, even if they're not going to become a scientist. And I try to have good expectations for that. A lot of teaching I've done in first year was for students who are going to be scientists, chemists, biologists, some earth science, some in math or computer science. I include mathematicians — they're not exactly scientists but they're close enough. With engineers, it's a bit different but, in some sense, engineering is applied science.

When they are people in the arts disciplines — and I have done a little bit of teaching arts courses at the University of Toronto and in Waterloo — then I know they're not going to be scientists. But I try to give them a little bit of insight: "This is how scientists think about a problem." And I do that with the general public as well. I'm not trying to get them to be like me, because I know they're not going to be. But I do try to get them to see what it's like to be that kind of person, I guess. Here is where the drama comes in. When you go to see a drama or watch a movie, what makes a drama good is when you can see something from a particular character's viewpoint. I think for the people that are not going to become scientists, it's the same kind of thing. How can you understand this subject from their viewpoint to the extent you are able? Whereas for the aspiring scientists the technical skill is also very important. That matters a lot. That doesn't matter as much for people that are not going to be scientists.

Interviewer: So, it sounds like when you're teaching, you're trying to understand the people that you're teaching—

Robb Mann: Yeah.

Interviewer: —to make progress. But on the other hand, you also want them to understand you better.

Robb Mann: Well, to understand the viewpoint — I don't want to say "me", I mean a scientist in general. But to some extent, me, because … I'm not every scientist, of course. Scientists have their own personality spectrum. But there are things they value, they look at the world from a certain viewpoint and it's a very valuable viewpoint. And they all share this in common. I would hope that those who are not in the sciences, even if they don't want to adopt a scientific viewpoint, can at least perhaps understand how and why others do. I think that would help a lot instead of being fully repelled by it.

Interviewer: Definitely. A population that would be pretty close to being a scientist would be grad students. You mentioned that there's very little research done on how grad students learn.

Robb Mann: Well, there seems to be little. I could find one paper on how they learn. I found a number of papers on their attitudes to teaching.

Interviewer: Do you have any ideas on how to support people who want to study how grad students learn?

Robb Mann: I have several ideas. Someone should write a PER proposal on doing studies of how grad students learn. The study I saw was consistent with my own experience: grad students cross conceptual thresholds. I've supervised a lot of grad students now … if you count research students, if you include undergrad summer research, I've supervised on the order of 120. From this database I have (informally) found that there is a maturing process. A PhD student in the second half of their program will, if they're doing well, cross a threshold of scientific maturity where they just somehow intuitively know how to do better. Every now and then, there's one that doesn't make it, but most of them do.

This needs patience. I often find supervisors want their students to be more mature than they really are. And I think if we overemphasize that expectation, there's a high probability that a grad student will never reach the state of scientific maturity and competence they can reach. It's what I meant when I said in my talk that we cand and do lose talent if and when we don't pay attention to these things. So it needs some patience. It's a very funny push-pull combination. I'm not saying we need to be so laissez-faire that students don't do anything, because some students need a good metaphorical kick. But it's got to be a smart metaphorical kick when they need it, not just a powerful one.

So yes, I do think grad students — I've gotten away from your question — I do think that understanding how grad students learn merits study. My impression is that the physics community generally feels that by the time students have completed undergraduate work, they should know how to learn physics. But there are additional conceptual thresholds to cross — that's my conjecture. The one study I read bore it out, but I think a lot more could be done on this.

Interviewer: Actually, we have one little study waiting to be written up that we did on a flipped graduate course. We looked in depth into how the students learn. It was quite surprising.

Robb Mann: What did you find out?

Interviewer: They struggled with identifying the parts of the content that were most relevant, with time management, planning and organizing their calculations and all that. We're going to use it as a pilot for the next implementation of the course. That's the plan.

Robb Mann: I think that's really good. I mean, it's like — you could have said that about a first-year course, right?

Interviewer: Yes.

Robb Mann: That they're not good at organizing. I think it's not because the students are stupid. I think it's primarily the nature of the subject, that when they're in grad school they have new conceptual thresholds to cross. So, they're sort of back to being first year students again, in some ways.

Interviewer: Another thing you mentioned that I found very interesting was that faculty have more need for interaction. They should learn from each other, if I understand you correctly. Is that how you meant it?

Robb Mann: Well, what I meant was that, yes, I think it is helpful. That was partly the motivation for a teaching workshop we have had at Waterloo for the past 15 years. We call it a teaching retreat day where we can discuss ideas of what works, what doesn't, and how we teach. Quite frankly, I think we would benefit from more of this, but it's very hard to carve out time and resources to do this for teachers.

Our university, and probably many others, have teaching centres that encourage education in teaching. However my experience is that these centres — even at Waterloo — tend to be heavily slanted towards arts disciplines. Those methods and techniques either don't apply in the sciences, or they apply very weakly. I have advocated this over the years, and at Waterloo they have done a lot to gear things more towards the sciences … but there's still a lot of distance to cover. I think that universities could allocate more resources in that direction, particularly to hire people that specialize in training science instructors. I am guessing if we had the resources, there would be a reasonable fraction of our PhD graduates in this country that would love that as a career job.

I think that universities could allocate resources towards hiring people that specialize in training science instructors.

Interviewer: I think a combination of teaching and education development or research would be fantastic.

Robb Mann: That's exactly what I mean. We have a few people that do it. One of my former students is doing that in the math faculty of Waterloo, a mixture of the two. But still, there is a long way to go.

Interviewer: I think that perhaps just like research faculty do research, teaching faculty should do research in teaching. But that's just my personal view. So, you say for your department, you have this once-a-year teaching retreat? What do you talk about?

Robb Mann: Usually we have a theme. It's been common to invite in an external speaker. We've had Peter Knight, we've had Eric Mazur come in, we've had quite a number of different people come through. It consists of a plenary talk for everybody, and then sometimes workshops with people. One year we had a whole session about developing better labs, for example.

Interviewer: Is there something you would like to do in this retreat that you're currently not doing?

Robb Mann: It probably would be worth having a workshop about how to get PER going at Waterloo. Basically very little is done on that at Waterloo in physics. I would put that high on the list as to what's needed and what could be done. Another one would be a workshop about how grad students learn, and what are good policies for supervising grad students. We sort of assume faculty intuitively know how to do it. I think a lot of them don't intuitively know how to do it. Some of this is being looked at now at Waterloo, but it is early days.

Interviewer: One thing that I find valuable for faculty members, as an educational developer, is feedback on their teaching. So, something that we offer is observing classes, giving feedback on teaching materials and course design. Does that appeal to you?

Robb Mann: You mean to do it or to get it?

Interviewer: To get it.

Robb Mann: Yes it does. When a person comes up for tenure, at Waterloo we do have other faculty members go and sit in a class and provide feedback. But that's about the only peer-reviewed feedback for teaching that we actually have. The rest is student evaluations. And in some sense, you could argue that, well, we peer-review research, why don't we peer-review teaching? Of course, the chief problem with doing this is that it is very labour-intensive.

Interviewer: And people are not trained to do it.

Robb Mann: And people are not trained to do it, that's right. So, does it appeal to me in the sense — do I think it should be done? Yes. Do I think it should be added to faculty workload? Well, even if I did, it is hard to believe it would ever happen. But I think it's one of those things that would be useful. Again, you could imagine if universities build up a cadre of teaching faculty to do teaching research, they could provide this kind of feedback. Sometime in the nineties, I did have people come in and give me feedback in my own classes — people from the teaching centre came in and gave me feedback on how I was doing, and I took pointers from them. But they were not from scientific disciplines. So, they could and did give useful feedback in some ways but not in others.

Interviewer: When you think about your experience as a teacher, how has it changed over time? Do you think the students have changed? Do you think how you approach them, that has changed over time?

Robb Mann: I think all of it has changed. As far as the students go, in my talk I said I think the biggest change is that the best students are better than they've ever been. By this I mean that undergraduates and grad students are carrying out research at levels and capacities that I never saw happen 25 plus years ago. Their computational skills, their skills in labs, their comprehension of research is all much much better. And probably even right out of high school, in the first year, you can see these students that take off. I don't know why that is but I conjecture it's because of more flexible polices in education that encourage student creativity. However the flipside of that - maybe for the same reason - is (I think) that middle-of-the-road students are depleting in number. Or another way of saying it: the weak students are getting weaker. Why this is, I don't know. Let's just pick a semi-arbitrary baseline. A 1990 student that got between 70 and 75 as a grade in a course was a decent, solid student. They had a reasonable grasp of the subject material. They weren't going to take off like a 90+ student, but I felt they really had a good basic grasp of the material, whereas a student that got 60 or lower was weak. My impression now is that students getting grades in the low seventies have a level of comprehension and a grasp of the subject material that is just not as solid as their 1990 predecessors. Perhaps they get the grade because we're too easy on them. I don't quite know the reason, but I think they are weaker. Why is that? It may be because of the same more creative policies in high school that emphasize less the basic reading, writing, and arithmetic skills. That's possible.

Another possibility might be the growth in the number of students. And offering programs in such a way that have led students to think, "Okay, to get through this year and this program, I need five courses — but I only really care about three of them so I'll work on those and not on the two I don't care about." They're being more utilitarian. That's quite possible. I really don't know why. But when I talk to other people, anecdotally, I find people tend to agree with me. I don't know how you'd study it, but I think the students have changed in that regard, so it's sort of good news and bad news.

For me, the advent of projecting on screen, PowerPoint, is something I use for two reasons. One, my blackboard writing is lousy, whereas PowerPoint is clean. Two, I'm facing them most of the time instead of the board. Of course there is value in a class for students to see an instructor work something out in front of them and I try and do that a bit. But I also provide rather detailed PowerPoint slides. They have equations with full solutions on them and so on, and I let them have that.

Is that good for them or bad? It's a mixture. In the old days, they would have to copy: there was no choice. In these new days I like to think, ideally, they should work through the solution and see it. Some of them do, some of them don't. But in the old days, some of them took good notes and some of them didn't, right?

I think that teaching styles have changed. If you need to show videos, it is easy now. 30 (even 20) years ago you never used to be able to do that, at least not easily — you could show a movie, but it was a lot of trouble to set up. I haven't used clickers but a lot of people do. That's another new phenomenon. In first year, I tend to emphasize demonstrations more than I used to. I have more demonstrations now by a notable margin than I did when I first started teaching first year almost 20 years ago. That's another way I've changed.

Interviewer: Do you find these developments that you talked about both in domestic and international students?

Robb Mann: What do you mean by developments? Do you mean changes in the students?

Interviewer: The strong students are getting stronger; the weaker students are getting weaker.

Robb Mann: That's a good question. The international students from the Orient I would say have — statistically — better technical skills. But their reflective skills appear to be weaker. The converse tends to be true for domestic students. Their technical skills, statistically, are not as strong but they appear better able to understand why they're doing what they're doing. They want to talk about the big ideas. But as for doing the ``bricks and mortar" calculations, they're not as strong at it as most international students are. Of course, there is a range everywhere, but if I had to give a crude classification, that's how I would say they would differ. It would be great to have a survey that could test my impressions.

Interviewer: From that what you have observed, where do you think this is going?

Robb Mann: Where do I think it's going? I think that technical skills seem to be sliding and getting weaker — that's what the high school teachers told me a month ago when I was at an OAPT [Ontario Association of Physics Teachers] meeting. Quite a number of high school physics teachers felt that students coming out of elementary school were notably weaker technically, so they were trying to play catch up. But there is only so much they can do. I have a niece who, when she finished grade 12 in Toronto two years ago (and that was in a stronger Toronto high school). I said to her "I hear kids have a lot of anxiety, is that true?" She said "yes". I asked why. She said "because by about grade 12 a lot of us have figured out it's been too easy for us and we know university isn't going to be that easy. So we have anxiety that we're not well enough prepared." I think that needs to be reversed. It's easy to say, "well teachers, you're just not hard enough on them", but there is only a limited extent to which this is true. Part of the problem everybody is facing is simply the enormous growth in the body of knowledge of everything, particularly science. We want to show students all the new dazzling things in science to keep them interested — but there are so many dazzling things and there is still only 24 hours in a day. I think that's an enormous challenge. Plus you want them to learn the basic skills. I don't have a good answer for how to deal with that issue, but I think it is an issue.

Interviewer: If you had a magic wand — providing infinite time, infinite money and anything else you need — how would you like to teach students?

Robb Mann: You mean how would I like students to be taught at all levels, or how would I like to teach them in what I teach?

Interviewer: Both.

Robb Mann: Alright, let me do the first one then. The first, if I had a magic wand, would be to carve out a certain amount of time for basic skills. The argument of the old school system pre-1980 was that it was boring. The bright students got bored easily, and even the ones that weren't as good got bored. However it had a strong emphasis on basic skills. Not a lot of flexibility for creativity, but there was something valuable in learning basic skills. It trains you. It gives you a base to be creative. So I think more emphasis needs to be on that.

But I would not want to lose the creativity. So, if I had a magic wand, I'd tell the wand to find me the right balance between the two, and I would go "ping" and strike it. So that's one thing I would do.

What would I do at the university undergrad level? I like to give bonus questions, to have carrots instead of sticks. I still think physics can be a bit fearsome — the courses tend to have more sticks than carrots, perhaps because we think that we have to be tough so that they learn. I'd rather have carrot-and-stick balance. Engineering programs in Waterloo take students who got grades in the 90s, but their physics midterm average is typically 10 points below the other courses. I don't see why the physics average should be substantively lower than averages in other science or engineering or math courses. I think we need to create corrective measures to ask questions that the students are just capable of answering at that time. The problem with the `tough approach' is that it just demoralizes most people. My experience is that many students think "Okay, I have had it with physics. You know, I don't need to get a 60 in something I used to get an 85 in and also, I don't need to get a 60 in something while I'm getting 79 or 81 in in the other courses". I think that is a real phenomenon that probably reflects the need for improvement in pedagogies. So, if I waved a magic wand, I would solve that problem of demoralization that I think affects too many undergrads in physics.

Interviewer: So, I hear that you are thinking of this as a result of pedagogy, not so much the students not working hard enough?

Robb Mann: Well … it's a mixture. There are some students that really don't work and for them, honestly, my sympathy is very low. But what I generally see is a lot of students that really do work and yet they get hammered. Those are the ones I have the most sympathy for, because they really are trying, and not getting anywhere. That's the group that needs the real improvement. It could be that some students are a lot brighter than their grades give them credit for, but for certain reasons, they are not mature enough or something went wrong for them that they weren't expecting. They're not developing the way they should, and I think we need mechanisms to help them with that.

There are studies being done on how one's emotional mood and dispositions strongly affect one's ability to work. I don't want to mollycoddle students to make it really easy for them, but on the other hand, I think a tooth-and-claw Darwinism approach to learning isn't very good either. It just appeals to the cream at the top. I think there is a lot more cream that could be up there if we change things.

I'm an idealist. I really think we could do better. I've seen it with grad students, students that really felt inadequate and thought they couldn't do research. I have seen students leave programs that shouldn't leave the program. Under the right conditions, students can and do flourish.

Interviewer: Is there anything else you would like to say to your readers that I have not asked you yet?

Robb Mann: That's a good question. Having worked with the CAP Award for Teaching Excellence in High School / CEGEP Physics for a while, I have been very impressed with the hard work that high school physics teachers are doing. I would like more interaction and networking between high school teachers and university teachers. I would also like to see more emphasis on research on how grad students learn, because all the emphasis is on the first year/second year. We need more emphasis on the upper years and on grad school and need to put the resources behind it to support that. We tend to think that their learning is going to happen automatically and osmotically, but it doesn't. It happens, but weakly, poorly, and slowly, for too many students. I think that PER research has helped first year teaching a lot. Let's do that same kind of research for upper levels too.

Interviewer: That's a good way to end. Thank you, Robb.

Robb Mann: Thank you.

High School / CEGEP Physics Teaching Awards / *Prix ACP en enseignement de la physique au secondaire et au collégial*

2019 Winners / Récipiendaires 2019

British Columbia and Yukon / Colombie-Britannique et Yukon

Louay El Halabi
Semiahmoo Secondary School
Surrey, BC

Louay's innovative teaching methods, including extensive opportunities for hands-on labs and demonstrations, allow him to bring passion and fun into physics in a way that takes the "abstract and scary" part out of physics, engages students, and allows them to take risks. Many of his students have taken the annual CAP exam and made it to the finals and national team. Louay also coaches senior students for two provincial science competitions: UBC Physics Olympics and the Kwantlen Science Challenge. Over the past decade, Semiahmoo physics students have displayed their talents with consistently placing in the top ten with first place finishes six times.

Louay has also served as a board member for the British Columbia Association of Physics Teachers for the past six years where he has enjoyed working with educators who share his passion for physics. Louay continues to contribute to the field of Physics Education through his development and implementation of numerous workshops and professional development opportunities offered to his colleagues throughout the province.

Louay has been recognized for his leadership and excellence in teaching in his home community, where he was nominated for the Surrey Community Leader Award for Teacher of the Year in November 2018 and received Honourable Mention.

Les méthodes d'enseignement novatrices de Louay, dont de grandes occasions d'ateliers pratiques et de démonstrations, lui permettent d'insuffler la passion et le plaisir en physique d'une manière qui dégage cette discipline de son côté abstrait et intimidant, engage les étudiants et leur permet de prendre des risques. Nombre de ses étudiants se sont présentés à l'examen annuel de l'ACP, se sont rendus en finale et ont joint l'équipe nationale. Louay est aussi l'entraîneur d'étudiants de cycles supérieurs pour deux concours provinciaux en science : UBC Physics Olympics et Kwantlen Science Challenge. Au cours des dix dernières années, les étudiants en physique de Semiahmoo ont fait montre de leurs talents en atteignant chaque fois l'un des dix premiers rangs, dont six premières places. Louay est sans cesse à la recherche de façons novatrices de connecter la physique au « monde » de ses étudiants et des autres membres de son entourage.

Louay a aussi siégé comme membre du conseil de la British Columbia Association of Physics Teachers ces six dernières années, où il a aimé travailler avec des enseignants qui partagent sa passion pour la physique. Il contribue sans cesse au domaine de l'enseignement de la physique en élaborant et en instaurant divers ateliers et activités de perfectionnement professionnel offertes à ses collègues de partout en province.

Louay a été reconnu pour son leadership et son excellence en enseignement au sein de sa collectivité d'origine, Surrey, qui a proposé sa candidature au prix de professeur leader de l'année dans sa collectivité en novembre 2018. Il s'est mérité une mention honorable.

Prairies and Northwest Territoires / Prairies et Territoires du Nord-ouest

Brad Langdale
Spruce Grove Composite High School
Spruce Grove, AB

Brad Langdale has spent the past fourteen years making the study of physics more accessible to students as well as teachers in the Province of Alberta. In his classroom, students are encouraged to get up out of their seats and "do physics" by building, testing and analyzing everything from table-top trebuchets to water-rockets to floating buckets. Students discover physics isn't a subject to be afraid of or, even worse, bored of, but a vivid and colourful story of the world around us, like a fairy tale but with more numbers and units.

His zest for teaching overflows to the larger educational community, where he is a frequent speaker at provincial Teachers' Conventions and Specialist Conferences, creates educational YouTube videos on a number of topics, and works with teachers on formative and summative assessment in Alberta. He mentors new teachers to the profession and endeavors for others to catch the same passion he himself has for his subject area. As one student put it: "Being in Mr. Langdale's class for all three years of my high school career has been a true gift. As a student that wishes to pursue science in post-secondary Mr. Langdale has helped me build confidence in myself and my academic abilities. Mr. Langdale is the kind of teacher that has true faith in his students and he gives his students the encouragement they need to reach their full potential. Without all of Mr. Langdale's help over the past three years I don't know how I would be able to be prepared to go onto post-secondary with confidence and excitement."

Brad Langdale a passé les 14 dernières années à rendre l'étude de la physique plus accessible aux étudiants et aux professeurs de la province d'Alberta. Dans sa classe, il incite les étudiants à quitter leurs bancs et à « faire de la physique » en construisant, testant et analysant tout, des trébuchets de pupitres et des fusées à eau jusqu'aux seaux flottants. Les étudiants découvrent que la physique n'est pas un sujet de crainte ou, pire, d'ennui, mais bien la description pleine de vie et captivante du monde qui nous entoure, tel un conte de fées mais contenant plus de chiffres et d'unités.

Son enthousiasme pour l'enseignement déborde dans l'ensemble de la collectivité de l'enseignement et il entretient souvent les professeurs spécialisés de la province lors de congrès et de conférences, il crée sur YouTube des vidéos éducatives traitant de divers sujets et il travaille avec des professeurs à l'évaluation formative et sommative en Alberta. Il joue le rôle de mentor auprès des nouveaux professeurs de la profession et cherche à inculquer aux autres sa propre passion pour sa matière. Comme le disait un étudiant : « Ce fut un privilège d'être dans la classe de M. Langdale pendant mes trois années au niveau secondaire. Il m'a aidé, à titre d'étudiant désireux de poursuivre en sciences au niveau postsecondaire, à acquérir de la confiance en moi et en mes capacités scolaires. C'est le type de professeur qui a vraiment foi en ses étudiants et il leur prodigue l'encouragement requis pour atteindre leur plein potentiel. Sans l'aide de M. Langdale au cours des trois dernières années, je ne sais comment je serais prêt à entrer au niveau postsecondaire avec confiance et passion. »

Ontario

Sarah Torrie
Victoria Park Collegiate Institute
Toronto, ON

Sarah Torrie is the kind of physics teacher that everyone should have. She inspires her students at Victoria Park CI to explore the joys and challenges of physics during her classes. Drop into her classroom and you will see a room full of students actively and enthusiastically engaged in learning. This usually involves lots of discussion and lots of hands-on problem solving. They are not memorizing science facts; they are learning to act like scientists and figure things out. Her room is always busy at lunch and after school. This is when Sarah helps her students prepare for the many out-of-school projects and contests that they compete in. The biggest draw is the Science Olympics. Sarah fielded her first team in 2007 and it has grown each year! It now includes several other teachers and about a hundred students competing in many teams at several different locations. The older students help train the younger ones and each year they bring back numerous awards and have lots of fun.

The senior students get involved in other activities that are a little less raucous but just as engaging. Her students create award winning physics photos and they prepare for and write several different physics contests each year. They go on field trips to different universities and research centers around Ontario and one year, a group went to the CLS synchrotron in Saskatoon to run an experiment that the students had designed. Sarah also runs a Physics Club where students present topics outside the curriculum, screen physics movies and eat lots of pizza. Sarah has created an environment where science rules and physics is cool. She is nurturing and inspiring the young scientists that the world needs.

Sarah Torrie est le type de professeur de physique que tous devraient avoir. Au Victoria Park CI, elle incite ses étudiants à explorer les joies et les difficultés de la physique. Passez dans sa classe et vous trouverez une salle remplie d'étudiants embarqués dans l'apprentissage de façon active et enthousiaste. Cela suppose normalement beaucoup de discussion ainsi que de solutions pratiques de problèmes. On ne s'applique pas à mémoriser des faits scientifiques, mais à apprendre à agir en scientifique et à comprendre les choses. La salle de classe de Mme Torrie est toujours occupée à l'heure du déjeuner et après les cours. C'est à ces moments-là que Sarah aide ses étudiants à se préparer aux nombreux projets parascolaires et concours auxquels ils prennent part, dont les olympiades scientifiques sont l'occasion par excellence. En 2007, elle y a inscrit sa première équipe dont les rangs grossissent tous *les ans! On y retrouve maintenant bien d'autres professeurs et une centaine d'étudiants concurrents dans de nombreuses équipes de différents endroits. Les étudiants plus âgés aident à former les plus jeunes et, tous les ans, ils remportent de nombreux prix et ont beaucoup de plaisir.*

Les étudiants des dernières années prennent part à d'autres activités un peu moins bruyantes mais tout aussi engageantes. Les étudiants de Sarah créent des photos primées en physique et se préparent à subir plusieurs concours différents en physique tous les ans. Ils se rendent dans différents centres de recherche et universités en Ontario et, une année, un groupe est allé à Saskatoon réaliser une expérience conçue par eux au Centre canadien de rayonnement synchrotron. Sarah dirige aussi un club de physique qui amène les étudiants à exposer des sujets débordant le programme, à visionner des films de physique et à manger des pizzas en abondance. Sarah a créé un milieu baigné par la science, où la physique est « cool ». Elle nourrit et inspire les jeunes scientifiques dont le monde a besoin.

Quebec and Nunavut / Québec et Nunavut

Andrea Venditti
Rosemere High School
Rosemere, QC

Andrea Venditti takes pride making physics accessible to all students. Andrea facilitates physic-based experiences within her small community, introducing science within other curricular or extra curricular venues that children and young adults are already engaged in — "All students can learn — I believe in teaching the WHY to bring meaning/purpose to their learning process."

Within her classrooms, she leads students through exploring STEM using everyday items, like toys, to demonstrate concepts and encourage dialogue amongst the student teams. The most meaningful outcomes of these lessons are the engagement felt by the students and the seriousness of the discussions that occur.

In recognition of the diverse learning needs of a classroom, her commitment to learning spans to outside the classroom. Andrea ensures her materials are available in all medias, for her students or others within the school to access and absorb. As a result of mentoring relationships that she has built over the years, and her role within the community, many former students volunteer their time to return as guest speakers within her classrooms.

Andrea is an educator with over 15 years of experience. She received the 2011 AMGEN award for Science Teaching Excellence (Quebec) and the 2015 Prime Minister's Awards for Teaching Excellence – Certificate of Achievement.

Andrea Venditti (école secondaire Rosemère) s'enorgueillit de rendre la physique accessible à tous les étudiants. Andrea favorise les expériences fondées sur la physique dans sa petite communauté, incluant les sciences avec d'autres sujets scolaires ou parascolaires que les enfants et les jeunes adultes étudient déjà — « Tous les étudiants peuvent apprendre — Je crois qu'enseigner le POURQUOI donne un sens/motive leur processus d'apprentissage. »

Dans ses salles de classe, elle guide les étudiants dans l'exploration des STIM à l'aide d'objets courants, comme des jouets, pour démontrer les concepts et inciter les équipes d'étudiants à dialoguer. Les fruits les plus significatifs de ces cours sont l'engagement des étudiants et le sérieux des discussions qui s'y déroulent.

En reconnaissance des divers besoins d'apprentissage d'une classe, l'engagement d'Andrea à l'égard de l'apprentissage déborde la salle de classe. Elle veille à ce que ses matières soient accessibles dans tous les médias afin que ses étudiants et les autres membres de l'école y aient accès et puisent les assimiler. En raison du rôle de mentor qu'elle joue de plus en plus au fil des ans, ainsi qu'au sein de la collectivité, nombre d'anciens étudiants offrent de revenir bénévolement comme conférenciers invités dans ses classes.

Andrea est une enseignante de plus de 15 années d'expérience qui a reçu le Prix AMGEN 2011 d'excellence en enseignement des sciences (Québec) et le Prix 2015 d'excellence en enseignement du Premier Ministre – Certificat de mérite.

Sarah Torrie was selected to receive the 2019 Perimeter Institute Physics Education Scholarship which includes travel support (provided by Perimeter Institute, the CAP, and the Institute for Particle Physics) to attend a special three-week international workshop for high school teachers hosted by CERN, the world's premier particle physics laboratory located in Geneva and an opportunity to attend a future Perimeter's Einstein Plus camp. Sarah Torrie's report on the 2019 workshop is included in this issue of PiC. The remaining winners were offered the opportunity to participate in a one-week research experience at TRIUMF, SNOLAB or CLS.

Sarah Torrie s'est vu décerner la bourse 2019 de l'Institut Perimètre en enseignement de la physique, comprenant une aide aux déplacements (fournie par l'Institut Perimètre, l'ACP et l'Institut de physique de particules) pour assister à un atelier international spécial de trois semaines pour enseignants au secondaire donné par le CERN, premier laboratoire du monde en physique de particules situé à Genève, et permettant de prendre part au Programme « Einstein Plus » au futur. La rapport de Sarah Torrie sur l'atelier est inclus dans cette numéro de la PaC. Les autres lauréats se sont vu offrir l'occasion de participer à une expérience de recherche à TRIUMF, SNOLAB ou au CCRS.

Summer at CERN!

by Joe Muise, Christopher Sarkonak, and Sarah Torrie

Group photo of the International High School Teacher Programme 2019

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Summary

The twenty-first edition of this annual two-week program in July saw 45 high school teachers from 33 countries around the world participate in a series of lectures, on-site visits, exhibitions, and hands-on workshops that were designed to invigorate and introduce these teachers and, through them, their future students to cutting-edge particle physics.

The summer of 2019 will be one to remember! Canadians Christopher Sarkonak, of Manitoba, and Sarah Torrie, of Ontario, had the incredible opportunity to participate at the International High School Teacher (HST) Programme 2019 at CERN in Geneva, Switzerland. The twenty-first edition of this annual two-week program in July saw 45 high school teachers from 33 countries around the world participate in a series of lectures, on-site visits, exhibitions, and hands-on workshops that were designed to invigorate and introduce these teachers and, through them, their future students to cutting-edge particle physics. Fellow Canadian Joe Muise, of British Columbia, was selected this year to participate in the International Teacher Weeks (ITW) 2019 in August. The three Canadian participants in this year's programmes at CERN are just the fifteenth, sixteenth, and seventeenth Canadian educators to have ever been selected to attend with Christopher and Joe being the first two ever selected through direct application to CERN.

Sarah had the tremendous honour of being awarded the Canadian Association of Physicists (CAP) Award for Excellence in Teaching High School/CEGEP Physics for Ontario. Nominated teachers submitted a nominator form, five letters of support, a curriculum vitae and other supporting documents. Successful candidates were then given the opportunity to apply for the 2019 Perimeter Institute Physics Education Scholarship via a statement of intent in which candidates explained why they would like to be considered and how the activities would enhance their teaching. Through this process Sarah was selected to participate in HST 2019 and the Perimeter Institute's Einstein Plus workshop.

Christopher and Joe both applied directly to CERN for their positions in these programmes and that meant answering a series of four short essay questions and producing a one-minute video, where you have to explain why you are the ideal candidate to participate in CERN's international teacher programmes. These essay questions include why you want to attend the programme, how you will disseminate the knowledge acquired, an opportunity of where your students could investigate particle physics concepts, and what you

Jeff Wiener discusses the "most feared question at CERN"

3D printed quarks

might name a new particle detector in the LHC. Applicants are encouraged to show originality in their videos, and leave an impression with the selection committee regarding their appreciation for modern physics and their teaching style.

One of the most amazing things that strikes almost anyone that goes to CERN for a program like this is the level of collaboration that goes on here. There are physicists, both of the applied and theoretical varieties, engineers, students, and so many others that all work together to try to achieve a deeper understanding of the universe around us and answer the big questions: what is the universe made of? How did it begin? What are the laws that govern the universe? These questions unify the people here regardless of where they come from, even countries that are typically at war with each other, as they seek answers that are bigger than any of us.

At the beginning of July, both Christopher and Sarah set out from Brandon, Manitoba and Toronto, Ontario to make Geneva, Switzerland their home for the next two weeks. The program kicked off on the Sunday with a welcome reception, a CERN treasure hunt, and the first introductory sessions. On Monday there were the first sessions on particle physics and a tour of the Synchrocyclotron, the first particle accelerator to be built at CERN, starting operation in 1957. Most of Tuesday and Wednesday afternoon were then used to continue building an understanding of the operation of particle accelerators and how to deliver that knowledge back to high school students.

Wednesday morning started off with a presentation by the host, Jeff Wiener, on elementary particle physics in early physics education. Here he talked about his research where he is looking at the best practices for teaching particle physics, and quite often science in general, to avoid student misconceptions. Then came the opportunity to see the S'Cool Lab where the team gave a presentation on budget-friendly, interactive labs and demos for the classroom. S'Cool Lab develops resources for classroom teachers to build, and most often 3D print, lab equipment to be used in the classroom. Participants we also given the opportunity to tour the CERN exhibit halls during this time.

Sarah Torrie building a proton in CERN's S'Cool Lab

Thursday and Friday of the first week then focused on particle detectors, including the opportunity to build a particle detector, a cloud chamber, in the S'Cool Lab, and the medical applications of the work done at CERN. Some people already know that CERN is the birthplace of the internet, where the touchscreen was first developed, and, of course, where the Higgs Boson was discovered just a few years ago, but most people don't realize the contributions that CERN has made to medicine. In 1977 two physicists from CERN, David Townsend and Alan Jeavons, built and used a PET (positron emission tomography) system in Geneva Hospital. Today, the MediPix, a particle track detector originally developed for use in high energy physics, is now being used to create the first 3D colour x-ray images of a human. There is ongoing research into hadron therapy in cancer treatments and how this will allow the maximum radiation dose to be targeted on the tumour with little damage to surrounding tissue. This technology has been known since 1946, but it is only recently that cancer patients have started to receive treatments in this way. However, there have since been even better methods of cancer treatment discovered with carbon-ion therapy and anti-positron therapy.

Friday afternoon was one of the highlights of the program with the tour of the CMS Experiment! This is one of the two major experiments at CERN, the other being the ATLAS Experiment, as 4300 particle physicists, engineers, technicians, students, and support staff from 42 countries work to make new discoveries about the universe. The CMS detector is 21 metres long, has a diameter of 15 metres, weighs 14 000 tonnes, and produces a magnetic field 100 000 times stronger than the Earth! The sense of awe and wonder that one is immediately struck with upon entering the CMS cavern is something that cannot be put into words.


One of the teacher groups in the CMS Cavern.


Teachers exploring The Perimeter Institute's resources

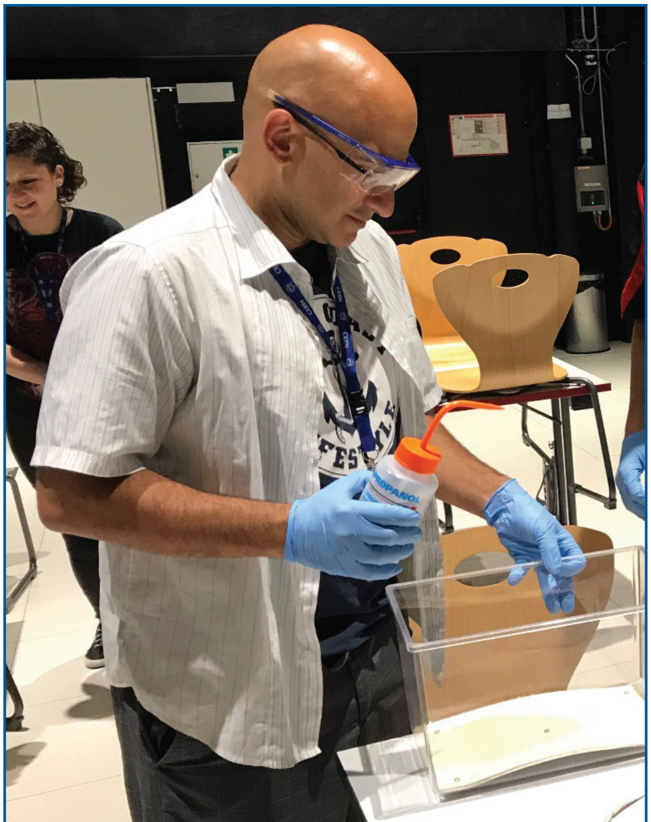
The second week started with learning about the data processing and analysis that goes on at CERN as they try to organize information from the 40 million particle collisions per second that occur when the LHC is fully up and running. Tuesday featured an incredible day of workshops from the Perimeter Institute. Dave Fish and Laura Pankratz walked the teachers through resources on climate change, introductory quantum physics, relativity, the principles of dark matter, and the basic processes of science that are offered through the Perimeter Institute's outreach program and are ready to be implemented in any high school physics classroom.

Wednesday's focus was on antimatter research being done at CERN with a fantastic lecture from Michael Doser and a tour of the Antimatter Factory. This was definitely one of the most fascinating lectures and tours of the program! The lecture portion of the program on Thursday with talks on the engineering challenges at CERN and the possibility of future accelerators. Can you imagine that they might next build an accelerator 100 km in circumference?!

Joe's experiences at CERN's International Teacher Weeks Programme was very similar to Chris' and Sarah's with the High School Teachers Programme, with 47 teachers from 38 countries taking part. Instead of a session with representatives of the Perimeter Institute, the International Teacher Weeks Programme had the opportunity to learn from Neil Atkin, founder of Rubbish Science of the UK. Neil brought incredible enthusiasm and challenged the teachers to find interesting ways to engage all students. The group were fortunate to be able to visit a second detector, in addition to a tour of CMS. The group spent an afternoon at the ALICE detector learning about how it used to study quark-gluon plasma. The two programmes are for the most part parallel offerings, with small differences based on tour and presenter availability.

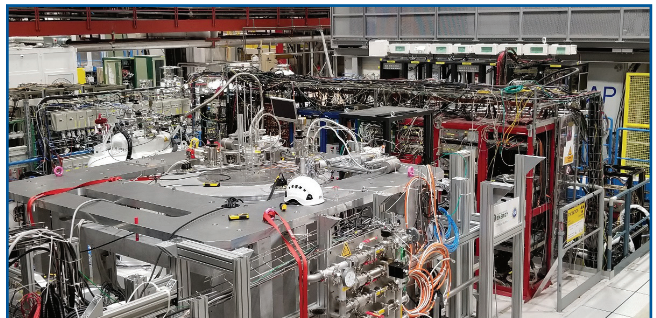
Throughout the programs there was also a tremendous opportunity to talk and collaborate with colleagues from around the world and this resulted in the final reports and presentations on Friday. With each topic presented throughout the program a different focus group was assigned to put together a report and presentation on how to bring that information back to the classroom. One of the most amazing parts of these programs was being able to speak and collaborate with colleagues from around the world, whose passion for physics is so clearly visible. Sharing stories about classrooms, ideas, and resources has had a tremendous impact on what any physics classroom will look like from this point forward for those that participate in this program.

Sarah Torrie, Dave Fish of the Perimeter Institute, Christopher Sarkonak, and Laura Pankratz of the Perimeter Institute.

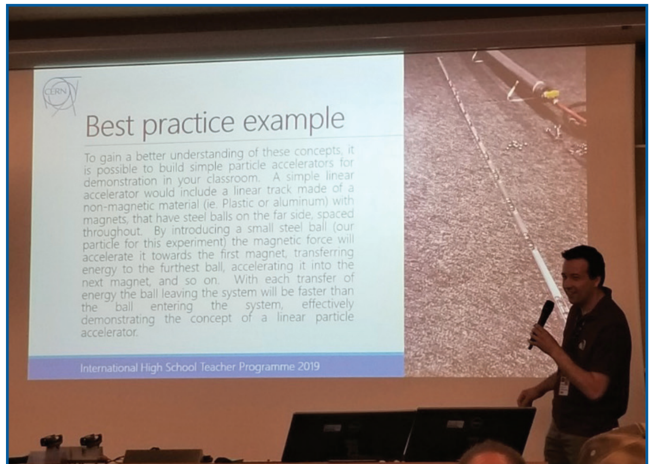


Joe Muise works to build a cloud chamber during a session in CERN's S'Cool Lab.

If you are interested in nominating a teacher for the CAP Award for Excellence in Teaching High School/CEGEP Physics you can visit https://www.cap.ca/programs/medals-and-awards/



Antimatter Factory



Christopher Sarkonak presenting a particle accelerator best practice example.

medals-teaching/hscta/nomination-procedures-hc/. Applications are due February 28th 2020.

Teachers interested in attending CERN's international teacher programmes also have the option of applying directly through CERN's online platform. Details can be found at: https://teacher-programmes.web.cern.ch/itp/international-teacher-programmes. Applications close on January 13, 2019.

Educators can also visit https://scool.web.cern.ch/classroom-activities to learn more about the activities developed by CERN's S'Cool Lab.

The Perimeter Institute's resources can be found at https://www.perimeterinstitute.ca/outreach

Report on Canada's Participation in the 50th International Physics Olympiad in Tel Aviv, Israel

by Andrzej Kotlicki and Lior Silberman

The 50th International Physics Olympiad (IPhO) took place July 7th to 15th, 2019, in Tel Aviv, Israel. Again due to lack of funding we were unable to organize a Canadian Olympiad Finals. Instead, the five students scoring the highest in the Canadian Association of Physicists (CAP) High School exam were invited to represent Canada in the IPhO. This year the CAP exam attracted 762 students from 161 schools.

The generosity of our sponsors, the Trottier Family Foundation, the Toronto Olympiad School and the UBC Physics and Astronomy Department allowed us to organize the 4-day training camp for the team in Vancouver (this should be compared to training times of 6 weeks up to 2 years in other countries) and pay the team's participation fees and travel expenses.

The members of the Canadian team this year were:

Zhening Li (Sir John A. Macdonald Secondary School, Waterloo ON), student of David Vrolyk

Yuheng (Jack) Xu (Unionville High School, Markham ON), student of Elaine Howard

Roger Li (Marc Garneau Collegiate Institute, Toronto ON), student of Henri Van Bemmel

Eric Shen (University of Toronto Schools, Toronto ON), student of Marisca Vanderkamp

Isaac Liao (Earl Haig Secondary School, Toronto ON), student of Adam Morin

Team leaders were Dr. Andrzej Kotlicki (UBC), Director for the Canadian Physics Olympiad Program, and Dr. Lior Silberman, associate professor of mathematics at UBC and past IPhO contestant (1994 Israeli team). Additionally Dr. Yadong Jiang from the Olympiads school in Toronto participated as an observer.

This year's IPhO was hosted by the Ministry of Education of Israel and Tel Aviv University.

This was the best academically prepared and organized IPhO in my (AK) memory. This success is, in large part, due to the leadership and input of Dr. Eli Raz, long time Israeli leader, who was not only chaired the organizing committee but also contributed two theoretical and one experimental problem and participated in preparation of all five problems. The IPhO International Board (consisting of all the team leaders) gave him a standing ovation at the end of the last meeting and the Israeli Government awarded him a special certificate of appreciation.

The opening ceremony took place at the main auditorium of Tel Aviv University. There were the usual (but unusually short and few) speeches by the organizers and the President of IPhO, interspersed by great music and dance performances by various high school aged, but very professional, dance troops and bands. The teams paraded across the stage, while the images of their countries were flashing on the big screen.

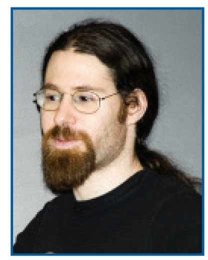
Seventy-eight countries participated this year (nine less than last year), with Kosovo as the only new country.

All the problems (three theoretical, two experimental) were very well prepared and thus accepted by the International Board (the team leaders) with very minor corrections. All of them included parts requiring creative thinking, going beyond knowledge and technical problem-solving abilities.

The first problem concerned kinematical analysis of a falling Slinky. Students were shown a drawing of consecutive phases of the fall of an initially stretched spring and had to calculate the time of collapse and the generated heat, among other quantities.

The second problem required students to estimate different operating parameters of a typical microwave oven's klystron and to describe quantitatively the process of microwave absorption in pure water and in salt water.

The third problem required calculating the efficiency and other parameters of thermo-acoustic engine.



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and

Lior Silberman, <lior@math.ubc.ca>,

Department of Mathematics University of British Columbia, 1984 Mathematics Road, Vancouver, BC V6T 1Z1

The first experimental problem asked students to measure the refractive indices of the materials of a disc and a prism as well as the spacing of a diffraction grating. However, the contestants had to discover methods which are more accurate than the most obvious ones.

The second problem called for accurate measurements of the conductivity and thermal conductivity of three metals. The electrical conductivity was determined by measuring the time of fall of magnets in tubes made of these metals. The thermal conductivity was determined by measuring the temperature gradient along a rod heated at one end, with the other end kept in contact with a cold reservoir. The students had to take into account the corrections due to heat losses along the rod and the fact that the heat flow along the rod is not exactly in its steady state. Finally the students were expected to use the measured conductivities to calculate the constant in the Wiedemann-Franz Law (the “Lorenz number”).

When additional information needed to solve the problems was not covered by the syllabus of the IPhO, it was very well presented and clearly explained.

The problems were difficult, with a best overall score of 87% and only 41 students out of 364 scoring more than 50%! 251 students were awarded medals or honorary mentions.

Our students did very well considering their very limited preparation:

Zhening Li, Isaac Liao and Jack Xu received Silver medals, Roger Li received Bronze and Eric Shen received the certificate of participation.

After each exam the students had a chance to meet with the leaders at dinner (Fig. 1), which allowed us to learn quickly about their progress and excitement.

The organization of the whole event was perfect. For the first time in the history of the Olympiad, copies of the students’ papers were delivered to the leaders on time. There was a lot of time (35 minutes per team per problem) for moderation – more than ever.

There was a great cultural and social program. Students had a chance to visit Jerusalem with its historical and holy places of three major religions, enjoyed Bedouin hospitality in Kfar Ha’Nokdim, checked their buoyancy in the Dead Sea, visited Old Acre, Haifa, and the Golan Heights, and rafted on the Jordan river. They even had a safe cracking competition won by British team. Leaders and observers also had a chance to visit some of the places mentioned but we missed the Dead Sea. The closing ceremony was held in the Charles Bronfman Auditorium (Concert Hall) in Tel Aviv with amazing music and dance performances and some (again short) speeches. Medals, honorary mentions and special prizes were awarded to the students (Fig. 2).

The Lithuanian Minister of Education announced that the 51st IPhO will be hosted in Vilnius, Lithuania from July 18th to July 26th, 2020.

The closing ceremony was followed by the farewell party with some teams’ talent shows and a lot of dancing.

Fig. 1 Our students having dinner in Jerusalem following the theoretical exam. From the left: Roger Li, Eric Shen, Isaac Liao, Zhening Li and Yuheng (Jack) Xu.

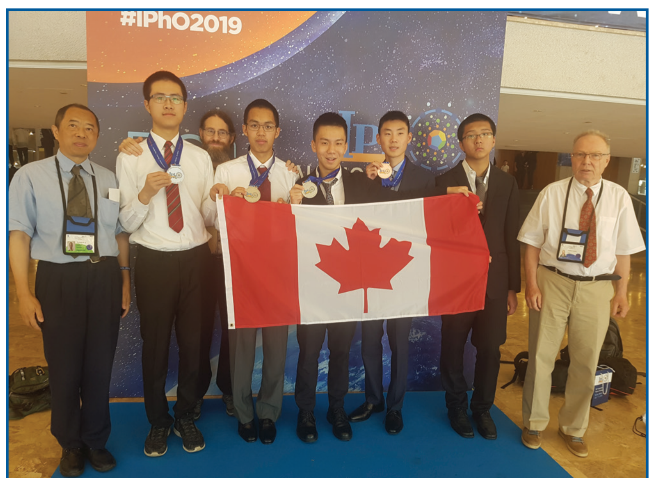

Fig. 2 Our team after the closing ceremony. From left: Dr. Yadong Jiang, Isaac Liao, Dr. Lior Silberman, Zhening Li, Yuheng (Jack) Xu, Eric Shen, Roger Li and Dr. Andrzej Kotlicki.

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Books Received / *Livres Reçus*

The following titles are a sampling of books that have recently been received for review. Readers are invited to write reviews, in English or French, of books of interest to them. Unless otherwise indicated, all prices are in Canadian dollars.

Lists of all books available for review, books out for review and book reviews published since 2011 are available on-line at www.cap.ca (Publications).

In addition to books listed here, readers are invited to consider writing reviews of recent publications, or comparative reviews on books in topics of interest to the physics community. This could include for example, books used for teaching and learning physics, or technical references aimed at professional researchers.

Les titres suivants sont une sélection des livres reçus récemment aux fins de critique. Nous invitons nos lecteurs à nous soumettre une critique en anglais ou en français, sur les sujets de leur choix. Sauf indication contraire, tous les prix sont en dollars canadiens.

Les listes de tous les livres disponibles pour critique, ceux en voie de révision, ainsi que des critiques publiées depuis 2011 sont disponibles sur : www.cap.ca (Publications).

En plus des titres mentionnés ci-dessous, les lecteurs sont invités à soumettre des revues sur des ouvrages récents, ou des revues thématiques comparées sur des sujets particuliers. Celles-ci pourraient par exemple porter sur des ouvrages de nature pédagogique, ou des textes de référence destinés à des professionnels.

GENERAL LEVEL

Advanced Series on Directions in High Energy Physics: Volume 30 [v], ATLAS Collaboration at CERN, World Scientific, 2020; pp. 372; ISBN: 978-981-3271-79-1; Price: 58.00.

Symmetry [v], Hermann Weyl, Princeton University Press, 2016; pp. 176; ISBN: 9780691173252; Price: 20.74.

UNDERGRADUATE LEVEL

An Introduction to Radio Astronomy (Fourth Edition), Bernard F. Burke, Francis Graham-Smith, Peter N. Wilkinson , Cambridge University Press, 2019; pp. 540; ISBN: 978-1107189416; Price: 91.95.

Classical Field Theory, Horaţiu Năstase, Cambridge University Press, 2019; pp. 480; ISBN: 978-1108477017; Price: 91.95.

Do We Really Understand Quantum Mechanics? 2nd Edition, Franck Laloë, Cambridge University Press, 2019; pp. 546; ISBN: 978-1108477000; Price: 68.95.

Experimental Methods for Science and Engineering Students: An Introduction to the Analysis and Presentation of Data (Second Edition), Les Kirkup, Cambridge University Press, 2019; pp. 236; ISBN: 978-1108418461; Price: 56.95.

Introduction to Modern Magnetohydrodynamics, Sébastien Galtier, Cambridge University Press, 2016; pp. 288; ISBN: 978-1107158658; Price: 85.95.

Meteoroids: Sources of Meteors on Earth and Beyond, Galina O. Ryabova, David J. Asher, Margaret D. Campbell-Brown, Cambridge University Press, 2019; pp. 318; ISBN: 978-1108426718; Price: 160.93.

QUANTUM CONCEPTS IN THE SOCIAL, ECOLOGICAL AND BIOLOGICAL SCIENCES, Fabio Bagarello, Cambridge University Press, 2019; pp. 310; ISBN: 978-1108492126; Price: 85.43.

SENIOR LEVEL

A DYNAMICAL SYSTEMS THEORY OF THERMODYNAMICS [V], Wassim M. Haddad, Princeton University Press, 2019; pp. 744; ISBN: 9780691190143; Price: 128.99.

ASYMPTOTIC DIFFRACTION THEORY AND NUCLEAR SCATTERING, Roy J. Glauber, Per Osland , Cambridge University Press, 2019; pp. 206; ISBN: 978-1107104112; Price: 160.95.

CLASSICAL KINETIC THEORY OF WEAKLY TURBULENT NONLINEAR PLASMA PROCESSES, Peter H. Yoon , Cambridge University Press, 2019; pp. 362; ISBN: 978-1107172005; Price: 177.95.

ELECTROWEAK PHYSICS AT THE LHC, Matthias U. Mozer, Springer, 2016; pp. 115; ISBN: 978-3319303802; Price: 111.39.

MASS DIMENSION ONE FERMIONS, Dharam Ahluwalia, Cambridge University Press, 2019; pp. 132; ISBN: 978-1107094093; Price: 160.95.

MHD WAVES IN THE SOLAR ATMOSPHERE, Bernard Roberts, Cambridge University Press, 2019; pp. 524; ISBN: 978-1108427661; Price: 200.95.

MODERN OPHTHALMIC OPTICS, José Alonso, José A. Gómez-Pedrero, Juan A. Quiroga, Cambridge University Press, 2019; pp. 562; ISBN: 978-1107110748; Price: 95.88.

MORE THINGS IN THE HEAVENS: HOW INFRARED ASTRONOMY IS EXPANDING OUR VIEW OF THE UNIVERSE [V], Michael Werner and Peter Eisenhardt, Princeton University Press, 2019; pp. 304; ISBN: 9780691175546; Price: 46.13.

NON-INERTIAL FRAMES AND DIRAC OBSERVABLES IN RELATIVITY, Luca Lusanna, Cambridge University Press, 2019; pp. 336; ISBN: 978-1108480826; Price: 175.63.

OPTICAL EFFECTS IN SOLIDS, David B. Tanner, Cambridge University Press, 2019; pp. 410; ISBN: 978-1107160149; Price: 100.03.

PHYSICS PROBLEMS FOR ASPIRING PHYSICAL SCIENTISTS AND ENGINEERS: WITH HINTS AND FULL SOLUTIONS, Ken Riley, Cambridge University Press, 2019; pp. 346; ISBN: 978-1108701303; Price: 37.95.

QUANTUM WORLDS: PERSPECTIVES ON THE ONTOLOGY OF QUANTUM MECHANICS, Editors: Olimpia Lombardi, Sebastian Fortin, Cristian López, Federico Holik, Cambridge University Press, 2019; pp. 408; ISBN: 978-1108473477; Price: 177.95.

RELATIVISTIC FLUID DYNAMICS IN AND OUT OF EQUILIBRIUM: AND APPLICATIONS TO RELATIVISTIC NUCLEAR COLLISIONS, Paul Romatschke, Ulrike Romatschke, Cambridge University Press, 2019; pp. 204; ISBN:; Price: 160.95.

SOLVING FERMI'S PARADOX, Duncan H. Forgan, Cambridge University Press, 2019; pp. 426; ISBN: 978-1107163652; Price: 177.95.

SPACE-TIME, YANG-MILLS GRAVITY, AND DYNAMICS OF COSMIC EXPANSION [V], Jong-Ping Hsu and Leonardo Hsu, World Scientific, 2019; pp. 300; ISBN: 978-981-120-043-4; Price: 138.58.

WAVEFRONT SHAPING FOR BIOMEDICAL IMAGING, Joel Kubby, Sylvain Gigan, Meng Cui, Cambridge University Press, 2019; pp. 468; ISBN: 978-1107124127; Price: 200.95.

BOOK REVIEWS / *CRITIQUES DE LIVRES*

A STUDENT MANUAL FOR "A FIRST COURSE IN GENERAL RELATIVITY", by Robert B. Scott, Cambridge University Press, 2016, pp. 310, ISBN 9781139795449, price 29.95.

This is an excellent companion volume for anyone contemplating teaching a first course in General Relativity. Ideally the course manual should be the corresponding book by Bernard Schutz called "A first course in general relativity" also published by Cambridge University Press. The book by Schutz is an excellent first course in General Relativity, which presents the subject by first explaining in detail special relativity in the first 4 chapters followed by 8 chapters which gently lead the student into the complexity of General Relativity where it starts with the definition of curved manifolds followed by physics in curved spacetime, to Einstein's equations and then followed by applications to gravitational radiation, spherical solutions for stars, black holes and ending with a short introduction to cosmology.

Scott's Student Manual follows Schutz' book exactly, chapter by chapter, indeed the chapter headings in the two books are identical. There are according to Scott, 388 exercises in Schutz's book. Scott suggests that the interested learner do each and every one of them. In Scott's book, he does give the solution of most of the exercises of Schutz and he gives many more solved supplementary exercises, in addition to some exercises for which the solutions are not provided. Scott uses the notation eq.(n.m) to denote the exercises/equations in Schutz's book while the notation eq.(n.m) to denote exercises/equations in the Student Manual. The solutions are always placed in a grey background so that it is clear when one is reading a solution as opposed to the exercises themselves. Scott goes through very much detail in explaining the solution, hence some might find the solutions a bit laborious, however, they are very pedagogic. Scott does this expressly, his aim being "to be complete, to spell it all out". Scott also has provided an accompanying Maple worksheet, which is available for download from the Cambridge University Press web-site.

The first 4 chapters of Scott's book are on special relativity. The subject is presented to the reader through many exercises that are based on very fundamental aspects, starting with exercises on the basic definition of natural units, then the principles of special relativity: that no observer can measure the absolute velocity of any other observer and that the speed of light is universal, invariant for all inertial observers. These are followed by two chapters of exercises on the notions of vectors and tensors in Minkowski spacetime and ending with a chapter on the definition of a perfect fluid in special relativity.

Then come the exercises on the heart of the matter, General Relativity. The next four chapters, 5 through 8, give exercises on the mathematical structure and the notions of differential geometry leading to the Einstein equations. I have done several of the problems in each of the chapters and I find some of them quite challenging. I compared my solutions to those offered by Scott and I am happy and relieved to know that they compare pretty well with those provided, the difference being largely that Scott gives far more details! There are in depth exercises on the first corrections to the Newtonian theory and how they arise in Einstein's theory, which is very educative.

The final four chapters, 9 through 12, are exercises on the fundamental applications of Einstein's theory, to gravitational radiation, solutions (spherical) for stars, black holes and cosmology. These chapters capture the essence of the excitement of General Relativity. They correspond to predictions of Einstein's theory that go beyond the Newtonian theory, including time dependent phenomena, strong gravity and gravitational collapse, event horizons and a first exposure to cosmology. The exercises are again very detailed and expose the various pedagogical aspects of the rather theoretical analyses in Schutz's book.

Thus in summation, this book is a perfect companion to a textbook for teaching a first course in General Relativity. Ideally, it goes hand in glove with the book by Schutz. However, it could be used as a source book of exercises to accompany any similar course based on another book (like that of Hartle or Carrol). The instructor could use the book to assign solved problems and unsolved problems suitable for homework problems.

Manu Paranjape,
Université de Montréal

A Well-Ordered Thing, by Michael Gordin, Princeton University Press, 2019, ISBN:978-0-691-17238-5, pp. 351, price 22.58.

Michael Gordin's "A Well-Ordered Thing" is a carefully researched and scholarly account of the life and surroundings of Dmitrii Mendeleev, the late 19th century co-inventor of the periodic table. Gordin covers Mendeleev's academic beginnings, his famous work on the periodic table, and takes time to discuss the lesser known pursuits of Medeleev: his economic and political thought, his work in industry and in service to the Russian empire, and his investigation into the Spiritualism movement. Mendeleev's diverse interests are used to explore the setting Mendeleev lived in; indeed, Gordin emphasizes that the book is not so much the story of Mendeleev as it is an examination of imperial St. Petersburg.

Due to its emphasis on St. Petersburg, the book is a biography of a scientist without being a scientific biography. With the exception of the famous periodic law, to which Gordin devotes a chapter, Medeleevs scientific thought is presented in an incidental way. Further, the scientific context in which Medeleev worked is never discussed in detail. Consequently Gordin's priorities may not align with those of a scientist-reader. Nonetheless, the book contains some interesting scientific details. Gordin stresses that Medeleev's thinking on the periodicity of properties of the elements stemmed from a pedagogical need: to organize the known elements into a form suitable for a first year chemistry textbook. I also found Medeleev's views on the ether to be of interest. Medeleev believed the ether was composed of particles which could be placed in the periodic table and attempted to predict properties of the ether by using his periodic law, just as he had predicted the existence and properties of unknown elements.

Gordin explores in depth Mendeleev's economic and political thought, and his role in shaping imperial policy. Gordin stresses how, to Mendeleev, scientific societies were models for how technical expertise could be employed by the empire. The book emphasizes Medeleev's "Imperial Turn", a transition from a focus on local affairs in St. Petersburg to a top-down approach to enacting reform. In Gordin's analysis, this turn was initiated by Mendeleev's rejection from the St. Petersburg Academy of Sciences, as Mendeleev had taken the Academy to be a model of how reform could be organized locally. Gordin also argues that the ensuing outrage in the popular press made Mendeleev's reputation.

"A Well-Ordered Thing" aims to explore imperial St. Petersburg through one of its great citizens. In his writing, Gordin has emphasized analysis over narrative. In some places the analysis felt stretched or obvious. For instance, Gordin draws a parallel between Mendeleev's work on gases and his meteorological work, noting that in both cases he was "amassing data on irregularities in order to determine laws", but the parallel could have been made to nearly any scientific work. As well, the lack of narrative left me without a clear sense of Mendeleev as a person. In general though the historical analysis makes interesting points, especially regarding Mendeleev's rejection from the Academy and consequent Imperial Turn, and the book largely succeeds in its aim.

Alex May, PhD student,
University of British Columbia

Fearful Symmetry: The Search for Beauty in Modern Physics, by A. Zee, Princeton University Press, 2016, ISBN 9780691173269, pp. 376, price 31.99.

There are few popular physics books which are worth recommending to a student beginning a new subject. Tony Zee's "Fearful symmetry" is one of them. This book should be productive reading for students studying particle physics or group theory in physics. This is not only because the book presents technical material honestly, but also because the book reads easily. To achieve this, Zee maintains the unusual writing style he is known for in his textbooks — short and pointed sections colored with references to art, literature and anecdote.

Zee covers some of the usual ground for a popular physics book, for instance quantum mechanics, relativity, and the Standard Model. Additionally however he reaches topics rarely touched: groups, non-abelian gauge theory, spontaneous symmetry breaking and supersymmetry. By presenting these topics and tying them to a unifying theme of symmetry and the aesthetic sense of the theorist, Zee presents one of the most recognizable portraits of work as a theoretical physicist available in popular work.

To Zee, beauty, largely as expressed through symmetry, is a powerful guiding force in theoretical physics. Also running throughout the work is a persistent reference to God or a Designer. Usually among theorists such references are linguistic conveniences or metaphors (as was the case for Einstein, a frequent source of such usages), though this subtlety is an inevitable point of confusion. In Zee's case however the references are more than metaphor, as he believes in a presence of some kind responsible for creating the universe. Indeed, Zee views the aesthetics of the universes design, as evidenced through the role of symmetry, along with the basic fact of the universes comprehensibility as evidence for this deistic view.

Zee's views on deism and aesthetics contribute much of the uniqueness of the book. At times though Zee risks portraying theoretical physics as a mystic art, and it is worth emphasizing a counterbalancing view. My own view is that theoretical physics is not at all divorced from observation - and so not at all a mystic art - even in a case such as string theory. In that case, theorists have chosen to focus on the core principles of quantum mechanics and gravity, and work mathematically to tie them together into a consistent theory. Those principles however are well grounded in experiment. Momentarily ignoring some details and beginning from basics is sometimes necessary to make conceptual jumps. In fact, Zee makes a similar point in the context of general relativity - Einstein did not arrive at his theory by studying observations of the orbit of Mercury, but by revisiting long known simple observations.

While Zee's views may not align precisely with my own, he has written an excellent book. It will be of interest not only to the new student, but also to any artist or layperson interested in beauty. Zee has made great progress in making the beauty of symmetry in physical law accessible for a wide audience.

Further Adventures of the Celestial Sleuth, by Olson, Donald W., Springer, 2018, pp. 334, ISBN 978-3-319-70319-0, price 32.84.

I selected this book because I was intrigued by its premise: using astronomy to solve mysteries regarding the time, date and location of the origins of works of art. As a secondary school physics teacher, I am always interested in finding other ways to teach students about the applications of the knowledge and skills we teach them in school, and this text did not disappoint.

The book reads much like a Sherlock Holmes case file. Donald W. Olson describes how he and his team from Texas State examined paintings, battles, photographs, and literature through an astronomical lens, to locate, re(examine) and challenge their understandings of the works, as well as the conclusions of other researchers. Clues, such as historical documents (e.g., letters, train schedules, tide tables, newspaper clippings) are combined with modern means (e.g., computer planetarium simulations), to build their own portrait, which includes information about the astronomy, as well as the artists themselves.

Broken into four parts — *Astronomy in Art, Astronomy in History, Astronomy in Literature, The Terrestrial Sleuth* — Olson begins each chapter outlining the questions he and his team had set out to solve. In Part One, the challenge was often to deduce the location and date for a painting. Olson works with an underlying assumption that the artist included an accurate representation of what was present in the night sky from their location. From this, he uses stories about the artists and other references to the work, to deduce his answers. Olson also includes in this section an examination of *Times Square Kiss* — and specifically the shadows on the buildings — to add more information to the ongoing discussion on the as-yet unidentified woman and sailor. In Part Two, the team sought to better understand the factors which influenced strategic battle preparations (such as the case for the Battle of Stirling Bridge or the Battle of Normandy), and worked with data to highlight misconceptions. Part Three focuses on literary passages, to determine their accuracy, in terms of celestial movements and season. Olson, uses knowledge of each author's astronomical competence to frame the possible legitimacy of the passages, and then move on to determine whether authors had accurately described astronomical events or celestial movements based on the season or location of a scene. In the final part, Olson turns to two final puzzles: a railway and locating the Millais oak tree.

This is the second ***Celestial Sleuth*** book, and Olson makes reference to other case files in that volume — although not required to understand what is discussed here. The background knowledge required to understand the text is at the secondary level, and new material and terminology is explained succinctly to allow the reader to follow key ideas of analyses. For me, I felt it did provide some interesting options from which to teach physics at the secondary level, such as Chaucer's description of the moon's path in terms of Kepler's Laws of motion. For the higher education educator, I feel the book gives enough information to provide a roadmap of the kinds of information and tools one would need to endeavor on a similar quest.

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On Gravity—A Brief Tour of a Weighty Subject, by Anthony Zee, Princeton University Press, 2018, ISBN 9780691174389, price 19.95, www.press.princeton.edu/titles/11235.html.

In the preface, Anthony Zee tells his readers that **On Gravity** is supposed to bridge the gap between popular books and textbooks on Einstein gravity. After reading the 142 pages of the main text and the eight page appendix, I am convinced that he succeeded. The area between popular books and textbooks is somewhat of a no man's land, and especially for individuals with an interest in a particular field (say, gravity, for instance) this can be quite frustrating. What should you read when you already understand the basic idea of gravitation, know the main players in the history of its development, and have perhaps watched a few documentaries on the topic as well?

Well, you should read **On Gravity**.

The book is divided in four parts which consist of a handful of chapters each, and each chapter is again split into digestible sections with fitting and sometimes tongue-in-cheek headlines. Zee is one of the few physics authors who write so fluently and seemingly effortlessly that I didn't even realize I was already halfway through the book. His tone, as usual, is relaxed, conversational, and laid-back, making the seeminlgy complicated topic of Einstein's General Theory of Relativity a lot more approachable.

In part I, Zee introduces gravity as the weakest of the four fundamental forces in our Universe, and explains the nature of electromagnetic (and gravitational) waves. In part II we learn about Einstein's main idea: the principle of relativity. We also learn why we shouldn't call it "principle of relativity." Part III is devoted to a detailed explanation of the action principle in both classical mechanics and gravity theory. Finally, in part IV we learn about black holes, Hawking radiation, gravitons, as well as the concepts of dark matter and dark energy. In the grand finale Zee highlights the importance of gravitational waves, which, and that's the hope, will provide scientists with new powerful methods of observing and understanding the Universe.

On Gravity takes its time with the reader, and most concepts are explained brilliantly and in quite some detail: the idea of relativity, the action principle, gravitational waves, and even curved spacetime (in the appendix). I wish more professors would read this book and use these explanations in their undergraduate courses! The explanation of Hawking radiation, on the other hand, after a thorough introduction into the quantum uncertainty principle, seems a bit rushed and barely surpasses that given in popular science texts. Moreover, what I would have liked to see (and what is lacking in Zee's treatment) is a deeper discussion of the *limitations* of General Relativity. The Evergreen, a.k.a. the quest for the still elusive theory of quantum gravity, is clearly adressed, but problems at the classical level (say, in the form of gravitational singularities inside of black holes) are not mentioned. I think this is a missed opportunity to make this book more balanced.

Overall, **On Gravity** is a fantastic read. It is supplemented by a whopping 12 page index as well as 13 pages of annotations providing additional anecdotes, insights, and kindhearted encouragements to the reader. Zee's book might be a good choice for undergraduate students who are contemplating to enter the field but don't want to read 800 pages in a standard textbook. And if you work on gravity yourself, and you want to talk to your friends a bit more about your work, give them this book. Seriously. Zee's unique style will surely entice them and present research in gravity from its truly attractive side (pun intended).

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Practical Bayesian Influence: A Primer for Physical Scientists, by Coryn A. L. Bailer-Jones, Cambridge University Press, 2017, pp. 295, ISBN: 9781316642214, price 105.95.

Few fields are as fraught with a history of controversy as that of Bayesian inference. Although born in the 18th century in the work of Bayes and Laplace, its "subjective" view of probability fell out of favour in the 20th century after Neyman, Pearson, and others developed statistics based on a frequentist interpretation of probability. In the former, probability measures degrees of rational belief in the truth of a proposition; in the latter, probability is viewed as the limiting frequency in an infinite number of trials.

More recently, there has been a tremendous resurgence of Bayesian methods, which are at the heart of many successful methods in data science and machine learning. With this growth in popularity has come the need to teach the methods to broader scientific audiences. However, perhaps because of its “insurgent” past, many texts have been original and quirky. Think of the books by Harold Jeffreys, Edward Jaynes, D. S. Sivia, and David MacKay for example. Perhaps what makes such books brilliant and inspirational also makes them harder to teach from. Insights that appear deep to the expert may just confuse the student. (The same critique has been made of the Feynman Lectures.)

Coryn A. L. Bailer-Jones’ book is an interesting pragmatic alternative. It is straightforward and clear, if not always original — many of its examples and ways of presenting material come from the “quirky” books above. Still, it may be easier to follow than other, deeper treatments. For example, Chapter 9 goes carefully through the procedure for curve fits using Markov-Chain Monte Carlo (MCMC) and also offers a treatment of data outliers using mixture models. The latter example provides a simple way to automatically identify and, in effect, exclude “bad” points from otherwise “good” data. And the introductory discussion to model selection — clarifies many points, such as why use odds ratios, that are often glossed over in other discussions.

An attractive feature of the book is its many numerical illustrations, supported by explicit code available online. Perhaps unfortunately, the chosen language is R, an open-source program from the statistics community that is not widely used by the physics community (at least that part I am familiar with). Matlab, Mathematica, and Python are more common. Of course, these languages share common features, and transcribing a routine into your favourite language can be a good exercise. A similar critique is that the notation, for example E[x] for expectation rather than <x>, reflects conventions of statistics more than physics.

In short, Bailer-Jones has written an attractively brief, direct, “practical” introduction to Bayesian Inference. While its presentation and examples are often standard, it is well organized and very clear and should be much appreciated by upper-level undergraduates looking for an introduction to the field, assuming they do not get too hung up on the use of R and statistics notation. For graduate students seeking more depth and derivations, *Bayesian Probability Theory*, by Wolfgang von der Linden, Volker Dose, and Udo von Toussaint, is a comprehensive alternative. And, for inspiration, I still prefer Sivia’s *Data Analysis: A Bayesian Tutorial*.

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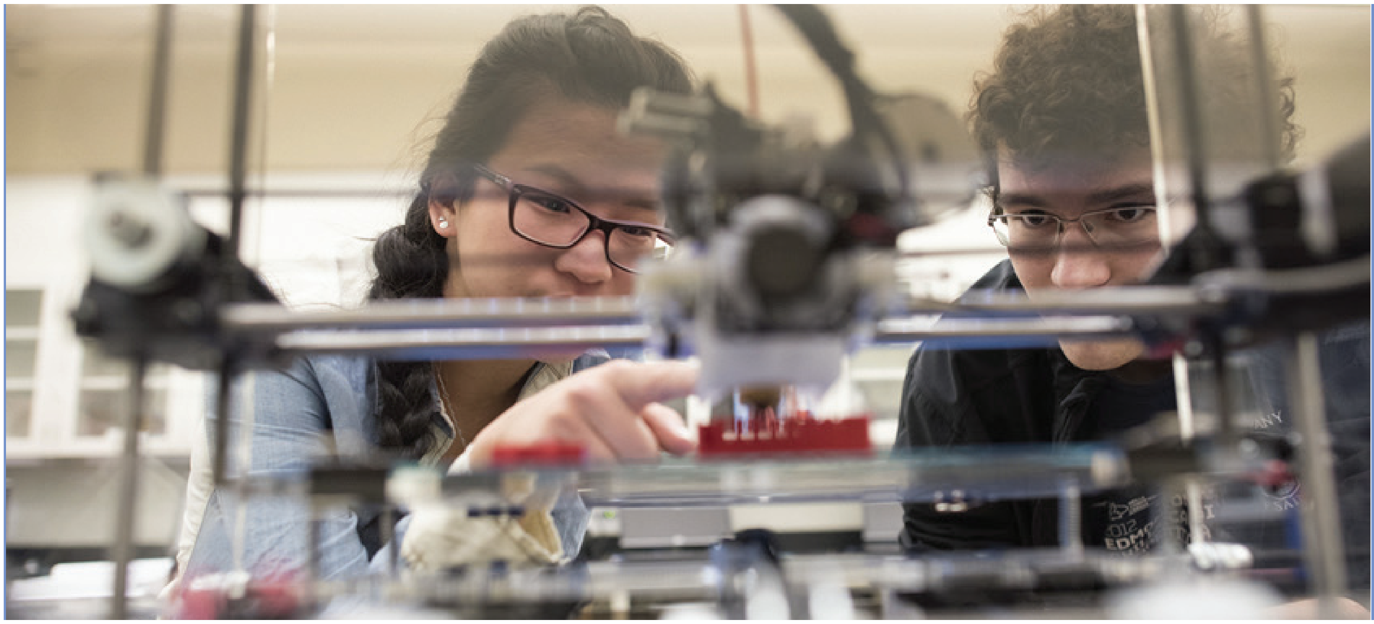

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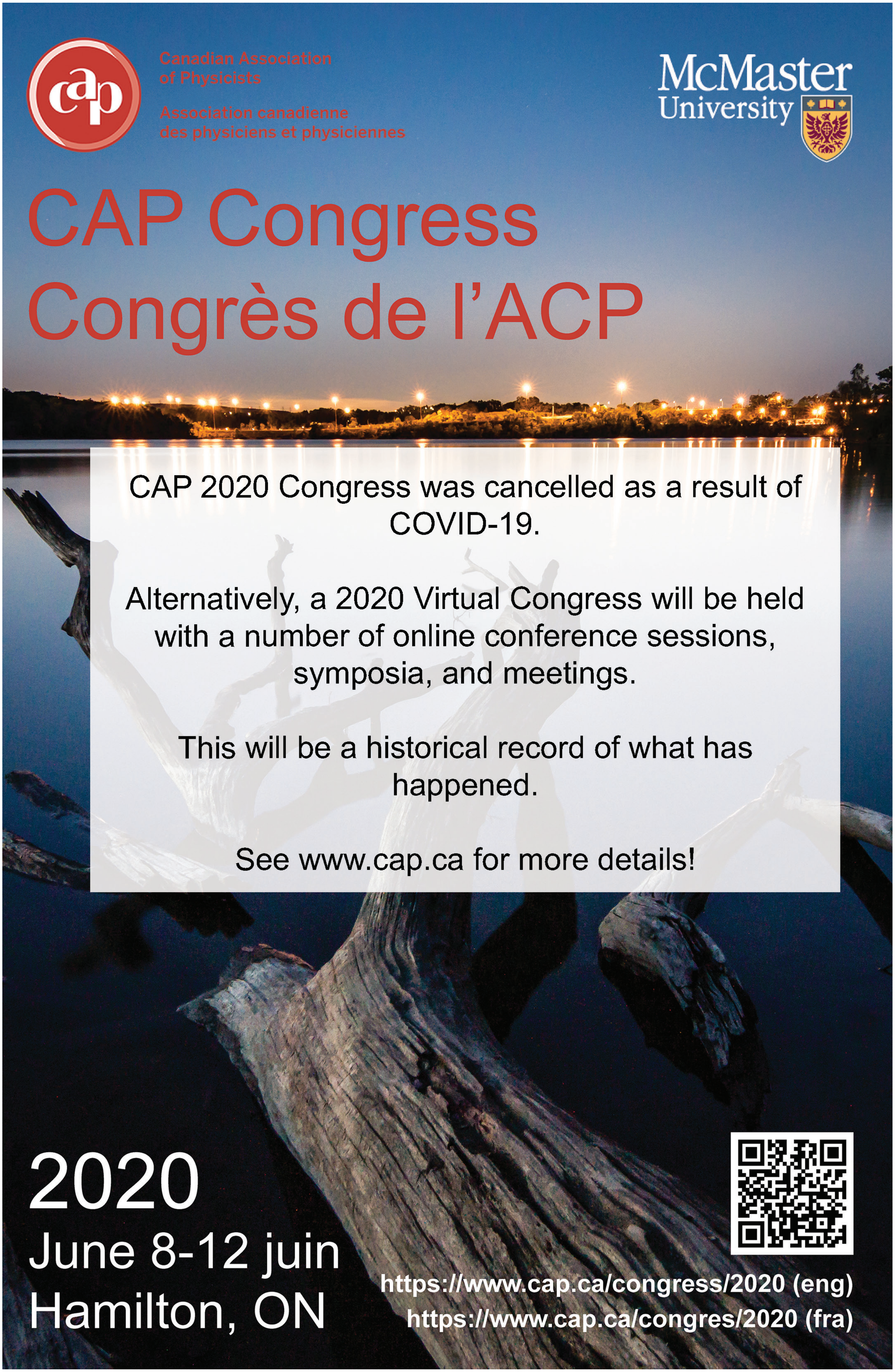

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