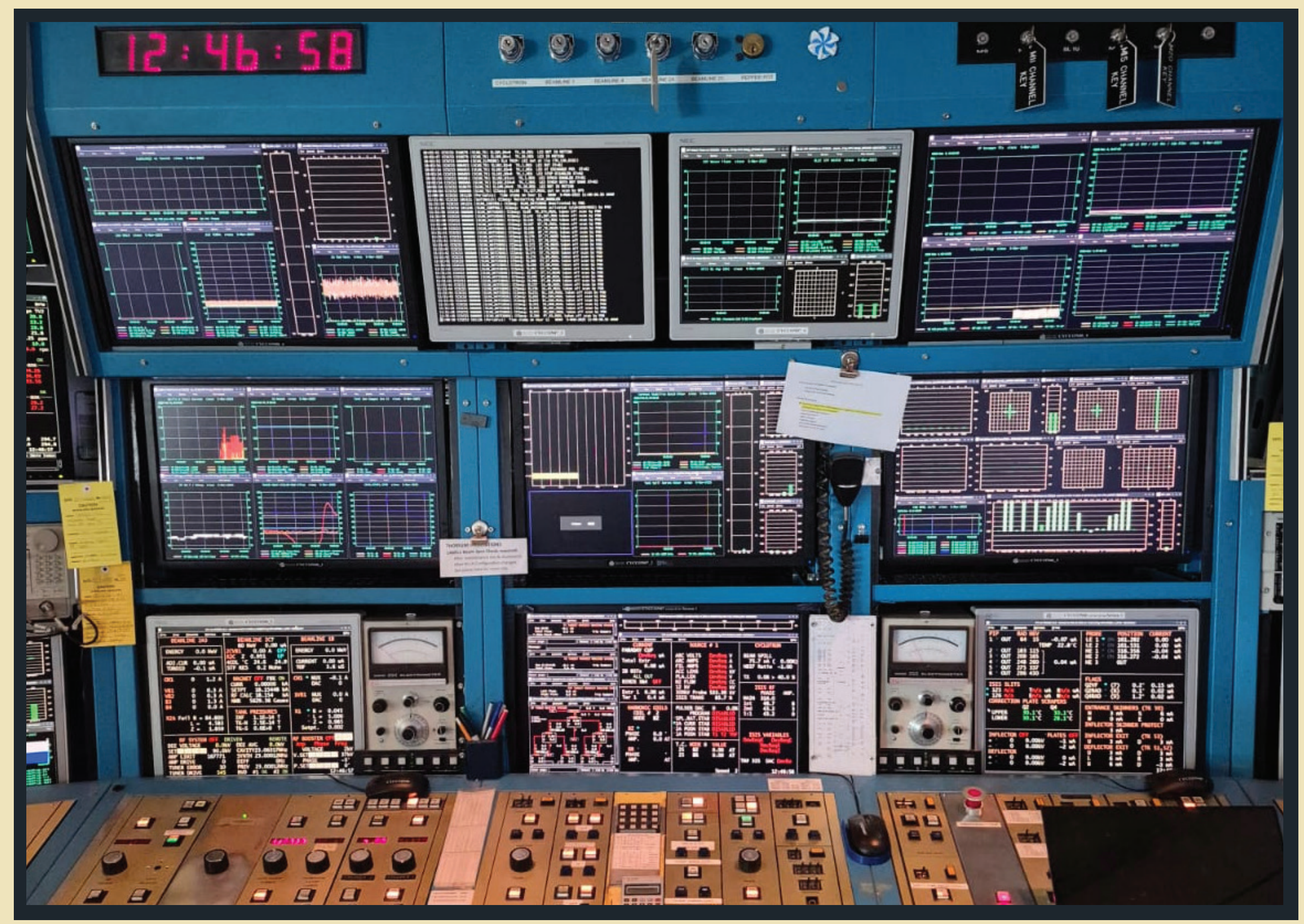
- Michel Lefebvre Interview
- Thrilling Thought Experiments
- Short Fiction
- Academic Advice
- And more!

VOLUME 3 ISSUE 2

Phase$^{i\varphi}$ Shift

A Phasers Publication



Pħase Shift

φ

VOLUME 3
ISSUE 2

JULY 25, 2025

ISBN: 978-1-77430-516-4
2025, Pħase Shift

We acknowledge and respect the Lək̓ʷəŋən (Son̓ghees and Xʷsepsəm/Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ Peoples whose historical relationships with the land continue to this day.

Greetings, readers!

The Pħase Shift Magazine publishing team is excited to present the long-awaited second issue of the third volume to you. Inside, you'll find a revamped look and aesthetic, as well as a redesign of the segment logos that were introduced in the previous issue. This issue marks the debut of three new segments: Psi-Phi, with our first-ever fiction piece; Student Spotlight, focusing on the work done last summer by incoming Pħasers VP Marketing Lauren Harrison on the ALMA Primer series; and Thrilling Thought Experiments, highlighting a centuries-old thought experiment attributed to Galileo. Psi-Phi and Thrilling Thought Experiments feature original art by Holly Partridge.

Academic Advice has been retooled into a recurring segment. This time, it consists of short contributions from various Pħasers members on software we think is useful for every physics and astronomy student to know, but isn't necessarily covered in a course. Additionally, we have an article on the use of 'law' in science. This edition's featured article is an exclusive interview with our very own Dr. Michel Lefebvre, detailing his decades-long career here at UVic.

We are immensely proud of this issue, and we hope you have fun reading it. If you want to contribute to the next one, either as an author or as a member of the publishing team, don't hesitate to join the Pħase Shift Discord below or email us at uvicphasers.newsletter@gmail.com.

Enjoy the rest of the summer, and we'll see you in September!

The 2024-2025 Pħase Shift Publishing Team

Join the Discord!

Calendar

August

Wednesdays 8:30 pm-10:30 pm, through August 27: UVic Observatory open house (Bob Wright Centre, free to attend)

Saturdays 7:30 pm-10:00 pm, through August 30: DAO Star Parties (Free admission, ticket required)

August 4: BC Day, campus closed

August 5-16: May-August session exam period

August 11-12: Peak of the Perseid meteor shower

August 21-22: Canadian Undergraduate Medical Physics Conference (Virtual, free to attend)

September

September, TBA: Pħasers general meeting

September 1: Labour Day, campus closed

September 3: Fall classes begin

September 19: Fall course add deadline

September 10: UVic Observatory open house reopens, Wednesdays 7:30 pm-9:30 pm

September 10-11: Club and Course Union Days

Contents

Cover Photo

Founded by UVIC, UBC, and SFU in 1968, TRIUMF (TRI-University Meson Facility) is home to the world's largest cyclotron. The driver control room, as shown in the image, is responsible for controlling nearly all the cyclotrons and accelerators on site at TRIUMF. In total, 3,000 devices are monitored from this room, which is constantly staffed by at least two personnel, 24 hours a day, every day. The part of the control room shown in this image has, in ever-modernizing forms, been in place since 1974, when the cyclotron was completed. It has the activation keys for the cyclotron and beamlines, along with multiple screens to monitor the equipment when it is active. This image was taken during my co-op with the theory group at TRIUMF.

-Roan Stafford

STUDENT SPOTLIGHT

Lauren Harrison

Lauren Harrison: ALMA

High in the Atacama Desert of Chile sits the world's largest radio telescope, ALMA. ALMA is the Atacama Large Millimeter/submillimeter Array which consists of 66 high-precision antennas. The main array is composed of 50 12-metre diameter antennas which function together as an interferometer. This main array is complemented by a compact array of four 12-metre diameter antennas and another 12 7-metre diameter antennas. The antennas themselves can be configured in various ways from 150 metres to 16 kilometres apart. This gives ALMA the capability to really zoom in on an astronomical object, even producing clearer images than Hubble!

QR code linking to the ALMA Primer YouTube channel.

I was fortunate enough in the summer of 2024 to contribute to the education of ALMA astronomers. I was on a co-op placement at the Dominion Astrophysical Observatory (DAO) as a Video Developer in Astronomical Concepts where I was part of the radio astronomy team at Herzberg Astronomy and Astrophysics Research Centre (HAA). In this position, it was my responsibility to produce educational videos for ALMA, contributing to the existing ALMA Primer series on YouTube. The videos are short and targeted towards astronomers who are new to concepts in radio astronomy and interferometry.

During my co-op, four videos were produced for the ALMA Primer series. A trilogy of videos were released all explaining how Sidebands, Basebands and Spectral Windows affect observation considerations. If you want to know what those terms are, you'll have to check out the videos! The fourth video was an excerpt from one of the earlier three. Its purpose was to be used in presentations to show how different molecules can be viewed with various observing setups. The short extract was created by a PhD candidate, Jess Speedie, who collaborated with our team over the summer.

For the four videos we produced, we gained over 1000 views and over 75 new subscribers. All the video production was done in Adobe Premiere Pro. Working in this team environment was a wonderful experience which I am so grateful for! It was really nice to see the various options that exist when working in a scientific field. This position stressed the importance of science communication and education, and really inspired me to continue to explore that direction in my future studies. It was also great to see how a professional team operates and what really makes a team thrive.

Our mascot Astro looking through a telescope.

I was very lucky to be paired up with another co-op student, Natalie Perelygin from Camosun College. Natalie and I were responsible for creating and editing the videos. We also had the opportunity to record the narration for one of the videos, which was definitely a highlight! Natalie is incredibly talented in animation and animated various short clips of our mascot, Astro. My favourite is one where Astro looks through a telescope. Natalie created various other animations for ALMA Primer, and I recommend checking out the YouTube channel to see them all!

During my co-op, I learned a lot regarding the functions and operations of ALMA. The most notable thing I learned was how ALMA contributed to the first images taken of a black hole! In 2019, the first image of a black hole at the centre of M87, an elliptical galaxy, was released by a global collaboration of telescopes called the Event Horizon Telescope (EHT) collaboration. In 2022, an image of the black hole at the centre of our galaxy, Sagittarius A*, was released by the same team. EHT works through a process called Very Long Baseline Interferometry (VLBI). This is a process where radio waves are simultaneously recorded from various radio telescopes all across the globe, which simulates a single telescope with a size equal to the maximum separation between the telescopes. In the case of the EHT, we are simulating a single telescope with an effective aperture equivalent to the entire planet!

ALMA played a huge role when the imaging of the black holes occurred, as it was home to the most sensitive VLBI station. ALMA functioned as a "giant light-bucket" and joined a network of other radio telescopes to have very high resolution at millimetre wavelengths. The measurements taken were significantly improved simply due to how precise ALMA is!

I am so thankful I got the opportunity to contribute to such an incredible telescope. If you are interested in checking out the videos, they are available on YouTube under the ALMA Primer channel! This is an exciting time in astronomy, and I am eager to see what ALMA discovers in the future.

One of the many ALMA configurations as seen from a drone.

Thrilling! THOUGHT EXPERIMENTS

Allen Keefe

Falling Bodies

Galileo's Leaning Tower of Pisa is a thought experiment on the motion of falling bodies. You may have heard of the experiment where Galileo supposedly dropped objects of unequal weights off of the Leaning Tower of Pisa. While historians have differing opinions about whether or not Galileo actually performed this experiment, we do have records of the thought experiment behind it that corrected earlier understandings of gravitational acceleration.

The set-up is as such: two objects of different weights are connected by a string. They are dropped as one from a height. According to mechanics derived predominantly from Aristotle's work, the speed of a falling object is proportional to its weight. This means an object that is twice as heavy as another object would fall twice as fast. If we assume this to be true for our experiment, we would expect to see the lighter object pull the string taut as the two fall together due to its slower falling speed, and therefore slow the fall of the heavier object.

If we instead took these same two objects and tied them tightly together so that they act as one big object, we would expect it to fall faster, its speed increasing in accordance with its increased weight. Considering these two situations and the results that theory predicts, we see a contradiction. Aristotelian mechanics tell us that the system should fall slower when we consider each component individually, but it should fall faster when we consider it as a single object.

So which is it? How should we expect this system to behave? As the thought experiment shows, the fact that this system suggests two directly contradictory outcomes means that the idea of objects falling at speeds proportionate to their weights is inaccurate. There must be a different set of mechanics governing how fast things fall.

Eventually, Galileo ended up developing the Law of Falling Bodies, which states that falling objects are all accelerated at the exact same rate, and that the distance they travel is dependent on the amount of time elapsed, not the weight of the object. We now know this constant rate of acceleration as the acceleration due to gravity.

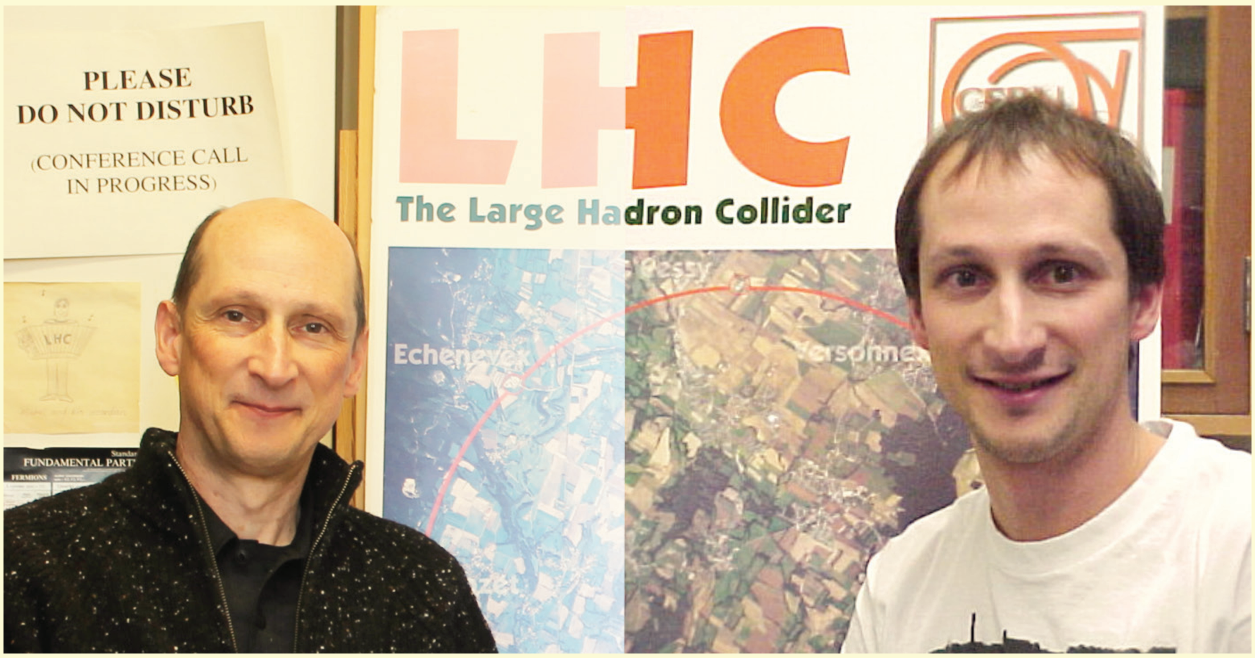
Unlike most other thought experiments, this one is physically able to be performed, and simple enough that on many occasions, it has been. Typically when the experiment is actually done, the objects are dropped simultaneously in an air-resistance-free environment and shown to fall equally fast instead of being fastened together as described above. Despite the differences, both experiments show that the speed at which an object falls is not determined by its weight, so the same conclusion still holds. An especially notable instance of this experiment was performed on the moon by one of the Apollo 15 crew members, where the lack of an atmosphere–and thus air resistance–showed that a hammer and a feather fall at exactly the same speed when dropped simultaneously despite the difference in their weights.

THE ELLIOTT EXCLUSIVE

Ash Samra

LHC: Lefebvre's High-Energy Chat

Physics and astronomy students likely know Dr. Michel Lefebvre as the enthusiastic instructor for PHYS 130, 215 and 326. Over the course of his career as a professor of physics at UVic, Dr. Lefebvre has taught almost every physics course, from the undergraduate to the doctorate level. Some current faculty members were even his students while completing their undergraduate degrees. Dr. Lefebvre has been with the department for over 34 years and has been involved in research focusing on experimental particle physics for even longer, dating back to his time as a student. Phase Shift reached out to discuss his storied career, what he's seen change, advice for readers and everything in between.



Michel Lefebvre in front of the same LHC Poster, 29 years apart, first in 1996, then again in 2025.

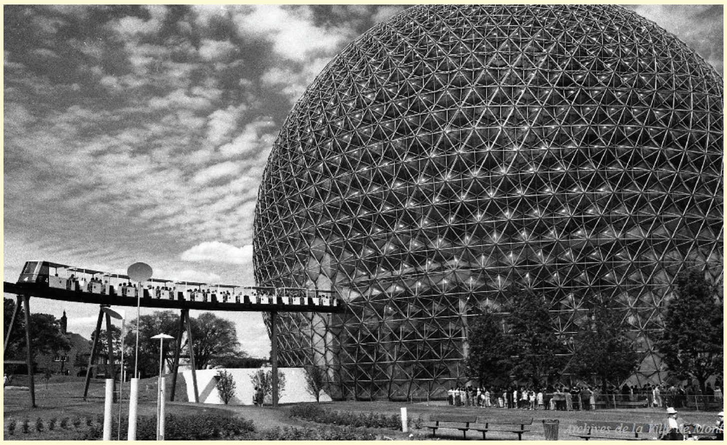
Ash: How did you figure out you wanted to do physics, and what's the story of getting to where you are now in your career?

Michel: I benefited a lot from having had very good teachers in science: at high school; at cégep in Quebec, which is like senior high school; and then university. Also, my dad was an architect and though he didn't have a pure science degree, he had some engineering type formation. When I was very young, I was introduced to interesting scientific concepts.

At around six or seven I was already self-motivated to learn mathematics, and that's where it started. It's just something that I like, numbers and geometry. When I was in grade one, we were supposed to do our adding tables. I did mine in two seconds, put it in a corner and then on a piece of paper I was practicing extracting square roots of four digit numbers by hand with two digits after the dot. I knew the technique to extract square roots of numbers by hand. At six I could do this and I could multiply the thing back to see whether I had it right and I could estimate the error. So the profs thought I was weird. But I was never gifted in pure math, just algebra, numbers.

I was fascinated by regular polygons and eventually polyhedrons and maquettes made of domes, things that were very popular in the 70s and 80s. I became fascinated with how you obtained the volume of these things and I was interested in formulas of geometry, like the area of a circle. As a kid, I thought it was amazing that you could express the area of a circle in square centimetres. There's no corners in a circle, so how can you say it's square centimetres? Of course, this fascinated people over many millennia. I asked my dad, "How do you prove [a circle's area is] πr^2? How do you prove this?" He said, "You've got to learn calculus." So by the age of 13, I had learned algebra and trigonometry on my own. I asked my high school teachers where I should learn calculus, to give me the reference textbooks.

University was like a mecca for me. I was 14 and went with my dad to the university bookstore to buy those books—which I still have. I studied them for about a year and a half and got to the point where I could do basic university calculus. When I got to cégep and started doing more physics I realized the math I liked and was good at was applied mathematics—the kind physicists, chemists, and engineers use. When I went to university I went into a physics degree because I knew that's what I wanted to do. I figured out I wanted to do particle physics after my first year. I was interested in the fundamental structure of matter, and the underlying laws that govern everything else. Then you're naturally drawn toward the Standard Model of particle physics.



Montréal's Biosphere geodesic dome, constructed for Expo67 and displaying the kind of experimental polyhedral architecture that became popular around that time. Michel visited in 1967 at the age of four.

In 1983, my first job that wasn't cleaning baths or ovens, or painting fences, was a research job at l'Université Laval in the Van de Graaff accelerator. I learned computing and more about Einstein's special relativity. After that I came here, to Victoria, as a summer student in 1984. I had never been west of Ottawa before, so this was like a new planet to me. I met people here I really liked, and they liked me. We kept in touch, and I came back for a second summer. Then I spent six years in Europe doing my PhD and postdoctoral work. Eventually, a job opened here, and I applied for it and got it. The group I met here were world experts. I was the first summer student of Alan Astbury and Richard Keeler. Richard is still here, as an active emeritus professor. Alan Astbury passed away 11 years ago, but he was my mentor and then colleague and then friend. He was director of TRIUMF for many years and a world scientist—a Fellow of the Royal Society of London (England), and of Canada. An amazing scientist. He came here in '84 and founded the particle physics group, and I just happened to meet him at that time.

I got very interested in the frontier work at CERN in Geneva. When the time came to choose a grad school, I asked my colleague for his advice and ended up choosing Cambridge in England, and that was the best choice I've ever made in my life.

I really got lucky to meet these people as a young man. I had connections with people in Europe, and when I was a PhD student in England and working in Geneva, I was working with amazing people. Just incredible, the brightest, most amazing people I've ever seen. That kind of puts you on rails.

Ash: As you've been working in it for over 40 years now, how have you seen the particle physics field evolve?

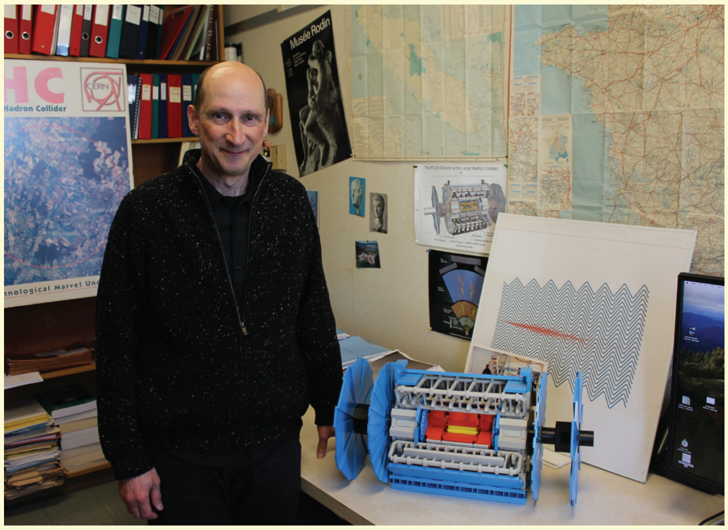
Michel: Particle physics has quite an interesting history. There was a time of big confusion in the 60s where lots of new particles were discovered in bubble chamber experiments, and nobody had an understanding of where they came from. It took a while to shake all this down and get what we call the Standard Model of particle physics.

As a PhD student, when I joined the experiment at CERN in '85 in Geneva, the W and Z bosons had just been discovered two years earlier. Those were the big pieces in understanding electroweak physics. During that time we discovered a lot of interesting phenomena, like hadronic jets, and how to build detectors the right way. There was a period from 1988 to 2000, when the tunnel was built for the Large Hadron Collider—then it was a Large Electron-Positron collider, LEP. That collider operated from 1989 to Christmas 2000. This was a machine where you could probe electroweak physics very precisely. You collide an electron and positron together at a centre-of-mass-energy equivalent to mc^2 of the Z boson. You sit on a quantum mechanical resonance and produce Z bosons like popcorn. There were four experiments around the ring that did this work. I was not part of that effort because I spent all my time designing and building what was eventually the ATLAS detector, which was supposed to be the next phase after all this.

Ash: That sounds like an electric environment.

Michel: Yes, also it was a pleasant environment. People were very accommodating to students, and we had a lot of opportunities to learn. The big bosses were tough on the postdocs and other professors, but the students were allowed to make mistakes. I was given that opportunity and I think it's good to give it back. My students make mistakes and I'm very happy to find their bugs. I keep telling the students when they feel sad that they have a bug in their computer program or make a mistake in analysis, "Look, the only people that don't make any mistakes are people that don't do anything."

Once the W and Z particles were discovered, analyzed, and studied, the next bit of the Standard Model postulated was the existence of the Higgs boson. That is a very big piece of the puzzle. We predicted it, and we knew that if it existed, we wanted to build a machine and a detector that could detect it. That's how we set about to design and eventually build the ATLAS detector. The LHC itself is a project which I was not directly involved with, but people had to build magnets and change all the magnets that were in the tunnel, in order to get the proton-proton collisions at the right energies. So all this was in parallel.



Michel Lefebvre in his office, with a scale model of the ATLAS detector as well as an original drawing of the liquid argon calorimeter, including a simulated particle detection.

The reason behind it was this quest to understand how all the forces work, and the Higgs mechanism was the only way we understood at the time how fundamental masses can be produced while preserving what we call gauge invariance—the principle that allows us to understand all the forces that we know today, including general relativity. They're all gauge theories, which has to do with local symmetries.

The so-called symmetry breaking mechanism was critical to allow our understanding to move forward, but it did predict this extra field in the universe which shows itself through a single particle, a scalar particle. It's about as simple a particle as you can imagine. The real physics is the Higgs mechanism, but the Higgs boson is like the signature of this mechanism that we can see in the lab. It has a very feeble signal. In the 70s, some famous theorists wrote some papers that said experimentalists have to be crazy to look for the Higgs boson because it's so difficult to find it'll never be possible. Ten years later, people launched a project to start doing this.

When I was still a PhD student, I'd already started working on research and development for detection techniques for the LHC. At that point ATLAS didn't exist as a detector, but we already had a group of people that were doing the research and development to build the right detectors. When I became a prof here in '91, I brought that project with me. I was the founding spokesperson of the ATLAS Canada collaboration.

The US had a project also: they wanted to do the superconducting supercollider in Texas. It was supposed to be 100 kilometres around, 40 TeV centre-of-mass-energy, much bigger. They dug a third of the tunnel at huge cost, but eventually the government pulled the plug on it. This sent ripples that we still feel today in physics. That left the LHC as the only place where you could look for the Higgs boson and have this kind of collaboration. After that, the US joined en masse, which was a beautiful thing.

"Michel and his accordion", drawn by then-PhD student, now Carleton professor Manuela Vincter, ca. 1992. She is a Fellow of the Royal Society of Canada, and remains a colleague on the ATLAS experiment.

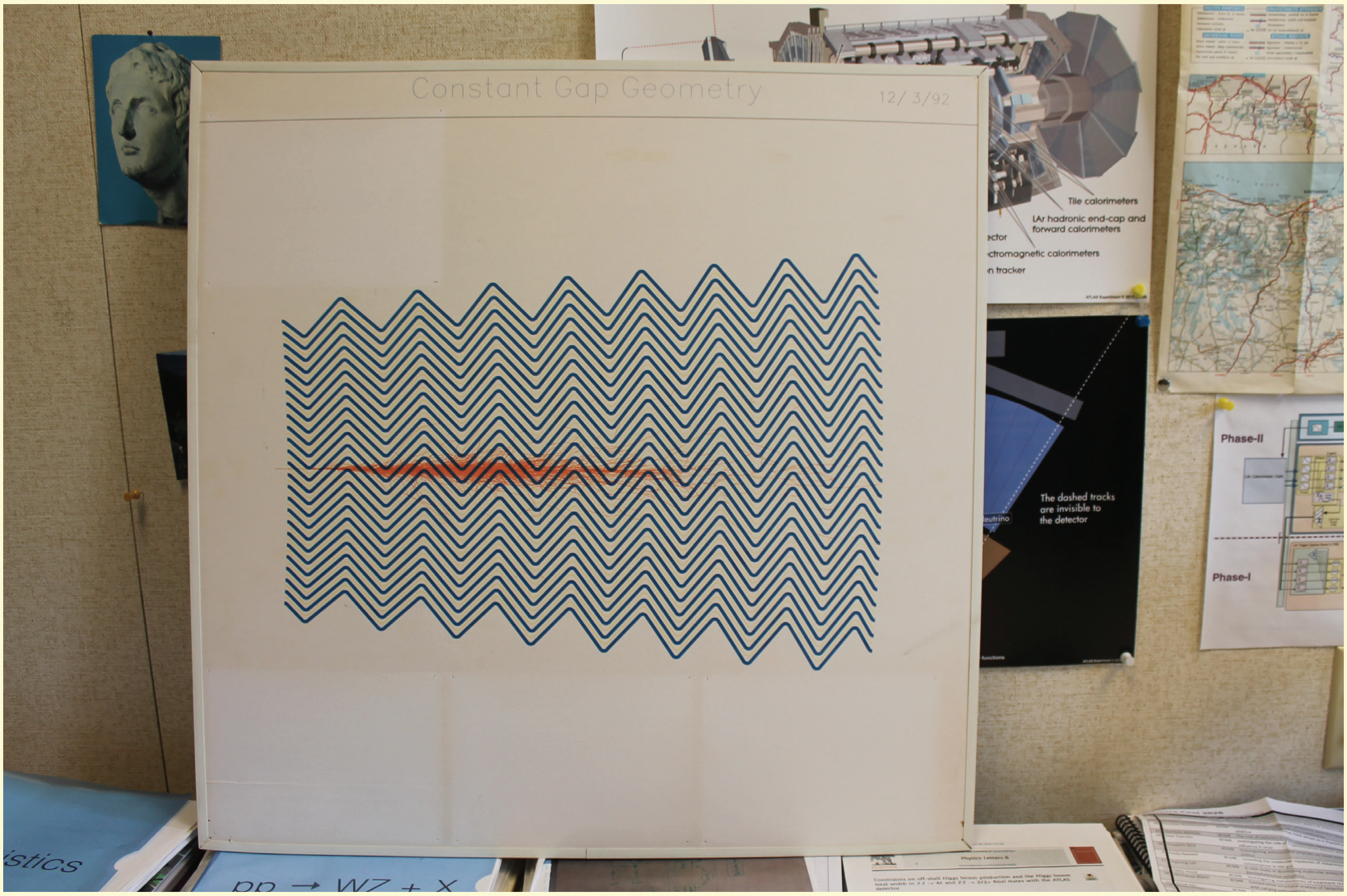


Diagram of liquid argon calorimeter, drawn by Michel in 1992. The plates all have a constant gap between them, created by slightly varying the angle at which the zig-zag occurs. In red is a simulated electromagnetic shower caused by an incoming electron.

Ash: Tell us about your research and what you have been working on.

Michel: Since the beginning, I've been interested in electroweak physics, mostly, but not only. Electroweak physics means everything to do with the W and Z bosons and the weak interaction. I did my PhD on W boson production in antiproton and proton collision. At the LHC, eventually, when we got data, I was very interested in pursuing electroweak signatures.

Beyond that, something that took a big piece of my career—almost the first 20 years as a professor—was developing, then constructing and commissioning, particle detectors. We developed, as part of a small team back in 1988 or 1989, a new technique to do electromagnetic calorimetry: the Liquid Argon (LAr) calorimeter. It had this accordion structure. I kept a drawing I made in 1992.

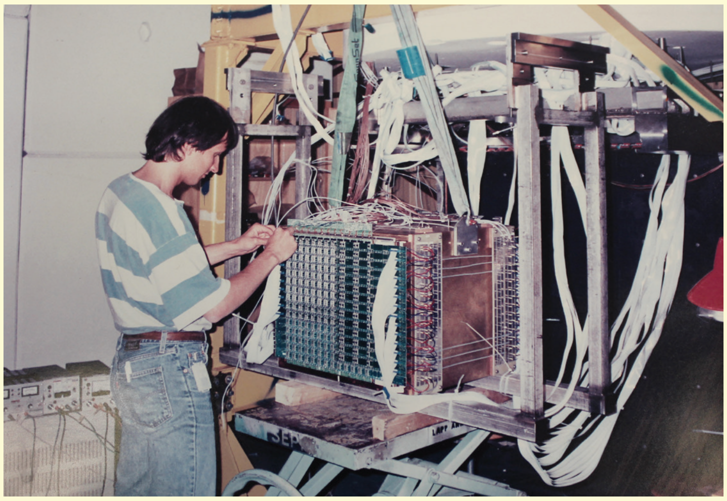
The real detector is a cylinder, six metres long, and the beam would collide in the middle. I made this simulation because I optimized the geometry. I have log books from more than 30 years ago where I was doing all these geometrical calculations and putting them into a computer program to simulate all of this. I keep them to show what kind of different geometries we tried. I started working on prototypes for a Cartesian geometry, just a square box with 45 degrees, just to see if the principle worked. After that, our ATLAS Canada collaboration needed to decide what component we would build for the detector, then we pivoted to the hadronic calorimetry. We built prototypes. All of this took place between 1992 and when the last pieces were sent to CERN in 2006. By 2008, the detector was completely assembled.

This was a big piece of my life, to make all these detectors, to work on these big projects. At the same time I was teaching quantum field theory. It was a lot of fun, I was mixing different stuff.

Data analysis started in earnest in 2010, when we had our first collision at the LHC. The Higgs boson was discovered in 2012. You might wonder how it was so fast—it's amazing it only took us two years. The main reason is because we were supposed to get our first collisions in 2008. But then, when they tried to start the LHC, there was a short somewhere in the magnets. It is a cryogenic system and there was a place where there was a vacuum breach and a quench occurred. Quench means suddenly the superconducting property of the material of the magnets warms up in some places, you have less cryogenics and eventually it just backs up and the energy has to go somewhere. If you do your quenching system correctly, the energy is dumped and doesn't destroy anything. But there was an issue with the quenching mechanism and protections and it caused mechanical damage to about a 200 metre section of the beam.

That took two years and millions of Swiss francs to repair. During that time, we had our detectors in the pit and we didn't twiddle our thumbs waiting for the beam to come back. The ATLAS detector is like building a ship in a bottle. All the parts have to go down two shafts. These shafts mean that you can have cosmic rays going through. That allowed quite a lot of tests to be made.

If we'd taken data in 2008 as planned, we would not have been ready. Those two years, we polished everything. When the real data came in 2010, we were up and running and ready to go. Both the ATLAS detector and CMS detector did the same thing; we discovered the Higgs boson about the same time. This was the fourth of July 2012.

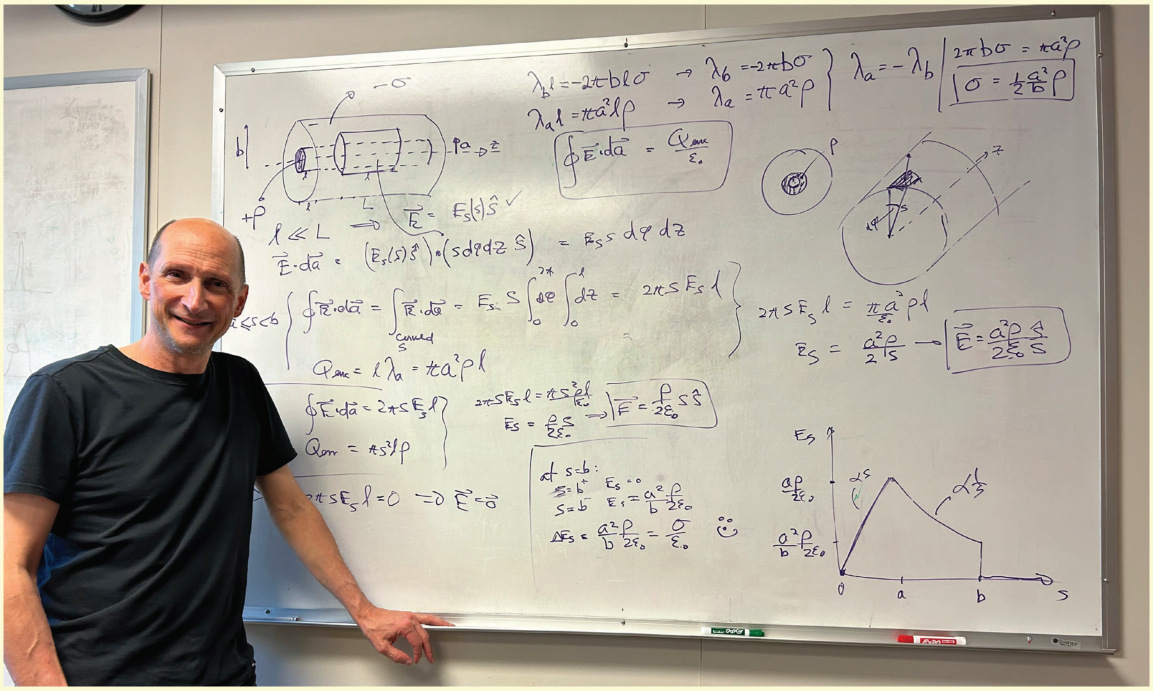


Michel working on a prototype of the liquid argon calorimeter in 1990.

Ash: When you look back on all you've done throughout your career, what moment stands out to you as the most memorable?

Michel: Well, of course, the Higgs boson discovery is amazing. I'm lucky that in my lifetime, I have been part of an effort to discover a new component of the universe. Many scientists work all their lives and never find that level of novelty. But I'd say that to me the moments that were very exciting were when we started to see the ATLAS detector being built. Because this is after almost 20 years of R&D and hard work and then you can see all the components being put together and you start realizing, "Hey, this is actually gonna work. It's real."

Then maybe earlier, my first excitement was to analyze my first proton-antiproton collision when I was a Cambridge grad student, and to identify from the data the Ws and eventually some Z bosons. I was very, very excited about it because that was the only place on the planet you could study these particles. They're fundamental building blocks, the carriers of one of the four forces that we know. I thought this was magical.



Whiteboard after office hours for PHYS 326. Here, the electric field strength of a wire surrounded by a shielding conductor is determined using Gauss's law. Michel commented that this was one of the "greatest whiteboards" he had ever written.

Ash: How have the university and department changed since you started here?

Michel: Just to give you a quick example, when I started here, I was put on the curriculum committee right away. The chair of the curriculum committee, Harry Dosso, who passed away just a few months ago, had built basically single-handedly the curriculum of this department. He started in the late 50s with Victoria College and built the whole curriculum from scratch. But by about 1990, it was starting to be a little dusty. You don't teach things in the 90s the same way you do in the 50s or 60s, in particular quantum mechanics. I worked very hard to revamp the quantum mechanical stream and the way it's taught today is something that I did in the 90s. And now, this is being rediscussed because it's been 30 years. You don't teach quantum mechanics today the way you taught it in the 90s. Now it's much more quantum optics, two-level systems, mixed states entanglement. So the wheel keeps turning.

Today it's weird because I am the most senior full faculty member in the department, weird because for the first 10 years of my career here, I was the youngest guy in the department. Something that has changed a lot is the number of graduate students in our department. When I came in there were like, you know, 25, 30 grad students. Now it's over 100. The number of professors in the department hasn't really changed much. The reason is because we have a lot more adjunct professors now. We're very lucky in Victoria to have big labs and national labs nearby. You know, the Institute of Ocean Science, Pacific Geoscience Centre near the airport, the Herzberg Institute, TRIUMF in Vancouver and now also the BC Cancer Agency in Victoria. All of this means that we have adjunct professors that want to have graduate students to work with them and we have a system to make sure that they remain adjunct professors with us. That has allowed us to multiply the number of graduate students.

Another thing that has changed a lot is, of course, just the affordability in Victoria. I've seen this [go from] being a normal place to live to being a very expensive place to live. For young people like you, you're now in it and you see it in its full force. But you've got to soldier on and make the most out of it. Hopefully things will get a little better.

Ash: What have been your favourite courses to teach?

Michel: Well, I've loved to teach all the courses. I've taught at every level: first, second, third, fourth, masters, and PhD. It's good to see the whole range, so when you have to teach at a lower level, it's great, because then you know where it's leading.

But I love teaching first year, that is probably my favourite. Students are really bright and it's a time where you can make sure that they learn skills to solve problems. It's not just formulae, it's more how do you think? Can you use laws of nature to solve a problem? You have to think like a physicist; that's what I try to do in [PHYS] 130.

Dimensionless ratios. That's what I do a lot in 130. Students are puzzled. Some students come and tell me, "The assignments had almost no numbers in them!" I say, "Good." It means you get general formulas at the end that are valid for any cases, you know? That's when they start realizing the power. I mean at the end you might want to get numbers for some application, but if you want to understand the laws of physics, you want to see the relations between things.

Even for simple things like, I don't know, a cylinder rolling down an inclined plane, and you say, what's gonna be the time it takes to get to the bottom? Well, you can get a result where you don't assume the moment of inertia, you can say it could be a hoop, it could be a full cylinder and you write it in terms of I/mr^2 or something. First year's great because students start to realize that you can have a general result.

This is the biggest kick I get. That's why I love teaching that age group, lots of intellectual power and they're ready to learn.

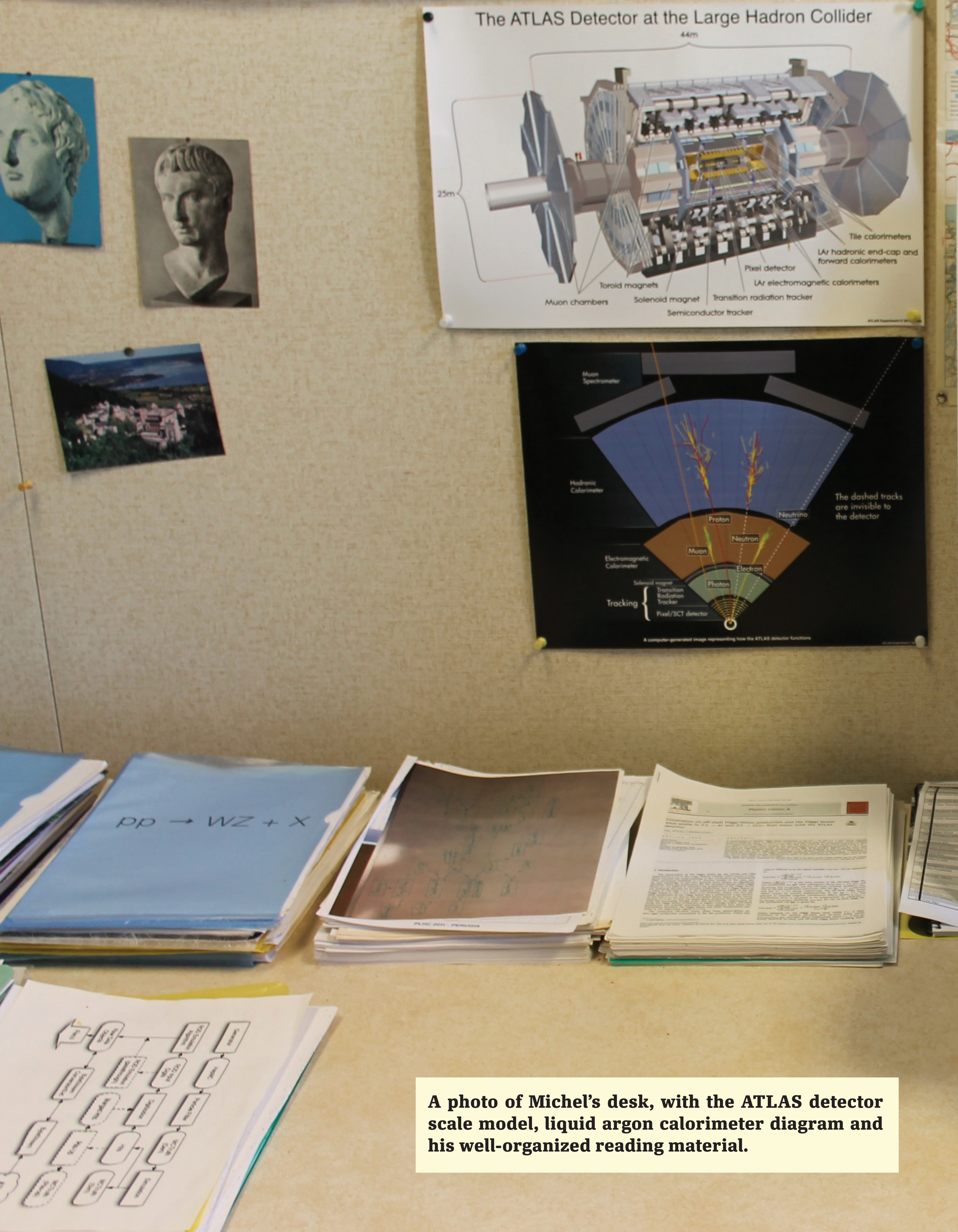
Michel: Sometimes people ask me, "Michel, are you gonna retire, what's gonna happen?" It's true that in a few years I should probably retire, but I have to balance different things. I still love teaching and I don't want to retire and just do nothing. I will maybe continue to be involved in some kind of intellectual activity, research or something. Over my career, I have accumulated a lot of books thinking that one day I'll be able to read them. But I've been always too busy to read most of them. So now I'm thinking, "Wow, I need to live to a hundred to read all these books." We'll see how it goes.

So yeah, been in this office since 1991. I put these posters on the wall in 1991. All of them have been there since then. This is a museum.

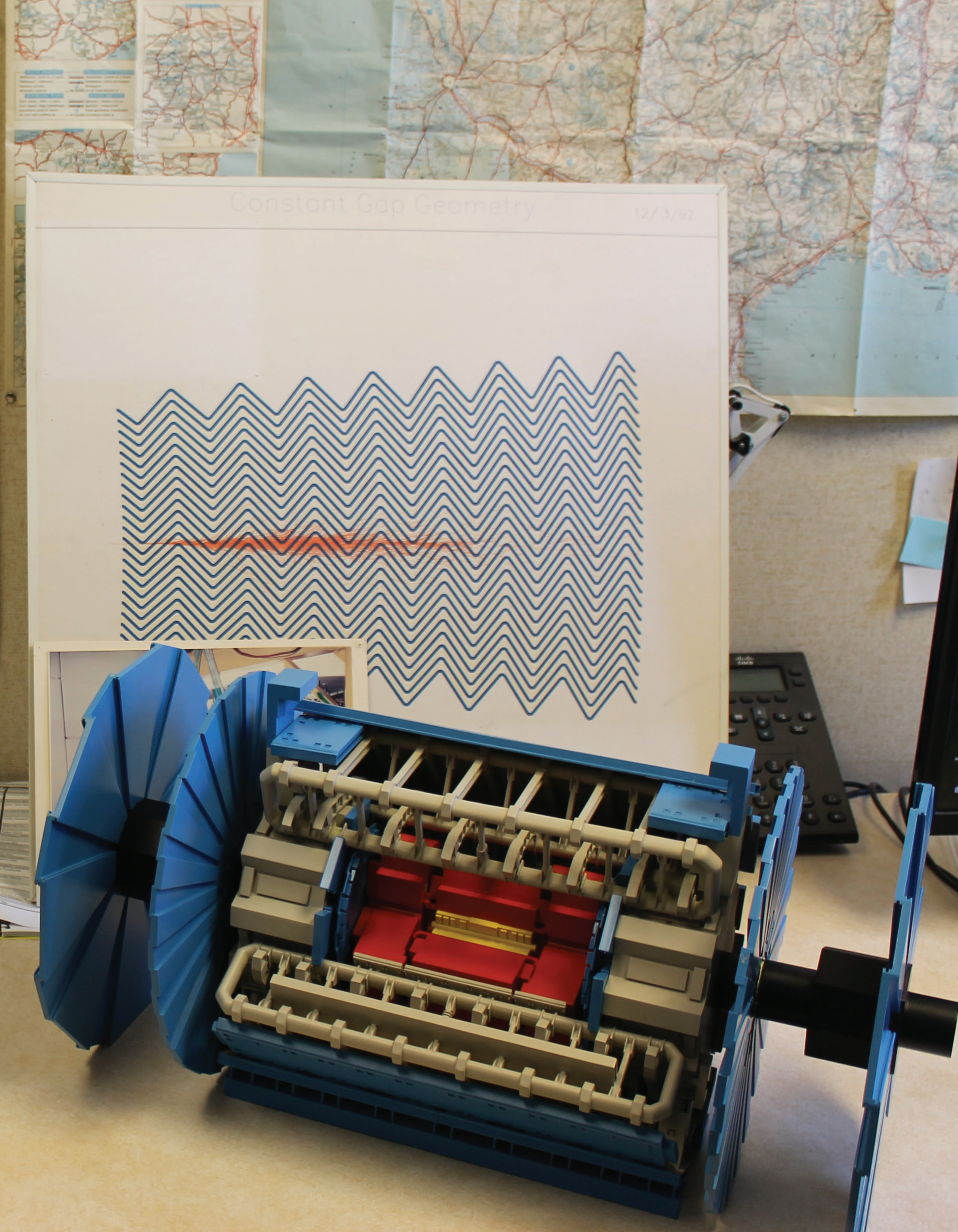
I've got another piece of work, I won't get into the details, but I did this in 1989. It was a tour de force. This was a quick and dirty analysis just to prove to the world that I could make this measurement of this W cross-section. Almost as good as the very sophisticated analysis that a big team of people did. And it turned out that I was right. It's not as good, but it's very close. I remember being quite proud of this actually. And you know what? This is written in LaTeX.

A piece of history: this is my LaTeX book. Bought in Cambridge in '88. And, you know, I signed here "This book belongs to Michel Lefebvre" because everybody was borrowing it, I could never find it. And a friend of mine wrote, "and now all his friends." This was when I was a grad student. LaTeX came up in '86, I think. And you know, I wrote my thesis in '89 using LaTeX and if I had the TeX file with minor modification, I'm sure I could LaTeX it today.

Michel teaching PHYS 130, lecturing on special relativity.

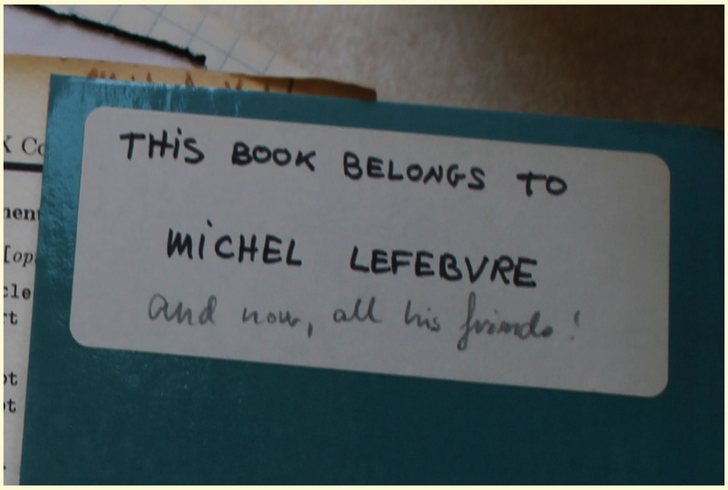


A photo of Michel's desk, with the ATLAS detector scale model, liquid argon calorimeter diagram and his well-organized reading material.


Constant Gap Geometry
12/ 3/92

Ash: That's incredible. You're one of the first LaTeX users.

Michel: I was the first one in the particle physics group in the Cavendish Laboratory, for sure. And then of course everybody wanted to use it, and once you get into it it's quite simple. And so, I've seen the beginning of all this. When I started my PhD in '85, we had VT100 terminals with big keyboards and a big cursor flashing. You didn't have any colour screens, you printed stuff on paper with dots on the side. It was archaic. And by the end of my PhD, we had workstations with colour screens, LaTeX, laser printers. It went from the end of the dark ages to sort of an era that's not so different from today.



Signed inside cover of Michel's LaTeX book, bought in 1988.

Ash: What is one piece of advice you would give to undergraduates?

Michel: Be more confident with your abilities, and also be more confident that you have an impact to make here, even though you feel like you might not. But you are the future. A lot of the older people are gonna retire, disappear and just do other things—play golf, you know. The future is yours, so I think to be more aware of that is important.

There's a tendency because of the fact that the world is a bit unstable now and there are difficulties to overexaggerate this. I'm not saying there's no climate crisis, and a lot of stuff happening that is frightful, but I think that this has been true at almost any time in the past. We've had a period in the last 50 to 60 years that has been particularly stable. That's been very rare in the history of humanity. I doubt it'll remain like this, but it doesn't mean that you have to exaggerate. Things take time to develop and people are resilient and I think there's a bright future ahead for the young people. It's just that I would wish that many of them were less depressed about what's happening.

It's good to be aware of the challenges. There are tons of them. But you gotta go and tackle them, and do the best you can, right? To me, I think it's a question of self confidence and realizing the future is yours. You are the ones that are coming up, young people, and in a few years, you're gonna be running the place here. It happens faster than you think.

Michel at his most recent Night with a Prof, with a group of Pħasers members.

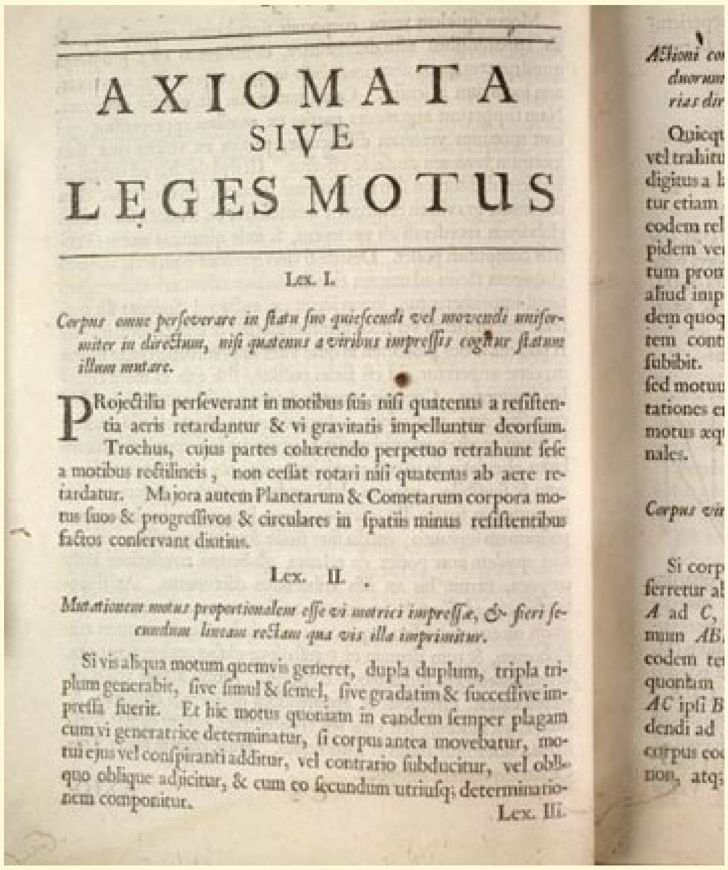
TECHNICAL TERMINOLOGY

Kyle Brown and Eliza Partridge

On the Nature of Laws

The English word "law" derives itself from the Old English "lagu" meaning "to fix or lie", and its first known use predates the 12th century. The word's meaning varies in different contexts, and it only became a standardized scientific term more recently. In the judicial sense, it may refer to governmental legal practices and legislation with colonial roots that includes common and civil law, or to traditional Indigenous justice systems. The scientific sense of "law" differs from the legal one, though its meaning is similar across the fields of astronomy, physics and mathematics. English is fairly young as a language for scientific communication, having only recently superseded Latin and French, but the equivalent terms saw increasing use in other languages from the 12th century onwards. The Latin word "*leges*", for example, was used by Roger Bacon to refer to various phenomena in his 1267 treatise *Perspectiva*. The term had gained more mainstream popularity in physics by the 1600s, appearing in Newton's 1687 *Principia* to describe his "*leges motus*" or "laws of motion".

The term "natural law" to describe the concept of inviolable structures dictating the way the natural world behaves is documented from the first century in Nicomachus' Introduction to Arithmetic, and may have been employed even earlier. However, its meaning in math and physics was not yet clearly defined. Many historians point to René Descartes as one of the first concrete users of the phrase in a scientific context. Descartes was educated as a lawyer, and was also a devout Catholic familiar with "canon law". His use of the term "natural law" in his mathematical treatises was in no small part inspired by the terminology employed in both his trained profession and his faith.


AXIOMATA
SIVE
LEGES MOTUS

Lex. I.

Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare.

Projectilia perseverant in motibus suis nisi quatenus a resistentia aeris retardantur & vi gravitatis impelluntur deorsum. Trochus, cujus partes cohaerendo perpetuo retrahunt sese a motibus rectilineis, non cessat rotari nisi quatenus ab aere retardatur. Majora autem Planetarum & Cometarum corpora motus suos & progressivos & circulares in spatiis minus resistentibus factos conservant diutius.

Lex. II.

Mutationem motus proportionalem esse vi motrici impressae, & fieri secundum lineam rectam qua vis illa imprimitur.

Si vis aliqua motum quemvis generet, dupla duplum, tripla triplum generabit, sive simul & semel, sive gradatim & successive impressa fuerit. Et hic motus quoniam in eandem semper plagam cum vi generatrice determinatur, si corpus antea movebatur, motui ejus vel conspiranti additur, vel contrario subducitur, vel oblique oblique adjicitur, & cum eo secundum utriusq; determinationem componitur.

Lex. III.

A page of the first edition (1687) of Newton's *Principia*, containing the phrase "*leges motus,*" Latin for "laws of motion."

The Isaac Newton Apple Trees at TRIUMF, seven scions of the original apple trees at Newton's family home.

In physics today, a law of nature must be invariant with respect to both time and space, meaning that it is true everywhere and at all times. As a description of how the surrounding world works, natural laws in physics must include a statement of the limited physical conditions under which they are valid and be supported by experimentation. This differs from math, where a law most often means a proven relationship or axiomatic definition that has very broad applicability in a given subfield. Familiar examples from math and physics include the commutative law for addition of the natural numbers and the law of universal gravitation respectively. "Law" may also be used in empirical statistics, where a statistical law in a complex system is a proposed correlation or definition based on empirical data, such as the law of large numbers.

Mathematical principles and scientific phenomena known well into antiquity by members of different cultures around the world were renamed as laws in the western world when the term began to gain popularity. For instance, what is now called the law of sines was proposed by Ptolemy of Egypt in the second century and was further developed by the Persian mathematician and astronomer Abū al-Wafā al-Būzjānī in the 10th century, who proved the spherical case. Further work was done in the 13th century by Persian mathematician Naṣīr al-Dīn al-Ṭūsī and in the 16th century by German astronomer and mathematician Regiomontanus, the latter of whom published one of the first full European compilations of trigonometry. It was only in the mid-1800s that this relation between a triangle's side lengths and the sines of its angles came to be known as the law of sines, nearly two millennia after it was first documented.

While mathematics, physics, and astronomy have rich vocabularies of jargon, there is no central organizational body responsible for the maintenance of conventions and naming of laws in these fields. Instead, accepted terminology is the result of the academic community adopting and maintaining the names of laws through publications. This allows privileged individuals to disproportionately influence the language of science. Consequently, many eponymous laws were not named after their discoverers, and the figures they immortalize can indicate the political and social conditions under which they were named. What is commonly called Snell's law in English is more often called Descartes' law in French, and occasionally Ibn-Sahl's law in other languages. The various names prioritize different parts of the law's history.

It is thus an exercise for the reader to discover the origin of the name of a law or other term they encounter. Students are encouraged to dig into the history of the scientific and mathematical language they take for granted, and to consider the context they might otherwise overlook.

Ninth century astrolabe, which uses the law of sines to make astronomical predictions.

Alia Damji

Across the Divide

The following is a work of fiction, and as such is not bound by the rules on scientific accuracy that we uphold throughout the rest of the publication. We acknowledge that quantum mechanics is a field whose misrepresentation has become a common literary device, especially in science fiction. Doing your due diligence to determine where the science ends and poetic license begins is a responsible practice.

I never expected to have a conversation with myself—at least, not with a self that answered back. Our project started out innocently enough, a bold attempt to entangle quantum states across dimensions. The math worked on paper, but none of us was confident it would actually *work* work.

And yet, here I was, staring at the data stream on my screen. At first, it looked like random noise—a cascade of quantum state measurements jittering in and out of coherence. But as I analyzed the sequence, patterns emerged. It wasn't noise. It was binary.

I ran the sequence through a translator. The message was short, chillingly deliberate:

Finally, we've connected. *—Kira*

I glanced around the lab. The usual hum of equipment and quiet chatter continued as if nothing had happened. I flipped open a notebook and pretended to jot down a reminder. My heart was pounding.

The connection was faint at first—little glitches in the experiment's setup. But as I leaned into it, the signals became clearer. I wasn't just entangling particles across dimensions, I was talking to *me*. Well, a version of me.

There was the version of me who'd pursued art instead of physics. Another who'd dropped out of school to start a bakery. Every choice I'd never made, every path I didn't take, existed out there. And somehow, I'd built a bridge with one of them.

At first, it was fun. Harmless, even. We swapped stories, compared favourite books, and debated whether pineapple belongs on pizza (it absolutely does). It felt like chatting with an old friend who just happened to share my face. But then things started... changing.

It started with small things. My lab notebook wasn't where I'd left it. Keys disappeared and reappeared in places I never put them. At first, I chalked it up to stress. I was juggling too many late nights and too much coffee.

Then people around me started acting off. My colleague Jess called me by a nickname I've never used. Our lab manager insisted I'd sent an email rescheduling a meeting—an email I'd never written.

The strangest part? Every time I connected with my alternate self, the anomalies grew worse. I'd asked my alternate, a version of me who stayed in academia but chose theoretical work, for advice on a project. The results were a disaster. Equations she'd suggested I use returned impossible results, and when I tried to explain my intentions to my team, the words sounded foreign, like someone else was speaking through me.

And then there was the book.

The other Kira had casually mentioned a novel she loved. "It's an old favourite," she'd said. I didn't think much of it at the time. But when I went to my bookshelf later that night, there it was. I hadn't bought it. I hadn't even heard of it before that conversation. And yet it was there, sitting front and centre, as if it had always belonged.

I stared at it for what felt like hours. The edges of the room seemed to ripple, like I was underwater. Was I imagining this? Or was my reality slipping out of place?

Time, once my reliable companion, turned fickle. I'd arrive early to a meeting only to be told I was late. My morning coffee would be cold, as if it had been sitting out for hours, even though I'd just poured it.

People around me became inconsistent too. Jess, who always hated coffee, was suddenly sipping a latte like it was her usual order. My roommate swore I'd told her I was going to visit my parents for the weekend.

Then came the worst part: I started to feel like I wasn't alone in my own head. There were moments when I'd look in the mirror and catch a flicker of someone else looking back. Not a stranger—me, but different somehow.

One time, I could swear I was in two places at once. I was sitting in the lab, staring at a screen full of data, when I felt it: a pull, like a rubber band stretched too tight. For a split second, I was in my apartment, holding that mysterious book. Then I snapped back to the lab, gasping for air.

Theories spun through my mind like a tornado. Were the alternate dimensions merging with mine? Or was my perception of reality fracturing under the weight of the connection? Neither answer offered much comfort.

I thought I could fix it. Isn't that what I do? Analyze the problem, find the variables, and determine a stable solution. But the more I tried to make sense of what was happening, the worse it got.

Desperate, I tried to sever the link. I stopped responding to the other Kira, shut down the entanglement experiment, and avoided anything that might trigger another interaction. But the anomalies persisted, growing wilder with each passing day.

I sat alone in the lab, staring at the blinking console. The equipment hummed softly, oblivious to the havoc it had unleashed. Around me, reality felt fragile, like a jigsaw puzzle missing key pieces.

Every interaction with my alternate self had left subtle, irreversible distortions in my world that I could no longer ignore. I had to make a choice: disrupt the quantum connection we'd discovered, or risk causing catastrophic damage to my own reality.

The entanglement wasn't just a connection. It was a resonance, a symphony of harmonized states threading through the multiverse. To silence it, I had to break the harmony, introduce dissonance. But dissonance in a quantum system wasn't easy to create; randomness had to feel almost deliberate.

I configured the lab's electromagnetic field generator to emit a chaotic pattern, a kind of white noise. The theory was sound, but the execution was risky. If the pattern synced with the wrong frequency, the entanglement could spread instead of being severed.

The system hummed ominously as the generator powered up. I glanced at the console one last time. My reflection stared back at me from the darkened screen, but there was something off. A flicker. A shadow. Was it me, or... a different me?

“Here goes nothing,” I muttered, activating the sequence.

The room seemed to twist, the air charged with static. A high-pitched whine filled my ears, and the display screens flickered wildly. I watched as the quantum states on the monitor began to unravel, their coherence giving way to noise. But as they did, the noise became deafening—not just audible, but visible and tactile. The lab felt like it was disintegrating around me.

All at once, it stopped.

I gasped for air, the silence in the lab more unsettling than the chaos. The console was dark. The resonance, the connection—it was gone. But the air felt heavier somehow.

As I walked home that night, I passed a bookstore. In the window was the novel that had appeared on my shelf. I stopped and stared, my reflection merging with the book’s cover in the glass.

Maybe I’d closed the door. Or maybe it was still ajar, just enough to let the chaos peek through.

Authors Listed Inline

Tech Testimonials

Familiarizing yourself with a variety of programming languages and software packages can make your experience as a student easier in myriad ways, but there are so many options out there that it's difficult to decide what's worth the effort of learning. Your fellow Pħasers members are here to help with that decision! The following is a list of digital and computational tools that physics and astronomy students recommend using to get a leg up in your coursework, your research, and your future career.

Statically Typed Languages (C, C++, Rust, etc.)

Ollie D. Brown

Many research positions and industry jobs require a basic understanding of programming, and for most practical purposes knowing Python can be enough. Python is fairly simple to understand, has many scientific and statistical computing packages, and can be utilized for projects that range from small scripts all the way up to humongous codebases. However, most of the Python packages that we import with nearly every script (SciPy, NumPy, nearly anything that does large computations) are written using a compiled and statically typed language such as C/C++ or Rust.

Compiled languages require the code to be put through a compiler, which optimizes the program for you and translates our human-readable code into machine-readable code for efficient execution. Statically typed means that everything in your code must be defined to be a certain variable type, such as an integer or floating point value. C/C++ and Rust are lower-level languages that are statically typed, which roughly translates to stricter rules for writing code. But they are orders of magnitude faster than Python, which is dynamically typed. The dynamical typing of Python makes writing code easier, but requires the computer to check what type of variables are being used at every step of the program, which slows processes down. Since nearly all the packages we use are written using these compiled languages, it is handy to understand a little bit of what is going on under the hood. Not only for your sake while debugging, but also in case you ever find yourself needing to write your own lower-level code, which is not as uncommon as it may sound!

LaTeX

Amith Valath

If you've looked at research papers or even some of the notes given in class, you might have wondered how those consistent fonts and spacings are achieved. Trying to use Microsoft Word or Google Docs to mimic such formats quickly becomes a headache due to all the formatting issues. For those who haven't encountered this problem, it presents itself with a vengeance in third year physics labs. Unlike second year labs, which use black notebooks to write reports, third year labs require reports similar to scientific papers. This can be quite challenging for those used to pen and paper. Moreover, the dramatic increase in coursework in third year leaves less time to get acquainted with alternative text editors.

LaTeX solves many of these problems because of how it is designed. All text must be assigned to a chosen section type, which ensures uniform formatting and prevents spacing issues. But writing reports with LaTeX can initially be slow compared to writing by hand due to the time required to become fluent. This is where Overleaf shines. It shows syntax errors in real time and has an option to make the LaTeX writing process similar to MS Word for an easier transition. Many other features like copying and pasting tables directly from Word into your code save users from having to learn extra LaTeX syntax. What's even better is pairing the typesetting process with ChatGPT, which is very reliable for coding in LaTeX. Learning LaTeX before the third year would be ideal, so that you have the skills under your belt before you're crunched for time mid-semester.

Sahil Mehmi

LaTeX was first introduced to me in Math 122: Logic and Foundations, as a bonus part in an earlier assignment. This involved using the program to format a specific question, and for me, this was enough motivation to learn LaTeX! An initial text file was provided to update which was great for beginners like myself, but I wanted to learn more, like how to write integrals or partial derivatives. After some scrolling through Google and YouTube, I was introduced to the YouTube series "LaTeX Tutorials" by Dr. Trefor Bazett, a prof here at UVic. After a short while of binging these, I felt like an expert.

Currently I use LaTeX to complete all my lab reports and any other professional scientific documents, and I'm really glad that I took the time to learn it. It might seem complicated at first but in the end it is very rewarding.

$$\omega = \sqrt{\omega_0^2 - \left(\frac{b}{2m}\right)^2} \tag{9}$$

for underdamped oscillations. Note that for a sufficiently high b value, specifically $\frac{b^2}{4m^2} \geq \frac{k}{m}$, the oscillator will be critically damped or overdamped, at which point no oscillations occur, and the oscillator returns to equilibrium with no oscillation.

By comparing two successive peaks in the motion, the damping constant can be determined as follows, with T being the period of motion.

$$\frac{x_1(t)}{x_2(t)} = \frac{A_0 e^{-\frac{b}{2m}t_1}\cos(\omega t_1)}{A_0 e^{-\frac{b}{2m}(t_1+T)}\cos(\omega(t_1+T))} \tag{10}$$

$$= e^{\frac{b}{2m}T} \tag{11}$$

which can be solved for b as

$$b = \frac{2m}{T}\ln\left(\frac{x_1}{x_2}\right) \tag{12}$$

Short LaTeX snippet, which is one column of a double-column page.

Linux

Jacob Atkinson

No matter what area of research you plan to pursue in physics or astronomy, familiarity with a command-line interface on Linux or Unix systems is becoming essential. Research software—such as MadGraph for particle physics, ppmstar for stellar interiors, or TOPAS for medical physics—often comes pre-built and runs best on powerful computing systems. When these calculations are computationally expensive, your advisor may direct you to run them on supercomputers or on local clusters here at UVic. In these environments, you'll interact almost exclusively with Linux terminals via secure shell (SSH) protocols. Mastering basic commands and file manipulation early on will streamline your workflow and allow you to focus on the science itself, rather than on troubleshooting system navigation. Whether you're managing data, running simulations, or automating repetitive tasks, the command line is often the most efficient, flexible tool you'll have. Knowing how to use it will set you apart as you progress in your studies and research.

Allen Keefe

Knowing the basics of Git and Linux commands can be very helpful. Not only are these skills very useful for research, they can also come up in your classes, so familiarizing yourself with the basics on your own time will certainly come in handy in the future. For example, homework assignments and exams in PHYS 248: Computer Assisted Math & Physics are saved and submitted using Git commands via a Linux terminal, and knowing some file manipulation terminal commands is very helpful when it comes to organizing your environment. These concepts are introduced early on in the course, but going in already knowing a few things can make for a much smoother start. A later course that uses these skills is ASTR 329: Observational Astronomy. It relies on the terminal to access and complete lab work, depending on your personal Python interface.

Julia

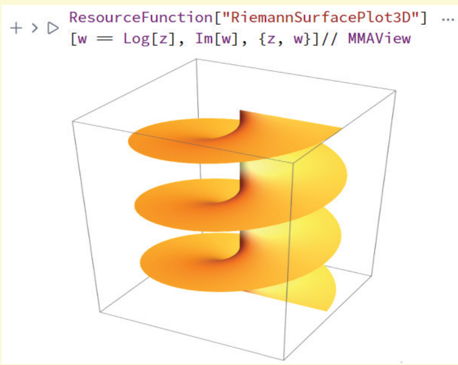
Dominic Largoza

Julia is a programming language that was initially designed for numerical and scientific computation, allowing large calculations to be made quickly and efficiently. This makes it very useful for physicists, as it can compile large amounts of data or create comprehensive visualizations. In terms of functionality, it is nearly identical to Python. There are only a few nuances, such as lists being indexed starting from one instead of zero. So if you already know Python, Julia is simple to learn and definitely worth picking up. My experience with Julia was helping my research group to develop the DMRjulia package, which is a package used for tensor network calculations. We used Julia because it is significantly faster than Python, especially for datasets at the scale this research required. If you want to learn more, Julia is a well documented language and there are many resources out there.

Mathematica

Owen Sandner

Any question you have can be answered by Wolfram|Alpha—until it can't. If you've ever tried to compute a massive integral, Wolfram will throw a computation time error, limiting you to simple integrals and equations only. This is where Mathematica comes in. Wolfram runs on Mathematica, so if you can run Mathematica on your machine, you'll have the capabilities of Wolfram|Alpha without any limits. In your classes, depending on the professor, you can use Mathematica to solve integrals and other math problems; all you need to do is include a code snippet when you submit your assignment!



This Riemann surface plot of the complex logarithm was generated using Wolfram Engine with the WLJS Notebook frontend.

Eliza Partridge

This is great, but how do we get over the paywall? Students previously had access to Mathematica licenses through UVic, but those are expiring this year. Instead, you can download Wolfram Engine, a free terminal-style Wolfram Language interface. Then install a free notebook frontend (many are available for download—WLJS Notebook is a good one), and you've essentially recreated Mathematica!

One of the nicest characteristics of the Wolfram Language is that since it is a very high-level language, commands are intuitive and painless to learn. Even better, it is tailored to scientific computing applications, with some really handy symbolic expression manipulation and graphing capabilities built in. My favourite application of Mathematica (beyond its convenient integration functions) is data visualization. Heat maps and contour plots, 3D graphs, and representations of the complex plane can all be generated with a few lines of comprehensible code and don't require importing new packages, as opposed to our old friend Python. Plots are interactive by default and can be zoomed and, in the 3D case, rotated. Sliders are easy to add to visualize the effect of changing parameters.

MATLAB

Cameron Louie

MATLAB is a coding language designed with scientists and engineers in mind. Most things that can be done in MATLAB can also be accomplished with Python, but I personally found the MATLAB environment to be easier to work with and the plotting syntax to be less of a headache to learn. There are a plethora of online resources for help with MATLAB, when you inevitably run into coding problems. As a geophysicist, plotting data collected from gravity surveys to construct models for inner earth structures is much easier with MATLAB, and I can recommend trying it out to see if it works for your uses too!

Adithi Balaji

Last summer, I was working on assessing the impact of a pointing error on the performance of a spectrometer for an upcoming CSA satellite mission. To figure out how significant errors from off-target pointing would be, I performed a spatial autocorrelation analysis on a variety of satellite images of varying surface type. While you could do this in Python, I found MATLAB's signal processing toolkit to have many built-in functions that were much better optimized for high-resolution imagery.

pandas

Martin Williamson

```
import numpy as np
```

We all love NumPy. Fast, efficient, and perfect for numerical calculations and plotting. It's a physics student's bread and butter. But what about when datasets get large (think millions of data points)? Or when you're working with a time series that has missing values due to sensor malfunction or power disconnect? NumPy doesn't like NaNs! The solution? pandas.

```
import pandas as pd
```

Think of it as an Excel spreadsheet, but better. With pandas, handling, cleaning, and analyzing your data becomes effortless. You can collect datasets from sensors in the field, read in the CSV files, clean the data, combine it into a huge dataset, and plot the results all before lunch. Easy. So the next time you're dealing with large time series or environmental data, think pandas.

Jay Robertson

I once wrote a program that needed to read in information from a 1000 line CSV file and filter the data based on specifications I provided. Rather than the tedious task of going line by line and column by column looking for cases that matched (a highly computationally intensive, slow, and memory-inefficient process that we all know Python does not handle well), I was able to use pandas to filter the data almost as simply as a grep terminal command. By importing pandas, my code ended up being simpler, faster, and took about half the time to write.

Plotly

Sujit Suram

I used Plotly for PHYS 411: Time Series Analysis. I wanted to produce interactive plots—to plot a bunch of time series, for example, and zoom in on a certain section that I found interesting. Matplotlib's interactive functionality was too limiting, at least with the understanding I had of it. I always had to invoke `.xlim(x0,x1)` and `.ylim(y0,y1)`. Eventually I got sick and tired of this, and with a brief Google search I found Plotly. I never had to transition from my existing code: I would just use ChatGPT to convert directly from Matplotlib to Plotly. It was as simple as that. I could grab a section of the plot and scroll in and zoom out, and even take screenshots. Plotly gave me an interactive version of Matplotlib.

Kyle Brown

I was introduced to the web GUI version of Plotly in first year physics as the recommended plotting software in the PHYS 110 and 111 lab manuals. The link in the manual PDFs took me straight to the online chart studio where I could directly enter or import my spreadsheet data to be plotted. Plotly's clean user interface made this very easy. In particular, Plotly's Zoom In and Out feature was useful in identifying the trends and behaviour of a smaller region that might not otherwise be obvious. I could then directly export this region of the graph as an image file to be typeset in a report later. Beyond the interactive viewing, Plotly has all the other features you would expect in a spreadsheet editor such as error bars and trendlines, making it a viable alternative to Excel and Sheets. Upon using the Python package version of Plotly I found all the same functionality and features were present, with the added benefit of being able to leverage other Python packages, such as pandas, simultaneously.

Word Search

B	N	A	I	Z	I	X	Z	H	R	Y	T	I	N	T	L	X	A	X	N
Y	R	X	D	V	Q	W	V	O	O	L	R	R	D	C	X	M	Z	M	E
X	U	J	G	J	P	T	V	G	V	A	U	P	Z	O	J	A	H	A	E
P	S	W	T	B	K	E	P	F	E	N	W	M	K	M	S	R	Z	F	T
X	T	M	C	R	Z	S	V	K	R	G	N	P	P	P	A	F	Y	F	Q
G	N	A	N	P	V	A	D	M	L	U	H	I	M	I	D	L	M	N	G
X	A	T	W	Y	T	T	Y	A	E	A	B	A	H	L	N	O	W	E	Z
C	R	H	C	E	G	A	B	T	A	G	H	T	O	E	A	W	P	X	A
I	E	E	R	O	S	D	K	L	F	E	N	N	Q	D	P	T	L	Y	F
T	S	M	Q	J	M	D	M	A	Q	W	A	M	S	F	Z	O	O	T	V
A	E	A	V	B	Q	P	D	B	D	O	H	G	D	R	E	B	T	R	Z
T	A	T	E	H	X	Q	U	M	C	Z	P	W	M	E	Y	Z	L	V	E
S	R	I	L	Z	Z	C	O	T	H	H	J	M	F	G	X	X	Y	S	Q
N	C	C	V	Z	Y	G	P	F	A	B	D	B	L	A	F	T	G	H	H
E	H	A	E	T	I	C	Z	Y	V	T	R	E	S	K	Y	F	W	O	O
Y	Y	C	J	L	D	C	T	K	T	Q	I	B	O	C	G	S	R	L	Z
U	D	R	Y	O	I	T	H	H	H	H	I	O	J	A	J	U	L	I	A
T	Y	P	E	S	E	T	T	I	N	G	O	U	N	P	R	Y	P	N	F
Z	H	J	G	R	R	B	N	F	V	N	A	N	N	E	Y	R	P	U	I
L	A	T	E	X	O	D	L	N	A	Y	M	S	M	P	A	A	Q	X	B

Words appear in straight lines horizontally, vertically, and diagonally down and to the left

COMPILED
MATHEMATICA
RESEARCH
COMPUTATION
MATLAB
RUST

DATASET
OVERLEAF
STATIC
JULIA
PACKAGE
TYPESETTING
LANGUAGE

PANDAS
WOLFRAM
LATEX
PLOTLY
LINUX
PYTHON

References and Credits

Student Spotlight: ALMA, by Lauren Harrison

[1] ALMA Website. https://www.eso.org/public/teles-instr/alma/
[2] ALMA Primer YouTube Channel. https://www.youtube.com/@almaprimer920
[3] Event Horizon Telescope Collaboration et al. 2019 *ApJL* **875** L1. https://arxiv.org/pdf/1906.11238
[4] Event Horizon Telescope Collaboration et al. 2022 *ApJL* **930** L12. https://iopscience.iop.org/article/10.3847/2041-8213/ac6674/pdf

Astro drawn by Natalie Perelygin, peregyr.com, @peregyr_art on Instagram

Logo by Grace Tomasi and Owen Sandner

Thrilling Thought Experiments: Falling Bodies, by Allen Keefe

[5] Galileo Galilei, Galileo's Two New Sciences, p. 61-70. http://galileoandeinstein.physics.virginia.edu/tns61.htm
[6] Galileo Galilei, On Motion. https://galileo.library.rice.edu/sci/theories/on_motion.html
[7] NASA, The Apollo 15 Hammer-Feather Drop.

Falling duck drawn by Holly Partridge, @themoonmollusk on Instagram

Logo by MJ Anderson

The Elliott Exclusive: Lefebvre's High-Energy Chat, by Ash Samra

[8] Geodesic dome: https://archivesdemontreal.com/documents/2015/06/004_VM94-EX136-779.jpg. Credit: Yvon Bellemare, 1968
[9] Young Michel LHC Photo: https://particle.phys.uvic.ca/~lefebvre/pics/lefebvre_lhc.jpg. Credit: Michel Lefebvre, 1996

All other images taken by Ash Samra, Owen Sandner and MJ Anderson

Logo by Owen Sandner

Technical Terminology: On the Nature of Laws, by Kyle Brown and Eliza Partridge

[10] Merriam-Webster Dictionary, Law. https://www.merriam-webster.com/dictionary/law
[11] Online Etymology Dictionary, Origin and History of Law. https://www.etymonline.com/word/law
[12] Nicole Schabus, Implementing Truth and Reconciliation Commission Calls to Action, Ch 3: Indigenous Laws. https://implementingtrc.pressbooks.tru.ca/chapter/natural-law/
[13] Jane E. Ruby, The Origins of Scientific "Law". Journal of the History of Ideas.

[14] Jacqueline Feke, Ancient Greek Laws of Nature. https://www.sciencedirect.com/science/article/pii/S003936812400058X
[15] Peter Harrison, The Development of the Concept of Laws of Nature.
[16] John Tabak, Mathematics and the Laws of Nature Developing The Language of Science.
[17] Weisstein, Eric W., Law. MathWorld-A Wolfram Resource. https://mathworld.wolfram.com/Law.html,
[18] Jonathan Law, Richard Rennie, A Dictionary of Physics.
[19] Steven Schwartzman, The Words of Mathematics. An Etymological Dictionary of Mathematical Terms used in English.
[20] Ian F. Putnam, MATH 212: Introduction to Algebra Course Notes
[21] Eduardo G. Altmann, Understanding Complex Systems, p. 8.
[22] Richard Earl, James Nicholson, Oxford Concise Dictionary of Mathematics.
[23] Britannica, Law of Sines. https://www.britannica.com/science/law-of-sines
[24] Britannica, Ptolemy. https://www.britannica.com/biography/Ptolemy
[25] Britannica, Abu al-Wafa. https://www.britannica.com/biography/Abu-al-Wafa
[26] St Andrews University, MacTutor: Earliest Known Uses of Some of the Words of Mathematics. https://mathshistory.st-andrews.ac.uk/Miller/mathword/l/
[27] International Astronomical Union. https://www.iau.org/Iau/Iau/About/About.aspx
[28] International Math Union. https://www.mathunion.org/organization/about
[29] International Union of Pure and Applied Physics. https://iupap.org/
[30] Steven Strogatz, What Makes for 'Good' Mathematics? Quanta Magazine. https://www.quantamagazine.org/what-makes-for-good-mathematics-20240201/
[31] Laura Ball, Why Mathematicians Should Stop Naming Things After Each Other, Nautilus. https://nautil.us/why-mathematicians-should-stop-naming-things-after-each-other-237951/
[32] Alistair Kwan et al., Who Really DIscovered Snell's Law? Physics World. https://iopscience.iop.org/article/10.1088/2058-7058/15/4/44/pdf

Principia image credit: Library of Congress, World Treasures: Beginnings, Newton's Laws of Motion. www.loc.gov/exhibits/world/earth.html#obj123

Astrolable image credit: Khalili Collections
https://www.khalilicollections.org/collections/islamic-art/khalili-collection-islamic-art-planispheric-astrolabe-sci430/

Newton Trees image credit: Denaisha Kraft

Special thanks to Rowan Dowler and Maya Mishra
Logo by Owen Sandner

Psi-Phi: Across the Divide, by Alia Damji

[33] John Gribbin, The Many-Worlds Theory, Explained, MIT Press. https://thereader.mitpress.mit.edu/the-many-worlds-theory/
[34] Chad Orzel, How Do You Create Quantum Entanglement? Forbes. https://www.forbes.com/sites/chadorzel/2017/02/28/how-do-you-create-quantum-entanglement/

Bookstore Window drawn by Holly Partridge, @themoonmollusk on Instagram

Logo by Owen Sandner

Academic All-Star Advice: Tech Testimonials

C, C++ logos used under public domain
Rust, LaTeX and Julia logos used under Creative Commons license
DMRjulia logo courtesy of Dr. Thomas E. Baker
LaTeX snippet courtesy of Owen Sandner
Riemann surface courtesy of Eliza Partridge

Logo by Kyle Brown
Special thanks to Sandhya Rottoo

Publication Team

Editor-in-Chief: Kyle Brown
VP Publications: Owen Sandner
Copy Editing Lead: Eliza Partridge
Design Lead: Grace Tomasi

Copy Editors: Eliza Partridge, Owen Sandner, Kyle Brown, Ash Samra, Alia Damji
Designers: Grace Tomasi, MJ Anderson, Owen Sandner
Cover Image and Writeup: Roan Stafford, special thanks to Stuart Shepherd