Pacific Institute for the Mathematical Sciences

NEWSLETTER

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Spring 2015

Event Spotlight

Frontiers in Biophysics

March 14, 2015 at the Djavad Mowafaghian Centre for Brain Health, UBC

This event, which encourages discussion and collaboration within the mathematical biology and biophysics community in the Pacific Northwest, attracted approximately 100 participants from UBC, SFU, BCIT, UVic, U Washington and other institutions, with academic backgrounds ranging from math and physics to neuroscience and engineering.

For graduate and undergraduate students, who comprised about 70% of the attendees, this conference was particularly beneficial and about half of the talks, and most of the posters, were presented by graduate students. Katie Goodwin (MSc student at UBC) won best talk for "Cell-ECM adhesion is required for force transmission during morphogenesis," and Jacob Price (PhD student at the University of Washington) was the runner up for discussing "Beyond Structure-Function Relation: A Biochemical Circuit with Kinetically Regulated Activation-Inhibition Switching." Momcilo Gavrilov won best poster for "Scattering-based illumination for a feedback trap," and Laura Geisler was runner up for "DNA replication: Inferring what happens and when." Congratulations to the winners and all the presenters for such diverse and intriguing work!

One of the highlights of this conference is always the keynote speaker, who delivers an in-depth lecture on a rapidly-developing area of mathematical biology or biophysics. This year's keynote was given by Dr. Michael Hasselmo, the director of the Center for Systems Neuroscience at Boston University, and the Principal Investigator of an NSF EAGER grant for the Initiative on Physics and Mathematics of Neural Systems. His lecture was on "Grid cells and the Dynamics of Entrohinal Cortex". Grid Cells are neurons in the brain that fire in a spatially-periodic way as an animal moves through an environment. These, along with the place cells that fire in specific locations, are often referred to as the "brain's GPS system". The discovery of these cells was the basis for the 2014 Nobel Prize in Medicine or Physiology. After the conference, Dr. Hasselmo joined a group of interested students, postdocs, and professors for dinner, where this work was discussed in more detail.

The conference was a great was a success, with ample opportunity for participants to present and learn about the diverse research being performed locally and the many of new challenges in this field. We are already looking forward to next year's conference!

While PIMS was the primary sponsor for this event, the event was also made possible by the support of a number of other generous sponsors including: Bruker; LightIntegra Technology; the UBC Department of Physics and Astronomy; the UBC Institute of Applied Mathematics and the UBC Graduate Program in Neuroscience.

What's Inside

Director's Message

After 10 years at PIMS, first as Deputy Director and then as Director, Alejandro Adem stepped down from his position on February 1st, to become the new CEO of MITACS. We are sad to lose Alejandro, but he is leaving PIMS in excellent shape, with stable (and increased) funding over the next few years. We wish Alejandro all the best in his new position.

I have been appointed Interim Director of PIMS through to June 2016; and as previously announced, James Colliander will join PIMS as Deputy Director this summer. We are pleased to welcome Michael Lamoureux to our new position of PIMS Innovation Coordinator; he will be building on our existing programs to extend the collaborations between mathematical scientists and industry. This is a joint project with the CRM and Fields and is supported by the NSERC Research Partnerships Program.

This April saw the start of two new Collaborative Research Groups (CRGs). The CRG on Abelian Varieties is coordinated by Michael Jacobson at UCalgary. Abelian Varieties are classical and fundamental objects in algebraic geometry, but they have recently found new applications in coding theory and cryptography. This CRG will focus on the computational aspects of the theory, an area which is assuming increasing importance. The CRG on Applied Partial Differential Equations is based at SFU, UBC and UAlberta and will focus on nonlinear PDEs, especially those which give rise to pattern formation.

Two further CRGs, on Algebra and on Geometric Analysis, were approved by PIMS' Scientific Review Panel (SRP) in October and will start in 2016.

PIMS has many exciting activities planned for the summer. A major conference at SFU will honour the 80th birthday of Ron Graham, who has assisted PIMS in many ways and served on our SRP for nine years. Summer schools are taking on an increasingly important role in graduate education, and this summer PIMS will support five. Two of these are with our partners in Eastern Canada: a probability summer school at McGill (also supported by CRM) and a summer school on differential equations at Dalhousie (also supported by AARMS). A summer school at USaskatchewan is part of our Applied Combinatorics CRG, and is one of several events taking place there this summer. Finally, we have summer schools on rigorous computing at SFU and on the representation theory of finite groups at UBC.

Let me take this opportunity to thank PIMS' excellent staff, who have continued to run a smooth operation throughout the recent changes.

With best wishes,

Martin Barlow
Interim Director, PIMS

Pacific Institute *for the* Mathematical Sciences

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Math Manias

On November 18, 2014 at Torquay Elementary School (Victoria, British Columbia) approximately 120 parents, students and teachers attended a Math Mania. The special activity, Bubbles, was presented by Denny Hewgill, a University of Victoria Professor Emeritus. For this very popular activity, students are encouraged to dip various wire frames in a glycerine/liquid soap mixture to create interesting forms. (The shape of the bubble is given as a solution to Plateau's problem, an early problem in the calculus of variations).

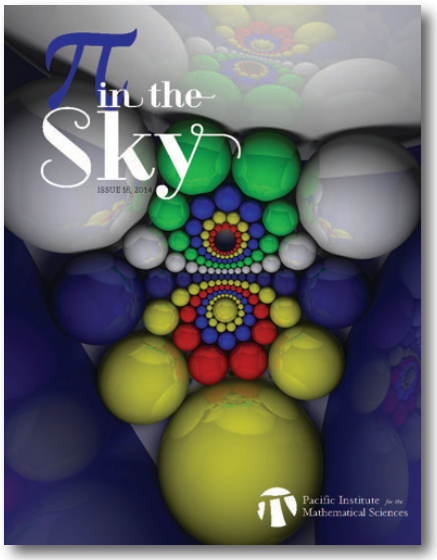
On Thursday, February 5, 2015, the Math Mania team of volunteers produced an event at View Royal Elementary School (near Victoria, British Columbia). The program has recently recruited a dozen student volunteers from the Math for Elementary Teachers course and was lucky to have them as a part of the team for this event.

Due to a very successful promotional campaign, nearly two hundred and fifty parents, kids and teachers were in attendance. The thoughtfulness and creativity was enjoyed by parents and children alike and included such activities as: Bubbles, the Set Game, Tower of Hanoi, Goats and Gold, error correcting codes, balancing blocks, straw constructions, puzzling popsicle sticks and the ever-popular Sorting Network.

The feedback from both events was very positive and, as usual, the team has been invited to return for more Math Mania events in the near future.

On Friday, March 6 2015, a group of UBC students taking Math 335 presented their Math Fair projects at a Math Mania hosted by Capilano University. In addition to the Math Fair projects, the math faculty at Capilano University presented a variety of mathematical activities. The Math Fair projects' common theme was Aboriginal Culture and Heritage. The event was made possible by PIMS, in partnership with UBC and Capilano University.

Pi in the Sky: Call for Submissions



Each year *Pi in the Sky*, a magazine which is intended for high school teachers and their students, is distributed to over 1500 math educators and students in over 15 countries worldwide. We are now accepting submissions for issue 19 and hope that you will consider submitting an article, or encouraging a colleague who you think may be interested.

To view previous issues, please visit *www.pims.math.ca/resources/publications/pi-sky*.

We welcome submissions at any time, but only articles submitted by July 1 will be considered for our next issue.

If you have any questions, or would like to submit an article, please contact Anthony Quas, Chief Editor, at aquas@uvic.ca.

Thank you!

Around the Sites

University of British Columbia Martin Barlow

UBC's many regular activities continue, including our numerous seminar series. In addition, the weekly Geometry and Physics Seminar, which is associated with the CRG in that area, is run jointly by UA and UBC, and is now being live-streamed between the two sites and captured for mathtube.org.

A number of high profile talks have already taken place in 2015, including the *IAM-PIMS Distinguished Colloquia* by Olaf Schenk (Institute of Computational Science, Universita della Svizzera italiana) and Dan Hammer (University of Pennsylvania), the *PIMS/UBC Distinguished Colloquia* with Tom Hou (Caltech) and Jill Pipher (Brown University) and the *CRM-Fields-PIMS Prize Lecture* with Kai Behrend (UBC) on *Algebraic Stacks and the Inertia Operator*.

James Colliander will be taking over as Site Director, part of his duties as our new Deputy Director.

Jill Pipher

University of Washington Christoper Hoffman

PIMS sponsors several lecture series at the UWashington campus, including the *UW-PIMS Mathematics Colloquium* and the *CORE Seminar,* an interdepartmental talks series focused on optimization, machine learning, big data, statistics and numerics. Recent colloquium lectures have included: Andrea R. Nahmod (University of Massachusetts, Amherst) on *Randomization and Long Time Dynamics in Nonlinear Evolution PDE*; Mark Rudelson (University of Michigan, Ann Arbor) on *Non-asymptotic Approach in Random Matrix Theory* and Lauren Williams (University of California, Berkeley) on *The Positive Grassmannian*. CORE Seminar speakers included: Peter Bürgisser (TU Berlin) on *Condition of Convex Optimization and Spherical Intrinsic Volumes*; James Renegar (Cornell) on *Extending the Applicability of Efficient First-Order Methods for Convex Optimization*; Jon Kleinberg (Cornell) on *Incentives for Collective Behavior: Badges, Procrastination, and Long-Range Goals* and Jeannette Wing (Microsoft Research) on *Computational Thinking*.

Simon Fraser University Nils Bruin

Barry Merriman

SFU saw a number of lectures in our *PIMS-CSC Distinguished Speaker Series* including: Barry Merriman (Human Longevity, Inc) on *How to Solve Disease on a Population Scale*; Lisa Fauci (Tulane University) on *Waving Tails, Flexible Fibers, and Sticky Situations: Explorations in Biological Fluid Dynamics* and Omar Ghattas (University of Texas at Austin) on *Bayesian Inversion for Large Scale Antarctic Ice Sheet Flow*. We also hosted a distinguished lecture by Michael Singer, on *Connections Between Galois Theory and Differential and Difference Equations*.

Upcoming scientific events include the *PIMS-SFU Undergraduate Summer School on Rigorous Computing* and the *Connections in Discrete Mathematics* conference in honour of Ron Graham. On the educational front we will have another edition of the *Changing the Culture* conference and, for the first time, a summer school for elementary math teachers.

University of Lethbridge Amir Akbary

Our weekly *PIMS Lethbridge Number Theory and Combinatorics Seminar* continued in fall and spring. The external speakers in fall were Kevin Henriot (University of British Columbia) and Soroosh Yazdani (Google). The list of the speakers in spring includes Robert Craigen (University of Manitoba) and Ram Murty (Queen's University). In January we hosted a PIMS distinguished visitor, Fairouz Kamareddine (Heriot-Watt University) who delivered two lectures entitled *Types and Functions Since Principia and Computerisation of Language and Mathematics* and *Computerising Mathematical Texts with MathLang*. This year our weekly *Fun With Math* sessions for high school students is organized and run by Jeff Bleaney and Allysa Lumley, former graduate students. In addition, Jana Archibald organized a *Day of Math* for junior high and high school students on March 29th – a contest that is divided into: *Bernoulli Trials*-made up of a number of true/false questions, *Math Jeopardy*, and the *Kangaroo Math Competition*.

University of Saskatchewan Raj Srinivasan

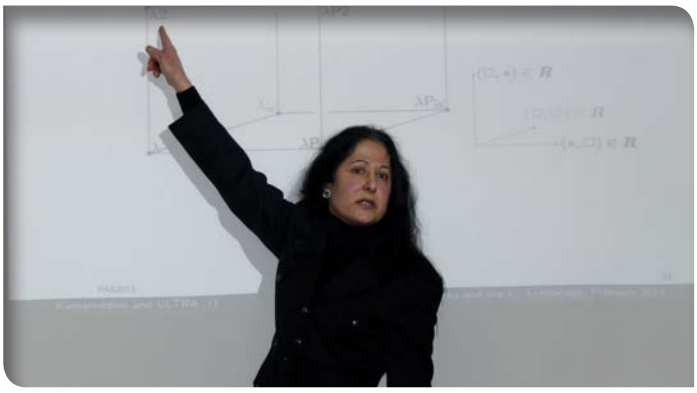
Stavros Stavrou, Saskatchewan's outreach coordinator, is currently working in 14 classrooms in 10 schools (including a school on Whitecap Dakota First Nation) presenting hands-on activities that explore the connections between math and local First Nations cultures. Some activities include: looking at patterns and geometry in Aboriginal artwork, factoring integers while counting in Cree, learning about probability through Indigenous games of chance and using the treaty map of Canada to motivate the coordinate grid.

In the coming months, the site prepares for the Applied Combinatorics Summer School (a CRG activity) and the Industrial Problem Solving Workshop.

University of Regina Donald Stanley

The URegina site has had a quiet winter session, with one highlight being the distinguished lecture with Stephen Kirkland on *Sensitivity Analysis for Perfect State Transfer in Quantum Spin Networks*. They are looking forward to hosting the *Combinatorial Constructions in Topology* conference this coming August.

University of Victoria Anthony Quas



Fairouz Kamareddine

A highlight at the end of 2014 was the Hugh Morris Lecture, delivered by Cedric Villani (University of Lyon & Institut Henri Poincaré and winner of the 2010 Fields Medal). The lecture boasted an attendance of over 300 people, including high school and university students, university faculty, UVic senior administration and community members. The year started strong, with two high-profile lectures from Rahul Mukerjee (Indian Institute of Management) and Sampath Kannan (Chair of the Department of Computer Science at the University of Pennsylvania). Upcoming, Mike Henning (University of Johannesburg) will be a PIMS Distinguished Visitor in 2015 and two conferences will be held on campus: *BC Combinatorics Day*, April 25th and a summer school and conference on *Applied Topology and High-dimensional Data Analysis*, in August.

University of Calgary Clifton Cunningham

Brian Russell

Research highlights include three PIMS Voyageurs: Ila Varma (Princeton) on the *p-adic Langlands Correspondence*; Charles Weibel (Rutgers University) and Juan Santos (Purdue University, Universidad de Buenos Aires). We also hosted Steve Awodey (Carnegie Mellon University) for the first lecture in a new series on *Mathematics and Philosophy*.

Industrial highlights include five P*IMS/Shell Lunchbox Lectures*: Brian Russell (University of Calgary, PIMS Chairman of the Board, VP Hampson-Russell); Ben Adcock (Simon Fraser University); David Wood (University of Calgary); Peter Forsyth (University of Waterloo) and Michael Doebeli (University of British Columbia).

Educational outreach highlights include *Math Mania* at Rosscarrock School, numerous professional development events with the Calgary Board of Education as well as Banff and Canmore high school teachers. Many thanks to Indy Lagu (PIMS Education Coordinator, Mount Royal University) for his hard work on this portfolio!

University of Alberta Charles Doran

UAlberta has continued its Distinguished Lectures with one by Rafael de la Llave (Georgia Institute of Technology) on *Geometric Mechanisms for Arnold Diffusion* and another by Edgar Knobloch (UC Berkeley) on *Spatially Localized Structures: Experiments, Theory and Numerics.* The site also hosted the *36th Annual Meeting of Alberta Statisticians* in October and the *Lie Theory Workshop on Geometry and Lie Theory* in May. Chuck Doran will complete his second term as site director on July 1; the search for a replacement is underway.

Explicit Methods for Abelian Varieties (2015-2018)

Abelian varieties are fundamental objects in algebraic geometry with a long, rich history of study. They are indispensable in number theory, and an important source of practical settings for cryptography. Although there are wide-ranging general structure theorems, efficient explicit computational tools required for applications are only available in the simplest cases.

Although many powerful theoretical advances have led to significant breakthroughs (eg. the Taniyama-Shimura-Weil Theorem and Fermat's Last Theorem, Weil descent and the elliptic curve discrete logarithm problem), efficient explicit methods for computing with abelian varieties in general are not known. For example, all abelian varieties by definition have a group law, but to date efficient methods to compute it are restricted to Jacobian varieties of algebraic curves, and most existing literature treats only the simplest cases of elliptic and hyperelliptic curves. Similarly, explicit methods to compute arithmetic data on abelian varieties, or even to tabulate interesting examples and tables of abelian varieties, only exist for relatively simple cases. Cremona's extensive tables of elliptic curves over the rationals of bounded conductor are a well-known resource that has proved to be valuable to many researchers, but there is very little data available for other types of abelian varieties. Even for the simplest case of algebraic curves, there is considerable interest in improving the state-of-the-art in these areas.

The CRG on Explicit Methods for Abelian Varieties represents an extensive network of regional, national, and international researchers focused on improving the state-of-the-art in this area. Building on existing relationships, we plan new partnerships and joint activities that will enable us to continue working together for years to come.

Research Interests

- Properties of Galois representations and automorphic representations attached to Abelian varieties
- Prym varieties and intermediate Jacobians
- Constructing varieties with given endomorphism rings, zeta functions and related properties
- Rational points on moduli spaces
- Point counting on varieties over finite fields
- Efficient group arithmetic for Abelian varieties
- Cryptographic applications of Abelian varieties

Organizers: Jeff Achter (Colorado State University), Amir Akbary (University of Lethbridge), Mark Bauer (University of Calgary), Nils Bruin (Simon Fraser University), Craig Costello (Microsoft Research), Clifton Cunningham (University of Calgary), Laurent Imbert (CNRS, Montpellier), Michael Jacobson (University of Calgary), David Jao (University of Waterloo), Kumar Murty (University of Toronto), David Roe (University of British Columbia), Renate Scheidler (University of Calgary), Andreas Stein (Oldenburg, Germany), William Stein (University of Washington)

$$\frac{\left|H_{X/K,\ell} - J_{\ell,m}(G)\right|}{\left|H_{X/K,\ell}\right|} < C'$$

$$\sigma_{\mathfrak{b}^{-1}}(\mathfrak{a}, \xi, B) = \left(\mathfrak{a}\,\mathrm{N}_{\Phi^r}(\mathfrak{b}), \frac{\xi}{\mathrm{N}(\mathfrak{b})}, \gamma(B')\right)$$

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Applied Partial Differential Equations: Modeling, Analysis, and Computation (2015-2018)

The scientific focus of this CRG will be to study nonlinear partial differential equations (PDEs) with particular emphasis on problems involving pattern formation, defined in the broadest sense. Specific topics in this area include the study of reaction-diffusion patterns with applications to the biological and social sciences, the study of nonlocal PDE and ODE models of swarming or collective behavior and problems involving concentration or localization behavior including singularity formation and the interplay between geometry and PDEs.

The mathematical methodologies needed to analyze problems in this area include stability and bifurcation theory, asymptotic and singular perturbation analysis, stochastic methods, dynamical systems, symmetry methods, differential geometry and PDE analysis. From a numerical viewpoint, several areas of focus that have direct applications to pattern formation problems are the development of algorithms for computing PDEs on surfaces, the design of fast multipole methods based on integral equation formulations, the development of numerical methodologies for rigorous computing and numerical methods for the computation of sharp interfaces using front tracking or level set methods.

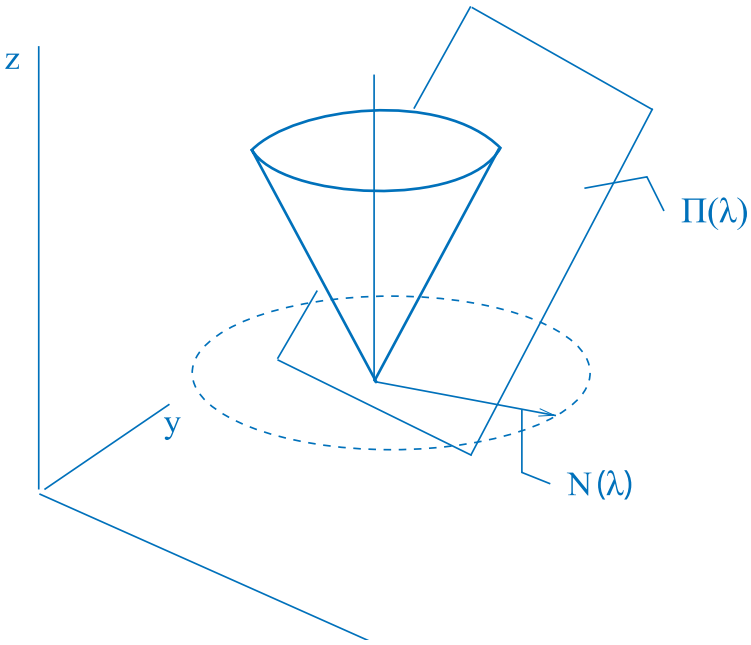
There is a strong and diverse collective of researchers in Western and Atlantic Canada involved in either the analysis or computation of applied partial differential equations with relevance to pattern formation problems.

The three primary goals of this CRG are:

1. To create new mathematical and numerical methodologies for the analysis of pattern formation problems in diverse applications that foster new and lasting collaborations within the membership of the CRG, as well as with international researchers. (This will be achieved through hosting short term [two-day summits] and long term [five-day workshops] events and from the shared mentorship and training of postdoctoral fellows and graduate students with CRG members in Western and Atlantic Canada.)

2. Cross-fertilization of mathematical and numerical techniques and methodologies to scientific communities outside mathematics where pattern formation problems arise in concrete applications.

3. To offer high-level training for graduate students and postdoctoral fellows in the analytical and numerical methodologies needed to study and model pattern formation problems in a variety of areas of application. This training will be done through a month-long Atlantic Association for Research in the Mathematical Sciences (AARMS) summer school in 2015, a two-day graduate student summit in 2016 and a three-day short course in 2016 on stability theory.



Research Interests

- Collective Dynamics in Biology and Social Sciences
- Concentration Phenomena and PDE's on Surfaces
- Stability, Bifurcation and Rigorous Computing

Organizers: Thomas Hillen (University of Alberta), Theodore Kolokolnikov (Dalhousie University), Steven Ruuth (Simon Fraser University), Michael Ward (University of British Columbia), Juncheng Wei (University of British Columbia)

On February 27, 2015, Tom Hou (Caltech) visited the PIMS UBC site to deliver the lecture *Blowup or no blowup? The Interplay Between Theory and Computation in the Study of 3D Euler Equations*. The essence of the research (performed jointly by Professor Hou and Professor Guo Luo [City University of Hong Kong]) behind the talk was whether the 3D incompressible Euler equations can develop a singularity in finite time from smooth initial data. This is one of the most challenging problems in mathematical fluid dynamics and is closely related to the Clay Millennium Problem on 3D Navier-Stokes Equations.

The lecture included a review of some recent theoretical and computational studies of the 3D Euler equations, then presented results which suggest that the convection term could have a nonlinear stabilizing effect for certain flow geometries. Hou presented strong numerical evidence that the 3D Euler equations develop finite time singularities and share many features with 1D models which they recently proved do develop finite time singularity.

The question of blowup or no blowup is very well-known, but a definitive answer is elusive, explains Hou, "Almost all of the well-known applied mathematicians, PDE analysts, and fluid dynamicists have been searching for decades. Many people have claimed to have found a finite time singularity, but later were disproven." Hou has been working on the problem for over a decade himself, and for many years tried to prove that the blowup was not possible. "I approached it from a more fluid dynamic and applied mathematics perspective. Most others had treated it as a pure mathematics problem, but in that case it was too difficult, the analysis did not capture some essential physics in the Euler equation. I believe that you have to respect the physical nature of the problem, which all contributes to potentially depleting the singularity."

When he began to examine the problem with Luo, "Because we had worked for so long to prove the opposite, we were extra diligent to ensure we had accurate and reproducible findings" says Hou. "With math, you can only believe what you can prove." Very recently, in collaboration with Drs. K. Choi, A. Kiselev, G. Luo, V. Sverak, and Y. Yao, they have proven rigorously that the 1D Hou-Luo model does blow up in a way that has similar properties to those seen in the 3D equation. "The problem we consider is not exactly the millennial problem, which was posed in a space without boundaries; here, the physical boundary plus various symmetry constraints play an important role in making the nonlinear alignment of vortex stretching sustainable."

With their work on the 1D case as a basis, it has become increasingly believable that such a blowup scenario, compatible with the Euler equation, may be possible in two or three dimensions. The next step, Hou says, "is to show how to generalize the one 1D analysis into the 2D and 3D geometry, but that will require a different set of techniques."

Developing an analytical tool that will enable a solution to the 3D problem may require borrowing from other branches of mathematics. That, notes Hou, is one of the beautiful things about this problem. He explains that in mathematics, people often separate into different fields and do not communicate outside their specialities, but because this problem is so difficult and has kept people's attention for so long, many people have made a connection beyond their field, making it possible to not only crack open this difficult problem, but also encourage interdisciplinary collaboration.

"When I talk to my students/postdocs and junior collaborators, I say, 'Look, don't be too scared, we can look at this from a very unique angle, from the applied mathematics angle, so we can do modelling, computation, we can do analysis – we do not need to get stuck in one mindset.' Computation is like an experiment; we can get inside the problem and build a model to test our ideas." And, he says, "If you have a good idea, why not try to challenge yourself, push your boundaries, take some risks, there is so much potential!"

For young people pursuing research he acknowledges that there is a lot of pressure to produce results and as such, they are afraid to work on challenging problems like this one. "It is easy for me to say, since I have tenure, but realistically, there is never a good time to work on a challenging problem, it is always risky. As a young Ph.D. student, you often actually have more time – you have a cushion of three, four, five years to work on a project. I think it is really important to develop that kind of taste early, because once you get used to working on easy problems, you begin to think that's all there is for you."

When Hou first began seriously pursuing the 3D Euler it was actually slowing down as a topic of interest, "There was no serious competition and no one was expecting that we could deliver something significant. But we were pleasantly surprised by what we have accomplished. If you have an idea, you have to pursue it. And when you have the time and the space to pursue it at your own pace and really let your ideas unfold organically and passionately, that's when the big breakthroughs will find you."