UC **SANTA BARBARA**

Kavli Institute for Theoretical Physics

Newsletter

Fall 2019

www.kitp.ucsb.edu

A Simulation of Two-Dimensional Rayleigh–Bénard convection, Dedalus Project

JAKUB OSTROWSKI

Lars Bildsten

Fall is the time of change. Six postdoctoral scholars have moved on to new positions as others arrive. Xiao Chen will be an Assistant Professor at Boston University, while Chao-Ming Jian is at Station Q for one year and then will move to an Assistant Professor position at Cornell University. Adam Jermyn will be a postdoctoral scholar at the Flatiron Institute, where Yan-Fei Jiang has just started as an Associate Research Scientist. Le Yan has taken a Research Scholar position at the Chan-Zuckerberg Lab, and Shahriar Shadkhoo is pursuing a teaching career starting as a lecturer here at UCSB.

We have six new postdoctoral scholars who arrived this fall, with three in theoretical condensed matter physics: Anna Keselman from Station Q, Zhu-Xi Luo from University of Utah, and Meng-Xing Ye from University of Minnesota. Other arrivals are Sean Ressler, an astrophysicist from UC Berkeley, Ken Van Tilburg, a particle physicist from the Institute for Advanced Study and New York University, and Evan Bauer, an astrophysicist from UC Santa Barbara. They are settled into their offices and fully participating in KITP's activities! On pages 4 and 5, KITP staff member Megan Turley tells the story of former KITP postdoc Ben Brown's adventures here in the creation of an open-source software tool for fluid dynamics.

This Fall's newsletter has a nice mix of stories for you. Art has always had a strong presence in Kohn Hall. Gary Smaby tells his story on page 2 of his strong involvement at KITP. I worked very closely with him on art production for the Munger Physics Residence, including stunning recent additions to the music room from his collection. Ulysses is back! That's the name of a remarkable active piece of sculpture designed by our Artist-in-Residence Jean-Pierre Hebért that we describe on page 3. Eva Silverstein and Rob Leigh contributed a brief summary for the back cover of our one-day celebration of Joe Polchinski's science in December 2018. Please enjoy!

We plan about 10 conferences per year, and now and again, we hit a resonance where new results stream in during the event and we make the news! That happened this July, during the "Tensions between the Early and the Late Universe" conference organized by Adam Riess, Tommaso Treu and Licia Verde. Adam (2011 Nobel Physics Prize) approached David Gross about this idea of a conference focused on the growing discrepancies between observations at early and late cosmological time. If confirmed at high significance, it would require an expansion of the standard model, and may perhaps lead to the discovery of new physics. Sounded perfect to me, so I agreed and set to working with Adam, Licia and Tommaso. They did a fantastic job recruiting all of the research groups that were making measurements with different techniques, and we started to see media interest as the conference approached. The conference was perfectly timed. Many new results were announced, and it was a roller-coaster ride to witness the real-time unveiling. The science writers in the room did a great job at summarizing the "Hubble Tension," resulting in articles in *Science News, Science, Scientific American, and Quanta Magazine*. I especially enjoyed the article in *Quanta Magazine* written by Natalie Wolchover as it highlighted KITP Program Manager David Kaczorowski's assist in the science nomenclature by introducing the word "surd". Look it up! The coordinators have since authored an article for *Nature Astronomy* (Vol. 3, page 891) that summarizes the current state of the observations.

Of course, programs and conferences are the hallmark of what we do at KITP. On page 7, KITP staff member Maggie Sherriffs summarizes the landmark 2001 program Statistical Physics of Biological Information which helped scores of physicists launch their quantitative biology careers. We host a special conference for US high school teachers once every year. Page 6 of the Newsletter contains a touching testimonial from one of these teachers.

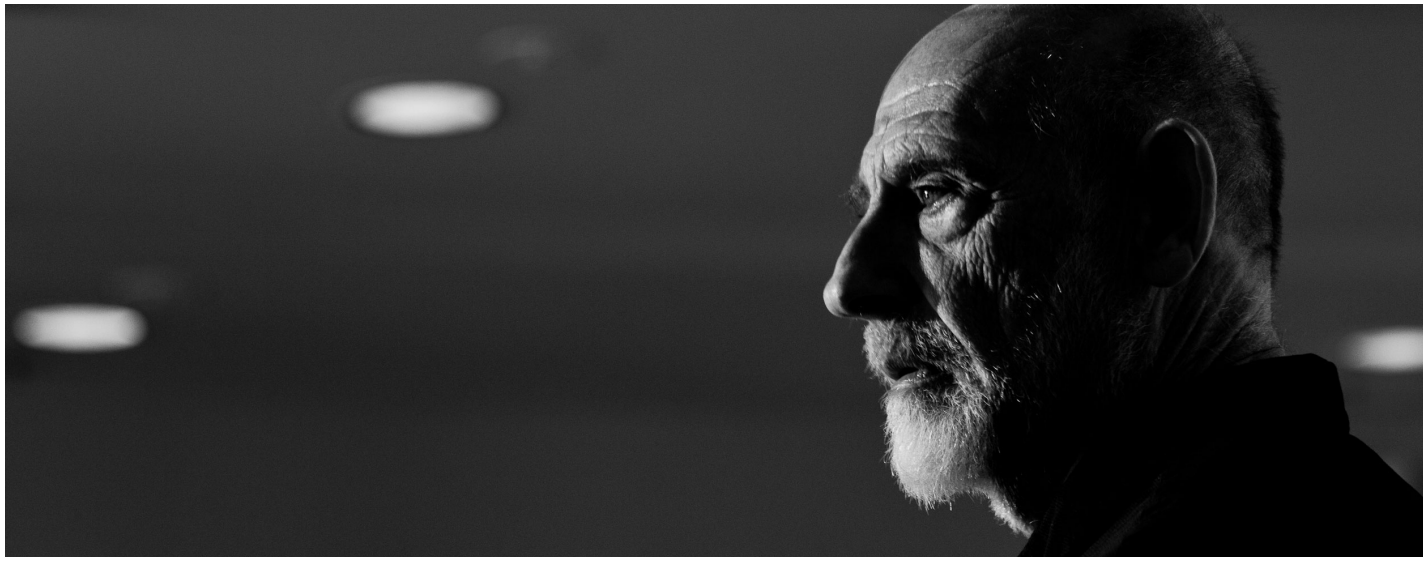
Spontaneous donations that enhance the experience of KITP's visitors continue to arrive. This spring I received a call from Chris Seaton, the longtime assistant to Walter Kohn. Walter's spouse, Mara Kohn, had recently passed away and the family wished to donate an Astin-Weight upright piano. According to Mara's daughter, Naomi Schiff, "At the time the piano was made, Mara was eager to give Walter a very special present and so she came up with the idea of a custom-built piano. Walter was a very musical person, who played flute and was dedicated to classical music as a listener." We were honored to receive this donation and placed the piano prominently in the family room of the Munger Physics Residence. In September, longtime Friends of KITP Michael and Nancy Gifford donated their custom pool table, which we immediately placed in the family room, adjacent to the Kohn Piano. This has already inspired a round-robin billiard tournament and we expect many new physics inspirations from the audio synergy of billiards and piano playing!

In closing, I note the passing of J. Robert Schrieffer on July 27, 2019. Schrieffer earned the Nobel Prize in Physics in 1972 with John Bardeen and Leon Cooper for the theory of superconductivity. He came to UC Santa Barbara in 1980 as one of our first ITP Permanent Members. Schrieffer later served as ITP's second Director from 1984-1989 and played a major role in establishing ITP as a resource for the international physics community. In 1992, he moved to the National High Magnetic Field Laboratory at Florida State University and served as the Lab's Chief Scientist until his retirement. His impact across condensed matter physics was profound and he will be missed.

- Lars Bildsten, KITP Director

Where Scientific Method Meets Artistic License

Viewing science at KITP through a different lens



GARY SMABY

Leonard Susskind, Professor of Physics at Stanford University

It was the spring of 2012 when I entered Kohn Hall for my first day as visiting KITP Artist-in-Residence. I didn't really know quite what to expect. This Michael Graves-designed mecca, spectacularly perched on the cliffs overlooking the Pacific Ocean, is of course world-renowned in the field of theoretical physics. But less well known is the fact it likewise stands apart as a naked singularity for those of us in science-oriented arts and letters. There's nothing else quite like it in our universe.

I was curious to learn the secret behind KITP's cross-disciplinary notoriety; how is it that this place not only attracts the world's greatest physicists to share great ideas, but also welcomes visiting journalists, producers, playwrights and artists like myself to observe and participate in the harmonic convergence?

The answer became apparent when, immediately upon arrival, I was warmly received and ushered into the office of then-director and Nobel-laureate, David Gross. Before I left that short meeting, I had keys to an office (with my name on the door), an invitation for my wife and me to join David and Lars Bildsten for dinner the next evening with a leading authority on Albert Einstein, and finally, a request to deliver a noontime "blackboard talk" the following week to all of KITP's visiting scientists.

As a photographer and filmmaker, I have developed a keen eye for observation. As I left that meeting in an afterglow to find my office, I noticed that every square inch of available wall space in the contemporary Kohn Hall was lined with old-fashioned slate blackboards, covered with incomprehensible (at least to me) white chalk squiggles. It was at that moment that I began to ponder David's final request; my awe turned to trepidation. A blackboard talk. . . I'm a visual artist but not with chalk!

Upon reflection I realized that I was invited to KITP to share my world view, not to try to dazzle present and future Nobel laureates with my utter lack of knowledge about theirs. I quickly realized, upon entering the darkened lecture hall to observe the daily presentations, that I was basically watching a series of foreign films - without subtitles. I began to think of each lecture as a performance of sorts where I didn't understand the lexicon.

Then I got an idea. I sought and was granted permission by David to do what I do best: observe and record the performances during that first six-week residency through the lens of my camera, just as I did in my early 20s as a rock concert photographer. I became an inconspicuous, non-intrusive observer of the unfolding daily drama. With a sense of relief, I settled into that groove, culminating on the final day with an exhibit of black and white photographs entitled "@work, @play". I've been welcomed back to KITP every year since, each time with a unique project in the works.

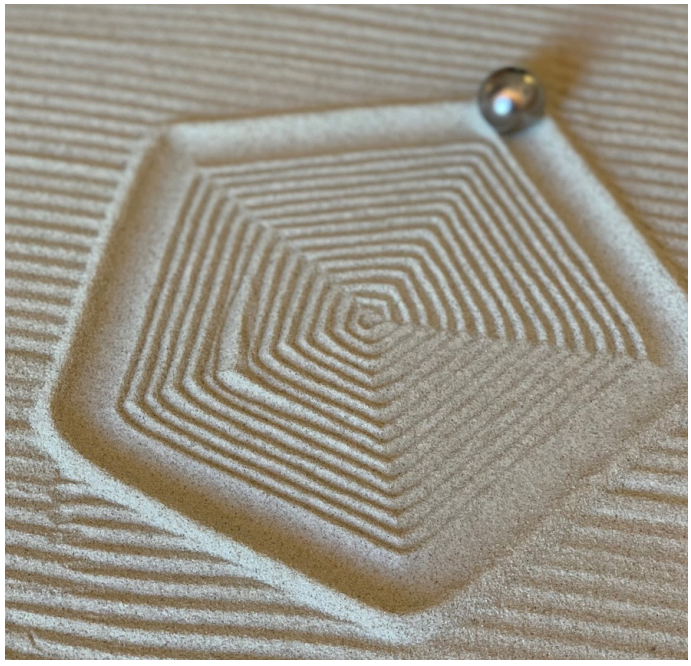
- Gary Smaby, KITP visiting Artist-in-Residence

GARY SMABY

Fay Dowker, Professor of Theoretical Physics at Imperial College London

An Artistic Odyssey

Beloved interactive art piece *Ulysses* returns to Kohn Hall



LISA STEWART

A magnetic ball traces the beginnings of a geometric image in the sand – every day brings a new design

MEGAN TURLEY

Ulysses sits on an African mahogany base at Kohn Hall, Surrounded by other Hebért pieces

We were very excited this month to see the return of *Ulysses*, the unique sculpture designed and built by KITP's Artist-in-Residence Jean-Pierre Hebert. First installed in Kohn Hall over a decade ago with support of a David Bermant Foundation grant, *Ulysses* had been away for upgrades and repairs for quite a while. Indeed, many of our visiting physicists were asking: "Where is the sand machine?", as they affectionately refer to *Ulysses*.

Ulysses consists of a stunning African mahogany *(Khaya ivorensis)* base, built by local fine furniture builder Victor DiNovi, and a hidden programmable mechanical device conceived by Jean-Pierre and designed and built by UCSB engineer David Bothman that moves the ball through the sand to create captivating patterns that provide countless hours of distraction for all in Kohn Hall. I'm convinced that the contemplations inspired by watching *Ulysses* in action has moved physics forward over the years. The photo below shows all three reveling in *Ulysses*' successful return!

Jean-Pierre has been KITP's Artist-in-Residence since June 2003, first adorning the corridors of Kohn Hall with geometric ink drawings derived from his algorithmic approach to art. Internationally recognized, he has exhibited his pieces around the world, recently at the Pompidou Center in Paris, and received a prestigious Pollock-Krasner Foundation grant. I had the honor of working with him to identify and select new art pieces for the Munger Physics Residence, allowing for the exposure of thousands of physicists to the "Algorist" approach to art. For over a decade, Jean-Pierre has also been designing and producing the now-famous holiday cards that we distribute to the Friends and Supporters of the KITP.

Please stop by to see *Ulysses* when you can. Still images do not do it justice!

- Lars Bildsten, KITP Director

LISA STEWART

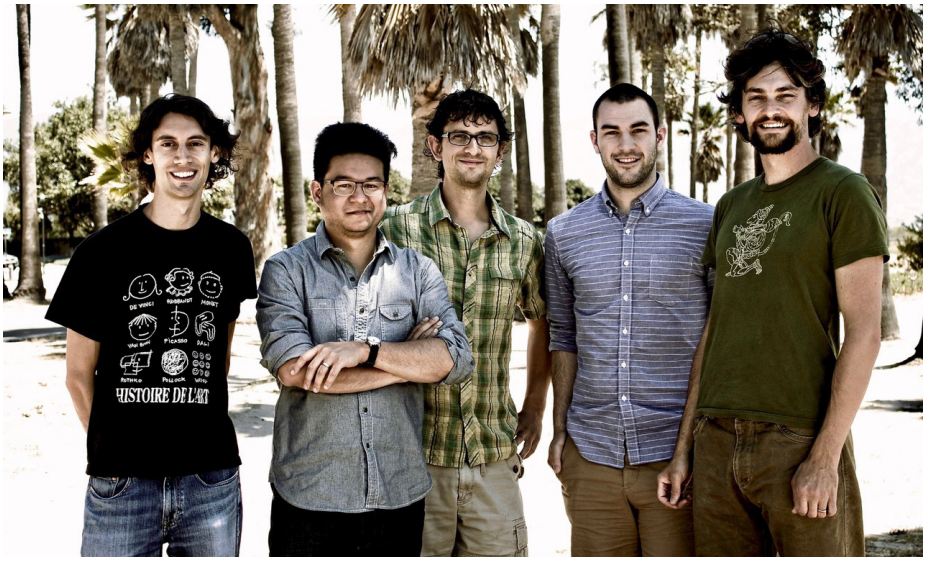
Left to Right: David Bothman, Victor DiNovi, and Jean-Pierre Hebért during installation of Ulysses

Waves of Change

KITP collaborators create a computational framework for fluid dynamics

The 2014 Wave-Flows program at the KITP was the ideal place to formulate Dedalus, an open-source computational framework that solves intricate classes of problems accurately and efficiently. Potential applications for Dedalus include fluid, chemical, radiation and biological transport problems in stars, planets, and laboratories.

Among geophysicists, climate scientists, plasma physicists and astronomers, the five collaborators (Geoff Vasil, Ben Brown, Keaton Burns, Daniel Lecoanet, and Jeff Oishi) came together as the Dedalus Project. Named after a James Joyce character, Dedalus represents "important ideals for us in terms of inventing something new, not bound by the baggage of past practices," explains Ben Brown. "The original Dedalus of Greek myth (Joyce's inspiration) was also a master tool builder, so it comes together rather nicely," added Geoff Vasil.



BEN BROWN

Dedalus Project collaborators outside of Kohn Hall during the Wave-Flows Program in 2014, Left to Right: Daniel Lecoanet, Jeff Oishi, Geoff Vasil, Keaton Burns, and Ben Brown

Past practices were forefront in Brown's mind as a KITP Postdoctoral Scholar in 2013 when he dove into researching what he describes as "big, complicated stellar interior models." "I had become a bit unsettled about how much we could trust any of the computational results," he admits. At the suggestion of long-time KITP Senior Fellow Bill Paxton, Brown spent his time at KITP diving into the entirely new-to-him field of applied mathematics and differential equations. Paxton pioneered the open-source Modules for Experiments in Stellar Astrophysics (MESA) computational instrument and knows how difficult, and imperative, it is to be able to trust computational solutions and results.

For a postdoctoral scholar, Dedalus was a high-risk choice, as the timescale to produce co-authored papers and tangible results could significantly exceed the duration of a short-term position. However "KITP gave me complete freedom to try and figure out problems, to find out where the interesting problems lay and what I could do to contribute to solving them," Brown explains. Those problems, as it turns out, went far beyond Brown's original scope of stellar interiors, to become a core piece of the Dedalus Project.

As Vasil explains, "We need to understand 100% of what is happening at the bottom mathematical level. Past projects could get away with small hacks here and there because they expected some level of trained human intervention. We are releasing this into the wild. It has to work for everyone as best as possible. In the old days, elevators were dangerous and needed operators. Now anyone merely walks in and pushes the button."

Before the Wave-Flows Program, the Dedalus Project team members had never all been in the same place at the same time. They are a truly global team, currently spread between University of Colorado (Brown), MIT (Burns), Princeton (Lecoanet), The University of Sydney (Vasil), and Bates College in Maine (Oishi). Despite the distance, the five collaborators - connected through former offices, institutions, and shared research interests - had already begun to work on the bones of a community code from their home institutions via teleconference.

Each member of the team brought particular expertise as well as questions and problems specific to their research. Before Brown's dive into the computation of differential equations, most groups were using mathematical techniques developed over 60 years ago. "I was able to bring myself up to the late 90s to early 2000s in terms of technique," he explains. "We used those exact techniques in our time evolution within the Dedalus code, and those allowed us to solve problems that were not solvable using other techniques." Brown's postdoctoral efforts began to pay off.

"Dedalus uses a lot of computational methods from the last five years," Burns adds. "A lot of our time now is spent designing and implementing advanced numerical techniques. Much of what we do constitutes novel mathematical research." The collaboration also must now answer its users, notes Oishi "We still maintain an active email list to troubleshoot the inevitable problems and misunderstandings".

From January to the end of the program in June of 2014, the Dedalus Project convened at KITP to work on developing and testing. Brown and Lecoanet were already at KITP, while Oishi and Burns arrived as program participants in that formative Wave-Flows program. "Our friend and colleague, Geoff Vasil, just showed up without having arranged anything. We fit him into the porthole," says Brown, describing Kohn Hall's distinctive second-story Tower Room. "We used that amazing room a lot for meetings."

Having the team all in residence at Kohn Hall accelerated the pace of their work. "It was a unique and very high-intensity experience," Brown describes, "The first time that all five of us had been in the same physical spot, meeting with each other in the same room,

working on the same blackboards, really able to work on ideas." An idea would arise one day and after an inspired question by one collaborator and focused work by more, the group would have a solution by sunset the following day.

Lecoanet, Oishi, and Brown pooled their assigned talk time-slots during the Wave-Flows program to demonstrate the fledgling functionality of Dedalus to scientists with diverse backgrounds. They fielded questions and criticisms and began to understand more deeply the story they would need to craft to get scientists from different communities to use Dedalus.

Dedalus is now an interdisciplinary tool that is free and accessible for anyone to use, every contribution visible and acknowledged. By June of 2014, Dedalus had a clean and powerful user-interface, and scientists began seriously utilizing it. Oishi added, "It's impossible to overstate the importance of the user interface. We all expected to make a nice interface eventually. But at some point early on Keaton [Burns] disappeared for a few weeks. When he surfaced, he said, 'I have something to show you guys...' That's when Dedalus really became a serious option for a lot of other groups."

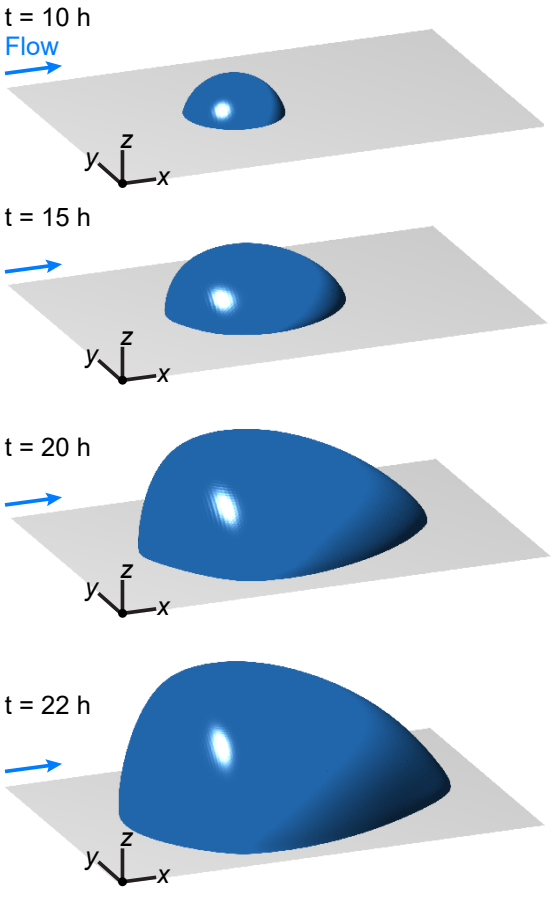
The community of Dedalus users is diverse, including stellar, geo, plasma, and quantum physicists, and even a few biologists. The project mailing list has over 200 distinct users. Five years on, the impacts of Dedalus are continuing to ripple outwards. Thus far, Dedalus has enabled roughly 60 published papers, a majority of those not including any member of the core collaboration team.

Harder to measure is the impact Dedalus's philosophy will have on future generations of scientists. A faster, more robust, and more accurate framework for solving interdisciplinary problems "may open up whole new realms of science," explains Brown.

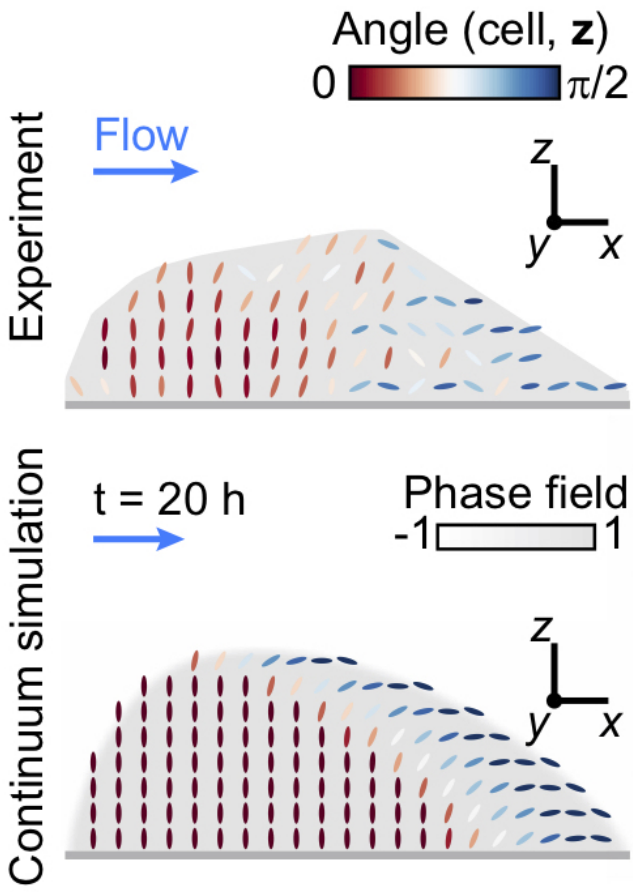
For former KITP Graduate Fellow Daniel Lecoanet, Dedalus is a jumping-off point for his future. "I'll be starting a new faculty position in Applied Mathematics in 2020 at Northwestern University." He explains, "A big reason for seeking, and getting, this job is because of the cutting-edge mathematical research that goes into Dedalus. It's been an exciting change to the course of my career. My KITP Fellowship was an important part of this."

For Brown, his time at KITP and working on the Dedalus Project has profoundly shaped his career. Originally a firm stellar theoretical astrophysicist, Brown and his students now work on a wide range of interdisciplinary topics such as fundamental fluid dynamics, computational algorithms, the atmospheres of gas planets, and massive stars. He reflects, "I don't know if I would have the courage or the skills to be quite so broad if it hadn't been for my time at KITP."

- Megan Turley, KITP Development Coordinator



Complex matter simulations of biofilms, with comparison to experiments



Real-World Impact

A Testimonial from the KITP Teacher's Conference

BRUCE BOEHNE

KITP Teacher's Conference presenter Miles Stoudenmire (Flatiron Institute) explains magnetism to middle school students in an interactive activity

I was very fortunate to attend the KITP Teacher's Conference "Automating Insight: Pushing the Frontier of Quantum Physics with Machine Learning" held in February 2019. This was a very worthwhile educational experience. I learned about Artificial Intelligence (AI) and machine learning and was able to directly use that knowledge with my students to make math and science more relevant to them and to better connect what is going on in our classroom with the real world.

I was able to meet one of the presenters - Miles Stoudenmire, of the Flatiron Institute in New York City - enabling a visit to Flatiron during my class trip in May to New York City. During our visit to Flatiron, Miles gave my class a presentation on what they do at Flatiron, and how math, AI, and advanced software programming techniques are being used to expand our understanding of quantum physics. In the picture above some of my students are being led through an activity to demonstrate how electron spin patterns give rise to magnetism. Miles did a great job and our visit was very well received by both my students and my adult chaperones.

Besides outstanding professional development, this kind of networking is another one of this amazing benefits of the KITP Teacher's Conference. I would like to take this opportunity to express my gratitude for the KITP and the wonderful work they are doing to advance professional development in science and math education.

- Bruce Boehne, Middle School STEM Teacher

BRUCE BOEHNE

Boehne is a middle school teacher at Zion Lutheran School in Dallas, TX

MAGGIE SHERRIFFS

Zorana Zeravcic (ESPCI Paris) leads teachers in a demonstration of using biology-inspired design to assemble complex materials at the 2018 KITP Teacher's Conference

No Disciplines in Nature

How quantitative biology arrived at the ITP

In the late 1990s and early 2000s, new technologies were allowing biologists to generate massive amounts of data, but such data could be messy, and taking advantage of it demanded new quantitative tools. Statistical physics was a mature field, rich with ideas for making complex systems tractable by describing their features in aggregate. Statistical physicists realized they had powerful concepts and tools at their disposal but needed an education in biology. The two communities had much to offer each other but to bridge academic cultures they needed to learn each other's languages.

OLGA MASLOVA

The design for the 2001 INFOBIO Program logo was created by Olga Maslova, costume designer and spouse of program participant Sergei Maslov (both at University of Illinois, Urbana Champaign).

Terry Hwa, a statistical physicist from UC San Diego, realized that the KITP was the perfect place to bring these communities together. "The term 'quantitative biology' did not really exist back then," he says. "I wanted to do a survey of different branches of biology and identify the scientific areas that were ripe for quantitative studies by physicists. Because of the challenge presented messy data, enough biologists were willing to spend some time and efforts to engage the physicists. That set the stage for a broad dialogue. It wasn't clear in my mind what physicists could bring into biology; but whatever it might be, it would likely be quite different from what the biologists was initially expecting. I thought that once the scientific opportunities were revealed and made known to interested physicists, activities in various sub-fields would self-organize." He assembled an interdisciplinary team to organize the 2001 program "Statistical Physics of Biological Information." The program was a phenomenal success: it was instrumental in launching the field of quantitative biology, helping dozens of physicists initiate careers in it.

The KITP, then the Institute for Theoretical Physics, has always prioritized interdisciplinary science and positioned itself as an incubator for progress at the rich interfaces between fields. "There are no disciplines in nature," explains David Gross, KITP Permanent Member and then-Director. However, academic institutions necessarily divide the world into domains like physics and biology. When a university makes a foray into a new area, it makes a risky, long-term investment of limited space and funds. In contrast, KITP can run a few-month program and bring together scores of scientists on a relatively small budget. "We can experiment!" Gross enthuses, "You've got to fail sometimes, but you can do the experiment. In most places you can't."

Even with the ideal venue secured, doing the experiment was no small challenge. Hwa calls it "a first large-scale attempt in the modern era to have physicists seriously interact with biologists." For decades, theoretical physicists had embraced the KITP model of long-stay programs centered around informal discussion. Biologists could not imagine leaving their labs unattended for several weeks and needed to be convinced that even 3 days at KITP could benefit them.

Formal lectures run differently in physics and biology, too. An hour-long biology talk usually consists of 45-50 minutes of lecture followed by 10 to 15-minutes for questions. Theoretical physicists discuss work as it is being presented, which can unsettle the unaccustomed. So, Hwa's first task was to identify and court biologists who could communicate effectively with physicists. In order to convince experimentalists to participate, KITP had to relax its requirement for long stays. The two communities had to learn each other's jargon and appreciate (if not agree on) what each valued as beautiful and important. In order to achieve these pedagogical goals, the Institute embraced twice its normal density of talks for the entire 5-month program.

It was a resounding success. "Looking back, the 2001 INFOBIO program is perhaps one of the projects I'm most proud of engaging in," Hwa recalls fondly. Early quantitative biology talks are among the most-viewed in KITP's online archive of recorded lectures. Mehran Kardar, a statistical physicist at MIT who participated in the entire program, confirms its impact: "Many young people [who] were devoted statistical physicists or condensed matter physicists beforehand became biophysicists."

Three years later, Boris Shraiman joined the KITP as a Permanent Member. Shraiman has provided tireless leadership to grow KITP and UC Santa Barbara into a center of innovation in quantitative biology; particularly the fields of evolution, neuroscience and morphogenesis. His initiation and successful stewardship of the Santa Barbara Advanced School or Quantitative Biology Summer Research Course (informally known as QBio School) has also made KITP an influential environment for biologists. Molecular biologist Dominique Bergmann shared the benefit of the interactive, interdisciplinary environment she encountered during her participation in the 2019 "QBio" summer course: "It really did change the way we thought about our developmental system and inspired a new set of experiments back in our home lab. The atmosphere at KITP promotes collaboration in real ways."

- Maggie Sherriffs, KITP Special Programs & Evaluation Manager

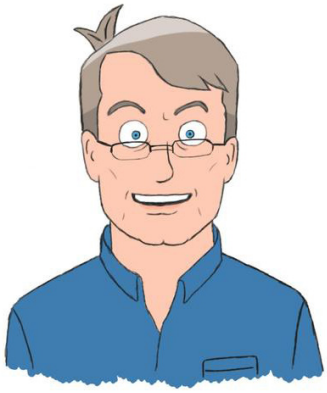
A Meeting to Remember: The Polchinski Symposium

JUAN MALDACENA

Joe Polchinski (right) shares an amusing moment with UCSB Physics Professor Mark Srednicki

In December 2018, we held a one-day symposium to celebrate the life and career of late KITP Permanent Member Joe Polchinski. This included research talks on exciting developments in several major areas strongly impacted by Joe's work: the landscape of cosmological string solutions, conceptual issues in black hole physics, and the renormalization group structure of quantum fields including applications to condensed matter. The afternoon contained a series of reminiscences from friends and colleagues, displaying Joe's intense effect on colleagues as an extraordinary physicist and human being. Highlights included former student Ahmed Almheiri's affectionate imitation and numerous accounts of Joe's exploits in activities ranging from cycling and foozball to the theory of strong interactions and the energetics of string theory. Joe's own words about quantum gravity research closed the session: "The quest now is to understand 'What are the atoms of space?' Well, that's what we're doing every day, and that's where the fun is." He has left us with wonderful memories and much to pursue in science.

- Robert Leigh, University of Illinois, Urbana Champaign, and Eva M Silverstein, Stanford



AHMED ALMHEIRI

A comic depiction of Joe from IAS Fellow and UCSB Ph.D. Ahmed Almheiri's presentation "I'm (still) Addicted to Joe."

UC SANTA BARBARA
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Engaging with the KITP

There are many ways to contribute to the life of KITP. We urge you to become involved by:

- **Becoming a Friend of KITP**
- **Attending a public lecture or Café KITP event**
- **Making a Philanthropic Gift**

To do so, call (805) 893-6307, email friends@kitp.ucsb.edu or visit our website at www.kitp.ucsb.edu/support-kitp.

Kavli Institute for Theoretical Physics
Kohn Hall
University of California
Santa Barbara CA 93106-4030