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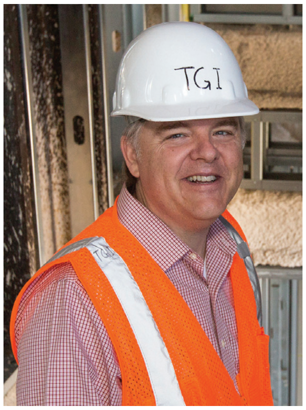
Kavli Institute for Theoretical Physics
UC Santa Barbara

Newsletter

Fall 2016

TONY MASTRES



TONY MASTRES

Lars Bildsten, KITP Director.

I am writing to you this Fall, as we complete construction of KITP's new Residence, shown above, fully funded by Charlie Munger. We remain on track for an early 2017 opening, and describe, on the back page, the efforts we are making during construction so as to hopefully achieve Platinum in Leadership in Energy and Environmental Design.

We are very proud of the achievements of our postdocs here at KITP. As expected, many departed in Fall 2016 for new positions. Tarun Grover accepted an assistant professor position at UC San Diego, while Matteo Cantiello is departing for the newly established Flatiron Institute in Manhattan where he will be an Associate Research Scientist at the Center for Computational Astrophysics.

Five new postdoctoral fellows arrived in September. Xiao Chen and Chao-Ming Jian are theoretical condensed matter physicists who respectively study entanglement and dynamics of many body quantum systems, and topological phases of matter and quantum information-theoretic studies of correlated matter. Mike McCourt and Yan-Fei Jiang are both astrophysicists; Yan Fei studies magneto-hydrodynamic instabilities in accretion disks, while Mike is focused on gas and plasma dynamics of material around supermassive black holes and large galaxy clusters. Shahriar Shadkoo, who has just arrived from UCLA, is a statistical physicist interested in living matter and morphogenic processes.

After two years of great service to KITP, Deputy Director John Berlinsky departed this September, and will return to Canada in 2017. Mark Bowick of Syracuse University arrived and is off to a running start as our newest Deputy Director. There have also been some staff transitions, with the arrival of Amy Burgard as our new financial manager. Please welcome them next time you are in Kohn Hall!

Walter Kohn, the institute's first Director, passed away this spring. An article celebrating his life and achievements is on page 3. We continue outreach to the community, and on page 2, we describe the Cafe KITP given by Elisabetta Matsumoto, one of our program participants. Our visitors have also been kind enough to describe the science they carried out while here at KITP. Articles describing programs on Olfaction and the Large Hadron Collider can be found on pages 4-6.

Our programs also strengthen existing collaborations and nucleate new ideas. As an experiment funded by the Kavli Foundation, we have been hosting "Follow-ons" (see page 7) that allow for collaborating groups of former KITP program participants to return for an intense 1-2 week working period. Since starting in January 2015, this has allowed us to host an additional 150 visitors at KITP, resulting in at least an additional 30 papers in the refereed literature.

I'm pleased to close out this note with the thought that next time I write, we will be housing most of our visitors in the Residence and I will no longer be wearing a hard hat. I also hope to be sharing with you that we have successfully renewed the National Science Foundation's support for KITP. Growing and diversifying the Institute's support from multiple sectors has been my charge since becoming director in 2012, and I am pleased to share all we have accomplished in this newsletter.

– Lars Bildsten, KITP Director

The Universe in the Heel of a Sock

A KITP program participant explains how math used in sewing and knitting also describes cosmic curvature

Little-known fact about socks: The mathematics that determines the heel curvature of hosiery is akin to that in Einstein's theory of relativity, which describes curved space-time.

Physicist Elisabetta Matsumoto, a KITP program participant, unpacked the math of curvature in easily understandable terms in her presentation "Purls of Wisdom." Her talk, part of the ongoing science series Café KITP, addressed the geometry and topology used in sewing garments and knitting clothes.

"The human form — particularly the female body — has innate curvature," said Matsumoto, currently a postdoctoral scholar in the Applied Mathematics Group at Harvard University. "Fabric is two-dimensional, yet seamstresses, couturiers and dressmakers all know how to make it fit a three-dimensional body by adding darts and pleats, which physicists like to call topological defects. Darts in clothing are an example of positive curvature, where area is removed."

Matsumoto comes by her penchant for fiber arts genetically. Her mother is a fiber artist who taught her to sew and knit. Matsumoto used her own designer wedding dress as part of her slideshow, comparing its ruffles to human intestines.

"You might think that these two things have absolutely nothing in common, but surprisingly, it is actually the same physical mechanism that gives both their shape — negative curvature," Matsumoto said. In negative curvature, the surface curves away in two different directions in the same way a saddle or a Pringles potato chip does.

Matsumoto's ruffled wedding dress was created by stretching tulle — adding extra area — and stitching it to stiff boning. When the tension on the fabric was relaxed, a ruffled structure appeared. "It turns out that the same thing is going on in this fabric treatment and in your intestines," Matsumoto explained. "A small membrane that connects the intestines to the spine created tension when your intestines grew and ruffled them."

Matsumoto also used knitting to discuss two categories of topological defects: dislocation and disclination. "Dislocations are where we add in new columns of material — for instance, on the bustline of a sweater," she said. "But you also see dislocations when you knit in new rows of material —this is called adding in short rows — and this is exactly what's going on in the heel of a sock."

Both dislocation and disclination can also be seen in the stripe pattern of a zebra. The dislocations are areas where the girth of the animal changes and a new stripe is added. The disclinations are areas where curvature changes to accommodate the animal's limbs.

At the core of Matsumoto's presentation was her handmade fabric rendition of the hyperbolic plane geometry known as Klein's Quartic Curve. Her creation consists of 24 heptagons (seven-sided flat pieces) coordinated in groups of three. "I took all this space and I wrapped it in on itself to come up with a compact object containing three holes," Matsumoto said.

Matsumoto also walked the audience through the math of Euler's formula in order to demonstrate the deep relationship between the geometry (the counting of edges) and the topology of the object (the number of holes).

SONIA FERNANDEZ

Elisabetta Matsumoto and the Klein's Quartic Curve she created from fabric heptagons.

"You may have remembered your geometry classroom as something dry, but I hope I've convinced you that if you keep your eyes open, you can find interesting geometry all around you in your daily life," Matsumoto concluded.

– Julie Cohen, UCSB Public Affairs & Communication

In Memoriam: Dr. Walter Kohn

Walter Kohn saw the very worst the world has to offer — and he also saw the very best

Born in Vienna in 1923, the Nobel Prize-winning scientist was a teenager when World War II began and terrifying — and seemingly unimaginable — events unfolded around his family. Desperate to get their son and daughter to safety, Kohn's parents sent them out of Austria, rescued from the Nazi regime in one of the last Kinderstransport missions that brought children out of Nazi Germany, Austria and other German-occupied territories and placed them with surrogate families in England.

The effort saved young Walter and Minna, along with some 10,000 other predominately Jewish children, most of whom were the only members of their families to survive the Holocaust. Kohn's parents, Gittel and Salomon, were killed at Auschwitz.

In a 2014 interview, recalling his childhood in Austria, his rescue and the families in England and, later, Canada, that embraced him and encouraged and supported his studies, Kohn spoke of the lasting impact on his life of "the acts of good people."

Perhaps then, in a philosophical sense, that kindertransport helped take Kohn, decades later, all the way to Stockholm, where in 1998 he was awarded the Nobel Prize for Chemistry for his development of the density functional theory. It was the highlight of his long and illustrious career as a scientist.

Kohn, the first of six Nobel laureates at UC Santa Barbara since 1998 and founding director of the Kavli Institute for Theoretical Physics (KITP), died April 19, 2016.

"Walter's friendship has been a gift to me personally as well as to our entire campus community," said Chancellor Henry T. Yang. "Though he is no longer with us, he has left a living and lasting legacy through his inspiration and impact, which is beyond anything I could adequately put into words.

"Our campus is devastated by the sad news of Professor Kohn's passing, and our hearts go out to his beloved wife, Mara, and their family," Yang continued. "Walter was an internationally regarded colleague, scholar, mentor and role model and proudly, the first of six Nobel Laureates at UC Santa Barbara since 1998. His development of the density functional theory, for which he received the Nobel Prize in Chemistry, revolutionized scientists' approach to the electronic structure of atoms, molecules and solid materials in physics, chemistry and materials science."

Also among UCSB's six Nobel laureates is David Gross, who received the prize physics in 2004. A permanent member and former director of the KITP, Gross holds the Chancellor's Chair in Theoretical Phyics. He described Kohn as "a great scientist, a compassionate humanitarian and an inspired scientific statesman.

"As director of the KITP I learned to appreciate the genius who created the essential features of this institution that he first directed and guided at its very beginning," Gross said. "Although we will miss him greatly his spirit lives on at the KITP."

The Institute for Theoretical Physics (ITP), as it was then known, was essentially launched by Kohn; he first came to UCSB in 1979 to serve as its inaugural director. Under Kohn's leadership, the ITP quickly developed into one of the leading research centers in physics, and has since been widely emulated internationally.

"Walter led the ITP to a strong start," recalled Jim Langer, a permanent member and former director of the institute, who first met Kohn in 1954. "[It] quickly became a destination of choice for both program participants and postdocs. Its activities had a multidisciplinary flavor from the beginning. There were research programs in neural networks and nonequilibrium dynamics as well as activities in particle and nuclear physics, astrophysics and condensed matter.

"In a few years, the institute became a major asset for the university as a whole when recruiting new faculty in physics and in engineering and related disciplines," he continued. "The rise of UCSB as an internationally prominent research university was due in large part to the growing reputation of the ITP. Walter set a tone of modest, warm and thoughtful leadership for the ITP, especially in guiding talented young scientists at the beginnings of their careers."

Langer himself was once a young scientist who drew inspiration from Kohn. The two first met in 1954 at Carnegie Tech (now Carnegie Mellon), where Langer was then an undergraduate student and Kohn was a faculty member and emerging leader in solid-state physics. They would eventually work together closely, when Langer joined UCSB and became a permanent ITP member and, later, its director.

Said another former KITP director and founding member James Hartle, a research professor and professor emeritus of physics at UCSB: "It is said that a great man leaves behind more opportunities than he finds. That is certainly true for Walter and the Kavli Institute for Theoretical Physics. As founding director he shaped the world-class institution that we have today. We will miss him as a friend and as a colleague. We will remember him for the opportunities that he created here, and for his wise guidance and energy in realizing them."

Beyond his research, Kohn was deeply engaged in matters spiritual and societal. In 2001, he was the inaugural speaker for the Templeton Research Lectures on Science, Religion, and the Human Experience, sponsored by the Templeton Foundation and hosted by UCSB. He spoke about the interaction between science and religion, and about how science and technology pose both great promises and great threats to mankind in this global age

-Shelly Leachman and Andrea Estrada, UCSB Public Affairs & Communication

Reports from KITP's Scientific Programs

See you in the Smellyverse

Olfaction is the final frontier of our senses, the one that is still mysterious to us. Despite large amounts of genetic, physiological, and perceptual data, many fundamental questions about our sense of smell remain unresolved. For example, unlike the analogous cases of vision and hearing, to a large degree, we do not understand what properties of molecules lead to olfactory signals. Attempts to predict a smell quality based on molecular structure do not produce reliable results. This is not to say that olfaction is not important to humans. Our sense of smell contributes much to of our perception of the taste of food, is involved in mechanisms of sexual imprinting, and otherwise strongly enhances our quality of life.

One of the possible reasons for the elusive nature of our sense of smell is its enormous complexity. The olfactory epithelium of our nose can be viewed as a single pixel with about 350 types of smell "color" sensors, often called odorant receptors. Each odorant receptor is a protein that can recognize odorant molecules floating in the air. Imagine an LED display with a single pixel and 350 types of color diodes, and you will get an idea of how rich and complex smell can be. Olfactory epithelia in mice and dogs contain a stunning 1000 different types of odorant receptors (humans have lost a large fraction of their olfactory receptor repertoire since the acquisition of three-color vision). If odorant receptors were all independent and evolved without awareness of each other, we would need to untangle the structure of a 1000-dimensional phase space – a task intractable with current experimental methods. Another possibility is that the odorant receptors sample a lower-dimensional subspace of the 1000-dimensional space. Some recent human perceptual data suggests that olfactory perceptual space, i.e. the phase space sampled by the olfactory receptors, is less than ten dimensional. Some of these dimensions are easy to comprehend, such as a smell's pleasantness or complexity. Other dimensions represent molecular properties, such as hydrophobicity. Most of the ten dimensions are identified only by computational correlations found in the data, and are thus far unrelated to a particular human experience. Ten dimensions is a lot, but it is much better than 1000! The 10D odor universe, or Smellyverse, as we have called it, has the potential to be understood, in the same way that the 3D red-green-blue color universe has been understood by visual scientists.

This April, a group of theorists got together at KITP in a Follow-on Program to the program "Deconstructing the Sense of Smell" held last year. The main focus of the Follow-on Program was to design a combination of experimental and computational methods to probe the low-dimensional structure of the Smellyverse. We also attempted to speculate about the reason why this space may have evolved to be low dimensional. The reason why color space was hypothesized to be only 3D is because of the limited space in each of the retinal pixels: increasing dimensionality of color space would mean putting more types of color sensors in each pixel and would lead to worsening of the eye's spatial resolution. Limits to the dimensionality of sensory space are usually produced by the biological constraints imposed on the sensors. What types of constraints can exist in the olfactory system that restrict the dimensionality of the Smellyverse? We speculate that the constraints imposed on the olfactory system are behavioral: we have to sense and identify smells at minute concentrations to be able to differentiate hazards from attractants before other individuals. Being able to tell friend from foe at the smallest odor concentrations can differentiate a successful hunter/

From left to right: Roman Shusterman from University of Oregon, Alexei Koulakov from Cold Spring Harbor Laboratory, Massimo Vergassola from UC San Diego, and Dima Rinberg from New York University School of Medicine.

gatherer from some predator's dinner. The need to balance sensitivity with complexity of odor signals limits the dimension of the odor space, in the same way that the balance between the diversity of colors and the spatial resolution of the eye limits the dimensionality of color space to three.

This hypothesis was fleshed out by data obtained by one of the Follow-on program participants, Dima Rinberg, an Associate Professor at the New York University. Dr. Rinberg is both a theorist and an experimentalist. As an experimental neuroscientist, he designs methods for stimulating mouse odorants receptors by light, turning a mouse's nose into an extra retina. Using these methods, Dr. Rinberg can both create new unexpected odor signals and interfere with existing ones. Drawing new smells in the nose with light gives researchers a unique opportunity to explore the sense of smell. By interfering with the responses of the odor receptors, Dr. Rinberg and his collaborators managed to deduce that, in identifying smells, mice rely on the receptors with strongest affinity to odorants, i.e. those most sensitive to molecules at smallest concentrations. These receptors are the first activated after the odorant reaches the nose, and, as such, allow the fastest recognition of the identity of odors present at minute concentrations. Says Dr. Rinberg: "Using the most sensitive receptors to recognize odors is similar to aiming your eye's most sensitive part at important objects in the environment -- we can force ourselves to recognize objects without directly looking, but we tend to aim our eyes at something that is important to us at the moment".

Another way of thinking about the space of odors is to imagine them placed in physical space. Several researchers, including Massimo Vergassola from UC San Diego and Lucia Jacobs from UC Berkeley, propose that the olfactory system, perhaps on a very high level, computes the map of odorants in the physical space. Thus the olfactory system answers not only the "what" but also the "where" question. Evaluating the "where" information from elusive plumes of smells carried by the turbulent flow of air involves a very special type of computation. Understanding these neural algorithms will shape our thinking about the brain's processing of odor information. Indeed, perhaps, some of the many dimensions of the Smellyverse are real space dimensions.

One of the foci of the KITP program, supported in part by the National Institutes of Health (NIH) and the Gordon and Betty Moore Foundation, was to understand the type of computational algorithms used by olfactory networks. Some of these algorithms are known, such as compressed sensing or Bayesian inference, but others are only beginning to be understood. The most exciting possibility, however, is that our KITP program will inspire the creation of new mathematical frameworks that will apply generally to olfactory, visual, auditory networks and beyond, It is our hope that the brain is up to the challenge to create theories enabling it to understand itself. A single brain, however magnificent, will not be sufficient. Combining several brains is necessary to achieve this worthy goal, which is something that the KITP program accomplished.

-Alexei Koulakov, Program Coordinator, Deconstructing the Sense of Smell

Getting Ready for the Precision Frontier at the LHC

High-energy physics has entered a new era of discovery as the Large Hadron Collider (LHC) at the CERN laboratory has begun colliding protons at an energy almost 7 times greater than the best previous machine. The LHC occupies a 27-kilometer circumference tunnel outside Geneva, Switzerland. A few enormous particle detectors, weighing up to 14,000 tons, record proton collisions at various points around the ring. They were built by collaborations of thousands of experimentalists, who also analyze the data they collect.

The first run of the LHC, from 2009 to 2012, culminated with the announcement of the discovery of the Higgs boson particle on July 4, 2012. This discovery led to the award of the 2013 Nobel Prize in Physics to Francois Englert and Peter Higgs, who predicted this particle over 50 years ago. The Higgs boson was the last missing building block completing the Standard Model of particle physics -- in fact it is the centerpiece. On the one hand, the Standard Model (SM) successfully describes essentially all subatomic experimental phenomena, and has proven to be extremely robust against all experimental tests. On the other hand, it cannot account for dark matter, and it leaves many conceptual puzzles unexplained.

In 2015 the LHC began colliding protons again, at almost twice the energy of the first run. In this ongoing Run II, the detectors have now recorded more collisions than were collected in all of Run I, and the probability of making the Higgs boson, or many other new particles, is much greater than at the lower energy of Run I. The LHC will operate for another decade or two, collecting over a hundred times as much data as it has so far, enabling many more discoveries beyond the Higgs boson.

For the first time in the history of particle physics since the introduction of the SM in 1972, we are searching only for truly new and unexpected signals of new physics, i.e. phenomena not described by the SM. However, finding new physics is like finding a needle in a haystack. Even the Higgs boson is only produced once in every billion proton collisions. We need to

LHC program participants at the Santa Barbara Harbor.

understand the haystack (the SM) incredibly well. That is, we need to be able to predict the probabilities for producing many different kinds of particles in proton collisions at the LHC, within the rules of the SM, to high precision, to match the high experimental precision that is being achieved.

Proton collisions at the LHC are exceedingly complicated. Protons are not simple particles, but are bags containing many constituents, quarks and gluons. Proton collisions are really collisions of quarks and gluons, but even the description of these collisions requires highly complex calculations in quantum field theory (QFT), the framework that unites quantum mechanics and Einstein's theory of special relativity. Quark and gluons interact with each other through the theory of the strong nuclear interactions, quantum chromodynamics (QCD). Quarks interact with the rest of the Standard Model through the electroweak (EW) interactions, forces that are mediated by the photon and its two super-heavy cousins, the W and Z bosons (the former is responsible for some kinds of radioactive decays). And quarks and gluons do not exist in isolation; they are always bound into particles called hadrons, the most familiar of which is the proton. When they emerge from collisions at the LHC, they do so as collimated sprays of hadrons called jets.

Theorists use the rules of QFT and the SM to compute the many possible outcomes of LHC collisions to high precision. These computations are becoming very sophisticated, involving hundreds of thousands of the diagrams invented by Richard Feynman. The progress has been breathtaking: what once was thought impossible to compute is now commonplace. Yet this improvement is necessary to match the high precision of the experimental data, including the determination of properties of the Higgs boson. With the energies reachable in Run II of the LHC, new EW effects are becoming important, which previously could be ignored. Theorists are also involved in determining the initial conditions for the collisions, that is, the composition of the proton in terms of quarks and gluons. And they produce detailed probabilistic simulations, called Monte Carlo programs, which describe effects in the final stages of the collision, that is, how various particles decay and how quarks and gluons materialize into jets of hadrons.

The KITP program in Spring 2016, LHC Run II and the Precision Frontier, brought together a diverse group of theorists – experts in all of the above areas – to scrutinize all aspects involved in making precise LHC predictions. We also interacted closely with participants of the concurrent KITP workshop on the experimental challenges at the LHC, which allowed for comparisons between state-of-the-art theory predictions and experimental results. The theorists were able to not only provide guidance to their experimental colleagues, but also gained a better understanding of where further theory improvements are still needed.

Our program's activities have resulted already in 41 (and counting) papers submitted to professional journals, manuscripts in preparation, review articles or working group reports. Much of this research involved newly formed collaborations among participants of the workshop. The KITP proved to be the perfect environment for further advancing the precision frontier to the stage needed to enable both measurements and discoveries at Run II of the LHC.

-Radja Bougezhal, Lance Dixon, Frank Petriello, Laura Reina, and Doreen Wackeroth, Program Coordinators, LHC Run II and the Precision Frontier

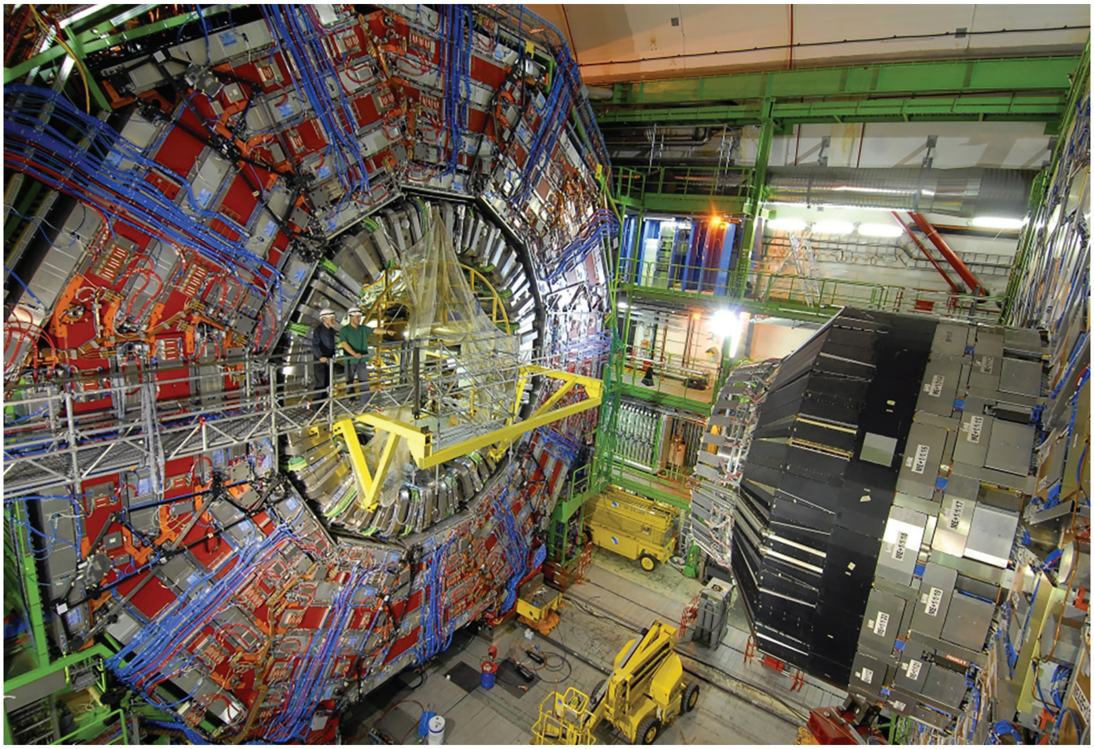


IMAGE COURTESY OF CERN

The Compact Muon Solenoid detector at CERN's LHC.

Research Reunions

A new program enables visiting scientists to return to UCSB's Kavli Institute for Theoretical Physics to work together again in small groups

Can the flapping of a butterfly's wing over the Amazon really set off a hurricane in, say, Houston? The idea that small causes can have large effects would suggest it is a distinct possibility.

In chaos theory, however, the so-called Butterfly Effect — the sensitive dependence on initial conditions in which a small change in one state of a deterministic nonlinear system can result in large differences in a later state — may not apply.
At least that's the hypothesis of a group of theoretical physicists who met last month at KITP.

As participants in the institute's Follow-on Program, they returned to the KITP for a week or two to work in small groups on projects initiated there earlier this year. Through the Follow-on Program, the physicists had the opportunity to finish works in progress or write papers together.

"The idea is to allow people to continue collaborations in one physical location," said Deputy Director John Berlinsky. "The program gives us the opportunity to see long-term outcomes we wouldn't normally be able to discern."

Among this year's participants were three returning visitors who worked with the Deputy Director Greg Huber on an outgrowth of "New approaches to non-equilibrium and random systems: KPZ integrability, universality, applications and experiments," a previous two-month program devoted to the Kardar-Parisi-Zhang (KPZ) equation, a mathematical description of the temporal change of an interface at a particular place and time. That session explored recent progress on the KPZ equation from both a mathematics and a physics perspective.

"Our motivations come from quite a different angle than that program," Huber explained. "The original program exposed connections between all kinds of problems that on the surface seem very different. Some of those problems had to do trajectories of particles and others with the interfaces between two states of a material or two phases of matter. We focused on trajectories but with a connection to turbulence and chaos."

The theorists examined simplified chaotic systems — models for the turbulent kicks experienced in fluid flows — and found some surprising properties. Typically in such systems, trajectories separate at exponentially increasing rates. However, the researchers found that certain trajectories showed a tendency to cluster together.

"We've been trying to understand what lies behind this and also to think about its implications," said Michael Wilkinson, a theoretical physicist at The Open University in the United Kingdom. "We're pretty close to getting a good understanding of it. There are one or two hard mathematical results that we have yet to show conclusively but for which we are getting strong evidence."

It seems that in chaotic systems while almost everything separates exponentially, there is at least one trajectory that is forever contracting. The Follow-on group is developing quantitative measures of the structure of these patterns, which have the property of being a fractal or self-similar — looking the same when viewed up close or from farther away.

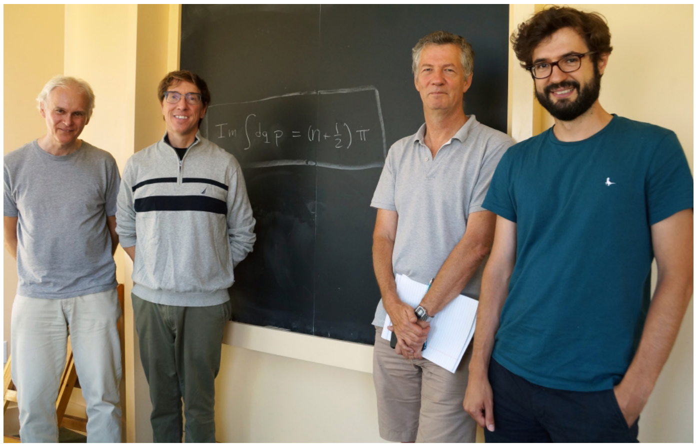
The first Follow-on participants returned to KITP in 2015. One particularly enthusiastic gathering studied the deformation properties of two types of solid materials, including bulk metallic glasses, which may one day be used for cellphone casings. During their two-week stay, the team of five submitted six manuscripts to peer-reviewed journals and two papers to arXiv, a preprint library that posts thousands of physics, mathematics and computer science articles. The group also started a ninth paper and now, more than a year later, is preparing a tenth, with more forthcoming.

"Those extra two weeks at the KITP significantly strengthened our collaborations and gave us the time and space to initiate new synergistic group efforts," said Karin Dahmen, a professor of condensed-matter physics at the University of Illinois at Urbana-Champaign. "Not only did the program provide a unique opportunity to finish discussions and joint work that we had started at the KITP, it also helped us think up new ideas and design new projects that could lead to groundbreaking larger research projects for the next decade or longer."

The Follow-on Program, thanks to funding from the Kavli Foundation, allows theorists to delve more deeply into topics that interest them, while at the same time bolstering the KITP mission: to foster discover and collaboration.

"The program is a nice tool that we can use to identify work that had some impetus here and then shepherd it toward completion," said Huber. "And that fits into the goal of our institute as a whole."

– Julie Cohen, UCSB Public Affairs & Communication



SONIA FERNANDEZ

Left to right: Michael Wilkinson from Open University in the UK, KITP Deputy Director Greg Huber, Alain Pumir from Laboratoire de Physique in Lyon, France, and Marc Pradas from Open University.

KITP Residence Designed to LEED Specifications

LEED, stands for Leadership in Energy and Environmental Design and is a green building certification program that recognizes best-in-class building strategies and practices.

We are working toward Platinum certification, and highlights of LEED specified design in the KITP residence include:

- No carpet installed within three feet of any exterior entry, bathroom, or kitchen and use of water resistant flooring (no carpet) in kitchen, bathroom, and laundry room
- CO Sensors in each unit
- Low-flow plumbing including toilets with 1.3 gallons per flush or less, lavatory faucets with 1.5 gallons per minute or less, and shower heads with 1.75 gallons per minute or less
- All lighting fixtures are LED, 90% of lamps are ENERGY STAR
- ENERGY STAR appliances in all units, including refrigerator, dish washer with 6.0 gallons per cycle or less, clothes washer, and bathroom fan of at least 110 cfm
- Environmentally responsible paint and materials such as low VOC paint and adhesive/sealant as well as low VOC and 25% post-consumer recycled insulation
- Cement and aggregate specification showing locally manufactured within 500 miles
- Environmentally responsible landscaping with no invasive plants and 90% of plants are drought tolerant

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Engaging with 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) 893-6316
or visit our website at www.kitp.ucsb.edu/support-kitp.

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