Kavli Institute for Theoretical Physics
UC Santa Barbara

www.kitp.ucsb.edu

Newsletter

Fall 2017

JAKUB OSTROWSKI

Lars Bildsten

It's the time of year for changes. The most profound one for us is the retirement of Permanent Member Joe Polchinski, one of our most prominent faculty members and the inaugural holder of the Pat and Joe Yzurdiaga Chair in Theoretical Physics. Joe continues his research and engagement here at KITP while recovering from brain cancer. Joe's retirement celebration had many great moments, so please look to the back cover to see the photos from our celebration, and if you want to learn from Joe about his remarkable adventures in science, go read his just released scientific autobiography at https://arxiv.org/abs/1708.09093.

Our postdocs continue to do very well in their careers beyond KITP. This year, four moved on to new positions. Jim Fuller is an Assistant Professor at Caltech, Louk Rademaker is a five-year fellow at the Perimeter Institute in Canada, Sebastian Streichan is an Assistant Professor in the Physics Department here at UCSB, and Tonomori Ugajin is a postdoc at the Okinawa Institute of Science and Technology in Japan. Three new postdoctoral fellows will arrive at KITP this academic year. Chiara Toldo is a high energy theorist who just arrived from Columbia University, while Eyal Karzbrun (a quantitative biologist at the Weizmann Institute in Israel) and Chris White (a computational astrophysicist at UC Berkeley) will both arrive in January 2018.

We are now through nine months of operating the Charles T. Munger Physics Residence, and it has proved a success. Our visitors love being there, and, as expected, the KITP programs now use the Munger Residence as their hub of social activities. Late at night, you will find physicists debating at the black boards and challenging each other at ping-pong, foosball or snooker. It's really quite the scene. We had our opening celebration on July 15, 2017. Please have a look at pages 4 and 5 for photos of the event and great quotes from Charlie Munger, Chancellor Yang, and myself.

Our programs remain the hallmark of what we do at the KITP. On page 2, you will find KITP participant Ilya Mandel's summary of his participation in the Spring 2017 program on Massive stars. The program on hearing was a fun one for us, as we all were able to learn so much about how hearing really works. Please read about that program on page 3. We also enjoyed a wonderful public lecture on Hearing by James Hudspeth. You can find it here: http://online.kitp.ucsb.edu/online/plecture/jhudspeth17/. This was one of the many programs that Greg Huber managed during his five years of service as KITP Deputy Director. Greg is continuing his research efforts here at KITP through the end of the calendar year and then will be moving on to be the first member of the newly formed Theory Group at the Chan Zuckerberg Biohub in San Francisco.

Our other Deputy Director, Mark Bowick, was also in the news for a paper with Suraj Shankar (KITP Graduate Fellow) and Cristina Marchetti (KITP General Member). Though all three harken from Syracuse University, clearly their time here at KITP has led to some fun insights on complex flows in unusual geometries (see page 6).

Like our postdocs, our staff also often move on to new adventures. Cori Montgomery, our Business Officer for nearly three years, accepted a new position on campus as the Director of the Humanities Administrative Support Center. She did a wonderful job for us and I wish her the best of luck in her new position. Our search for her replacement took much of the summer, but we succeeded! Lisa Stewart arrived at KITP on August 28, 2017 from the Univ. of Virginia, where she was the Director of the Institute for Business in Society.

Other staff transitions are the addition of David Kaczorowski as our new Program Manager. He has already embraced his role as the lead staff member involved with the Deputy Director in program planning. Maggie Sherriffs will continue at KITP as our evaluations coordinator, assisting with our need to assess program outcomes. Alina Gutierrez has joined KITP as my new assistant, and is well known here for her work as a student computing assistant. Martine White joined KITP as the special assistant to David Gross, and Bibiana ("Bibi") Rojas is now the special assistant to the visitors. Please say hello to all next time you are in Kohn Hall!

~ Lars Bildsten, KITP Director

The Mysteries and Inner Workings of Massive Stars

On September 14, 2015, the Laser Interferometer Gravitational-Wave Observatory (LIGO) detected the mergers of two black holes in a distant galaxy, ushering in the era of gravitational-wave astrophysics. Since then, two additional mergers of binaries containing pairs of black holes have been observed by LIGO. These events, and the surprisingly high mass of the black holes (more than 30 times the mass of the Sun in one case) has opened up a large range of questions that were addressed over the 11 weeks of the "The Mysteries and Inner Workings of Massive Stars" program in Spring 2017.

Gravitational waves are only efficient in driving black hole binaries to merger if the black holes are very close, a fraction of the distance from the Earth to the Sun. One scenario for reaching such high black hole masses in merging binaries relies on keeping the radii of the progenitor stars small, allowing the stars to avoid mass transfer in a close binary. This could be achieved by mixing the star while it is fusing hydrogen into helium. Efficient mixing powered by stellar rotation can bring nuclear fusion products out of the cores of stars to their surface, and fresh fuel into the cores; this allows for the formation of these black holes without the progenitor star becoming very large. Meanwhile, the efficient transport of angular momentum while the star is evolving, together with the details of the final collapse to the black hole will determine the spin (or rotation rate) of the black hole that remains. The masses and spins are being measured by gravitational-wave observations, which can therefore inform our understanding of the progenitor channels and evolutionary physics. New papers on this topic inspired by the KITP program have already begun to appear, and many more are in the works.

Other important issues discussed during the program, both from a modeling perspective and using the latest observational constraints, included stellar winds and the associated mass loss rates, which again determine the mass of the black hole left behind at the end of the star's life. Mass transfer between massive stars in binaries was another area of active investigation: how much of the gas lost by one companion ends up on the other, and when mass transfer may become dynamically unstable (the so-called 'common envelope' phase), are key factors determining the outcomes of isolated binary evolution.

Of course, the observational signatures and impact of massive stars are not limited to gravitational-wave sources. We discussed the modeling and observations of topics as diverse as supernovae, X-ray binaries, and asteroseismology. The program benefitted from a very stimulating conference on ``Phenomena, Physics, and Puzzles Of Massive Stars and their Explosive Outcomes", as well as a special short program for High School physics teachers on "Exploring the universe with LIGO". The vibrant discussions, freely shared ideas, and new collaborations formed at KITP will continue to drive development in this field for years to come.

Hands-on illustration of mixing in stellar interiors at the KITP residence. From left to right: Thomas Rivinius (ESO), Stan Owocki (Delaware), Natasha Ivanova (Alberta), Rich Townsend (Wisconsin), Ed van den Heuvel (Amsterdam).

Improving understanding of stars by getting closer to them in the Los Padres mountains. From left to right: Selma de Mink (Amsterdam), Chris Belczynski (Warsaw), Thierry Foglizzo (CEA), Mathieu Renzo (Amsterdam).

~ Ilya Mandel is a Professor of Theoretical Astrophysics at the University of Birmingham, UK, and was in residence at KITP for this program.

Hearing: A Biophysical and Neurological Enigma

Humans harbor an extraordinary auditory capacity: the cocktail party effect. We can tune out background noise in a room full of conversation and focus on the speaker we intend to converse with. We can tune out the constant tick-tock of a clock in a room just as we can ignore a car's motor running while driving. At the same time, we can instantly tell when a car makes a peculiar noise or a glass breaks at a dinner party.

The way the human brain is able to analyze a complex auditory setting by focusing on one particular stimulus while filtering out a range of other stimuli remains a mystery.

The KITP program "Physics of Hearing: From Neurobiology to Information Theory and Back" held during the summer of 2017 integrated scientific research from different subject areas in order to make sense of the information theory of complex auditory signals. "The goal of the program was to foster new collaborations and projects between physicists and neurobiologists that work on hearing and scientists who use machine learning to analyze and process speech," program coordinator Tobias Reichenbach, a senior lecturer in the department of bioengineering at the Imperial College of London, said.

A significant volume of research has clarified the biophysical mechanisms through which the inner ear is able to encode sound stimulation into neural signals that are subsequently processed in the auditory brainstem and cerebral cortex. However, there is still a lack of understanding on how a complex auditory scene is broken down into its individual, natural signal such as speech.

In an effort to better understand the connection between the ear and brain at a deeper level, the eight-week program examined many different perspectives, including "the interdisciplinarity between physicists, neurobiologists and speech-recognition engineers who were all interested in speech and hearing," Reichenbach said.

"We were really lucky to have top-notch researchers from across the globe who came eager to share their unpublished work and to engage ideas outside of their field of interest," program coordinator Maria Geffen said. Geffen is an assistant professor at the University of Pennsylvania who has built the Laboratory of Auditory Coding that explores neural mechanisms of auditory processing.

Physicists are particularly interested in the biophysics of the inner ear, as they are able to replicate this in a front-end machine learning speech recognition, helping to improve performance. Furthermore, they show curiosity of the neural mechanisms through which sound is processed since they can mirror these mechanisms in artificial deep neural networks.

Similarly, neurobiologists are showing interest in machine-learning approaches because they allow them to analyze datasets that are obtained from multi-cellular recordings. They are also intrigued by artificial neural networks and are attempting to see how the computational actions of artificial neurons in such networks compare to those of living neurons.

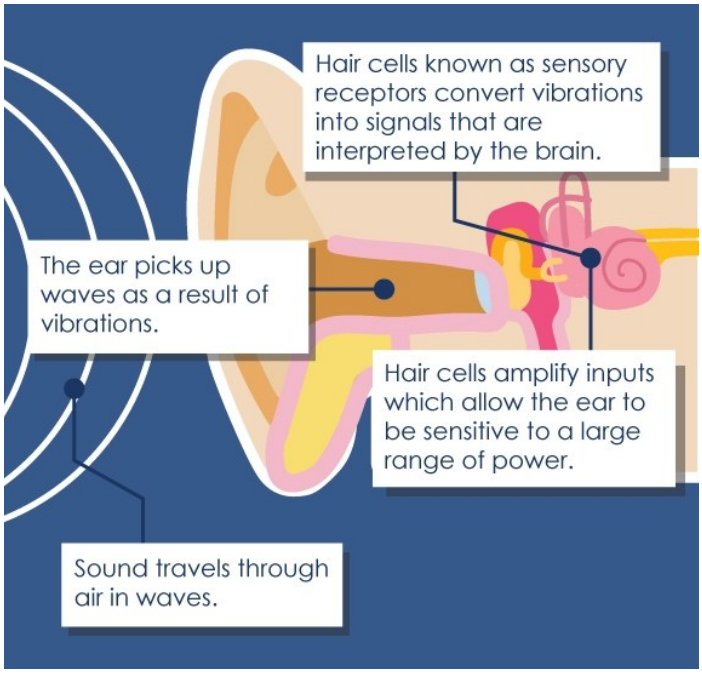
The program looked at how biology and technology work together. There have been many advancements with hearing technology, such as the cochlear implants as well as voice-recognition devices.

"We discussed how to make them work better in hearing noise, listening to music, more sophisticated aspect of sound processing," Geffen said.

Therefore, maintaining collaboration with professionals from many disciplines is fundamental in analyzing how the brain processes complex sounds and replicating this mechanism in hearing aids and voice-recognition devices.

The sense of hearing is an intricate process that consists of multiple actions and reactions in order to work. Sound travels through the air in waves that are picked up by the ear as a result of vibrations. Hair cells on the ear called sensory receptors convert the vibration into signals that are interpreted by the brain. These hair cells are of particular interest to scientists due to the limited understanding of their operation as well as their degeneration, which causes many hearing impairments for a large population of people.

Hair cells employ a mechanical active process to amplify the signal inputs, allowing the ear to be sensitive to sounds in a large range of power. In the same way, as the active process decreases, so does the ear's sensitivity to differences in frequency of sound, which leads to the ear lacking the ability to distinguish the different sources of sounds.



Kevin Son / Daily Nexus

"Lack of hearing is a very important problem; most of us, if we live long enough, are guaranteed to lose some hearing. When we lose hearing, our ability to detect sound is lost, but more so, we lose the ability to hear sound in the presence of noise," Geffen said.

By hosting the physics of hearing workshop, the KITP was able to foster collaboration among various disciplines in order to comprehend the complex mechanisms of the auditory process and build upon potential ideas to cultivate growth for the future.

"What we wanted to do is bring people across the full spectrum, from people who study speech processing and speech recognition — for example, from Google, where they try to recognize speech, words and text — to people who study biological processes of hearing — either humans or in animals — in the central auditory system and people who study dynamics of the cochlear inner ear," Geffen said. "Our hope was that by learning about what people do in speech recognition, we can better design stimuli to use in our experiment and understand neural aspects of auditory systems and participants will be able to start collaborations with many researchers."

~ By Erin Haque, Student Writer at the UCSB Daily Nexus.

At the Inauguration, Chancellor Henry T. Yang presented Charlie Munger with the Santa Barbara Medal, the highest honor UCSB bestows on a friend of the University, which was inscribed with the following message:

Charles T. Munger

With heartfelt gratitude for your vision, creativity, generosity,
and gift of time that will forever impact physics and our university

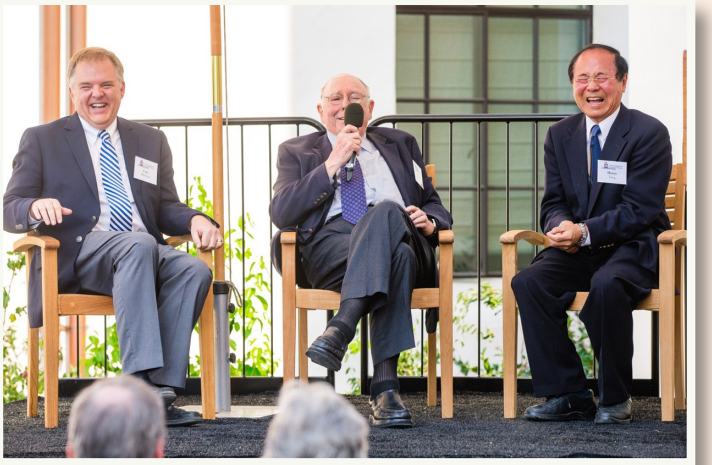
When given the Santa Barbara Medal, Charlie said:

"Thank you very much. That's what I need is a medal. Really, the real pleasure here is not getting the medals, it's working with good people. It is absolutely one of the main privileges of life to work together with good people, and you bond in a way that won't occur in ordinary social life."

If you want a great life, you've got to collaborate on something difficult with other good people.
It's a simple rule. When you get an opportunity to do it, it's not a minor opportunity; it's what life is all about.
Thank you Henry."

RESIDENCE INAUGURATION

2017



In his concluding remarks, Lars Bildsten said:

"I would like to close with the best compliment I have heard from one of our visiting scholars (all of whom rave about the new Residence!) as they were telling me how much they enjoyed staying at the Residence, they slipped up and referred to it as going home. Indeed our KITP visiting scholars feel that this place is not just a home away from home, but that the Munger Residence is their home, which is exactly what we had hoped for, so thank you again Charlie!

Curious Properties

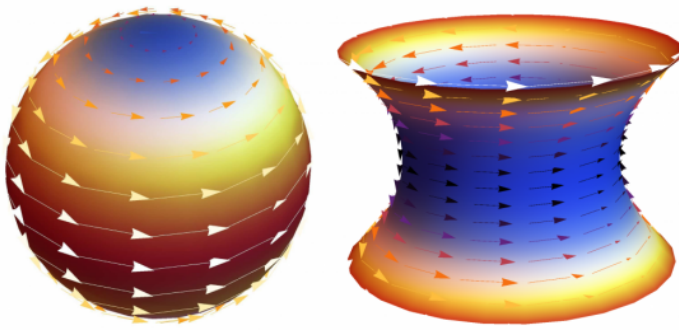
KITP Researchers analyze flocking behavior on curved surfaces

A murmuration of starlings. The phrase reads like something from literature or the title of an arthouse film. In fact, it is meant to describe the phenomenon that results when hundreds, sometimes thousands, of these birds fly in swooping, intricately coordinated patterns through the sky.

Or in more technical terms, flocking.

But birds are not the only creatures that flock. Such behavior also takes place on a microscopic scale, such as when bacteria roam the folds of the gut. Yet bird or bacteria, all flocking has one prerequisite: The form of the entity must be elongated with a "head" and "tail" to align and move with neighbors in an ordered state.

Physicists study flocking to better understand dynamic organization at various scales, often as a way to expand their knowledge of the rapidly developing field of active matter. Case in point is a new analysis by a group of theoretical physicists, including Mark Bowick, deputy director of the KITP.



SURAJ SHANKAR

Steady flocks on a sphere and a catenoid.

Generalizing the standard model of flocking motion to the curved surface of a sphere rather than the usual linear plane or flat three-dimensional space, Bowick's team found that instead of spreading out uniformly over the whole sphere, arrowlike agents spontaneously order into circular bands centered on the equator. The team's findings appear in the journal Physical Review X.

"Whether it's bacteria swarming, cells roaming or energy-consuming 'arrows' flying, these systems share universal characteristics independent of the precise size and structure of the agents as well as their detailed interactions," said corresponding author Bowick, who is on leave from Syracuse University while in his role at KITP. "The ordered states of these systems are never perfectly uniform, so fluctuations in density generate sound, much in the same way that wind instruments create music."

On curved surfaces, the team, which includes KITP general member Cristina Marchetti and KITP graduate fellow Suraj Shankar, found "special" sound modes that don't dissipate and flow around obstacles. According to Bowick, these special modes correspond to special harmonics or tones that don't mix with all the other harmonics.

He also noted that these modes are special precisely because the band geometry of the equator is very different from the planar geometry of a flat surface. For example, a particle moving on a ring comes back to its starting point even though it moves along a "straight" path. This doesn't happen on a plane, where entities continue forever in a straight line, never to return, unless they encounter an edge. This feature is a direct consequence of the very different topology of the sphere and the plane.

"Even though a sphere itself has no edge, the swarming patterns have an edge — the edge of the band," Bowick said. "So simply by locally consuming energy, active agents on the sphere spontaneously swarm and create an edge."

The authors also analyzed another curved shape, an hourglass-shaped figure called a catenoid. Unlike a sphere on which parallel lines converge, the catenoid's concave curvature causes parallels to diverge. This opposite curvature pushes the flocking entities and associated sound waves to the top and bottom edges of the hourglass, leaving the middle bare — the opposite of what happens on a sphere.

"Just the fact that these systems flock is pretty remarkable because they dynamically generate motion," said Shankar, a doctoral student in the soft matter program in Syracuse University's physics department. "But they are far richer systems than we expected because they also generate these 'topologically protected' sound modes."

~ By Julie Cohen, Science Writer, UCSB Public Affairs

SONIA FERNANDEZ

Mark Bowick

KITP Scholars

Creating opportunities for teaching professors to do research

The KITP Scholars Program supports and encourages the research interests of physicists based at primarily undergraduate teaching institutions, thereby helping them maintain active research programs. Interested candidates apply directly to the KITP and are then selected by the KITP Director and permanent members. KITP Scholars receive an award that underwrites a series of visits to the KITP, allowing them to interact fully with programs of interest. Roughly 20 Scholars are active at any one time. By making it easier for theorists to pursue research careers outside the customary research centers the KITP also expands job opportunities for physicists and enhances the quality of faculty at teaching institutions. More broadly, by facilitating KITP Scholars continued research efforts the Institute is contributing to the quality of undergraduate education in sciences in the United States. Following are three testimonials from current KITP Scholars.

Ryan Wilson teaching midshipmen at the Naval Academy.

KITP Scholar Ryan Wilson is an Assistant Professor of Physics at the United States Naval Academy (USNA) and is the first service academy professor selected for a KITP Scholars Award.

"Working as a theoretical physicist at a primarily undergraduate institution can be rather isolating. To produce relevant, creative research, it is important to share ideas with and get feedback from a broader community of scientists. This is precisely what the KITP Scholars program provides. In my three years as a KITP Scholar, I've been introduced to many other theorists working at primarily undergraduate institutions, I've met and discussed with world experts in my field of research, and I've been introduced to entirely new research questions that have steered my research program in new directions. In fact, I am working on two exciting projects with collaborators that I met at the KITP! Aside from the great science, the "icing on the cake" is being a short walk from a beautiful beach, in a relaxing climate. I strongly recommend the KITP Scholars program to any theorist who has considerable teaching responsibilities and research ambitions. There's nothing else like it!"

~ Ryan Wilson

KITP Scholar Jason T. Haraldsen is an Assistant Professor of Physics at the University of North Florida

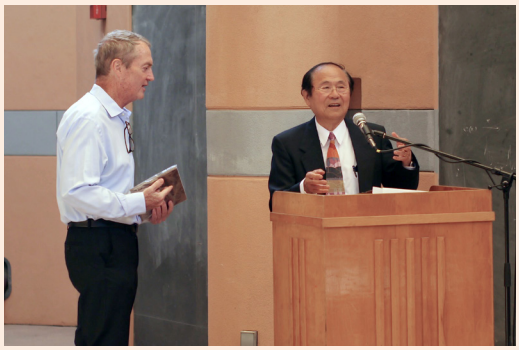
"I find the program to be very helpful in keeping me connected with the condensed matter community. The ability to meet with and have interesting and informative discussions with researchers and faculty not just from UCSB, but from around the country and the world has been useful for both my teaching and my research. One particular discussion that was very useful was with David Gross on the subject of an undergraduate Quantum Field Theory course that I developed and taught at the University of North Florida." ~ Jason Haraldsen

KITP Scholar Joel W. Walker is an Associate Professor of Physics at Sam Houston State University

"It is a great good that the Institute has championed, now for almost 20 years, integration of theorists from non-doctoral and teaching-intensive departments into the primary research community. I personally credit new colleagues, new topics of research, and an active research grant from the NSF to the KITP Scholars Program, and send a most sincere "Thank You"!"

~ Joel Walker

Joe Polchinski's Retirement Celebration












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.

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