UC SANTA BARBARA
Kavli Institute for Theoretical Physics

Newsletter

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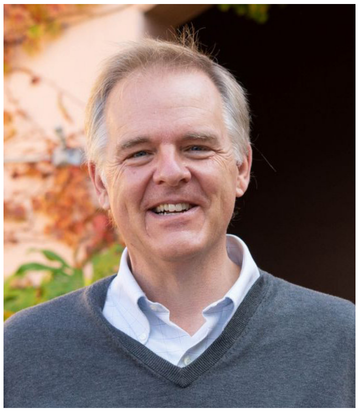


Lars Bildsten

The image above shows the start of construction for KITP House! Since I last wrote, we have achieved many milestones. In early February 2026, we received our Coastal Development Permit from the California Coastal Commission, enabling the start of site development. We are spending the first few months bringing utilities to the site as we prepare to lay the building's foundation. Meanwhile, we completed all of the design documents, received our final building permit from UC Santa Barbara, and awarded the construction contract to Edwards Construction Group. So, from now on, you should only hear from me about construction progress as we approach our July 2028 opening!

In a strong collaboration with UCSB and the UC Office of the President (UCOP) we are undertaking this project as a donor-developed endeavor to allow for the consortium of generous donors to not only fund the whole project, but also participate in the process of design and construction. Many staff here at UCSB and UCOP were key to getting the agreements in place, and I thank them all. Just as with the Munger Physics Residence, KITP will operate the facility in collaboration with UCSB's Housing operation.

We have many accolades to share about KITP's scientists. Permanent Member Boris Shraiman received the Max Delbruck Prize in Biological Physics this year with the citation: "For contributions to morphogenesis, evolution, and biological information processing, combining mastery of biological knowledge, innovative analysis of biological data, and rigorous theoretical reasoning to uncover deep insights into the underlying principles of biological processes." Congratulations Boris!

Page 2 tells the story of the awarding of the 2026 Special Breakthrough Prize in Physics to KITP Permanent Member David Gross. I simply cannot imagine anyone more deserving of this award. Not only is David a remarkable scientist, but he also places importance and his own personal time and energy in assuring that physics is thriving around the world. As part of the Breakthrough Prize, a wonderful video was made (*tinyurl.com/reubb62s*) that captures David's enthusiasm for science as well as his passion for alerting the world of the perils of nuclear weapons.

Our largest activities here at KITP are the programs we run, bringing more than 1200 physicists to the institute every year. On Page 4, we have a story from writer Claire L. Evans who participated in a program that just ended this July. Her perspective on witnessing and participating in a program that brings together biologists and theoretical physicists is wonderful to read and so nicely captures an important element of what we strive to achieve here at KITP: bringing scientific communities together for true dialog and learning.

On page 6 is the story of two intellectual threads we have pursued for more than two decades, emission of gravitational waves by in-spiraling black holes and the interactions of particles in high energy accelerators. Ira Rothstein (Carnegie Mellon University) tells the story of how these two distinct activities have now come together to enable calculations of gravitational waveforms that would otherwise be nearly impossible. As one of the key coordinators of the recent program and innovator in the field, Ira provides an excellent perspective.

We close on page 7 with the story of the awarding of the Richard DiPrima Prize to KITP Postdoctoral Scholar Fatih Dinç. Fatih came to KITP in fall 2024 and has been very impactful both here at the institute and in his science. The story (written by Harrison Tasoff, of UCSB's Public Affairs and Communications Office, and a long-time contributor to this Newsletter) explains Fatih's science and impact quite well, so I will not elaborate here. Rather, I want to highlight Fatih's inexhaustible enthusiasm for ensuring a rich intellectual life for all of us here at KITP. Not only in his energies to ensure that our Monday Local's Lunches are exciting and well attended, but also in his continual exploration of what more KITP can do!

We have just announced KITP programs for the 2027-2028 academic year, and we look forward to the exciting science that continues to happen here at the institute. Thanks to all of you for your support and interest in all we do!

- Lars Bildsten, KITP Director

KITP's David Gross wins Special Breakthrough Prize in Fundamental Physics

CREDIT: BREAKTHROUGH PRIZE

The Breakthrough Prize Foundation announced David J. Gross, KITP Permanent Member and Chancellor's Chair Professor in Theoretical Physics at UCSB, as the winner of the 2026 Special Breakthrough Prize in Fundamental Physics. The citation noted: "A lifetime of groundbreaking contributions to theoretical physics, from the strong force to string theory, and for tireless advocacy for basic science worldwide"

The Breakthrough Prizes—popularly known as the "Oscars® of Science"—were created to celebrate the wonders of our scientific age. Co-founded by Sergey Brin, Priscilla Chan and Mark Zuckerberg, Julia and Yuri Milner, and Anne Wojcicki, the prizes are now in their 14th year. Former KITP Permanent Member Joseph Polchinski was awarded the 2017 Breakthrough Prize in Fundamental Physics.

This year, six Breakthrough Prizes of $3 million each were awarded. In addition, the Foundation recognized 15 early-career physicists and mathematicians, who share six $100,000 New Horizons Prizes. Three women mathematicians recently completing PhDs each receive a $50,000 Maryam Mirzakhani New Frontiers Prize.

"This year's laureates show what great science can do – deepen our understanding of the world and lead to discoveries that improve millions of lives," said Mark Zuckerberg and Dr. Priscilla Chan, founders of Biohub. "We're proud to recognize their work."

"The brilliant scientists who win the Breakthrough Prize," said Yuri Milner, co-founder of Breakthrough Prize Foundation, "are building a cathedral of knowledge on foundations laid down by the giants who came before them. We owe our civilization – and its future – to them."

Winner of the 2004 Nobel Prize in Physics, Gross has been a leading figure in fundamental physics for six decades. In the early 1970s, there was a gap in quantum field theory, our best theory of particles and forces. The theory could not describe or accurately predict the strong nuclear force, which holds the nucleus of the atom together. But in 1973, Gross and his graduate student Frank Wilczek (as well as, independently, David Politzer) solved the mystery.

They discovered that the strong force works the opposite way to familiar forces like gravity: it gets weaker as particles approach

CREDIT: BREAKTHROUGH PRIZE

each other, but stronger as they move apart. This explained why quarks, the particles inside the atomic nucleus, can never escape or be observed in isolation, and it enabled the development of quantum chromodynamics – the theory of the strong force and the final foundation stone of the Standard Model of particle physics.

Gross has gone on to make seminal contributions across multiple areas of theoretical physics. For example, he and his collaborators developed a simplified quantum field theory that helped explain how particles can acquire mass; and developed new theoretical approaches attempting to unify all fundamental forces, including gravity, in a single framework known as heterotic string theory.

Alongside his theoretical work, Gross has a longstanding record of leadership in the physics community, in roles including Director of KITP and President of the American Physical Society. He has helped establish physics institutes in India, China, and South America. He directed the Jerusalem Winter School in Theoretical Physics and chaired the Solvay Physics Conferences for the last 25 years. In 2025 he was one of the authors of an ambitious 40-year plan for particle physics on behalf of the National Academies of Sciences, Engineering, and Medicine. And over the course of his career, he has been a mentor to numerous brilliant students who became leaders themselves, passing on his vision of physics as a collaborative international endeavor.

"On behalf of UC Santa Barbara, I offer our hearty congratulations to Dr. David Gross on winning the 2026 Special Breakthrough Prize for his lifetime contributions to fundamental physics," said UCSB Chancellor Dennis Assanis. "Dr. Gross has advanced the frontiers of particle physics and string theory, including his discovery of asymptomatic freedom and the formulation of Quantum Chromodynamics. His seminal work has been recognized with the 2004 Nobel Prize in Physics. He has also made groundbreaking contributions to the theory of Superstrings, a burgeoning enterprise that brings gravity into the quantum framework. Similarly, his impact at UCSB cannot be overstated. As the former director of KITP and now the Chancellor's Chair Professor in Theoretical Physics, Dr. Gross embodies the spirit and the promise of interdisciplinary research."

by Shelly Leachman
Editorial Director, UCSB Public Affairs & Communications

CREDIT: BREAKTHROUGH PRIZE

Report from Goleta

An account of three days haunting the halls of the Kavli Institute for Theoretical Physics.

CREDIT: CLAIRE L. EVANS

The Castagnola-Hunter Tower Room at KITP.

KITP sits on a wedge of prime real estate between the Pacific ocean and a quarter-acre of restored wetlands in Goleta, on the campus of the University of California Santa Barbara. It's an idyllic place for a life of the mind. The air smells of jasmine and brine; just beyond the sandstone bluffs, local teenagers slap each other with ropes of beached kelp and seabirds hang low in the sky.

At each entrance to KITP are signs warning undergraduates away. The signs are new. Recently, a student TikTok about the building's vibey architecture went semi-viral, exposing its apricot-colored seminar rooms and shiplike circular windows. As a result, there has been an epidemic of selfies, much to the exasperation of the chalk-dusted figures who ordinarily roam its halls. The inner sanctum of KITP is off-limits to everyone but a rotating group of these invited scientists, whose credentials are signaled by the matching brown coffee mugs they're assigned on arrival.

Every morning, the scientists take turns giving technical morning lectures and vociferously interrupting one another. To an outside observer, the social dynamics revealed by this display are inscrutable. Barely two slides into a presentation on gene regulatory networks, the volley of interjections has already begun:

"In principle, couldn't you…?" a wild-haired physicist in the back row begins.

"But what, *exactly*, is this data set?" blurts a computer scientist.

Things continue in this mode, the questions coming faster than I can jot them down. An equation onscreen sends the room into a brief orthographic hysteria.

"What's D?"
"What's T?"
"What's S(y)?"
"Sorry, *what* was Y?"
"B is a random vector of no importance."
"And C is a random walk?"
"Does that number scale with the square root of D?"
"No, this is W, not X."
"So S(y) is zero?"
"And what is K?"
"Can I move on?"

I'm here for an interdisciplinary program on the subject of

Biological Learning Without a Brain. It has drawn neuroscientists, biophysicists, computer scientists, and biologists from all over the world. During these seminars, it's easy to tell which is which. Any time a specific field is invoked, its representatives lurch forward in their seats, signaling with their bodies not only their interest in the matter at hand, but their keenness to contest its finer points. The more acute the angle of this lean, the more imminent the torrent of commentary. There's nothing hostile in this, as far as I can tell. The scientists aren't jockeying for prominence; they're motivated by an earnest desire for clarity, for closeness to an elusive, unambiguous truth. I have sat in on many analogous seminars in the humanities, and in countless art-school critiques, and I've never witnessed such adversarial conviviality.

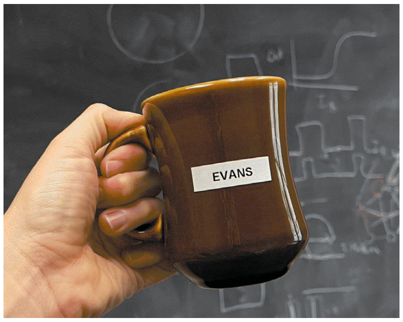
"Oh, I'm used to all that," says Sam Gershman, the Harvard neuroscientist who invited me out to Goleta. Gershman is freckled, with a runner's build and a perpetually squinting expression. After the morning seminar, over burritos in Isla Vista, he tells me about a theory that cancer is what happens when cells revoke multicellularity and revert to an archaic state, recapitulating their origins as solitary cells—with the commensurate drive to divide and multiply. We chew our burritos. Maybe our cells yearn to be free of us, I think, most unscientifically. Maybe they're exhausted by the constant negotiations in time and space it takes to maintain the form of an eye, a limb, a mind. Lord knows I'm tired too.

Dr. Gershman studies, among other things, the biochemical basis of memory. While most neuroscientists are convinced that memories are stored in the connections *between* cells—in the networks of synapses and neurons upon which AI systems are modeled—Gershman, like many of the scholars here, has a hunch that some aspect of memory is chemical, stored in the cell itself. After all, our cells trace their evolutionary origins to independent, free-swimming ancestors, and those distinctly brainless creatures must have had the capacity to adapt to their experiences and remember the relevant features of their world, or else they never would have survived.

Biology is the product of adaptation to a long series of coincidences and constraints. Evolution has produced countless solutions to the problem of survival over eons of trial and error, and those solutions—eyes to see danger, minds to anticipate it, potential cellular machinery to store and pass on what we've learned—are not always the most straightforward or logical. They're certainly not the kind of solutions that engineers would come up with. What we're left with is merely what has *worked,* what successfully carried those unicellular ancestors all the way to personhood.

But biology's possibility space is greater than the configurations in which it currently exists. This has been a theme of my time here. A test tube full of DNA molecules can store data and perform basic computational tasks. The internal networks of cells, modeled in the computer, become fascinating mathematical abstractions to tweak and fiddle with. The vascular networks of slime molds inspire new algorithms. And so on.

Back at KITP, I've been assigned an office on the second floor, which I'm sharing with Michael Elowitz, from Caltech. Elowitz is a pioneering synthetic biologist; he devotes his life to engineering molecules that can identify and kill cancer cells. When I ask him about this notion of cancer cells as individualists disavowing the collective body, he gives a jovial harumph. "Well, that's a bit anthropomorphic," he says.



CREDIT: CLAIRE L. EVANS

The brown coffee mug in question. There's a blackboard in every room at KITP.

After all my years spent talking with scientists, I'm still never quite sure when it's appropriate to speak in metaphor. As Philip Ball observes, there are plenty of metaphors in science. Molecules *recruit* one another, for example. Cells *signal* to one another. The so-called central dogma of molecular biology is that DNA *transcribes* genetic instructions onto messenger RNA, which then *translate* them into proteins. These are accepted analogies, so absorbed into the language of biology as to be effectively invisible. Others, more emergent, remain hotly contentious.

In KITP's Castagnola-Hunter Tower Room, a hexagonal crow's nest overlooking the ocean, a group gathers to discuss this matter—specifically, if "learning" is an appropriate metaphor to use when talking about cells, plants, or the physical properties of living matter. Biology is counterintuitive; the molecular mechanisms driving the behaviors in question are still unclear. In the face of such uncertainty, language might constrain knowledge as much as it summarizes it. What might we miss by approaching the unknown with a narrative framework already in place? On the other hand, without metaphors, how are we supposed to grasp complexity? Is it anthropocentric to port human concepts to the nonhuman world? Is it anthropocentric *not to?*

Naama Brenner, a theoretical biophysicist from the Technion in Israel and one of the organizers of the program, kicks things off. "We all like to think in equations," she offers. "But our equations have words behind them." At this, a physicist pushes back—*aren't equations just boring stories?* The computer scientists bristle. *Boring to who?* A plant biologist suggests everyone watch a time-lapse video of a climbing vine. "It's clear there is something complicated going on," she says. Lots of things *look* like learning, but are they? A neuroscientist suggests a distinction between *learning* and *inference,* but all anyone can agree on is that neuroscientists are intransigent about language. The machine learning researchers are less so, for obvious reasons. "We don't have a strong bias against this term," one shrugs. As the resident humanist, I try and make a case for ambiguity. Maybe it's a good thing language isn't fixed, I suggest—like life, it evolves. Biophysicist Arvind Murugan of University of Chicago dutifully writes everyone's suggestions on the blackboard; by the end of the discussion, his hands are white up to the wrists with chalk dust. The answers, as ever, remain elusive.

by Claire L. Evans
Wild Information on Substack

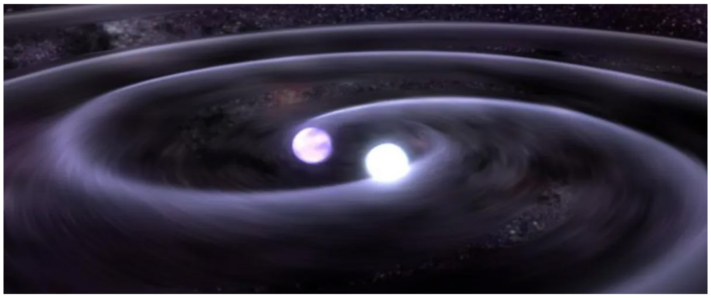
High-Precision Gravitational Waves

It is remarkable that over the past 20 years, we have seen two significant scientific discoveries: the Higgs boson and gravitational waves, both of which were made possible by monumental efforts by experimentalists and the support of forward-thinking government funding agencies. These discoveries, while pertaining to nominally different fields, shared multiple important characteristics. Perhaps most importantly, in both cases, the theoretical community had predicted them. This is in contrast to the discovery of quantum mechanics in the early 20th century, which was quite unexpected.

However, a crucial distinction between these two recent discoveries is that, while gravitational waves were predicted to exist, we did not know if they could be measured. These waves are detected by looking for small deviations, on the order of the radius of an atomic nucleus, between mirrors that are kilometers apart, and are emitted more than millions of light-years away by black holes or other astronomical objects such as neutron stars inspiraling into each other. However, prior to the discovery, there was no consensus in the community as to whether or not measurable events would occur in the career of an experimentalist. It is very hard to know how many black holes are out there exactly because they are black; we cannot count them like stars.

As such, prior to the discovery, the theoretical community working on this problem was composed of experts in general relativity. These pioneers of the field of theoretical gravitational wave astrophysics were pouring their sweat into making predictions for the expected signal for various types of inspirals. They made a bet and won. Since the initial discovery in 2016, there have been hundreds of detections, each of which needs to be analyzed and compared to theoretical predictions in order to determine the masses and spins of the merging objects. This is similar to the Higgs discovery in that we do not actually see the Higgs boson in a detector; we see its remnant. It was the theorists' job to precisely predict what this remnant signal would be. However, in the case of gravitational wave signals, the methodology for making the predictions was not nearly as well developed as it was for Higgs boson production and detection, which had been worked on by a large community for many decades.

Predicting gravitational wave signals for binary inspirals is typically split into two pieces. The final stage is dominated by so-called "nonlinear effects" as the two black holes become one, which we presently only know how to handle with numerical computations. The early stage is calculated analytically, as numerical methods for this slower part of the inspiral are computationally expensive and are susceptible to error accumulation over many orbits. The numerical calculations of general relativity presented a considerable challenge to the theoretical community. It was not until a breakthrough in 2005 that the first stable simulation of a black hole inspiral was achieved. Interestingly enough, this was around the same time that it was realized that the analytic calculations necessary for the early inspiral stage could be tackled using techniques from quantum field theory (QFT)—yet another interesting connection to the Higgs predictions, which are based on QFT. The idea of using QFT techniques lay relatively dormant until the discovery event in 2016. Slowly but surely, more of the particle physics community became involved in working on gravitational wave theory, as it became clear that there were many open questions in the field that could be attacked using QFT.



This illustration shows the gravitational waves produced by two orbiting stars in a binary system.

It was at this auspicious time that we decided to propose a KITP program entitled *High Precision Gravitational Waves,* which would bring together experts in gravitational wave theory and particle physics to serve as a science accelerator. Our program was approved and ran in the spring of 2022. It was, and still is, a very exciting time in the field, as scientists from various subfields of the high-energy community, including amplitudes, effective field theory, and string theory, realized that they had tools that could help generate more precise predictions.

Since then, progress in the field has been remarkable as predictions are becoming ever more precise, allowing experimentalists to extract detailed information about the properties of the observed systems. In particular, one mind-bending prediction is that black holes cannot be deformed. Planets or stars, when placed near other gravitating objects, will undergo "tidal deformations." That is, the gravitational field of one object will tend to pull apart the other, just as the moon's gravitational field causes tides on Earth. The idea that we can actually test whether black holes deform seems almost ludicrous, but using gravitational wave detectors, we have the potential to achieve this goal. However, the effect we are interested in is extremely small (one part in a billion) and will require incredibly precise theoretical predictions. In 2022, we were still very far away from reaching this milestone calculation, but a large communal effort involving contributions from relativists and field theorists is bringing us very close. I would not be surprised if that milestone is reached in the next few years.

That 2022 KITP program was a springboard that led to this progress. Since then, there have been annual programs and conferences that bring together these communities. So much so, that now the fields are starting to merge. I consider this a great success of interdisciplinary science that KITP enabled through its ability to so effectively convene scientists for sustained interactions.

by Ira Rothstein
Carnegie Mellon University

New Mathematical Frameworks Reveal How Stable Thoughts Emerge from Chaotic Brain Activity

"The mind is what the brain does," as the pioneering artificial intelligence researcher Marvin Minsky once said. So, it'd be fantastic to understand at what level of anatomy, or complexity, the brain actually carries out its processing and computation. This quandary is precisely what captivates Fatih Dinç, a KITP Postdoctoral Scholar in UCSB's Geometric Intelligence Lab. His doctoral dissertation on this topic has earned Dinç the Richard C. DiPrima Prize from the Society for Industrial and Applied Mathematics (SIAM). The prize is awarded every two years, recognizing an early-career researcher in applied mathematics. Dinç was selected for his work developing a bridge between mathematics and neuroscience.

"Fatih is a deep thinker, and his expertise vastly broadens the base of knowledge at KITP," said KITP Permanent Member Boris Shraiman, one of his postdoc advisors. "His work aims to shed light on the black box of AI, addressing the mystery behind present day machine learning, what makes it work and how similar, and how different, it is from the neural circuits of the brain. We're proud to have him on our team."

"Fatih is a visionary with a unique ability to bridge mathematical rigor with real-world applications," added his co-advisor Nina Miolane, an assistant professor in the Department of Electrical and Computer Engineering. "Watching his research evolve from ambitious ideas into an internationally recognized, award-winning dissertation has been a privilege. The DiPrima Prize is a well-deserved recognition of his exceptional work."

MAKING SENSE OF BEWILDERING COMPLEXITY

The human brain may well be the most complex system we know of. The mind somehow emerges from the activity of around 85 billion neurons with some 100 trillion connections between them. "On a simpler level, imagine trying to understand a symphony by recording each musician individually," Dinç said. "But in our case, the musicians keep switching seats and changing instruments from day to day. Also, you get to observe only 0.1% of the musicians at any given time. That's roughly the problem we face when studying the brain."

Modern technology allows us to record the activity of millions of neurons simultaneously and can track specific brain regions across many weeks. But individual neurons are unreliable narrators, Dinç explained: "A cell that responds vigorously to a stimulus on Monday might be unresponsive by Friday." However, the system clearly works. The brain reliably processes information and coordinates the functions of the body and mind. Dinç's work is to reveal the brain's hidden language beneath the noise.

And he has a few goals. He wants to determine the fundamental unit of neural computation. If it's not the individual neuron—which seems noisy and variable—then what is the right level of description? What's more, he's curious why behaviors remain stable even as the tuning properties of these individual neurons drift over time. Answering these questions requires figuring out how to make sense of data generated by a million neurons over several months.

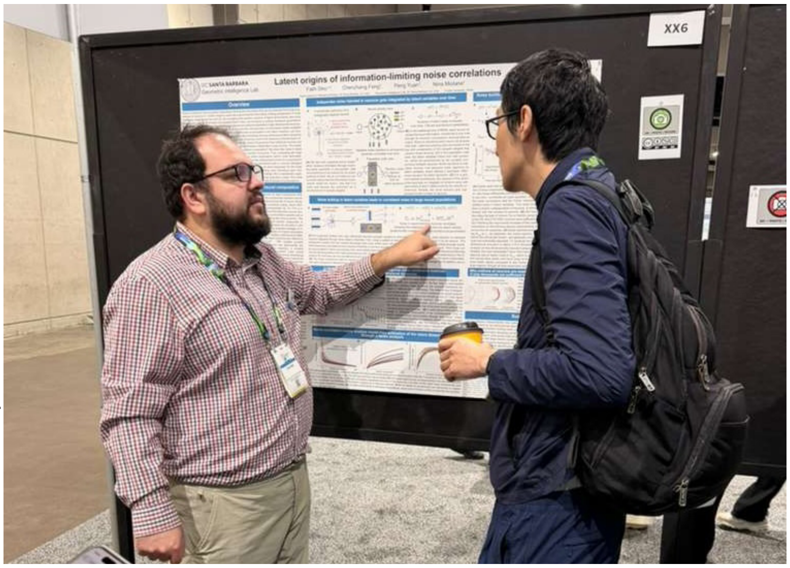
AN UNEXPECTED FIELD OF STUDY

Dinç studied physics and still considers himself a physicist. His integration into the field of neuroscience was quite accidental. In fact, he describes earning the Richard C. DiPrima Prize as "a bit surreal." Incoming doctoral students at Stanford, where Dinç earned his Ph.D., can enter a rotation that places them in a series of different labs on campus. Dinç decided to join Mark Schnitzer, a physicist studying the brain. "I quickly realized that the problems about the brain were mathematically rich and the data were extraordinary," he said. "I never left."

"To have work that grew out of that unlikely combination recognized by SIAM—a community I deeply respect for its rigor at the interface of applied mathematics and real-world problems—means a great deal to me."

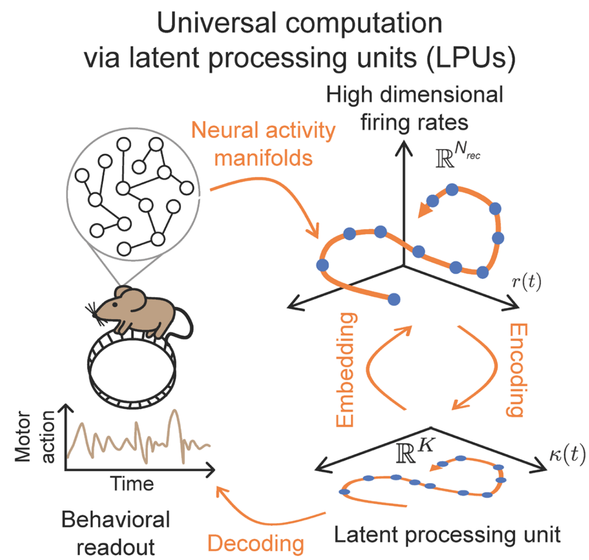
CREDIT: FATIH DINÇ

Fatih Dinç presenting his PhD defense at Stanford University.



CREDIT: FATIH DINÇ

Fatih Dinç at the Society of Neuroscience 2025 in San Diego.



The theory maps individual musicians (in brain, neurons) to collective notes (in brain, latent variables) that make up the music.

IDENTIFYING THE MOTIFS IN THE SYMPHONY

In his doctoral thesis, Dinç built algorithms that extract clean signals from terabytes of messy brain imaging data. He then developed the mathematical frameworks that explain how stable computation emerges from this apparent chaos.

The brain appears to encode information in relatively large, simple patterns embedded in a system that's much more complex. "Think of it like this: Even though a symphony involves 80 musicians playing simultaneously, the emotional arc of the piece might be captured by just a handful of musical themes," Dinç explained. "The brain is similar, thousands of neurons are active, but the meaningful computation might live in a 3- or 4-dimensional subspace." Finding that subspace is the key challenge, because presumably it's these larger patterns that account for the stability of the system.

Researchers around the world are already applying Dinç's algorithms to process large-scale brain recordings. These tools enable the kind of data analysis that simply hadn't been feasible in areas like pain, memory and motor control studies, among many others.

Meanwhile, his mathematical framework has direct implications for brain-machine interfaces. "If you want to decode intended movement or speech from neural activity, you need to know where in the high-dimensional neural space that stable information lives, and the framework provides exactly that," Dinç said. More broadly, understanding how the brain maintains memories and makes decisions informs how we might eventually treat disorders like Alzheimer's or Post Traumatic Stress Disorder, where those mechanisms break down.

Dinç believes his recognition reflects something important about how neuroscience is evolving. The most interesting problems seem to require the tools of applied mathematics, optimization and dynamical systems. "I hope the award draws more mathematically-minded people toward these questions," he said. "The fact that I found my next home here at KITP means that this process has already started."

by Harrison Tasoff
Science Writer, UCSB Public Affairs & Communications

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