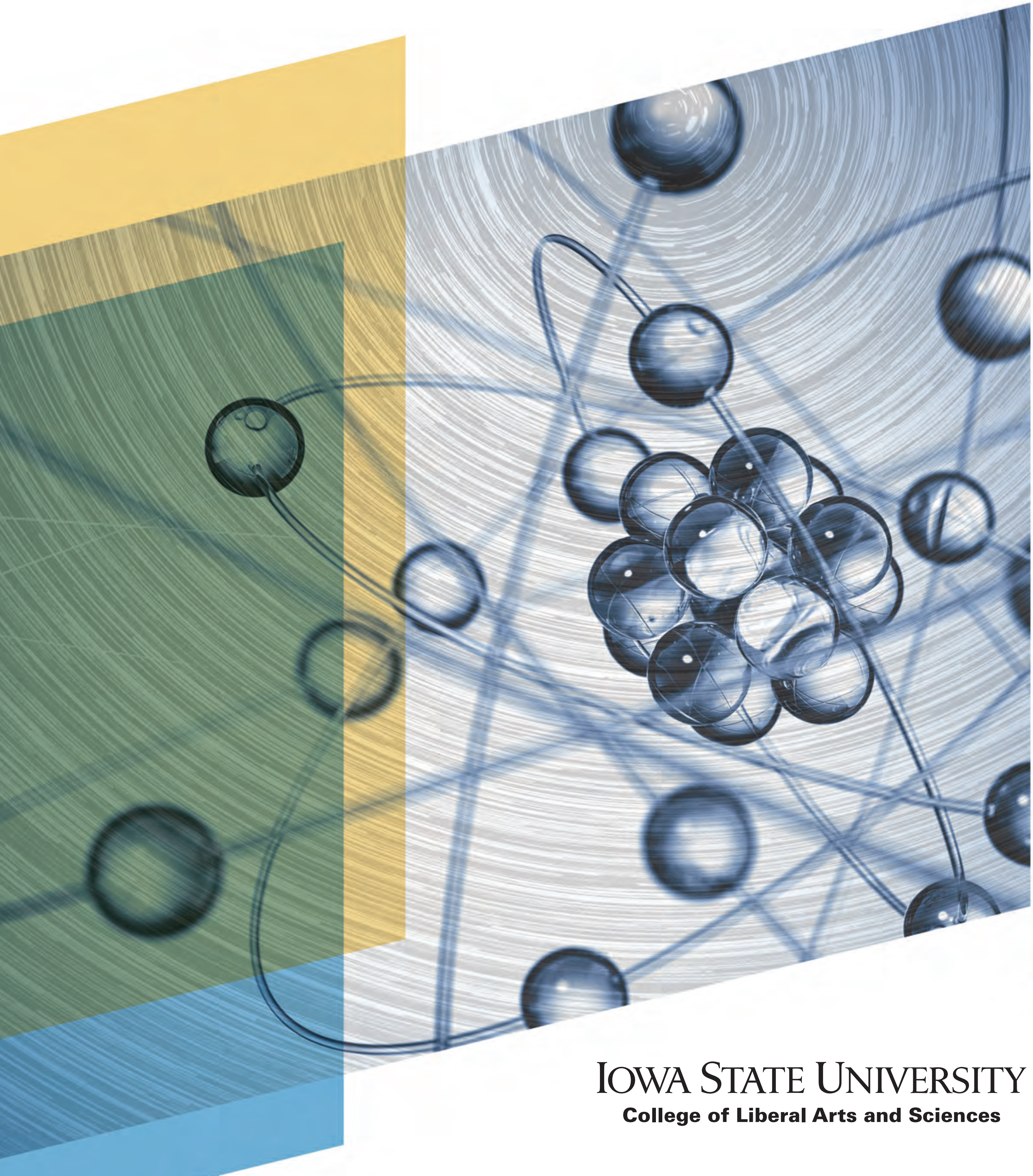
Quanta&Cosmos

Department of Physics and Astronomy | 2017 Newsletter



Iowa State University
College of Liberal Arts and Sciences

A Message from the Chair

Another academic year has come to an end. It was a year that saw many successes of our faculty, students, and postdocs in teaching, research, and scholarship making important contributions to society at large. Research in physics and astronomy is progressing globally at an unprecedented pace. Many of society's current and future challenges require technological innovations. The foundations of these are the discovery and understanding of fundamental physical processes—the type of understanding that is continuously built over generations of scientists in their respective subfields in physics and physical science in general. This basic paradigm is threatened by recent state budget cuts and the troubling notion that higher education is no longer a priority in the state of Iowa. Our students and faculty are rightly concerned about these developments.

In spite of these challenges, this newsletter focuses on the positives. Support from the federal funding agencies and private foundations continues to enable our students and faculty to be highly productive and competitive in a myriad of exciting research and development projects.

A snapshot of forefront research in the Department of Physics and Astronomy is given in this newsletter (see Faculty Profiles), and it covers the fields of astronomy and astrophysics, biophysics, neutrino physics, and condensed matter physics. For example, Steven Kawaler's long-standing interest in asteroseismology is now met by data from the Kepler space telescope providing unprecedented precision in light intensity variations and temporal sampling of stars. With the rise in applications of physics concepts and techniques to the biosciences, our department started a biophysics program in the early 2000s. Research of biophysicist Xuefeng Wang includes the development of new tools to exert and map forces at the molecular level to gain further insight into how cells function. An effort that has become a national priority in high-energy physics research is experimental neutrino physics, which led to our hiring of Matt Wetstein. He plays a key role in ANNIE, a new experiment at Fermilab that aims to measure the properties of neutrino-nucleus interactions and to deploy a new type of photo detector in a physics experiment. Fundamental research in condensed matter physics with potential applications to the next generation of information technology is carried out by Jigang Wang and is enabled by a grant from the W. M. Keck Foundation. In the section on Faculty Profiles, he describes his work to build a nanoscope that uses ultrafast terahertz radiation to explore a new regime in space-time-energy scales for studying materials.

As a community of researchers and students, we share the excitement that comes with the annual announcements of the Nobel Prizes in the fall. In the Nobel/Faculty Awards section, you will find an article by Rebecca Flint giving her perspective on the 2016 Nobel Prize in Physics. You will also find some pictures of our own faculty receiving significant national recognitions—e.g., this year's James C. McGroddy Prize winner given by the American Physical Society, this year's winner of the Theodore E. Madey Award (American Vacuum Society), and our most recent AAAS Fellow. Congratulations!

Research involving the next generation of scientists—i.e., our students and postdocs—is at the heart of what we do. When our students graduate from the Department of Physics and Astronomy to embark on their careers, they become ambassadors of the department to the world of research, education, industry, government, and nonprofit organizations. When they do well, we do well! In the section on Students, you will find a description of our newest program (Physics+) to broaden our offerings to physics majors and better prepare them for a wide range of future careers. You will also find testimony from some of our undergraduate physics majors who attended the 2017 APS March meeting to better position themselves for graduate school. We hope to see all of our current students pursue successful careers and keep in touch with their alma mater, similar to the three alumni featured in the Alumni/Zaffarano section of this document.

Our alumni play an important role in supporting the department. It is because of their generosity that we are able to host the Zaffarano Lecture series. After the inaugural speaker Professor Sir John Pendry from Imperial College London discussed the Physics of Invisibility in 2016, this year's Zaffarano Lecture will be given by Professor Roger Blandford from Stanford University on the subject of Black Holes. A preview is given in the Alumni/Zaffarano section. We would be thrilled to see you at this year's Zaffarano Lecture on October 26, 2017, to be held in Benton Auditorium.

Please keep in touch.
Warm Regards,

Frank Krennrich

Frank Krennrich, Professor and Chair, Department of Physics and Astronomy
515-294-5442 | Krennrich@iastate.edu

HOW TO CONTRIBUTE

We hope that you would designate your contribution directly to the Department of Physics and Astronomy. Please feel free to call Frank Krennrich (515-294-5442), department chair, to discuss possibilities to donate or if you have questions about the different endowment funds.

1) Contributions to the Physics and Astronomy Unrestricted Fund provide the department with the greatest flexibility to finance awards and projects.
2) Contributions to the Zaffarano Lectureship fund allow us to sustain the event over years to come.
3) Inaugural contributions to the Postdoctoral Prize Fellowship in Astronomy and Astrophysics will allow us to establish the fellowship fund.

Other existing endowed funds include the following:

- Robert M. and Evelyn W. Bowie Physics Fellowship
- Charles E. Ruby Scholarship in Physics
- Bernice Black Durand Undergraduate Research Scholarship
- Mather Observatory Fund
- ISU Planetarium Fund
- Gordon C. Danielson Memorial Endowment Fund

If you are considering making a significant gift, you could establish a new endowed fund for a purpose that you designate—e.g., the Postdoctoral Prize Fellowship.

For details and guidance, please refer to Michael Gens, Executive Director of Development (call 515-294-0921 or e-mail mgens@iastate.edu).

Sounding stars while hunting for planets

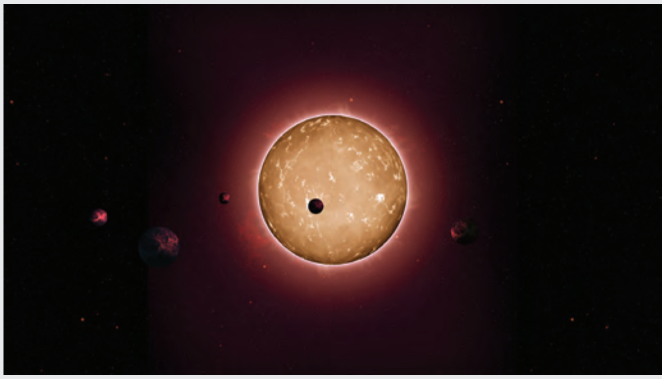
By awakening us to the amazing variety and abundance of other planetary systems, the Kepler mission (and its follow-on mission, K2) has been a landmark in advancing our understanding of the Universe. Launched in March 2009, Kepler's main goal was to observe a statistically controlled sampling of a large number of stars to quantitatively assess the exoplanet population—that is, what fraction of sun-like stars host planets and what is the variety of architectures of planetary systems.

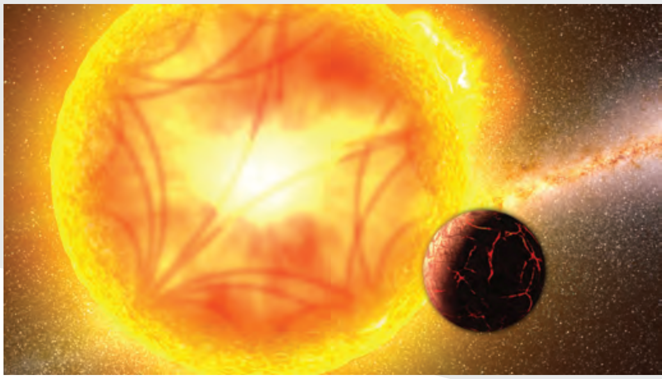
The basis for these discoveries is continuous, extremely accurate, brightness measurements of more than 140,000 stars to search for dips in a star's light when and if one of its planets crosses the star's face. These photometric time series also reveal the subtle vibrations of the stars themselves—star quakes—that can enable us to determine their internal structure via a technique known as asteroseismology.

Asteroseismic investigation of the host stars of planetary systems is an integral part of the Kepler mission. Since transit measurements only determine the radii of planets relative to their host stars, accurate determination of the radii of the host stars is crucial to determining the planetary properties. Through asteroseismology we can accurately measure the masses, ages, and radii of the stars—properties that are needed to specify the dimensions of their planets, and the circumstances of their formation and dynamical evolution.

One example of this synergy is the remarkable planetary system known as Kepler 444, announced in 2015 . Using asteroseismology, the Kepler asteroseismology team (including Iowa State's Steven Kawaler) determined the precise mass and radius of the star and, importantly, found that its age was 11.2 billion years. The system has (at least) five planets—all smaller than the Earth—that orbit very close to the host star. This means that the planetary system formed in the early days of the Milky Way, before the vast enrichment of our Galaxy's heavy element content. It is those heavy elements that make up the bulk of the mass of small terrestrial planets. While not a system capable of hosting life as we know it, the fact that planets were able to form so early in the history of the Galaxy suggests that planetary systems have been features of stars for far longer than we initially believed.

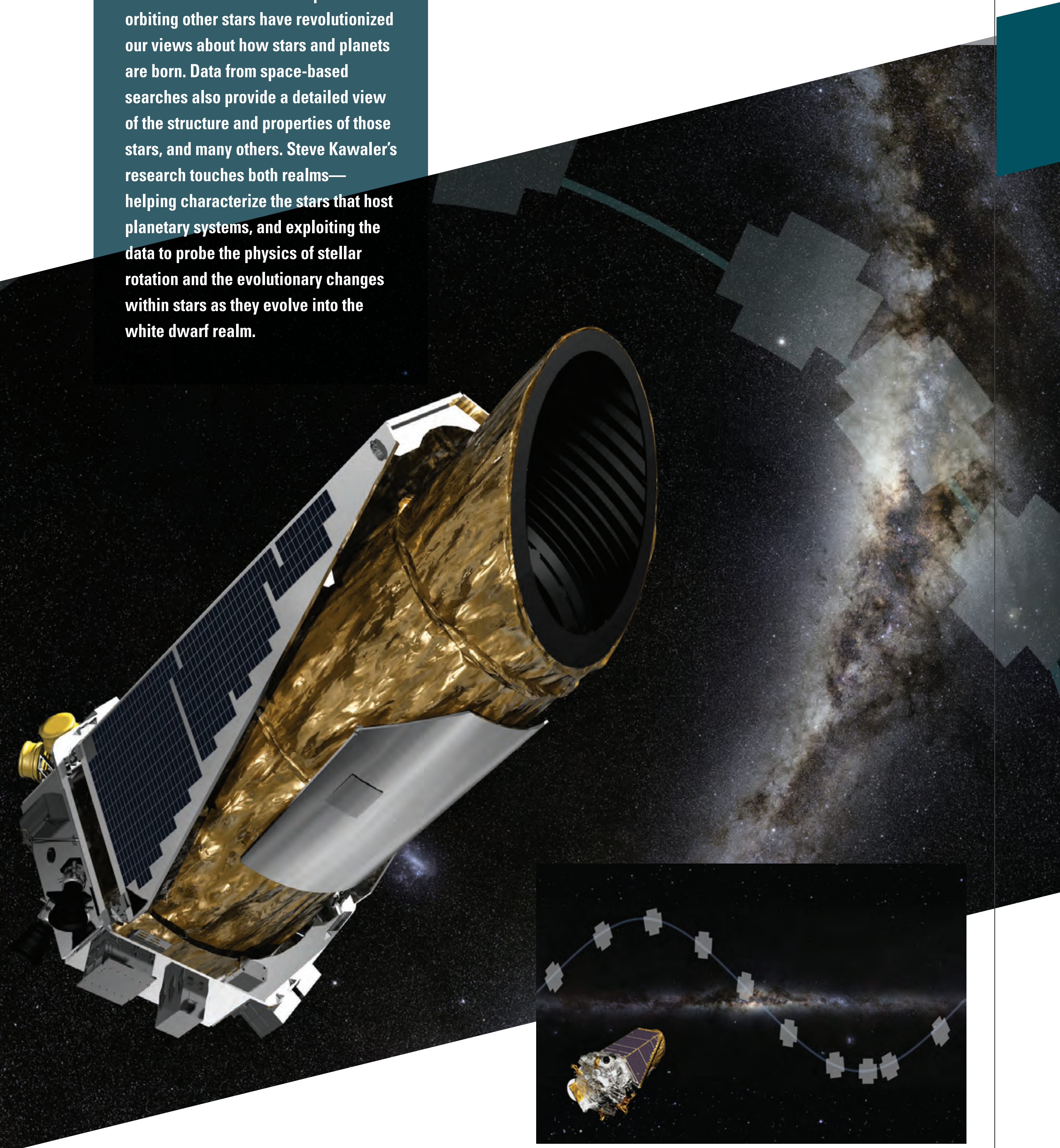
Though the data from planetary transit events is far less than 0.1% of the total amount of data obtained, the remaining >99.9% of the data is an exquisite record of the time-domain behavior of an enormous variety of stars. Kawaler and his colleagues have been using Kepler and K2 to make asteroseismic inferences on a wide variety of stars, including stars like our Sun, red giant stars, and white dwarfs. The flood of data has been breathtaking. Kawaler's prior efforts using ground-based telescopes with the Whole Earth Telescope would require nearly 1,000 years of operation to match the amount of data on just white dwarf stars obtained over the course of the Kepler and K2 missions.





Steve Kawaler

Successful searches for planets orbiting other stars have revolutionized our views about how stars and planets are born. Data from space-based searches also provide a detailed view of the structure and properties of those stars, and many others. Steve Kawaler's research touches both realms—helping characterize the stars that host planetary systems, and exploiting the data to probe the physics of stellar rotation and the evolutionary changes within stars as they evolve into the white dwarf realm.



Artist's conceptual views of NASA's Kepler telescope.

Measure, map, and manipulate integrin molecular tensions in live cells

Cells are the basic building blocks of life. These micron-sized entities are amazing signal receivers and processors. They actively communicate with the local environment by exchanging both chemical and physical signals. On the cell membrane, there are a variety of proteins functioning as signal receptors that receive and transduce chemical and physical signals to inner cells and regulate many critical cellular functions accordingly. Among these receptors, a membrane protein named integrin is the major mechano-sensitive receptor. Each cell has thousands of integrins that grab on the surrounding medium (called the matrix) and establish physical linkage between cells and the matrix.

Meanwhile, cells also actively produce tensions on integrins to sense the mechanical properties of the local environment. The integrin-transmitted forces trigger a variety of signal transduction cascades and eventually regulate cell adhesion, migration, proliferation, stem cell differentiation, immunological cell activation, and so on. Because of their critical roles in many important cellular functions, integrin-transmitted cellular forces have attracted significant research interest. To study these forces, one must be able to measure and map the forces in cells. However, currently available methods for cellular force detection and mapping have significant limitations in terms of both sensitivity and resolution. In these methods, cells are plated on a soft substrate and the surface deformation caused by cellular forces can be imaged and converted to the force maps of the cells. This force-to-strain strategy has been used to visualize cellular forces for almost four decades. Despite numerous improvements, these methods still suffer from both low resolution (2~5 μm) and poor sensitivity. To advance the research of cell mechanics, new methods with better resolution and sensitivity are in urgent demand in the field.

To meet this demand, we developed a novel molecular tension sensor named integrative tension sensor (ITS). Instead of force-to-strain conversion, ITS directly converts force signals to fluorescence signals. As a synthetic molecule, ITS permanently transforms into a fluorescent unit if sustaining a critical molecular tension. A surface grafted with ITS targeting integrins can be lighted up by local integrin tensions, thus converting cellular force mapping to fluorescence imaging and inheriting the sensitivity and resolution of fluorescence microscopy. With ITS, cellular forces can be mapped with unprecedented 0.3 μm resolution, which is ten times higher than the resolution of conventional cell traction force microscopy.

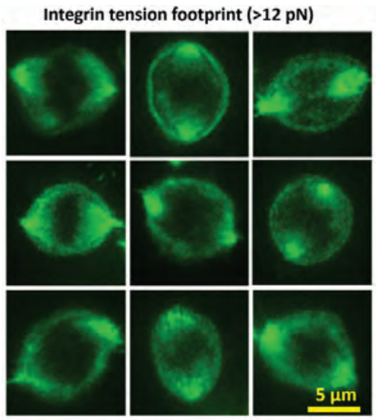
We have applied ITS to the calibration and mapping of integrin molecular tensions in cell migration. Using fast migrating keratocytes as cell models, we found cell membrane instead of actomyosin produces 54-100 picoNewton (pN) tensions exclusively on integrins at the cell rear edge to rupture integrin-ligand bonds, de-adhere cells, and facilitate cell migration. This research revealed a unique mechanical role of cell membrane in cell migration.

We also applied ITS to the study of platelet contraction forces. Platelets are small anucleate blood cells that aggregate and form blood clots to stop bleeding. Platelet forces are essential to strengthen blood clots and stop bleeding. However, because platelets are much smaller than other regular cells, conventional traction force microscopy with 2~5 μm resolution cannot resolve the cellular forces in platelets. In collaboration with Professor Dana Levine in the Department of Veterinary Clinical Sciences, we mapped platelet forces for the first time with ITS and found that platelet forces are polarized with two or three force foci in each platelet. In the force foci, single integrin tension can reach above 60 pN. We further confirmed that these tensions are responsible for platelet contraction, revealing the separate force level during platelet adhesion (10~50 pN) and contraction (>60 pN).

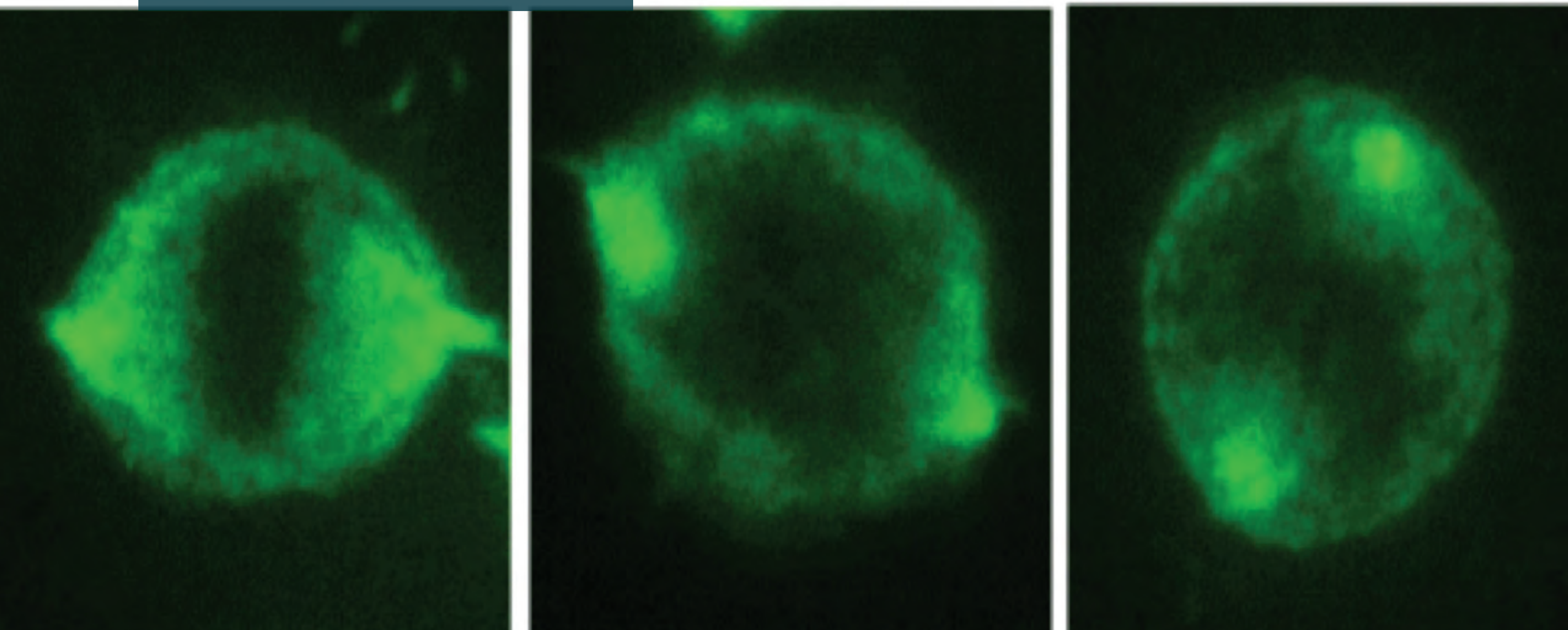
Molecular biology has revolutionized our understanding of how life works by identifying and categorizing the molecular components participating in biological functions. We gain knowledge by testing drugs targeting certain receptor proteins and studying how chemicals affect their functions and the associated cell and animal behaviors. However, for cell mechanics and mechanobiology, which concerns how mechanical force affects cellular functions, we envision that measuring, mapping, and manipulating molecular tensions on mechano-sensitive receptors on cells and studying consequent cellular responses would yield significant insights to how mechanical signals regulate many cellular functions and transform the way we study cell mechanics. For these, our lab will continue to develop innovative methods and apply them to the study of cellular forces at the molecular level.

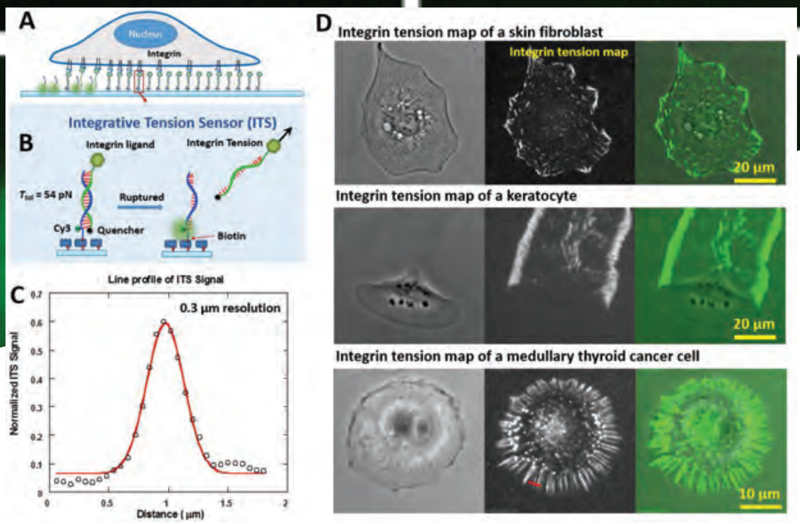
Xuefeng Wang

Our lab studies cell mechanics by measuring and controlling cellular forces at the molecular level. Cells adhere and mechanically interact with the local environment by producing forces at the cell-substratum interface. These forces regulate a variety of fundamental cellular functions. We developed innovative molecular tension sensors to measure, map, and manipulate cellular forces at the molecular level in live cells, and we investigated the regulative roles of these forces during cell adhesion, migration, and platelet contraction.



Polarized platelet force maps.





Cellular force map reported by ITS, a novel molecular tension sensor.

Accelerator Neutrino Neutron Interaction Experiment (ANNIE)

Neutrinos are the most abundant of the known matter particles, and yet they are the ones we know the least about. We know that they have mass, and yet the absolute scale of their masses (at least 1,000,000 times smaller than the next lightest particle) is unmeasured. We know that neutrinos oscillate, morphing from one type to another as they propagate through time and space. But the detailed patterns of this behavior are not yet fully measured. As electrically neutral elementary particles, it is yet unknown whether neutrinos are their own anti-particles. If neutrinos treat matter and anti-matter differently, they may be able to explain why matter and anti-matter did not completely cancel out in the early Universe, leaving enough material to make the stars and planets and, ultimately, us. This so-called charge-parity (CP) violation should be visible in the patterns of neutrino oscillation and could be discoverable in the coming decades.

Unfortunately, experimental efforts to measure these neutrino properties are challenging. The low probability of neutrino interactions necessitates the construction of huge detectors the size of skyscrapers, buried deep underground to suppress background noise from cosmic rays and other radioactivity. Unknown details about how neutrinos scatter off of the messy nuclear structure of the target atoms make precision reconstruction of neutrino energy difficult.

The ANNIE experiment at Fermilab is a 13-ton water-based neutrino detector, small by particle physics standards but with big ambitions. The goal of the Iowa State lead effort is to develop a next-generation neutrino detector using advanced photosensors and new experimental techniques, all while making important progress in understanding how neutrinos interact with matter.

ANNIE is looking at one particular aspect of neutrino-nucleus interactions: how many neutrons get knocked out. It turns out that the presence and abundance of these knock-out neutrons can shed a lot of light on the nature of the underlying interaction, addressing a major uncertainty on future experiments.

To meet these physics goals, ANNIE is blazing trails in two new areas of detector technology. ANNIE will likely be the first full physics experiment to use Large Area Picosecond Photodetectors (LAPPDs), which are new advanced photosensors capable of measuring individual photons with time resolutions counting in tens of picoseconds (that's tens of trillionths of a second) and with millimeter spatial resolutions. This fine-grained resolution will enable the experiment to better reconstruct high-energy tracks in the water based on the pattern of light emitted in the water by the Cherenkov effect. ANNIE will also be loaded with gadolinum, a substance that will make the ANNIE detector sensitive to individual neutrons.

Phase I of the experiment, a measurement of neutron backgrounds on the physics analysis, was approved by Fermilab in 2015 and is now built and running. ANNIE was also one of two experiments awarded funding through the Intermediate Neutrino Program of the Department of Energy. The collaboration is now drafting a proposal for the full execution of its Phase II—the implementation of LAPPDs and gadolinium and the execution of its physics program. With four Iowa State faculty and a team of top-notch postdocs and graduate students, Iowa State plays a leading role in the effort. With data taking on going and work toward Run II under way, it is an exciting time for the experiment and for Iowa State physics.

Matt Wetstein

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is an exciting newcomer to the Fermilab neutrino program. The Iowa State-led experiment has two goals: (1) to understand the complicated many-particle dynamics of neutrino interactions with nuclei; and (2) the development of an advanced, next-generation neutrino detector. Two technological advances make the experiment possible. First is the development of Large Area Picosecond Photodetectors (LAPPDs), new light sensors capable of measuring the arrival times of single photons with a precision of 20 billionths of a second. The other advance is the use of gadolinium dissolved in water to detect neutrons. Gadolinium has a high affinity for free neutrons and emits a burst of light when they are captured. This will enable, for the first time, the efficient detection of neutrons knocked out by interacting neutrinos. The presence and number of neutrons will shine light on uncertainties in the nature of the interactions and will therefore have a big impact on a wide number of neutrino measurements probing some of our deepest questions about the nature and formation of the Universe.

Below: Iowa State postdoc Carrie McGivern installing the ANNIE phase I photomultiplier tubes.

Iowa State graduate students Erika Catano Mur and Jose Sepulveda-Quiroz inspecting the cable of an ANNIE photomultiplier tube.

The ANNIE collaboration pointing at a first full-functional LAPPD prototype.

Iowa State physicists win W. M. Keck Foundation grant to develop new nanoscope

The W. M. Keck Foundation of Los Angeles—one of the country's largest philanthropic organizations—recently awarded a three-year, $1.3 million grant to support construction, commissioning, and initial use of the nanoscope. The project will be known as the W. M. Keck Initiative in Ultrafast Quantum Microscopy of Emergent Orders.

The nanoscope will work using a probing antenna, a mere 10 nanometers across, thousands of times smaller than the width of a human hair. It "visualizes" things with far-infrared or terahertz light, which has wavelengths much longer than visible light, yet being put to use for observing the minuscule antenna in a deep sub-wavelength manner. Ultrashort pulses lasting for as little as one quadrillionth of one second will strike the probe, causing it to broadcast waves that will return with information about the properties of the studied object and that can in some cases manipulate those properties.

Jigang Wang

A DIVERSE TEAM AND EXTREME SCALES

The quantum nanoscope project was made possible by the expertise, technical resources, and close collaboration of Iowa State and Ames Laboratory scientists. The project team includes the following:

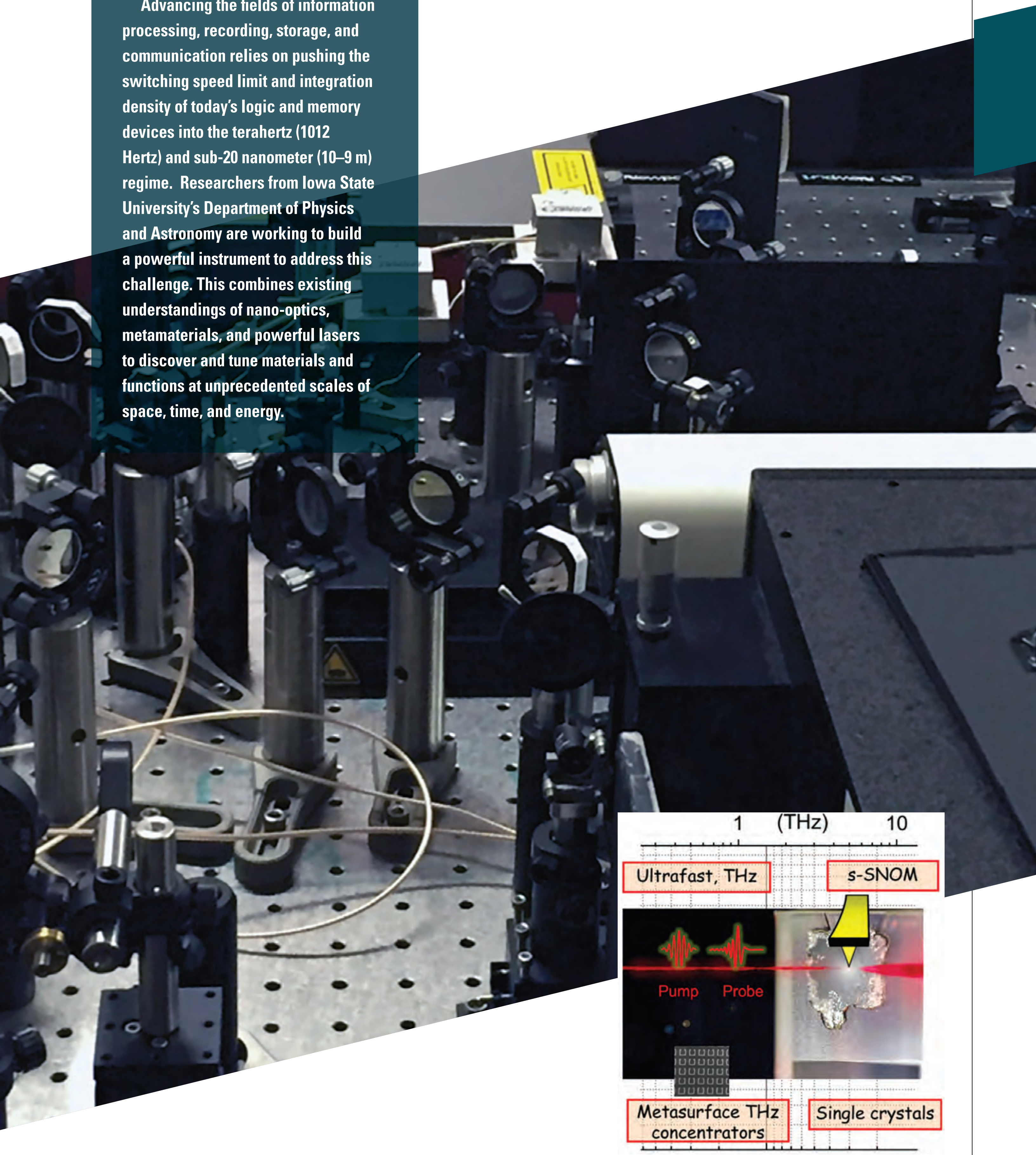
- Jigang Wang, an Iowa State professor and Ames Laboratory physicist, who has expertise in terahertz spectroscopy and microscopy of complex materials.
- Zhe Fei, an Iowa State assistant professor of physics and astronomy and Ames Laboratory associate, who has expertise in scanning near-field optical microscopy.
- Paul C. Canfield, an Iowa State Distinguished Professor of physics and astronomy and Ames Laboratory senior physicist, who has expertise in new materials design and discovery.
- Costas Soukoulis, an Iowa State Distinguished Professor of physics and astronomy and Ames Laboratory associate, and Thomas Koschny, an Iowa State University Adjunct Associate Professor and Ames Laboratory associate scientist, who both have expertise in metamaterials.

The researchers will work together to develop a nanoscope that collects data at three extreme scales: billionths of a meter in space (nanometers), quadrillionths of a second in time (femtoseconds), and thousandths of electron volts in energy (milli-electron volts or terahertz). The team views each of those three dimensions—space, time, and energy—as like the side of a triangle. On each side of that triangle, humanity has achieved tremendous progress and understanding. However, what about the region on the inside of the triangle, this forbidden region that combines the best of all three fields? For many outstanding scientific and technological problems, our answers are largely limited by our inability to see inside this region.

The researchers will experiment with using the nanoscope to manipulate electrons so they can tune materials with minimal heating of the samples. Study goals include discovering new states of matter and establishing the shortest times and smallest lengths for these states to switch.

All of this will create a new paradigm to understand materials, control their properties, and have far-reaching consequences to promote science and future technology. More importantly, the project will benefit Iowa State and physics students who like to get involved in the state-of-the-art research. Stimulating the imaginations of these students and general public is one of the ultimate goals of the educational and scientific enterprise.

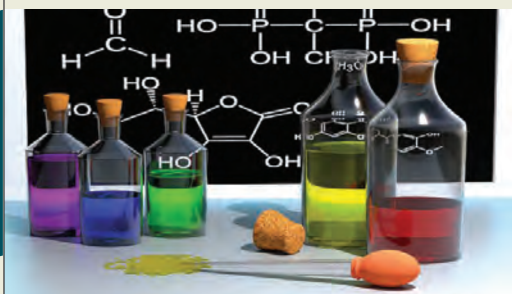
Advancing the fields of information processing, recording, storage, and communication relies on pushing the switching speed limit and integration density of today's logic and memory devices into the terahertz (1012 Hertz) and sub-20 nanometer (10–9 m) regime. Researchers from Iowa State University's Department of Physics and Astronomy are working to build a powerful instrument to address this challenge. This combines existing understandings of nano-optics, metamaterials, and powerful lasers to discover and tune materials and functions at unprecedented scales of space, time, and energy.



Teaching/Physics Plus

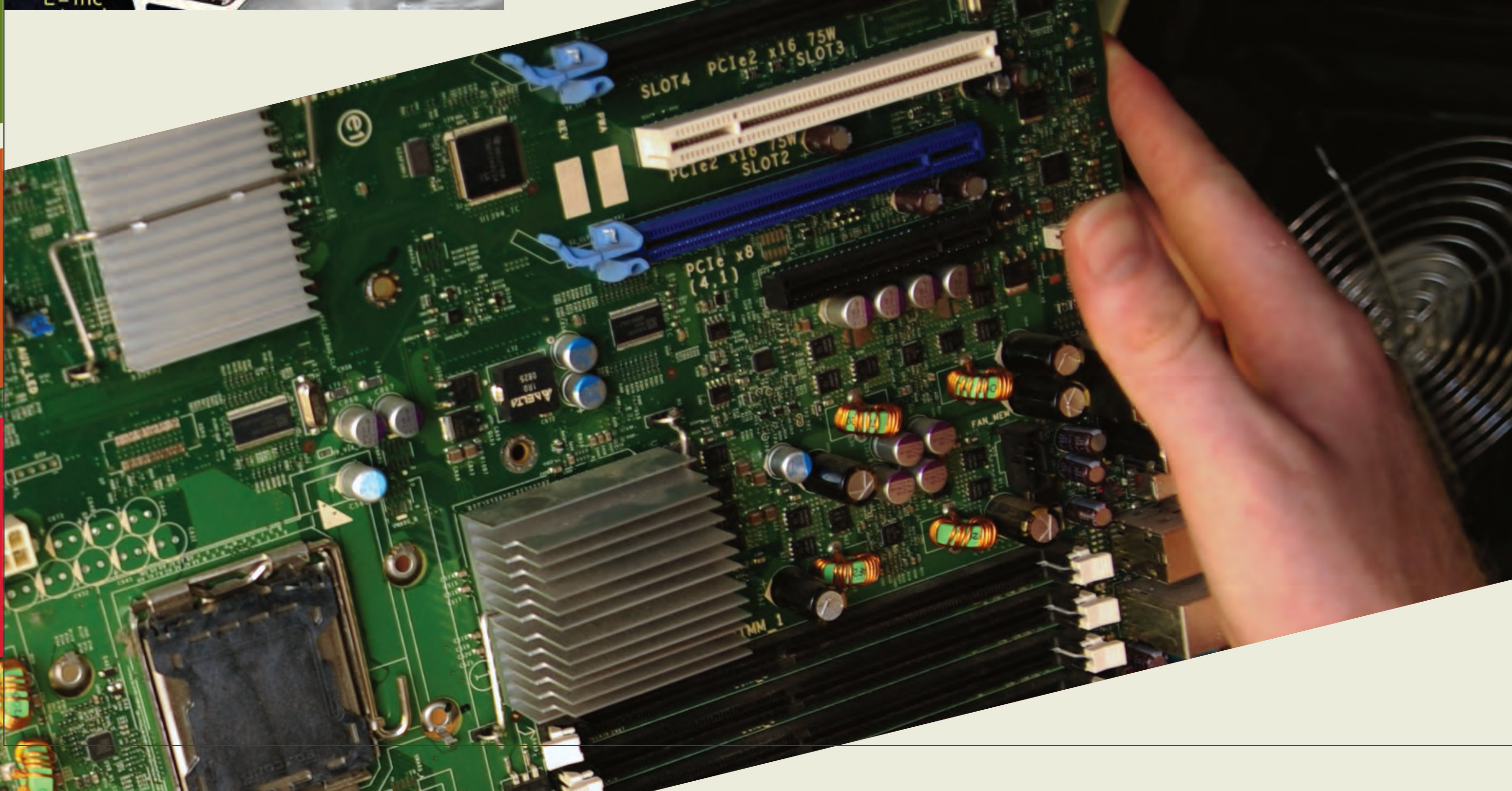
To increase the size of our physics major population by attracting excellent students with other academic interests, we have created several Physics+ undergraduate curricula that include a common core of physics and mathematics courses but replace other physics courses with comparable courses in other disciplines.

An undergraduate degree in physics prepares students for a variety of opportunities, especially in the industrial development and application of existing and emerging technologies. Students who meet the necessary scholastic standards often continue their studies in a graduate program, where opportunities exist to explore and contribute to the most recent developments in the field. Our department has major research programs in condensed matter physics, elementary particle physics, nuclear physics, astrophysics, and biophysics. Undergraduates often work in these research groups to broaden their experience. Regardless of your specific career plans, our undergraduate program strives to provide laboratory, computing, problem-solving, and communication skills valuable in any career.



The Physics+ curriculum is a flexible program for students who plan to pursue technical or professional careers in areas requiring a sound grounding in physical science and mathematics. Students can use the concentration to prepare for employment immediately upon graduation. The specific path students choose beyond the core physics and math courses will depend on their interests and career goals. The physics+ undergraduate program stresses the basic physics that underlies most developments in engineering and the mathematical tools that are important to both physicists and engineers. Since the advances in technology lead to rapid changes in state-of-the-art techniques, the program aims to provide the student with a broad base of fundamental science and mathematics and provides specialization with a set of selected specialty courses for each of the emphases.

We currently have several Physics+ options: aerospace engineering, biology, chemistry, electrical engineering, and mechanical engineering.



March Student Meeting

PHYSICS MAJORS AT THE 2017 MARCH MEETING OF THE AMERICAN PHYSICAL SOCIETY

"I really enjoyed that the talks at the meeting covered a multitude of different areas. I learned a lot about areas from condensed matter physics to robotics, to biophysics. It was an extremely beneficial experience for me and my physics career." **—Jacob Speltz**

"The APS March Meeting was a great opportunity to expand my physics knowledge. I learned about many new physics topics that I had never encountered prior to attending the March Meeting. Overall, I think the March Meeting was a very rewarding and educational experience that furthered my growth in my study of physics." **—Robert Miller**

"The APS March Meeting was a great opportunity for me to get an experience for what life is like in academia. I learned some interesting things in the fields of extreme mechanics and robotics. I appreciate being given the opportunity to experience the APS March Meeting." **—Samuel Buckrey**

"The APS March Meeting was an amazing opportunity that helped expand my idea of what physics has to offer. One of my favorite parts was attending lectures by two Nobel Laureates. I also enjoyed seeing my Iowa State physics professors discussing their research in a professional setting." **—Alec Mangan**

"March Meeting was fun. It developed my interest in condensed matter physics. I think this might be the last time I go for my undergrad program, so it was cool that I was able to go." **—Daniel Carber**

"On behalf of the ISU Physics and Astronomy Club, I would like to thank the Department of Physics and Astronomy for the opportunity to attend the APS March Meeting." **—Alec Mangan**

Departmental Awards 2017

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1. Andre Garcia was recognized for his scholarship with the Graduate College Research Excellence Award.

2. Ray Peterson was recognized for his unusual interest in innovations and inventions with the "Mal Iles Innovation Award."

3. David Atwood received the "Most Valuable Instructor" award presented by Josh Wolanyk, the graduate student representative.

4. Scott Saunders and Saba Sharikadze were recognized with the First Year Teaching Award for the highest teaching rating by their students.

5. Andrew Goulette, Miles Lucas, Alec Mangan, Michairl Onyszczak, Jacob Speltz, Jesse Stufflebeem, and Bryan Vilcek were recognized for their academic achievements as junior or senior with the "Gene Ruby Scholarship."

6. Gloria Oberender was recognized for her superior performance and her numerous contributions to the department with the "Superior Service Award" on behalf of the faculty.

7. Jacqueline Blaum, Hannah Myers, and Savannah Downing were awarded the Benice Black Durand research scholarship that consists of a $2,000 scholarship to promote meaningful undergraduate research and to support women and minorities as undergraduates.

BRETT FADEM

After obtaining my PhD from Iowa State in 2002, I accepted a two-year teaching position at Colby College and then, in 2004, secured my current position at Muhlenberg College. Looking back upon my time at Iowa State, one of my proudest moments was winning the Outstanding First-Year Teaching Award in 1996. My love of teaching remains undiminished to this day.

Currently, I am an associate professor of physics at Muhlenberg College, chair the Department of Physics, act as the department liaison for the combined Columbia University/ Muhlenberg College engineering program, and sustain an active undergraduate research program with PHENIX/sPHENIX at Brookhaven National Laboratory—supported over the last decade by four National Science Foundation grants.

My current research program was only made possible with the assistance of the experimental nuclear physics group at Iowa State. I am forever grateful for the support and guidance they have provided.

I live in Allentown, Pennsylvania, with my wife, Sara, and my children, David and Sophia. I also have a grown daughter named Laura. While I haven't stayed in touch with all of my friends from Iowa State, I think of them fondly and frequently.

MICHAEL J. PADGETT

While at Iowa State from 1976 to 1980, I studied under Dr. Robert A. Leacock, a member of the High Energy Theory group. The dissertation project focused on Quantum Hamilton-Jacobi Theory as it applied to "Quantum Action-Angle Variables." The formulation of a version of quantum mechanics using action-angle variables constitutes an independent formulation of quantum mechanics and was ultimately published in a sequence of papers in the 1980s and extended to scattering states by various authors.

After leaving Iowa State, I pursued a career in industry, first with McDonnell Douglas in Houston writing code for the space shuttle program and then doing oil-and-gas geophysics for most of the last 35 years. While it might seem strange to transition from high energy theory to oil-and-gas geophysics, it turns out that modern seismic exploration is an application of elastic wave scattering theory to truly strange structures. Applying physics and its ways of thinking to earth science or commercial problems always brings fresh perspectives to gnarly problems.

I have often thought that Dr. Leacock taught me how to think and to analyze. I am certain that there are many of us who recognize a real sense of debt for the knowledge, training, and friendship that our mentors shared with us during our brief stays on the Iowa State campus.

GREG PICKRELL

I was raised on a farm in northwest Iowa and graduated with a degree in physics from ISU in 1973. My diverse campus activities included two years as a Government of the Student Body representative and as a photographer for the *Iowa State Daily*. Based on a suggestion by President Robert Parks, who had appointed me as a student representative of the Science & Humanities College Dean's Search Committee, I attended law school and received a law degree from the University of Michigan. In the summer prior to entering law school, I bicycled solo on Highway 1 along the West Coast from Canada to Los Angeles, which led to my fondness for the region.

I moved to Silicon Valley following graduation and joined Wilson Sonsini, one of the few technology law firms, and focused on a broad corporate law practice representing emerging technology companies. Many of those companies grew into household names and/or developed fundamental technologies in semiconductors, computers, software, telecom/ communications, storage, satellites, the Internet, etc., such as Apple Computer (where I was involved in the company's initial public offering and licensing arrangements). My practice later expanded into international work, with a focus on Asia.

My interests include international travel, camping, photography, scuba diving, jazz music, and Asian art. My family and I live in Palo Alto, California.

Daniel Zaffarano Lectureship

The tradition of bringing prominent scientists to Iowa State University dates back to the John Franklin Carlson Lectures (1955–1969), which were inaugurated *(top right)* **by J. Robert Oppenheimer (1955), followed by Niels Bohr (1957) and Percy W. Bridgman (1957) as well as others. The Zaffarano Lectureship is an effort by the Department of Physics and Astronomy to revive this fine tradition.**

Last year Sir John Pendry *(bottom right)* from Imperial College London gave the inaugural Zaffarano Lecture on the topic of metamaterials, the physics of invisibility, and practical applications such as an "invisibility cloak." More information about the past event can be found on *http://www.physastro.iastate.edu/events/zaffarano-lecture*.

The next Daniel Zaffarano Lectureship will be held at Iowa State University in October 2017. This lecture series was established in 2015 and was made possible by the generosity of our alumni. The purpose of the lectureship is to bring an outstanding scholar to central Iowa and Iowa State University each year to speak on a topic in the physical sciences and discuss relevant technical applications, philosophical implications, and relation to broader human affairs.

Professor Roger D. Blandford from Stanford University is a theoretical astrophysicist and works in the area of black holes and relativistic phenomena. He is famous for a model for the extraction of energy from a black hole (Blandford-Zjanek Process). He is a Fellow of the Royal Society and a member of the National Academy of Science, and he has won major international awards, including the Eddington Medal and the Crafoord Prize.

2017 ZAFFARANO LECTURE

Black Holes in the Universe (and Hollywood)

OCTOBER 26, 8 P.M. • BENTON AUDITORIUM

Albert Einstein's General Theory of Relativity implies that black holes could exist, astrophysicists demonstrated that they should exist, and astronomers, observing with many different telescopes, have demonstrated that they are common in the universe. They are found with masses ranging from a few times to more than ten billion times that of the sun. They are observed from the lowest radio frequencies to the highest energy gamma rays and most recently through gravitational radiation. We are getting close to the point where they can be imaged directly so that we should be able to test our ideas of how they work. The strange and wonderful behavior of black holes will be described and compared with some alternate realities created in the movies.

The Rise of Topology in Condensed Matter: Nobel Prize in Physics 2016 *by Rebecca Flint*

The 2016 Nobel Prize in Physics was awarded to David J. Thouless, F. Duncan M. Haldane, and J. Michael Kosterlitz for "theoretical discoveries of topological phase transitions and topological phases of matter." These three physicists initiated the rise of topology as an essential tool to understand and characterize different phases of matter. This topological matter holds great promise for technological applications, including the possibility of quantum computation.

David J. Thouless
Provided by Mary Levin/University of Washington

F. Duncan M. Haldane
Provided by Bengt Nyman

J. Michael Kosterlitz
Provided by Bengt Nyman

Symmetry ruled condensed matter for many decades. Phases of matter are, with a few exceptions, characterized by what symmetries they break. For example, a solid is a crystal that breaks translation and rotation symmetries. Other phases, like ferromagnets and superconductors, break different sets of additional symmetries. Much of the behavior of these phases is dictated by the symmetries that they break, including how they are affected by thermal fluctuations. For example, there is no symmetry breaking in two dimensions at finite temperatures for any continuous symmetry, like planar ferromagnets, superfluids, and superconductors.

However, over the last thirty years it has become clear that symmetry breaking alone cannot describe all phases of matter. Kosterlitz and Thouless were the first to show that, while finite temperature symmetry breaking is forbidden, two-dimensional systems like thin superfluid films or planar magnets undergo a finite temperature phase transition due to the proliferation of topological (vortex) defects.

In fact, topology has turned out to be an essential tool. Whereas symmetries can be understood by looking at a small part of a sample ("locally"), topology requires a more global view. Topology tells us that an orange and a water glass are the same; similarly, a coffee mug and a doughnut are topologically the same. Although up close, a water glass and coffee mug might look pretty similar, the two are distinguished by having different numbers of holes. The local structure is actually irrelevant, and one must instead look at the global picture. This turns out to be true for some materials as well.

One hallmark of "topological phases" is the quantization of some physical quantity. Just as a doughnut has an integer number of holes, certain measurable quantities must take integer values in topological phases. Thouless, with others, proved that the transverse electrical (Hall) conductivity is pinned to integer values in the integer quantum Hall effect, which occurs in two-dimensional electron gases in large magnetic fields. These are insulating in the bulk, with all of the conduction taking place along the edges. Haldane realized that certain theoretical models could realize these sorts of topological phases without external magnetic fields. This work underlies the recent boom on "symmetry-protected" topological phases of matter, which includes topological insulators and superconductors that require certain symmetries. The electronic wavefunctions are characterized by topological invariants and, while the bulk is insulating (or superconducting), the surfaces are conducting, with this conductance protected by topology. There are now a plethora of real materials exhibiting this topological behavior.

Faculty Awards

MCGRODDY PRIZE TO PROFESSOR PAUL C. CANFIELD:

Paul Canfield, a Distinguished Professor and the Robert Allen Wright Professor of Physics and Astronomy at Iowa State University, was given the prize "for development and use of solution growth of single crystalline intermetallic materials to design, discover, and elucidate new heavy fermion, superconducting, magnetic, and quasicrystalline states." He was awarded the prize, which consists of a certificate and honorarium, at the 2017 APS March Meeting in New Orleans.

See also *https://www.ameslab.gov/news/news-releases/ames-laboratory-senior-scientist-paul-c-canfield-receives-aps-mcgroddy-prize*.

AAAS FELLOW TO PROFESSOR CURT STRUCK:

Curt Struck, a professor of physics and astronomy, has been elected Fellow of the American Association for the Advancement of Science (AAAS). The recognition is bestowed on AAAS members by their peers and recognizes scientifically or socially distinguished work to advance science or its applications.

His citation reads: "For distinguished contributions to astrophysics, particularly in modeling the dynamics of colliding galaxies and applications to observations of star formation in interacting galaxies."

See also *http://www.news.iastate.edu/news/2016/11/21/aaas16*.

MADEY AWARD TO PROFESSOR MICHAEL TRINGIDES:

Michael C. Tringides, a professor in the Department of Physics and Astronomy, received the 2017 Theodore E. Madey Award from the American Vacuum Society for his excellence in internationally collaborative research.

"Dr. Michael Tringides is an outstanding surface physicist who has great insight into physical mechanisms that explain the unusual behavior of complex systems at the atomic scale," said Shirley Chiang, professor of physics at the University of California at Davis and collaborator with Tringides. "It is a great honor for me to collaborate with him on these issues. Since he has numerous international scientific collaborations and is widely known in the scientific community, he is highly deserving of the 2017 Theodore E. Madey Award of the AVS."

See also *https://www.ameslab.gov/news/insider-highlight/avs-honors-tringides-collaborative-research*.

Would you like to receive your copy of the report delivered promptly to your mailbox? Please fill out the Alumni Contact Information at *http://www.physastro.iastate.edu/alumni/info*.

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