

CHICAGO PHYSICS ONE

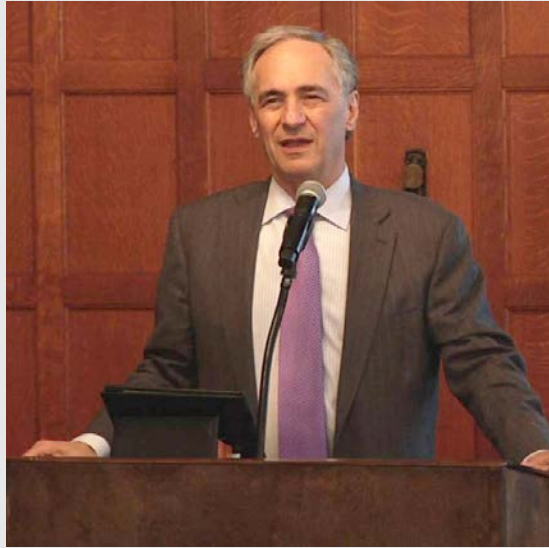
3:25 P.M. DECEMBER 02, 1942

"All of us... knew that with the
advent of the chain reaction,
the world would never be
the same again."

*former
UChicago
physicist
Samuel K. Allison*



THE UNIVERSITY OF
CHICAGO



Physics at the University of Chicago has a remarkable history. From Albert Michelson, appointed by our first president William Rainey Harper as the founding head of the physics department and subsequently the first American to win a Nobel Prize in the sciences, through the mid-20th century work led by Enrico Fermi, and onto the extraordinary work being done in the department today, the department has been a constant source of imagination, discovery, and scientific transformation. In both its research and its education at all levels, the Department of Physics instantiates the highest aspirations and values of the University of Chicago.

Robert J. Zimmer
President, University of Chicago





Welcome to the inaugural issue of *Chicago Physics!*

We are proud to present the first issue of *Chicago Physics* – an annual newsletter that we hope will keep you connected with the Department of Physics at the University of Chicago. This newsletter will introduce to you some of our students, postdocs and staff as well as new members of our faculty. We will share with you good news about successes and recognition and also convey the sad news about the passing of members of our community. You will learn about the ongoing research activities in the Department and about events that took place in the previous year. We hope that you will become involved in the upcoming events that will be announced.

In the past year, our faculty was busy developing a strategic plan for the short- and long-term future of the Department. In looking toward the middle of the next decade, this strategic plan outlined five broad research themes where the Department can have particular impact: Elementary Particle Physics, Geometry & Topology, Particle Astrophysics & Cosmology, Quantum Systems, and Soft Matter & Biophysics. The report developed a faculty hiring strategy for the Department to reach our two overarching goals: to promote research excellence in all five of these thematic areas and to increase significantly the number of women and underrepresented minorities.

Each issue of *Chicago Physics* will have a specific theme. **The theme of this inaugural issue is Chicago Pile-1 or CP-1.** Seventy-five years ago, University of Chicago scientists led by Enrico Fermi ushered in the Atomic Age by achieving the first controlled, self-sustaining nuclear chain reaction. Recognizing the historic significance of this development, the University is organizing a series of public events beginning in Autumn 2017 to commemorate and discuss the complex legacy of what transpired on December 2, 1942. The anniversary presents an opportunity to engage scientists, artists, policymakers, and others around a set of issues that continue to change our world in profound ways. You will learn more about the plans for these events in this issue.

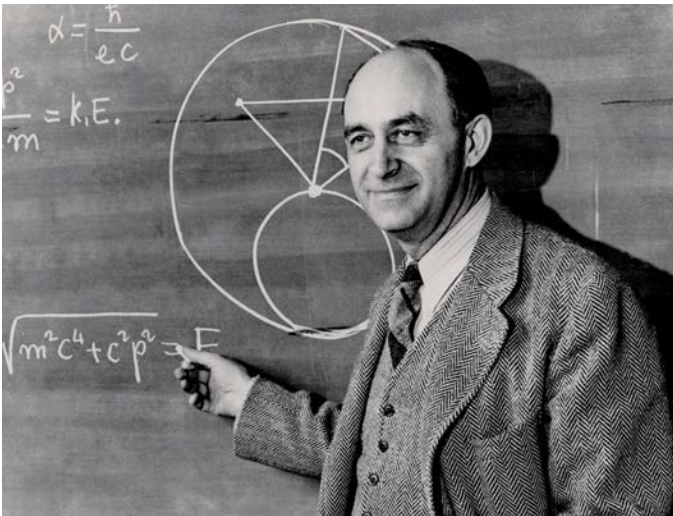
We hope the stories we share in our annual newsletter will inspire you to become more involved and engaged in the Department. Please let us know what you think.

Yours Sincerely,

Young-Kee Kim

Louis Block Distinguished Service Professor
Chair, the Department of Physics





FERMI THE ULTIMATE PHYSICIST

“At the moment of great achievement his face showed no sign of elation. The experiment had worked precisely as expected. The theoretical calculations were confirmed and that was that.”

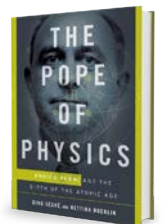
In “Atomic Quest,” Arthur Compton, the head of the University of Chicago’s Metallurgical Laboratory, described how Enrico Fermi reacted to the pile going critical on that December 2, 1942 afternoon, “At the moment of great achievement his face showed no sign of elation. The experiment had worked precisely as expected. The theoretical calculations were confirmed and that was that.” Fermi’s own December monthly report simply said “The chain reacting structure has been completed on December 2 and has been in operation since then in a satisfactory way.”

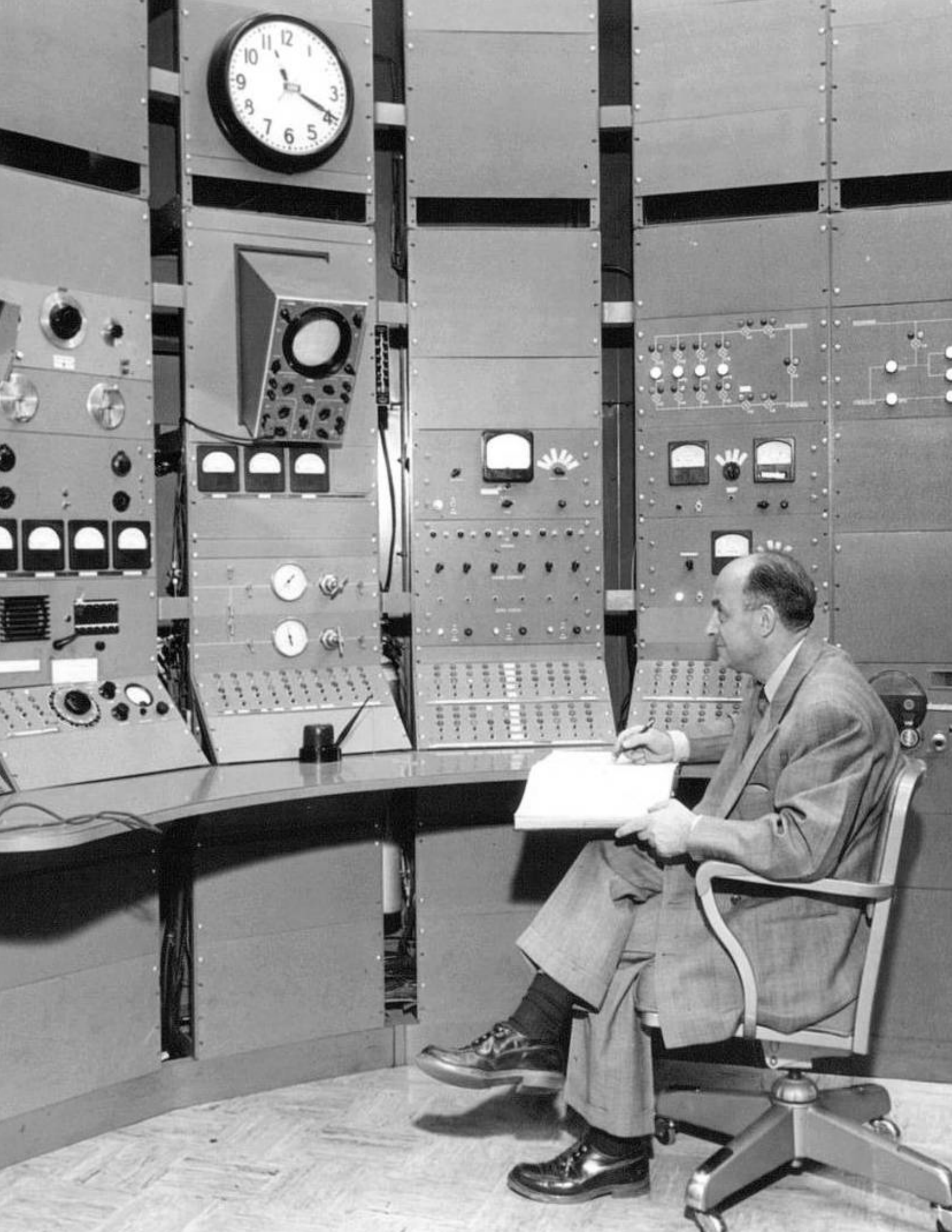
Fermi was more confident than anyone else that the experiment would proceed according to plan since he had been in full control at every stage of the operation and had complete confidence in his understanding of physics. This confidence surely radiated to the almost fifty observers, most of them scientists, gathered with him on that historic day in a squash court under the University of Chicago’s football field.

As his close collaborators have attested, the aspect of the experiment’s success that most excited Fermi was that he now had a tool that could generate a neutron beam of previously unimaginable intensity. All that had to be done was to change the initial flux of neutrons a little bit; the output could be magnified by a previously unimaginable factor. Others focused on the possibility of nuclear energy to generate power for both peaceful uses and weaponry but physics pure and simple had always been and would continue to be the center of Fermi’s world.

Less than two years later physicists in a remote New Mexico desert saw for the first time a mushroom cloud rise in the sky. The source of its power was plutonium generated in a pile far larger than the prototype erected in the Chicago squash court. While others were attempting to grasp the significance of the event they had just witnessed, Fermi was seen tearing up a piece of paper. Throwing the bits into the air as the explosion’s shock wave reached him, he quickly estimated the blast’s magnitude by pacing off the distance the paper shreds had been blown. Another physics experiment had been carried out. Its implications could be left for tomorrow. Fermi wanted to know its results today.

Gino Segrè and Bettina Hoerlin are the authors of the recently published, *The Pope of Physics: Enrico Fermi and the Birth of the Atomic Age*.





AFTER CHICAGO PILE ONE

ROGER BLOMQUIST
PRINCIPAL NUCLEAR ENGINEER AT
ARGONNE NATIONAL LABORATORY

December 2, 1942: the first man-made self-sustaining neutron chain reaction (Chicago Pile 1) at the University.

Argonne National Laboratory

On December 2, 1942, a group of researchers at the University began an energy revolution. Chicago Pile 1 (CP-1) was taken critical for the first time under the west stands of Stagg Field by Enrico Fermi's crew of scientists. Part of the Manhattan Project was to beat Nazi Germany by developing a nuclear bomb. The pile's mission was to provide data and experience in support of the 250 MWth plutonium production reactor to be built at Hanford in the Washington desert. Also a physics experiment, it demonstrated that the neutron chain reaction was achievable and controllable, i.e., power reactors were feasible. Vast resources were poured into the Project for fear that Germany's world-class scientists would build the bomb first – there was little doubt that the Nazis would use it if they had it.

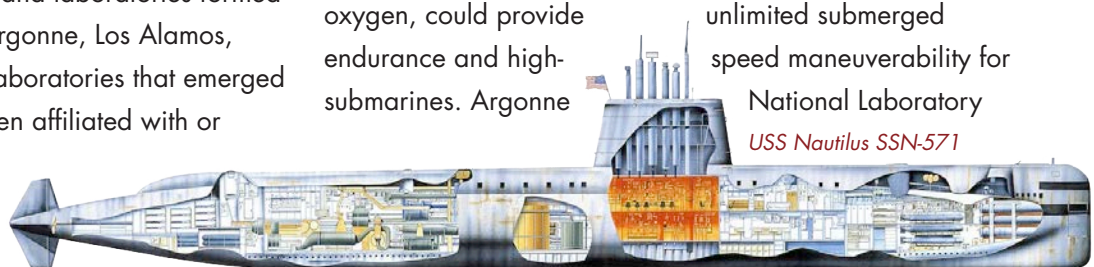
The Manhattan Project changed the face of research and development in the United States. Universities such as Chicago, Columbia, and Berkeley were involved, and their large concentrations of researchers and laboratories formed the kernels of Lawrence Berkeley, Argonne, Los Alamos, Sandia, and Oak Ridge National Laboratories that emerged right after the war. Argonne has been affiliated with or

managed by the University since its founding in 1946 as the first US national laboratory. Over time, these labs diversified into basic and applied science and engineering research institutions that leave technology commercialization to private companies. They have built big-science facilities that are difficult for universities to acquire but are widely used by them.

Those involved in the CP-1 experiment knew this process could provide a vast energy resource in the civil sector. The energy stored in nuclear bonds is roughly a million times that in chemical bonds, so the amount of fuel consumed per megajoule released is tiny – one fission in uranium releases the same energy as the combustion of 5.5×10^6 methane molecules. This fact makes nuclear energy both environmentally attractive and technically challenging

Shortly after the war, Hyman Rickover, who grew up in Chicago, saw that the huge energy density of uranium, coupled with the fact that the fission process needs no oxygen, could provide unlimited submerged speed maneuverability for submarines. Argonne

National Laboratory
USS Nautilus SSN-571



performed the enabling physics experiments and designed the first submarine reactor core. Westinghouse, the Navy's contractor for the entire propulsion system, designed and built a prototype power conversion system, and the USS Nautilus was commissioned in 1954. Hundreds of naval propulsion reactors followed. Westinghouse exploited the advances funded by the Navy and commercialized the pressurized water reactor (PWR), which provides 60% of the 100 gigawatts of nuclear power in the US today.

But while the energy density of uranium is enormous, in the 1940s and 1950s, the mineral was thought to be so rare that large-scale deployments of nuclear-electric generators would quickly exhaust the natural supply of fuel. The breeding of plutonium or U-233 for reactor use was an obvious solution to this projected shortage. Only nine years after CP-1 and just over three years before the USS Nautilus put to sea for the first time, Argonne's Experimental Breeder Reactor-I (EBR-I) had generated small amounts both of electricity from fission and of fissionable plutonium by neutron capture in U-238. EBR-I also demonstrated the use of liquid metal coolants (far better heat transfer than water) and the production of plutonium for other reactors. The pressure to develop breeder reactors eased with the discovery of more uranium resources during the commercialization of PWRs and other thermal-spectrum reactors.



Experimental Breeder Reactor-I begins electricity generation in 1951

The chain reaction's immediate sustainability is determined by the materials present in the reactor core and their temperatures. Initially, it was feared that if cooling water boiled in the core, the result would be an autocatalytic,

self-destructive transient due to a vicious cycle of boiling increasing the chain reaction, which would then further increase boiling. By 1955, Argonne had carried out a series of boiling water reactor experiments at its laboratory in the Idaho desert that proved the opposite – the chain reaction was stable in the presence of boiling in the reactor core. After further validation at a demonstration plant at the Argonne Chicago site, the boiling water reactor (BWR) technology was commercialized by General Electric, and now provides the remaining 40% of the U.S.'s nuclear electricity generation.

Small- and medium-sized commercial PWRs and BWRs went into operation in the 1960s, and by the 1970s dozens of today's more economical 1,000 MWe plants were being built each year. During the oil producers' boycott in 1973, France was forced to recognize its paltry fossil fuel reserves and built a large fleet of standardized nuclear power stations based on US designs. This was accomplished quickly enough to nearly eliminate fossil fuels for electricity generation in a mere fifteen years. Its electricity is now nearly 80% nuclear, and its electrical system's carbon intensity is an order of magnitude less than Germany's. Today, about two-thirds of the zero-carbon electricity and 19% of all electricity in the US is generated with nuclear. There are currently nearly 450 nuclear power plants operating in the world, with 59 more under construction, only two of which are in the United States.

Work continues at the national labs, several traditional nuclear energy companies, and a host of small companies exploring radical reactor designs for electricity generation. Our current fleet of nuclear power plants has never hurt anyone, but to be licensed, they require expensive add-on safety systems. Smaller, simpler systems that are safe without additional safety systems are under development using capital from industrial titans like Bill Gates – reactor design, licensing, and deployment is a long game. In 1986, Argonne demonstrated the completely passive safety of its EBR-II sodium-cooled fast reactor, which would be a very tough system to break even if the operators tried. The Laboratory continues work to radically redesign advanced reactors for safety, efficiency, and sustainability. Fast neutron reactors with metal fuel and on-site recycling should be able



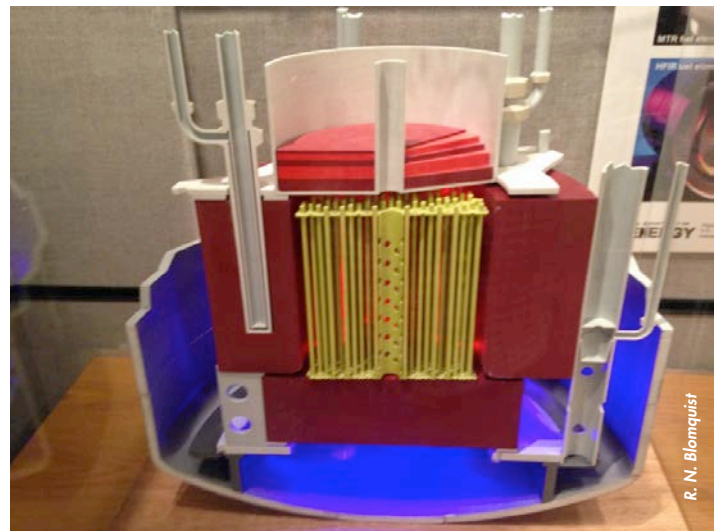
Experimental Breeder Reactor II, operated by Argonne in Idaho for 30 years, demonstrating metal fuel recycling and "walk-away" safety.

to reduce the radiotoxicity period of the used fuel material from about 300,000 years to a few hundred years. The 100-fold increase in the amount of energy extracted from uranium in fast reactors would allow us to use seawater as a fuel source. This would be a crucial development as there is about a million times more uranium in the oceans than there is uranium recoverable from the earth's crust. It is constantly being replenished by natural leaching of uranium by rivers and streams, making uranium a sustainable energy source for many thousands of years.

But there are other uses for civil nuclear reactors. There are roughly 250 research or test reactors in the world today that perform a wide variety of missions. One is to produce medical isotopes by capturing excess neutrons not needed to sustain the chain reaction. These isotopes are used in revolutionary medical diagnostics and therapies. Many cancer therapies involve either radiopharmaceutical injections or direct, focused high-dose radiation. Radiation is a weak carcinogen, but is effective at killing the rapidly dividing cancer cells. One-third of patients in American hospitals today are imaged or treated with radioisotopes, and about half of all medical procedures use radioisotopes. As a result, exploratory surgery is now required far less often, and therapeutic surgeries are performed only when required. The average American now receives about as much radiation from medical procedures as from natural background.

Radioisotopes produced in these reactors are used in biomedical research on many illnesses and conditions, including AIDS, cancer, and Alzheimer's disease. As tracers, these materials are also used as markers in scientific experiments in genetics, animal and plant physiology measurements, and hydrology studies.

Neutrons from research reactors are also used to perform materials science experiments and environmental assays. These include crystallographic analyses of materials and very sensitive neutron activation analyses of materials. For example, Jamaica has a low-power (20kWth) reactor with a core just a bit bigger than a one-gallon paint can that can detect some pollutants of interest, in concentrations of parts per billion. Activation analysis can discern whether heavy metal pollutants in Jamaican rivers are naturally occurring or the result of poor practices by the country's large bauxite mining industry.



A model of the Jamaica "Slowpoke" research reactor, used for research and environmental assay. The core (yellow) is nine inches tall.

Neutron-activated sources produced in research and test reactors have a wide variety of industrial applications. Flaws in welds in massive metallic structures such as pressure vessels can be detected with gamma radiography using these sources. Industrial radiography materials are used to detect flaws in castings and welds and test electronics for the high-radiation environment in space. Tiny activated alpha sources are used in smoke detectors. Very intense gamma sources are used in agricultural pest control in lieu of toxic chemicals and to preserve food by killing pathogens. As

much as one-third of the world's food spoils before it can be consumed, so food irradiation may eventually do much to ease the pressure on the world's food supplies.

Like many wartime science and technology efforts, CP-1 spawned other major developments besides nuclear energy. To design economical reactor cores, it is necessary to accurately solve several sets of equations: the Boltzmann neutron transport equation over the volume of the core, the coupled energy, momentum, and mass conservation equations throughout the reactor cooling system, and the stress equations in solid components such as reactor fuel cladding and system pressure vessels. These and other Manhattan Project computing needs, pushed the envelope of scientific computing for decades and drove the initial development of supercomputers. Calculations on these machines required development of the applied mathematics and numerical methods of solving partial differential equations for large, complex multiphysics systems that are now widely applied across science and engineering on high-performance computing systems.

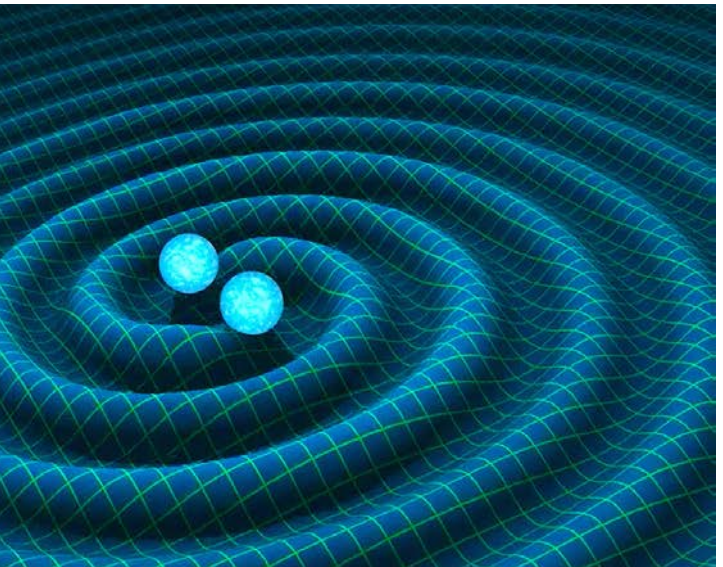
CP-1 may not have started “big science”, but it certainly was part of its initial program. The most utilitarian developments that followed have helped transform modern life and will likely do so for some time to come.



*Roger Blomquist
Principal Engineer-Section Manager
Nuclear Engineering
Argonne National Laboratory*

*M.S., Ph.D., Nuclear Engineering,
Northwestern University, 1979*

**A BILLION YEARS AGO, IN A GALAXY FAR,
FAR AWAY, TWO MASSIVE BLACK HOLES
CRASHED INTO EACH OTHER AT ALMOST
THE SPEED OF LIGHT.**



The spacetime storm resulting from this collision had a peak power output that was an order of magnitude larger than the light output from all of the stars in the entire observable universe **combined**. This energy was radiated in the form of gravitational waves which sped away from the merged black holes at the speed of light. At 5am on Sep. 14, 2015, the waves, after traveling for a billion years, swept through the Earth and registered as a loud chirp in the two LIGO detectors.

I spent most of the ensuing five months huddled in conference rooms with the rest of the UChicago LIGO group, including Ben Farr (a McCormick Fellow in the EFI; heading to a faculty job in the Department of Physics at the University of Oregon in the Fall), Hsin-Yu Chen (a graduate student in Astronomy & Astrophysics and recipient of the James Cronin Fellowship; heading to a Postdoctoral Fellowship at the Black Hole Initiative at Harvard in the Fall), Zoheyr Doctor (graduate student in Physics; recipient of an NSF Graduate Research Fellowship), and Maya Fishbach (graduate student in Astronomy & Astrophysics; recipient of an NSF Graduate Research Fellowship).

On the morning of February 11, 2016, we presented the results of our analysis to a standing-room-only crowd in the ERC. A century after Einstein developed his theory predicting them, we had beautiful evidence that black holes and gravitational waves exist.

Our group played a major role in trying to elucidate the nature of the source. From a few wiggles in the data streams, we inferred that the waves were the result of two black holes, with masses 36 and 29 times the mass of our Sun, colliding somewhere in the general direction of the Large Magellanic Cloud, at a distance of over 1.3 billion light years. In about 0.2 seconds a total of 3 solar masses ($\sim 6 \times 10^{30}$ Kg) was turned into pure gravitational-wave energy.



DANIEL E. HOLZ

Associate Professor

Ph.D., University of Chicago, 1998

One interesting result was our ability to perform unprecedented tests of Einstein’s century-old theory of general relativity. In Fig. 1 (reproduced from Fig. 6 of PRL 116, 241102 (2016)) we show the data for GW150914. On top of the data we plot the best-fit waveforms. The cyan curve (“BBH Template”) is the prediction from general relativity. These are waveforms that come out of Einstein’s theory, as solved by numerical relativity on supercomputers. The dark blue (“Wavelet”) band is the result of an unmodeled search, where we look for a linear combination of sine-Gaussian wavelets. This band does not assume general relativity, and is instead a generic search for any coherent signal in the two LIGO detectors. What is absolutely staggering is that the blue and cyan bands lie on top of each other. This is compelling evidence that general relativity really does describe the signal found in the data.

Einstein was right!

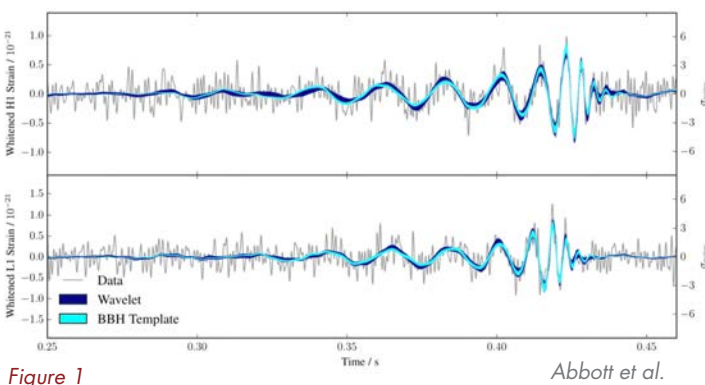


Figure 1 Abbott et al.

In addition to helping to show that Einstein’s theory agrees with the observations, the UChicago group was also involved in calculating the parameters of the system. The spins of the black holes are among the most interesting quantities, since these are related to how the black holes formed. For example, Fig. 2 (Fig. 5 of PRL 116, 241102 (2016)) shows the spin of the two black holes which composed GW150914. The left slice represents the spin

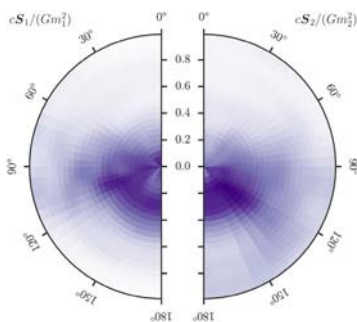


Figure 2 Abbott et al.

of the more massive component, while the right slice is the less massive one. In the same way that nothing can travel (locally) faster than the speed of light, there is an absolute maximum at which black holes can spin, represented by the circumference of the circle in the figure. The intensity shows the most likely values of spin amplitude and direction. From the left hemisphere, we conclude that the more massive black hole in the GW150914 system was not spinning at its maximum possible value. This is an interesting clue as to how it might have formed!

Very broadly speaking, one can imagine making each black hole in GW150914 in one of two ways: either through the death of a star (a star burns all of its fusion fuel and subsequently collapses, forming a black hole), or through the merger of smaller black holes. We have shown that in the latter, hierarchical, model the resulting black holes inevitably end up spinning. Roughly speaking, this is because it is difficult for a binary black hole system to shed its orbital angular momentum, and so the resulting larger black hole has no choice but to be spinning. By measuring the individual spins of the black holes, we are able to determine how LIGO’s black holes were formed.

One radical possibility for the origin of GW150914 is that it could be dark matter. In particular, although most theorists believe the dark matter is likely to be composed of sub-atomic particles, current observational constraints just barely allow for the possibility that all the dark matter in the Universe is made out of black holes of roughly 30 times the mass of the Sun. These would presumably have formed very early in the history of the Universe, and are therefore called primordial black holes. In these models you might form many black holes in the early universe, and these might continuously collide and build up to ever more massive black holes. In this case the resulting black holes should be rapidly spinning, and LIGO can test for this observationally.

I am also very interested in the astrophysical implications of the LIGO detections. We want to understand how the Universe makes an event like GW150914. To do this the Universe needs to make two black holes of unusually high mass. The conventional model is that these black holes are made when a star burns all of its fusion fuel, resulting in a catastrophic collapse, which in some cases can result in a

black hole being created. To make black holes in the range of 30 times the mass of the Sun, however, requires fairly large stars to collapse. And for this to happen the stars need to be made of the pristine material (primarily Hydrogen and Helium) which existed early in the evolution of the Universe. In short, we think that the black holes we are detecting today with LIGO likely originated from the deaths of the very first stars in the Universe. Furthermore, the black holes need to be born at just the right separations. If you place them too far apart, then the merger won't happen in many times the age of the Universe. If you place them too close, then the mergers all happen early in the history of the Universe and we wouldn't expect to detect any nearby today, 14 billion years after the Big Bang. One possible model for how the Universe might make GW150914 is shown in Fig. 3 (Fig.

1 of Nature 534, 512 (2016), which is based on work I did with collaborators Chris Belczynski (Warsaw), Tomek Bulk (Warsaw), and Richard O'Shaughnessy (Rochester). We show many of the steps along the way to creating an event like GW150914. The detection of GW150914 was the birth of the entirely new field of gravitational-wave astrophysics. This is only our first step, and as we continue to probe the heavens in gravitational-waves we look forward to discovering what the Universe has in store for us!

The detection of GW150914 was only a humble first step. We are now able to probe the Universe in an entirely novel way, and there is little doubt that new and exciting discoveries lie ahead.

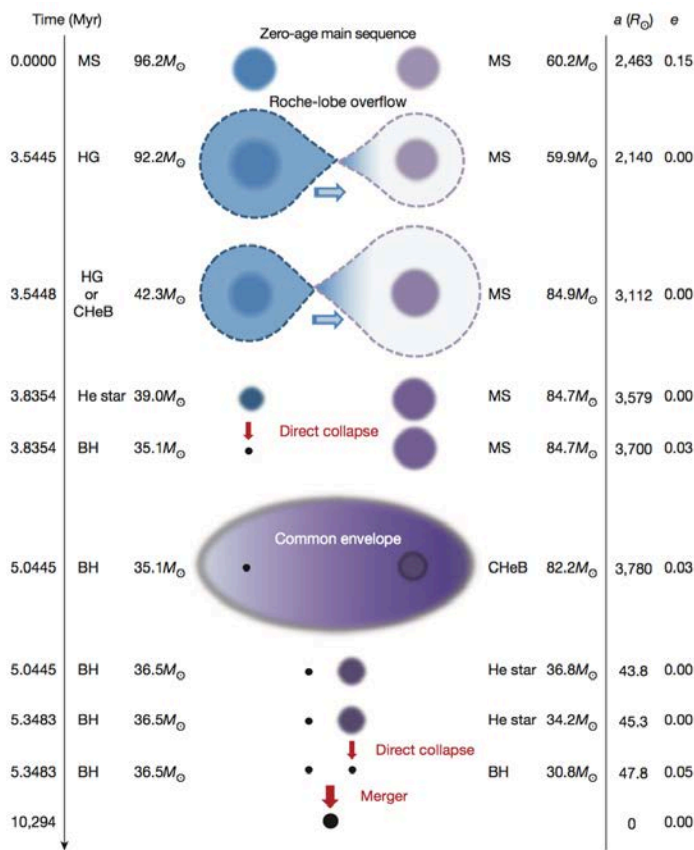
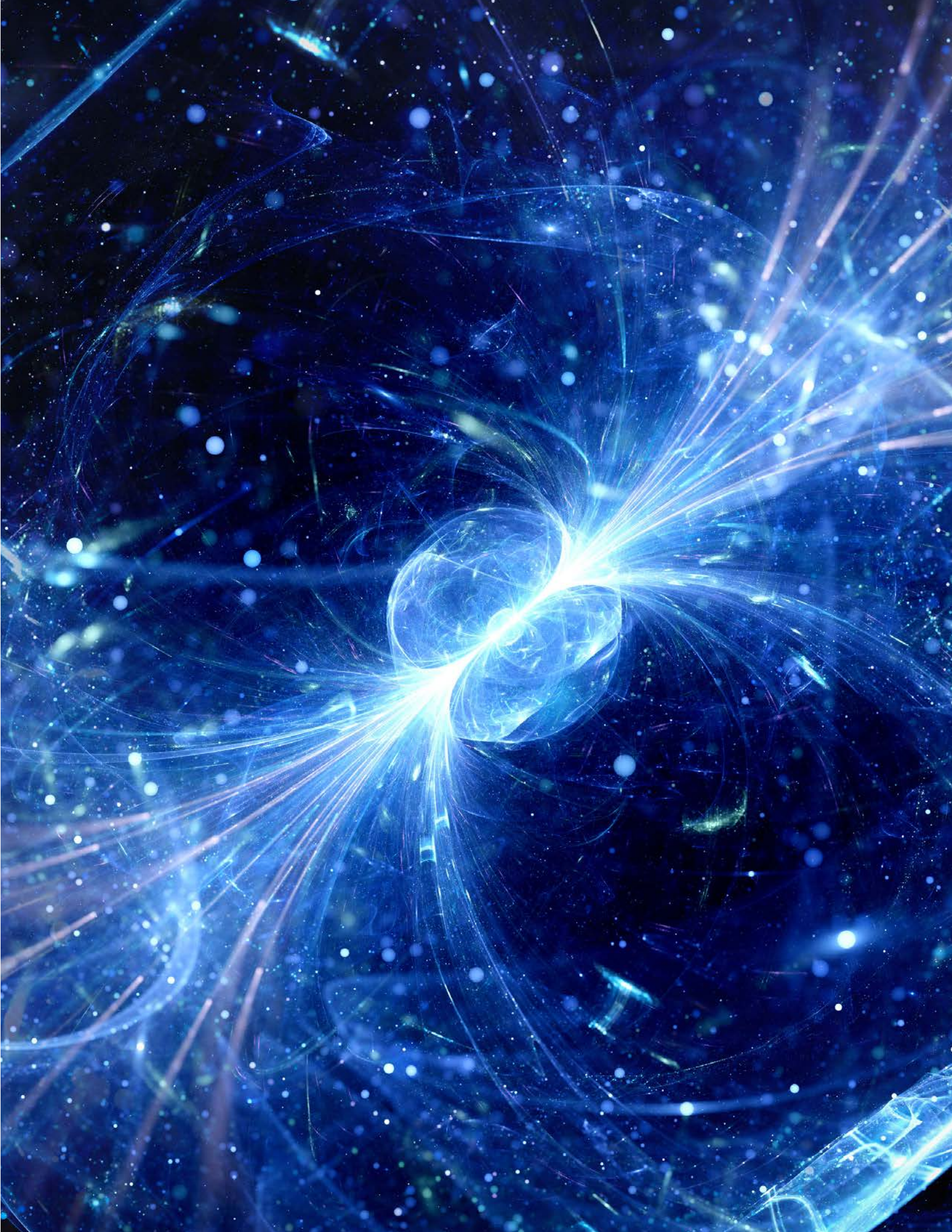


Figure 3

Abbott et al.



The University Welcomes New Faculty to U ofC Physcis



Erez Berg

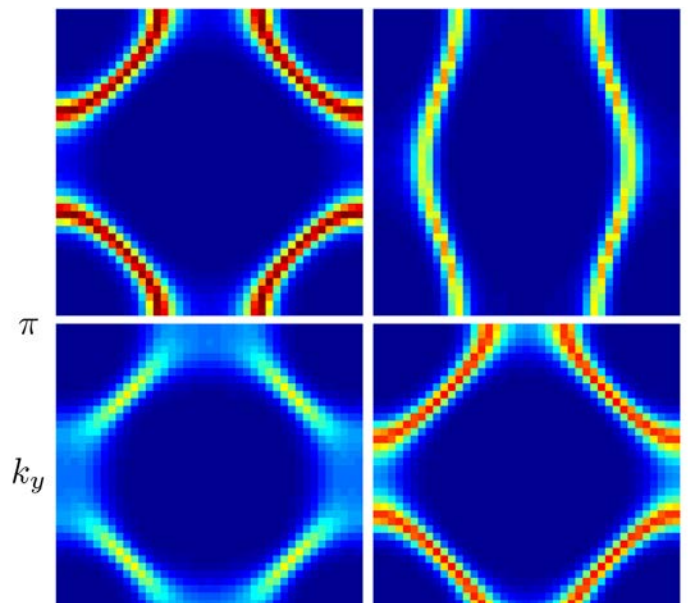
Associate Professor

Ph.D., Stanford, 2006

Understanding the emergent properties of a system composed of many interacting particles is a central problem in theoretical physics. Even systems made of simple microscopic constituents often reveal, upon cooling to low temperatures, astonishingly complex behavior. At low enough temperatures, quantum mechanics adds an extra dimension to the problem (both figuratively speaking, and in many cases, also literally). It opens up exciting new possibilities, such as entanglement, macroscopically coherent states, and new forms of non-local (“topological”) order; however, it also brings with it extra complications which have hindered a complete understanding so far. The difficulty of the many-body problem lies in the fact that the phase space of possible microstates grows exponentially with the number of particles. In a large class of quantum many-body systems (most notably, ones that involve fermions), the situation is even more severe, as Monte-Carlo sampling techniques cannot be used effectively (due to the so-called “minus sign problem”).

Most of my research is devoted to different aspects of the quantum many-body problem. My long-term goal is to contribute to the understanding of such systems. Some of the questions I hope to answer are: Which behavior is generic to highly correlated many-body systems, and which is system-specific? For instance, how does unconventional superconductivity arise, and what is the nature of its interplay with other types of competing or coexisting

emergent orders? In which physical systems (either newly discovered correlated materials, or artificial systems, such as synthetic low-dimensional materials and cold atom systems) can such phenomena be observed, and what can they teach us about the many-body quantum problem? What non-classical, “topological” forms of order can arise, and how are they affected by inter-particle interactions?



Electronic spectral function as a function of momentum across the Brillouin zone taken from a Quantum Monte Carlo simulation of a system undergoing a phase transition at zero temperature. Such a phase transition is believed to play a crucial role in the physics of several families of high temperature superconductors.



Stephanie Palmer

Assistant Professor
Ph.D., Oxford, 2001

I am thrilled to add a Physics Department affiliation to my primary appointment in Organismal Biology and Anatomy because it connects, in an explicit way, my two dominant intellectual pursuits: neuroscience and statistical physics. My research operates at the intersection of these two fields. We study the collective behavior of neurons in the early visual system, in order to understand the brain's ability to make fast and accurate predictions about the positions of moving objects in the environment. Physics and biology were interleaved yet unconnected in my early academic career, but they are now completely entwined.

As a kid, I wanted to be a brain surgeon and arrived at Michigan State University ready to pursue a chemistry degree and then head off to medical school. But physics was in my blood and after adding it to my curriculum, I dropped the pre-med bit by the end of my freshman year. My father had studied physics in college and spent his career as an instrumentation engineer in the aerospace industry. What I did not know at the time, however, was that the now familial tradition of studying physics stretched back to his mother, Mary Jane Palmer née Morrison. Mary Jane graduated from the University of Chicago with a degree in Physics in 1941. She worked on radar in New Jersey during the war before eventually taking up a post as head librarian in the Detroit metro area. This last job was the career I thought was the beginning and end of her story. When I started taking physics classes, my grandmother lamented that she had thrown away all her notes from college. Notes on what, I wondered? It turned out that she had taken notes on thermodynamics and mechanics and E&M; she had notes on algebra and differential equations and analysis; she had returned to Chicago during and after the war and had bumped into Oppenheimer and Fermi; she had been studying physics during one of the most active periods in American history. It is humbling to return to the physical and intellectual space she occupied all those years ago. My return to brain surgery (of a kind) was more speedy.

I studied theoretical physics at Oxford University as a Rhodes Scholar and worked with John Chalker on geometrically frustrated antiferromagnetic systems. We explored order induced by dipolar interactions on the pyrochlore, or corner-sharing tetrahedral, lattice. The simple ordering pattern we predicted has been found in recent years in some experimental systems. We figured out this neat and even correct thing, which was extremely satisfying, but I was attracted by the breadth of open questions in biology. I had some friends at Oxford who were working in neuroscience labs, including current UChicago/Argonne faculty member Narayanan (Bobby) Kasthuri; they were working on memory in a brain area called the hippocampus and their work touched on some of the most fundamental questions about how our brains store and process complex information. I decided to try to explore this new frontier myself. When I applied for postdocs, I was most excited by a Sloan-Swartz fellowship opening at UCSF that took mathematicians and theoretical physicists and transformed them into neuroscientists. I did postdoctoral work there and next at Princeton University in theoretical and experimental neuroscience, bringing what I knew about how to model collective states in spin systems to the binary spiking of neurons in the brain.



Mary Jane Palmer

My work aims to develop broad theories of neural function and connect them to specific, testable predictions about neural response in experimentally measured datasets. In particular, I evaluate the collective behavior of groups of neurons in the visual system and define how these coordinated responses signal what will happen next in the world. My present research focuses on the type of fast predictions that are used to overcome sensory and motor processing delays in simplified as well as naturalistic motion environments. My work in this area began with showing that retina optimally encodes the future position of single, simple moving objects in the visual field; my current and future work aims to extend this theory and measurement both to higher visual areas and to more natural visual scenes. My theoretical and computational work is done in close collaboration with experimental groups that each record from a different stage in the neural pathway for visual motion processing. We also record our own data in-house from neurons in the butterfly color vision system. That work aims to uncover how evolution shapes the computations that are added to a neural system and seeks to describe how the ancestral state can be “seen” in the extant computational solution brains use to represent the world.

I have also always been deeply committed to education throughout my career. I have taught chemistry, physics, math, and biology to a wide range of students. At the University of Chicago, I have founded and run the Brains! Program, which brings local middle school kids to campus to learn hands-on neuroscience. Thus far, we have hosted nearly 300 seventh graders from local southside CPS middle schools. We are working on a teacher training program to develop a curriculum module for seventh graders that leverages the fact that kids have an innate interest in their own brains. This natural curiosity serves as a wonderful gateway to many STEM subjects such as chemistry, cell biology, and even statistics. Finally, I am also very excited to be co-directing a course each fall for all of the incoming graduate students in the biological sciences. Stefano Allesina and I have put together a week-long intensive program that introduces these students to quantitative methods in biology, starting from the very moment they set foot in grad school. My hope is that we show them the power of a physicist’s approach to modeling biological systems.



Shinsei Ryu

Associate Professor

Ph.D., University of Tokyo, 2005

In early 1900’s, the discovery of quantum mechanics completely changed the way we think about physical entities. In contrast to classical mechanics, elementary particles, such as electrons, are described in terms of their wave functions. They can propagate in space, interfere, and can be superposed. Furthermore, predictions from quantum mechanics are probabilistic in nature. There are a lot of bizarre features in quantum mechanics, which even Einstein had trouble accepting. But to what extent do quantum mechanics matter in our daily lives?

In condensed matter physics, my area of expertise, it was established already in late 1920’s that quantum mechanics is essential to understanding the different states of condensed matter. Metal, insulators, and semiconductors – these distinctions arise because of the wave nature of electrons. Electron waves propagating in solids experience a regular periodic potential formed by atoms in the solids, and the bands of energies are formed. The structure of energy bands is the key to understanding different kinds of solid states. Thus, energy eigenvalues in quantum mechanics are clearly important, but how about wave functions? Is there any phenomenon in which quantum mechanical wave functions have direct observable consequences? This is the question I’ve been pursuing. In modern condensed matter physics, the role played by electron wave functions, not just energy eigenvalues, has been increasingly important.

The Nobel Prize in Physics in 2016 was awarded to three theoretical condensed matter physicists: David Thouless, Michael Kosterlitz, and Duncan Haldane. The prize featured the importance of topology, which turned out to be a key way in which/mechanism that explains how electron wave functions manifest themselves macroscopically. Topology

is a subfield or concept in mathematics, and deals with robust properties of spaces, such as curved surfaces. Here, by robust properties, we mean something that does not change when we smoothly deform spaces. Different spaces/surfaces can then be classified and characterized in terms of this loose criterion of topology. Similarly, we can focus on properties of electron wave functions, which are robust under perturbations to our systems. Different states of matter can then be distinguished by different topologies of electron wave functions.

This line of thinking has led to remarkable successes in modern condensed matter physics. For example, the condensed matter physics community had long believed that insulators were fully understood and rather boring states of matter. However, it was discovered recently that there are insulators whose wave function topology is completely different from ordinary insulators. This new state of matter, "the topological insulator," has come as a complete surprise and created great excitement and led to a number of revolutionary developments in condensed matter physics.

I feel extremely lucky to be a condensed matter theorist in such an exciting time. We are now in a new era where we have started to see the effects of electron wave functions directly and even to manipulate them for useful applications. For example, one of the key features of topological insulators is their peculiar transport properties. The usual flow of an electric current in solids is accompanied with dissipation (Joule heating). On the other hand, topological states of matter can support, while insulating in the bulk, a form of a dissipationless quantum transport phenomenon through their peculiar boundary states. These quantum transport phenomena of topological origin are promising candidates for electronics and spintronics with low energy cost. Excitations in topological media have also been expected to provide a promising platform for decoherence-free quantum computation. So, please keep your eyes on quantum condensed matter physics!



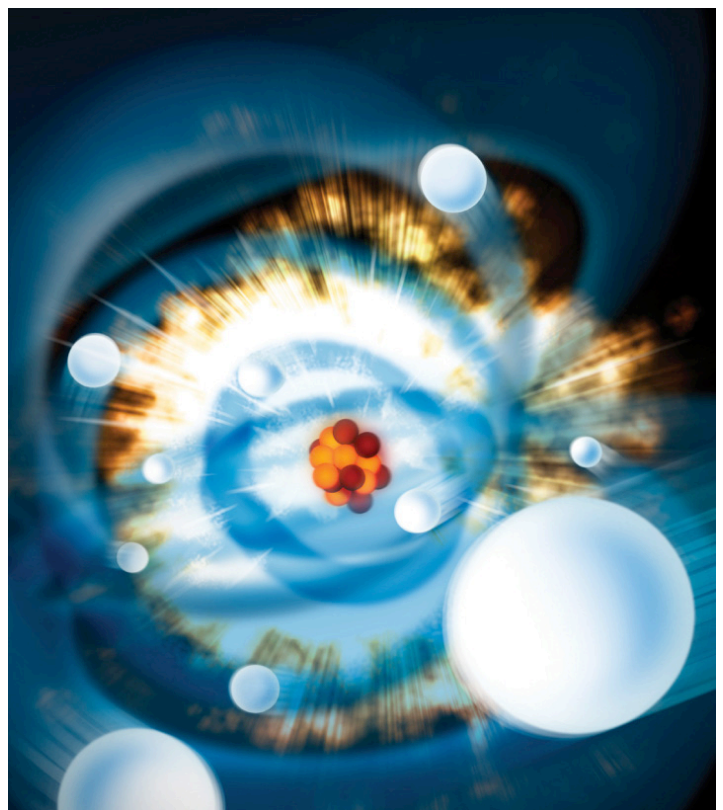
Linda Young

Professor

Ph.D., UC Berkeley, 1981

X-ray free electron lasers have provided a billionfold increase in peak brightness of readily tunable x-ray pulses, immediately creating the field of nonlinear x-ray science where multiphoton effects dominate.

This is an entirely new regime for x-ray science relative to that explored at synchrotrons, where the probability of multiphoton absorption in a single pulse is typically less than one in a million. It is a challenge to harness these ultraintense, ultrafast x-ray pulses for three-dimensional flash imaging to record combined nuclear and electronic motions in complex systems on their natural timescales. This challenge involves extending the experimental and theoretical toolkit of nonlinear spectroscopies from the optical to the x-ray regime. Although these large-scale accelerator-based ultra-intense x-ray lasers are a rarity at present, with only two operational at Angstrom wavelengths in the United States (LCLS) and Japan (SACLA), several projects worldwide promise to increase capabilities for these remarkable 21st century coherent x-ray sources.



Recent Honors

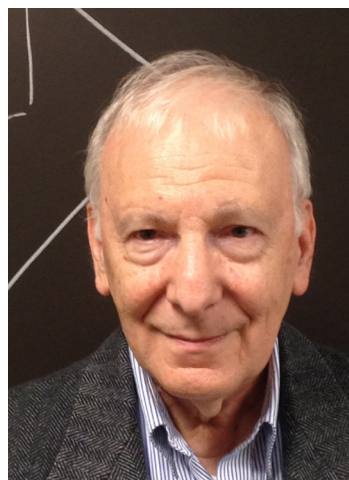


Paul Wiegmann received the 2016 Onsager prize of the American Physical Society "For the pioneering discovery of the exact solution of the Kondo and Anderson models, opening a new field of exact treatments of quantum impurity systems."

This work was done at the very beginning of his career. After extensive works on integrable systems, he recognized the importance of topological phenomena in condensed matter and worked essentially alone on this in the 1990's. Recently, topological matter has become one of the dominant themes of modern condensed matter physics. He remarks that "The next step of my development is a recognition that the interesting physics of quantum states beneath the topology is actually driven by the geometry and is essentially non-linear. This brought me to hydrodynamics, quantum and classical, and geometric properties of hydrodynamics. These days I focus on geometry and hydrodynamics properties of electronic fluids in quantum Hall effects."

Paul Wiegmann, Ph.D., is the Robert W. Renneker Distinguished Service Professor at the University of Chicago (Ill.). Dr. Wiegmann contributed to the broad spectrum of fields in condensed matter, statistical physics, and mathematical physics. His work on integrable models of quantum field theory lead to exact solutions of important problems, such as Kondo and Anderson models for magnetic alloys, nonlinear sigma models of magnetism and quantum field theory, and electronic models with strong interaction. During the 1990's, Dr. Wiegmann focused on topological phenomena in electronic and magnetic systems with strong interaction, identifying the role of topology in

formations of quantum states by interaction. He developed a theory of topological mechanism of superconductivity which has a potential application in doped Mott insulators, while also obtaining the exact solution of the celebrated Hofstadter problem, describing a singular continuum spectrum of a particle on a lattice in a strong magnetic field. During the 2000's, Dr. Wiegmann developed the theory of Laplacian growth and the Hele-Shaw problem, finding a deep relationship between growth processes and the theory of random matrices. This led Dr. Wiegmann to the theory of singularities and viscous shocks in the problem of viscous fingering instability. At the same time, he proposed a theory of quantum hydrodynamics to address nonlinear dynamics in electronic systems with a restricted geometry. His current interest is the geometric interference phenomena, the geometric theory of quantum Hall effect, and hydrodynamic description of quantum states with topological characterization. Dr. Wiegmann graduated from the Moscow Institute of Physics and Technology (Russia) in 1975 and obtained his Ph.D. from the Landau Institute for Theoretical Physics (Chernogolovka, Russia) in 1978. He has been a Humboldt Fellow, a Simons Fellow, and has held the Internationale Blaise Pascal and Kramers chairs. He is a fellow of the American Physical Society.



Bob Wald is the 1917 winner of the Einstein Prize of the American Physical Society. The prize is to recognize outstanding accomplishments in the field of gravitational physics, and the citation reads

"For fundamental contributions to classical and semiclassical gravity studies, in particular, the discovery of the general formula for black hole entropy, and for developing a rigorous formulation of quantum field theory in curved spacetime."

Robert M. Wald, Ph.D., is the Charles H. Swift Distinguished Service Professor in physics department and at the Enrico Fermi Institute at the University of Chicago (Ill.). He received his B.A. in physics from Columbia University (New York, N.Y.) in 1968 and his Ph.D. in physics from Princeton University (N.J.) in 1972, under the supervision of John A. Wheeler, Ph.D. After a two-year postdoctoral fellowship at the University of Maryland, College Park, he was a postdoctoral fellow to the University of Chicago in 1974 and joined the faculty in 1976. Dr. Wald's main research interests have centered on the theory of black holes, particularly their thermodynamic properties, and the role of quantum effects in making black hole thermodynamics consistent. Dr. Wald has also made significant contributions to putting the formulation of quantum field theory in curved spacetime on a rigorous mathematical footing, and to the development of the theory of gravitational self-force effects on bodies. He is the author of the textbook/monograph "General Relativity" (University of Chicago Press). Dr. Wald is a fellow of the American Physical Society and of the American Academy of Arts and Sciences and is a member of the National Academy of Sciences.



Assistant Professor Abigail Vieregg was named a 2017 Sloan Research Fellow, "in recognition of distinguished performance and a unique potential to make substantial contributions to their field." She also received

the 2017 Shakti P. Duggal Award, "to recognize outstanding work by a young scientist in the field of cosmic ray physics." Vieregg's research focuses on exploring the most energetic phenomena in the universe, through searches for ultra-high energy neutrinos using radio detection techniques. She is currently designing and fabricating an interferometric phased array trigger for radio detection of ultra-high energy neutrinos, which will lower the energy threshold and increase the sensitivity of the radio-detection technique, and will be incorporated into the ARA experiment at the South Pole in early 2018. Read more about her group at <http://kicp.uchicago.edu/~avieregg/>



Stephanie Palmer, a theoretical neuroscientist with a background in condensed matter theory, was recently awarded an **NSF CAREER award for her work on prediction in the brain**. She is also the recipient of a **research fellowship from the**

Alfred P. Sloan Foundation. Palmer joined the physics faculty as a joint appointment in Autumn 2016, and holds a primary appointment in the Department of Organismal Biology and Anatomy. You can read more about her work in the new faculty section.

Michael Rust

HHMI-Simons Faculty Scholarship

Jeff Harvey

Simons Fellow

Young-Kee Kim

Fellow of the American Academy of Arts and Sciences

CHICAGO PHYSICS FRESH FACES



DAVID JIN

Sophomore

President of Society of Physics Students
Research Assistant to Young-Kee
Summer Intern at Fermilab in CMS Collaboration

Most embarrassing moment: Forgetting the quadratic formula on my PHYS 143 final.

Who are you and why physics?

I hail from Los Angeles, and the subject that I found the most exciting has always been the sciences. I originally thought I was gravitating towards going into medicine or some form of business/finance, until I took my first physics course in 10th grade. Although I found it difficult, the challenge “awakened” my mind in a sense to a whole new way of thinking in physics, that combines a natural/built intuition with mathematical prowess. However, I was worried about fully committing to physics, as a then 16-year old choosing to enter a field where a doctorate is a pre-requisite. I wasn’t sure if I could do it, but I knew that I had to at least put in my best effort.

Why did you choose UChicago? And did you find what you expected when you came here? Did Chicago turn you on to physics?

In the end, I chose UChicago based on a coin flip, between here for physics, and Berkeley for electrical engineering & computer science. It wasn’t so much about the schools, but the schools were sort of a proxy in choosing between science and engineering. I knew that if I wanted to do physics, UChicago was the right choice, and unsurprisingly, that Berkeley was right for engineering. I didn’t know which field was right for me as a high schooler, but I vividly remember many days of getting home and reading

about some physics topic, like black holes or the Standard Model, and I never did that for engineering. As my father flipped a quarter to help me decide, I realized that going to UChicago & committing to physics was something I couldn’t pass up, despite jokes like “What’s the difference between an electrical engineer and a physicist? \$65,000 a year!”

I expected UChicago, and especially UChicago physics, to challenge me to my core, and I was not wrong. To be honest, I was initially turned off by the rigor/difficulty of the honors physics sequence– it’s hard to do vector calculus without a formal understanding of what a vector is. By spring quarter, I felt that if my next physics course was this grueling, I couldn’t do it. But I stuck through it, and taking courses like modern physics & quantum mechanics made it worthwhile, especially since succeeding in those courses requires firm mathematical footing that I acquired through the rigor of my first year. I particularly remember my first experience doing research, working in the CMS Collaboration at Fermilab my 1st year summer researching dark matter. Walking into Wilson Hall, and seeing the rows of flags and physicists of every creed and call unite to study fundamental particles was more than inspiring. And I remember asking my advisor Dr. Anadi Canepa if I could sleep in the lab even, to save travel time to-from home.

Any passions for science developed while you have been here? Or indeed passions in general connected to your UChicago experience.

I’ve always had a passion for science, but I’m very interested in how to improve pedagogy, especially in physics. It’s surprising that whereas students spend so much time studying physics, there’s really no formal education in optimal ways to learn/teach physics. And I’m especially passionate about making physics more inclusive and accessible– to non-traditional groups, personalities, even laypeople. There’s a lot of amazing discoveries that are buried under buzzwords and misinformation, and especially in the current political landscape, I believe it’s important to recall why we do science, and how to make physics relatable & approachable for all groups of people, as opposed to something that inspires fear, as is the case for many of my friends.

When I'm not studying or working as an RA in Prof. Young-Kee Kim's group, I enjoy exploring the city, longboarding around, discovering new music, reading about & engaging with culture/fashion, and trying new things in general. I used to enjoy playing video games, watching TV/movies, and water polo, but UChicago doesn't leave much time for that.

What do you see yourself doing next in your career – both immediately following graduation, and longer term?

That's a tough one. My dream is to pursue a PhD in hep-ex, and work in the field either at CERN or as a professor. However, with the long delay until a new, higher energy collider is built and future funding up in the air, I'm uncertain if I'll be able to probe new physics.

I've been recently curious about medical physics, especially with regards to applying/training machine learning algorithms to identify tumors within medical imaging. And I've also been interested in quantum computing, both hardware/design and applications to encryption, optimization, and etc. I'm attempting a double major in Physics and Computational & Applied Mathematics, so these would be great opportunities to synthesize my knowledge. However, I still remember watching the CERN documentary "Particle Fever" when I was 16, and I still find myself drawn to particle physics.



SOFIA MAGKIRIADOU

Postdoctoral researcher in William Irvine's Laboratory

Who are you and why physics?

I grew up in Thessaloniki, Greece. At school, we had our first physics course when we were ten; I remember learning the basics of how batteries worked and how interesting I thought it was. That was one of the first times I realized I liked physics. I liked the science classes, because I got a kick of understanding how things work; but I also really liked our literature classes and our foreign language classes (the

Greek systems mandates that we learn two). So for a long time the humanities teachers thought I'd go the humanities route, and the science teachers thought I'd go the science route. But really with all this classwork I think I'd have gone mad if I weren't doing something non-scholarly, and some of the best moments of my school life were with the school orchestra, which I still miss.

My first stop after graduating high school was at Yale, where I got my B.S. I then moved to Harvard for my PhD, and I am now in my third year of postdoc.

Could you explain in two sentences what your research is about?

We study the collective behavior of microscopic spinning magnets in water. Just like birds, when in large numbers, can move in complex ways, so can our magnets. In particular, we see that our little magnets tend to come together and form a material that can flow like a peculiar fluid.

Are there any experiences about your time at Chicago that you would be happy to share?

When I arrived here from Boston, I was startled by how stark contrasts there can be between nearby neighborhoods. To get from point A to point B, it's not really enough to draw the line of closest approach; one has to superimpose, on top of that, a metric of safety. This idea was new to me.

On a more positive note, I am still not quite used to the abundance of cultural activity here. I still find it hard to believe, how close I am to some of the world's best music ensembles, not to mention the collections at the Art Institute and the museums. It would be quite possible to not do any work at all and still be busy!

I remember the day the Cubs won the World Series. I don't follow sports at all, but I was home sick on the following day. Even though it was a workday, the streets were full of people in blue shirts, celebrating. It was fun to see so many cheerful people skipping work for the occasion.

What do you see yourself doing next in your career?

Good question! I will be looking for an academic position quite soon, I am excited about the prospect of research and teaching, combined. That said, I will probably also entertain the idea of a research position outside of academia, since there are many interesting open questions that are addressed in non-academic institutions.

Recent Happenings

HONORING MARIA GOEPPERT-MAYER

On May 25th, the Department opened an exhibit about Maria Goeppert-Mayer, a theoretical physicist who developed the nuclear shell model while at Argonne National Laboratory and the University of Chicago from 1946 to 1959. One of only two women ever awarded the Nobel Prize in Physics and the University's only female recipient, Goeppert-Mayer received the prize in 1963 for her "discoveries concerning nuclear shell structure." She shared the award that year with Eugene Wigner and Jans Jensen. This permanent exhibit was installed on the wall of the Kersten Physics Teaching Center's Auditorium. President Robert Zimmer, the University's Trustee Steve Kersten, and Dean Rocky Kolb made remarks about the accomplishments of Maria Goeppert-Mayer and of the Physics Department.



The Physical Sciences Dean Edward (Rocky) Kolb, The University President Robert Zimmer, the University's Trustee Steve Kersten, Chair of the University's Women's Board Priscilla Kersten, and the Physics Department Chair Young-Kee Kim in front of the Maria Goeppert-Mayer exhibit.

A more extensive program will be held this coming fall when the auditorium's renovation is complete. We will be renaming the auditorium the Maria Goeppert-Mayer Lecture Hall and will hold the first lecture in her honor. This will acknowledge not only her work, but will also celebrate and inspire women in the sciences. This event will be open to the public. We especially welcome our alumni to this event. Detailed information will be available at <http://physics.uchicago.edu/maria-goeppert-mayer>

CAREER NIGHT

Arne M. Olsen

It was a pleasure speaking to such interested students who are considering going "rogue", i.e., leaving the physical sciences. While your stay here has given you a valuable science background, you have been taught something even more valuable, how to think and figure it out for yourself. With that and some hard work (you are used to that), you can take on any task

Now, to prepare for Plan B. Take a writing course, because good communication skills are always useful. Take some courses in your areas of potential interest; even the graduate schools will let you take a class to test drive a new area.

Finally, pick up some humility and you will do fine.

SPS BARBECUE



PROFESSOR EUGENE PARKER: A HOT CELEBRATION



A good time was shared by UChicago Physics as faculty and friends gathered to celebrate the birthday of Professor Emeritus Eugene Parker who joined the faculty in 1967 and later made the landmark discovery of solar wind. The Parker solar probe is scheduled to launch in summer of 2018.

NASA RENAMES SOLAR PROBE MISSION TO HONOR PIONEERING PHYSICIST EUGENE PARKER

NASA has renamed the Solar Probe Plus spacecraft — humanity's first mission to a star, which will launch in 2018 — as the Parker Solar Probe in honor of Eugene Parker. The announcement was made on May 31, 2017 at a ceremony at the University of Chicago, where he serves as the S. Chandrasekhar Distinguished Service Professor Emeritus, Department of Astronomy and Astrophysics and Department of Physics. Parker Solar Probe mission will revolutionize our understanding of the sun, where changing conditions can propagate out into the solar system, affecting Earth and other worlds. Parker Solar Probe will travel through the sun's atmosphere, closer to the surface than any spacecraft before it, facing brutal heat and radiation conditions — and ultimately providing humanity with the closest-ever observations of a star. Parker joined the physics faculty in 1967 and chaired the Department of Physics from 1970-72.

On June 13, 2017, we celebrated Parker's 90th birthday at the Kersten Physics Teaching Center (KPTC) with colleagues and friends from the Physics, Astronomy and Astrophysics Departments as well as from the Enrico Fermi and James Franck Institutes..

At his birthday party, he signed the Parker Solar Probe poster, writing, "This is hot stuff!". This poster will be hung next to the Hubble Space Telescope, Chandra X-ray Observatory, and Compton Gamma Ray Observatory posters at the KPTC.



Diary Dates

This Fall, the Department has turned its Colloquium series over to CP-1 and its impacts. Colloquia are held at 4pm in the Maria Goeppert-Mayer Lecture Hall of the Kersten Physics Teaching Center.

See <https://physics-sites.uchicago.edu/page/colloquia> for up-to-date information. **All are welcome**

Thursday, October 5, 2017 Nuclear Physics: Then and Now

Barbara Jacak, UC Berkeley and Lawrence Berkeley National Lab

Thursday, October 12, 2017 Nuclear Energy

Carlo Rubbia, Nobel Prize in Physics 1984

Thursday, October 19, 2017 Big Sciences

Melissa Franklin, Harvard University

Thursday, October 26, 2017 Social Implication

Robert (Bo) Jacobs, Hiroshima Peace Institute and Hiroshima City University

Thursday, November 2, 2017 Biomedicine

Chin-Tu Chen, University of Chicago

Wednesday, November 8, 2017 Ongoing Challenges Surrounding Nuclear Waste

Rodney Ewing, Stanford University

Thursday, November 16, 2017 Impact on University Research

Eric Isaacs, University of Chicago

Thursday, November 30, 2017 Enrico Fermi: The Pope of Physics

Bettina Hoerlin and Gino Segrè

Campus-wide events for the CP-1 75th Anniversary are listed here: <https://www.lib.uchicago.edu/scrc/exhibits/upcoming-exhibits/>

December 9, 2017 Physics with a Bang

Students, families, teachers and especially the curious are invited to attend our annual Holiday Lecture and Open House. See fast, loud, surprising and beautiful physics demos performed by our distinguished staff. Talk to scientists about their latest discoveries. Participate in hands-on activities related to their research.

January 12, 2018 Physics Career Night

Physics graduates will learn about the exciting and rewarding career opportunities open to them by hearing from alumni, professors, and postdocs.

March 2, 2018 Graduate Student Open House

Updated information is always available on the Chicago Physics website <https://physics-sites.uchicago.edu/>

We're Building

**PRC
BE
FORE**



**PRC
AF
TER**



UChicago physicists look forward to the completion of the new Physics Research Center (PRC) in the Fall of 2017.

The building will serve as the home of the Enrico Fermi Institute, bringing together experimental and theoretical particle physicists who for many years were housed in separate buildings. New experimental facilities at the PRC will enable Chicago to maintain and build upon its long-standing leadership role in the exploration of fundamental particles and their interactions. A new Center for Bright Beams will exploit novel concepts in accelerator science and technology, and develop new approaches to overcome limitations affecting the acceleration, intensity and quality of particle beams.

The building will also provide a home for the new Kadanoff Center for Theoretical Physics, which seeks to provide a research environment that bridges a variety of physical disciplines, and advances our understanding of physical

phenomena ranging from condensed matter physics and statistical mechanics, to high energy physics, astrophysics and mathematics. For example, a major unifying theme of current research into quantum properties of materials emphasizes the role of geometrical structures which also arise in string theory. The Kadanoff Center will serve as a platform for the exchange of common ideas and methods across these disparate areas of research.

For over 50 years, the Laboratory for Astrophysics and Space Research (LASR) building was home to space science at Chicago. In 2013, planning began for a complete renovation of LASR, including an expansion adding two floors to the structure. Construction began in the Fall of 2015 and will be completed this summer.

The current state of construction (as of June 2017) is shown above, together with the old LASR building pre-renovation.

In Fond Memory



Mildred S. Dresselhaus

1930-2017

Mildred Spiewak Dresselhaus (known to all as Millie) was born in Brooklyn and received her bachelor's degree in 1951 from Hunter College, followed by a Fulbright fellowship to Newnham College, Cambridge. Returning to the US, she earned an MA from Radcliffe College in 1953 and her **PhD in 1958 from the University of Chicago, where she studied under Enrico Fermi.** In 1960 she joined the faculty at MIT where she served for the rest of her career, becoming the first female Institute Professor in 1985.

In the biography for the Kavli prize, she wrote about her experience in Chicago. "It was at the University of Chicago that I learned physics in some depth under the Enrico Fermi system. In my first year at the University of Chicago I took a course in quantum mechanics from Enrico Fermi, where I learned how to think as a physicist. I got to know Enrico Fermi and his family quite well during that year (1953), which unfortunately turned out to be the last year of his life. He had a great influence on me and on everybody who crossed his path. My PhD thesis was on the microwave properties (measured at a microwave wavelength of 30 cm) of a superconductor in a magnetic field. At the March 1958 meeting of the American Physical Society I reported some anomalous behavior that could not be explained by the Bardeen-Cooper-Schrieffer theory of superconductivity published in 1957, and this work attracted the attention of

Bardeen, Schrieffer, and others and helped my early career. In 1958 I both defended my PhD thesis and married Gene Dresselhaus, whom I had met when we were both at the University of Chicago."

As a researcher, she made fundamental discoveries in the electronic structure of so-called semi-metals using the tools of magneto-optics. She was a pioneer of the science of carbon, in all of its forms – sheets of graphene, hollow spheres of 'buckyballs' and especially carbon nanotubes. Her recent research moved into other layered materials such as the transition metal dichalcogenides, and she discovered how to tune nanostructures to improve their thermoelectric behavior.

Her influence on the community extended far beyond her science. Amongst her leadership roles, she served as director of the Office of Science of the Department of Energy, and as president of the American Physical Society. She was internationally known for her work to develop and promote opportunities for women in science and engineering. Those many who knew her closely valued her teaching and mentorship. She was awarded the National Medal of Science in 1990, the Presidential Medal of Freedom in 2014, numerous science prizes including the Kavli Prize, the Enrico Fermi Award of the Department of Energy, and the Buckley Prize of the American Physical Society.

The Queen of Carbon



Follow your interests, get the best available education and training, set your sights high, be persistent, be flexible, keep your options open, accept help when offered, and be prepared to help others.

— Mildred Dresselhaus —



Leo Kadanoff

1937-2015

Leo Kadanoff, a Professor at the University of Chicago from 1978 and active in the Department until his death, was one of the great formative thinkers in modern physics. Leo was raised in New York City, received a PhD and undergraduate degree from Harvard, and before coming to Chicago was on the faculty at the University of Illinois, and Brown University.

His work on scale invariance and universality in phase transitions, apparently a recondite topic to understand the details of phase transitions in matter, is a huge intellectual legacy for science. The importance of Kadanoff's work on scaling — the idea that in collective phenomena a system will look similar on large and small scales — was not confined to one area of physics. As put by our colleague Paul Wiegmann: "It has a huge range of applications and scaling perhaps is one of the most important and successful concepts of modern physics." These ideas have had impact in areas as diverse as urban planning, fluid dynamics, computer science, biology, and geophysics, many of which Leo contributed to directly.

His work covers an enormous range but with a unique style, producing some of the defining ideas in quantum field theory and statistical physics, and modern understanding

of the role of chaos and the effects of disorder. He wore his greatness lightly, with an impish and humble demeanor. **For us in Chicago, he was a unifying figure and guru, bringing together many people by the diversity of his interests and the clarity of his thinking.**

In 2013, an anonymous donation to the University of Chicago founded the Leo Kadanoff Center for Theoretical Physics, which brings together researchers from different fields of theoretical physics, to explore the connections between various disciplines. It is already a vibrant destination attracting new junior and senior faculty to the department, and soon to be housed in the new Physics Research Center.

He received the Buckley and Onsager Prizes of the American Physical Society, and served as that organization's president in 2007. He was also awarded the Wolf Prize, the Boltzmann Medal of the International Union of Pure and Applied Physics, the Isaac Newton medal of the Royal Society, and in 1999 a National Medal of Science.

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Current University of Chicago Physics faculty:

So many of the accomplishments associated with Physics at the University of Chicago have been made possible by the generous support of alumni and friends through direct contributions and estate gifts. If you would like to join them, please feel free to contact:

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