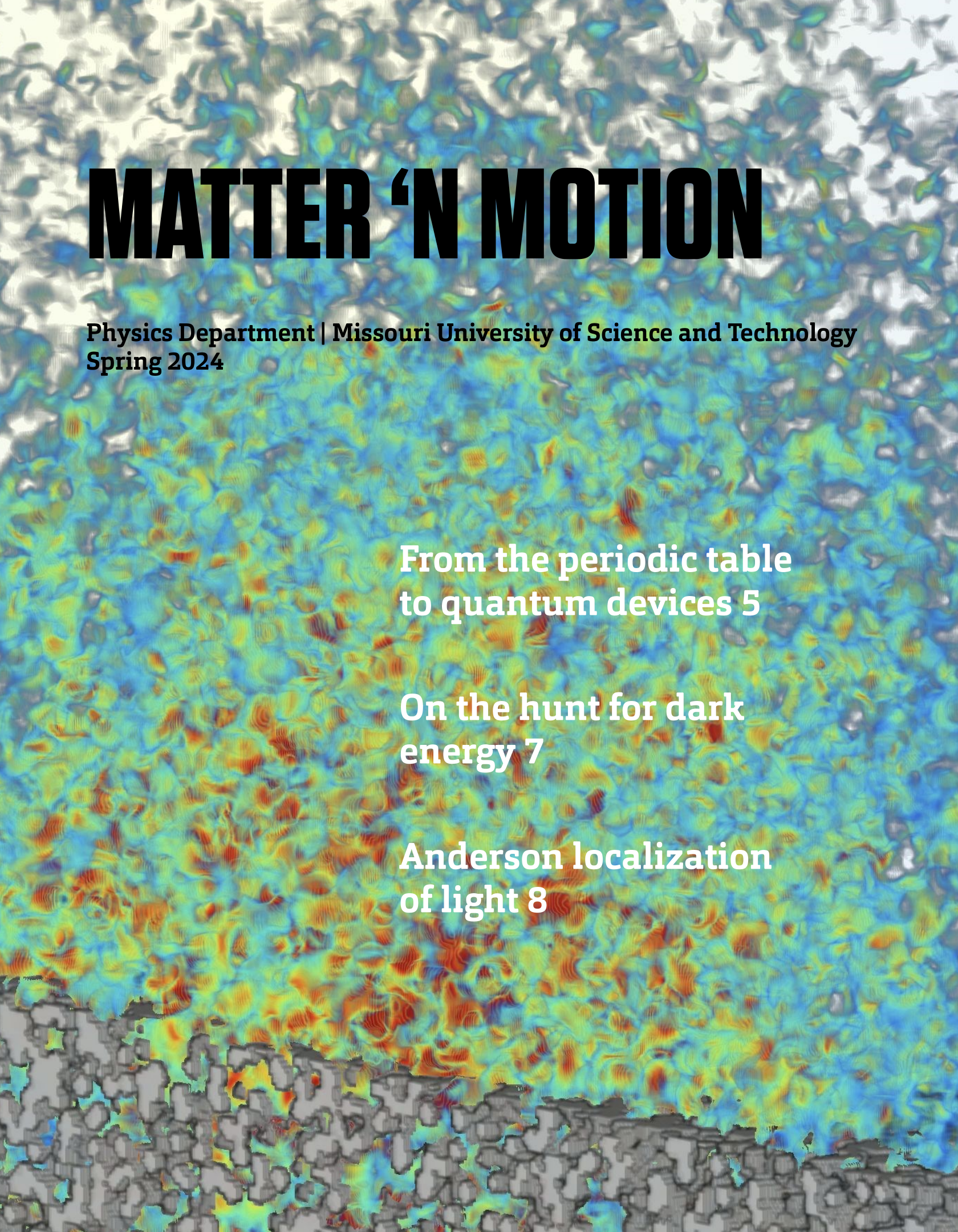


MATTER 'N MOTION

Physics Department | Missouri University of Science and Technology
Spring 2024

ENDOWMENTS: GIFTS THAT CONTINUE TO GIVE

We are grateful for the generosity of the donors who funded the endowed scholarships and prizes that helped so many students this academic year. Our warm thanks go to the families and estates of

Dr. Richard Anderson
Dr. Harold Q Fuller
John L. & Betty L. McDaniels
Dr. Oran Allan Pringle
Dr. Laird D. Schearer
Leon E. Woodman
Gerrie Fletcher
Dr. Richard W. Hannum
Burke H. Miller
Dr. John R. and Patty Rogers
Ed and Mary Sue Sickafus

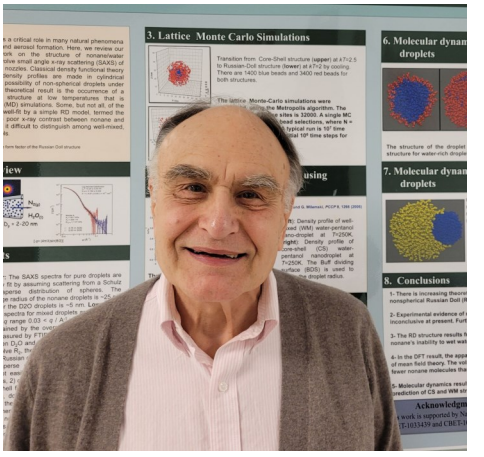
Donald L. Packwood and Lona Lewis Packwood Memorial Scholarship

We thank Donald and Lona Packwood for their generous donation of $56,000, establishing a new endowment to provide scholarships for undergraduate and graduate students. Donald Packwood received a BS in Physics with minors in Chem, EE, and Math from MSM in 1963, and MS in Physics from UMR in 1965. He then went on to earn his Ph.D. in Physics from the University of Missouri Columbia in 1971. He was honored with a UMR Professional Degree in Physics in 2001.

GERALD WILEMSKI GRADUATE RESEARCH FUND

We thank Dr. Gerald Wilemski, professor emeritus of physics, for his generous donation of $89,000, establishing a new endowment. The "Gerald Wilemski Graduate Research Fund" will support our graduate program by providing summer stipends and bridge funding to deserving graduate students. We are very grateful to Gerry for such a generous gift that will benefit the department in perpetuity.

Please consider donating to the fund at give.mst.edu



Front cover:
Frozen light - spreading of the electromagnetic waves in the disordered slab halted in its track by Anderson localization.
Credit: Dr. Alexey Yamilov.
See article on pg. 12.

Note from the Editor:

This year's newsletter is arriving later than usual. Just as we were going to print, we got word about the passing of Dr. Barbara Hale and wanted to include an article about her on page 3.

DEAR ALUMNI AND FRIENDS,

The ancient Greek philosopher Heraclitus once said that the only constant in life is change. This certainly applies to the physics department. I am deeply saddened to report that Professor Emerita Barbara Hale passed away on January 17, 2024. Barbara was a true pioneer who paved the way for women in physics. She left her mark not only on the department but on the entire university.

Dr. Dan Waddill retired after 29 years at UMR/Missouri S&T including more then 10 years as the physics department chair. Thanks for your dedication to the department, Dan, and best wishes for the future!

I am happy to report that we are welcoming two new professors this year. Drs. Simeon Mistakidis and Garyfallia (Lia) Katsimiga are both theorists working in atomic, molecular, and optical physics. We also welcomed new staff members Trish Aston and Michelle Mayhue who keep the physics office running efficiently.

The physics department mourns the passing of PhD student Jose de Jesus Nicasio Hidalgo at the end of last year, just days after he had passed the comprehensive exam. He will be remembered as a promising student, mentor, and friend.

2023 was another outstanding year for faculty achievements. Dr. Shun Saito had a banner year. He received two large grants from the DOE and NASA, totaling more than $1 million and won a campus Faculty Research Award. Drs. Halyna Hodovanets and Marco Cavaglia both received new major NSF grants, and several faculty obtained additional funding for their awards. Dr. Alexei Yamilov published an article in the prestigious journal Nature Physics. Lecturer Joel Peacher and PhD student Mat Pollard are the winners of the department's inaugural Outreach Award which recognizes activities that promote physics to children, students, and the general public.

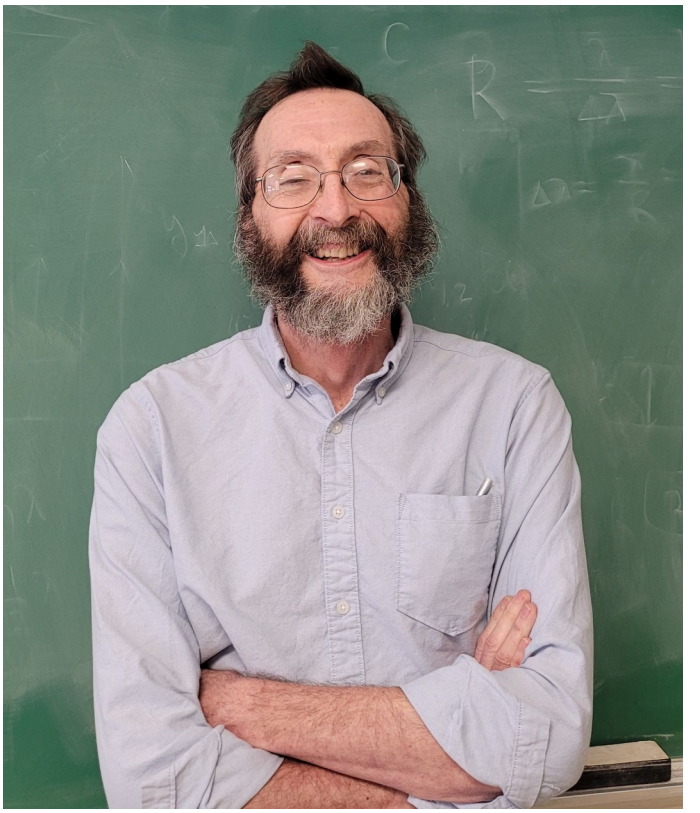
After years of decreases, S&T's student population has finally stabilized, leading to an improved financial outlook for the university. The physics department currently has 81 undergraduates and 27 graduate students. Our students won prizes at the S&T Undergraduate Research Conference and the department's Fuller and Schearer competitions. We awarded 11 BS degrees, three MS degrees and five PhDs in 2023.

As always, I would like to close by thanking our alumni and friends for their dedication and generous donations without which the department's success in teaching, research, and service would not be possible. I know that we can count on your continuing support. Thank you very much!
Warm Regards,

Thomas Vojta
Chair

IN THIS ISSUE:

DAN WADDILL RETIRES



After twenty-nine years in our department, Dr. Dan **Waddill** retired at the end of the spring semester.

Dan joined the university in 1994 . He is an experimentalist and specialized in atomic scale investigations of surfaces and interfaces, x-ray photoelectron spectroscopy and photoelectron diffraction. His research activities led to 119 publications in refereed journals and more than 160 presentations at conferences and workshops.

Dan served as department chair for twenty-one semesters, from August 2006 until December 2017. He successfully led the department during a period of many changes that included the name change from UMR to S&T, the elimination of the colleges in 2007, and their reestablishment in 2014.

Dan taught classes ranging from introductory engineering physics to upper-level classes such as physical mechanics and solid-state physics and was popular as a teacher and advisor for the physics majors. His contributions to the university were honored with five Faculty Excellence Awards and numerous Teaching Commendations.

Dan is looking forward to having more time for his outdoor pursuits and is happy that he is finally able to hike during the beautiful fall months.

MEET OUR NEW OFFICE STAFF:

Trish Aston & Michelle Mayhue

Trish Aston and **Michelle Mayhue** joined our department in March. Trish moved back to Missouri from Texas, with her husband Barry, her children Dakota and Tatum, and her dog Bailey. Michelle is an avid crafter who loves to spend her spare time crocheting, knitting, and making jewelry. We are happy they are here and our front office runs smoothly once again.

BARBARA HALE PASSED AWAY

We are deeply saddened by the passing of Dr. **Barbara Hale**, Professor Emerita of Physics, at age 86 on January 17, 2024.

Barbara earned a Ph.D. in physics from Purdue University and a bachelor's degree in physics from Syracuse University. She came to Rolla in 1969 as a visiting assistant professor of mathematics. In 1973, she became assistant professor of physics and a senior investigator in the Graduate Center for Cloud Physics Research. She was named associate professor of physics in 1977 and professor of physics in 1982.

Barbara was an expert in nucleation theory with an emphasis on theories of water and ice cluster formation. Her work led to over 40 publications and made important contributions to the field. Her scaled model of nucleation was one of the most significant contributions to the understanding of this phenomenon in the last 30 years. At S&T, her research generated almost $1 million in external support.

Barbara Hale was one of the first two female faculty in the physics department and a life-long advocate for women in science. She was named Woman of the Year in 2013 and served as advisor for the Chi Omega women's fraternity from the local chapter's founding in 1979 until her retirement in 2018.

We remember Barbara as a dedicated scientist and an inspiring role model who left her mark on our department and the entire university.

JOSÉ NICASIO PASSED AWAY

We are mourning the passing of our graduate student **José de Jesus Nicasio Hidalgo** in a tragic accident. José joined our department as a graduate student in 2022. He moved here from Mexico to work with Prof. Ulrich Jentschura. José was a promising student. He won a prize in the 2022 Schearer Prize competition for graduate research, had passed his comprehensive exam, and was getting close to completing his doctoral thesis. We remember him as a talented student, kind mentor, and good friend.

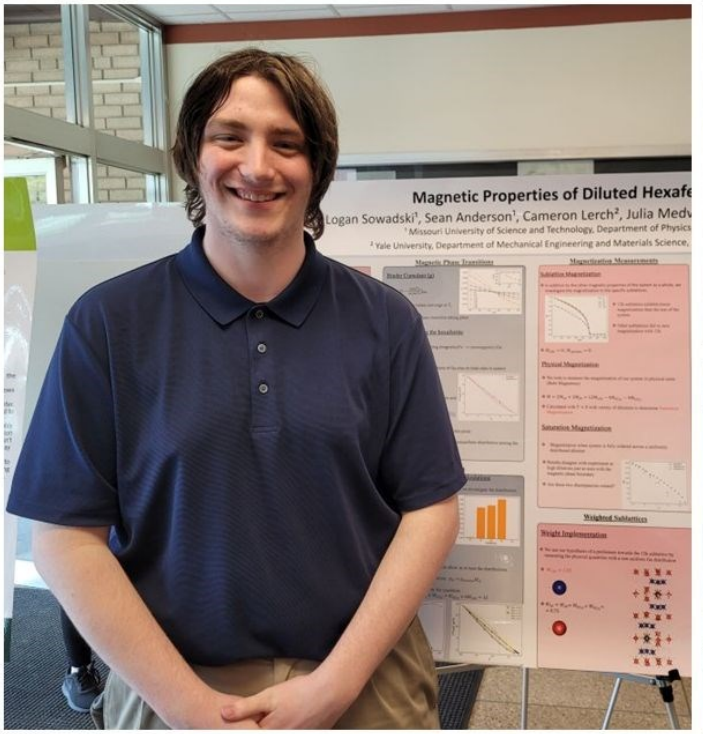
FULLER PRIZE 2023

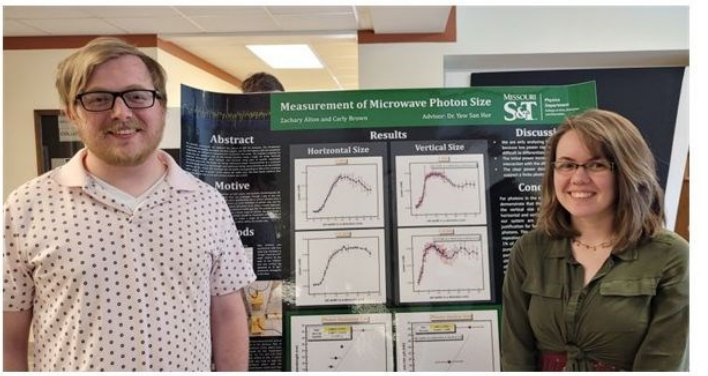
The Fuller Prize Competition for Undergraduate Research honors the memory of Dr. Harold Q. Fuller, former chair of the physics department.

1st place: Logan Sowadski
“Magnetic properties of diluted hexaferrites" (advisors Dr. Julia Medvedeva and Dr. Thomas Vojta).

2nd place: McGowan Toombs
“Influence of Momentum Spectrometer Resolution on Fully Differential Data of Atomic Collisions" (advisor Dr. Daniel Fischer).

3rd place: Carly Brown and **Zachary Alton**
"Measurement of Microwave Photon Size" (advisor Dr. Yew San Hor).





Physics majors win at S&T Undergraduate Research Conference

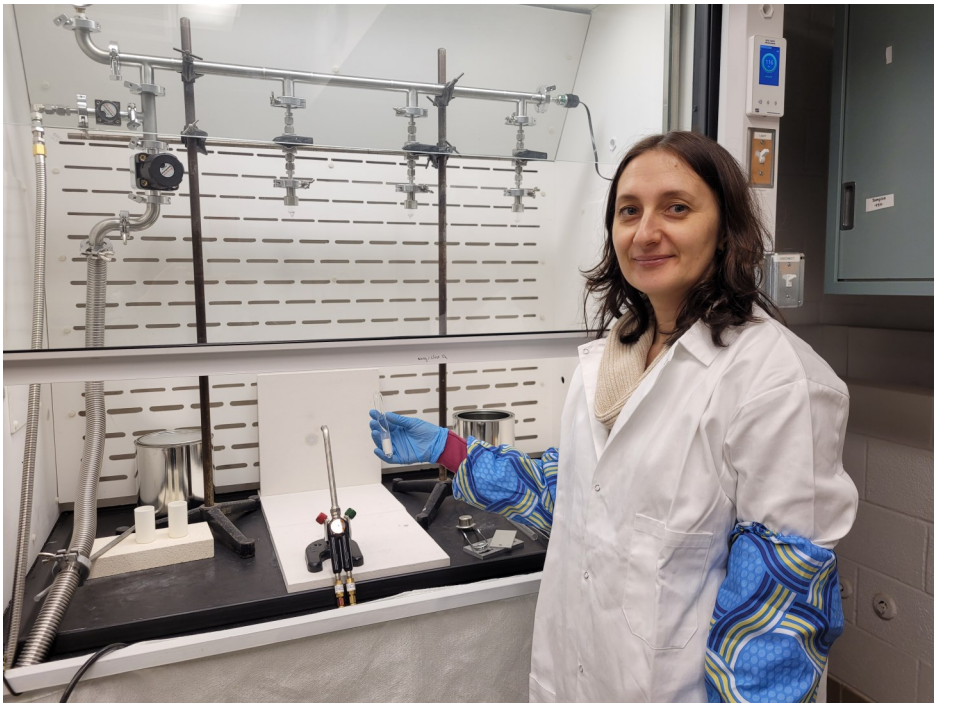
Eleven of our physics majors presented at the S&T Undergraduate Research Conference!

Zachary Alton and **Carly Brown** won a 2nd prize for their joint project "Measurement of Microwave Photon Size". **Samuel Schrader** won a 2nd prize for his work on Radon-Carbon Nanoparticle Design.

Steven Karst was awarded a prestigious OURE Fellow scholarship for his project "Enhancing Galaxy Surveys With Machine Learning.”

Kathryn Zychinski, a double major in physics and biology, won a 2nd prize for her biology research project.

FROM THE PERIODIC TABLE TO QUANTUM DEVICES



Dr. **Halyna Hodovanets** puts on her protective glasses and fires up the torch to seal the quartz ampule. The transparent tube contains two ceramic crucibles separated by a ceramic sieve that hold a mixture of different elements, with a "pinch" of the rare-earth element, in precise proportions. The sealed ampule with an Ar atmosphere will be placed in a furnace to be heated to 1200 °C and then slowly cooled over the course of several days or even weeks to above the melting temperature of one of the elements that is used in abundance and serves as a flux. When the furnace reaches this temperature, the crucible will contain single crystal and liquid flux. This liquid flux is then spun off when the ampule is placed in the centrifuge and the remaining few single crystals are used for research.

Hodovanets is a condensed matter experimentalist who grows high-quality single crystals and studies their physical properties. She is interested in creating and optimizing novel quantum materials whose properties can be tuned with chemical substitution, magnetic fields, or the application of pressure. One class of materials she investigates are Weyl semimetals which exhibit unique electronic behavior. Their electronic band structure gives rise to special Weyl nodes, locations in momentum space where the conduction and valence bands touch and form a gapless state. Weyl nodes exhibit chirality and occur in pairs, which leads to the creation of pairs of relativistic fermions with opposite chirality. The nontrivial momentum-space topology leads to various fascinating phenomena, such as the chiral magnetic effect and the anomalous Hall effect. Moreover, Weyl semimetals possess surface states with a special topology, which provide a means for quantum information transfer on the material's surface. These properties make them candidates for faster and more efficient electronics components, as well as for qubits in quantum computing.

Dr. Halyna Hodovanets is an assistant professor of physics. She won a major NSF award for her project "Design and discovery of new magnetic Weyl semimetals"

SCHEARER PRIZE 2023

Pablo Jara, Kevin Romans, Tuhin Das, and Shruti Majumdar

The Schearer Prize Competition for graduate research is held in memory of Laird D. Schearer, the department's first Curators' Professor of Physics, and rewards graduate students for outstanding research performed during the course of their graduate study.

First prizes: Pablo Jara "Simulation of coherent emission in planar disordered medium" (advisor: Dr. Alexey Yamilov)
and
Kevin Romans "A pump-probe experiment in cw mode on the ionization of Rydberg atoms" (advisor Dr. Daniel Fischer)

Second prize: Shruti Majumdar "Separation of PCI from non-PCI higher order effects in ionization of helium by proton impact" (advisor Dr. Michael Schulz)

Third Prize: Tuhin Das "Retardation effects in atom-wall interactions" (advisor Dr. Ulrich Jentschura)

From Schearer Prize winner Pablo Jara:

It is my honor to be among the winners of the 30th Schearer Prize competition. I would like to thank the Schearer family for making this competition possible. I am also very thankful to my advisor Dr. Alexey Yamilov who has continuously supported me throughout my PhD research. I would also like to thank the committee for give me the opportunity to present my work.

My research topic is related to light propagation through a disordered medium. Waves reflected off a scattering medium carry information that can be used for non-invasive imaging and sensing. In a slightly modified remission geometry, the recent progress in optical wavefront shaping has enabled us coherent control with an order-of-magnitude enhancement of the intensity of the remitted light. Our analysis reveals a significant improvement in the sensitivity of remitted waves to local changes of absorption deep inside diffusive media. Currently, my work is focused on the extension of remission into time domain.

From Schearer prize winner Kevin Romans:

I am grateful and relieved to have been tied for first place. I extend this gratitude to my advisor, Dr. Daniel Fischer, and my good friend, Dr. Ali Sarikhani, both of whom gave advice and time which proved invaluable towards preparing my talk. Last but not least, I am thankful to the S&T Physics department and Schearer family for organizing this wonderful opportunity for up-and-coming researchers to practice, compete, and hone our craft.

I presented my research on incorporating continuous wave lasers into atomic pump-probe ionization studies. The standard technique allows for the exquisite measurement of the final momentum distributions for both the resulting recoil-ions and corresponding photoelectrons after ionization, but it relies on the precise timing information gathered by the use of pulsed lasers. With a continuous wave optical dipole trap, we were able to reconstruct the momentum distributions by taking advantage of the coincidence measurements of each reaction pair's momenta and their conservation before and after ionization. This method yields the time of ionization for every event between each pulsed excitation, adding a true sense of "real-time probing".

ON THE HUNT FOR DARK ENERGY:

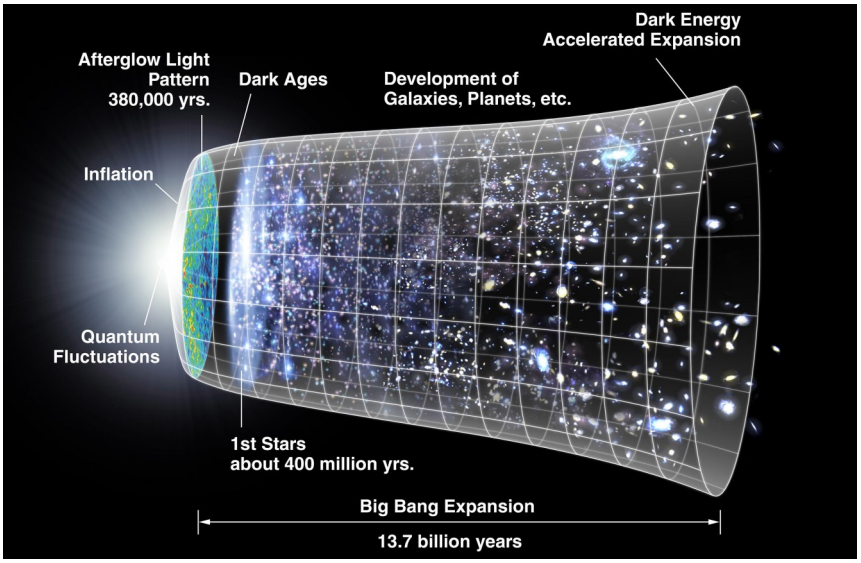
Mapping the Universe

Dark energy, the mysterious force behind the accelerating expansion of the universe, is one of the most intriguing questions of modern cosmology. Origin and nature of this "dark" energy are unknown, but it is thought to account for about 70% of the current energy budget in the Universe and to create a negative pressure which causes cosmic objects to move apart faster and faster.

Dr. **Shun Saito** is one of the scientists attempting to shed light on the nature of dark energy. He and his group are involved in several large galaxy survey projects. One of them is the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) at the University of Texas at Austin McDonald Observatory. HETDEX captures spectroscopic data on Lyman-alpha frequency light from hydrogen emission in distant galaxies. Emission of such light indicates that these galaxies contain star-forming regions. Using redshift to determine velocity and distance, the survey aims to map the locations of over one million galaxies that are 9 billion to 11 billion light-years away, representing a time when the universe was only 2 to 4 billion years old.

Saito is the chair of the Cosmology Scientific Working Group in HETDEX. He and his team are using simulations to predict clustering of these galaxies. Studying the evolution of such patterns throughout the history of the universe will lead to a better understanding of the accelerated expansion and hopefully yield clues to the nature of dark energy.

Saito's group has also been selected to join the Project Infrastructure team of the galaxy redshift survey for the Nancy Grace Roman Space Telescope, NASA's new $3.2B flagship space mission. The team will do valuable preparatory work for the launch that is planned for 2026. The hunt for dark energy is on!



A representation of the evolution of the universe over 13.77 billion years Credit: NASA/ WMAP Science Team

Dr. **Shun Saito**, assistant professor of physics, is an astrophysicist with an interest in cosmology and founder of the Midwest Cosmology Network. He is the recipient of a 2023 Faculty Research Award of Missouri S&T. He recently received two large grants from the Department of Energy and NASA, totaling over $1 million. His research papers have over 10,000 citations, yielding an h-index of 44.

One of Saito's papers was awarded the PASJ Excellent Paper Award 2023. This award is presented annually to authors of the most outstanding paper appearing in Publications of the Astronomical Society of Japan (PASJ).

Dr. Alexey Yamilov , professor of physics, is the author of a groundbreaking paper in Nature Physics.

A. Yamilov et al., "Anderson localization of electromagnetic waves in three dimensions," Nature Physics, Springer Nature, Jun 2023.

FROZEN LIGHT:

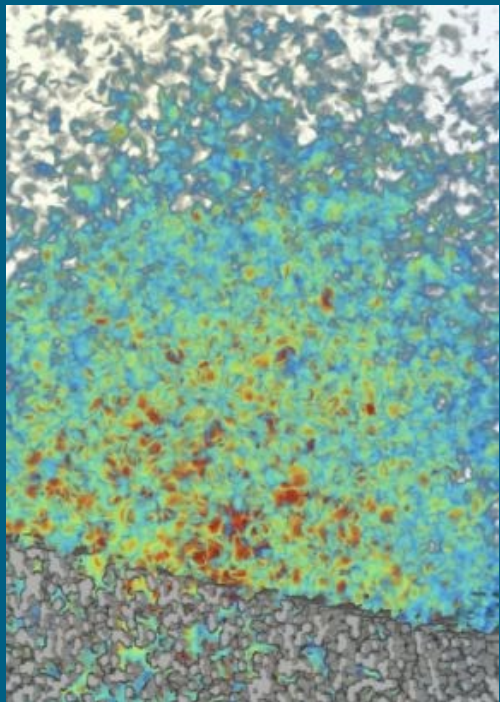
Forty-year search for Anderson localization of light at last yields results

In 1958, the renowned condensed matter physicist Phillip W. Anderson published a seminal paper suggesting that waves propagating in strongly scattering systems may become trapped. The intriguing aspect of this prediction was that the phenomenon, which became known as Anderson localization, occurs due to persistent interference of the waves that undergo an otherwise random-walk-like process – diffusion.

Following experimental observations of electron localization in the 1970's, Anderson received the Nobel prize in 1977. Since then, localization of other kinds of waves, such as sound and cold-atom matter waves, has been observed. However, repeated attempts to detect Anderson localization of electromagnetic waves, i.e. light, had been unsuccessful until this year.

To unambiguously prove the existence of light localization, Dr. **Alexey Yamilov** and his colleagues teamed up with the startup company Flex-Compute. The company, spun out of Stanford, developed a breakthrough implementation of the finite-difference time domain (FDTD) simulation, hardware-optimized for computer chips used for machine learning. Armed with a computational tool that could perform a staggering 15 petaflop, i.e. 10^{15} floating-point operations in a matter of minutes, Yamilov was able to obtain the long-sought proof of light localization by the direct brute-force solution of the Maxwell equations.

Yamilov's article, published in the September 2023 issue of Nature Physics magazine, reports that systems made of dielectric particles, favored by the experimentalists for years, are unlikely to harbor the localization. Instead, it is suggested that future experiments should focus on disordered metallic systems. And the race is on again!



The cover image in of the newsletter shows a numerical simulation of 'frozen light' - the spreading of electromagnetic waves in the disordered system is halted in its track via the phenomenon of Anderson localization. This long-hypothesized behavior of light is being convincingly demonstrated for the first time after a 40-year search.

CONGRATULATIONS TO OUR 2023 GRADUATES

Bachelor of Science in Physics:

Spring 2023: McGowan Toombs, Matthew Miller, Logan Sowadski, Reece Beattie-Hauser, and Dillon McNamara .

Fall 2023: Carly Brown, Jason Thurow, Erin Brady, Ellie Decker, Jacob Thiel, Zachary Szatkowski

PhD in Physics:

Ali Sarikhani, Kevin Romans, Yanyan Zheng, Yungcheng Qui, Younas Khan (not pictured)

HONORARY DEGREE AWARDED TO RON EPPS, BS'67

Ron Epps, retired chief of the NASA flight design and dynamics division and a Missouri University of Science and Technology graduate (BS in physics 1967), was awarded the doctor of physics, honoris causa. Epps began his 38-year career with NASA at Johnson Space Center as an aerospace technologist with the landing and recovery division, serving as a technical advisor to the U.S. Navy. Assigned to recovery ships for Apollo 8, 9 and 14, he was deployed all over the world to recover spacecraft returning from the moon and to cover unplanned landings following system failures.

Chancellor Mo Dehghani, Ron Epps, Provost Colin Potts.
Photo credit: Michael Pierce, Missouri S&T

After *Apollo 14*, Epps spent 12 years as a flight dynamics officer in Mission Control. He was involved in the two final Apollo flights, the launch of *Skylab*, the docking of the Apollo spacecraft with the Russian Soyuz capsule, and the first nine space shuttle flights. He then spent three years training astronauts for shuttle ascent and entry. He finished his career at NASA as chief of the Flight Design and Dynamics Division, having overseen 35 space shuttle missions.

ALUMNUS PROFILE: KUL BHASIN

It is always a pleasure to welcome our alumni back on campus and find out what happened in their lives. The 2023 homecoming speaker was Dr. **Kul Bhasin**, founder and CEO of Comsat Architects, who earned his PhD in 1976. He gave an engaging talk with the title "A physicists journey through the ever-changing world of high technology."

Kul Bhasin founded Comsat Architects after decades of work in space communications at NASA Glenn Research Center. Comsat Architects' mission is to enhance connectivity for spacecraft in various Earth orbits and lunar assets to ensure rapid, robust, reliable delivery of data to Earth, serving the aerospace industry, NASA and the DoD. This is just one example for the wonderful diversity of our alumni's career paths. We'd love to hear about yours!

FROZEN FRONTIERS OF QUANTUM MATERIALS RESEARCH:

Ultra-Low Temperature Lab Pushes Boundaries

Quantum computers process information using quantum bits, or qubits. These qubits are based on short-lived quantum states and keeping them coherent for a sufficiently long time without errors is a significant challenge.

One class of materials that promises more stable qubits are topological superconductors. Those are materials that exhibit both superconducting behavior, i.e. zero resistance to electric current below a critical temperature, and a non-trivial topology of their quantum wave functions. In such materials, unique states arise that can host exotic particles called Majorana fermions. These particles are their own anti-particles, and their quantum states are less susceptible to decoherence from local perturbations, which allows for more reliable storage of quantum information.

Topological superconductors usually have very low critical temperatures, and their intrinsic properties become most apparent near absolute zero. Dr. **Hyunsoo Kim** studies the physical properties of these quantum materials in his ultra-low temperature lab. The central piece of equipment of the lab is a dilution refrigerator which can create temperatures lower than 10 mK. Kim can conduct experiments under high pressure of up to 3 GPa and a high magnetic field of up to 12 T. These unique experimental techniques allow high-precision measurements of magnetic properties with a spatial resolution on the near-atomic scale.

Topological superconductors are just one example for emergent quantum phenomena that occur in solid states when intricate many-body interactions bring about exotic electronic ground states. Another field Kim is investigating is the superconducting tunneling effect known as the Josephson effect. When two superconductors are separated by an insulating barrier, a supercurrent of Cooper pairs flows through the barrier. The current depends on the phase difference between the two superconductor wave functions. This effect has important applications in quantum computing. Kim's experimental techniques enable him to determine the symmetry of the interaction of the Cooper pairs. Understanding these mechanisms will be an instrumental step in developing materials for next-generation information technology.

Dr. Hyunsoo Kim, assistant professor of physics, operates the ultra-low temperature lab.

This dilution fridge can achieve temperatures below 10 mK.

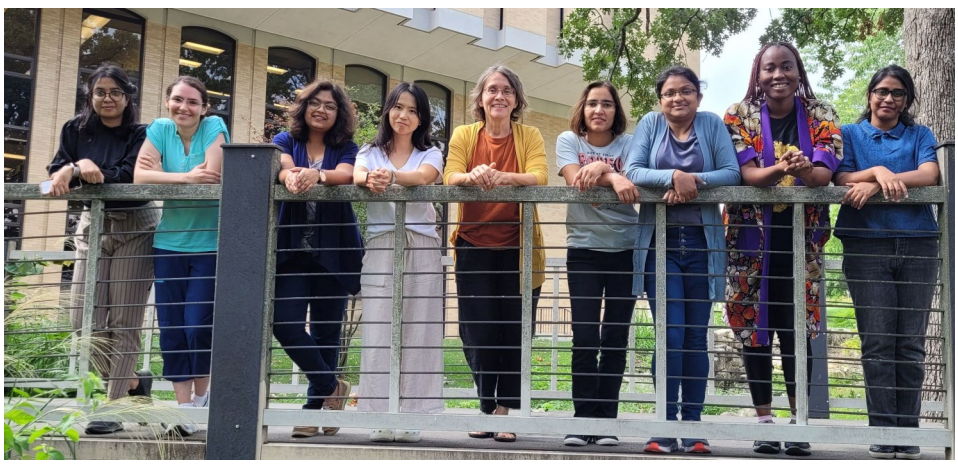
THERE'S MORE THAN JUST CLASSES

Our departmental student organizations had a productive year!

The **Society of Physics Students (SPS)** enjoyed an influx of new members as several first-year students joined. The weekly pizza nights with guest speakers are as popular as ever, and the SPS room on the second floor is a great place to hang out between classes and work on the homework. Over fall break, the SPS took a trip to Chicago to visit Argonne National Lab.

Students with a special interest in astronomy come together in the **S&T Astronomical Research Society (STARS).** Over the course of the year, they hosted twelve viewing nights at the campus observatory. Free and open to the public, these events give the community a unique opportunity to view celestial objects. They publicize their events on their Facebook page https://www.facebook.com/STARSMissouriST

The **Women in Physics (WiP)** group had a busy semester preparing for the APS Conference for Undergraduate Women in Physics (CUWiP). The CUWiP takes place in January 2024 and is held at fifteen different sites throughout the country. Our department will host over one hundred physics students from the Midwest.



We are grateful for the support of these alumni and friends in 2023:

CORPORATE:

Baker Hughes Foundation
Boeing Company

$1,000 - $2499

Charlotte A. Bhasin
Kul Bhasin
Thomas K. Gaylord
Timothy H. Kaiser
Gary S. Kovener
Kevin Moll
Amy Morriss
Casey Morriss
Charles W. Myles
Agnes and Thomas Vojta

$500 - $999

Theresa Kajs
Shella Dawn Keilholz
Nathaniel D McClure, IV
Nancy Stepp
Richard D Thom
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Daniel N. Payton, III, PhD
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Donnie W. Priest
Frederick H.K. Rambow

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Robert T Smith, PhD
Terrence R Ward
David J Wolters

$100-$250

Robert E Caldwell
James P Canner, PhD
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Christopher John Wood
F. Matthew Woodward
Gary K Woodward
Choon Bee Zahn

Under $100

Derek Murphy Anderson
Gary D Bickel
Melva Darlene Crocker
Mary Ruth Hershey
Jerry G Johnson, PhD
John Daniel Jones, PhD
William A Lindgren
Havva Malone
Mark Allen Peckham
Nancy L Ranek
Morgan P Slusher
Charles Gerald Williams

MAKING PHYSICS FUN

Joel Peacher and **Mathew Pollard** are the recipients of the physics department's inaugural Outreach Award. The award recognizes outstanding contributions to outreach activities that promote physics to children, S&T students, and the general public. Joel and Mat performed numerous liquid nitrogen demonstrations for school groups, organized STEM summer camps, assisted with the regional Science Olympiad, and hosted other events on and off campus. Their enthusiasm and dedication made physics exciting and inspired a new generation of scientists.

Many other department members are involved in STEM events on campus and across the region which are instrumental for recruiting future students and explaining our research to the public. Dr. Saito's cosmology group and Dr. Cavaglia's LIGO group offered visitors a chance to talk about dark energy and black holes at the Missouri State Fair in Sedalia and the Astronomy Festival and Sci Fest in St. Louis. At *Expanding Your Horizons*, hosted by the S&T Kummer Center for STEM, Dr. Yamilov and a group of physics graduate students led middle-school children in conducting an experiment on light attenuation (pictured). Prospective students and their families can see superconductivity and lasers in action during their tours of Dr. Kim's low-temperature lab and Dr. Fischer's laser lab. What better way to get them excited about physics?

(Photo credit: Michael Pierce)

MISSOURI S&T

Physics Department
102 Physics
1315 N Pine Street
Rolla, MO 65409—0640

Keep in touch!

Drop us an email at **physics@mst.edu,** visit the campus when you are in town, or plan a special trip for Homecoming 2024. We would love to show you what we have accomplished

Tell us what you're doing with your physics degree, and what you've been up to since you left Rolla. We love to hear from our graduates!

You can follow us on facebook at **SandTPhysics** or on LinkedIn at

https://www.linkedin.com/company/missouri-s-t-physics/

Our website is **physics.mst.edu**