PHYSICS NEWSLETTER

UMassAmherst
DEPARTMENT OF PHYSICS
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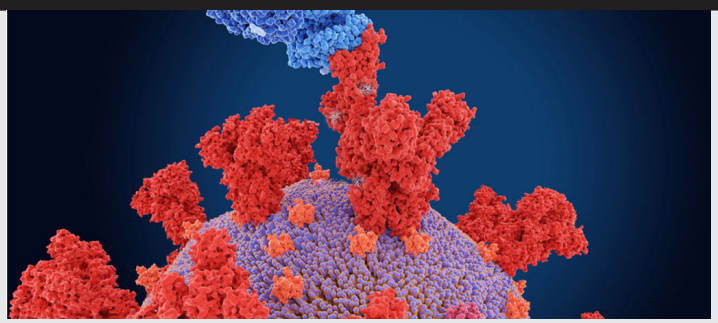
FACULTY / STUDENT SCIENCE COMMUNICATION DURING COVID SEQUESTERING



Corona virus variant B.1.1.7, which was the most prevalent in the US in early 2021.

Changes in how we communicate in teaching, research, and service, are likely to be a lasting effect of the pandemic.

As in most of the world, face-to-face communication at UMass moved almost overnight to online last spring via Zoom, a cloud-based video conferencing service that facilitates "synchronous" interactions. From classes, research, and advising, to game nights and the Newsletter committee, nearly all meetings have been held over Zoom. Zoom can be run on any device or through a web browser, and the University IT department offers recurring modules, individual support for Zoom, and a constant monitor for emerging security issues.

For "asynchronous" communication, many at UMass make use of Slack, and learning management systems like Moodle or Blackboard, in addition to email. Slack® provides users with an easy way to keep track of different courses or topics. Students and/or faculty and work collaboratively in a "channel-based" messaging platform to solve problems or keep track of material relevant to a recitation section or lab. Blackboard® (also called Blackboard Learn® or Bb) and Moodle are online learning management system for students to access course materials asynchronously anywhere they have an internet connection. For storing and sharing documents on the cloud, the University has also provided Box, Google Drive, and OneDrive.

Skype®, another synchronous communication application that is preferred by some in the USA, also has a niche at UMass, but Skype calls are limited to 50 users. Launched in 2003 and acquired by Microsoft® in 2011, Skype will terminate its business use in July 2021, replaced by Microsoft Teams®.

COVID AND THE PHYSICS DEPARTMENT

WE HAVE ALL BECOME MASTERS OF ZOOM

The COVID-19 pandemic has impacted all aspects of life and work in the Physics Department. Faculty, especially those teaching lab courses, scrambled to adapt courses to operate in a remote setting (see P.26: Teaching Labs Remotely). Research labs adjusted to a reduced density of socially distanced workers. Faculty and staff, many now with young children at home rather than school,

Ben Heidenreich teaching remotely

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EDITORS

BEN BRAU
bbrau@physics.umass.edu

DON CANDELA
candela@physics.umass.edu

IRENE DOJOVNE
dujovne@physics.umass.edu

LORI GOLDNER
lgoldner@physics.umass.edu

BARRY HOLSTEIN
holstein@physics.umass.edu

DAVID KASTOR
kastor@physics.umass.edu

MARGARET E. MCCARTHY
mem@umass.edu

MONROE RABIN
rabin@physics.umass.edu

JUN YAN
rabin@physics.umass.edu

CAITLIN DRISCOLL, DESIGNER
ctlndrscll20@gmail.com

DEPARTMENT OF PHYSICS
1126 Lederle Graduate Research Tower
University of Massachusetts Amherst
Amherst, MA 01003-9337
www.physics.umass.edu

Dear alumni and friends of UMass Physics:

The year since the last newsletter has been uniquely tumultuous for all of us. All of us have experienced the stresses and uncertainties of the pandemic, along with the major upwellings of political debate and activism around the agitations for racial equity and a fraught, contentious, election season. As we look out to other parts of the nation and the world, UMass and its environs have been relatively healthy. And yet, our lives on and off campus have been complicated to varying degrees and in varying ways: our staff have been hit with the stresses of the campus financial situation, colleagues with young children have been stretched thin with home-schooling and lack of daycare (as have others with health care responsibilities at home), and students have been restricted from travel to their homes, and isolated from their peers and co-workers.

With that said, all parts of the department community have responded with remarkable resilience to the challenges of the pandemic regimen and kept advancing our instructional and research missions. Our administrative staff have had to learn to migrate their work from paper, telephone, and in-person conversations, to shared electronic repositories and email. Remote teaching has been a major adjustment for students, instructors and teaching assistants, and we have all had to scramble to learn new tricks with technology, and new ways to maintain student engagement. Laboratory classes, for example, have been completely overhauled, with the department mailing out hundreds of kits for students in spring, summer, and fall of 2020, and winter and spring of 2021. Assembling, cleaning, repairing and restocking kits in the brief intervals between academic sessions became a major logistical operation. As another example, evaluation and assessment of students taking exams from home also had to be rethought, with our department largely deciding against more intrusive forms of electronic proctoring.

On the research front, experimental activity resumed in the summer of 2020, with laboratory scientists testing weekly, following enhanced cleaning protocols, and arranging work schedules to maintain a low density occupation of our spaces. All of our theory and experimental research groups took individual and group meetings to a remote format. Some of our colleagues also contributed their scientific expertise to the public health effort: Andrea Pocar joined a collaboration with

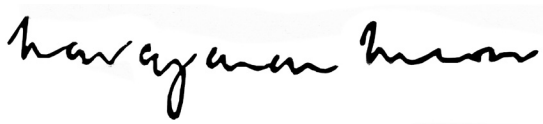
other neutrino physicists to design and build new ventilators; our newest faculty colleague, Varghese Mathai, an expert in fluid mechanics who arrived at UMass right in the middle of the pandemic, turned his experience to modelling high-Reynolds number flows in automobiles to minimize air-borne transmission of the disease.

Other research achievements also continued to be recognized: for example, Chen Wang and Romain Vasseur received prestigious young investigator awards from the DOE and the AFOSR respectively. Our machinist and tool-maker, Walter Pollard, was recognized with a College Outstanding Staff award for his expertise in supporting the research mission. Many of our senior colleagues were also recognized with leadership roles by their research community: Stephane Willocq served as the Physics Coordinator of the giant ATLAS collaboration at CERN in Geneva, and Jennie Traschen and Krishna Kumar served in the Chair lines of the American Physical Society's Divisions of Gravitational Physics and Nuclear Physics, respectively. Bob Hallock, a leader of long-standing in the university, the department, the classroom, and in his own field of low-temperature physics, retired at the end of last academic year after an exceptional fifty years of service as a faculty member in our department. Bob will continue to be associated with the department for some years to come in a post-retirement teaching role.

Though we've all missed the collegial contact of the scientific process, there have been some surprising benefits of our migration online – our seminars and colloquia have featured speakers from all over the world, at times dialing in from late-night time zones. Workshops hosted by the ACFI also went online, and the online version of our annual Soft Matter physics summer school had the largest group of students we've ever entertained. Several students finished the PhD degree in this period, and their online thesis defenses had a personal touch that we rarely

have, as families and friends in distant places were able to connect and participate in this most happy event at the end of the long road to a PhD. We're looking forward to retaining some of these practices in the future.

In my view, there's light at the end of the tunnel. All signs point to the department rebounding to vigorous health in short order. The university is in reasonable financial health, and it is to the credit of the faculty, grads and staff contributing to our instruction, mentoring, and advising efforts, that undergraduate enrollments have held steady. Our students have been understanding of the circumstances through this time of diminished contact, and our goal is to repay that patience as soon as we get back to normalcy. We only have one in-person physics class this semester but are hopeful of renewing contact and reviving the robust daily life in the classroom and the lab in the Fall of 2021.
Good health to you in these trying times! Please do keep in touch with us if you are an alumnus or in any other way connected to our department family. If we have learned anything in this last year, it is a renewed appreciation of the value of these human connections.



COVID AND THE PHYSICS DEPARTMENT

WE HAVE ALL BECOME MASTERS OF ZOOM CONT.

struggled to balance their time. Students now spread over many time zones, some in situations not conducive to academic pursuits, had to deal with isolation from their peers and the demands of the pandemic.

TEACHING

In March 2020, UMass announced that students would not be returning to campus after spring break. Faculty had two weeks' notice to re-tool their classes for remote meetings. For those teaching lecture courses, the actual class meetings were relatively straightforward. For large classes taught using PowerPoint slides, one could just share that window in Zoom. For chalk lectures, some faculty setup blackboards at home, while others made use of various types of tablets to simulate being in the lecture hall. There were some upsides, particularly because Zoom makes recording lectures easy. Many students appreciated being able to view or re-view lectures "asynchronously," particularly when technology or the demands of the pandemic made attending a "synchronous" lecture difficult.

Administering exams created some difficulties, especially for large classes. Although the large majority of students is honest, significant minorities in some of these classes will cheat if given the opportunity. Commercial services exist for proctoring remote exams, checking in on students through their webcams, but are prohibitively expensive and controversial. Instructors of these courses made use of software that randomly changes numbers in the questions and answers, so that each student gets an individually tailored exam. Combined with a definite time limit between start and finish provided a significant (though by no means 100% effective) barrier to cheating.

Smaller, physics major courses typically went with take-home style exams (typically open book, but not open internet) that students worked on when it best fit their schedules.

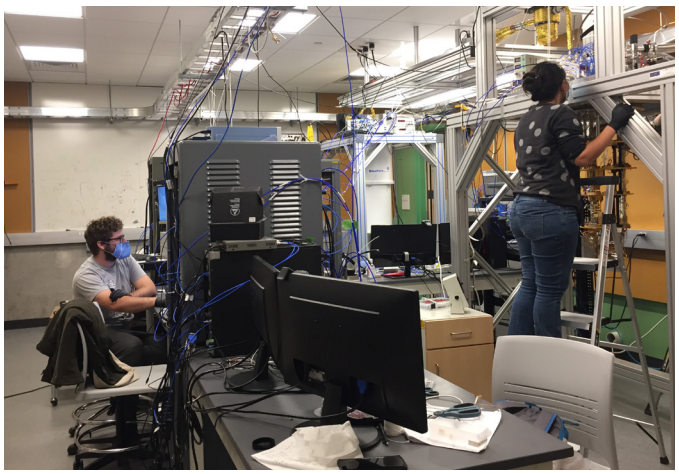
Prof. Jenny Traschen teaching remotely

Some students appreciated this flexibility, as well as the lower pressure compared to typical closed book, evening exams. Faculty worked to restrain themselves against the tendency to make take-home exams more difficult.

Faculty teaching lab courses faced the most significant challenges. For large introductory courses, one could either devise labs that could be done with common household items, or ship out equipment to large numbers of students. Both strategies were used. Department staff mailed equipment out to many students. Faculty got creative. Later on, for the Fall 2020 semester, with classes still online, students ordered lab kits directly from commercial vendors for some of the large service classes, while other classes made use of at home items and apps that can capture physically relevant data from the sensors on a student's cell phone. More advanced physics major lab courses posed the biggest challenges. In Spring 2020, quick adaptations were made. For example, students in the sophomore lab course took data using a remote-controlled Millikan oil drop experiment physically located in Germany. Meanwhile, iLab instructors had students working primarily with data from numerical simulations. With more time to prepare for the Fall 2020 semester, faculty were busy over the summer creating specialized kits for many labs that could be mailed out to students. For lower- level labs, these were based on an iOLab device. For iLab and the electronics course, kits were based on a powerful multi-function device including an oscilloscope, logic analyzer and variable power supply. Many of these innovations have been highly successful and may, in fact, be here to stay.

RESEARCH

For theorists in the Physics Department, research life could go on more or less unchanged by the pandemic. Theorists are used to communicating with collaborators who may be spread throughout the world. Meetings with graduate students and postdocs were moved to Zoom. Seminar series too have moved to Zoom, with the benefit that speakers can now be invited from much farther afield without breaking limited budgets for travel expenses. Theorists miss the direct day-to-day interactions of campus life, but generally get by fine.



The lab of Chen Wang under COVID restrictions

For lab-based researchers, the experience has been very different. Most labs were closed in the initial response to the pandemic. Lab activity was allowed only to the extent "necessary to avoid a catastrophic loss of research results, materials, or infrastructure." Faculty, postdocs and graduate students spent time analyzing data, writing up results of completed work for publication, and planning for when labs could reopen. Beginning in June 2020, faculty were allowed to submit and get approval for a Research Laboratory Opening Plan (RLOP) that detailed plans for social distancing and staggered work schedules for lab personnel. As the months progressed, laboratories were allowed to slowly increase the density of students in the lab. But life in the lab is still not back to normal.

Some faculty reoriented their work, at least in part, to address issues related to the pandemic. Andrea Pocar, an experimentalist focused on dark matter searches and neutrino physics, worked with a team of collaborators to design a new mechanical ventilator (see accompanying

article on P.16). Varghese Mathai, new faculty member in soft matter experiment, worked with collaborators to model air flow within cars with the goal of making carpooling safer (see accompanying article on P.20: Riding in a Car in the Pandemic).

The exchange of results and ideas through seminars and colloquia are part of the lifeblood of the physics community. Although we can't physically gather for these in the COVID-19 era, there have nonetheless been some benefits. No longer limited by travel expenses nor time commitments, we are able to invite high caliber speakers from much further afield than in normal years. Talks from colleagues in e.g., China, Japan, Australia, Austria and diverse other countries have now become a common phenomenon. Incorporating some remote seminars in our schedule may be another thing that is here to stay.

There has been a similar effect with physics conferences. The 2020 APS March meeting, which attracts thousands of condensed matter physicists, was cancelled with only a one-day notice. Some speakers did spontaneously organize to carry on parts of the meeting remotely in an informal way. However, the April meeting, focused on particle physics, gravity and astrophysics, went ahead as a fully remote meeting and attracted many more participants than ever. For faculty, this saves on both expenses and disruption to teaching schedules. Allowing for remote participation in meetings is another thing that is most likely here to stay.

STAFF AND ADMINISTRATION

One of the biggest struggles for physics administrative staff has been the leap to being fully electronic with our systems and processing. Prior to the shutdown, only a couple of the Staff utilized laptops in their daily tasks; by far the majority of the work was on desktops with close access to a printer/copier/scanner on an internal department network with shared administrative information files. Many tasks involved paper and actual wet signatures. Once we went off campus, all that became inaccessible. Our IT staff very quickly located laptops, found a safe way to deliver them, set up a remote file system in Box (an American internet company with cloud content management and file sharing service for businesses), transferred the shared files and did lots of troubleshooting and training on an individual basis. There were challenges finding spaces within our homes for productive work locations, including limited space, internet access, or tiny screens and keyboards. Staff have pulled together and worked with campus contacts to solve technological quirks and then share their knowledge department-wide.

Over the past year, UMass has continued to roll out new administrative processing systems and procedures. This has been one of the greatest challenges for the admin staff, because on top of figuring out the best way to utilize paperless systems for approvals and information management, entire established procedures for submitting information and documentation into UMass programs have been altered with little testing or training.

Mandated staff furloughs hit individuals hard and created disruption in the department's workflow. Worse yet, some staff claiming unemployment compensation for furloughed time, faced stolen identities and months of delay in receiving benefits. The Physics Faculty did their best to help, donating financially for staff support and gracefully accepting inevitable delays that furloughs created. Still, the lack of face-to-face interactions only increased the sense of isolation and wish for a return to some normalcy.

COMMENCEMENT 2020

Graduation in May 2020 was a major disappointment. The Department traditionally

hosts an event on commencement day where faculty get a chance to talk with graduating students and their families. After all the time we spend on lectures and labs and exams, this is something we really enjoy, but it obviously couldn't happen this time around. As a substitute, faculty created visual or audio congratulatory tributes to students. The highlight was a very fine and touching accordion rendition of "Pomp and Circumstances" by Lori Goldner (https://youtu.be/WtjiNG9HbNc). With a year of remote events now under our belts, we should now be able to pull off some form of virtual meet-and-greet for Commencement 2021.

Prof. Lori Goldner on the accordion

COVID ISOLATION

Our physical isolation from one another in this period has been another huge challenge. Some faculty (particularly younger ones) have created Slack channels for their classes, or other means to facilitate students interacting with one another remotely. [A Slack channel is a dedicated online space by invitation only for work collaboration, www.slack.com.] These can be great, but can't entirely replace the shared experience and camaraderie of actually working together on e.g., difficult problem sets in the same place (often late at night).

To close this piece, we share some undergraduate physics major and faculty comments on this subject of learning in isolation.

Undergraduate Physics Major

> "Grades-wise, OK. Mental health-wise, pretty destructive. Maybe it's isolation, maybe it's the stress. Probably both."

Undergraduate Physics Major

> "Because of remote learning, I 100% struggle to focus on physics. This is because I'm not immersed in it. None of my friends or house-mates are physics majors. If I were to close my computer, there is nothing 'physics' in the world around me. No other physics students, no teachers, no cool lab classrooms, no buildings. Physics feels even more distant from reality. This makes the subject extremely hard to take seriously and find relevance for. I've asked myself more this semester than any semester previously, "why am I doing this?". With remote learning there is that constant feeling that the stressful academic world can be simply shut out by closing the computer. My point is; remote learning has made the academic world seem impossibly irrelevant to my everyday life. Imagine how hard it is to bring myself to consistently apply myself to physics. Yet I have to keep doing it. Remote learning is teaching us lessons the hard way."

Undergraduate Physics Major

> "Remote learning has certainly been interesting, to say the least. I've still been enjoying my classes, but it's incredibly different to be learning things remotely. I've at least been fortunate enough to be able to keep my grades up and learn the material, because I've heard from a good number of my friends that this situation has made those things difficult for them. I've been able to save money on my college bills, which is nice at least. Still though, I wish I could go back. I only get to see people on a screen and I stay up in my bedroom all day (we converted it into an office by putting a big

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desk in the middle of it). I don't get nearly enough exercise anymore, and I feel like I have so much work (during the semester at least) that I barely have time to breathe, let alone cope with life right now. So, in short, I can learn remotely, but the lifestyle that it has come with has been tough to deal with."

Undergraduate Physics Major

"I think that one thing that makes learning physics fun and understandable is doing it with others. That human connection of helping each other out and struggling with problems helps people to understand the topic more completely and profoundly. This obviously has been a causality of COVID and as a result has made learning physics more difficult and less gratifying."

Faculty member

"Logistically, remote teaching went, I think fairly well for me. However, I was not fully prepared for the depth and breadth of challenges faced by my students. Their determination to keep working under, in some cases very adverse, circumstances was both inspiring and heartbreaking.

Faculty member

"Two students graduated with their PhDs and it was hard for all of us not to have the normal kinds of interactions and celebrations. A plus side is that screen-sharing on zoom is very effective for research meetings. The spring-time focus on data analysis was also helpful for many of us."

RESEARCH

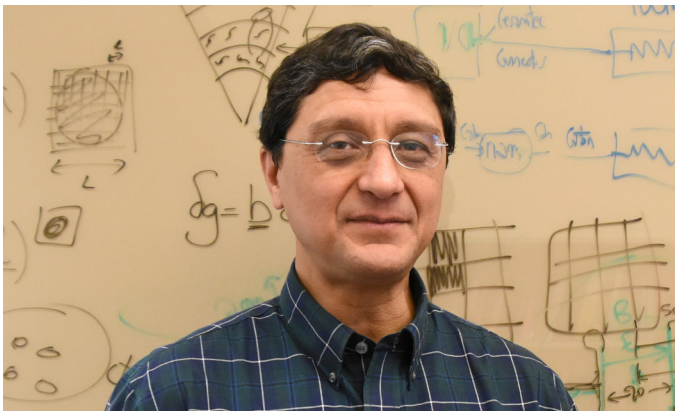
MUON G-2 MEASUREMENT

g_μ-2 Collaboration Announces Results

Recently the first results from the long awaited g_μ-2 experiment were announced by an international collaboration which included UMass Professor Dave Kawall's group. In order to understand what is measured here, it is important to recall that the electromagnetic interactions of any spin ½ particle like the proton or electron is characterized not just by the charge q, but also by the magnetic moment μ, which is a vector quantity in the direction of the spin which, in the presence of a magnetic field, changes the energy by amount $\Delta U = -\boldsymbol{\mu}\cdot\mathbf{B}$. In addition, there exists a torque on the magnetic moment $\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B}$. The size of the magnetic moment is defined in terms of a natural unit called the Bohr magneton $\mu_B = q/2m$ via

$$\boldsymbol{\mu} = 2g\mu_B\mathbf{S}$$

where **S** is the spin, and g is called the g-factor. According to Dirac's theory of a spin ½ system, the g-factor should be 2 for an elementary system like the electron but can (and does) differ from 2 for a particle like the proton which has internal structure. Even for a point particle like the electron there exist, however, tiny corrections to the g-factor on account of interactions with virtual photons which appear and disappear into the vacuum. The result of these quantum vacuum effects has been (heroically) calculated by UMass Adjunct Professor Tom Kinoshita to be

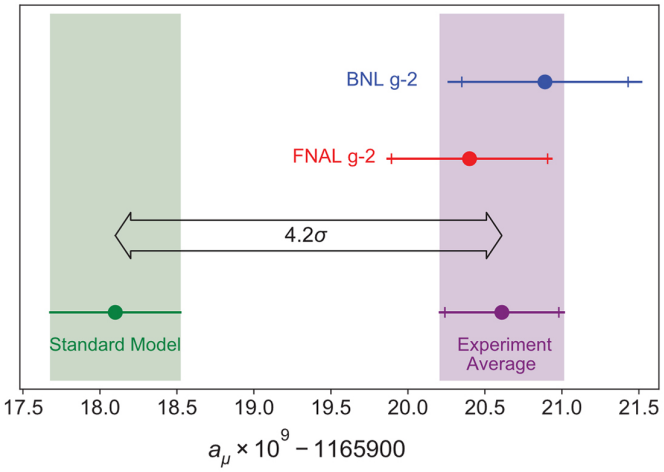


Dave Kawall

$1/2(g_e\text{-}2(\text{theory})=1.165847188.41(40)\times10^{-3}$
and compares spectacularly well with the experimental finding
$1/2(g_e\text{-}2)(\text{experiment})=1.16592089(63)\times10^{-3}$

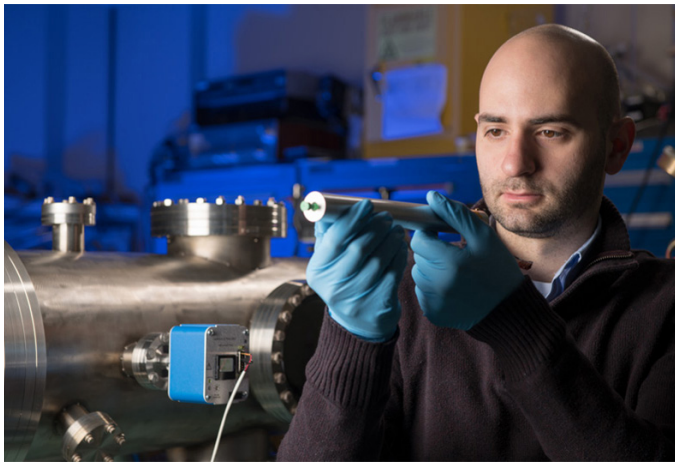
The way that the experimental result is obtained is to place a moving electron in a transverse uniform magnetic field, whereby it travels in a circle of radius $r=mv/qB$ with rotational frequency $\omega_R=qB/m$. At the same time, torque causes the magnetic moment to precess around the magnetic field direction with the Larmor frequency $\omega_L=\mu B=2Sg\mu_B B$. If $g=2$, we see that the Larmor frequency ω_L is equal to the rotation frequency ω_R, so that after one complete orbit (or many complete orbits) the spin direction is unchanged. On the other hand, if g is not equal to its Dirac value, then after n orbits, the spin direction will be changed by angle $\Delta\varphi(n)=2\pi n(\omega_L-\omega_R)=n(g-2)\mu_B B$, which is directly sensitive to g-2. Thus, even if g-2 is very small, as is the case here, after many orbits it becomes measurable. In this way the quantity g_e-2 has been determined and agrees with the tour de force (five loop) theoretical calculation.

The muon is heavier than the electron ($m_\mu\approx207m_e$) and is unstable, with a lifetime of about 2 μsec, but is in most other regards just a heavy version of the electron. Kinoshita's theoretical calculation can be straightforwardly extended to the muon, yielding the prediction
$1/2(g_\mu\text{-}2)\ (\text{theory})=1.16591810(43)\times10^{-3}$
and the challenge becomes to perform a precision experiment using a muon rotating in a uniform magnetic field. This measurement was performed a number of years ago at Brookhaven National Laboratory (BNL) and showed a small (3σ) deviation from the standard model (Kinoshita) prediction. In order to see whether this disagreement was due to some small experimental imperfection, a large international collaboration was assembled, including Prof. Kawall's group, to redo this experiment with higher precision at Fermilab (FNAL). The first challenge was to move the very large magnet from BNL to FNAL, and once this goal had been achieved,



Measurement of the Positive Muon Anomalous Magnetic Moment to 0.46 ppm

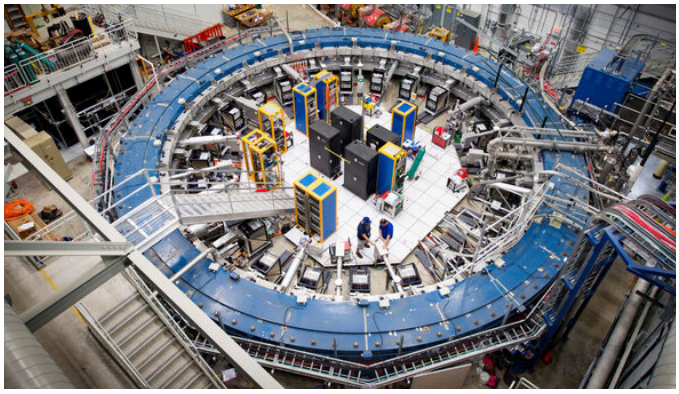
it was important to upgrade many aspects of the previous work, including the size and uniformity of the magnetic field, and this is where the primary UMass contribution came in. Kawall's group, which included postdocs David Flay and Jimin George, graduate student David Kessler, and undergrad Alysea Kim, worked on measuring the strength of the field through which the muons passed, as well as preparing the magnet itself, a feat requiring almost unimaginable precision.



David Flay examines the Muon g-2 plunging probe installation

"One of the innovations we were responsible for," says Kawall, "was developing a system

involving 8000 sheets of laser-cut iron foil to make the magnetic field as homogeneous as possible. With our system, we were able to achieve results nearly three times better than the previous experiment."



Muon g-2 ring and magnet at FNAL

The team also spent years developing special calibration probes of incredible fidelity, precise to 15 parts per billion. Together with improvements provided by other members of the collaboration, the experiment had a successful first run at Fermilab and determined $1/2(g_\mu-2)$ (experiment-1)=$1.16592040(54)\times10^{-3}$ which was published in a recent volume of *Physical Review Letters*. While this number will no doubt be refined by additional running, it is already precise enough, when combined statistically with the BNL result to indicate a 4.2σ deviation from the standard model prediction, raising the distinct possibility of a contribution from currently unknown ("new") physics. Their experimental findings received considerable press coverage, including a lengthy *New York Times* piece.

NEUTRON SKINS AND NEUTRON STARS

As is evident in the periodic table of the elements, lighter nuclei tend to have equal numbers of protons and neutrons. But as nuclei get heavier, nuclear stability requires an excess of neutrons: the attractive strong nuclear force must offset the increasingly larger electromagnetic repulsion among protons. For example, the most abundant and stable Lead isotope, ^{208}Pb, contains 82 protons and neutrons and 44 excess neutrons. The strong nuclear force is predominantly symmetric with respect to protons and neutrons; one might naively guess that the protons and neutrons, though unequal in number, occupy the same volume in a nucleus. Perhaps electromagnetic repulsion might push protons slightly farther apart.

Remarkably, it has been surmised over many decades of research that neutrons bulge out beyond protons in a heavy nucleus, generating a neutron "skin". But why? By how much do neutrons stick out? Why does it matter? How does one measure the skin thickness? In this article, we discuss these questions, motivated by a new and precise measurement of the neutron skin of ^{208}Pb (The Pb Radius Experiment: PREX), just submitted to *Physical Review Letters* [https://arxiv.org/abs/2102.10767] by an international nuclear physics collaboration, with members of our department playing key roles.

We care about the neutron skin at the very least because physicists like to know the size of things. For more than a half-century, the technique of accelerated, relativistic electrons scattering off fixed targets has precisely mapped out the *proton* rms radii of nuclei. However, since electrons probe the nucleus via the electromagnetic force, this technique is essentially blind to the neutron distribution.

Physicists have tried to measure neutron rms radii using so-called "strong" probes. For instance, accelerated protons or pions interact with nuclei primarily via the strong force, resulting in sensitivity to both protons and neutrons. Unfortunately, the very nature of the strong force makes the theoretical interpretation of the process as a "single scattering" event untenable and the resulting extracted neutron rms radii are fraught with uncontrolled theoretical uncertainties.

A little over thirty years ago, three nuclear

theorists including John Dubach from our department proposed a new electron scattering technique to measure the neutron rms radius accurately by exploiting the neutral weak force to probe the nucleus [*Nucl.Phys*.A503(1989)589-63]. When an electron is in the vicinity of a nucleus, both the electromagnetic and the weak forces are involved and the authors pointed out that the latter is sensitive to the neutron distribution. Why?

The answer arises from a remarkable accident of Nature. Modern particle theory provides a unified framework, the Standard Model of particle interactions, in which the weak and electromagnetic interactions are described together as the electroweak force. Particles possess weak charges that are closely related to their corresponding electric charges. It turns out that in the Standard Model the neutron's weak charge is roughly 10 times larger than that of the proton. Dubach and collaborators pointed out that isolating the weak force component would then essentially provide a measurement of the neutron rms radius.

Unfortunately, this is not easy to do since the weak force is one thousand times weaker than its electromagnetic counterpart, so how to tease out the weak force component? Here one can use the unique feature of the weak force: it is not mirror-symmetric. So, if one were to selectively scatter "right-spinning" electrons (the spin and momentum vectors are aligned) and compare the probability of scattering to that of "left-spinning" electrons (vectors anti-aligned), *keeping all other conditions the same*, the difference can be attributed to the weak force component.

In practice, this measurement is very technically challenging; one has to measure part per million (ppm) fractional differences between the scattering probabilities for left- and right-spinning electrons. Over the past 3 decades, nuclear experimentalists, including Krishna Kumar's group in our department, have progressively improved measurement techniques; it is now possible to measure the fractional asymmetries with uncertainties approaching a few parts per billion (ppb). Such a measurement was carried out at the Thomas Jefferson National Accelerator Facility in Newport News VA by the PREX collaboration to extract the neutron rms radius of ^{208}Pb. A pilot measurement (PREX-I) in 2010 was published in 2012 [*Phys.Rev.Lett*.108(2012)112502]. Data collection for the final precise measurement (PREX-II) was carried out in 2019. Data analysis was just recently completed and the results have been submitted for publication.

Krishna Kumar

Before discussing the PREX-II result and its implications, we return to the basic physics of the neutron skin. As has happened many times in physics, once scientists find novel ways to make precise measurements, implications are felt in seemingly unrelated subfields. The beautiful connections in this instance are nicely articulated in a 2019 *Physics Today* article which we summarize in the following [*Physics Today*.**72**, 7, 30 (2019)].

Many of the bulk properties of nuclei can be understood in the traditional liquid drop model, in which the nucleus is modeled as a combination of two incompressible quantum

NEUTRON SKINS AND NEUTRON STARS

fluids made up of protons and neutrons. The binding energy of a nucleus, which characterizes its stability, is driven by two dominant principles. For symmetric nuclear matter (equal numbers of protons and neutrons), the nature of the nuclear force points to a universal central density of all nuclei, close to the so-called saturation density. Secondly, as the neutron to proton ratio becomes asymmetric in heavier nuclei, the Pauli exclusion principle imposes an energy penalty. The coefficient of this so-called "symmetry energy" term and its density dependence also drives the size of the neutron skin.

In recent years, the density dependence of the symmetry energy is part of the larger quest to determine the complete equation of state of dense nuclear matter. Even though we know a great deal about nuclear forces at a fundamental level, there exist technical challenges to this equation from theory alone. The variation of the energy with density is imprinted in the pressure of pure neutron matter at saturation density, which is in turn closely related to the neutron skin. Remarkably, this pressure also dictates the properties of one of the densest and most fascinating stellar objects in the universe, namely neutron stars.

A neutron star is the compact remnant from the gravitational collapse of a dying massive star. It typically weighs between 1 and 2 solar masses and has a radius of only about 12 km, i.e., the size of a small city or a largish comet and therefore far denser! The interior density is two to four times the saturation density of a nucleus! In such an environment, the electrons and protons are "squeezed" out, leaving mostly neutrons. The same nuclear equation of state that governs the neutron skin impacts the bulk properties of neutron stars!

The past couple of decades has seen the rapid and exciting rise of multi-messenger astronomy. A spectacular example is the fascinating sequence of scientific discoveries triggered by the 2017 observation of a binary neutron star merger by the LIGO gravitational wave interferometer [*Phys.Rev.Lett*. 119(2017)16,161101]. When telescopes sensitive to a wide range of the electromagnetic spectrum trained their eyes in the region pinpointed by LIGO and VIRGO (the sister interferometer in Europe), the resulting data over subsequent days and weeks provided direct evidence that neutron star mergers are a significant source for the synthesis of heavy elements in the universe.

The LIGO data on this same neutron star event provided important new information on the nuclear equation of state. Just milliseconds before the final merger, the two neutron stars are so close together that they deform into "tear drops" under the extreme mutual gravitational force, thus modifying their trajectories from that of ideal spheres. This neutron star "tidal deformability" can be correlated to the size of the neutron skin of a heavy nucleus, bridged by the nuclear equation of state! Both of these phenomena provide quantitative information to develop the empirical neutron star mass-radius relation.

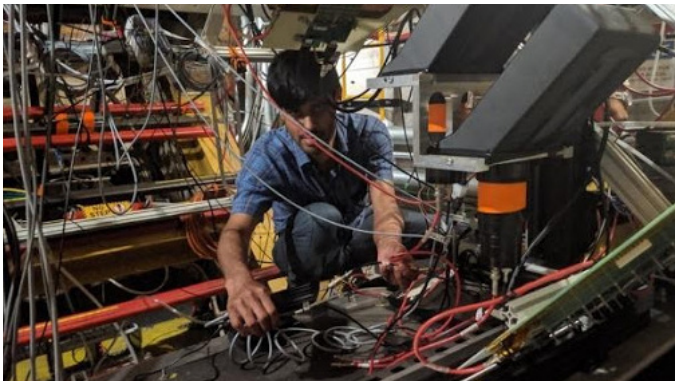


Figure 1: UMass postdoc Chandan Ghosh assembling the PREX-II detectors at Jefferson Lab before the 2019 run.

Now we pivot back to the PREX results. The technical challenges that were overcome in making the measurement would be a separate article in itself, and we only make brief comments here. A 1 GeV electron beam at Jefferson Lab is incident on an isotopically pure ^{208}Pb foil sandwiched between two diamond

foils (to avoid melting from beam heating). The fractional difference in the incident right- and left-handed electrons scattering probabilities was measured to be 550 ± 16 (stat.) ± 8 (syst.) ppb.

Setting up the beam conditions and the complex and sophisticated detection apparatus, maintaining optimum performance over a three-month period ("24-7"), carrying out periodic calibration runs to determine the absolute momentum scale and the average electron longitudinal beam polarization are examples of the ingredients to achieve a measurement of such sensitivity. Overall, 13 PhD students and 7 postdoctoral research associates as well as more than 50 other scientists from about 20 institutions participated in the construction and commissioning of the apparatus, data collection and analysis.

Using theoretical calculations pioneered by Chuck Horowitz of Indiana University that explicitly account for so-called "Coulomb distortions" in the scattering process, the PREX-II measurement combined with the previous 2012 result yields the neutron skin of ^{208}Pb with little additional theoretical uncertainty: $R_n - R_p$ = 0.28 ± 0.07 fm. This remarkable result is already creating quite a stir and will generate animated discussions in nuclear physics conferences and workshops in coming months. It is a bit bigger than the "lore" that the ^{208}Pb skin is around 0.15 fm, implying that the pressure of neutron matter at saturation density is a bit larger than previously assumed.

Figure 2 shows an example of how various inputs to the nuclear equation of state are beginning to be disseminated in the community; this is from a paper that appeared a day after the submission of the PREX-II result! [https://arxiv.org/abs/2101.03193]. Such figures are certain to initiate many interesting discussions between disparate sets of investigators and trigger new calculations and measurements. The y-axis is a dimensionless parameter characterizing neutron star tidal deformability. The upper x-axis is the radius of a 1.4 solar mass

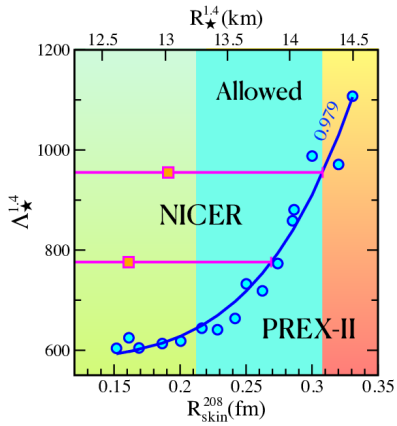


Figure 2

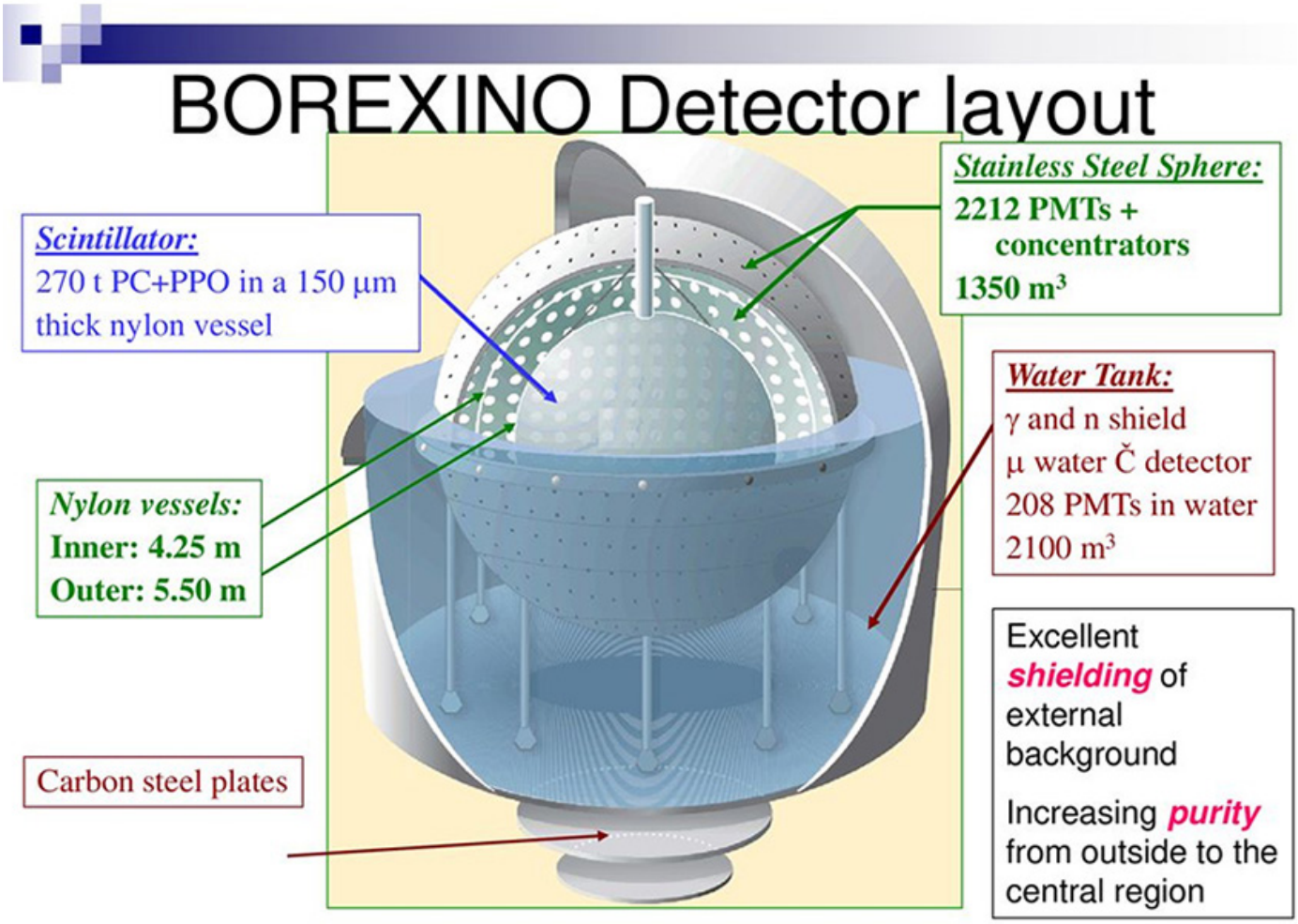
neutron star in kilometers. The lower x-axis is the neutron skin of ^{208}Pb in femtometers. The blue curve is constructed as a best fit over the blue dots depicts the empirical correlation between the x- and y-axis parameters from the nuclear equation of state. The third input in Figure 2 is from NICER, an x-ray telescope currently operational on the International Space Station. It measures neutron star compactness (mass to radius ratio) by discerning how space-time curvature modifies electromagnetic wave trajectories in the vicinity of a neutron star. The two pink horizontal lines depict two analyses of NICER data to extract the radius of a 1.4 solar mass neutron star. One can see that all three inputs are compatible near the bottom end of the blue curve.

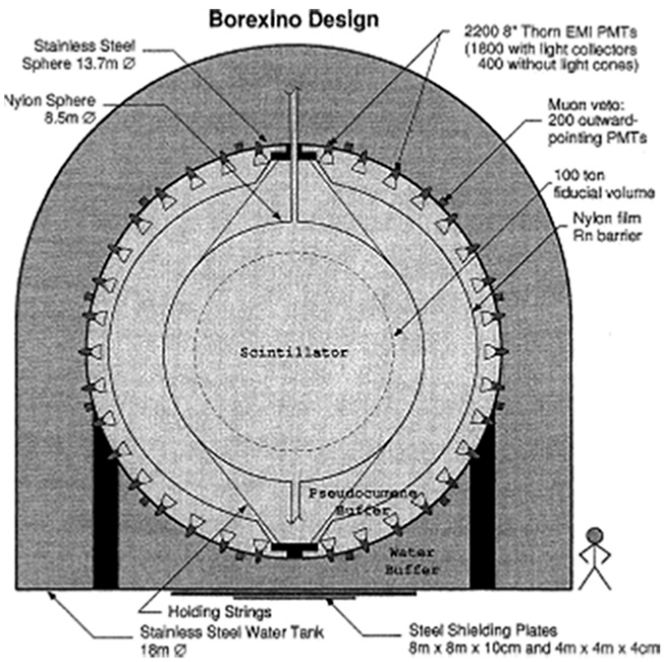
As new data become available from NICER and LIGO, these bands will narrow. As for PREX, this is the final measurement from Jefferson Lab. However, the techniques developed lay the technical foundations for a new weak force measurement on a hydrogen target (the MOLLER experiment) to make an ultra-precise measurement of the weak charge of the electron itself and test the Standard Model of particle interactions in a manner complementary to searches at the Large Hadron Collider.

Nevertheless, the great interest in the larger nuclear physics community being generated by the precision of the PREX measurement, the provocative central value and its clean interpretation has already spurred the design of a new experiment named MREX at the Johannes Gutenberg University in Mainz, Germany, where a new low energy, high intensity electron accelerator is currently being constructed.

BOREXINO DETECTS CNO NEUTRINOS

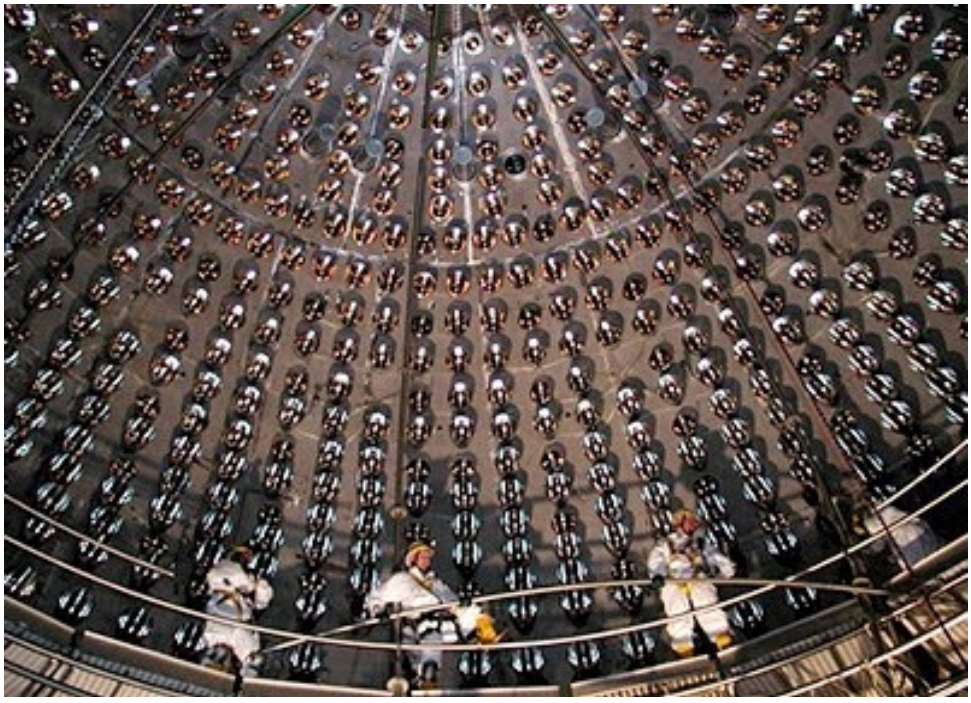
In a previous (2019) Newsletter [https://www.physics.umass.edu/newsletters], the work of Professor Andrea Pocar in the Borexino collaboration was described. The collaboration operates a detector filled with 300 tons of liquid scintillator located in the nearly two-mile-long Gran Sasso highway tunnel which connects Rome and the Adriatic Sea. The goal of Borexino has been to study the mechanism by which the Sun produces energy--a prodigious ~4 × 10^{17} gigawatts. The origin of this energy was identified by Hans Bethe in the 1930s to be nuclear fusion, wherein four protons are "fused" into helium accompanied by the release of 24.7 MeV of energy, with much of this energy carried by photons and neutrinos. Since protons are positively charged and repel one another, fusion can only occur near the center of the Sun, where the temperature reaches 15.7 million K. Photons from fusion reactions diffuse out to the surface via numerous absorptions and emissions and eventually reach the solar surface, whose temperature is only about 3000 K, at which point they continue their journey into free space and eventual observation by Earthbound detectors. The observed photons are thus far removed from those originally emitted in the fusion reactions and tell us little about the fundamental reactions wherein they arise. Not so for the emitted neutrinos, whose tiny (~10^{-42} cm^2) cross sections for interactions with matter mean that any neutrinos observed in Earthbound detectors are essentially those emitted in the original reactions in the solar core. These tiny cross sections, however, also have the consequence that such neutrinos are also extremely challenging to detect, which is why a very large detector mass, such as that used by Borexino is required.





According to the theory developed by Bethe, this conversion of hydrogen to helium can occur in two ways. For our Sun, the primary reaction is the pp process, which begins at about 4 million K and which was detailed in the 2019 *Newsletter*. Three distinct neutrino energies (pp, ^{7}Be, and ^{8}B) are pieces of this chain and all three were detected by Borexino. A second possible route is the CNO chain, which involves catalysis of the basic 4p→ ^{4}He fusion by carbon, nitrogen, and oxygen nuclei. This CNO process does not begin until a temperature 15 million K is reached and therefore represents only ~1% of the energy produced by the Sun, although it is expected to be the dominant reaction in more massive and therefore hotter stars. The detector energy spectral intensity associated with CNO is therefore strongly suppressed with respect to that arising from the pp process. However, this is only one reason that detection of the CNO cycle by Borexino has been so difficult. The other is that the energy spectrum must be distinguished from that of radioactive decay of trace elements such as ^{210}Bi, with which it has a significant overlap. These elements are present in trace amounts in the nylon container housing the scintillator and can convectively leach into the interior. The solution found by the Borexino collaboration was to carefully thermally stabilize the detector, which enabled observation of the neutrino events associated with the CNO process. Only a few counts per day above background per 100 tons of detector were seen but this was enough to confirm for the first time the contribution of the CNO process to solar energy production. The work is published in the 26 November issue of *Nature*.

The importance of this result goes beyond merely observing the CNO neutrinos, since the rate of the reaction also carries significant information about the "metalicity" of the solar core, metalicity meaning the presence of elements other than hydrogen and helium. This number is a critical ingredient to solar models and, in order to provide a careful measurement of this quantity, the Borexino run, which began in the early 1990s and had been expected to end in 2020, has been extended into 2021.



POCAR INVOLVED IN CORONA VIRUS RESPONSE

Previous newsletters have described Professor Andrea Pocar's involvement in major international experiments that look for dark matter, a mysterious component of the universe which accounts for a significant fraction of its mass-energy density, but whose nature is completely unknown. However, this year, in addition to these efforts, he was also associated with an initiative by many members of the same international collaboration to generate a response to the COVID-19 crisis by designing plans for a new and simplified mechanical ventilator.

A collaboration led by Cristiano Galbiati (a college classmate of Pocar's) of Princeton University and the Gran Sasso Institute, L'Aquila, Italy, was put together in order to find a simplified way to manufacture such respiratory-assist devices. The device was designed with supplies that are readily available in Italy, Europe, Canada and the US. Pocar points out that experimental physicists, such as he, are used to designing unique devices to address difficult challenges presented by seeking rare processes; so, it was natural to look at some of the problems presented by the corona virus response. At the beginning of the pandemic, one of these challenges was a shortage of ventilators, so this was the issue addressed by the collaboration. As we learned more about the disease and developed improved ways of treatment, the "shortage" was found to dissipate, so that the new design was not needed.

However, as the virus resurges, finding enough ventilators may again represent a problem; so, it is good to know that a simplified construction method is available, if needed. A descriptive paper is being submitted for publication in IEEE's Transactions of Biomedical Engineering, (and available on https://arxiv.org/abs/2003.10405 and https://www.medrxiv.org/content/10.1101/2020.03.24.20042234v1).

Note: In Canada the MVM [Mechanical Ventilator Milano] ventilator has actually been completed and is being built with government funding.

PIO LIFETIME

Precision measurement of the neutral pion lifetime: a 20-year effort

Since the development of quantum field theory, it has been known that the basic symmetries of the classical world are at the origin of the fundamental conservation laws of particle and nuclear physics. Classical symmetries are generally respected in the quantum realm, but it was realized several decades ago that there are exceptions to this rule, in the form of so-called anomalies. The most famous such is arguably the axial anomaly, which enables the decay of the lightest strongly interacting particle in nature, the π^0, into two photons, denoted as $\pi^0 \rightarrow \gamma\gamma$. In quantum field theory the axial anomaly is represented by graphs that do not require renormalization, thereby enabling a purely analytical prediction without free parameters of the lifetime. Thus, experimental verification of this phenomenon with the highest accuracy is a fundamental test of quantum field theory and symmetry breaking by purely quantum effects. UMass theorist Barry Holstein and his collaborators played a major role in the calculation of small higher-order quantum corrections to this axial anomaly prediction.

In the early 1990s, with construction in Newport News, Virginia, of a new national electron accelerator facility, the Thomas Jefferson National Laboratory (JLab), UMass faculty member Rory Miskimen and collaborators in the PrimEx collaboration realized there was an opportunity at JLab to perform a precision measurement of the π^0 lifetime. Precision would be a key aspect of the proposed experiment, as the lifetime had been previously measured in other experiments, though with large uncertainties. The technique that the collaboration proposed for the measurement is the "Primakoff effect", wherein a high energy gamma ray (6 GeV) interacts with a (virtual) photon in the Coulomb field of a target nucleus,

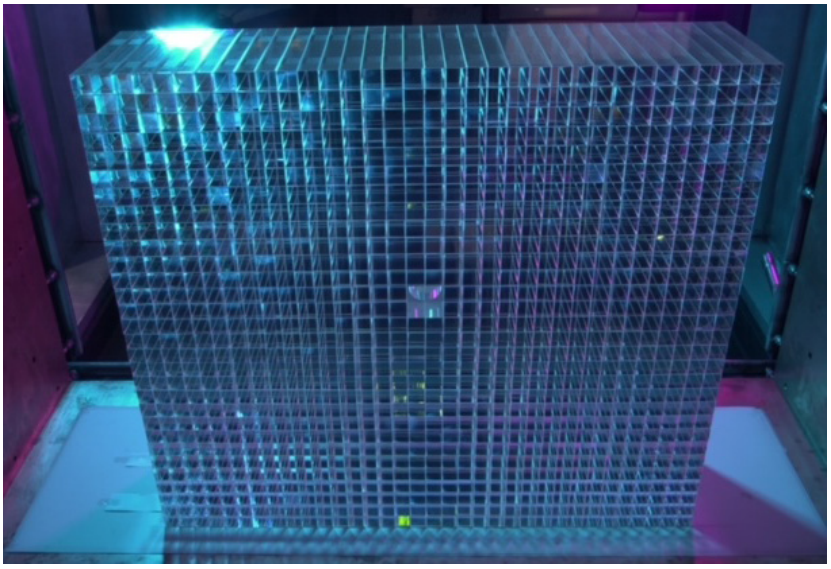
producing a neutral pion which subsequently decays into two photons. The probability for this process to occur is directly related to the lifetime.

This is all well and fine, but in the late 1990s precision measurements at the new JLab facility were just getting underway, and the detector required for such a measurement didn't exist, nor was it part of the portfolio of Department of Energy (DOE) funded instrumentation at the lab. Once JLab management had approved the physics of the experiment, the PrimEx collaboration went about obtaining funding and building the needed detector, running the experiment, analyzing data, and then publishing the results. Little did the PrimEx group realize at the time that this would be the genesis of a 20-year effort.

Although funding for basic research is always tight, the idea of doing the π^0 lifetime measurement at JLab caught on very strongly with the NSF and DOE, and the approximate $2,000,000 cost for building the experiment was roughly shared evenly among agencies. UMass received one of the larger shares of this funding, which was utilized for detector and electronics construction. Former UMass machinist Dick Letendre and electronics tech Steve Svoboda played key roles in machining detector parts and assembling the electronics.

In the late '90s a new scintillation material called lead tungstate had become available for photon detection, and the PrimEx group realized this crystal would be ideal for its measurement. Nowadays lead tungstate is ubiquitous in particle physics experiments. However, in the late '90s only very limited quantities of the crystal were available, primarily because CERN was buying up every crystal it could in preparation for LHC construction. At that time there were only two factories in the world growing this crystal, one in the former Soviet Union and another in China. To gain access to a supply of such crystals, it was necessary to send a Chinese speaking PrimEx member to China to negotiate directly with factory management. As a result of those negotiations PrimEx was allowed to select the best crystals coming out of the Chinese foundry, and PrimEx arguably "scooped" CERN/LHC in obtaining these crystals.

A major milestone for the measurement was to keep statistical and systematic errors at the 1% level. With high intensity photon beams at JLab, reaching this statistical precision was straightforward. However, achieving systematic uncertainties at the 1% level was a severe challenge; current state-of-the-art being approximately 5%. Although the PrimEx collaboration was not a large group, probably no more than 10 persons working on the experiment at any given time, a group of innovative young scientists in the collaboration successfully pushed the experiment to this systematic precision goal. At UMass these scientists included Eric Clinton, PhD student, Ilya Larin, currently Senior Research Fellow in the Department, David Lawrence, former research assistant professor, and BS students Candice Harris, Pjerin Luli, Phil Martel and Rich Rines. Through the efforts of this group and others in the collaboration,



pi0 lifetime Primex detector

PIO LIFETIME

the experiment was able to obtain the smallest combined statistical and systematic errors for any particle or nuclear physics experiment with high-energy photons incident on a fixed target.

Fast forward to the conclusion of this measurement, there were two experimental runs at JLab separated by several years. These runs led to two publications, the first being a paper in *Physical Review Letters*, I. Larin et al., *Phys. Rev. Lett*. 106, 162303 (2011), and a follow up and concluding paper in *Science*, I. Larin et al. *Science*, 368, 506–509 (2020). A perspective article on the experiment was also published in *Science*, H. Meyer, 368, 469 (2020). This period of time was a formative professional experience for many of the post-docs and young faculty members working in the group, with six former PrimEx post-docs moving into faculty or senior research staff positions, and was also formative on a personal level, with some starting families during this time.

The PrimEx measurement confirmed within experimental errors the quantum field theory predictions for the π^0 lifetime. Although the experiment considerably raised the precision bar for future measurements of the lifetime, there continues to be interest in the field for measurements that can push the error even below 1%, especially at CERN and at INFN, Frascati, Italy. At JLab, the detector built for the lifetime experiment has continued to be in use, most recently for a high-profile measurement of the proton charge radius. After twenty years, Rory Miskimen and the other core PrimEx investigators continue to collaborate and are preparing a proposal to measure the electromagnetic transition radius of the π^0 using their original detector.

[Ed. note: Founded in 1951, the INFN, Istituto Nazionale di Fisica Nucleare, is an Italian association of four national laboratories located in Gran Sasso, Legnaro, Frascati, and Catania. The first Italian electron accelerator was developed at Frascati in 1954.]

LISA – A GRAVITATIONAL WAVE DETECTOR IN OUTER SPACE

The first direct observation of gravitational waves, performed by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015, provided a spectacular confirmation of predictions made by Einstein in 1916 based on his General Theory of Relativity. Even more remarkably, it gave a strong, even if indirect, evidence of the existence of black holes, maybe the most striking of the predictions of General Relativity, and opened up a new dimension for astronomical observations.

Gravitational interferometers are based on the same principle as the Michelson interferometer that disproved, in the 1880s, the ether theory, paving the way to the discovery of the Special Theory of Relativity. A gravitational wave is a disturbance in space that travels at the speed of light; as it passes through the interferometer, the lengths of the arms briefly oscillate with a tiny amplitude, leading to a time dependence in the interference pattern of the interferometer. This effect is really tiny though and the typical displacement in the 4-km-long arms of the LIGO interferometer is about a thousandth of the diameter of a proton. Gravitational wave detection is a very delicate art!

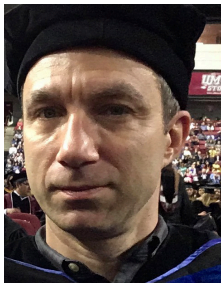
LIGO is just the beginning of an exciting story, and there are many proposed experiments that will either improve our sensitivity to the amplitude of gravitational waves or will be probing different frequency ranges. One of the most impressive of these projects is the Laser Interferometer Space Antenna (LISA), a gigantic LIGO in space. The LISA mission involves three spacecraft that will form an equilateral triangle whose sides have a length of 2.5 million kilometers, and will freely orbit the Sun along the Earth's orbit, trailing the Earth by about 60 degrees. Each pair of the sides of the triangle will act as an interferometer – so LISA is really

three interferometers in space. Thanks to its long arms, LISA will be sensitive to gravitational waves with a frequency of ~10^{-3} Hz, to be compared to LIGO's peak sensitivity at ~103 Hz. The mission is supposed to be launched in the (early, hopefully) 2030s.

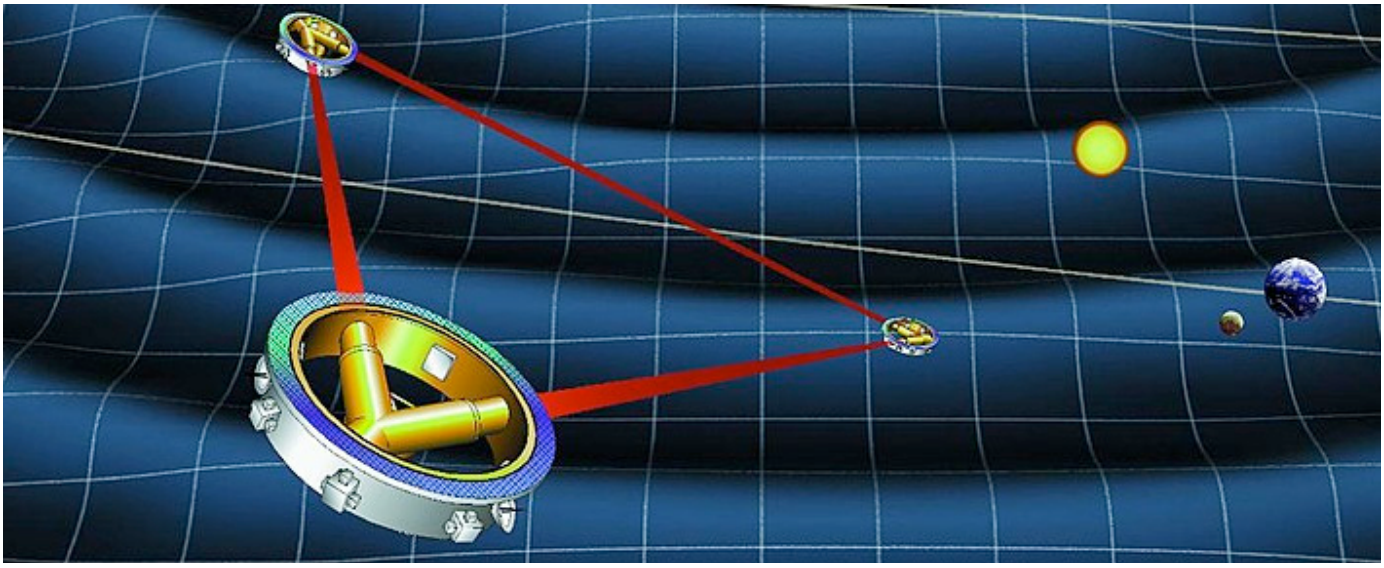
LIGO has observed so far individual packets of gravitational waves emitted by some of the most energetic phenomena in the sky – the coalescence of objects having several tens of solar masses. But we also expect the existence of a stochastic background – analogous to a constant buzzing noise – of gravitational waves, that has not been observed yet. A component of such a background is provided by the sum of the gravitational waves produced by events in the Universe which are too weak to be individually detected. But additional components might be of primordial origin, being generated for instance by phase transitions in the very early Universe, or by the period of primordial inflation, that is supposed to have stretched the initial seed of our Universe from subnuclear sizes to a macroscopic size in a time as short as 10^{-35} seconds.

During the last few years, UMass Professor Lorenzo Sorbo, together with a group of collaborators based mostly in Europe, has studied how LISA will be able to characterize

Lorenzo Sorbo



the stochastic background. In particular, this group has explored LISA's ability to constrain properties like the behavior under parity (an operation that exchanges, in particular, gravitational waves spinning clockwise and gravitational waves spinning counterclockwise – pretty much like photons, gravitational waves carry polarization), or the statistical properties of the stochastic background. Such characterization of the stochastic gravitational wave background will help determine, once such a signal is observed, whether its main component is of astrophysical or of primordial origin. For instance, there is no reason why gravitational waves produced by astrophysical phenomena should be, on average, spinning with a definite handedness. Observation of a stochastic background of definite parity would thus tell us that these gravitons have been traveling to us from the very first moments of the existence of the Universe and would provide hints about the dynamics that generated them. It will take at least a decade before LISA flies, but when it does it will open a new window on the sky and, if Nature is kind to us, even on the origin of our Universe.



An artist's view of the three LISA spacecraft and the 2.5 million km long laser beams joining them. The Earth and the Sun are in the background.

RIDING IN A CAR IN THE PANDEMIC: WHICH WINDOWS TO OPEN?

If you find yourself in a car with someone outside your household during the COVID-19 pandemic, your instinct may be to roll down your window, whether you're the driver or a back-seat passenger. But a University of Massachusetts Amherst physicist has shown in a new study that opening the car window closest to you isn't always the best option to protect yourself from coronavirus or any airborne infection.

In a paper published December 4, 2020, in the journal *Science Advances*, researchers have revealed certain surprising ways in which the airflow patterns within a car's interior could either heighten or suppress the risk of airborne infection during everyday commutes.

"One might imagine that people instinctively open windows right beside them while riding with a co-passenger during the pandemic. That may not be optimal – though it's better than opening no window," says lead author Varghese Mathai, an assistant professor of physics at UMass.

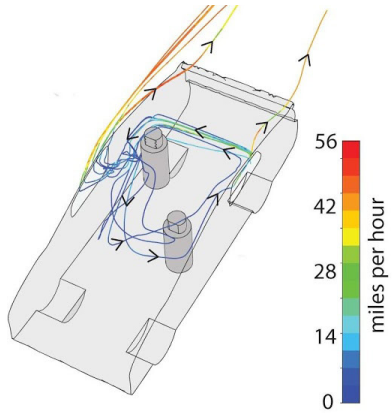
Varghese Mathai

He explains, "We designed this research with ride-sharing in mind…assuming a driver and one passenger seated in the back on the passenger side to provide the best possible spacing between the occupants."

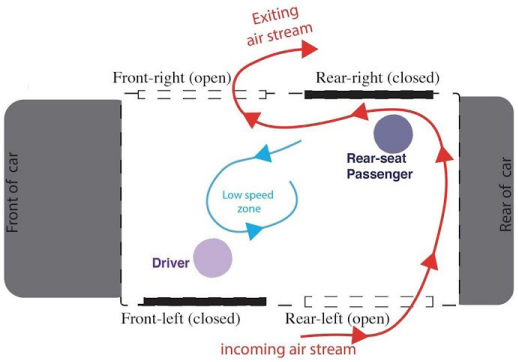
Briefly, the research suggests that opening the windows farthest from the driver and the back-seat passenger might offer some benefits (Fig. 1). The findings may provide COVID-19 risk reduction measures for the hundreds of millions of people driving in passenger cars or using a taxi or rideshare worldwide.

The most and least risky scenarios for airborne pathogen transmission in a car are understood by scientists: opening all the windows, along with bringing in fresh air through the vents, is thought to create the best in-cabin environment to reduce the risk of transmission by increasing ventilation. Keeping all the windows up and using only the recirculating air mode is likely the riskiest option.

Realizing the impracticalities of keeping all car windows open in winter or rainy weather, Mathai wanted to examine what happens to aerosolized particles exhaled by occupants inside the car's cabin under various configurations of open and closed windows. "These tiny, potentially pathogenic particles remain in the air for long durations without settling down, so if they are not flushed out of the cabin, they can build up over time posing an increased risk of infection," he explains.



Air flow paths from simulations



A simplified drawing showing the air flow paths (top view)

Fig 1. Air flow inside and surrounding a car with front-right and rear-left windows open, as seen from above at different speeds. At left is a computer simulation; at right a graphic illustration of the same situation. Image courtesy of the Mathai lab.

Generally, the air flowing around a car creates a lower pressure on the front windows as compared to the back windows, Mathai says. "We had this idea that if you open the rear and front windows on opposite sides, then you might create an air current from the rear to the front of the cabin, and crossing through the middle."

The study was conducted with colleagues Asimanshu Das, Jeffrey Bailey and Kenneth Breuer at Brown University, where Mathai worked previously and started the study. The researchers hypothesized that if all windows can't be left open, opening the front window on the right side and the rear window on the left side might best protect the driver and passenger from the hundreds of aerosol particles released in every human breath.

"To our surprise, the simulations showed an air current that acts like a barrier between the driver and the passenger," says Mathai. This phenomenon is similar to the air curtain created by a draft blown down vertically at some supermarket entrances, which prevents outdoor air from mixing with indoor air, even if the entrance door is open. "While these measures are no substitute for wearing a face mask while inside a car, they can help reduce the pathogen load inside the very confined space of a car cabin," he points out.

Like many other researchers during the pandemic, Mathai — an experimental physicist — decided to shift his focus toward computer simulations while working from home. The researchers used a simplified, time-averaged model for the turbulent air flow, and passive scalar transport as a proxy for infectious particles. The study implications are limited to airborne mode of transmission. Mathai later backed up his findings using smoke visualization and field tests that identified low-speed and high-speed zones inside the cabin of a Kia Optima.

[material in article excerpt from January 5, 2021, article in UMass News & Media Relations]

SUMMER SCHOOL ON SOFT MATTER AND COMPLEX FLUIDS

The twelfth UMass Summer School on Soft Matter and Complex Fluids was held in June 2020 as a completely remote, online event. The summer school annually brings together a group of early career graduate students in Soft Matter and related fields, and enlists three or four internationally known researchers to deliver courses to these students which are not usually available in their home departments. This year the summer school featured instructors Prof. Emanuela Del Gado from Georgetown University, Prof. Haim Diamant from Tel Aviv University, and Prof. Greg Grason from the UMass department of Polymer Science and Engineering (Greg is also adjunct faculty in the Physics department). The 2020 summer school was organized by Physics faculty Benny Davidovitch and Narayanan Menon (who created the summer school in 2008) along with Don Candela, Tony Dinsmore, Manasa Kandula, and Shuang Zhou.

Previous editions of the summer school were residential at UMass, with rooms provided in the North Residential Area and meals at the Dining Commons and Campus Center. But with the onset of the COVID-19 pandemic, those plans had to be canceled in 2020 and the summer school was reborn (through 2021) as an online event. Nevertheless, 74 students participated in the summer school--more than any previous year, reflecting the eagerness of these young scientists to progress in their research despite the obstacles posed by the pandemic.

2020 ACFI WORKSHOPS

Despite the challenges presented by the COVID-19 crisis, the Amherst Center for Fundamental Interactions (ACFI) was able to hold several (virtual) workshops using Zoom technology:

Neutrinoless Double Beta Decay: In December an effort organized by UMass faculty members Jordy DeVries and Andrea Pocar together with former UMass student Lisa Kaufman (SLAC) and others looked at possible future efforts in neutrinoless double beta decay, wherein a nucleus decays to another with atomic number decreased by two together with two electrons but no neutrinos. Such efforts would utilize detectors with greater than the ~ton masses envisioned in current proposals. One of these existing proposals is the ^{136}Xe (nEXO) experiment, involving Professor Krishna Kumar, which is currently being considered by the Department of Energy. The goal of all these efforts is to reveal whether the neutrino is its own antiparticle, a possibility first raised by Ettore Majorana, a student of Enrico Fermi, in 1936.

Baryon Number Violation: Two workshops examining both theoretical and experimental aspects of baryon number violation were organized by UMass faculty member Jordy DeVries and various outside researchers and held in April and August. A specific focus was on models having $\Delta B=2$, so that the proton is completely stable, as found experimentally. A second goal was to influence the long range (Snowmass) planning now under way in the particle physics community and to study the discovery potential of current/future efforts in this regard probing neutron-antineutron oscillation and di-nucleon decay, which will be studied at the European Spallation Source in Sweden, at Hyper-Kamiokande in Japan, and at PNPI Gatchina in Russia.

Inverse Methods in QCD: In an October workshop organized by non-UMass people, participants looked at the challenges presented by the need to understand nuclear matter in the context of quantum chromodynamics (QCD). This is a very difficult problem and involves extraction of various dynamical quantities from experimental data in terms of moments and/or other integral transforms. Many of these "inverse" methods are rather ill-defined and a workshop goal was to attempt to clarify and systematize these techniques.

It is hoped that 2021 will bring about an eventual return to the traditional type of ACFI workshop, wherein a small number of researchers assemble at UMass for detailed discussions focused on specific and important problems in nuclear/particle physics.

ASPEN WINTER CONFERENCE

During February 2--7, 2020, there was a 1-week workshop at the Aspen Center of Physics: "Low dimensional solids in hard and soft condensed matter: mechanics, thermodynamics, and electrons," organized by Benny Davidovitch and his collaborators (A. Geim, Manchester), F. Guinea (IMADEA, Madrid), C-N Lau (OSU, Columbus), and E. Sharon (Jerusalem).

The initiative underlying this workshop was born out of a persistent impression, shared among numerous members in the "soft" and "hard" wings of the condensed matter community, that there has been a considerable amount of progress in our understanding of the physics of 2D materials -- available in journal papers and books -- but not sufficiently disseminated and digested throughout the whole condensed matter community. Consequently, one may hope that considerable progress can be made by cultivating links among "softies" and "hardies", not only in resolving existing problems, but also in inspiring novel research directions.

A few examples of such a mutual interest between these research communities include the field of "strain engineering" (where electronic band-structure of a 2D crystal is sought to be manipulated by inducing strain in preferential bonds); the presence of long-wavelength "ripples" and "bubbles" in free-standing and supported graphene; the emerging hierarchy of "stress focusing" patterns in geometry-induced deformations; and the mechanical-geometrical principles underlying self-assembly and stability of ribbon-like and bundle-like, supra-molecular structures. In these areas, recent studies indicate a wide range of nontrivial phenomena, often characterized by coupling of mechanical and electronic degrees of freedom, and strongly affected by geometrical frustration and thermal fluctuations. The primary goal of the Aspen winter workshop was to bring together prominent experimentalists and theorists, whose research interests and expertise could inspire a fruitful dialogue and potential collaborations.

The workshop included 7 sessions, exploring these "interface" themes. Each session consisted of 4-5 presentations, as well as poster sessions, allowing ample time for lively discussions among participants. UMass Amherst has been highly visible in this workshop, with presentations by N. Menon (Physics) on the foundations of "surface stress" and G. Grason (PS&E) on the theory of geometrically-frustrated self-assembly, as well as a poster presented by the graduate student D. Atkinson.

See also: https://blogs.umass.edu/bdavidov/aspen-winter-workshop/

NECF WORKSHOP

In June 2020, Profs. Shuang Zhou and Tony Dinsmore hosted the 83rd New England Complex Fluids (NECF) workshop with three invited speakers and many research "sound bites" contributed by the participants. The NECF workshop was scheduled to be an in person event at UMass, but due to the COVID19 pandemic, it was switched to a fully remote, online conference. This was the first attempt to hold this quarterly event online, and by all measures, it was a success with over 100 online participants. The workshop served as an early test bed for several now-familiar strategies for engaging participants in an online format, including breakout-room discussions and a virtual online lunch hangout.

MAGNETIC FIELDS IN ANTI-DE SITTER SPACETIME

Large scale magnetic fields are ubiquitous in the universe, playing important roles within our own galaxy and out to much larger scales. The mechanism by which such fields originate is a topic of great speculation by cosmologists. Meanwhile, the interactions of magnetic fields with the curvature of spacetime has been a recent topic of study for UMass Physics faculty members Jennie Traschen and David Kastor.

In general relativity, there exist three spacetimes that can lay equal claim to be the simplest and having the highest degree of symmetry. The most familiar is flat spacetime, with no matter present, which has a total 10 symmetries – 4 translations (in space and in time), 3 rotations (about the x, y and z axes), and 3 Lorentz boosts (in the x, y and z directions). The other two "maximally symmetric" spacetimes are de Sitter spacetime, which has uniform positive spacetime curvature, and Anti de Sitter spacetime which has uniform negative curvature.

To try to get a feeling for this, the surface of a sphere has constant positive (spatial) curvature and de Sitter spacetime is a kind of spacetime analog of a (4-dimensional) sphere. A surface of constant negative spatial curvature cannot be realized in 3D space. However, a potato chip shape is a 2-dimensional example of a surface with (non-constant) negative spatial curvature. De Sitter and Anti de Sitter spacetimes are also not precisely empty, having respectively positive and negative values of the so-called cosmological constant, a form of stress energy that can permeate the universe. Einstein famously described his introduction of the cosmological constant as his greatest blunder, but observations now indicate that our universe either has a small positive cosmological constant, or something that acts quite like one. So, his "blunder" may turn out to have been prophetic.

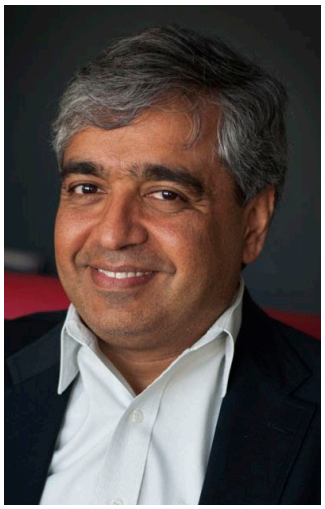
De Sitter and Anti de Sitter spacetimes have strikingly different properties, but both play key roles in physics research. The accelerated expansion characteristic of de Sitter tends to rapidly separate things. It solves certain problems in the very early universe and is the basis for inflationary models of cosmology. Anti de Sitter, on the other hand tends to bring things back together, acting rather like a confining box. It turns out that what goes on in the interior of Anti de Sitter spacetime leaves traces on the boundary of this "box". This leads to a "holographic" interpretation of physical phenomena in Anti de Sitter, which was first discovered in the context of string theory.

In non-gravitating physics, it is straightforward to write down a solution to Maxwell's field equations that describes a constant magnetic field. In general relativity, however, the energy stored in the magnetic field is a source for spacetime curvature. Solutions to Einstein's equations corresponding to a constant magnetic field (and vanishing cosmological constant) were found back in the 1960s and are known as Melvin spacetimes. However, Melvin spacetimes are greatly distorted geometrically compared to their non-gravitating versions, as follows:

If the magnetic field points in the z-direction, then Melvin spacetimes are symmetric under rotations about the z-axis. Near the axis, the spacetime is approximately flat and looks much like its non-gravitating analogue. However, as one moves away from the axis, the effects of curvature accumulate and eventually "close up" the spacetime; the circumferences of circles of larger and larger circles become smaller and smaller, a drastic difference from flat spacetime. Kastor and Traschen's work asks the question, what happens if Melvin magnetic fields are placed in Anti de Sitter spacetime? Do the distorting properties of Melvin win out, or are they tamed by the confining, box like properties of Anti de Sitter spacetime. To make a longish story short, the box wins out in the end. Static tubes of magnetic flux are much better behaved in Anti de Sitter. However, puzzles remain. It turns out that Anti de Sitter can hold only a finite maximum amount of magnetic flux, and for each value of the flux below this maximum there exist two distinct flux tube solutions, one fatter and one skinnier.

This behavior raises questions such as what happens if one tries to introduce more than the maximum flux? Is the solution then necessarily dynamical, rather than static? For fluxes below the maximum, is either the fat or the skinny fluxtube unstable? The fate of Melvin fluxtubes in de Sitter spacetime is also an open question; do they remain gravitationally bound, or are they ripped apart by the accelerated expansion of the universe?

SUBIR SACHDEV DELIVERS THE STERNHEIM LECTURE



The 2020 Helen and Morton Sternheim Lecture was delivered by Harvard University professor and National Academician, Subir Sachdev, on the topic of "Ultra-Spooky Action at a Distance: from Quantum Materials in the Lab to Black Holes". Professor Sachdev delivered his lecture to a large audience in the Integrated Sciences Building, a few weeks before the University was forced into remote mode by the COVID19 pandemic. Sachdev is the Herchel Smith Professor of Physics and department chair of physics at Harvard, a member of National Academies of Science in the US and India, and has received honors including the Lars Onsager Prize and the Dirac Medal. In his talk he explained how quantum entanglement helps us understand the unusual properties of such disparate systems as high-temperature superconducting materials and astrophysical black holes.

TEACHING LABS REMOTELY--BEFORE, DURING, AND AFTER THE PANDEMIC

The physics courses for life-sciences and engineering majors are the largest courses offered by the department, and there has always been demand for these courses from students who could not come to campus, particularly during the summer session. The problem has been that these courses have hands-on lab components that are necessary to fulfill their curricular requirements.

Even before the COVID-19 pandemic hit, Physics Department members Chris Ertl, Heath Hatch, Paul Bourgeois, and David Nguyen had started developing innovative solutions to this conundrum: lab kits with real equipment would be sent to students, so they could carry out the required labs at home. In this pandemic year demand for remote labs has skyrocketed, and the head start our department had in this area has helped our teaching-lab team get a massive remote lab kit operation off the ground. Looking forward as we move past the pandemic, the department will continue to be a leader in offering labs for remote teaching, albeit on a smaller scale.

The department has offered remote labs for life-sciences service courses as far back as 2016, and before the pandemic hit Chris had been working on remote labs for engineering services courses planned to start in 2021. All that changed suddenly in the middle of the Spring 2020 semester when students were told not to return after Spring Break. All of our lab courses would now need to be taught remotely: our two large life-sciences courses, our two large engineering-physics courses, and all of our lab courses for majors! Luckily our existing relationships with the companies that provide many of our lab-kit materials (Macmillan and eScience Labs) gave the department an inside track for obtaining materials in the face of skyrocketing demand from colleges and universities across the county.

Remote lab operation - David Nguyen

Remote lab operations - Masses and springs

Remote lab operations - IOLab devices

For that first pandemic Spring semester, 450 lab kits were purchased from eScience labs for the first-semester engineering service course. These kits included a mass set, a spring scale force sensor, and other accessories to study conservation of energy and simple harmonic motion. Also, in Spring 2020, 90 lab kits were purchased from Macmillan for our physics-major's Electricity and Magnetism course. These kits contained an IOLab device, many accessories, and a lab manual with 22 labs involving mechanics, waves and oscillations, and electricity and magnetism. The IOLab device is a multi-sensor device that transmits data wirelessly to software on a computer. The device contains a force sensor, a wheel sensor to measure position, velocity, and acceleration, an accelerometer, gyroscope, thermometer, magnetic field sensor, and several electronic sensors including analog, digital, and high gain sensors.

Remote lab operation - Big picture

For Summer 2020, demand for all of service courses more than doubled over the previous summer, as UMass was one of the few universities well-positioned to offer these courses with real remote labs. And, as the University has remained in mostly-remote mode through the Fall 2020 and Spring 2021 semesters, the department's remote-lab offerings have expanded further to include most of our upper-level lab courses. Specialized lab kits were developed, sourced, and sent out for the ILAB course, for the electronics course, and for the optics course, by their respective instructors Verena Martinez Outschoorn and Chen Wang, Rory Miskimen, and Shuang Zhou.

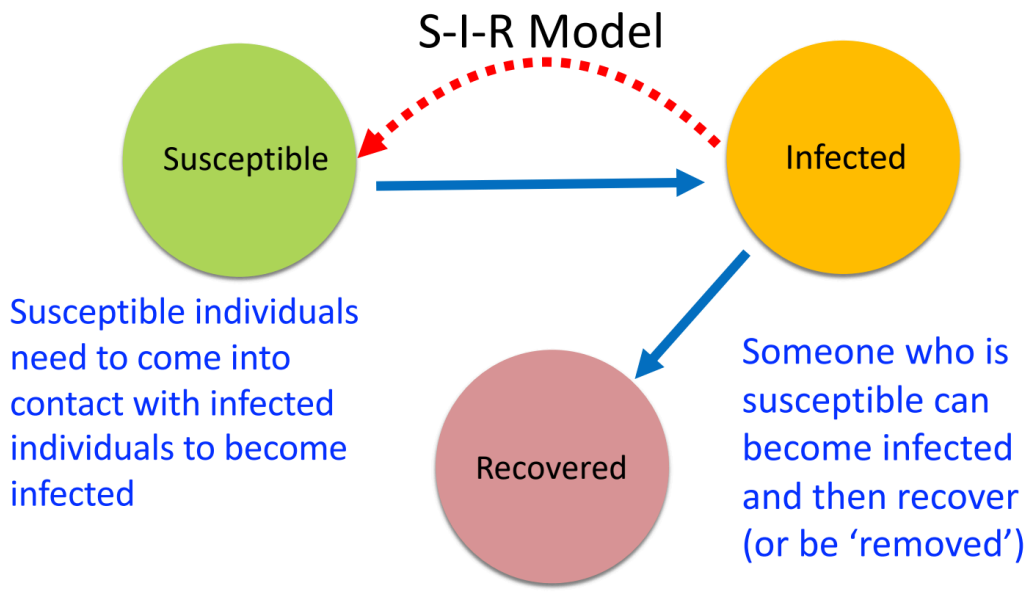
Successfully running these remote labs during the pandemic has required a massive logistical operation, which was set up in the temporarily unused teaching lab rooms on the second floor of Hasbrouck. Chris says, "A big thanks to David Nguyen for the work he has put in and continues to put in to purchase materials, pack and ship kits, pick up returned kits from the physical plant loading dock, unpack used kits and test items, organize all the materials, and determine what can be repurposed and what needs to be replaced. Lots of tape, bubble wrap and batteries! Also, a special thanks to Laurie Banas who took care of creating UPS shipping labels not only to send kits to the students but also labels so students could send them back to us. And thanks to the employees at the UPS drop-off in Staples who never once rolled their eyes when they saw David and me walking in with dozens of lab kits day after day!"

Remote lab operation - Lots of parts

PANDEMIC MODELING AND STEM EDUCATION

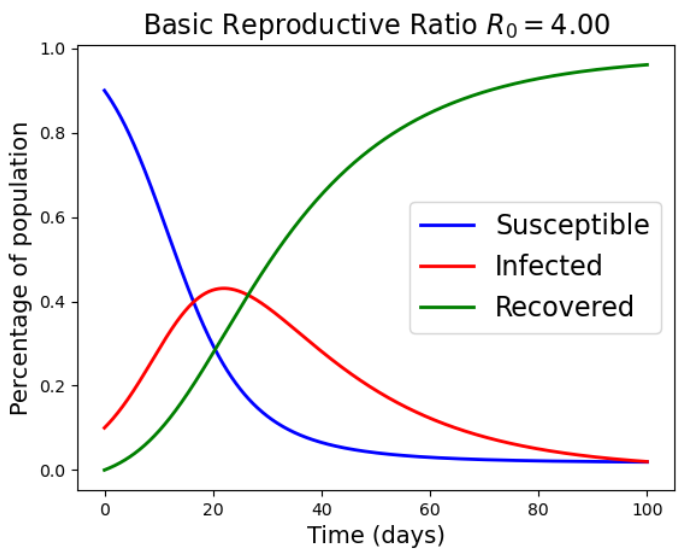
As with many other parts of the University, the pandemic has forced the UMass STEM Education Institute to cancel its plans for in person events and to respond creatively to the ongoing needs for K-12 outreach and education at all levels. The Stem Ed Institute was founded by Emeritus Prof. Mort Sternheim and now directed by Physics faculty Shubha Tewari (see the article in the spring 2020 Physics Newsletter).

Dr. Tewari put together a workshop, titled "Modeling Epidemics: An introduction," which ran remotely on May 14, 2020. The workshop first introduced the audience to two different resources: 1) the variety of places where data on caseloads and fatalities around the world was being published and made available to the public; and 2) links to some of the many models being used to predict the immediate future course of the disease, including the website maintained by UMass School of Public Health Professor Nicholas Reich, https://covid19forecasthub.org. Teachers were then shown the standard SIR (Susceptible-Infected-Recovery) model in detail. This is an example of what is often called a "container" model, in which you keep track of how different populations vary in time. You begin with a small number of "infected" individuals, who can then infect the "susceptible" population with a transmission rate probability. The number who move from the "susceptible" into the "infected" container depends on the number of existing infected as well as susceptible individuals. There is a recovery rate which causes individuals to move into the "recovered/removed" container. In this simplest version, the total population is fixed, and people do not get reinfected; the disease reproduction ratio R0 (pronounced "R naught") depends on the ratio of the transmission rate to recovery rate. As an example, the former can be changed by measures such as social distancing, the latter by the introduction of effective treatments. At the end, teachers were given both Excel-based and Python-based models to play with. Dr. Tewari's presentation "Modeling Epidemics: An Introduction" is available at https://scholarworks.umass.edu/stem_satsem/49/ and has been downloaded many times from educators all over the world.



Dr. Tewari then further adapted these materials for an undergraduate audience, students who were part of the Lee-SIP Summer Research Internship program. Because these students were unable to work in research labs over the summer, Tony Dinsmore led a mini-course on computation which was carried out remotely. Don Candela introduced the students to the idea of Jupyter Notebooks for compiling and running python code, and Shubha Tewari did a presentation on "Modeling Epidemiological Models in Python" at the end of which she provided all the students with the code for a simple python-based model. Students then formulated a research question based on a proposed intervention and modified the base model to investigate the predictions of their proposed intervention.

As we move into the post-pandemic era many of these new approaches and materials developed by the UMass Stem Ed Institute will be developed further, bringing ideas like computational modeling and tools like Python and Jupyter Notebook to a wide audience of educators.



UMASS SCIENCE OUTREACH CLUB GOES VIRTUAL

The mission of the Science Outreach Club has historically been to bring engaging science lessons and demonstrations to local area classrooms. The challenge this year was to figure out how to do outreach without the physical classroom. The club began by updating its web presence (https://scioutumass.wixsite.com/scioutumass and https://www.facebook.com/groups/umassscienceoutreach) and moving its weekly meetings to Zoom. The first meeting, which traditionally attracts new members with a display of entertaining science demos, was replaced with a "get to know us" presentation by the executive board. Even without the draw of the usual fireworks, more than two dozen members signed up. Weekly meetings were devoted not only to technical planning for school shows but also to community-building exercises with online games and lectures from grade school teachers.

In lieu of face-to-face demonstrations in the classroom, club members set about developing a set of video demonstrations they could present in the virtual classroom. Without easy access to the usual departmental equipment, they focused on experiments that could be done at home. The club's new YouTube channel (https://www.youtube.com/channel/UCe14Yu6CYt5rEthcLdQSF9A) includes demos for the how to make slime, how to balance a soda can on edge, how to extract DNA from strawberries, how to make oobleck, and how to turn a water glass upside down without spilling. Although much of the semester was spent developing materials and making videos, three well-received video shows were performed at the end of the semester with live commentary from club members. For next semester both the video library and the schedule of shows are to be expanded. Interested parties should contact the executive board at umassscienceoutreach@gmail.com.

UNDERCURRENTS RADIO

by Jennie Traschen
Professor of Physics and WMUA DJ

WMUA is a student-run college radio station whose license is held by UMass and area of reception is the Pioneer Valley.

Radio is a great way to communicate with people. When I was a postdoc at University of Chicago, I learned how powerful and informative interviews with people can be, by listening to Studs Terkel's iconic program. At UCSB, during my second postdoc, I connected with the weekly broadcast The Other Americas on KCSB. After joining the UMass Physics Department in January 1989, I stumbled upon the show Undercurrents on WMUA and started working with them. Though DJ training did not come naturally to me, I did get my FCC license and since then I have been doing shows.

Undercurrents describes itself as "giving voice to the community", and covers news and news analysis from a progressive perspective. A previous issue of this Newsletter included a photo of several physics undergrads who are members of under-represented groups in physics, and who, along with Prof. Lori Goldner, all crammed in the broadcast studio, which satisfyingly contains more equipment and CDs than space. They did a show about issues of sexism and racism in physics. The focus of the shows has included racism, sexism, and struggles to get the vote; militarism and work towards peace; global climate change and sustainability; health care crisis and single payer systems.

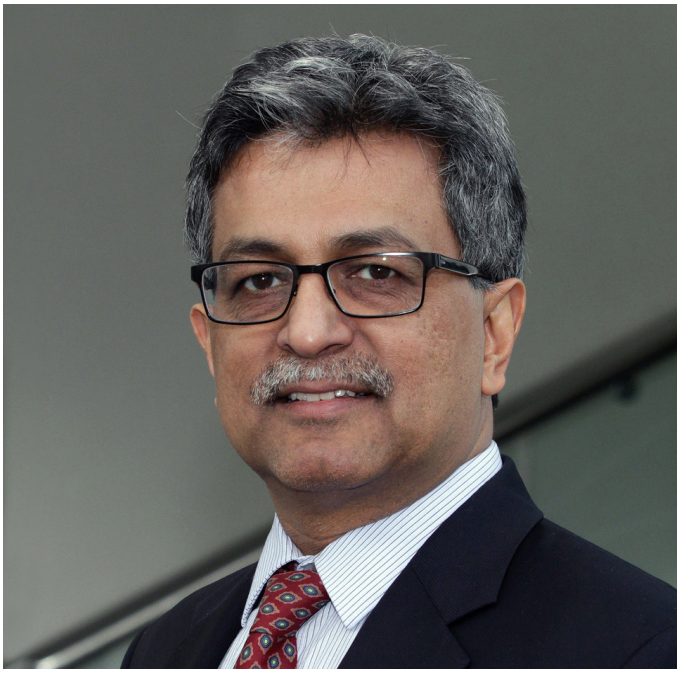
After a few years break, in Fall 2020 I decide to apply for a show slot again, as so many critical issues were/are threatening humanity. Following pandemic protocol all shows are now prerecorded. As with physics seminars the plus side is that guests and host are comfy in their homes wherever, but one also misses the experience of "being there" and pressing the various control board buttons at the right time. An archive of the show recordings can be found at https://anchor.fm/undercurrents-radio.

Radio is a great thing to get involved in. Even if you are no longer an undergraduate, many university stations welcome community involvement. An important niche is competent reporting on issues involving science, such as climate change and pandemic. One recent interview was about the impact of Antarctic ice melt on global temperatures, talking with Shaina Sadai who was a Physics major at UMass and is now finishing her PhD at UMass Climate System Research Center in Geosciences. And if you don't want to produce radio, just tune in.

Prof. Jennie Traschen teaching remotely

FACULTY EXTERNAL HONORS:

KUMAR NAMED CHAIR OF APS-DNP



On April 1 2020 UMass Professor Krisna Kumar (KK) became chair of the American Physical Society's Division of Nuclear Physics, following a year as vice-chair and a year of chair-elect of the division. The APS-DNP is one of the major divisions and has a membership of several thousand, distributed around the world. In addition to representing a major component of the annual APS April meeting, APS-DNP sponsors its own fall meeting at various locations around the country. Additional DNP responsibilities include the award of the APS Bethe, Bonner, Feshbach, Freedman, and thesis prizes and of the naming of APS fellows. The choice of leaders is determined by a vote by its members, and being named Chair is a major recognition of leadership in the field of nuclear physics. His appointment lasts for a year, after which he will serve a year as past-chair.

KK first came to UMass from Princeton University in 1999 and became a leader in experimental nuclear physics. He left in 2014 to take a similar position at SUNY Stony Brook but then returned in 2019 to assume the Gluckstern Professorship. He has had a wide-ranging research program at various laboratories, including MIT Bates, the Stanford Linear Accelerator Center (SLAC), the Thomas Jefferson National Laboratory at Newport News Virginia (JLab), and at the Waste Isolation Pilot Plant (WIPP) in New Mexico. Much of the work has involved parity violating electron scattering in order to measure the small strange quark content of the nucleon, the neutron skins of nuclei as well as the weak mixing angle, which is a fundamental quantity in the Standard Model. His work at WIPP involved looking for neutrinoless double beta decay using 200 kg of ^{136}Xe which, if detected, would demonstrate that the neutrino has a Majorana character. He is a leader of future efforts to improve the measurement of the weak mixing angle at JLab (MOLLER experiment) and to seek an even more sensitive probe for the existence of neutrinoless double beta decay involving nearly 5 tons of ^{136}Xe in a nickel mine in Sudbury, Ontario (SNOLAB).

JENNIE TRASCHEN ELECTED VICE-CHAIR OF APS DGRAV

Professor Jennie Traschen has been elected Vice-chair of the American Physical Society's Division of Gravitational Physics, (DGRAV), which serves as a focus for the organization and dissemination of research in all areas of gravitational physics. She will serve as Vice-chair for 2020--21, Chair-elect for 2021--22, Chair in 2022-23, and Past-chair the year after, keeping Jennie in the leadership line for the next four years. This happy news was announced at the annual April Meeting of the American Physical Society, which like many other scientific conferences, was moved from an in-person meeting to an online meeting due to the COVID-19 pandemic.

SHUBHA TEWARI ELECTED MEMBER-AT-LARGE OF APS GSNP

Dr. Shubha Tewari, Senior Lecturer in Physics, has been elected Member-at-Large of the Topical Group on Statistical and Nonlinear Physics, or GSNP, of the American Physical Society. She will serve a three-year term beginning at the 2020 APS March Meeting. (Although the 2020 March meeting was abruptly canceled due to Covid-19 concerns, the 2021 March Meeting was converted to a very successful all-remote event.) In addition to organizing focus sessions on current research topics at the March Meeting, GSNP confers fellowships, prizes and awards in this area of research.

FACULTY EXTERNAL AWARDS:

U.S. AIR FORCE RESEARCH PROGRAM SUPPORTS EARLY CAREER PHYSICIST ROMAIN VASSEUR

The Air Force Office of Scientific Research (AFOSR) announced this month that it will award approximately $16.1 million in grants to 36 scientists and engineers from 27 research institutions and businesses, including UMass Physics Assistant Professor Romain Vasseur. The awardees submitted winning research proposals through the agency's Young Investigator Research (YIP) Program.

Dr. Vasseur is a condensed matter theorist working on strongly correlated quantum systems. He says of the recognition, "I am thrilled and honored to be awarded this AFOSR YIP grant. The field of non-equilibrium many-body quantum physics remains largely uncharted territory, and I'm looking forward to using this award to explore emergent phenomena in non-equilibrium systems." He further explains, "One of the pillars of modern physics is the concept of emergence: at large scales, simplicity can emerge from complex physical systems in a universal way that is largely independent of microscopic details. This is well established for equilibrium systems, which are characterized by familiar properties like temperature. My proposal aims to uncover new emergent phenomena in quantum systems with many particles, driven far from thermal equilibrium."

The Young Investigator Research Program recognizes early career researchers who "show exceptional ability and promise for conducting basic research of military interest" and is intended to support "creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering." Recipients receive a three-year grant totaling $450,000.

Vasseur came to UMass in 2017 after working as a postdoctoral fellow at Lawrence Berkeley National Laboratory in the Condensed Matter Theory Center at the University of California, Berkeley. He earned his PhD at the Institut Physical Théorique, CEA-Saclay, France, and the Laboratoire de Physique Théorique Ecole Normale Supérieure, Paris.

PHYSICIST CHEN WANG RECEIVES DOE EARLY CAREER AWARD

Assistant Professor Chen Wang has been awarded a prestigious Early Career Award from the US Department of Energy's Office of Advanced Scientific Computing Research for his project "Enhancing Performance of Bosonic Qubits in Circuit QED with Reservoir Engineering." Using a three-dimensional microwave cavity oscillator as a qubit (a quantum bit, the fundamental unit of storage in quantum computing), he proposes to reduce errors in storage and manipulation of qubits with a new, counter-intuitive approach. He will harness friction – usually an unwelcome source of error in quantum devices – to make qubits perform with fewer errors. The work is most relevant for quantum computing, he says, but potential applications also include cryptography, communications and simulations. The award provides university-based researchers with at least $150,000 per year in research support for five years.

One of the basic differences between classical and quantum computing – which is not in practical use yet – is that classical computers perform calculations and store data using bits labeled as zero or one that never unintendingly change. Accidental change would introduce error.

"By contrast, in quantum computing, qubits can flip from zero to one or anywhere between. Quantum computing increases the ability to process information exponentially. With every extra qubit you add, the amount of information you can process doubles. This is a source of their great promise to vastly expand quantum computers' ability to perform calculations and store data, but it also introduces errors," Wang explains.

We are already familiar with how friction helps in stabilizing a classical, non-quantum system, he says, such as a swinging pendulum. "The pendulum will eventually stop due to friction – the resistance of air dissipates energy and the pendulum will not randomly go anywhere," Wang points out. In much the same way, introducing friction between a qubit and its environment puts a stabilizing force on it. "When it deviates, the environment will give it a kickback in place," he says. "However, the kick has to be designed in very special ways."

Wang's experiments will using a superconducting devices cooled to extremely low temperatures in a dilution refrigerator. His group will make these devices by depositing very thin, patterned aluminum films on sapphire chips.

INTERNAL UNIVERSITY AWARDS:

WALTER POLLARD RECEIVES CNS OUTSTANDING STAFF AWARD

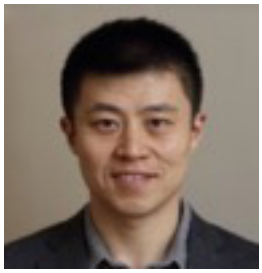
Physics Department machine shop foreman Walter Pollard has received the 2020 Outstanding Staff award from the College of Natural Sciences. Walter is an essential part of the research enterprise of the Department: he has DESIGNED AND custom-built many pieces of precision equipment for research labs, as well as equipment for the demonstration and teaching laboratories. WALTER ALSO CONSULTS WITH THE DEPARTMENT ON DESIGN AND MATERIALS FOR OUR APPARATUS and runs a machine shop course for students twice a year. Through this course, many have learned design, drafting, measurement and machine shop TOOLING from him. In receiving the award, Walter says "This is the highlight of my career here at UMass. This makes me proud, appreciated and respected as a part of the CNS team."

MANASA KANDULA MENTORING AWARD

UMass ADVANCE is "a collaborative quest begun in 2018 to transform UMass Amherst into a place where every faculty member, regardless of gender, race/ethnicity, or sexuality, feels respected and has equal professional opportunities."

This year, the UMass ADVANCE program awarded four teams of scientists Mutual Mentoring Grants to help support collaboration and equity in science. One of these went to Assistant Professor Manasa Kandula in Physics and Caitlyn Butler of Civil and Environmental Engineering, who together led the STEM Women's Interdisciplinary Group. The aim of this group is to promote research collaboration in the area of Particles and Polymers in Biofilms; the grant will help them develop high-risk/high-payoff research proposals. The UMass ADVANCE program is underwritten by a five-year, $3 million National Science Foundation grant to support gender equity for faculty in STEM fields with a focus on collaboration.

SHUANG ZHOU RECEIVES MENTORING GRANT



Assistant Professor Shuang Zhou has been awarded a Mutual Mentoring Grant by the Office of Faculty Development to lead a new Soft Matter Writing Group. This group is composed of faculty in the soft matter field with a focus on improving the quality and quantity of grant proposals of all members through open planning, accountable writing, and peer-review meetings. During the summer and fall of 2020, the group met regularly and provided peer mentoring to faculty in the Physics, Polymer Science and Engineering, and Mechanical and Industrial Engineering departments as they developed grant proposals. The group plans to mentor faculty writing for a new set of grant proposals starting summer, 2021.

ADVANCE FACULTY FELLOW - TOGGERSON

Brokk Toggerson was selected to be an ADVANCE Faculty Fellow for the 2020--2021 academic year. ADVANCE is an NSF program that seeks to increase the representation and advancement of women in academic science and engineering careers through systemic, institutional change. Professor Toggerson's Fellowship stems from his previous work as a TIDE (Teaching for Inclusiveness, Diversity, and Equity) Ambassador. "My experience with TIDE was truly transformative and caused me to expand my understandings of diversity and equity and how to create an inclusive and welcoming environment in the physics classroom. As a follow-on, I formed a group called the Integrated Introductory Life-Science Education Group (I^2LSE) with fellow lecturers Lara Al-Hariri (Chemistry), Adena Calden (Math), and Caleb Rounds (Biology). From conversations in both TIDE and I^2LSE, I have truly come to appreciate what Rendón in her Sentipensante (Sensing/Thinking) Pedagogy describes as 'diverse disciplinary forms of learning and [recognize] that learning can be enhanced with access to diverse forms of knowledge.' I feel that a deep understanding and appreciation of these significant disciplinary differences are critical when designing courses, particularly my 600-student Physics 132 Physics for Life-Science Students II course."

According to Professor Toggerson, centering these disciplinary differences makes other classroom discussions more natural and inclusive. Students appreciate his work, with one student noting that "I'd never really thought of myself as a scientist before, and the class discussions where we took time to discuss how we are scientists and the impact we could have were incredibly inspiring for me." Professor Toggerson hopes to continue to foster this sense of scientific self-identity through development of 132 labs that center design, choice, and data analysis.

Professor Toggerson's Fellowship also grew out of his work with physics graduate students Jake Shechter (PhD 2020) and Sara (Feyzbakhsh) Shechter to develop the Physics 691G seminar which, among other goals, works to develop a positive physics graduate student self-identity. In the coming year, Professor Toggerson plans

to keep working in this direction. He has a research project exploring the effectiveness of interventions to mitigate stereotype threat in physics for life-science courses done in conjunction with colleagues at Mount Holyoke and Smith Colleges. Another upcoming research project, done with an undergraduate student, looks at how different formulations of soliciting questions from students impacts classroom equity. He will work with his I²LSE colleagues to develop biologically and chemically authentic questions for his 132 course, and plans to present that work in an invited talk at the summer AAPT meeting. His work will also be disseminated through a pair of videos: one for the new UMass website and one for a lesson on implementing equitable and inclusive practices in large-enrollment classrooms. Among all of this, he hopes to find time to update the physics education blog: http://physedgroup.umasscreate.net/blog more regularly than in the fall, and (most importantly) to spend time with his 2-year old child!

STUDENT AWARDS:

KATE MALLORY RISING RESEARCHER

Kate Mallory '21 is one of eight undergraduates who has won a Fall 2020 Rising Researcher Award. The Rising Researcher program celebrates students who excel in research, scholarship or creative activity.

Kate is a physics major, a member of the Commonwealth Honors College, with a concentration in astronomy. Under the mentorship of Professor of Astronomy Daniela Calzetti, Kate researches star formation. As she explains, "Most star formation in the young universe, when it was only one to four billion years old, occurred in dusty galaxies. The young stars heat the dust, which shines in the infrared. The goal of this project is to demonstrate that star formation can be traced in dusty systems

using simple computer diagnostics to track infrared radiation."

Kate has been working with Prof. Calzetti and a graduate student on a scientific paper on the project. Their findings may be used to analyze images of dusty galaxies that will be taken by the powerful new James Webb Space Telescope, expected to be launched later in 2021.

Kate's interest in astronomy began in seventh grade. During her first year at UMass, Kate connected with Professor Calzetti and asked her to be her advisor for her Commonwealth Honors College thesis. Professor Calzetti says that "Kate is a promising researcher who is already rising to the challenge of producing innovative science results. She is poised to grow into a full-fledged scientist."

SEAN VANGELDERN - HONORABLE MENTION, NSF GRADUATE RESEARCH FELLOWSHIP PROGRAM

Sean van Geldern, a second-year PhD student, received honorable mention for his application to the National Science Foundation's Graduate

Research Fellowship Program. Sean did his undergraduate work at the University of Illinois Urbana-Champaign, where he received a dual degree in Chemical Engineering and Physics. Outside of physics, he enjoys cooking, reading, and hiking.

Sean works under the guidance of Professor Chen Wang, whose lab specializes in quantum information research and technology. They use qubits as quantum analogs to classical computing bits. According to Sean, "Our qubits utilize superconducting Quantum Electrodynamics, meaning that they are superconducting circuits with a non-linear circuit element called a Josephson junction. This element turns the circuit into a modified LC oscillator with anharmonic energy levels, allowing us to drive one transition of the qubit with microwave pulses and treat it as a two-level system where the ground and excited states can be then used as 0 and 1 logical states. The lab mainly looks at how these qubits interact with each other and how to preserve qubit coherence via quantum error correction schemes."

The aim of Sean's current project with colleague Yingying Wang is to understand how the incorporation of non-reciprocity affects quantum systems. "We have been studying how two microwave cavities that house qubits can interact with each other when they are connected by a non-reciprocal element in the form of a microwave circulator, where the degree of non-reciprocity can be tuned via an applied magnetic field. We have been looking at how things like photon shot noise-dephasing can be affected, when the photon population is non-reciprocally coupled to the qubit that is being measured to determine the de-phasing rates across different degrees of non-reciprocity. We have also been looking at how the dispersive shift between a qubit and a cavity acts, when the qubit is indirectly coupled to the cavity in a non-reciprocal manner. We have been working quite closely with Professor Aashish Clerk's group at the University of Chicago so we can take their theoretical predictions for this sort of system and compare it to the experimental values we obtain. We hope that this research will lead to an understanding of non-reciprocity in quantum elements that will yield useful architectures to further the capabilities of quantum information technology."

AWARDS LUNCH SPRING 2020 LIST

UNDERGRADUATE AWARDS, SPRING 2020

HASBROUCK SCHOLARSHIP AWARD (JUNIOR, ACADEMIC EXCELLENCE)

Mykhaylo Barchuk
Jacob McConley
Alexander Shilcusky

LEROY F. COOK MEMORIAL SCHOLARSHIP (ACADEMIC EXCELLENCE AND ACTIVITY IN OUTREACH OR TEACHING)

Anshul Bhargava
Linda Oster

MORTON & HELEN STERNHEIM AWARD (EDUCATIONAL OUTREACH AND/OR TEACHER PREPARATION)

Anthony Englert
Faizah Siddique

IDA AND JOSEPH SIMENAS AWARD (ACADEMIC EXCELLENCE)

Emma Lovett

KANDULA SASTRY BOOK AWARD (ACADEMIC EXCELLENCE AND VERSATILITY)

Ben Reggio

AWARDS

RICHARD KOFLER'S CLASS OF '76--'77 SCHOLARSHIP
(STRONG INTENTION OF CAREER IN PHYSICS)

Emily Martsen

EDWARD S. CHANG FUND
(SUPPORTING OUTSTANDING RESEARCH)

Mykhaylo Barchuk
Grace Chowdhry
Ben Feinland
Isaac Spivack

ENDOWMENT FOR FUTURE PHYSICISTS PROFESSOR KENNETH AND JOAN LANGLEY RESEARCH
(SUPPORTING PROPOSED SUMMER RESEARCH PROJECTS)

Linda Oster
Nicholas Popowich

GRADUATE AWARDS, SPRING 2020

ARTHUR QUINTON TEACHING ASSISTANT AWARD
(OUTSTANDING TEACHING ASSISTANT)

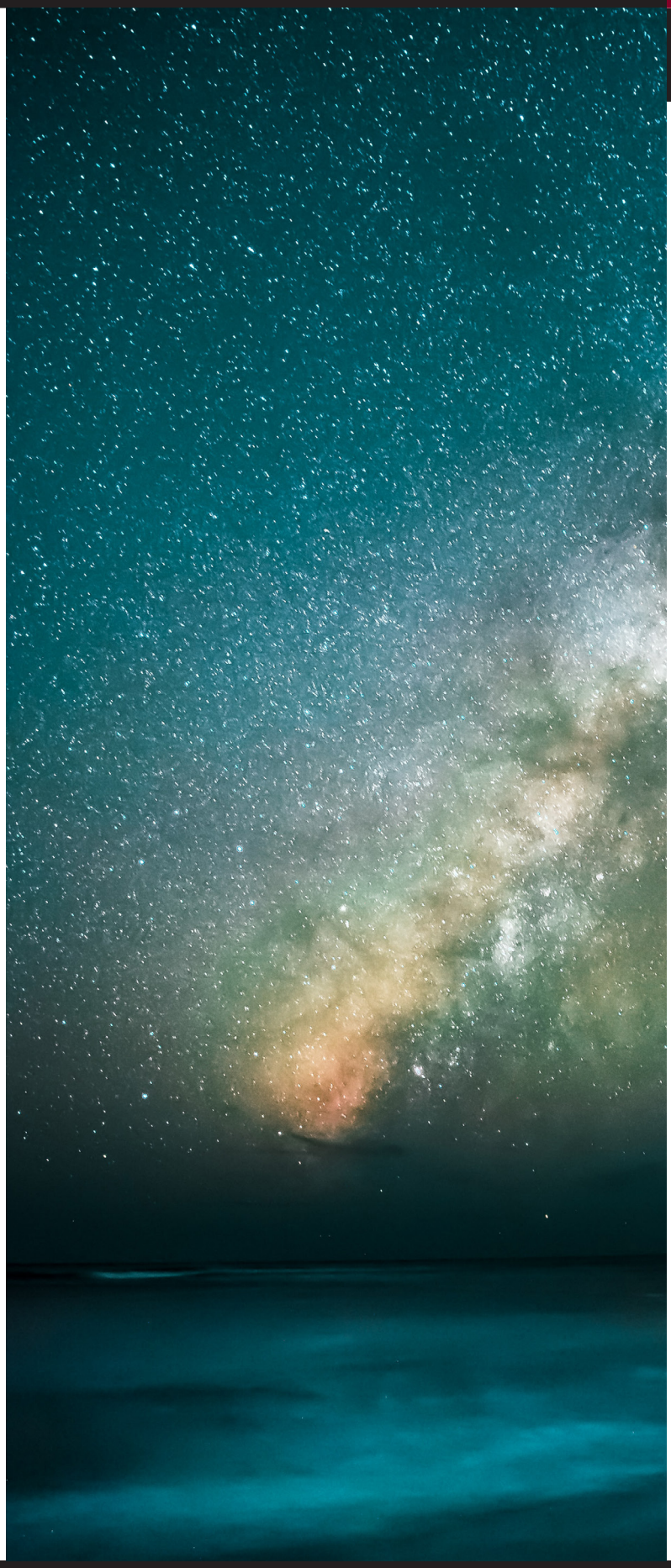
Sebastian Urrutia Quiroga
Chris Amey

DANDAMUDI RAO SCHOLARSHIP
(RESEARCH IN BIOLOGICAL PHYSICS OR CLOSELY RELATED AREA, IN MEMORY OF KANDULA SASTRY)

Vahini Nareddy

KANDULA SASTRY THESIS AWARD
(PRESENTATION OF OUTSTANDING THESIS)

Shao-Yu Chen



NEW ALUMNI

BS AND BA DEGREES

Undergraduate degrees awarded since the Spring 2020 Newsletter

Sophia Abi-Saad
Sasha Bakker
Brendan Barry
Joshua Bednaz
Jonathan Cali
Frederick Coburn
Zachary Curtis
Thomas Czernik*
Hani Dekaidek
Ian DeTore
Devan Dhand
Devon Endicott
Benjamin Feinland
Max Field
Olivia Flynn
Connor Gauthier (BA)
Lucy Grossman
Yanyu Gu
Emily Hansen* (iCons)
Matthew Harris
Jason Hathaway
Owen Henry
Zhixian Huang
Scott Israel
Calvin Johnson
Robert Keane
Zoe Kearney
William Kotlinski
Rishika Kumar
Senrui Li
Kenneth Lin
Daniel Lis
James Liu
Qihong Luo
Eric Lyon
Bridget Mack
Makala Maclean
Michael Maitland
Neil McCathy
Michael McNelly
Jack Mirabito
Kareem Mohamed-Aly
Mackenzie Naseery
Hanna Ng
Savio Oliveira
Linda Oster
Nicholas Popowich
Anthony Raykh
Benjamin Reggio
Johnathan Rizzi
Nathan Sherman
Tom Shneer
Jacob Smith
Sasha Stein
Benjamin Strain
Michael Tomson
Aubrey Wiederin
Dongge Yan
Louis Yoo
Yuxuan Zeng

**Completed Department Honors with a Capstone project.*

"iCons" means that the student is part of the Integrated Concentration in Science program here at UMass Amherst..

BS DEGREES

NAME	ADVISOR	THESIS TOPIC
Jack Bolster	Andrea Pocar	"Characterization of Silicon Photomultiplier for the nEXO Collaboration"
Thomas Czernik	David Kawall	"Low Magnetic Field Noise Electrodes and a Floating Nanoammeter for the CeNTREX Experiment"
Emily Hansen	Steve Acquah, Chemistry	"Combined renewable energy methods"
Jackson Harmon	Igor Kaltashov, Chemistry	"Polyanion Interactions with the Complex Formed by SARS-CoV-2 and Angiotensin Converting Enzyme Type 2 (ACE2)"
Robert Keane	Tony Dinsmore	"Growth and Formation of Microscopic Ultrathin Sheets in Suspension: Progress Toward Understanding Interactions with Vesicles"
Bridget Mack	Verena Martinez Outschoorn	"Search for long lived exotic particles decaying into pairs of muons"
Kate Mallory	Daniela Calzetti, Astronomy	"Dust Emission as a Function of Age in the Nearby Galaxy M3"
Samantha Maragioglio	Tony Dinsmore and Shubha Tewari	"Rate of Surface Charge Decay of Granular Media"

BS DEGREES

NAME	ADVISOR	THESIS TOPIC
Jacob McConley	Narayanan Menon	"Clumping in a Model of Self-Propelled Particles in One Dimension"
Cole Mirabito	Andrea Pocar	"Characterization of Charge Collection Tiles for nEXO with a Radon source"
Jack Moody	Rory Miskimen	"Nuclear Detonation Produced Ejecta Film Analysis"
Noah Paradis-Burnett	Narayanan Menon	"Study of Properties of Random Loose Packings of Immersed Collision and Granular Systems"
Ben Reggio	Shubha Tewari	"Properties of Two Particle Electrostatic Interactions"
Alexander Shilcusky	Chen Wang	"Modeling of a Ferrite Circulator in a State of Partial Saturation, with application to Cavity Quantum Electrodynamics (cQED)"
Isaac Spivack	Greg Grason, Polymer Science and Engineering	"Planar Self Assembly of Geometrically Frustrated Trapezoidal Monomers"
Benjamin Strain	Jennifer Ross	"Characterization of Novel Surfactant Molecules for Liquid Crystal Configurational Transition"

PHD DEGREES

NAME	ADVISOR	THESIS TOPIC
Atkinson, Daria	Lorenzo Sorbo	"Phenomenology of Fermion Production During Axion Inflation"
Du, Yong	Michael J. Ramsey-Musolf	"Searching for new physics at colliders and from precision measurements"
Duque Jimenez, Carlos	Christian Santangelo	"Distortion-Controlled Isotropic Swelling andSelf-Assembly of Triply-Periodic Minimal Surfaces"
Farhadi, Leila	Jennifer L. Ross	"Composite Network of Actin and Microtubule Filaments, Self-Organization and Steady-State Dynamics"
Meadows, Zachary	Stephane Willocq	"A Search for New Resonances Decaying into a Weak Vector Boson and a Higgs Boson in Hadronic Final States with the ATLAS Detector at the Large Hadron Collider"
Roberts, Michael	Lorenzo Sorbo	"Phenomenology of Fermion Production During Axion Inflation"
Zuraw-Weston, Sarah	Anthony D. Dinsmore	"Controlled membrane remodeling by Nanospheres and Nanorods: Experiments targeting the design principles for membrane-based materials"

MS DEGREES

Berry, Michelle

Conway, Alyssa

Miryala, Karthik

Wang, Winnie

Xie, Wanting

Zhou, Nuoya

INCOMING GRADUATE STUDENTS FALL 2020

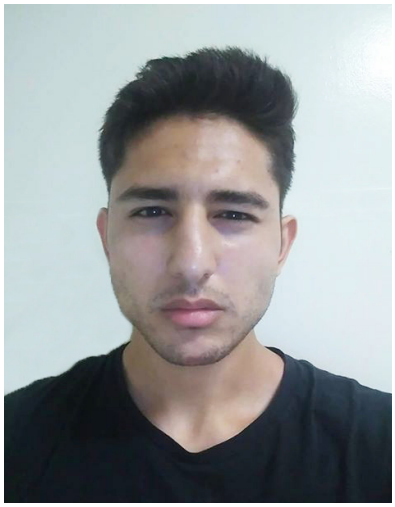

Alfaifi, Abdullah


Aly, Kareem Mohamed


Boggs, Aaron


Chaplinsky, Luke


Corba, Sofia


Diaz, Manuel


Dutta, Pronay


Harris, Matthew

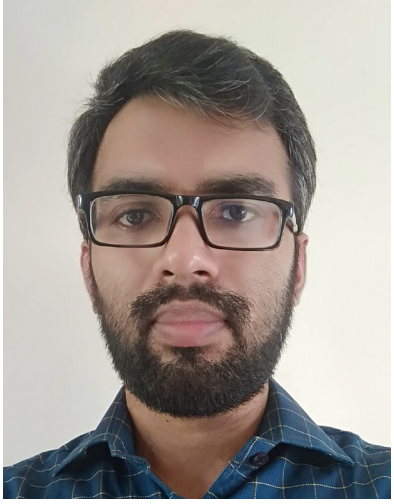

Humphreys, Daniel

INCOMING GRADUATE STUDENTS FALL 2020

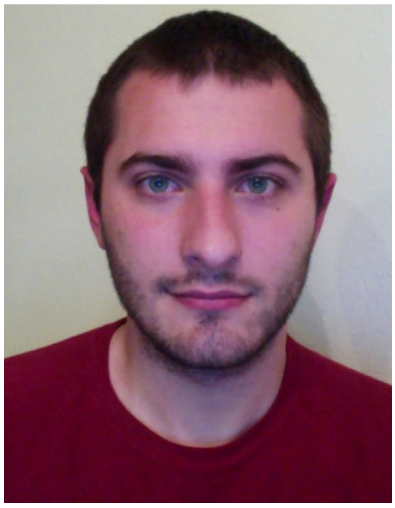
Kulkarni, Aditya

Mott, Jonathan

Roush, Dalton

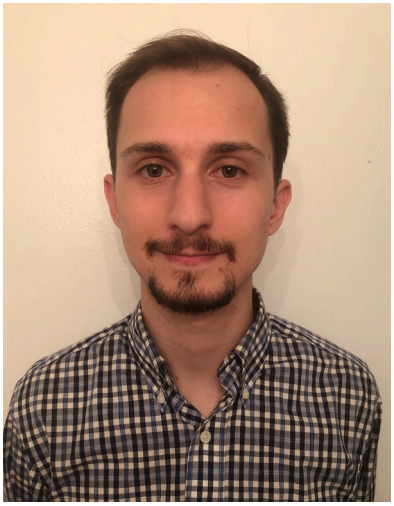


Sarker, Sakib



Sleczkowski, Jacob

Su, Jhih-Ying



Sullivan, Kyle

Wu, Sili

Yang, Zhiyu

NEW FACULTY

MANASA KANDULA

Manasa Kandula is a new faculty member who joined the department in September of 2019. Her research interests lie in the field of experimental soft condensed matter. Says Professor Kandula, "I first heard of the field "soft matter" during my masters. I was enthused to learn that a lot of materials we use every day fall under this umbrella of materials called soft materials. My interest in pursuing soft matter for Ph.D. started when I learned how distinct these materials are, with their atypical rheological properties, compared to the conventional solids or simple liquids. The other aspect of soft matter that increased my passion for the field is its interdisciplinary nature, which brings together physics, nanotechnology, materials science, and even biology."

Manasa received her PhD at the Jawahartal Nehru Center for Advanced Scientific Research in India. Her thesis was directed towards understanding the microscopic underpinning of fundamental phenomena in condensed matter, specifically the glass transition and crystallization, using colloids as model atoms. In comparison to their smaller atomic counterparts, the large sizes and slow dynamics of colloidal particles make it possible to investigate these phenomena using ordinary light microscopy and single particle tracking tools.

While single-particle visualization experiments are an exquisite way to study these macroscopic models of soft materials, Professor Kandula's postdoctoral work at the Center for Soft and Living Matter of the Institute for Basic Sciences in South Korea focused on dynamics at nanoscopic length scales. There, she adapted a new technique known as liquid-phase electron microscopy (liquid phase TEM) to the visualization of macromolecular motion in real time. Unlike traditional electron microscopies that require high vacuum, liquid-phase TEM permits imaging with nanometer resolution in liquids.

At UMass, Professor Kandula's lab is currently investigating non-equilibrium physics and bio-inspired materials physics using inorganic active colloidal particles. "We strive to understand the microscopic workings of soft and active materials and find connections to their macroscopic behavior. In this quest, we become "physics movie-makers," studying physics by combining microscopy with image processing tools and quantitative statistical analysis. Using optical microscopy and electron microscopy together for spatiotemporal dynamics, we can study a plethora of soft materials at a wide range of length scales and time scales. We believe the combination of these techniques and systems will provide unprecedented insights into microscopic underpinnings of the observed mesoscale phenomena in soft and living materials."

VARGHESE MATHAI

Professor Varghese Mathai joined the physics department in the Fall of 2020. He was born in India and obtained his undergraduate education from College of Engineering, Trivandrum, and his Master's from the Indian Institute of Science. Varghese moved on to pursue his PhD from the University of Twente in the Netherlands. His PhD thesis was on particle-laden turbulence and active matter, combining experimental and computational techniques. He then moved to the US for a postdoctoral position at Brown

NEW FACULTY

University, where his research focused on the interaction of soft materials and bubbles with turbulent flows. In addition to his academic training while he was in India, Professor Mathai also spent one and a half years in the Aircraft Engines Division of General Electric.

Currently, the primary focus in Professor Mathai's research group is active multiphase turbulence and soft fluid-structure-interactions. Professor Mathai is building a facility to conduct 3-D particle tracking experiments, which can lead to a better understanding of the interactions of soft materials and active particles with hydrodynamic turbulence. The research can help, for example, in our understanding of the physics of rain initiation in atmospheric clouds and the mechanisms of modified energy cascade in bubble-induced turbulence. On the applied side, his research has led to industrial applications where active, biphasic particles can be used to enhance the heat exchange and mixing properties of fluids. As described elsewhere in this Newsletter, recent research from Varghese's lab has addressed the transport of aerosol particles, and revealed ways to reduce airborne transmission risks in passenger cars and other confined environments. He enjoys interacting with students at both undergraduate and graduate levels and is looking for motivated graduate students and undergraduate students to join his group. In his first year at UMass, Professor Mathai taught a new Topics in Soft Matter course and the ILab (Intermediate Physics Lab) course for physics majors--both courses completely remotely, due to the COVID-19 pandemic.

NEW STAFF

CASTIEL PSALLIS

In July 2020 Castiel Psallis was hired as the department's new Director of Lecture Prep (our previous Lecture Prep Director, Chris Ertl, has shifted to teaching-related duties, as described elsewhere in this Newsletter). Castiel previously held technical support positions at Springfield College and at Smith College, where she also received her degree in Studio Art with a minor in Astronomy. Her hobbies and interests include music production, and singing in the Pride Chorus at the Northampton Community Music Center. Castiel comments that starting the Lecture Prep position in the middle of the pandemic has been complicated, and she has had to devise new methods for delivering lecture demo materials to complement remote teaching. As the University gets back to normal operation, Cas has been planning to work with faculty to develop some new demos, and also to reorganize the existing equipment and improve and expand the lecture-prep documentation and website.

FACULTY PROMOTIONS

BENNY DAVIDOVITCH PROMOTED TO FULL PROFESSOR

Benny Davidovitch has been promoted to Full Professor. Benny is a condensed matter theorist who works on problems of pattern formation in nature in both equilibrium and non-equilibrium situations, with a recent focus on thin elastic sheets and capillary phenomena. He is one of the co-founders of the annual Soft Matter Summer School at UMass.

FACULTY PROMOTIONS

TENURE FOR MARTINEZ OUTSCHOORN

Dr. Verena Martinez Outschoorn has been awarded tenure and promoted to Associate Professor. Prof. Martinez Outschoorn does research with the ATLAS collaboration at the CERN Large Hadron Collider. Her research is focused on searching for new physics, using the Higgs boson to try to probe the matter-antimatter asymmetry problem and dark matter. Dr. Martinez Outschoorn is also working on hardware upgrades to the detector, focusing on the muon trigger. Congratulations, Verena!

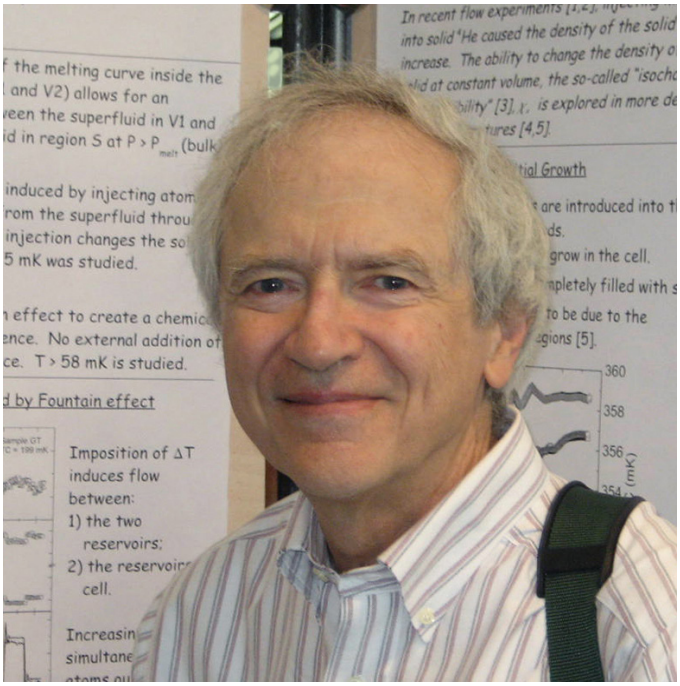
BOB HALLOCK RETIRES

Professor Robert Hallock retired from his regular faculty position at the end of the May 2020 semester after completing 50 years as a faculty member in our department. He will continue with the department for a number of years into the future with a post-retirement appointment, which will provide an opportunity to teach one course per year. He was an undergraduate Physics major in the Department here at UMass Amherst in the period 1961–1965 (BS). When he arrived as a freshman, there were about 6000 undergraduates on campus and few graduate students. He recalls that there were roughly a dozen or so faculty members in the Physics Department. Physics did offer a MS at that time, but only added the PhD later in the decade. He attended Stanford University and earned a MS in 1967 and a PhD 1969. He remained at Stanford as a Postdoc for a year under an AFOSR research fellowship and then joined the UMass Physics Department as an Assistant Professor in 1970, after a rather unusual hiring process. His addition, along with Edward Chang, brought the number of faculty members in the department to 52! He was promoted to Associate Professor in 1974, to Professor in 1979 and to Distinguished Professor in 2001. He served as Department Head of the Physics and Astronomy Department in 1985--1993 (and as Acting Head in 1999 for a semester while Professor Donoghue was on leave). He was Interim Dean of the College of Natural Science for the 2000-01 year, but turned down an offer to remain as Dean to return to full time teaching and his research program. Among a number of local awards, he received the Chancellor's Medal, the UMass Distinguished Teaching Award and the Distinguished Faculty Award presented by the Alumni Association. He is a Fellow of the Massachusetts Academy of Sciences.

His teaching has been aimed in a variety of directions. He developed a course on Physics for Nursing students and one for Junior Physics majors on Fluid Mechanics. He also helped to develop a course on the physics of light and developed, with colleagues in the Five College community, a laboratory course for upper division majors and an experimental course on the general use of graphics to make an effective and convincing case. In recent years he has taught the junior Physics major writing course and also the introductory course on the science of the weather and climate.

Over the years Bob has served the University community in a number of ways. He served as Chair of the Research Council (1981--82) and was instrumental in the creation of the "Conti" Fellowship Award, chaired a search for Chancellor (1982), and chaired or co-chaired searches for a Graduate School Dean, Provost, Dean of Nursing, chaired the NSM/CNS Distinguished Professor Nomination Committee for many years, and chaired committees to evaluate Deans, etc. He also participated as a member of various campus-wide committees including the committee that developed the post-tenure review process, committees to search for Deans,

BOB HALLOCK RETIRES



for Vice Chancellor for Research, and served as a member of the Provost's Advisory Council.

In the wider scientific community he chaired a Quantum Fluids and Solids conference, which he brought to UMass in 1998, attended by 226 scientists from around the world, which provided the genesis of the QFS Committee that regularized the sequence of such international meetings and continues to this day. He also has served as Secretary and Chair of the IUPAP C-5 Commission on Low Temperature Physics, and served for many years on the Board of Directors of Research Corporation for the Advancement of Science where he chaired the Science Advancement Committee and chaired one of its Strategic Planning committees.

His research specialization has been in Quantum Fluids and Solids (experiment), where he is recognized as one of the international leaders. He received an A.P. Sloan Research Fellowship in 1972, became a Fellow of the American Physical Society in 1982 and received a J.S. Guggenheim Memorial Fellowship in 1992. Bob often says how much he has benefited from his association with his colleagues in the Condensed Matter group in the department. In particular, his long series of experiments on liquid helium films benefited from interactions with Profs Guyer and Machta. More recently his work on solid helium was stimulated by Profs Svistunov and Prokof'ev. Throughout, he has benefited from many conversations with Prof. Bill Mullin, often over tea in his office. In addition to his colleagues, he greatly appreciates his long-term support from the National Science Foundation, and the superb help he has received from the many staff members in the department. In particular, the gifted craftsmanship from our Departmental machinists over the years has enabled a number of his experiments.

Bob often has said that one of the very best decisions he made as Department Head was to offer a position to hire Ann Cairl (from a phone booth while traveling to an APS Section meeting along I-91 in Vermont), who accepted to become the long-term Assistant to the Head. And, he has been enriched by the 33 graduate students who completed PhD degrees under his general supervision and the 19 postdocs who have worked with him over the years. He thinks of those folks as part of his extended family. Each has taught him something and often left him with lasting gifts, starting with Ephraim Flint who was the first of his graduate students to graduate; Eph brought his record collection, turntable and speakers into the lab, which vastly widened Bob's perspective on classical music.

His wife, Norma (whom he met in the sixth grade) retired a few years ago from a long career as a Registered Nurse and Pediatric Nurse Practitioner. He appreciates her unending tolerance of his devotion to Physics and her patience through the innumerable weekend days and long nights in the lab. Together they have two sons, one, Robert, an Optical Engineer, the other, Kevin, currently a Dean at Cornell University. They have five grandchildren.

OBITUARIES

ROBERT VLADIMIR KROTKOV 1929–2021

Emeritus Professor Robert V. Krotkov died in Northampton on February 14, 2021, of complications due to COVID-19. Bob was the elder of two children born to Russian immigrant parents on July 17, 1929, in Toronto, but was born and raised in Kingston, Ontario. He obtained an undergraduate degree in physics from Queens University in Kingston and then a PhD from Princeton University, where his thesis advisor was Bob Dicke. Together with Dicke and Peter Roll, he performed a classic and oft-cited equivalence principle test, measuring the equality of gravitational and inertial mass to one part in 10^{11}. While there he married Joan Mason. After leaving Princeton, he taught at Yale for six years before coming to UMass in 1966 as part of the Gluckstern expansion, and regularly taught many of the introductory physics courses. He set up an atomic physics laboratory on the second floor of "Old Hasbrouck" and eventually, together with Janice Shafer and Jimi Sakai, undertook a new test of the gravitational interaction using the gigantic amounts of water transfer involved in the Northfield Pumped Storage project. Bob retired in 1997 and relocated to Hadley, where he was able to continue to visit the department for colloquia, etc., and he was well known for asking difficult and penetrating questions.

Bob and Joan raised their three children in Amherst before divorcing amicably in 1980. His second wife Bonita Janes, whom he married in 1994, died in Hadley only weeks before Bob. Together they leave seven grandchildren and step-grandchildren.

JOHN JOSEPH BREHM 1934–2021

Emeritus Professor John J. Brehm passed away in Nazareth Hospital in Philadelphia, PA on 15 January 2021. Born in Memphis, Tennessee, on 6 December 1934, he grew up in Silver Spring, MD and went on to receive a BS and PhD in physics from the nearby University of Maryland in College Park. In November of 1959 he married Mary Ellen Kempers in Silver Spring, and the couple moved to Evanston, Illinois, where John had accepted a position as Assistant Professor at Northwestern University. His research was in the area of high energy physics and Northwestern was building a major group in this area. He was hired at UMass during the mid-60s Gluckstern expansion and continued his high energy work here, finishing his career as Professor of Physics in 1997. In the last years of his career, he had developed an interest in chaos theory.

John was known for his excellence in teaching, and he had a gift for explaining challenging concepts to his students, in both introductory as well as more advanced courses. This knack led to his writing, together with UMass Professor Bill Mullen, of a 926-page textbook, "Introduction to the Structure of Matter," aimed at second year introductory physics students, which was first published in 1988 and was eventually adopted at many universities worldwide.

He retired after three decades at UMass and moved first to Charlottesville, VA and then to Doylestown, PA in both cases to be near one of his four children John, Robert, Richard, and Jennifer. By the time of his passing his beloved family had grown to include ten grandchildren as well as two great grandchildren at which time he and Mary Ellen had been married for 61 years.

ALLAN M WALSTAD

I did my PhD thesis in cosmology under Ted Harrison. Ted was something of a larger-than-life figure in the astronomy program, with his British accent, his dominating presence at colloquia, and the ever-present fragrance of Gold Block tobacco from his pipe. In addition to his research accomplishments, Ted's visionary philosophical book Masks of the Universe, written many years later, is a gem.

I remember the excitement around Russ Hulse and Joe Taylor discovering the pulsar in a binary system that subsequently earned them the Nobel Prize. I had served as a TA in Joe's intro astronomy class. I also remember the daily table hockey matches in the astronomy grad student mass office in Hasbrouck Lab. And a sixth-year student, Bob Anton, whose patient tutoring in quantum mechanics during my first year probably saved my grade and my future.

After grad school, I taught two hectic years at a community college in New York, fled to temporary appointments at Penn State-Scranton and Bates College, and finally landed a tenure stream position at the University of Pittsburgh campus in Johnstown PA. During my brief stay at Bates, one of my astronomy students was Jeff Kenny, who later earned his PhD at UMass and served as department chair in astronomy at Yale. Jeff and I spent some of our time together investigating flying saucer reports.

At UPJ I taught mostly intro physics to mostly engineering students for 42 years before retiring in September. (Well, I'm back again this spring as an adjunct to teach my astrophysics course one more time.) A great advantage has been total exemption from teaching labs. As a college freshman, in my first lab my group broke two hygrometers. As an astronomy TA at UMass, I burned out two blackboard optics demos. And in one class at UPJ, demonstrating atomic spectra, I came within a whisker of grabbing a bare 5,000 Volt electrode before remembering to turn it off.

Falling behind research in cosmology, my interests turned to general physics and philosophy of science. Among an extremely modest list of publications, I'm most proud of the two on the Aharonov-Bohm effect. These days I enjoy pounding out old-time rock & roll songs on my guitar while my wife Sharon perseveres in the classroom as professor of psychology at UPJ.

JOE GALLANT

Hello UMass Physics! It was a pleasant surprise to hear from the newsletter committee and I am honored to give you a short update for the departmental newsletter.

After working out-of-state for many years, I moved back to Massachusetts in 2011 and since then UMass has continued to be a significant part of my life. Among the three of us, my family has 6 college degrees and 5 of them are from UMass! The most recent is my daughter's 2015 Master's Degree in Education that culminated with a Jack Ryan Award. Two years later, she brought into this world the world's most adorable grandson.

My last official interaction with UMass was in the Spring 2012 semester when I taught one section of introductory E&M. It was quite an experience to teach in the same Hasbrouck

ALUMNI NEWS

dungeon where I first took classes some 36 years ago. It was in that same building where I met John Dubach who would eventually be my dissertation advisor.

Since the Fall of 2012 I've been teaching fulltime at Western New England University. Karl Martini is a faculty/administrator hybrid there, and his memories of me from my grad school days were apparently vague enough that he offered me a 1-year sabbatical-replacement gig. That turned into a permanent position at a great place to work and I am lucky to be there.

I wrote a book about using a particular software to solve physics problems that was very well-received by both people that read it. My current research involves Newton and the Principia. Newton's arcane and outdated methods, and the fact that he was not an English major, makes reading the Principia more work than it's worth for many people. My goal is to express Newton's calculations in a form that modern physics students can follow, and I'm hoping there is a book in it as well.

As my retirement slowly starts to appear on the horizon, I look back with fondness, appreciation, appreciation, and gratitude for all I learned about teaching and physics at UMass. Thank you all!

OTHER ARTICLES

BOB HALLOCK – A FEW REMINISCENCES (1961–2020)

The Newsletter Committee has requested that I provide a few reminiscences from my many years in the department. So, I offer what appears below (from a much larger collection) in the hope that a few of these will be of interest. I was a Freshman Physics major in the department in 1961-62; tuition was $200 per year (vs. about $14,600 in-state now). My first Physics class was Physics 5 (equivalent to something like Physics 151). For Physics 6 the legendary William Ross (winner of the first UMass Distinguished Teaching Award) was the instructor. One day on entering class in Hasbrouck 134 we found a stuffed moose on the main lecture table. Physics Masters graduate students had "borrowed" it in the darkness of night from a display case in the Biology Department in Morrill Hall. Ross entered, was surprised, and climbed briefly onto the back of the moose. The next lecture day, below the moose was located a medical bedpan with a sign, usually present when a demonstration was set up, that read: "do not disturb apparatus."

In those days the entire department was housed in the old Hasbrouck and there were roughly 12 or 13 Physics faculty members. I recall that the only significant experimental research program was one on electron scattering led by Phillips Jones. The apparatus was constructed locally in the small Hasbrouck machine shop by the only machinist in the department at the time, Modest Poudrier – who happened to have only one arm. He used to say something like, "If it can be made, I can make it"! Modest also liked to carry enough cash with him to meet any need. One day in 1964 he showed me that his wallet contained close to $2000!

Hasbrouck Annex (new Hasbrouck) was ready for occupancy in about 1964. Professor Raymond Patten moved into room 9 and I was allowed to use room 5 as my "office". As a break from study, we (with fellow student Daniel Krauss) decided to create a rocket of sorts. With a little chemistry we came up with a fuel. We crafted a test rocket from a section of pipe and

used a standard gas jet (the kind that allowed natural gas to be used at lab benches) as a rocket nozzle. To test this safely we inverted the "rocket" and set it in a larger diameter and longer thick-wall length of steel tubing behind Hasbrouck, and used a match wrapped in fine wire that was attached to a transformer and a switch as an ignitor. One night from inside the building we ignited the inverted rocket. A spectacular 2-story high flame erupted from the nozzle, which charred a large v-shaped area on the side of a nearby white-painted dumpster. Success - except for the police car that was patrolling near Stockbridge Hall. Seeing the flashing lights coming our way, we promptly packed up everything, dropped it all in the lab and headed for the dorms.

In the fall of 1964 the department was joined by a new Department Head from Yale, Robert Gluckstern. He was recognized as a solid researcher, an exceptional teacher, and quite a fine leader. Bob Gluckstern had a mandate to build the department and he transformed it. The first PhD degrees in Physics were awarded in 1969.

After completion of graduate school, I wrote to UMass in the fall of 1969, but was told that UMass had no faculty position in Condensed Matter available. This is where the story gets unusual. At the Annual APS meeting in January 1970 in Chicago, which I attended, one of my thesis committee professors at Stanford (William Fairbank) was trying to convince Bob Gluckstern to hire his postdoc. Bill knew Bob from days at Yale. Gluckstern, who was by then Provost at UMass, was not interested, but Bob asked Bill how I was doing. Bob asked Bill to find me and to ask me to try to meet up with him. Within a day or two I managed to chat with Bob Gluckstern. After listening to what I had done and what my initial plans were for research, Bob asked if I had contacted UMass. I indicated that I had, but that nothing was available. After a brief pause Bob said, simply, "Contact them again." I did that, and not long after that I was offered a faculty position at UMass by Roy Cook with no further interviews. Remarkable! The offer from UMass in 1970 was for $13K for the academic year salary with $25K in start-up funds; my arrival brought the faculty count to 52. Today, start-up can amount to 10 to 20 times an initial academic year salary, sometimes more.

With a second office in my labs, it was easy to be readily accessible to the students. One day (in the late 1970s I think), while working at my desk in Hasbrouck room 5, a graduate student walked in and asked me where the "epoxy stripper" was. The student had epoxy covering both hands, up to the wrists. I asked how he happened to have epoxy all over his hands. The response: he said that the instructions said to "mix by hand." Something had to be done to encourage such a student to consider theoretical physics. The rescue came when Jon Machta offered the student a position in his group.

For many years we had a full-time carpenter in the department, Karl Kushi. He had a refrigerator and stocked it with soft drinks. One day when Karl was out of the shop my graduate student Fred Ellis extracted a bottle of Coca Cola from deep in the fridge collection, carefully removed the cap and inserted into the open bottle a dead cockroach (from the copious supply in the Hasbrouck basement). He replaced the undamaged cap and returned the bottle to its place deep in the fridge. A while later he returned to Karl's shop (with Karl now present), grabbed the bottle, looked at it and expressed astonishment that there in the bottle was a cockroach. Karl's reaction, as I recall it, was to call the Coke distributor and complain bitterly – with the result that four cases of Coke were delivered to Karl's shop, gratis.

In 1985 I was asked to become the Department Head; I served until 1993. Early in the position as Head, the administrative assistant position opened. As I thought about the candidates, along the way to an APS section meeting in Vermont, I decided that Ann Cairl would be the best choice and called her from a phone booth

I found along I-91. She accepted. And, as I have said many times, that hiring decision was one of the very best decisions that I made in my time as Department Head.

Another early event from my time as Head was the creation of what we called Science Days. I think that Barry Holstein first suggested to me that there might be value in engaging high school students who might ultimately enroll. In the first significant year of Science Days approximately 1800 high school students arrived on campus (600 at a time) for a few lecture/demonstrations, lunch and some tours of labs. I did a lecture/demonstration for each group called "a trip toward absolute zero" typically attended by about 240 students. In the second year 2400 students visited (again 600 at a time). These Science Days events involved several of the NSM departments, but many details were carried by the Physics Department – and the key person who did much of the substantial extra work was Ann.

Over the years I enjoyed going to a local book auction with David van Blerkom, who was a faculty colleague in the Astronomy side of the joint department. At one auction David bought a 7-volume collection of an obscure philosopher's works, all, as I recall it, for $5. I asked David what he planned to do with the books. He said, "Read them." I asked why. He said, "Somebody has to." At one of these auctions, I bought a book for 25 cents that subsequently resided on my Department Head Office bookshelf. I would glance at the binding from time to time when someone in my office was being particularly unreasonable. What was the book about? Proctology!

In 1998 the Physics Department hosted the international Quantum Fluids and Solids meeting, which I brought to the campus and chaired; Don Candella and Bill Mullin helped substantially. Roughly 250 low temperature experimentalists from around the world attended the meeting. Our Boris Svistunov came to campus for the first time for that event. It was decided to try to offer something new - free beverages at the poster sessions of the meeting. One of my graduate students, Winfried Teizer, contacted Massachusetts microbreweries and ten of them provided to the conference more than enough free beer for us to make the poster sessions especially enjoyable. Such free beverages have become a tradition at QFS meetings.

Many recollections concern what other people said in particular situations. One such took place at a dinner in the Chancellor's house. I recall being seated to the right of Sam Conti (who was Dean of the Graduate School or, perhaps by then, Vice Chancellor for Research). A senior administrator was speaking following the dinner. Sam leaned to me and said, "My houseplants have more brains than that guy"! Hilarious, in the context, simply hilarious. I resist offering even more unforgettable quotes from Sam. Ask me sometime.

In my year as interim NSM Dean, the senior development officer (Steve Tandy) came into my office to chat about development and fund raising. He mentioned that Steven Gluckstern (the son of Robert Gluckstern) had donated a professorship in the School of Education. I told Tandy that Bob Gluckstern had been a key player in the modernization of the Physics Department and had gone on to be our Provost. I pointed out how Gluckstern was responsible for my being at UMass. I suggested that Steven Gluckstern promptly be approached with the notion that he create a second professorship in Physics, named after his father Bob to honor him. Tandy thought that that story was a development officer's dream. One thing led to another and in due course Steven generously donated a second professorship for the campus, this time for use in the Physics Department. That is how the Gluckstern Professorship (currently held by Krishna Kumar) entered the department.

THE END OF ARECIBO

The Arecibo Observatory, or more formally, The National Astronomy and Ionosphere Center, is located just south of the city of Arecibo, Puerto Rico. It was built in 1963. The Observatory remained the largest single dish radio-telescope in the world until 2016.

Dated movies such as Contact (1997) and Species (1995) digitally enhanced the Arecibo telescope dish as a medium to interact with extra-terrastrial beings. In Golden Eye (1995) the dish became a weapon of mass destruction, which may have saved the James Bond re-emergent franchise series but not itself. A snapped cable in August 2020 led to the death knell by a catestrophic collapse on December 1, 2020, witnessed by drone footage released by the National Science Foundation (NSF). The only good news was that there were no reported human injuries.

In 1958, the Defense Advanced Research Projects Agency (DARPA) was established as an agency within the US Department of Defense (DOD). DARPA funded the construction of the Arecibo Observatory to study Earth's ionosphere as part of its missile defense program. The observatory also served a dual-purpose of a radio telescope. Coupled with engineering staff at Cornell, the project goal was to build a 305-meter diameter 2.5 MW peak power antenna / transmitter telescope ~400 MHz initially to detect ionospheric interactions. The research soon addressed other projects to make key discoveries. Its 900-ton instrument platform was suspended by cables attached to three towers, all of which collapsed in 2020.

The first discovery made by the observatory was that Mercury takes only 59 days to complete its orbit rather than 88. In 1992, observations of Mercury detected water on the north and south poles of the planet, demonstrating that ice persists in shadowed spaces despite the high surface temperatures of ~426 degrees Celsius. In cooperation with the NASA-supported Viking mission (1990—1994), Arecibo produced the first radar maps of the surface of Venus. Also, it had been part of the Search for Extraterrestrial Intelligence (SETI) program. In 1974, The Arecibo Observatory broadcasted the most powerful signal from earth aimed at a cluster of stars 25k light-years away. The radio message contained information on DNA, stick figures of a human, a map of our Solar System, and a message for aliens. During this time and to its end, the Observatory was on watch by NASA to identify near-earth asteroids and estimate the threat of their collision with earth.

OTHER ARTICLES

UMass Amherst Professor Joseph Hooton Taylor Jr. and his graduate student Russell Alan Hulse, during a survey for pulsars at the Arecibo Observatory, discovered the first binary pulsar in 1974 that led to the 1993 Nobel Prize in physics. Professor Taylor and colleagues also demonstrated that the changes in the star's period of rotation were precisely explained by Albert Einstein's general theory of relativity, with no adjustable parameters. The theory predicts that the pulsar emits energy in the form of gravitational waves, which results in its slowly declining periodicity, experimentally confirmed by Taylor in 1978.

Professor Taylor, during his 11 years on the faculty of UMass/Amherst became the Associate Director of the Five College Radio Astronomy Observatory. His Nobel acceptance speech mentions that he spent time at two stimulating institutions, UMass/Amherst & Princeton. Russell Hulse who received his PhD in 1975 remembers UMass well and returned with his former advisor to campus. The Spring 2018 issue of the Physics Newsletter [see https://www.physics.umass.edu/newsletters] showcased their on-campus academic lectures and personal journey stories. Alas, in Issue 18 is an image of the then functioning telescope.

This telescope weathered hurricanes, earthquakes, and graduate students. In the end, its demise was the result of poor maintenance.

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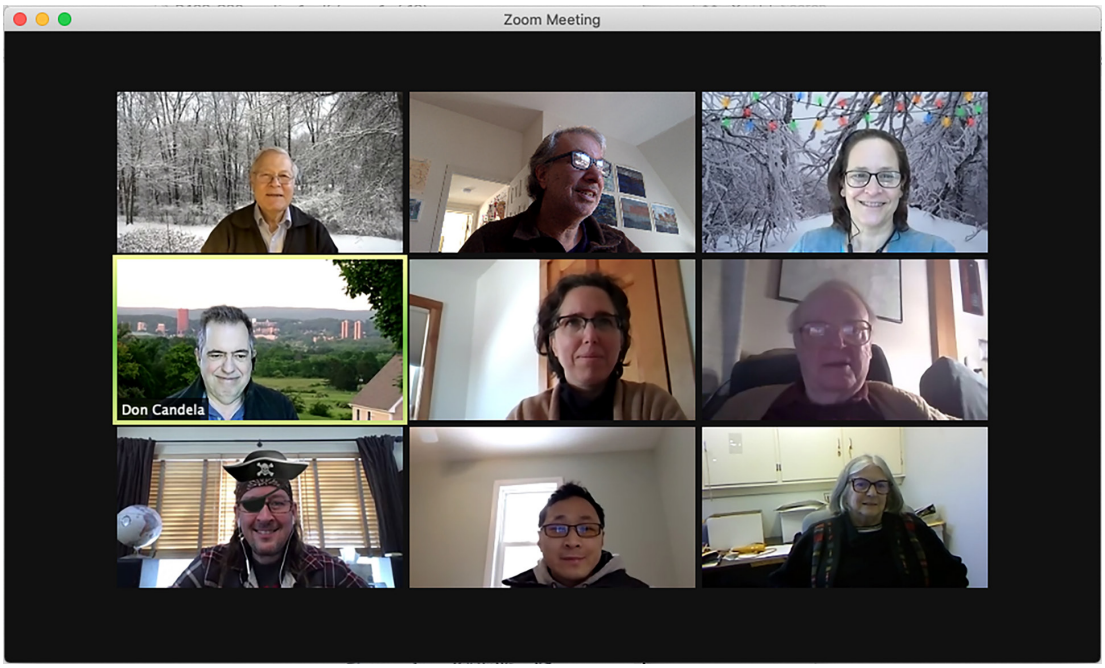

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