DOE NNSA Stewardship Science and Laboratory Residency Graduate Fellowships Virtual Program Review – Day 2

CELEBRATING SSGF 15 YEARS

LRGF LABORATORY RESIDENCY GRADUATE FELLOWSHIP

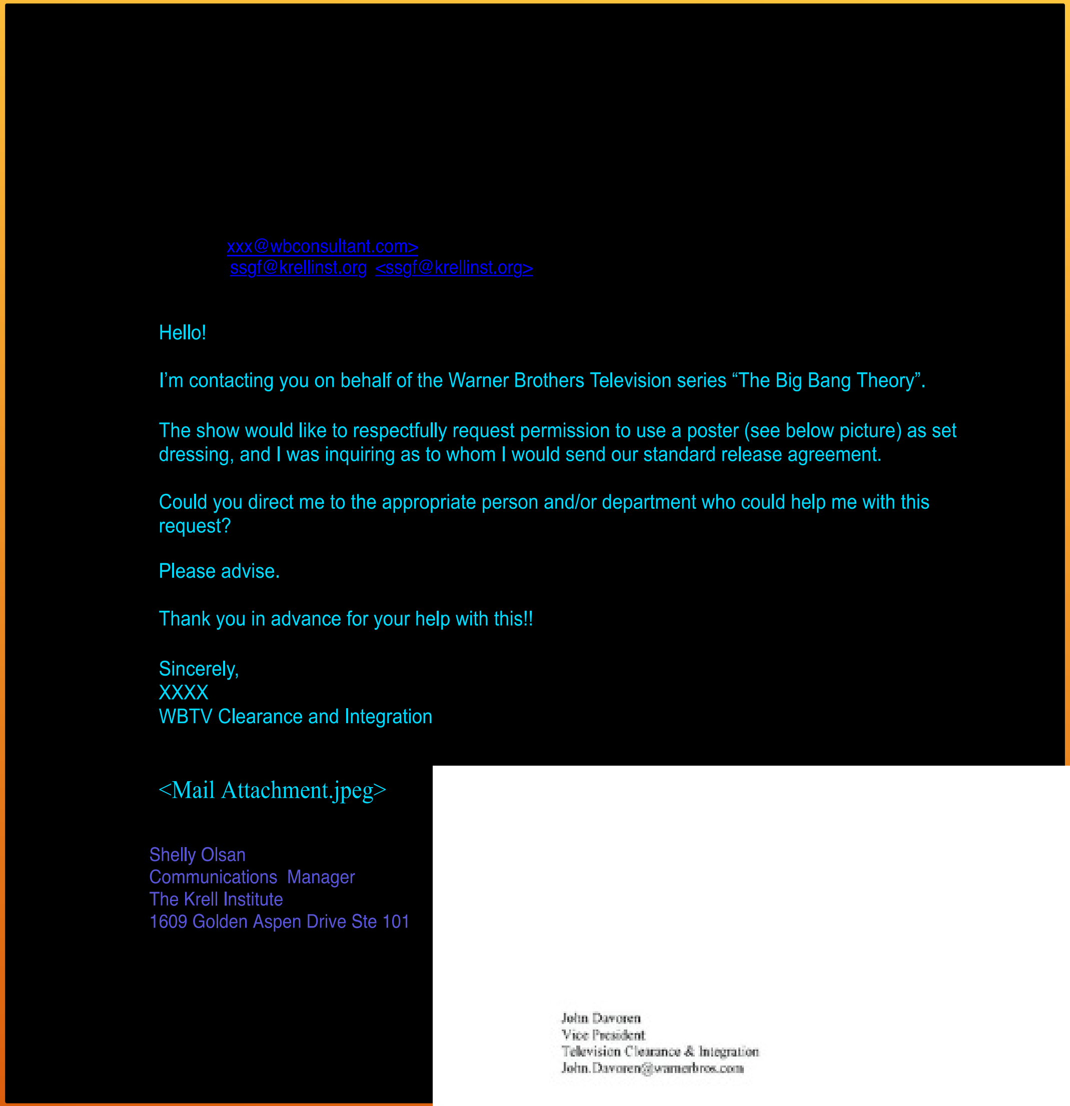
Recordings/content posted daily: ***www.krellinst.org/ssgf/conf/2021***

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Trivia Question:

What relationship does the SSGF program have with The Big Bang Theory?



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Hello!

I'm contacting you on behalf of the Warner Brothers Television series "The Big Bang Theory".

The show would like to respectfully request permission to use a poster (see below picture) as set dressing, and I was inquiring as to whom I would send our standard release agreement.

Could you direct me to the appropriate person and/or department who could help me with this request?

Please advise.

Thank you in advance for your help with this!!

Sincerely,
XXXX
WBTV Clearance and Integration

<Mail Attachment.jpeg>

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VIA EMAIL

March 14, 2017

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www.krellinst.org/ssgf/outreach/stewardship-science-magazine

THEORY IN PRACTICE

Yale University's Paul Fanto embraced physics relatively late, switching from political science his junior year at Princeton University. He was inspired by how physicists defined specific, addressable problems, checked their answers and built on their results.

Paul Fanto

His first semester-long research experience at Princeton: a theoretical project to simulate operation of the Large Hadron Collider's proton accelerator beam. Researchers assumed that the protons acted independently of each other, but Fanto examined whether correlated behavior among the particles could introduce error and how that might change experimental results. A senior year working with Princeton physicist David Huse inspired him to pursue graduate school in theoretical physics.

At Yale, Fanto worked with advisor and nuclear-reaction code expert Yoram Alhassid on a new way to calculate nuclear-state densities that help determine the number of stable configurations the nucleus can access as a reaction gives off energy. These values help researchers understand reactions because nuclear processes are more likely to occur if more energy levels are available for decay.

Fanto and Alhassid's simulations are based on Hauser-Feshbach theory, a long-standing framework that lets researchers use nuclear reaction experimental data to extrapolate to nuclei that haven't been tested. During his 2018 practicum at Los Alamos National Laboratory, Fanto worked with Toshihiko Kawano, who employs Hauser-Feshbach theory to produce nuclear data libraries used to model key stockpile stewardship-related reactions.

budding interest in national security and defense research. After completing his Ph.D. in 2021, he will start a research position at the Institute for Defense Analyses (IDA), a think tank in Alexandria, Virginia. Fanto learned about the institute from a Los Alamos postdoctoral researcher and later met another IDA researcher, SSGF alumnus Angelo Signoracci, at the fellowship's 2019 program review. Those connections led him to his new job.

Beyond his graduate work, Fanto sang with a Yale a cappella group and cofounded the online science magazine *Yale Distilled*.

PHASE DECIPHERER

LRGF recipient Dane Sterbentz was drawn to University of California, Davis, and advisor Jean-Pierre Delplanque through a shared fascination with the mysterious behavior of compressed water. Delplanque also had research connections with Lawrence Livermore National Laboratory (LLNL), which led Sterbentz to residencies there with Philip Myint and Jonathan Belof in 2019 and 2020.

Sterbentz studies phase transitions that happen when water is steadily squeezed or rapidly shocked. His test case is ice VII, a phase found on oceanic exoplanets and in other astronomical settings but also in compression experiments that force molecules into a repeating, cubic lattice. Phase transition kinetics dictate the magnitude of an energy barrier water nucleation and found that interfacial free energy – involved in disrupting molecular bonds – may have had more influence in phase transitions than transient kinetics. They described the work in an October 2019 *Journal of Chemical Physics* paper.

In another project, Sterbentz modeled experiments – conducted by Erin Nissen, an SSGF recipient (feature this issue, page 19), during her Sandia National Laboratories (SNL) practicum – that used powerful magnetic fields to ramp up pressure on a water sample to make ice VII. Sterbentz also has modeled laser-driven results from the University of Rochester's Omega Laser Facility, a NNSA-supported laboratory.

Sterbentz used ARES, an LLNL hydrodynamics code, to simulate Nissen's experiment and paired it with an optimization algorithm that seeks the problem's best solution from myriad options. The algorithm varied drive pressure values through multiple simulations until it found ones that produced output pressures matching real-world results. Because the approach doesn't explicitly simulate the pressure-producing drive mechanism, it's widely applicable to other compression experiments. The project led to a 2020 *Journal of Applied Physics* paper.

Sterbentz finished his dissertation in December 2020 and soon after started an LLNL postdoctoral research appointment. He hopes to land a staff job there or at another national laboratory.

Dane Sterbentz

Liquid Molecules · Solid Cluster · Solid · Pressure · Liquid

In dynamic-compression experiments (right), pressures tens of thousands times Earth's atmosphere push liquid molecules toward solid, nucleated clusters, leading to rapid growth and a phase transition that can occur within a microsecond. *Dane Sterbentz*.

Stewardship Science 2021

Rick Kraus

As a Harvard University doctoral student, Rick Kraus studied shock physics, in particular the enormous pressures created when planets collide at 30,000 kilometers per hour. Today, as a Lawrence Livermore National Laboratory (LLNL) research scientist, he applies his knowledge of high-pressure physics to stewardship of the country's nuclear stockpile.

Since completing a Department of Energy National Nuclear Security Administration Stewardship Science Graduate Fellowship (DOE NNSA SSGF) in 2008 and joining the lab, Kraus's career has been on a steady ascent. He's published landmark papers and has accreted lab leadership positions and accolades, not least a 2019 Presidential Early Career Award for Science and Engineering (PECASE), recognized as the U.S. government's highest honor for a young researcher.

PECASE noted that Kraus has advanced "the field of materials science, planetary science and material issues that are critical to the nuclear security mission, through elegant and innovative design, analysis and understanding of dynamic compression experiments using gas-gun, magnetic compression and laser sources."

When he discusses the honor, Kraus downplays his personal achievement and emphasizes the value of collaboration. "I had many incredible mentors along the way that have made this achievement possible," starting with his high school math and physics teachers and then as an undergraduate at the University of Nevada, Reno, where he met physics professor Aaron Covington.

Kraus thought he might be able to make extra money grading papers. Covington had no such financing, but he did run an NNSA-sponsored

Diversity and Inclusion in Technology and Policy

Moreena Robinson Snowden is a senior engineer in the Johns Hopkins University Applied Physics Lab's (APL's) National Security Analysis Department. She holds a Ph.D. in nuclear engineering from the Massachusetts Institute of Technology (2017), where she was a Department of Energy National Nuclear Security Administration Stewardship Science Graduate Fellowship (DOE NNSA SSGF) recipient (2012-16). She spoke with Stewardship Science's Sarah Webb. Her comments were edited for space.

What are you working on at the Johns Hopkins Applied Physics Lab?

I work half time on nuclear-related questions – for example, looking into the role of nuclear weapons in nuclear crises or supporting

I was never quite satisfied with just being in the lab. The nuclear security field is exciting because it's so interdisciplinary. To be an effective technologist, one has to have an appreciation for how the technology interacts with things that are much less quantitative. Understanding the culture and history in which technology will be deployed, or real-world constraints on development or implementation, increases the likelihood of successful adoption, in fields from radiation detection to education. Appreciating these subjective factors is essential for making the technological argument you put forward strong and effective.

What's the most rewarding part of your STEM advocacy work? What's the most challenging?

To me, science and engineering is a team sport. Broadening that community and feeling the support from and giving support to my colleagues and my peers – that is the most rewarding piece. Not only do you see the quality of the science improving, but also the people and the culture. The key is creating a space where people feel empowered to question conventional wisdom and the status quo. Respectful dialogue allows robust, innovative ideas to emerge.

One of the challenges is that diversity and inclusion work isn't a neutral conversation where there are no emotions; it is nearly certain that each person will be triggered at

top-down commitment to remove obstacles. Some leaders are not content experts on diversity, equity, and inclusion issues, and may feel uncomfortable about interventions and solutions proposed by their staff. So that requires an added level of consciousness to really reflect on where any discomfort might arise and its true cause. Today we have a direct test case for diversity in leadership: The current presidential administration now has the most diverse cabinet in history. This didn't happen by accident. It was signaled from the top down.

It's also important to ask what work this representation should be doing. Is this diversity the ends or is it the means? And the means to what? When we're thinking about topics, like deterrence or arms control or safeguards, is this cultural and gender diversity supporting the status quo, which isn't always promising? Or is that diversity trying to challenge systems, reinvent and innovate? Once we've achieved diversity, what work is it doing? The jury is still out about how diversity will shape policy and technical questions. But that's the next step in this work.

Who are your inspirations?

Many people inspire me, including my girlfriends from the different chapters in my journey. I don't think we have space to name them. Of people you may know, Dr. Shirley Jackson. She was the first Black woman to get a Ph.D. at MIT and went on to chair the

Stewardship Science 2021: Accomplished Alumni

https://www.krellinst.org/ssgf/outreach/essay-contest

Into the Darkness

By Sophia Farrell

Where there is darkness, there is light. We hear this proverb echoed in epic stories like *The Lord of the Rings* and *The Odyssey*, in prayers and throughout generations of old tales. But for me – and 180 fellow scientists around the world – the timeless struggle between darkness and light is literal.

Miles below the earth's surface, near a centuries-old mountain town in Italy, lies the world's cleanest, darkest and largest vat of liquid xenon: We call it the XENONnT experiment. Housing almost 9,000 kilograms – or about 10 tons – of ultrapure xenon, our beautiful experiment's many superlatives are all the product of a mission to detect dark matter. Dark matter makes up five times more of the universe than all the other matter that we know and love, like stars and planets. Normal matter interacts with light; it's why we see stars in the sky, or why you can read the words on this page. However, dark matter interacts with normal matter so rarely that we cannot see it from Earth or space. Instead, we go underground, hoping that there the world is so dark that dark matter might just shine brighter.

Our subterranean lab is quiet, cold and damp. It's also free from nearly all the atmosphere's radiation, thanks to the halting force of the mountains that shield our xenon. Here, we set up an ingenious detector to observe what particles interact with xenon far underground. There are the usual-suspect interactions, like background radiation from the detector materials or errant ultra-energetic particles from the atmosphere. But occasionally something unexpected happens.

The work of a physicist under this mountain is anything but glamorous. After you don a hardhat, steel-toed boots and, if you are working on the detector itself, a hazmat suit, you enter a delicate ecosystem of intricate electronics, cryogenic pumps, purification systems and, of course, the xenon detector itself. Yet except for the fortunate few (myself included) who helped build the detector, a XENONnT scientist may never see their own detector: We shield the detector from the radiation in the mountain and in our own bodies by sealing the device inside a three-story-tall water tank. Our detector rests contentedly while we buzz about, monitoring its many systems. The pumps, labyrinthian in their complexity, hum in unison; their rhythmic melody to us means, "We aren't broken!" We work in similar fashion, flowing along, intertwined throughout the lab. There is always an expert and a student, though each of us is a student in many respects. Working together on site keeps us informed and constantly learning. The more we can learn about the detector's every aspect, the better we can look for dark matter.

We see signals from our detector with cameras that record specks of light. We have to infer for every interaction the likelihood that it came from dark matter interacting with xenon. This is where I enter the scene. We can't see into our detector lest we contaminate it. Instead, we must observe its behavior with non-invasive sensors. Each signal is unique, imparting to the sensors hints to its origin via a digital fingerprint. I translate these signals into physics.

We reconstruct each fingerprint to determine whether a dark matter particle left it behind or if it's from a blithe neutron or some other particle. So far, only known particles have come out to play in our xenon, but observing what we know is not always a bad thing. It offers glimpses of particles behaving in new ways, and that has led to discoveries like the rarest nuclear decay ever recorded, that of xenon-124.

Our gentle giant, XENONnT, provides us hints at not only what dark matter is and is not but also how our known universe and its constituents behave. This helps us reconstruct the universe's past and infer our Earth's state today. Our detector tells us acutely about its surroundings. Particles that pass through us invisibly are blinding beams to the xenon atoms, allowing us to put our dark matter detector to practical use in many particle physics applications.

But the story is not all dark and light. There are gray areas as well. Recently, we saw a curious fingerprint, a slight excess of signal, that led to more questions than answers. It was unlike anything we had predicted. Perhaps nature is playing games with us. Or maybe it is humanity's first glimpse of dark matter. Only time, and the 180 passionate scientists devoted to this project, will tell.

We must always remind ourselves of our purpose, especially in times of darkness. Why go to these lengths? Why push xenon, physics and even ourselves past where we haven't gone before? For me, the reward of discovery is worth the struggle, the light brighter and more precious when it is seen in darkness. If we can see the dark matter, we know the story of our universe, and our place in it, that much more clearly. In pushing the bounds of dark matter to their limits, we push ourselves, too. Perhaps that pursuit is equally worthwhile.

The three-story-tall XENONnT dark matter experiment, cocooned inside a mountain in Italy. *XENON Collaboration.*

Essay Contest: Congratulations Sophia Farrell!

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Looking Ahead

- Laboratory Tour and Program for SSGF and LRGF fellows
  - Sandia National Laboratories, New Mexico
  - Mid-October – more information coming soon!
  - Attendance support for all fellows
- SSGF and LRGF Annual Program Review – June 2022
  - Santa Fe, New Mexico

Practicum/Residency

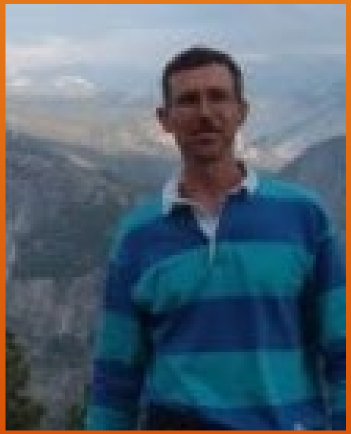
LLNL: Rick Kraus

SNL, CA: Tracy Vogler

LLNL: Laura Berzak Hopkins

Nevada National Security Site: Steve Sterbenz

SNL, NM: Matt Gomez



LANL: Paul Bradley

www.krellinst.org/lrgf/doe-lab-residency

www.krellinst.org/ssgf/doe-lab-practicum