

## Message from the Newsletter Editor



**G**reetings, FECS members! We are excited to present to you our third newsletter, for Fall 2018. We hope you find it informative and interesting. In these newsletters, in general, we aim to provide you with useful information about basic research in different fields of physics, information

about our activities at conferences and elsewhere, opportunities to actively participate in FECS, and helpful guidelines toward furthering your career.

This issue includes an overview of the exciting field of plasma physics by one of our FECS members, information about all FECS activities and sessions that happened during the APS March and April meetings in 2018, a Q+A article about successfully applying for NSF grants written by a NSF grant recipient and grant reviewer, a word of congratulations to our own FECS Chair-Elect on his being made an APS Fellow, and a word from the APS President on the critical role FECS plays in the strategic mission of the APS.

I offer my sincere gratitude to all the contributors for this issue of the FECS newsletter, who worked hard to provide useful and engaging content, and many thanks to all the FECS members for reading. Suggestions, comments about the newsletter, and article contributions are always very welcome, and you can reach me with these at [kludwick@lagrange.edu](mailto:kludwick@lagrange.edu) or on our Facebook group (called “APS Forum for Early Career Scientists”). I hope to connect with you on our Facebook group and at upcoming APS meetings!

Sincerely,

*Kevin Ludwick*  
Kevin

*Kevin obtained his Ph.D. from the University of North Carolina at Chapel Hill. After a two-year postdoc at the University of Virginia, he became an assistant professor at LaGrange College in 2015. His research is in theoretical cosmology, pertaining to dark energy and dark matter models.*

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*Views and opinions expressed in articles are those of the author and are not necessarily shared by the editor or the APS/FECS.*

# Letter from the FECS Chair 2018



Maria Longobardi

Dear FECS members,

The FECS aims at bringing together early career scientists working in academia, industry and research institutions, both in the USA and internationally. Our mission is to offer them support services and to provide them with an opportunity for increased inclusion and participation in the

activities and decision-making of the physics community. We welcome all scientists, not only early career but also senior members, who have a link to physics and wish to share their experience and knowledge or to stay in touch with colleagues and the advances in the field.

We firmly believe that the personal involvement of our members in all the activities is of crucial importance to meeting our mission.

For this reason, we are looking for your active collaboration!

What you can do and what we are looking for?

You can be an active member volunteering at our APS meetings and other activities; you can spread our voice in the physics community, or be a mentor to support younger scientists, or help us to organize our future events better. We are looking for both early career and more senior scientists to help the community.

This collaboration is a precious opportunity for all of us to better understand our needs, to continue to grow together as a healthy community, and to be part of our large family.

Don't miss this opportunity! Stay involved! Please send me an email to share your ideas, to give your availability for being an active member and to ask for more information.

I thank you in advance for all your help!

Let me now spend a few words on our activities at the March and April meetings 2018. Our collaboration with other APS units is continuously growing, and we organized shared sessions with the FIAP, FIP, and FPS units at the meetings. We understand that the interests and the needs of our members are different. Many members are working in industry and applied physics, and others



Some FECS Executive Committee members attending the annual meeting in Columbus: (from left to right) Kevin Ludwick, Maria Longobardi, Jason Gardner and Sara Clements

in the academy and on interdisciplinary studies; we have both US-based and international members, and many of them are interested in science communication and outreach programs. For these reasons, we decided to diversify the themes covered in our sessions at the APS meetings and provide a strong connection with other APS units. We tried to offer to the community a broad vision of the state of affairs and the potential opportunities offered by the physics community in both research and in work outside the laboratories.

At the March Meeting 2018, we had a very well-attended session, shared with the FIAP, on data science with speakers from academia and companies like Uber and Netflix who talked about the possibility offered by this emerging hot field. At the same meeting, we organized with the FIP a session where we presented ongoing and future experiments on condensed matter physics on board the International Space Station (ISS). At the April meeting, we talked about physics and human rights with our the FIP. During this session, a touching letter by the 2018 Andrei Sakharov Prize winner Narges Mohammadi was read by her friend Nayereh Tohidi. Mohammadi is an Iranian physicist, engineer, and human rights defender, and she wrote her letter from her jail cell in

Tehran. In another session, organized with the FPS, the session speakers discussed science communication, demonstrating how physicists can be involved in politics and educational programs and how communication can increase the effectiveness of presenting scientific data.

For the next year, we are currently organizing new sessions with our sister APS units, and I would like to extend a warm invitation to you to join us for the APS March and April meetings in 2019.

In Columbus, during the April Meeting 2018, we had our annual Executive Committee meeting. I want to thank all the Executive Committee members for their precious participation and support during the annual meeting and during the year. Thank you all, and thank you to everyone who contributed to the success of the first two years of the FECS unit!

I hope to hear from you all soon as active FECS members, and feel free to contact me with any suggestions of how we can better serve the cause of early career scientists!

With warm regards,



Maria Longobardi

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## Message from Roger Falcone

APS President



Dear Colleagues,

As President of the APS, I am pleased to communicate my enormous enthusiasm for FECS' efforts to provide mechanisms to enhance opportunities for early career scientists, and in particular to thank you for your recent input regarding APS' Strategic Planning

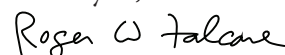
As an academic, a participant at national laboratories, a founder of a small company, and an advisor to international institutions, I see enormous opportunities for early career scientists in all of these venues; that is the good news. However, I think there are also concerns, in that it is often not clear to everyone what those opportunities are, how to make the right choices, how to get the best job, and how to advance one's career. Mentoring is not always available or optimal for everyone.

Of course there are also general and continuing

challenges in developing a career; these range from dealing with bias, to limited resources, to geographical and family constraints, to limited positions at the top. Having FECS as a place to share stories, ideas, and advice about careers, especially near the beginning, is one of the most important things that APS can facilitate.

Since this is the year of Strategic Planning for APS, your input on what our society should be doing with its resources has been welcome, and in fact, necessary if APS is going to have a healthy future and serve its members well. This is especially important as APS develops programs to serve its members who are early in their careers. Your recent input was forwarded to the appropriate subcommittees. For further input, please visit our Strategic Planning website, and share your ideas for the future: <https://www.aps.org/about/strategicplan/index.cfm>

Thank you,



Roger



# NEWS

## Our FECS Chair-Elect Jason S. Gardner Becomes APS Fellow. Congratulations!

Maria Longobardi, Chair



Jason S. Gardner

Jason S. Gardner was appointed a Fellow of the American Physical Society (APS). Scientists who have made extraordinary research developments are made APS Fellows. The number of APS Fellows elected each year is limited to no more than one half of one percent of the membership. It is a prestigious recognition by

peers of his outstanding contributions to physics.

He is honored for his “leadership in the application of neutron scattering techniques in geometrically-frustrated magnets, for global outreach in neutron scattering and the support of international students and scientists worldwide in their early careers”.

Jason Gardner’s scientific interests are primarily in frustrated magnets, but he’s also performed research in many areas of condensed matter over twenty years of study. After obtaining his Ph.D. at Warwick University in

the UK, Jason worked for several national laboratories in North America before moving to Sydney, Australia in 2013, where he led a group on neutron scattering at ANSTO.

He has published over 120 papers, giving extraordinary contributions to the research in quantum magnetism, and in 2008 he was made a fellow of the Institute of Physics (UK). Jason has also been a Member-at-Large of the APS Forum on International Physics (FIP) from 2015 to 2017 and has chaired the Distinguished Student program in the last few years. In 2016, he was one of the co-founders of the FECS and currently is the FECS Chair-Elect. During these years, he has always been involved in programs for supporting young scientists and international collaborations.

We are proud to have Jason on board in FECS, and we wish him an exceptional year as Chair in 2019.

Congratulations, Jason!

Maria Longobardi, on behalf of the FECS community

## Q&A

### NSF Grant Q&A

Brent Feske



Brent Feske

Brent was presented with questions about NSF grants that were collected from a poll on the FECS Facebook page in addition to other sample questions about grants. Below are the questions and his answers

**Can you talk about SBIR STTR grants which combine startup and academic research?**

I do not have much experience with these grants. However, I am part of an NSF-IUCRC – Industry-University

Cooperative Research Centers Program. This funds “translational” research by combining Universities and Industry. A key difference here is that it doesn’t focus on small business, but is open to all of the industry.

**Is there a better chance of getting a grant if I apply jointly with colleagues?**

Yes and No. Anytime you add a colleague or collaborator to a proposal (as long as it is value added) would strengthen the proposal. I come from a Primarily Undergraduate Institution, and time and resources tend to be more limited. As a result, I think faculty in these institutions benefit more from collaborations and joint grants. Why No? Typically

multiple PI/coPI proposals will mean higher grant budgets. I have served on several NSF review panels and I have heard “Don’t look at the budget; just rank the proposals based on merit” to “You are allowed to evaluate the budget to consider if it is reasonable as part of your evaluation”. Either way, consciously or not, I believe grant reviewers will take into account the total budget as part of their review.

### **Are there any key aspects that you look for in a successful grant application?**

The obvious key aspect is if the grant contains a good idea! The better the idea the more you can “slack off” on writing the perfect grant proposal. No one wants to take the risk and “slack off”, so what are some general tips?

### **Tips and Thoughts (Some more important than others)**

1. Poor writing – many reviewers have a hard time overlooking grammar mistakes and typos.
2. Well organized – Is your grant written in the required order (if there is a requirement) or in an order that makes sense?
3. Aesthetics – Does the grant have a professional look to it (figures are not blurry, format is clean)?
4. Why are these three above so important? When you write a proposal, this proposal is a reflection of your research or your work. If the proposal is disorganized, sloppy, and lacks attention to detail, then this would suggest that your work is the same.
5. Be sure to read the RFP thoroughly and address all areas mentioned in the RFP. To help with this, I always suggest trying to find a copy of a successful grant proposal (or at least a grant that has received a high score) for that exact RFP. In addition, have your proposal proofed by someone with experience with this RFP.
6. Keep the budget reasonable. Many reviewers don’t like seeing proposals with excessive requests (even if the requests are allowed). If unsure, talk to the

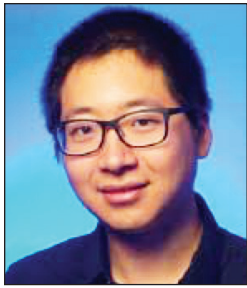
program officer about what is a reasonable (and normal) request and always justify your request.

7. Are you up to date on this topic? I have seen reviewers look at the references section to see what year most of your references are from. Are they all older references? Perhaps the PI is not aware of the newer literature that is out there?
8. Don’t submit a 10 page proposal if you are allowed 15 pages. Even if it is a strong proposal reviewers may think it isn’t well established. I generally will adjust line spacing (be sure you follow all font and spacing rules) to where my proposal sits right at 15 pages (or whatever the maximum allowed is). Sometimes it can be the little things.
9. For NSF grants, don’t overlook Broader Impacts. For the panels that I have served on, reviewers have been allowed to “weigh” broader impacts at their discretion. I have heard reviewers say that they weigh “intellectual merit” the same as “broader impacts” (50/50). Some reviewers give very little weight to broader impacts, but it is important to cover all aspects.
10. Previous support section – If you have received previous funding, you must describe this in the proposal. This is your chance to really sell yourself as someone worth investing in. Be sure to take advantage of this opportunity.

*Brent Feske is a Professor of Chemistry and serves as an Associate Dean in the College of Science and Mathematics at Georgia Southern University. Dr. Feske also served as the Interim Director for the Office of Sponsored Programs at Armstrong State University. He has been either coPI or PI on four funded NSF research grants and has served on many NSF review panels.*

# Distinguished Student Program

Yunseong Nam, Member-at-Large



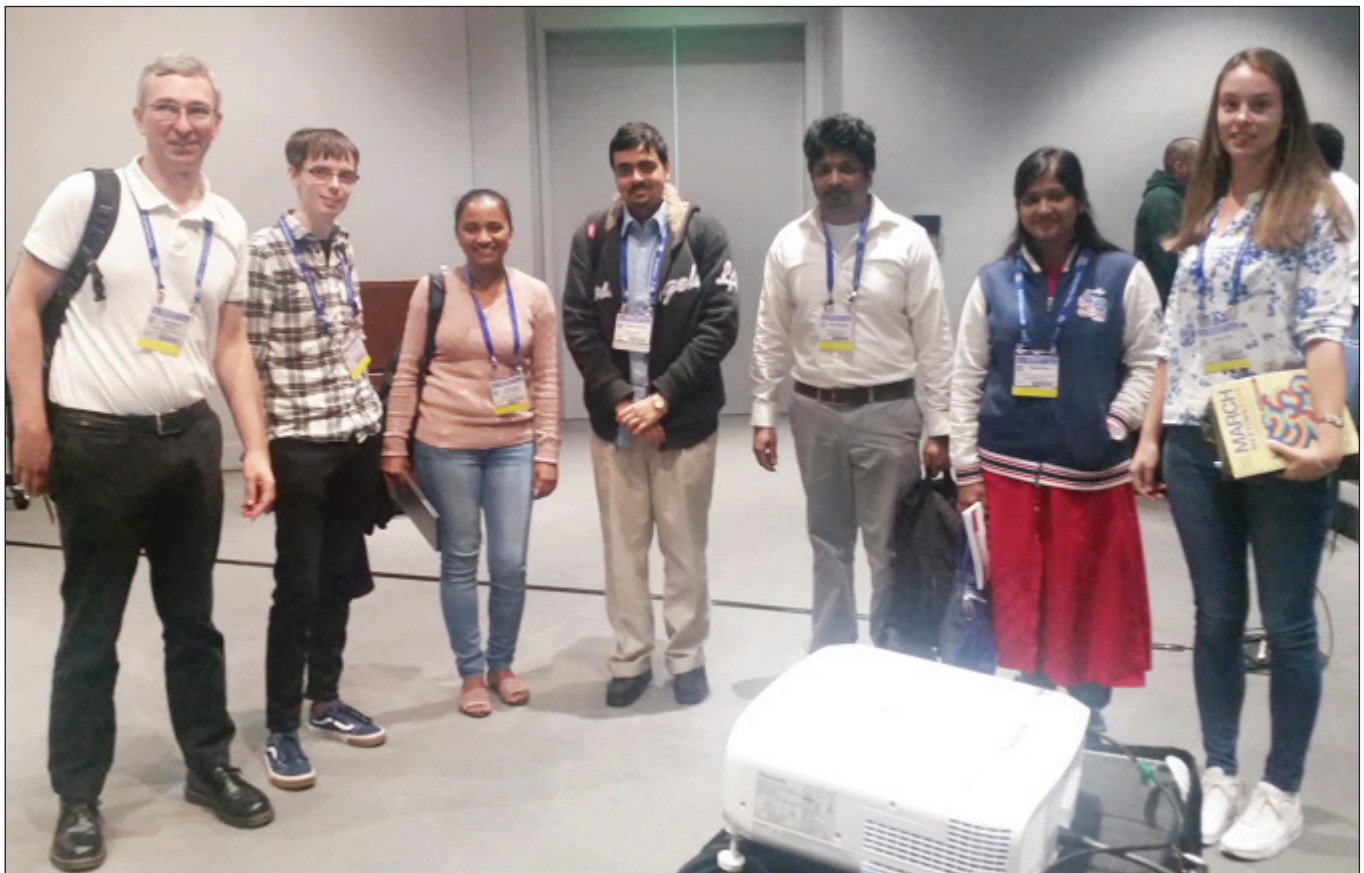
Yunseong Nam

We are pleased to share the good news that the Forum for Early Career Scientists (FECS), in close collaboration with the APS Office of International Affairs, co-sponsored this year's Distinguished Student (DS) program hosted by the Forum on International Physics (FIP). We also actively helped invite applicants

for the DS program, which recognizes outstanding students in any field of physics from around the globe.

The DS program helps promote the budding careers of graduate and exceptionally qualified undergraduate students abroad. The 8-10 awardees of this year's program will receive financial support for travel to present at either the APS March or April Meetings in 2019.

*Nam received his doctoral degree in physics from Wesleyan University in 2016 and is currently a postdoctoral associate in QuICS. His research focuses on streamlining and optimizing quantum circuitries, from a smallest possible single-qubit gate to a macroscopic circuit, such as Shor's algorithm. His current projects include investigating the error-resistance of a variety of architectures of quantum circuitries whose ideal, mathematical function is the same and determining which architectures to use in a practical, realistic setting when running a certain quantum code on a quantum computer.*



Past DS award recipients from the APS meeting in March 2018



# Report from the April Meeting 2018

Maria Longobardi, Chair



Maria Longobardi

The April Meeting in 2018, held in Columbus, Ohio, hosted two sessions sponsored by the FECS unit. One of the sessions was focused on human rights, and the second one was on science communication.

The “Physicists and Human Rights” session was organized in collaboration with the

Forum on International Physics (FIP) and chaired by Cherrill Spencer, the FIP Past Chair 2018. We had the pleasure of hearing the speeches from the two winners of the 2018 Andrei Sakharov Prize, Ravi Kuchimanchi and Narges Mohammadi (presentation on her behalf given by Nayereh Tohidi).

**Ravi Kuchimanchi** used his physics knowledge to help those in need in India with the Association for India’s Development (AID). Narges Mohammadi is currently serving a 16-year sentence in Iran and sacrificed her scientific career and liberty speaking up for the rights of others in her country.

The third speaker was Shelly R. Leshner, who reported on the work of the Committee on the Intellectual Freedom of Scientists (CIFS) of the APS.

Ravi Kuchimanchi, while a graduate student at the University of Maryland in 1991, founded the Association for India’s Development (AID) with the vision that if “problems are interconnected, so must be the solution.” Today, AID has over 500 volunteers with 30 chapters, and it works with 100 partner groups in different parts of India.

AID is active in the fields of agriculture, education, health, alternate energy, human rights, and environment, and it raises \$2 million annually for the development of several programs. Ravi presented his talk “Parity in Our World and in Physics” on the idea of restoring parity, both in physics and in the world. In the real world, he showed that parity in opportunity and equality between the privileged and the underprivileged is badly broken, and he presented the efforts of human rights movements in India towards equitable and sustainable development. He is a particle physicist with interests that include the strong CP problem, the hierarchy problem, leptonic CP violation, and left-right symmetric theories. In physics, Ravi showed that the parity can be restored very elegantly in the Minimal Left-Right Symmetric model. Ravi found that if CP violation is also present in the leptonic Yukawa sector, a strong CP



Ravi Kuchimanchi and Nayereh Tohidi at the “Physicists and Human Rights” session

phase is induced at one loop. So leptonic CP violation must be absent in significant regions of this model.

You can find his talk here: <https://www.iranhumanrights.org/2018/04/imprisoned-rights-defender-narges-mohammadi-gives-message-of-hope-and-strength-in-accepting-2018-andrei-sakharov-prize>

**Narges Mohammadi** is an Iranian physicist, engineer, and human rights defender. She was awarded the Sakharov Prize “for her leadership in campaigning for peace, justice and the abolition of the death penalty, as well as her unwavering efforts to promote the human rights and freedoms of the Iranian people, despite persecution that has forced her to suspend her scientific pursuits and endure lengthy incarceration.” Nayereh Tohidi, Professor of Gender and Women’s Studies, Director of Middle Eastern and Islamic Studies at the California State University, and a family friend of Narges Mohammadi, read the acceptance speech of Mohammadi, “Prisoners of Conscience in Iran”, which was written from her jail cell in Tehran.

Here an excerpt from her letter:

“For me, as a prisoner of conscience, it is uplifting and a great honor to be recognized by esteemed scientists like yourselves and to be awarded the Andrei Sakharov Prize. I was filled with joy when studying quantum physics at the university as a means to understand the universe. However, at the same time, I was preoccupied with the oppressive conditions in my country and the tyranny suffered by our universities, intellectuals, and the media. What we experience in Iran is a tyranny that in the name of religion restricts and punishes science, intellect, and even love. It labels as a threat to national security and toxic



Narges Mohammadi

to society whatever is not compatible with its political and economic interests. The power-holders who believe they stand above the law and who disregard justice and the urgent demands of the human conscience use “white torture” on political prisoners; keeping suspects in solitary confinement is a routine and prevalent procedure. I am one of the thousands of the victims of such horrible tortures in solitary confinement. You are not hearing here some random ideas of a distressed prisoner, but reflections rooted in the experience of a woman physicist and a mother of two kids who happens to have also advocated for equal rights and human rights by being active in eleven civil society organizations in the last 25 years. As a result, I have been subjected to threats, deprivation, arrests, continuous prosecutions, and finally sentenced to a total of 23 years of imprisonment, 16 years of which have to be served based on the IRI’s ruling laws. The harsh treatment and excessive sentence were not due to any underground violent or terrorist activity on my part, but-- as admitted by the judges of this very system-- because of my insistence on the rights of civil society and on human rights. Iran is an oil- and gas-rich country, but millions of Iranians are deprived of decent living standards. Mismanagement and corruption result in high rates of unemployment, widespread poverty and denial of people’s economic rights. I still hope and deeply believe that the path to democracy in Iran lies not through violence, war, or military action by a foreign government, but through organizing and strengthening civil society institutions. Sitting here in my prison cell, I am humbled by the honor you have bestowed on me, and I will continue my efforts until we achieve peace, tolerance for a plurality of views, and human rights.”

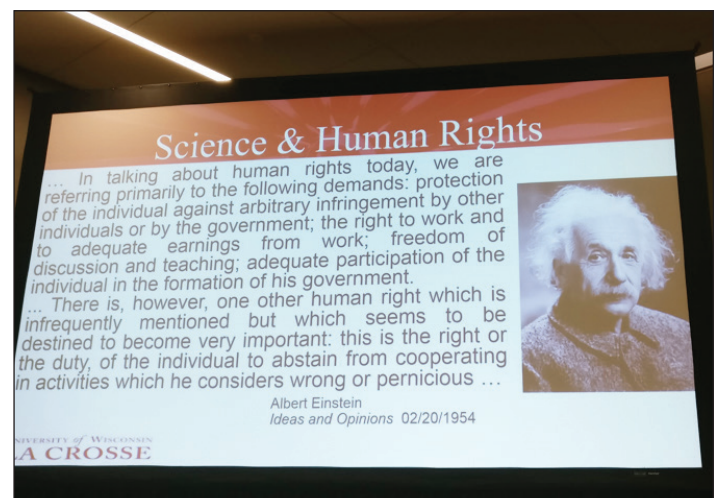
The full text can be found here: <https://www.iranhumanrights.org/2018/04/imprisoned-rights-defender-narges-mohammadi-gives-message-of-hope-and-strength-in-accepting-2018-andrei-sakharov-prize/>

**Shelly R. Leshner**, from the University of Wisconsin, LaCrosse reported on the work of the Committee on the Intellectual Freedom of Scientists (CIFS) of the APS. The CIFS has been a defender of the human rights of scientists in the US and abroad since its formation in 1976 and is responsible for “monitoring concerns of problems encountered by scientists in pursuit of their scientific interest or in effecting satisfactory communication with other scientists.” In this talk, “The Role of the Physicist in Human Rights”, Shelly Leshner provided some examples of violations of these rights, including: Omid Kokabae, an Iranian studying physics at the University of Texas, Austin who was in an Iranian prison for five years for refusing to engage in scientific research he deemed harmful to humanity; Wen Ho Lee, a Los Alamos researcher whose human rights were violated by the United States on accusations of spying for a foreign government; the current persecution of Turkish scientists; and the inability of free travel of scientists between Israel and Palestine. Sheila concluded her talk showing how individuals can become involved in these issues.

The session “Getting the word out” focused on science communication and was organized in collaboration with the Forum on Physics and Society (FPS). It was chaired by Maria Longobardi, the FECS Chair 2018.

The invited speakers of this session were Anna Quider, Joseph Bevitt, and Jesse Silverberg.

**Anna Quider**, from Northern Illinois University, is presently the Director of Federal Relations for Northern Illinois University and President of The Science Coalition, a national nonprofit dedicated to increasing US federal funding for fundamental scientific research. In her talk “From Natural Laws to Writing Laws: A Physicist Turned Policymaker”, Anna discussed her experience as a physicist-turned-policymaker working within the



A slide from Shelly R. Leshner’s talk



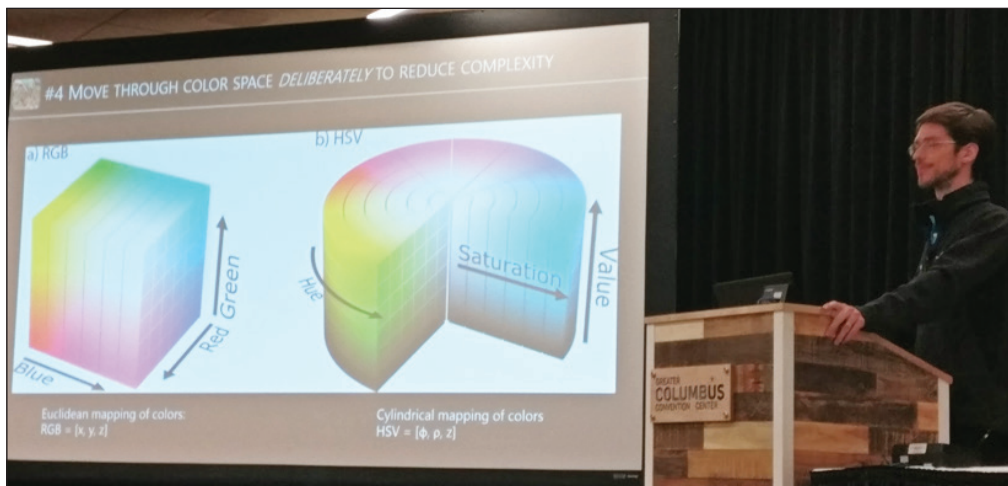
federal government at the US House of Representatives and US Department of State, and also external to the federal government as a higher education and science advocate. Attendees learned about career paths into federal policymaking and how input from physicists and the public inform the federal policymaking process.

**Joseph Bevitt**, a scientist from the Australian Nuclear Science and Technology Organisation (ANSTO), demonstrated how neutron science can be involved in interdisciplinary research on dinosaurs and outreach programs. In his talk “Dinosaurs, Neutrons and a little Alchemy - revealing the secrets of a long-lost past”, Joseph presented his work, performed at ANSTO in partnership with Australian and international universities and museums, on how combining neutron tomography and isotopic and spectroscopic methods to digitally excavate fossilized soft tissue determines dinosaur blood temperature and reveals nesting behavior and growth patterns. Importantly, before these discoveries are published in peer-reviewed outlets, they are shared on a regular basis with primary and secondary school groups through interactive and hands-on activities at museums, art galleries, and tours of the nuclear facilities. By partnering with local schools, they developed activities that incorporate dinosaur discovery as a contextual basis for introducing the scientific method and abstract physical concepts aligned with the standard curriculum. Students were encouraged to make their observations based on available material and to challenge a scientist through unbounded questioning. These children have directly impacted their research, and new research partnerships have been formed through their introductions and have led to the unexpected and unprecedented discovery of a new dinosaur species via neutron imaging. They have also bolstered broader community

awareness of the benefits of nuclear science to society.

**Jesse Silverberg**, a postdoctoral researcher from Harvard University, discussed how to increase the effectiveness of presenting scientific data. Jesse’s talk was entitled “Transformers, Origami, and Physics: Communicating Science While Navigating the Attention Economy”. Jesse shared some of his experiences of having research go “viral” and using visual design theory to reinforce research themes and explain the process of constructing a “message triangle”. Through these examples, he showed how linguistic framing devices and conceptual metaphors become the Swiss Army knife of science communication as he navigated emerging pathways in the attention economy. Along the way, Jesse dissected these strategies with examples from his work on the physics of Transformer- and origami-inspired reprogrammable materials.

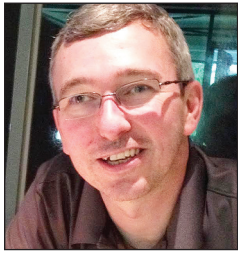
*Maria Longobardi earned her Ph.D. in Physics from the University of Salerno, Italy in 2010 in experimental condensed matter physics. She explored the local electronic and magnetic properties of several novel materials. In 2011, she moved to the University of Geneva, Switzerland where her studies focused on the 1D systems and 2D materials. She is currently performing interdisciplinary studies on bio-nanomaterials. Maria is also a science communicator and freelance journalist. She has been one of the founders of the FECS and has been active in the development of several international programs and outreach/educational activities. During the past years, she served the FGSA as International Student Affair Officer and Newsletter Editor (2011-2015) and the FIP as Member-at-Large and Newsletter Editor (2014-current)*



Jesse Silverberg during his talk at the April Meeting 2018

# March 2018: Los Angeles Full of Stars from the World of Physics and the Movies

Jason S. Gardner, Chair-Elect – Forum For Early Career Scientists, NSRRC, Taiwan



Jason S. Gardner

In early March 2018, Los Angeles was full of great scientists and Oscar goers. I'm sure many of our members found it hard to resist Hollywood and the red carpet, but maybe a few were chased into the safety of the Los Angeles Convention Center by the paparazzi.

## GERA Workshop

The Forum for Early Career Scientists (FECS) had a very active meeting; so active, we started before the meeting! On the Sunday before the main event, the forum proudly partnered with the topical Group on Energy Research and Applications (GERA) and held a workshop focused on “The Future of Sustainable Approaches to Energy”. The workshop consisted of a series of talks by leading experts in the field, lunch with the experts, and a panel discussion. We were fortunate to have Prof. Peter F. Green, the Chief Research Officer for the National Renewable Energy Laboratory, give the opening keynote address. He was followed by George Crabtree (Argonne), Bai-Xiang Xu (Technische Universität Darmstadt), and Amy Prieto (Colorado State) before a break for lunch. After lunch, the workshop continued with Nate Lewis (Caltech), Sue Carter (University of California), Reuben Collins (Colorado School of Mines), and Todd Monson (Sandia) giving very interesting talks. Over 80 early career scientists were able to mix with these



GERA workshop



Co-session with FIAP

eminent scientists throughout the day. The successful workshop ended with an informal reception sponsored by the *Journal on Renewable and Sustainable Energy* before most participants headed to the APS registration booths.

## Session co-sponsored with FIAP

FECS cosponsored two sessions during the week. On Wednesday the 7<sup>th</sup>, we joined the Forum on Industrial and Applied Physics (FIAP) at the start of their Industry Day. This year's Industry Day theme was “Big Data and Physics: Bits to Knowledge”. Our co-sponsored session, entitled “**Data Science as the Driving Force for Modern Industrial Physics**”, featured vibrant and enthusiastic speakers from industry and academia who discussed the mining and use of large datasets. Speakers included Neil Johnson from University of Miami, Sergey Yurgenson from DataRobot and St. Petersburg State University, Bryce Meredig from Citrine Informatics, and David Purdy from Uber. Unfortunately, Sundeep Das from Netflix couldn't join us in LA as advertised. Neil Johnson was awarded with the *Joseph A. Burton Forum Award* by the APS at this meeting. This dynamic session ended with many questions from early career scientists wondering if data science is in their future.

## Session co-sponsored with FIP

On the final day of this year's meeting, the FECS co-sponsored a session with the Forum on International Physics (FIP) about science out of this world. The lunch time session, entitled “**Condensed Matter Experiments**

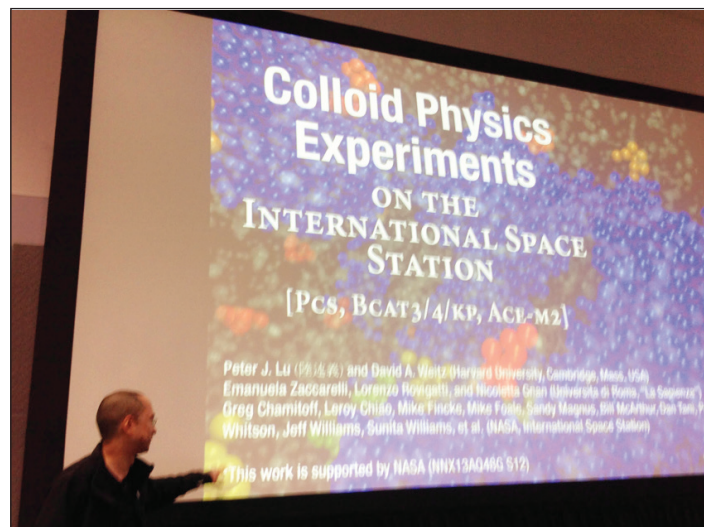


**Onboard the International Space Station**”, had five invited speakers that enthusiastically delivered to the audience their work on getting experiments into space. Joe MacClennan (University of Colorado, Boulder), Eric Furth (University of Delaware), Peter Lu (Harvard University), John Goree (University of Iowa), and Rob Thompson (Nasa, Jet Propulsion Lab) discussed their work on colloids, plasmas, fluids and ultracold atoms on the ISS. The speakers relayed the difficulties they encountered performing what are relatively easy experiments on Earth in the limited ISS workspace, within weight limitations and with the help of a busy, enthusiastic astronaut or cosmonaut instead of a bright young graduate student.

The March 2018 meeting had over 10,000 registered attendees. Not all could attend these excellent sessions organized and co-sponsored by FECS. The executive committee hopes that all those who did attend enjoyed the sessions. We are always open to ideas for future sessions, and we encourage ideas to be posted on our Facebook page or emailed to the chair-elect.

Of course, the APS meetings are not only about listening to exciting talks, but also about opportunities to network and to start conversations that might become long-lasting friendships or collaborations. To encourage this, the FECS co-hosted two receptions during the March meeting with our friends from FIP and FIAP. These events were well attended, with members overflowing into the corridors and FECS members who mingled with scientists from all over the world: from China and Iran, to Turkey and South Africa. The FECS was proud to see such a diverse and esteemed group of international APS members come together and celebrate the lasting global connections and collaboration our fields have to offer.

The 2019 March meeting is now being planned, and the executive team imagines that we will be hosting similar activities in Boston. We hope to see many of our members in our sessions, at our receptions, or participating in the Energy workshop. If you are interested in assisting the FECS in organizing such events, engaging with young researchers in the early



Session co-sponsored with FIP

stages of their careers, and/or encouraging international collaborations, be aware that we are looking for executive members. In the fall of 2018, we will be looking for candidates and holding elections. Please look out for this.

*After obtaining his Ph.D. at Warwick University in the UK, Jason worked for several national laboratories in North America before moving to Sydney, Australia in 2013. From Sydney, he manages a group of five people performing neutron scattering at ANSTO, Australia, and around the world. He is currently the Neutron Group Leader at the National Synchrotron Radiation Research Center, Taiwan. His scientific interests are primarily in frustrated magnets, but he's also performed research in many areas of condensed matter over thirty years of research. He has published over 120 papers and in 2008 was made a fellow of the Institute of Physics (UK). Jason was also a member-at-large of the APS Forum on International Physics from 2015 to 2017.*



## Plasma Physics: The State of the Universe

David Schaffner



David Schaffner

Everyone knows the three phases of matter: solid, liquid, and gas. A smaller subset knows about the so-called “fourth state of matter”: plasma. However, for all the attention and buzz that solids, liquids and gases get—from grade school science to college chemistry—it’s the plasma state that the universe reveals to be most abundant.

Upwards of 99.9% of baryonic matter exists as a plasma: from the bellies of solar furnaces, to the vast emptiness of interstellar space, to the raging death spirals of accretion disks around black holes. Closer to home, on the other hand, plasmas are a rarer occurrence. Naturally, they can occur in the Earth’s upper atmosphere in the ionosphere as well as the auroras Borealis and Australis (Northern and Southern Lights). Within the last century, plasma has been explored and utilized using human-made technology such as in discharge lighting (florescent lights), but also in industrial processing (plasma processing, chemical vapor deposition) and inside tokamaks and other fusion-relevant plasma experiments which aim to recreate the very nature of the solar furnace itself. Despite its growing importance, the fourth state of matter remains very much in fourth place in the hierarchy of terrestrial matter.

What is it about plasma that makes it such a rare occurrence on Earth? In short, our terrestrial world is just too crowded and too cold. A plasma is created by taking matter in the gaseous state and ionizing the constituent atoms or molecules into electrons and ions. This ionized gas, as plasma is sometimes called, behaves like a gas—it retains statistical properties such as pressure, temperature, and density—but consists of charged particles rather than neutral particles, and so attains additional features such as the ability to carry current, or be affected by electromagnetic fields. For a plasma to avoid returning to a neutral gas state, enough members of the system must remain distinct charged particles and exhibit collective behavior. (The requirement for collective behavior is what differentiates a beam of charged particles, such as from an electron gun, from that of a plasma). Given enough energy per particle, clouds of ions and electrons can coexist interspersed within one another. When a plasma gets too

crowded or too cold, enough recombination collisions occur to snuff out the long-range effectiveness of charged electrons or ions. This occurs approximately when the mean free path for 90° collisions between particles becomes smaller than the effective extent of long-range electromagnetic field interactions—a distance called the Debye length.

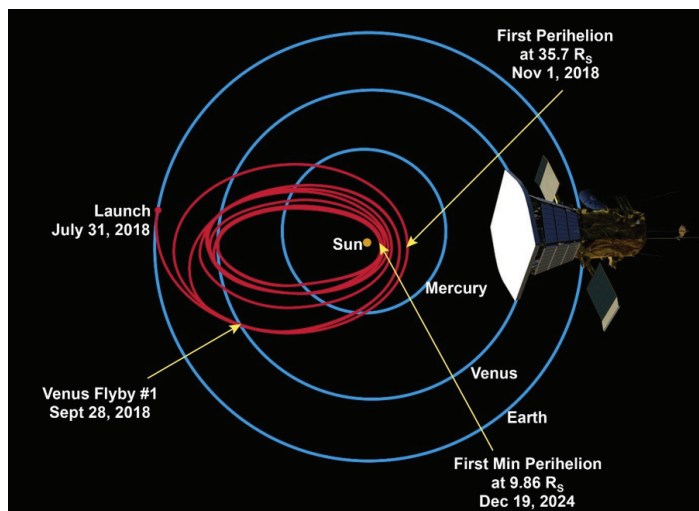
On Earth, such a condition is rarely met and any plasma generated very quickly recombines into a gaseous state. In vacuum conditions, either naturally created at high altitudes or hot temperatures, or artificially created in the laboratory, the mean free path can be made quite larger than the Debye length so plasma can persist. In space, there is just that much more, well, space. In regions of the solar system, mean free paths between particle collisions can be on the order of A.U.

When a plasma is allowed to persist, either naturally or artificially, it is a system that can exhibit an immense amount of complexity, driving interested plasma physicists to study it both for the sake of its inherently fascinating characteristics and for its potential utility as tool for technology.

For the physicists focused on basic physical principles, plasma systems offer an extremely wide range of phenomena to explore. Due to the long-range nature of electromagnetic interactions, the particle constituents of plasma can easily affect one another non-locally, as well as interact directly with static electric or magnetic fields, and electromagnetic radiation. This leads to a myriad of fluctuations that can propagate through the system as waves. Some waves are pressure-based in nature, akin to standard sound waves in a gas, while others can propagate due to electrostatic interactions, or full electromagnetic interactions. Moreover, when the kinetic properties of particles and the frequency variation of electromagnetic fluctuations are taken into consideration, some waves can morph into other waves types as parameters are varied or changed. To this day, a major component of plasma physics research remains the exploration and categorization of wave and instability phenomena in numerous variations of plasma systems, whether experimental, theoretical, or simulated. While particle physics holds the claim of being the “zoo of particles”, plasma physics clearly earns the title of “zoo of waves”.

Additionally, plasma researchers study these systems to better understand the global nature of complicated systems of particles. In particular, the study of plasma turbulence stands at the forefront of interest in the community. Like a fluid, a plasma can exhibit highly non-linear interactions between sections of the plasma or parcels. Given the right conditions, these non-linear interactions can lead to the formation of flow vortices and turbulence. However, the charged nature of plasma adds to the complexity of behavior—one can study simultaneous the turbulent structure of flows and fields in a plasma.

Beyond the basic plasma research aims, the plasma research community falls very roughly into three camps: astrophysical plasma, fusion energy plasma, and industrial or applied plasmas. Astrophysical plasma research seeks to understand the nature of the most common, naturally occurring plasma—that found in interplanetary, interstellar, and intergalactic space. Some focus on heliospheric plasma, ranging from the thermonuclear burning plasma at the sun's core, to the hot, wispy corona, to the interplanetary solar wind, and to the violent collision of solar wind plasma with planetary magnetospheres. Some seek to better understand basic plasma behavior in these massive systems, such as the massive transfer of energy that occurs in magnetic reconnection at the Earth's magnetopause or magnetotail, or the nature of magnetic turbulence in the pristine, expanding solar wind. Others have a more practical goal in mind—understanding and predicting solar weather. Characteristics and behavior of major solar events such as solar flares or coronal mass ejections are studied closely with an eye toward prediction and projection.



Parker Solar Probe, named after Eugene Parker who first theorized the existence of the solar wind, will reach as close as 9.86 solar radii. Its first close pass of the sun will occur in November of 2018. The spacecraft has a massive heat-shield behind which all the instruments are placed to protect them from the brutal onslaught of solar wind particles.

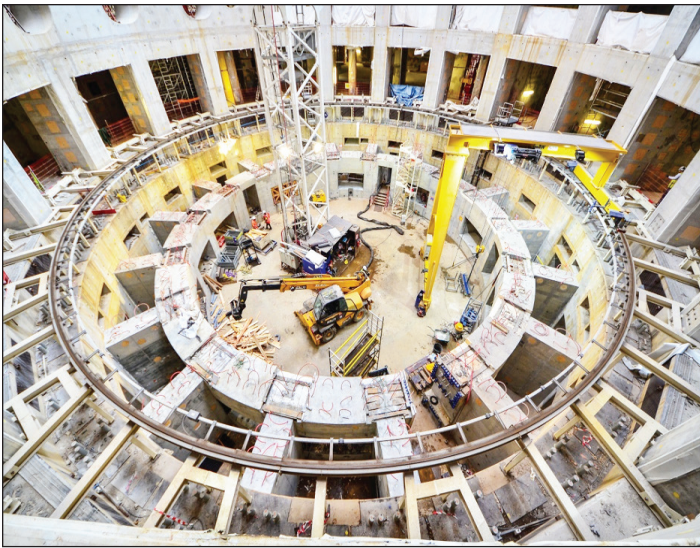
IMAGE FROM JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

For both goals, the primary tools have been in-situ spacecraft and remote observation. Satellites and space craft such as ACE, WIND, and Ulysses, have been measuring the properties of solar plasma for decades, accumulating reams of magnetic, temperature, density, and velocity data. Other craft, either in orbit, such as SOHO, or launched on sounding rockets, have taken numerous photos of the sun in action. Holding most researchers' attention, however, have been the two most recent major spacecraft launches, the Magnetospheric Multiscale (MMS) mission and the Parker Solar Probe (PSP) mission. MMS consists of four satellites orbiting Earth in a tetrahedral pattern. Its primary goal is to better understand magnetic reconnection mechanisms in the magnetosphere while also exploring wave and turbulence observations with unprecedented resolution. Launched just this summer, PSP is the mission "to touch the sun." Its planned seven-year journey around the sun will take it to within 9 solar radii of the sun itself, exploring the inner corona in an effort to unearth the mechanisms that generate the solar wind in the first place.

Astrophysical plasma research has a terrestrial component as well called laboratory astrophysics. In many Earth based experiments, astrophysical phenomena are modeled or recreated in a more controlled laboratory setting. Research at locations such as UCLA, University of Wisconsin, Madison, Naval Research Laboratory, Princeton Plasma Physics Laboratories, and Swarthmore College have developed and pursued techniques studying systems relevant to space physics, including the study of magnetic reconnection, solar dynamo, Alfvénic turbulence, and Whistler waves.

Plasma physics has maintained a vigorous applied focus since the field's conception, particularly in its dogged pursuit of fusion power. Since the understanding that fusing two smaller nuclei into a larger nucleus can result in a tremendous conversion of mass energy into kinetic energy, plasma physics has been a natural home for the development of a controlled method of this fusion. Since scientists on Earth do not have the luxury of a solar-mass amount of gravitation pull to bring nuclei together, other means have been sought. For a sustained fusion reaction to occur, and for more energy to be released than input, the system in question must attain a certain temperature at a certain density for a long enough time—a set of conditions called the Lawson criterion. A plasma is an ideal system to achieve such conditions as its properties lend to a multitude of ways of heating and confinement. Current fusion research is pursued along three avenues:

1. confinement in a magnetic bottle such as a tokamak (DIII-D and NSTX in the US, JET, MAST, and of course ITER in Europe, KSTAR and EAST in Asia), a stellarator (W7 in Germany), or a magnetic mirror (Gamma 10 in Japan and gas dynamic traps in Russia),



Construction of ITER, to be the world's largest tokamak and first burning plasma device, is underway in Provence in southern France. First plasma experiments are set to begin in 2025. Startup companies are racing to beat ITER to the fusion punch, however, including the recently announced SPARC, a joint venture between MIT researchers and venture capitalists.

IMAGE FROM ITER.ORG

2. confinement using inertially imploding plasmas driven by lasers (NIF at Livermore National Labs),
3. confinement using a combination of inertia and magnetic fields called magnetoinertial fusion (currently pursued by venture-capital startup companies such as TAE Technologies, General Fusion, Helion).

While the approaches can be very different, the problems are all too similar. Confinement of the plasma is limited by instabilities that grow, leading to turbulence or violent disruptions of equilibria and stability. Energy must be injected into the plasma to increase heat and density but inevitably leads to steep unstable gradients. Hot plasma can be damaging to materials designed to hold it. Most current research in fusion energy falls into solving these three issues. Attempts to mitigate turbulence and eliminate disruptions are pursued through computer modeling and experiments exploring plasma flows and magnetic structures. Methods for heating plasma through neutral beam injections and electromagnetic radiation are continuously developed and improved. Plasma-

material interactions are studied closely for improving confinement and lifetime of both plasma and container.




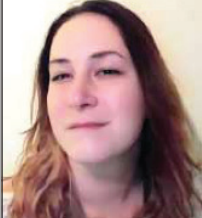



Finally, plasmas have played and are increasingly playing a crucial role in industrial processes and technologies including the semiconductor industry and propulsion. Solid state and nanomaterials are often constructed using plasma-based techniques such as chemical vapor deposition (CVD). Semiconducting material can be doped or probed using ion beam plasmas. Ion and plasma-based thrusters for rockets or spacecraft have been developed and employed for fine control of current spacecraft and potentially primary thrust for space exploration. Relatively recently, medical applications of plasmas have also been developed. These atmospheric plasmas are typically very weakly ionized but retain enough plasma properties to be utilized. In particular, plasmas can be used for anti-microbial applications or for modifying cellular behavior (such as cancer cells).

While plasma may be the least widely known of the four phases of matter, it is an ever-growing field with a mix of ambitious projects, expanding applications, and a forum for study of complicated systems. For the early career scientist, plasma physics offers a wide-open expanse of research opportunities along experimental, theoretical, and computer modeling avenues. Unlike many other mature fields where massive, collaborative aims dominate, fundamental questions about this fascinating medium can still be explored in small- to intermediate-size groups and settings. So grab some energy, ionize some gas, and start playing with plasma.

*David Schaffner received his bachelors degree in physics (minor mathematics) from University of California, Los Angeles (UCLA) in 2006, and his master's and PhD degrees in physics, also from UCLA in 2007 and 2013, respectively. After a postdoctoral fellowship in Department of Physics and Astronomy at Swarthmore College, he joined the faculty at Bryn Mawr college in 2015. David's research interests include: Study of magnetohydrodynamic (MHD) turbulence in a laboratory plasma device.*



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