Introduction to the Introduction to Fusion Energy and Plasma Physics Course

PPPL
Arturo Dominguez
Senior Program Leader, Science Education Department

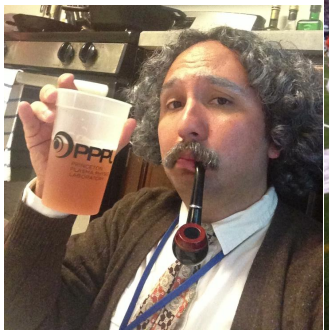
First, a bit about myself

- From Bogotá, Colombia
- Started studying physics at the National University of Colombia at Bogota.

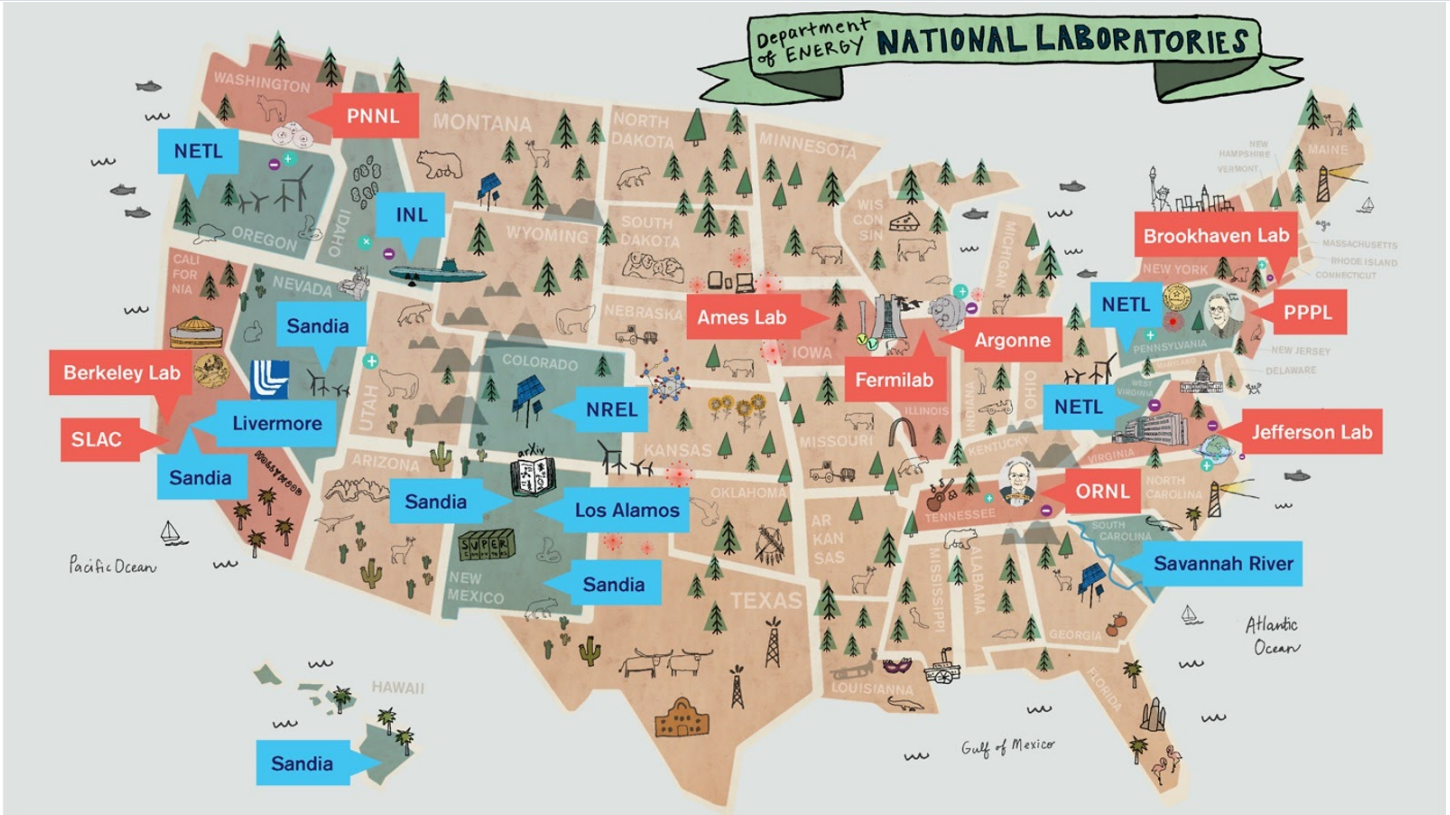
- Transferred to University of Texas at Austin where I finished undergrad (HOOK'EM HORNS!)

- Did my graduate work at MIT, in Boston on **fusion plasmas** (GO BEAVERS!)

- Now I'm at the Princeton Plasma Physics Lab (GO TIGERS!)



PPPL is one of 17 Department of Energy national laboratories



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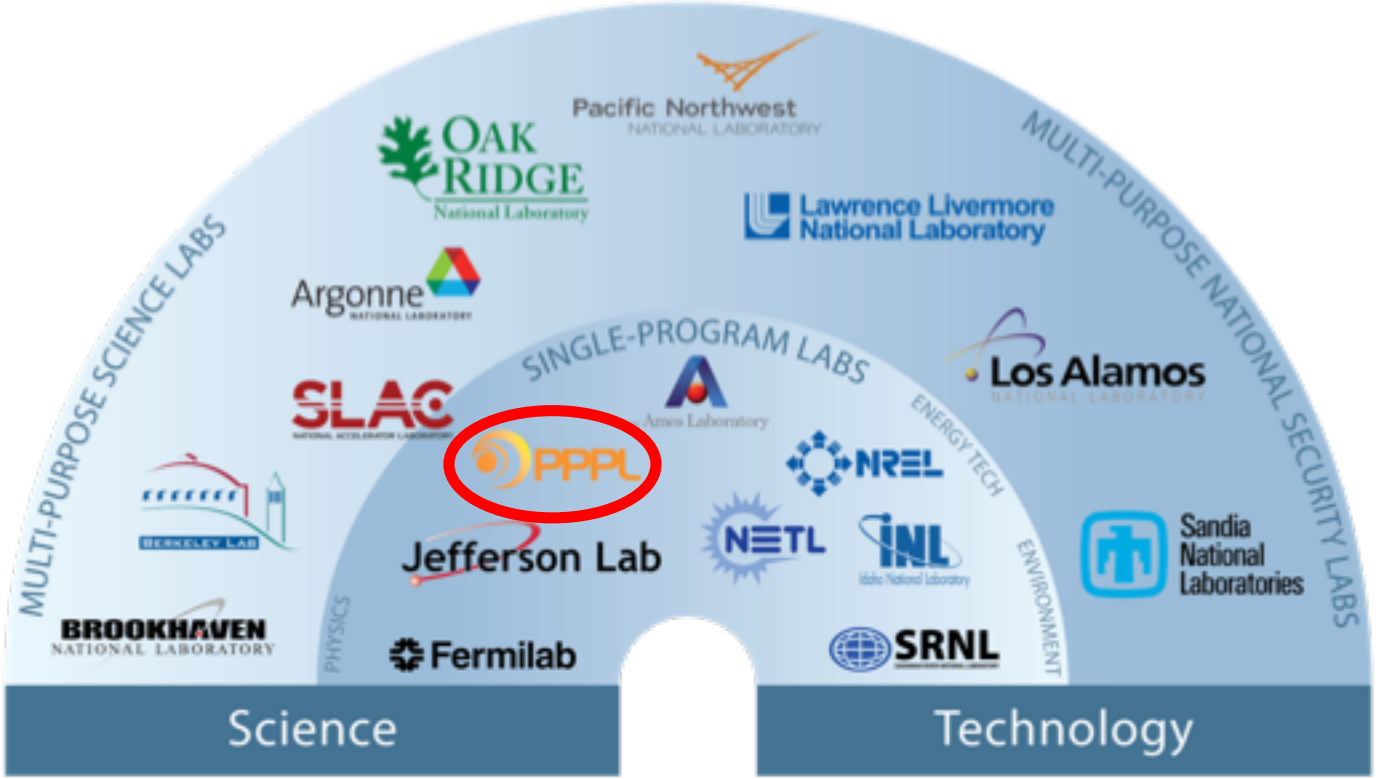

- ~600 employees
- 19 faculty (Princeton)
- ~22 post-docs
- ~40 grad students
- Operated by Princeton U.

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Lyman Spitzer started PPPL (originally Project Matterhorn) in 1951…Birthplace of US fusion

Inventor of the Stellarator

Founder of the lab

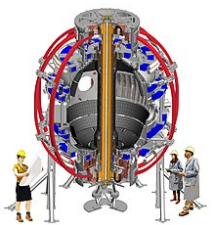
Made countless advances in plasma physics (his name is everywhere)

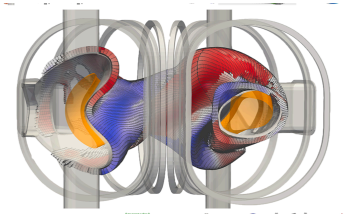
Proposed telescopes in outer space (hence the Spitzer Space Telescope)

PPPL's mission goes beyond fusion

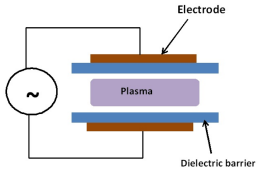
The Laboratory has three major missions:

1.Fusion: To develop the scientific knowledge and advanced engineering to enable fusion to power the U.S. and the world





2.Plasma Manufacturing: To advance the science of nanoscale fabrication for industries of the future



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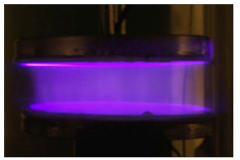
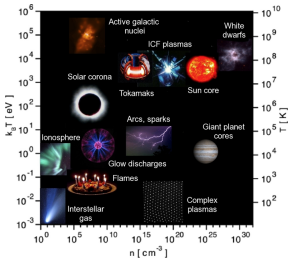
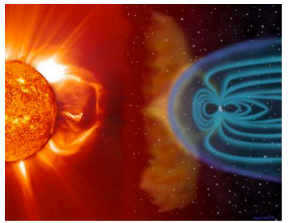


(b)

3.Frontiers of Plasmas: To further the scientific understanding of plasmas from nano- to astrophysical-scales





History of the Intro to Fusion/Plasma Course

- Originally started in 1992 by Prof. Nat Fisch and former assistant director (and former congressman) Rush Holt, as part of the National Undergraduate Fellowship (NUF).

1994 NUF class

Rush Holt

Nat Fisch

Changes during the pandemic

- Fully Remote
- 2 weeks long, but 4.5 hours a day
- Shorter talks (50+10 minutes, vs. 90 minutes)
- Many more talks (30 speakers vs. 15 in the past)!
- Many more participants!
- Broader scope, covering the full spectrum of topics under the Fusion Energy Sciences and Plasma Physics umbrella

All lectures are free to watch and will be posted

- All lectures will be streamed via Zoom Webinar. No registration is need.
- Enrollees, i.e. those who filled out the google form on the site and which we could fit, will have a Zoom-Brady-Bunch-Square, will get priority for questions, join the hallway discussions, and will join the networking events.
- Webinar participants can ask questions using the ask/chat feature.
- ALL written questions should be directed at the hosts and we will hold them for the Q/A portion.
- As has been done since 2015, the course lectures and the speaker videos will be posted on the site.

We had way more submissions than we could handle!

- We were pleasantly surprised by the number and breadth of enrollment submissions (>500)!
- Submissions included undergraduate students, grad students, postdocs, researchers, professors and general public.
- Because of technical limitations, we could only enroll ~300 participants so priority has been given to undergraduates conducting fusion/plasma research.

A birds-eye view of the undergrads

Undergraduate enrollees are based in the US and in many other countries, including: Mexico, India, Philippines, Colombia, UK, and many more!

Many enrollees are conducting internships/summer research. Some of the programs are:

- Science Undergraduate Laboratory Internship Program (SULI) and Community College Internship (CCI), run by DOE.
- NSF funded REUs and the Alabama Plasma Internship Prog.
- Students doing internships at their own colleges
- Private companies developing fusion
- Plasma and Fusion Undergraduate Research Opportunities (PFURO) program

2019 Intro Course Participants

Plasma and Fusion Undergraduate Research Opportunities (PFURO) Program

A new program that we'd like to highlight is Plasma and Fusion Undergraduate Research Opportunities (PFURO).

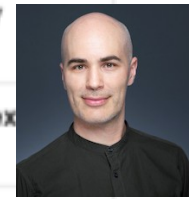
- Funded by the DOE Office of Fusion Energy Sciences
- Managed by PPPL and the US Fusion Outreach Team
- Students from different schools all over the country were selected to conduct research at universities and other undergraduate institutions.
- 8 spots were allocated in this pilot year, with the hope of expanding in future years
- Fully remote in 2021, hopefully in-person in 2022.
- Visit www.pppl.gov/pfuro for more details

2021 participants will conduct research at:

WHAT TO EXPECT IN THE NEXT COUPLE OF WEEKS

Today (6/14) we'll begin with Fusion

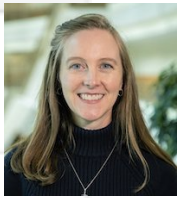
Eastern Time	Day 1 (6/14/21)
12:00 PM	**Introduction to the Course** *Dominguez*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Energy Contex** *Handley*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Intro to Fusion** *Collins*
4:00 PM	**Adjourn**



- Mr Malcolm Handley (Strong Atomics)) will motivate the US and global need for fusion energy by discussing the current energy context.
- Dr. Cami Collins (ORNL) will present the promise and challenges of fusion energy. And highlight the science and technology to make it happen

Tomorrow (6/15) we will talk Plasma

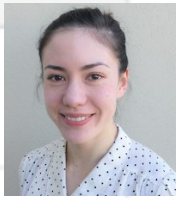
Eastern Time	Day 2 (6/15/21)
12:00 PM	**Introduction to Plasma Physics** *Matthews*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Single Particle Motion** *Hussein*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Plasmas as a Fluid** *Cerfon*
4:00 PM	**Adjourn**



- Prof. Lorin Matthews (Baylor) will introduce basic concepts in plasma physics and frame the field
- Prof. Amina Hussein (University of Alberta) will analyze the motion of ionized particles under the influence of electric and magnetic fields
- Prof. Antoine Cerfon (NYU) will explore another analytical approximation of plasmas, their dynamics as a fluid

Wednesday (6/16) we will continue to explore plasmas

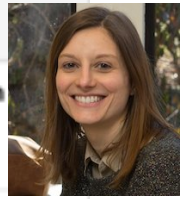
Eastern Time	Day 3 (6/16/21)
12:00 PM	**Magnetohydrodynamics** *Wright*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Turbulence** *Parra Diaz*
2:30 PM	Break/Hallway Discus
3:00 PM	**Plasma Waves** *James*
4:00 PM	**Adjourn**

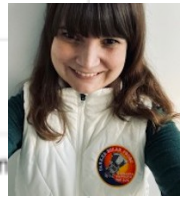


- We continue the introduction to plasmas with Dr. Adelle Wright (PPPL) who will explore the Magnetohydrodynamical (MHD) model of plasmas.
- Prof. Felix Parra Diaz (Oxford) will discuss the ubiquitous and important phenomenon of plasma turbulence.
- Prof. Royce James will highlight the role of waves in plasmas.

Thursday (6/17) we will concentrate on astrophysical plasmas

Eastern Time	Day 4 (6/17/21)
12:00 PM	**Magnetic Reconnection** *Pucci*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Heliosphere Plasmas** *Niembro Hernández*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Astrophysical Plasmas** *Zweibel*
4:00 PM	**Networking Hour**
5:00 PM	**Adjourn**





- Connecting Day 3 and Day 4, Dr. Fulvia Pucci (JPL) will discuss magnetic reconnection
- Dr. Rosa Tatiana Niembro Hernández (Harvard Smithsonian CFA) will touch upon plasmas within the solar system.
- Prof. Ellen Zweibel (UW Madison) will discuss astrophysical plasmas at larger scales

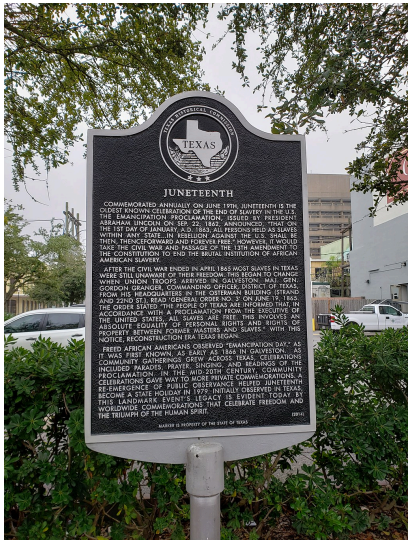
Thursday (6/17) we will also have the first of two networking sessions

Eastern Time	Day 4 (6/17/21)
12:00 PM	**Magnetic Reconnection** *Pucci*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Heliosphere Plasmas** *Niembro Hernández*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Astrophysical Plasmas** *Zweibel*
4:00 PM	**Networking Hour**
5:00 PM	**Adjourn**

- Day 4 will also feature the first of two network sessions in which the group will be divided into groups of ~10-20 and will meet with current graduate students in the field. This is a space to ask questions about grad schools, the grad experience, the field, etc.

Friday (6/18) Princeton and PPPL will be celebrating Juneteenth – NO COURSE

- **Juneteenth is a holiday commemorating the emancipation of enslaved people in the US.**
- It commemorates the day in 1865 when enslaved people of Texas, then the most remote region of the Confederacy, finally learned slavery had been abolished.
- In celebration of **Juneteenth**, Princeton U and PPPL will be closed on Friday, June 18th.
- We welcome you to take some time to learn about Juneteenth and about ongoing systemic racism in the US and in your own country.



Plaque in Galveston commemorating Juneteenth

Saturday and Sunday, we rest

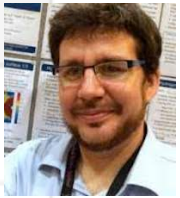
On Day 5 (6/21) we will explore magnetic confinement fusion

Eastern Time	Day 5 (6/21/20)
12:00 PM	**Tokamaks** *Thome*
1:00 PM	Break/Hallwa Discussion
1:30 PM	**Stellarators** *Paul*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Alternative Configurations** *Woodruff*
4:00 PM	**Adjourn**

- We begin our second week with magnetic confinement schemes. Dr. Kathreen Thome (GA) will discuss the most studied configuration, the tokamak
- Dr. Elizabeth Paul (PPPL) will present on the second most studied MFE device, the stellarator
- Dr. Simon Woodruff will close the day with the exciting realm of alternative configurations and alternative paths to fusion energy.

Day 6 (6/22) we will focus on the walls with a detour into computational physics

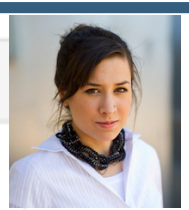
Eastern Time	Day 6 (6/22/20)
12:00 PM	**Plasma-Materials Interactions I** *Guterl*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Plasma-Materials Interactions II** *Abrams*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Computational Methods in Plasma Physics** *Dorland*
4:00 PM	**Adjourn**



- Dr. Jerome Guterl (GA) will introduce the topic of Plasma-Materials interactions with a physics overview of the challenges
- Dr. Tyler Abrams (GA) will continue the PMI conversation and discuss the state of the art in the field.
- We switch topics with Prof. Bill Dorland (U. Maryland) who will introduce a topic that will be relevant to the majority of the audience conducting remote research: Computational methods in plasma physics.

Day 7 (6/23): Structural materials, tritium systems, and computational workshop

Eastern Time	Day 7 (6/23/20)
12:00 PM	**Nuclear Materials and Radiation Damage** *Ferry*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Tritium Fueling, Processing, and Handling** *Mutha*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Computational Workshop** *PlasmaPy Team / Murphy*
4:00 PM	**Computational Workshop** *PlasmaPy Team / Heuer*
5:00 PM	**Adjourn**



- Day 7 will start with a discussion of the materials considerations in building reactors led by Dr. Sara Ferry (MIT)
- Dr. Heena Mutha (CFS) will discuss the systems necessary to deal with tritium in fusion devices
- The second half of the day will be a hands-on computational workshop led by members of the PlasmaPy team: Dr. Nick Murphy (CFA) and Dr. Peter Heuer (LLE).

Computational Workshop

- The computational workshop will be a “hands-on” event organized by the PlasmaPy team, led by Dr. Nick Murphy and Dr. Peter Heuer.
- This workshop will require you to have the Anaconda Python environment installed in your computer.
- In order to ensure the time is spent on the content and not on the setup, we’ve put together this document laying out the steps for installation.

Day 8 (6/24): Low temperature plasmas, High energy density, and networking

Eastern Time	Day 8 (6/24/20)
12:00 PM	**Physics of Low Temperature Plasmas** *Wendt*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Laser-driven HED Plasmas** *Merritt*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Applications of Low-Temperature Plasmas** *Foster*
4:00 PM	**Networking Hour**
5:00 PM	**Adjourn**

- Day 8 will start with a broad overview of the physics of low-temperature plasmas given by Prof. Amy Wendt (U. Wisconsin)
- There will be a brief detour into high-energy density plasmas, specifically laser-driven ones, given by Dr. Elizabeth Merritt (LANL).
- We will venture back into low temperature plasmas with a discussion on applications led by Prof. John Foster.
- The day will conclude with the second networking session event

Day 9 (6/25): LTP+HEDP part II and closing

Eastern Time	Day 9 (6/25/20)
12:00 PM	**Complex Plasmas** *Thomas*
1:00 PM	Break/Hallway Discussion
1:30 PM	**Pulsed-Power Driven Plasmas** *Hansen*
2:30 PM	Break/Hallway Discussion
3:00 PM	**Short-Pulse Driven Relativistic Plasmas** *Willingale*
4:00 PM	**Closing comments / Adjourn** *Dominguez*

- Prof. Ed Thomas Jr. (Auburn) will conclude the low temperature plasmas section with a discussion on complex plasmas.
- Dr. Stephanie Hansen (Sandia) will continue the HEDP section introducing pulsed-power driven plasmas.
- Prof. Louise Willingale (U. Michigan) will conclude the HEDP secition and the course, with a discussion on short-pulse driven relativistic plasmas.

We've started a Discord server for the incoming fusion/plasma community!

- Last summer, we created a venue to let the participants of this course, and, in general, undergrads and grads just starting out in the road of fusion and plasma physics, talk to each other and learn about summer opportunities. Conversations continued beyond the summer.

- With the help of Nigel DaSilva and Louise Ferris, we've created and maintained a Discord server for this purpose. Enrollees were all invited to join.

Nigel DaSilva, 2020 PPPL SULI
Incoming Columbia
grad student

Louise Ferris, 2020 LANL SULI
Incoming UW-Madison
grad student

Continue the conversations with the speakers!

- Some speakers will be able to stick around after their talks to continue discussions. We will share a “Hallway Discussions” zoom link with enrollees. We will announce if speakers will be available and when.

- We will also have Discord channels for each topic to continue discussions and we’re inviting the speakers to join (we’ll also send them the questions that arise there).

APS-DPP abstract submissions

- The American Physical Society Division of Plasma Physics (APS-DPP) meeting is scheduled for the week of November 8-12 @ Pittsburgh, PA. The conference will be held as a hybrid in-person/remote event. Visit the meeting website for up to date information.
- As with every year, undergraduates are invited to present their research at a dedicated poster session. There were more than 100 undergraduate posters at the 2020 APS-DPP meeting!
- **All poster abstract submissions are due July 15th and can be submitted on the meeting website**
- Registration and APS membership is free for undergrads!

These are not normal times and we should acknowledge this

- The reason the course is remote is because we are living during a pandemic.
- All talks are recorded and will be posted, so practice self-care. Take rests, sit out when you're exhausted, stretch, stay hydrated, etc.
- **YOUR HEALTH AND WELL BEING ARE THE PRIORITY!**

A healthy culture of diversity, equity and inclusion is needed for the future of fusion energy and plasma physics

- The US fusion energy and plasma physics community has a poor record on diversity, equity and inclusion, as evidenced by the few women and underrepresented minorities in the field as compared to other physics and engineering fields.

- Recent community-wide strategic plans have, for the first time, acknowledged these problems and put forth initial plans to address them. But an inclusive climate is the only way to start.

Code of conduct

Since this is a public forum we ask speakers and participants to:

- Make participation in our community a harassment-free experience for everyone
- Act in ways that contribute to an open, welcoming, diverse, inclusive, and healthy community
- We align with the Contributor Covenant Code of Conduct

Code of conduct: Unacceptable Behaviors

- The use of sexualized language or imagery, and sexual attention or advances of any kind
- Trolling, insulting or derogatory comments, and personal attacks
- Public or private harassment
- Other conduct which could reasonably be considered inappropriate in a professional setting

Code of conduct: Positive Behaviors

- Demonstrating empathy and kindness
- Being respectful of differing opinions and experiences
- Giving and gracefully accepting constructive feedback
- Accepting responsibility and apologizing to those affected by our mistakes, and learning from the experience

Code of conduct: Positive Behaviors

- Respect the pronouns of others
- Recognize that intent is not equal to impact
- **Self-Care is revolutionary!**

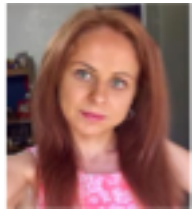
Thanks to the “Intro Course Brain Trust”

The Intro Course Brain Trust is the group of scientists from different topical groups and institutions, that helped with the speaker/topic selection and format of the course. Thank you!

Steffi Diem

Will Fox

Walter Guttenfelder



Eva Kostadinova

Florian Laggner

Ane Lasa

Oak Nelson

Thanks to Deedee and Harry

Special thanks to my colleagues, **Deedee Ortiz**, Program Manager at the Science Education Department, and **Harry Tsamutalis Jr,** A/V Technician.

If the logistics for this course works, it’s because of their hard work.

Finally, of course, thanks to all of the speakers!