June 2020

JINA-CEE

Center for the Evolution of the Elements

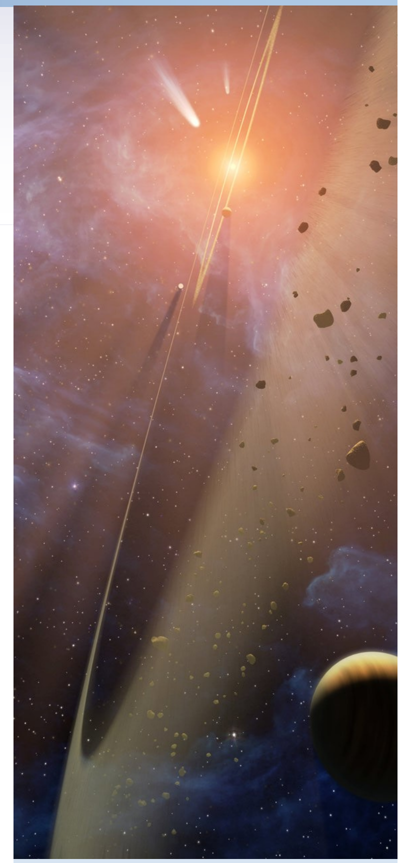
A note from the Director, Hendrik Schatz

Dear JINA-CEE collaborators,

Diversity and inclusion have long been goals of JINA-CEE. It has been frustrating for me to see how racism and implicit bias in academia, and in the communities scientists live in, jeopardize these efforts. I want to assure our black collaborators that we in the JINA-CEE collaboration stand with them and will not tolerate racism, discrimination, and harassment. We also understand that this is not enough. We renew our commitment to actively work against racism and discrimination in our organizations and the events we organize. Despite our efforts in the past we are aware that not enough has been done, but that should not prevent us from aspiring to do better in the future. We have updated our diversity resources in the JINA-CEE website with materials that we found helpful in this context. I hope you can have a look, and I welcome suggestions for additions.

At the same time, I would like to raise awareness of the difficult situation many scientists face due to stay at home orders, remote work, lack of child care, or illness in their family. These challenges exacerbate existing disparities, especially for women and minorities, and can lead to additional discrimination. We have to be understanding that not every collaborator can respond right away or attend every virtual meeting, and that some things will have to wait to get done. We should recognize that the new virtual work environment is less equitable and do what we can to address this issue, for example when organizing events, programs, or collaboration meetings.

With this in mind, we are excited that JINA-CEE, together with international IReNA partners, is forging ahead with new research initiatives, virtual workshops, online hackathons, virtual schools, and virtual summer camps, as well as initiatives to enhance diversity and broaden participation through online activities. I hope you will enjoy this newsletter. I also would like to encourage you to contact me with thoughts on how JINA-CEE can further increase diversity and improve the experiences of underrepresented minorities.



Inside this issue

Image Credit: NASA/JPL-Caltech

Composition and Ashes of Type I X-ray Bursts are Affected by Spallation Processes

Contributed by Jaspreet Randhawa (Michigan State University, USA)

Type I X-ray bursts are among the most fascinating stellar phenomena we can observe, releasing enormous amounts of energy within just a few seconds. Being the most frequent thermonuclear explosions in the galaxy, they provide unique laboratories for testing physics of the densest known form of matter: neutron stars. The basic mechanism behind X-ray bursts is understood, but an important open question is the composition of the material that fuels the burst, especially the amount of nuclei heavier than helium. A new JINA-CEE study led by postdoc Jaspreet Randhawa sheds new light on this question.

Type I X-ray bursts occur in binary systems consisting of a neutron star and a main-sequence companion, usually referred to as the donor star. In these so-called X-ray binaries, material from the donor's envelope is gravitationally pulled onto the surface of the neutron star, where it accumulates, raising the temperature and density until a thermonuclear runaway ensues, powering the X-ray burst. In the early 90s, Bildsten et al. pointed out that while accreted elements heavier than hydrogen and helium slow down quickly on the surface of the neutron star, incoming protons do not slow down as much. As a consequence, they slam into the already stopped heavy nuclei at high energies destroying them via nuclear spallation reactions [1].

Bildsten's study focused on how hydrogen and helium destroy carbon, nitrogen and oxygen (CNO cycle nuclei) by spallation, and showed that the CNO nuclei survival probability is very small. This new study originated as a student group project at a JINA-CEE network school, where it occurred to then grad student Radhawa that the heavy nuclei may not necessarily be completely destroyed by spallation. Indeed, him and collaborators now conclude that the heavy nuclei are often instead transformed into other heavy nuclei which themselves undergo further transformations, resulting in a network of spallation reactions. Through this mechanism, Randhawa et al. find that CNO elements can be replenished due to the destruction of relatively heavier elements by spallation (See Fig. 1).

The resulting higher abundances of carbon, nitrogen, and oxygen, especially at lower accretion rates, alter the amount of hydrogen present at the time of burst ignition. The new spallation-altered accreted composition will serve as an important parameter in future X-ray burst model calculations that aim to predict the thermal and compositional structure of accreted neutron star crusts and extract the elusive properties of neutron stars.

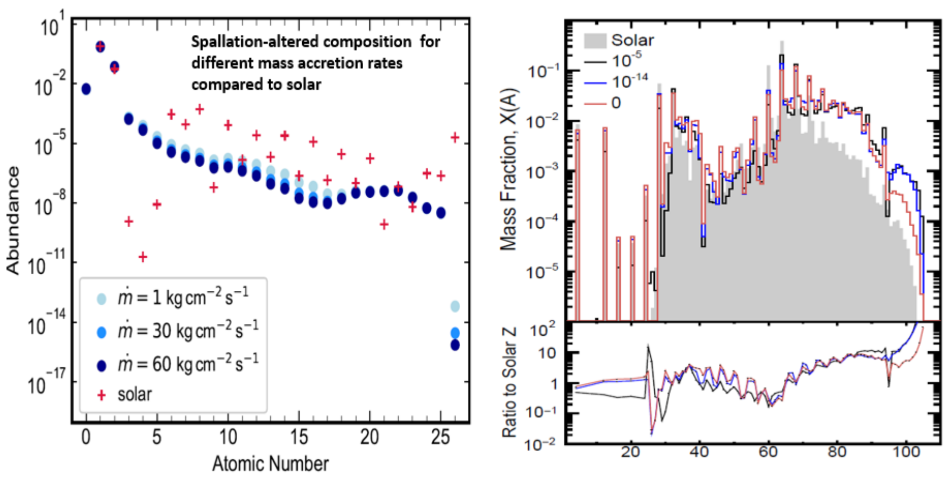


Figure 1.
Left: New predicted composition accumulating on the neutron star surface compared to initial solar composition.
Right: Predicted composition of the nuclear ashes of X-ray bursts for different amounts of heavy nuclei (metallicity). The black curve uses the new predictions, while the blue curve is based on the simple previous model.

Further reading: https://iopscience.iop.org/article/10.3847/1538-4357/ab4f71/meta

References:

[1] Bildsten, L., Salpeter, E. E., & Wasserman, I. 1992,ApJ,384, 143

The Dense Matter Equation of State is Important … Just not for this Reason

Contributed by Zach Meisel (Ohio University)

The dense matter equation of state is required to describe matter at ultrahigh densities. Its elucidation is one of the primary goals of nuclear astrophysics. Neutron stars cooling off after siphoning gas from a binary companion for months or longer, so called cooling transients, offer a potential probe to constrain the properties of matter at extreme densities [1]. Models calculating the cooling of the crust (the lattice of ions making up the outer kilometer of the neutron star) can be compared with cooling transient observations for such constraints. However, one lurking issue with crust cooling calculations is that the pressure (depth) at which the crust transitions to the core (the uniform, possibly exotic, matter comprising the bulk of the neutron star) is linked to the dense matter equation of state and is suspected to influence model results for crust cooling. This severely complicates model-observation comparisons for cooling transient systems.

In a recent work, graduate student Sudhanva Lalit and Zach Meisel from Ohio University teamed up with Ed Brown from Michigan State University to show that the crust-core transition pressure does not significantly alter results of cooling transient model calculations performed using the JINA-CEE code dStar [2]. While changing the crust-core transition pressure changes the neutron star crust thickness, the region near the crust–core interface reaches thermal equilibrium with the core long before the surface cools into equilibrium with these depths (See Figure 1). Thus, the additional crust thickness added by increasing the crust-core transition pressure is essentially invisible. This finding justifies the previously adopted approach in model–observation comparisons of neutron star crust cooling, where the neutron star mass and radius were varied irrespective of considering an equation of state to determine a consistent crust-core transition pressure. This also mitigates concerns about the dependence of the crust-core transition pressure on the procedure used to match equations of state at the crust and core interface.

Further reading

S. Lalit, Z. Meisel, and E.F. Brown, *the Astrophysical Journal* **882**, 91 (2019)

References

[1] Z. Meisel, A. Deibel, L. Keek, P. Shternin, and J. Elfritz, *Journal of Physics G* **45**, 093001 (2018)

[2] E.F. Brown, *Astrophysics Source Code Library*, ascl:1505.034 (2015)

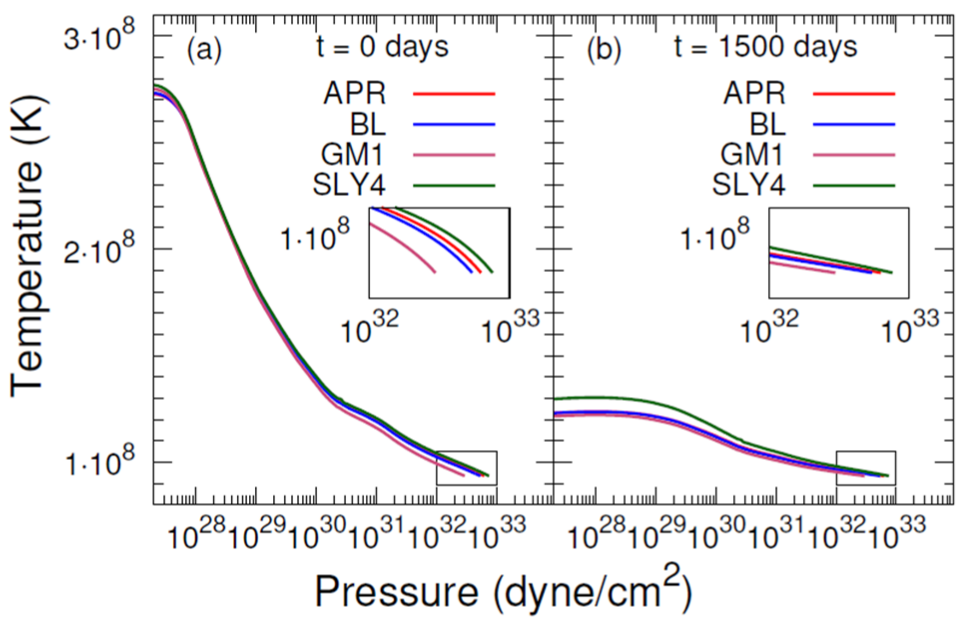


Figure 1. Temperate profiles for an accreted neutron star crust zero days (left panel) and 1500 days (right panel) after accretion ceases. The various lines refer to the dense matter equation of state that was adopted to calculate the crust-core transition pressure. The insets highlight that early differences (left panel) in the thermal profile near the crust-core transition region disappear prior to the (observed) temperature at the neutron star surface coming into equilibrium with this region.

Destruction Rate of ^{40}K in Stellar Nucleosynthesis and Radiogenic Heating of Earth-like Exoplanets

Contributed by Panos Gastis (Central Michigan University)

^{40}K, with a half-life of = 1.248 x 10^9 years, is one of the most important naturally occurring radionuclides that are responsible for the radiogenic heating of Earth-like exoplanets. Radiogenic heating, i.e. heating produced by exothermic decays of radioactive nuclei, affects the geological activities of a planet and has implications for the development of a habitable environment on its surface [1]. Depending on the age of the planet and the chemical evolution of its galaxy, ^{40}K can be the dominant heat-producing radionuclide in its mantle [2]. To predict the initial concentration of ^{40}K in the mantle, and subsequently the thermal evolution of the planet, we currently rely on Galactic Chemical Evolution (GCE) models. In a new JINA-CEE study, researchers from Central Michigan University and Ohio University teamed up to measure the destruction rate of ^{40}K via the $^{40}K(n,p)^{40}Ar$ reaction. The study aims to improve the accuracy of the calculated stellar yields for ^{40}K, an important input parameter for the GCE models that are currently employed for the study radiogenic heating in exoplanets.

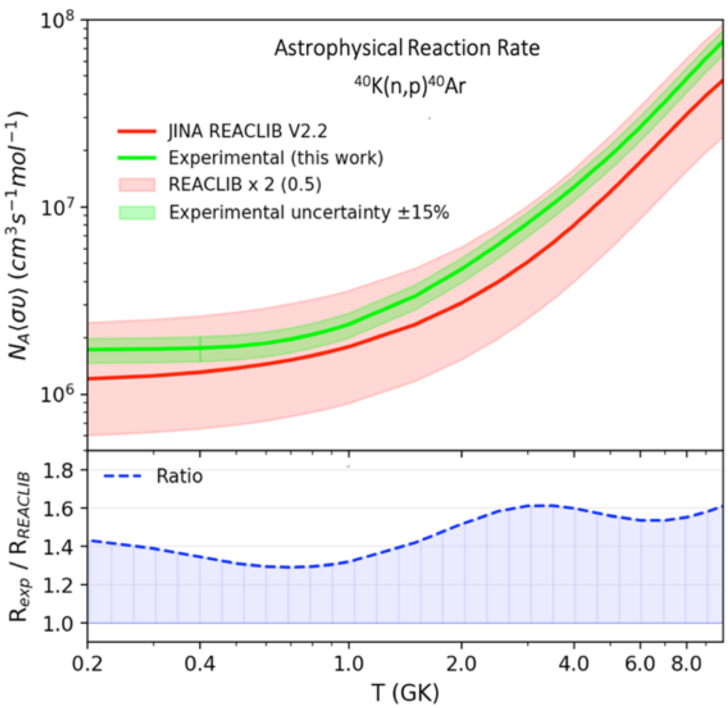


Figure 1. Reaction rate of $^{40}K(n,p)^{40}Ar$ as a function of temperature. The experimental rate was extracted based on the measured cross-sections of the reverse $^{40}Ar(p,n)^{40}K$ reaction.

^{40}K is synthesized during stellar evolution both via fusion reactions (during Oxygen burning) and via s-process nucleosynthesis. At the same time, it is destroyed through the $^{40}K(n,p)\,^{40}Ar$ and $^{40}K(n,\alpha)^{37}Cl$ reactions. In this study, researchers constrained for the first time the destruction rate of ^{40}K through the $^{40}K(n,p)^{40}Ar$ reaction, by measuring the reverse $^{40}Ar(p,n)\,^{40}K$ reaction. The experiment took place at the Edwards Accelerator Laboratory at Ohio University, using a proton beam and a ^{40}Ar target.

The team found that for temperatures suitable for stellar nucleosynthesis, the experimentally constrained rate is up to 40% higher than the suggested theoretical rate in the JINA-REACLIB library (see Fig. 1). The new rate is determined with an uncertainty of about 15%, which is significantly lower than the typical uncertainty of 100% (factor of two) of the theoretical reaction rates from statistical model calculations in this mass region.

These findings are expected to reduce the associated uncertainties on the calculation of stellar yields for ^{40}K [3] and improve the accuracy of the radiogenic heating models that are currently used for predicting the habitability in exoplanets.

Further reading P. Gastis et al., Phys. Rev. C 101, 055805.

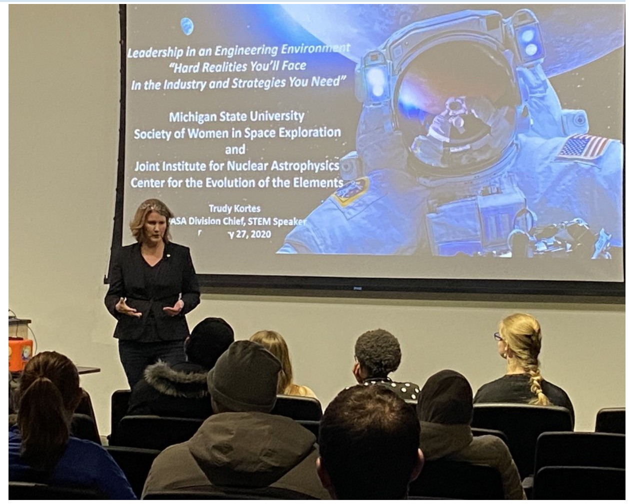
References:

[1] B. J. Foley and A. J. Smye, Astrobiology 18, 873 (2018)

[2] E. A. Frank, B. S. Meyer, and S. J. Mojzsis, Icarus 243, 274 (2014)

[3] R. D. Hoffman, S. E. Woosley, T. Weaver, T. Rauscher,and F.-K. Thielemann, Ap. J.521, 735 (1999)

NASA's Trudy Kortes Visits MSU to Deliver Talk on Leadership in STEM



As part of our efforts to improve the professional development of our students, JINA-CEE supported an initiative by the Michigan State University Society of Women in Space Exploration (SWISE), a club of undergraduate students at MSU, to invite NASA's Chief of Human Exploration and Space Explorations Division, Trudy Kortes, to MSU. On February 27th, after a tour around the FRIB laboratory, Trudy delivered a lecture on proven strategies for leadership in an engineering environment.

During her lifelong career at NASA, Trudy has worked on a variety of programs including the Orion crew module, designed to carry explorers on new missions to Mars, Glenn's Radioisotope Power Systems Program Office, investigating nuclear power technologies to enable future space exploration missions; and the Cryogenic Propellant Storage & Transfer project. She earned her bachelor's degree in aeronautical engineering from the University of Michigan, and a masters degree in environmental engineering from the University of Houston. A talented communicator, Trudy was the winner of the 2017 NASA Headquarters talent show for stand-up comedy.

Molly Janasik, president of the SWISE chapter at MSU, met Trudy while attending University of Michigan's Women in Aerospace Conference, where she was a keynote speaker, and invited her to visit MSU.

Trudy said of her visit: "*the tour of their impressive Facility for Rare Isotope Beams, their attentiveness and enthusiasm for my 'Leadership in an Engineering Environment' lecture, and excellent discussions with students went beyond my expectations. College students are craving this type of knowledge, advice, and guidance that goes beyond traditional academics. I'm a lifetime Wolverine, but their warm reception made me feel like a Spartan for a day!* "

Student testimonials:

"She was so inspiring, motivating and even funny too during her talk, and I chatted with her afterwards about advice to work at NASA someday among other things [...]. Her talk at MSU was keyed on essential leadership skills and advice to be successful in our careers, no matter our field. Her words resonated with me immensely." -Molly Janasik

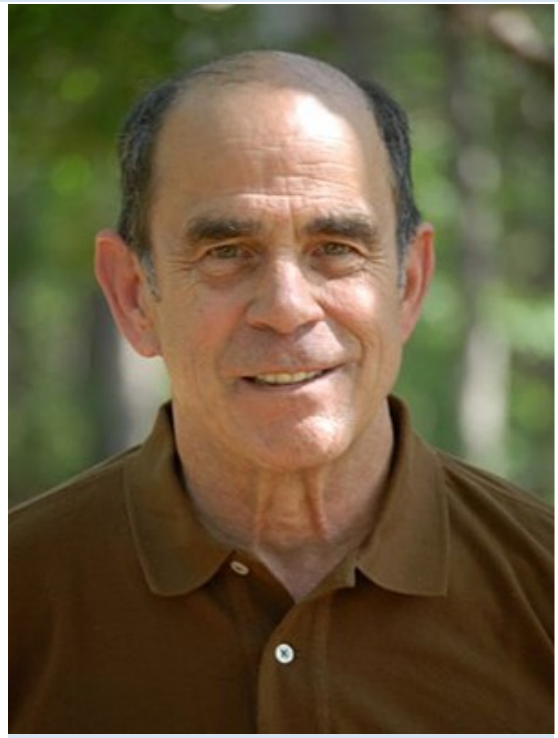
From left to right: SWISE eboard members Katelynn Ehlert, Alexa Gordon, Maya Watts, Aalayah Spencer, Molly Janasik and speaker Trudy Kortes

"*She spoke of leadership and teamwork in the professional world in a way that made me more excited to start my career as a woman in STEM."* - Katelynn Ehlert

"It was a great experience to have a strong woman leader talking to us about the issues women face in a male-dominated field. The talk was also very insightful on current issues to overcome in order to make science more inclusive and attract people of all backgrounds, races and genders." - Ashley Francis

JINA Co-founder Jim Truran is Awarded the 2020 LAD Laboratory Astrophysics Prize

We are pleased to congratulate Jim Truran, one of the founding Principal Investigators of JINA, for being awarded the Laboratory Astrophysics Prize, the highest honor awarded by the Laboratory Astrophysics Division (LAD) of the American Astronomical Society (AAS).



James Truran
The University of Chicago

The prize is given to individuals who have made significant contributions to laboratory astrophysics over an extended period of time. Jim has long been recognized as one of the most prominent scientists in nuclear astrophysics, having worked on nearly all aspects of the field during his long and outstanding career. Together with Sumner Starrfield, he was one of the first to simulate and interpret novae as thermonuclear explosions on accreting white dwarf stars, and he also made major contributions to the interpretation of neutron induced nucleosynthesis though the slow and rapid neutron capture processes and the chemical evolution of the Galaxy.

Jim was one of the Principal Investigators during the first two JINA funding cycles, leading the theoretical efforts on nucleosynthesis and explosive mechanisms of novae and supernovae. Always full of new ideas, he strived to stimulate discussion among people working on different aspects of nuclear astrophysics. He was key in JINA's success to establish and maintain close interaction and collaboration between modelers, experimentalists and observers.

Jim lead the nuclear astrophysics group at the University of Chicago, where he currently is Professor Emeritus at the Department of Astronomy and Astrophysics.

According to the AAS, Jim Truran is awarded the LAD prize in recognition of "his theoretical work on early star formation and the nucleosynthesis history of the universe, as well as for his seminal contributions to the study of astrophysical thermonuclear explosions, nucleosynthesis, and the use of nuclear-decay chronometers to determine ages of stellar and terrestrial matter".

"He is a most deserving recipient for the Laboratory Astrophysics Award 2020!" – Michael Wiescher.

Read the AAS press release here: https://lad.aas.org/prizes/2020_lab_astro_prize

JINA-CEE Faces:
Interview with Anna Simon

Anna Simon is an assistant professor of physics at the University of Notre Dame, near South Bend, Indiana. She is from Poland, where she obtained her PhD in atomic physics from the Jagiellonian University in Krakow.
She had her first encounter with the US Midwest when she ran her thesis experiment at Western Michigan University. She later returned to Michigan as a postdoc with Artemis Spyrou at Michigan State University, where she contributed to the commissioning of the SuN (**Su**mming **N**aI(Tl)) detector. After MSU she moved to the University of Richmond in Virginia to work on nuclear reactions and structure, as well as on applications like stockpile stewardship. She joined Notre Dame in 2014.

Anna Simon
University of Notre Dame, USA

When did you decide to pursue a career in science?
My high school physics teachers motivated me to go into science, they encouraged me to participate in competitions in physics and environment, and in the physics Olympics. I thought this was fun and challenging. Also, my dad is an electrical engineer and he used to be very interested in my physics homework, especially in electricity and magnetism. We often competed to see who could solve my homework problems first. It was fun and motivating to see his fascination with these topics.

How do you interact with JINA-CEE?
Mostly through workshops, and developing collaborations with people interested in similar work. We pair with theorists who incorporate our measurements into their models. I also use JINA-CEE as a platform to increase my students' visibility in the field, and to do lots of networking. I co-organized the JINA sponsored p-process workshop a couple years ago and it was a great collaborative experience.

What is the focus of your research?
My group performs measurements of capture reactions relevant for the astrophysical p-process in order to understand where heavy proton-rich nuclei come from, and how they are created. Our other main area is the study of statistical properties of nuclei. We measure gamma strength functions and level densities to later use them to model the cross sections needed to constrain astrophysical processes, like the slow and rapid neutron capture processes.

What are the main instruments you use in your research?

HECTOR detector installed at the underground CASPAR laboratory

Using the expertise gained while working with SuN, I led the construction of our own gamma-ray NaI summing detector at Notre Dame. HECTOR (High Efficiency Total absorption spectrometer) is already operational, and has recently been installed at the CASPAR lab, located 4850 ft underground in South Dakota.

What's your favorite part of your job?
The possible applications of what we measure in the lab. Whether it is understanding of the p-process and creation of elements in the universe, or providing information relevant to applications important for national security.
Also, helping my students getting involved in research and watch them become scientists.

What's your advise for junior researchers?
Look for role models and build a strong support network. In my case, watching Artemis as a group leader, and collaborating with other female researchers at Notre Dame, even outside of the nuclear group, has been very useful.

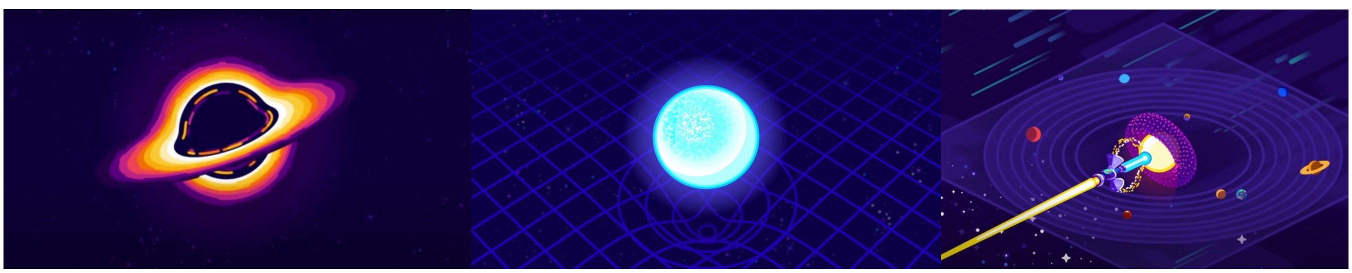
Nuclear Astrophysics Outreach, One Video –Reaching Millions of Viewers- at a Time

Matt Caplan
Illinois State University

Have you recently searched for ‘neutron stars’ on YouTube? If not, you probably will want to do that pretty soon.

Our collaborator and former JINA-CEE grad student Matt Caplan, now assistant professor of physics at Illinois State University, has been a long time script writer for the YouTube channel Kurzgesagt – In a Nutshell. One of his most recent contributions "Neutron Stars – The Most Extreme Things that are not Black Holes", is actually the first result if you search for ‘neutron stars’ on YouTube, and it has been viewed more than 6.6 million times, which is pretty cool. The video was released towards the end of last year and volunteers have captioned it in 33 languages at this point. A long list of JINA-CEE science from both major areas are discussed in the video, such as stellar evolution and nucleosynthesis, core collapse supernovae, exotic equations of state, crusts and nuclear pasta, pulsars and magnetars, and neutron star mergers and kilonova. The video ends with r-process elements making their way to the viewer’s laptop so they can actually watch the video!

Another one of Matt’s recent YouTube hits is "How to Move the Sun: Stellar Engines", where megastructures that could be used to move our entire solar system are described. With nearly 6.5 million views, "The Caplan Thruster" is now a famous hypothetical engine powered by solar wind, capable of saving us all from a deadly nearby supernova. If this doesn't sound cool enough yet, check out the peer-reviewed paper that came out of this idea: M. Caplan, Stellar Engines: Design Considerations for Maximizing Acceleration, Acta Astronautica 165, 2019, 96-104



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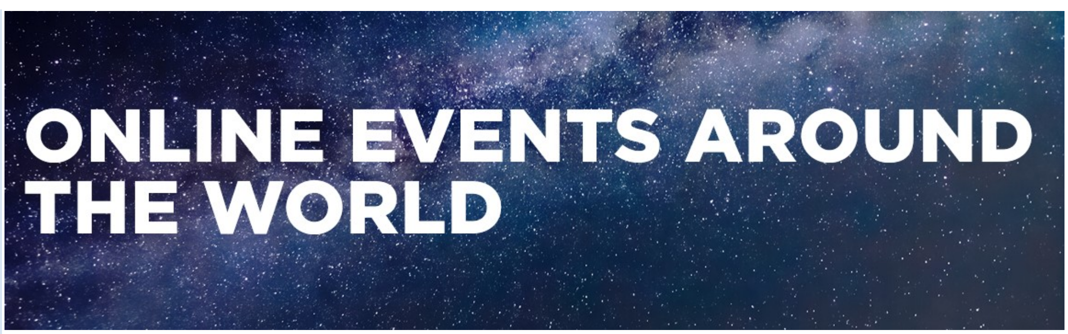

With most scientific interactions currently taking place online, we have complied a list of events in nuclear astrophysics that may be of interest to our members.

Most of the events listed are open to the public, but in some cases you may need to contact the organizers directly in order to gain access.

https://www.jinaweb.org/events/online-events-around-world

JINA-CEE Institutions

JINA-CEE is supported by the National Science Foundation through the Physics Frontiers Center Program

JINA-CEE Core Institutions:
Michigan State University, Physics and Astronomy Department, NSCL
University of Notre Dame, Department of Physics, ISNAP
Arizona State University, SESE
University of Washington, INT

JINA-CEE Associated and Participating Institutions:
CCAPP Ohio State University, CNA Shanghai Jiao Tong University Shanghai China, EMMI-GSI Helmholtz Gemeinschaft Germany, Florida State University, INPP Ohio University, Los Alamos National Laboratory / LANSCE-3, McGill University Canada, MoCA Monash University Australia, NAVI Germany, North Carolina State University, NUCLEI LANL, Argonne National Laboratory, Princeton University, Center for Nuclear Astrophysics China, Cluster of Excellence Origin and Structure of the Universe Germany, TRIUMF Canada, University of Amsterdam Netherlands, University of Chicago, University of Minnesota, University of Sao Paulo Brazil, University of Hull UK, University of Victoria Canada, Western Michigan University, Ball State University, Hope College, Indiana University South Bend, SUNY Geneso, University of Oslo Norway, ChETEC, and the National Astronomical Observatory of Japan.

JINA-CEE also has participants from:
Bucknell University, California Institute of Technology, Central Michigan University, Gonzaga University, Al-Balqa Applied University Jordan, LBNL, Louisiana State University, Massachusetts Institute of Technology, MPI for Extraterrestrial Physics Germany, UNAM Mexico, Ohio State University, Stony Brook University, TU Darmstadt Germany, University of Illinois, University of Michigan and Wayne State University.

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