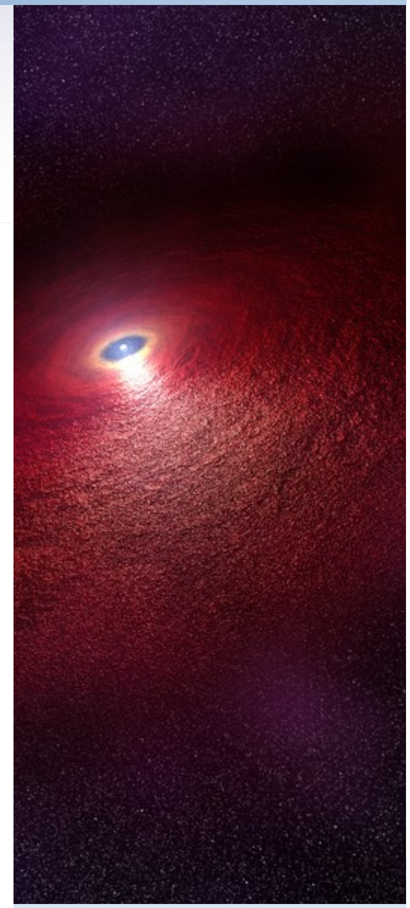
JINA-CEE

Center for the Evolution of the Elements

December 2018



A note from the Director, Hendrik Schatz

Dear JINA-CEE Community,

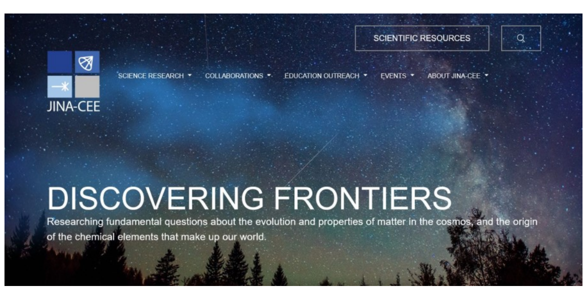
A lot of interesting things have happened in JINA-CEE in the last few months. In addition to all the exciting science that you can read in part about in this newsletter I am particularly excited about the launch of our new website. It not only looks much better, but it has also been optimized to guide users more easily to our most important scientific and educational tools - for example various data bases, the virtual journal, conference lists, outreach activities, and teaching materials. I hope you will check it out!

Another thing I am particularly excited about is the active role that young scientists in JINA-CEE play in creating new educational and scientific opportunities. When looking through this newsletter I was struck by the fact that five out of the six JINA-CEE workshops and conferences announced are organized by junior scientists (students or postdocs). In fact, the First Frontiers Summer School is an initiative of a group of young people from multiple JINA-CEE institutions and different subfields who developed their own vision, proposed the meeting to the collaboration, and are now in charge of organizing the event. I think this shows the vitality of the field of nuclear astrophysics. It also shows that interesting things can happen when people connect across disciplines and institutions.

In that same spirit I am very happy about the new formal connection we have created with the European ChETEC network (see Page 5). ChETEC is a nuclear astrophysics network across 30 European countries. We will work together over the next months to deepen existing collaborative connections and take advantage of new scientific opportunities. I encourage all JINA-CEE participants to engage in this effort.

I wish you all
Happy Holidays,

Hendrik Schatz



Inside this issue

Image: artistic representation of a disk around a neutron star. The warm dust produces an infrared signature as detected by Hubble. Credit: NASA, ESA, and N. Tr'Ehnl (Pennsylvania State University)

Using the Gaia satellite to study the environment of the r-process

Contributed by Ian Roederer (University of Michigan, USA)

Understanding the origin of the elements is one of the major challenges of modern astrophysics, and the r-process is one of the fundamental ways that stars produce the heavy elements. In the last few years, astronomers have found new ways to understand the r-process by observing its impact on the surrounding environment. This could be observed directly, as in the case of the "kilonova" electromagnetic counterpart associated with the merger of two neutron stars detected in gravitational waves (GW170817; [1, 2]). It could also be observed indirectly, as in the case of the r-process-rich dwarf galaxy Reticulum II, where the yield of a single r-process event can be estimated because other properties of the galaxy are known ([3, 4, 5]).

To help answer this question, JINA-CEE researcher Ian Roederer and his colleagues Kohei Hattori and Monica Valluri at the University of Michigan recently published [6] a new technique to assess the impact of the r-process on its environment.

This technique studies the orbits and other kinematic properties of highly r-process-enhanced stars in the Milky Way field population. Earlier this year, the European Space Agency's Gaia satellite released a catalog of astrometric data for 1.3 billion stars, including many of the known r-process-enhanced stars. Using these data, the team was able to calculate the shapes and sizes of the orbits of these stars and look for similar properties among them for the first time.

The results suggest that virtually all highly r-process-enhanced stars known are members of the Galactic halo population, and they just happen to be passing through the Solar Neighborhood right now. The results also suggest that these stars were likely born long ago in dwarf galaxies, which were later disrupted through tidal interactions with the Milky Way. If so, the study suggests that the birth environment, rather than the nature of the r-process site, may be the key factor contributing to creating the highly r-process-enhanced stars that are frequently studied by astronomers.

As the Gaia satellite continues to collect data on billions of stars in the Milky Way, larger and more distant samples of r-process-enhanced stars will be available for studies like this one.

Further reading: "Kinematics of Highly r-process-enhanced Field Stars: Evidence for an Accretion Origin and Detection of Several Groups from Disrupted Satellites" ApJ, 156, 179 (2018). We acknowledge support by NSF grants PHY 14-30152 (JINA-CEE), AST 16-13536, AST 18-15403 (to I.U.R.), and NASA-ATP award NNX15AK79G (to M.V.).

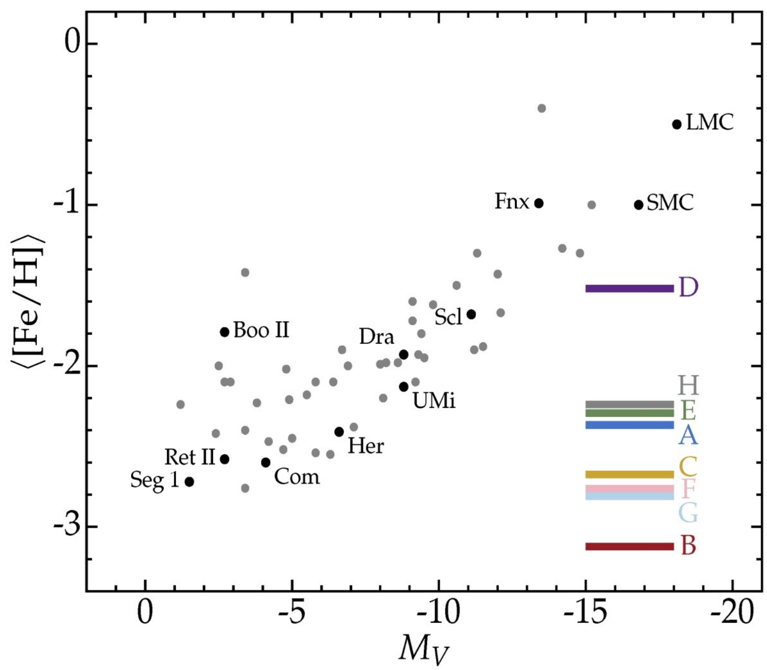


Figure 1. The average metallicities of kinematically-similar groups of r-process-enhanced stars (horizontal lines labeled A-H), compared with the dwarf galaxy luminosity-metallicity relation. The low average metallicities of these groups suggest the r-process-enhanced stars were born in dwarf galaxies similar in mass or luminosity to today's so-called ultra-faint dwarf galaxies.

References:

[1] Abbott, B.P., Abbott, R., Abbott, T.D., et al. 2017 Astrophys. J. Let., 850, L39

[2] Drout, M.R., Piro, A.L., Shappee, B.J., et al. 2017, Science, 358, 1570

[3] Beniamini, P., Hotokezaka, K., Piran, T. 2016, Astrophys. J., 832, 149

[4] Ji, A.P., Frebel., A., Chiti, A., Simon, J.D. 2016, Nature, 531, 610

[5] Roederer, I.U., Mateo, M., Bailey, J.I., et al. 2016, Astron. J., 151, 82

[6] Roederer, I.U., Hattori, K., Valluri, M. 2018, Astron. J., 156, 179

Rapidly-Accreting White Dwarfs and the i-Process in a Galactic Chemical Evolution Context

Contributed by Benoit Côté (Konkoly Observatory, Hungary)

A rapidly-accreting white dwarf (RAWD) is a white dwarf that accretes matter from a companion star (Fig.1), rapidly enough to steadily burn on its surface the accreted hydrogen into helium. Once a RAWD reaches a critical mass, the accumulated shell of helium undergoes a thermal flash that triggers convection. This convective motion ingests protons into the helium shell, which are thereafter captured by ^{12}C to form ^{13}N. While being transported by convection to the bottom of the helium shell, ^{13}N decays into ^{13}C. Neutrons are then released via the reaction ^{13}C + alpha —> ^{16}O + neutron. The number density of neutrons in this convective-reactive process can reach a value of about 10^{15} neutrons per cm^3, intermediate between those characteristic of the slow (s) and rapid (r) neutron-capture processes, thus called the intermediate (i-) process.

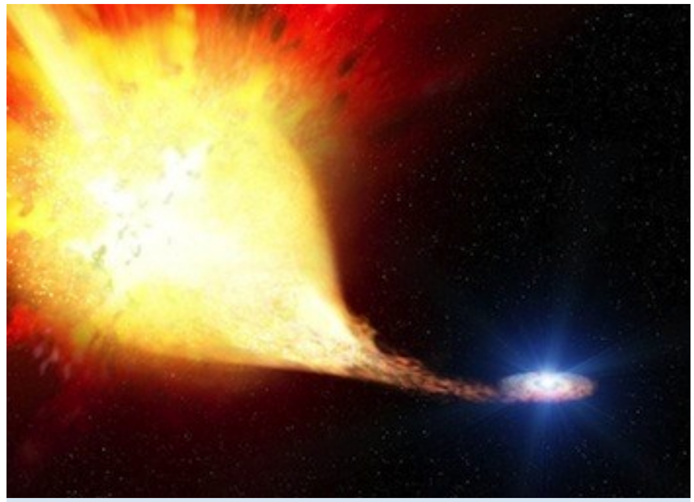


Figure 1. Artist illustration of a white dwarf (right object) accreting gas from a companion star (left object). ©ESA and Justyn Maund (Queens University Belfast).

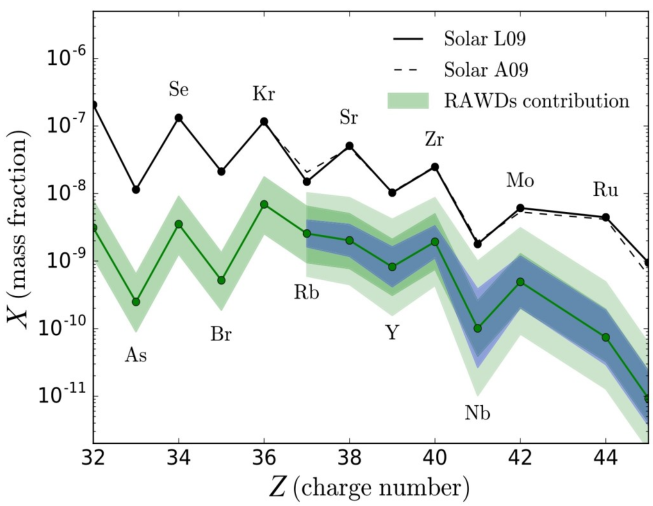


Figure 2. Abundances (y axis) of first-peak neutron-capture elements (x axis) observed in the Sun (black lines). The green line shows the predicted contribution of RAWDs using our galactic chemical evolution model. Dark-green and blue shaded areas highlight uncertainties from galaxy evolution modeling and from cross sections involved in nuclear reaction rates [4], respectively. The lighter-green shaded area shows the combined uncertainties.

In a recent study [1], we introduced the i-process yields calculated by P. Denissenkov [2] into our galaxy model [3] in order to quantify the contribution of RAWDs (via the i-process) on the chemical evolution of neutron-capture elements in the Milky Way. We found that RAWDs could contribute to a non-negligible fraction of first-peak neutron-capture elements observed in the Sun, such as Rb, Sr, Y, and Zr (Fig.2). We also demonstrated that the i process can complement the s process in recovering the isotopic composition of the Sun (e.g., ^{96}Zr, ^{95}Mo, and ^{97}Mo). In addition, this study clearly highlighted that nuclear physics uncertainties [4] have a major impact on the predictive power of chemical evolution models, a reminder of the necessity of inter-disciplinary collaborations.

Researchers: B. Côté (UVic, Konkoly Observatory), P. Denissenkov (UVic), F. Herwig (UVic), A. J. Ruiter (Australian National U.), C. Ritter (UVic, Keele U.), M. Pignatari (U. of Hull), K. Belczynski (Nicolaus Copernicus Astronomical Center)

References:

[1] B. Côté et al., 2018, ApJ, 854, 105

[2] P. Denissenkov, et al., 2017, ApJ, 834, L10

[3] NuGrid Python Chemical Evolution Environment (http://nugrid.github.io/NuPyCEE/)

The Strongest Material in the Universe

Contributed by Matt Caplan (McGill Space Institute, Canada)

Neutron stars are the densest objects in the universe, and new research by JINA-CEE researcher Matt Caplan, a postdoc at the McGill Space Institute, now finds that they may contain the strongest material in the universe.

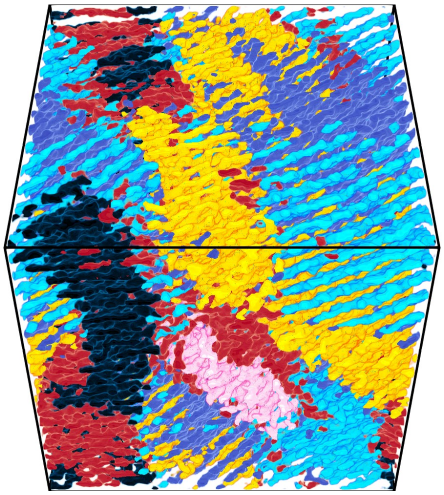


Figure 1. A closer look at the largest ever simulation of nuclear pasta, containing over three million protons and neutrons. The colors show the formation of "domains" where nuclear pasta is locally ordered, analogous to domains and cristallites observed in terrestrial materials.

Formed when the core of a massive star implodes in a supernova, a neutron star is like a giant nucleus, with protons and neutrons squeezed so closely together that the mass of the sun fits in a space smaller than the island of Manhattan. But in many ways neutron stars are more like the Earth than a star. Their intense gravity creates enormous pressure which freezes their outer layers solid, giving them a solid crust over a liquid core. Since this crust is the part of the star astronomers can observe, it's essential to understand its properties to probe the interiors of these extreme objects. On Earth, the strength of rock can affect the magnitude of earthquakes and the heights of mountains, and neutron stars are no different. The strength of the materials in the neutron star crust may affect similar phenomena. Crust breaking on neutron stars may produce electromagnetic radiation and strong materials may support mountains which, if large enough, could radiate gravitational waves.

Recently, Caplan and collaborators published a paper in Physical Review Letters [1] which includes the first ever calculations of the strength of the material at the base of the crust. A kilometer below the surface, the pressure is so great that nuclei get squeezed together and protons and neutrons rearrange into cylinders and sheets of nuclear material, named 'nuclear pasta' for its resemblance to spaghetti and lasagna. Caplan and his collaborators performed the largest ever simulations of nuclear pasta, containing over three million protons and neutrons, which took nearly 2 million processor hours to run. These simulations stretched and squeezed the pasta to calculate its strength and study how it breaks. They found that nuclear pasta is the strongest material in the universe, which makes it possible for neutron star crusts to have crustal mountains that are tens of centimeters high. While that may not seem like much, the incredible density of the neutron star crust means that these mountains contain far more mass than the Himalayas. If any nearby neutron stars have mountains this large, they could be radiating gravitational waves which LIGO and other gravitational wave observatories may soon detect.

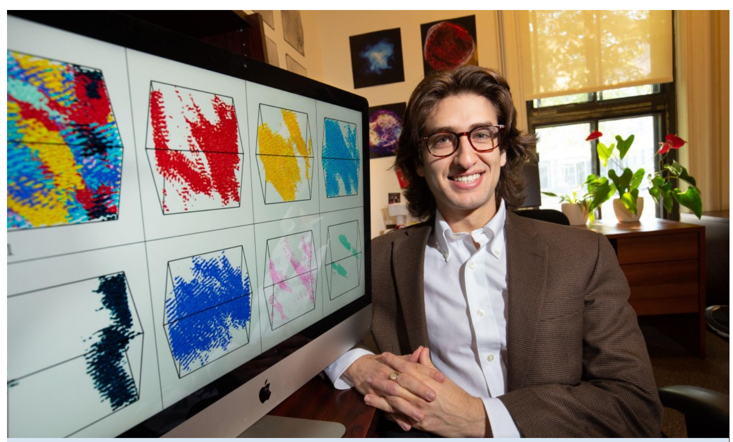


Figure 2. Matt Caplan pictured in the McGill Space Institute with his simulations of nuclear pasta.

Further reading:

[1] M. E. Caplan, A. S. Schneider, and C. J. Horowitz, Phys. Rev. Lett. 121, 132701

https://www.theatlantic.com/science/archive/2018/10/neutron-stars-nuclear-pasta/573166/
https://www.newsweek.com/nuclear-pasta-neutron-star-strongest-material-universe-1127491
https://www.sciencenews.org/article/nuclear-pasta-neutron-stars-may-be-strongest-material-universe
https://www.smithsonianmag.com/smart-news/universes-strongest-material-cosmic-lasagna-180970358/

Researchers: M. E. Caplan (McGill U.), A. S. Schneider (CalTech), and C. J. Horowitz (Indiana U. Bloomington)

TOF mass measurement experiments reach for r-process isotopes

Contributed by Alfredo Estrade (Central Michigan University, USA)

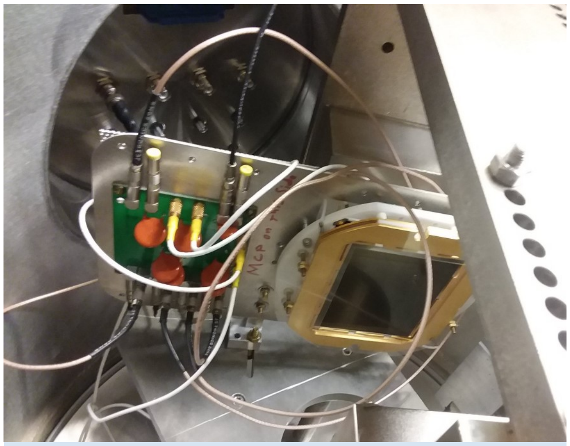


Figure 1. Detail of the experimental setup at NSCL.

Last August the collaboration for TOF-Brho mass measurements completed its latest experiment at the NSCL. The experiment aims to measure the nuclear mass of neutron-rich isotopes of elements around molybdenum, which are important in astrophysical models for weak r-process scenarios and the synthesis of medium-mass heavy nuclei.

The experiment was led by Prof. Mike Famiano of Western Michigan University, in collaboration with scientists from the NSCL, Central Michigan University, the University of Massachusetts at Lowell, and MPI at Heidelberg. The experiment was a success, in large part, thanks to the contribution of a number of enthusiastic students that participated in its preparation and data-taking beam time: 7 undergraduate students and 4 graduate students from CMU, WMU, and UML were involved.

Completing the experiment was a significant technical accomplishment. It extended the reach to TOF-Brho mass measurements at the NSCL beyond Z=28, and to isotopes relevant to neutron-capture processes. A big challenge with heavy beams is to separate bare nuclei from charge-states (ions that pick-up electrons in detectors as they fly through the beamline). The resolution of charge-states was made possible by an upgraded detection system, including a timing detector developed at CMU and a new silicon detector stack, and by detailed data analysis methods.

New International Partner: ChETEC

The Joint Institute for Nuclear Astrophysics, Center for the Evolution of the Elements (JINA-CEE) has a new partner in its effort to foster scientific collaboration across nuclear astrophysics at institutions around the world. Recently, a cooperation agreement was signed with Europe's network ChETEC http://www.chetec.eu/

The ChETEC COST Action funded by EU Horizon2020, stands for "Chemical Elements as Tracers of the Evolution of the Cosmos", and it is a network bringing European research, science and business together to further our understanding of the early universe using chemical elements as forensic evidence.

The ChETEC chair, Raphael Hirschi of Keele University, UK will be the point of contact for this cooperation agreement. From the JINA-CEE side, the point of contact will be Carla Frohlich of North Carolina State University. Please contact them with your ideas of projects between the two networks.

We encourage ChETEC members to learn about and apply for a **Short Term Scientific Mission (STSM)** to visit a JINA-CEE institution! All the details concerning the STSMs can be found in this page:
http://www.chetec.eu/activities/stsms

Neutrino Losses in Type I Thermonuclear X-ray Bursts: An Improved Nuclear Energy Generation Approximation

Contributed by Duncan Galloway (Monash University, Australia)

In this work we provide a new and more accurate estimation of the energy produced by thermonuclear bursts on the surface of neutron stars. Previously, it was assumed that 35% of the burst energy was emitted as neutrinos, and many calculations over the years had adopted that fraction. From experiments and model comparisons with the Kepler code, Adelle Goodwin et al., found that the typical fraction was significantly lower than this value, at most 14% (and may be less than a percent). The explanation for the discrepancy rests on the fact that the beta-decays involved in the rp-process chain aren't the only reactions producing the energy, and also that the burning is not complete. The new estimates can be used to more accurately estimate the composition of the burning fuel in bursting sources. The paper will shortly be published in ApJ.

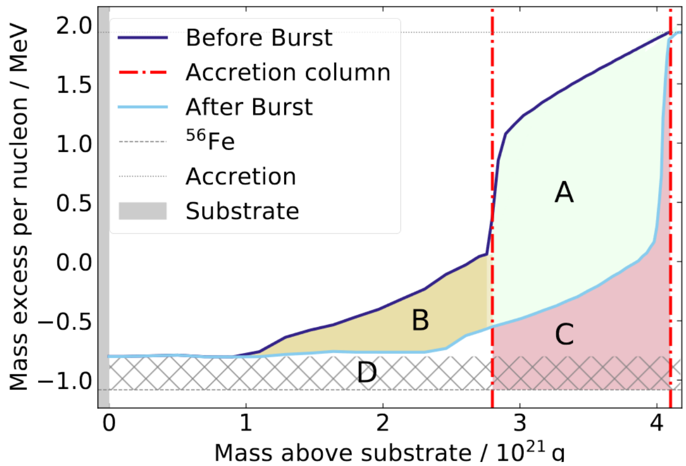


Figure 1. Mass excess per nucleon as a function of mass accreted on top of a substrate just before and after a burst with very low hydrogen content in the ignition column (X_{bar}=0.14). The dashed line corresponds to the mass excess of ^{56}Fe, the most stable nucleus. The labelled regions are as follows: A: energy released in burst in the accretion column; B: Energy released in burst below the accretion column, in the ashes of the previous burst; C: Energy from fuel in the accretion column not released in this burst; D: Energy always missing in the ashes of bursts from not burning all the fuel to just ^{56}Fe (about 0.3 MeV nucleon^{-1})

Further Reading: https://arxiv.org/pdf/1808.02225.pdf
Researchers: A. J. Goodwin, A. Heger, and D. K. Galloway

Remco Zegers Named Fellow of the American Association for the Advancement of Science

Remco Zegers, Professor of Physics & Associate Director for Experimental Research, NSCL

We are happy to congratulate our long time collaborator Remco Zegers, professor at NSCL and Michigan State University for being elected as 2018 AAAS Fellow!

Elected members will be recognized for their contributions to science and technology at the Fellows Forum on February 16, 2019 in Washington D.C. during the AAAS Annual Meeting. Remco was elected as an AAAS Fellow for his "distinguished contributions to the fields of nuclear science and nuclear astrophysics, particularly for determination of weak interaction rates inferred from heavy ion collisions."

"I am very thankful to be named a 2018 American Association for the Advancement of Science Fellow. I am particularly thankful to past and present members of the charge-exchange group, colleagues and staff at the laboratory and MSU, and collaborators from JINA-CEE and many other institutions, all of whom I have the pleasure to work with and learn from every day," said Zegers.

JINA-CEE faces:
Interview with postdoc Alexander Ji

Alex Ji became a JINA-CEE member while he was a grad student at MIT, working with Anna Frebel. After obtaining his PhD in 2017 he moved to California, where he is from originally, to work at the Carnegie Observatories in Pasadena as a Hubble Fellow.

Alex Ji , Hubble Fellow at Carnegie Observatories

Alex recalls: The Observatories are in Pasadena and are known for a few things but especially for being where Edwin Hubble worked and discovered that there are galaxies outside of ours and the universe is expanding.

What do you think was your earliest motivation to study science?

When I was a 7th grader I loved math and science, and I think that something that definitely pushed me into physics was reading Stephen Hawking's Brief History of Time. That motivated me to start, and then I also got very excited when the 2011 Nobel Prize was awarded to the discovery of the accelerating expansion of the Universe due to dark energy. I realized how many things we don't know about the Universe and thought that it'd be cool to learn more.

When did you decide to pursue physics?

I had always liked science but when I started college I was trying to decide between physics, philosophy and psychology. I graduated from Stanford University in 2011 with a Physics major, and a minor in Computer Science, and then got a MS in Statistics the following year. It wasn't until a little before applying to grad school that I decided to try to stay in physics. I enjoyed working with data analysis, and was undecided between science or the tech industry, but one of the cool things about science is that we collect lots of data! There are interesting problems to solve everywhere, but I decided I'd rather analyze stars than clicks.

What is the focus of your research?

Near field cosmology—we look at stars in the local universe (Milky Way and its neighbors) to try to understand the history of our universe. My main topics of interest are the origin of the elements (this is what I collaborate the most within JINA-CEE!), and the other is the first generation of stars.

Where do you see yourself in 20 years?

Hope to be working as a professor somewhere, and at that time I hope that the new 30m telescopes are completed and I can work with them to do awesome science! This includes the Giant Magellan Telescope in Chile, and the Thirty Meter Telescope in Hawaii.

What is your favorite part of what you do?

My favorite part of what I do is going to the Magellan Telescopes in Chile, every time there is a tingly feeling of not knowing what we're going to find. Just getting there takes about 30 hours and right now I go 3 or 4 times a year. You can really clear your mind and focus because there are no distractions. I also really enjoy working with students, and seeing their progress.

What else?

In grad school, we are taught to focus on and become experts in one very specific topic. But I think it is important to not lose the general curiosity that gets many of us into science in the first place. You should keep your horizons broad, and learn many different things even if they don't seem useful to your immediate project. There are lots of things to be excited about in the Universe!

JINA-CEE summer schools

JIOSS 2018

On September 10-14, JINA-CEE welcomed 24 national and international participants to its first **Ion Optics Summer School**, hosted at NSCL/FRIB in the campus of Michigan State University.

Ion optics is essential for the understanding, operation, and design of electromagnetic systems like beam lines, spectrometers, and recoil separators. The aim of the school was to introduce students to the basics of ion optical design, and to the use of the COSY software with emphasis on separators.
During the morning lectures, Georg Berg and Manoel Couder from Notre Dame University covered the examples of the SECAR and St. George recoil separators. Extensive afternoon hands-on sessions allowed students to collaborate in small groups with diverse backgrounds and levels of expertise. Students were able to learn about the details of the ion optics on the instrument of their choice, as well as its implementation and analysis in COSY. Participants also took the opportunity to tour the SECAR experimental area. As part of the coursework, a school wiki was developed by the students and lecturers that can be used for self-directed learning. The wiki is now publicly available at: https://wikihost.nscl.msu.edu/JIOSS/doku.php?id=start

NuGrid / JINA-CEE / ChETEC School: Software for Simulations in Nuclear Astrophysics

The EA Milne Center for Nuclear Astrophysics at the University of Hull, UK, hosted this 3-day school on September 17-19. The goal of the school was to present the current state and key open questions of the field of nuclear astrophysics, and to actively engage young scientists from different disciplines. Trainees learned how to use software tools that facilitate and enhance their interdisciplinary research. Through lectures and intensive hands-on software sessions, speakers Falk Herwig, Alison Laird, Chris Fryer, Rene Reifarth, Ondrea Clarkson, Raphael Hirschi, Brad Gibson and Benoit Côté trained the 32 international school participants on nuclear reaction rates, stellar nucleosynthesis, observations and implications for galactic chemical evolution.
Lecture notes and python tutorials from the school are available at this repository:
https://github.com/Milne-Centre/NuGrid-School-2018

Upcoming JINA-CEE Events

APS Conference for Undergraduate Women in Physics

Michigan State University, East Lansing, MI
January 18-20, 2019

The MSU conference will bring together over 150 regional undergraduate women in physics and successful female physicists to focus on supporting women in physics and on their professional development. The meeting will provide ample opportunities for interacting with fellow physicists

https://perl.natsci.msu.edu/aps-cuwip-at-msu/

r-process Sources in the Universe

Arizona State University, Tempe Campus
March 27-30, 2019

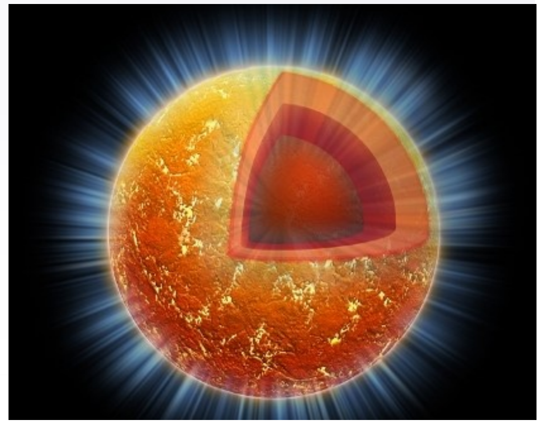
The goal of the workshop is to determine whether neutron star mergers can be considered the main source of r-process elements in the universe, from theoretical studies, nuclear experiments, and recent multi-messenger observations of GW170817.

https://r-process-sources.weebly.com/

Upcoming JINA-CEE Events

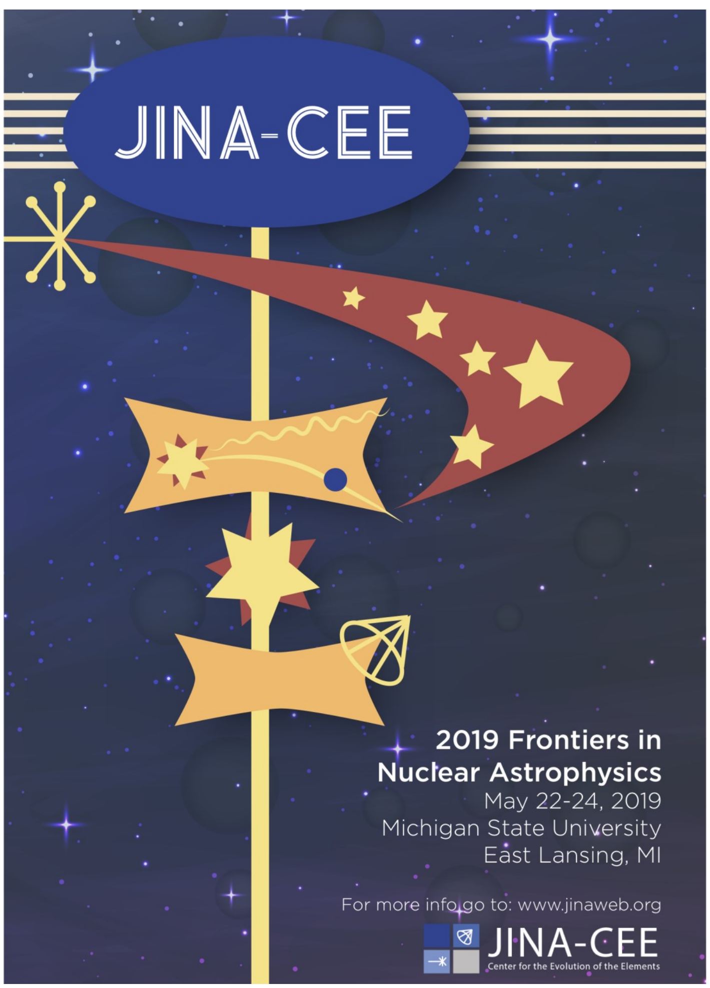
ICONS Workshop 2019: Investigating Crusts of Neutron Stars

Anton Pannekoek Institute for Astronomy, Amsterdam, Netherlands
April 15-17, 2019



This workshop will bring together different areas of research that all involve studies of heated neutron star crusts. One its primary goals will be to have a facilitated discussion about the puzzling source of shallow crustal heating, and what observations, experiments, and calculations are needed to move forward.

http://api.uva.nl/conferences-2019/icons/icons.html



Frontiers in Nuclear Astrophysics 2019

Michigan State University, East Lansing, MI

This is the ninth in a series of former JINA and now JINA-CEE meetings that brings together JINA-CEE participants, collaborators, and other interested researchers in nuclear physics, astronomy, and astrophysics to discuss progress and future directions related to the understanding of the origin of the elements and neutron stars.

First Frontiers Summer School

May 15-18, 2019
https://sites.google.com/view/ffss2019/home

Junior Workshop

May 20-21, 2019

Main Conference

May 22-24
https://indico.frib.msu.edu/event/1/

JINA-CEE Institutions

JINA-CEE Core Institutions:

Michigan State University, Physics and Astronomy Dept, 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, North Carolina State University, NAVI Germany, 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.

JINA-CEE also has participants from:

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, Wayne State University

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JINA–CEE

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