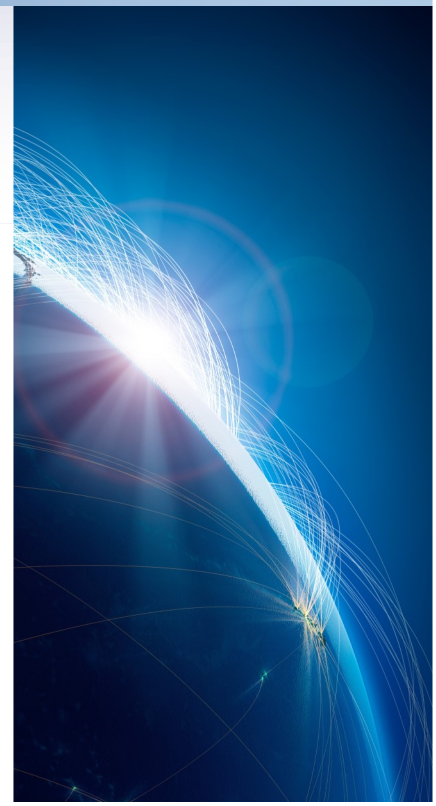
JINA-CEE
Center for the Evolution of the Elements

December 2019



A note from the Director, Hendrik Schatz

Dear JINA-CEE Community,

A major success last fall was the foundation of IReNA - the International Research Network for nuclear Astrophysics. IReNA is supported by NSF's Office of International Science and Engineering (OISE) AccelNet program to create a network of networks by connecting JINA-CEE with 5 foreign nuclear astrophysics networks. IReNA provides JINA-CEE researchers and the US nuclear astrophysics community access to complementary expertise and capabilities not available in the US, and further stimulates the exchange of ideas and the development of new directions. This is especially important in nuclear astrophysics, where a broad range of specialized expertise needs to come together to make progress. Please visit irenaweb.org or look at the article in this newsletter to learn more about IReNA and how to engage. I would like to encourage the entire JINA-CEE community, and especially the students and postdocs, to become active in IReNA and take advantage of this opportunity. Introducing young scientists to international collaborations is a specific goal of IReNA and JINA-CEE.

In the same vein I would like to welcome the National Astronomical Observatory of Japan (NAOJ) as a new partner institution in JINA-CEE. NAOJ offers new opportunities for collaboration on stellar spectroscopy and astrophysical modeling and represents an important link to the Japanese nuclear astrophysics community UKAKUREN, which is also part of IReNA.

I hope you enjoy reading this newsletter, and I hope I see you all at the 2020 Frontiers in Nuclear Astrophysics JINA-CEE collaboration meeting at the University of Notre Dame.

Inside this issue

IReNA 2

New clues into how star clusters formed in the early universe 3

Using multimessenger observations and nuclear theory to constrain neutron-star radii 4

Carl Fields receives 2019 Beth Brown Memorial Award...................... 5

New partnership with NAOJ 5

JINA-CEE Faces: Interview with Benoit Côté............................. 6

Upcoming JINA-CEE events 7

JINA-CEE Institutions 8

NSF awards JINA-CEE $2m grant to create a new International Research Network for Nuclear Astrophysics

The National Science Foundation (NSF) awarded a $2 million USD grant to the Joint Institute for Nuclear Astrophysics - Center for the Evolution of the Elements (JINA-CEE), to create a new international network of networks for nuclear astrophysics research.

The newly created International Research Network for Nuclear Astrophysics (IReNA) will connect JINA-CEE with five similar research collaborations in Europe (Chemical Elements as Tracers of the Evolution of the Cosmos (ChETEC) across Europe, and the ExtreMe Matter Institute (EMMI) and the Collaborative Research Centre "The Milky Way System" – both in Germany), Japan (Japan Forum of Nuclear Astrophysics/UKAKUREN), and the international Nucleosynthesis Grid collaboration (NuGRID). IReNA is composed of seven core institutions: Arizona State University, Central Michigan University, Massachusetts Institute of Technology, Michigan State University, North Carolina State University, University of Notre Dame and University of Washington. It also includes 62 associated institutions in 17 countries. The combined infrastructure and research capabilities available to IReNA scientists will accelerate the understanding of the origin of chemical elements and the nature of dense nuclear matter.

In the current age of multimessenger astronomy, extreme astrophysical environments like supernovae and neutron star mergers are studied through gravitational waves, visible light, infrared, X-rays, gamma-rays, radio waves and neutrinos. IReNA comes as a timely boost for the nuclear astrophysics community. The amount and range of nuclear and astrophysics data and expertise needed to answer open questions about the universe cannot be obtained by a single country. IReNA creates the necessary communication channels and collaborative structures. Together, IReNA scientists will have access to a variety of accelerators, astronomical observatories, experimental equipment, data, and computer codes.

IReNA will also create exchange programs, innovative workshops, and retreats that will foster network communication and training of the next generation of scientists.

IReNA is organized in with Focus Areas (FA) of research. FA1: Nuclear Reaction Rates, FA2: Stellar Abundances, FA3: Dense Matter in Supernovae and Neutron Star Mergers, FA4: r-process Experiments, FA5: Computer Models, FA6: Nuclear Data for Astrophysics, FA7: Weak Interactions, FA8: Professional Development and Broadening Participation. Members from all participating networks interested in international collaborations are encouraged to contact the respective FA coordinators to explore ways to participate in IReNA.

The NSF grant is part of the Accelerating Research through International Network-to-Network Collaborations (AccelNet) program. AccelNet is designed to tackle grand scientific challenges that require significant coordinated international efforts.

Learn more at www.irenaweb.org.

Figure 1. The IReNA Network connects JINA-CEE with five other research networks around the globe: ChETEC, EMMI, The Milky Way System, UKAKUREN and NuGRID. Image credit: Erin O'Donnell, NSCL.

New clues into how star clusters formed in the early universe

Contributed by Ian Roederer (University of Michigan, USA)

The diffuse halo of stars surrounding our galaxy, the Milky Way, was mainly assembled as smaller stellar systems were torn apart by the gravitational pull of the Milky Way. Although the progenitor dwarf galaxies and star clusters were destroyed in these encounters, the stars themselves survived and are found today orbiting the Milky Way in its halo in so-called "stellar streams." There have been potentially many hundreds of these streams, and new data are providing surprising answers to age-old questions about how the Milky Way halo was assembled.

A recent paper by JINA-CEE researcher Ian Roederer, and his colleague Oleg Gnedin at the University of Michigan, presents an analysis of stars in one stellar stream. The stream was discovered in early 2019 by a different team of researchers [1]. Roederer and Gnedin then collected high-resolution optical spectra of two of the brightest stars in this stream using the MIKE spectrograph at the Magellan Telescopes in Las Campanas Observatory, in Chile. They found that the two stars have the same composition across the 13 elements detected, and they have extremely low amounts of metals (elements heavier than hydrogen and helium).

When considered together, these two results are surprising. The identical chemical compositions of these stars—and, by extrapolation, the rest of the stellar stream to which they belong—are reminiscent of stars in present-day globular clusters. Globular clusters are dense collections of tens or hundreds of thousands of stars, and approximately 160 globular clusters are known around the Milky Way today. The metal content, however, is roughly 60% lower than any other known globular cluster (see Figure 1).

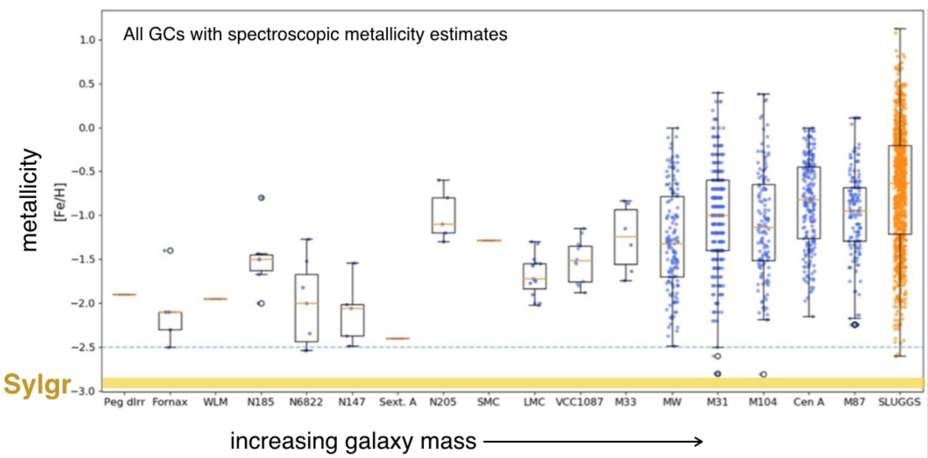


Figure 1. The metal content ("metallicity," on a logarithmic scale, relative to the solar ratio of Fe to H atoms) of known globular clusters around galaxies spanning a wide range of masses. The yellow band at the bottom, labeled "Sylgr" (the name given to the stream studied by Roederer & Gnedin), represents the metal content of the progenitor globular cluster, assuming the metallicities in the stars that were studied are representative of the entire stream. The figure, which has been annotated here, was originally published in [2].

Roederer and Gnedin examined different scenarios for the nature of the progenitor stellar system that was disrupted to form the stream. If the progenitor was a dwarf galaxy, the stream would probably have formed from a star cluster at its center. If the progenitor was a globular cluster, it would have been the most metal-poor globular cluster known. If confirmed by future studies, that result would have important implications because it disproves astronomers' current understanding that a "floor," or lower limit, exists in the metal content of environments where clusters can form. Either way, the new results suggest that star clusters could form in lower-mass galaxies than had been previously expected.

Further reading: https://iopscience.iop.org/article/10.3847/1538-4357/ab365c/meta

References:

[1] R.A. Ibata, K. Malhan, N.F. Martin, ApJ. **872**, 152 (2019)

[2] M.A. Beasley, R. Leaman, C. Gallart, et al., MNRAS **487**, 1986 (2019)

Using multimessenger observations and nuclear theory to constrain neutron-star radii

Contributed by Ingo Tews (LANL, USA)

Neutron stars are the densest stellar objects that we can observe in the cosmos, and are arguably the most interesting astrophysical objects in the multimessenger era. The properties of gravitational waves, electromagnetic radiation, and neutrinos produced by a variety of neutron-star phenomena are determined by the nature of the matter that they contain. The nature of this matter holds important information needed to understand phases of matter encountered in Quantum Chromodynamics, and is described by the dense-matter equation of state (EOS). A measurement of the neutron-star radius or its compactness is critical both to interpret multimessenger observations of neutron stars and to determine EOS of dense matter [1].

We have obtained the most stringent constraints on neutron-star radii to date by combining multimessenger observations of the fortuitously close binary neutron-star merger GW170817 [2] and its electromagnetic counterparts [3] with the nuclear EOS constrained by chiral effective field theory, which best accounts for density-dependent uncertainties [4]. Using conservative assumptions on the nuclear physics and the properties of the electromagnetic counterpart, our analysis [5] showed that the radius of a 1.4 solar mass neutron star is 11 [+0.9,-0.6] km. Implications are far reaching. For example, a kilonova or gamma-ray burst counterpart is only expected in a neutron star – black hole merger when the neutron star is tidally disrupted before the merger; a condition that depends crucially on the neutron-star radius. We have now shown that neutron stars are likely not disrupted in neutron-star black-hole mergers and that subsequently such events will not produce observable electromagnetic emission.

Further reading: http://inspirehep.net/record/1751405

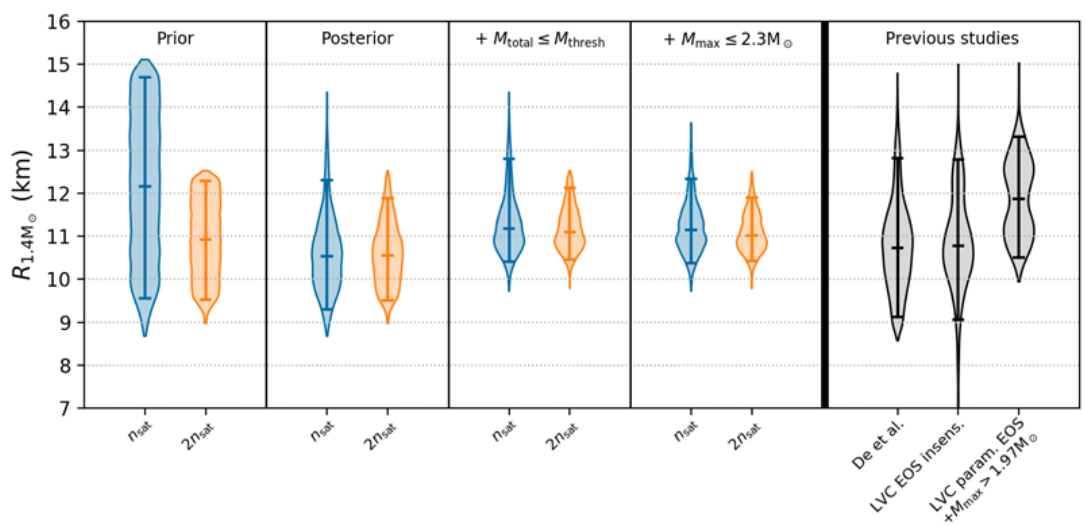


Figure 1. Radius of a 1.4 M_{sol} neutron star for the nuclear-theory EOS prior (left), after the gravitational-wave analysis (2^{nd} from left), after assuming no prompt collapse to a black hole (middle), and after constraining the maximum neutron-star mass (2^{nd} from right). Each panel shows the 1D probability distributions with 90% confidence regions indicated by lines, if nuclear theory constraints are enforced up to saturation density (blue) or twice saturation density (orange). The right panel compares with previous analyses.

References:

[1] J.M. Lattimer, M. Prakash, *Ap. J.* **550**, 426 (2001).
[2] B.P. Abbott et al., *Phys. Rev. Lett.* **119**, 161101 (2017).
[3] B.P. Abbott et al., *Ap. J.* **848**, L12 (2017).
[4] I. Tews, J. Margueron, and S. Reddy, *Phys. Rev. C* **98**, 045804 (2018).
[5] C.D. Capano et al., arXiv:1908.10352.

Carl Fields receives 2019 Beth Brown Memorial Award for Best Oral Presentation at NSBP Conference

JINA-CEE graduate student Carl E. Fields, was recognized with the Beth Brown Memorial Award for delivering the Best Oral Presentation at the 2019 Conference of The National Society of Black Physicists (NSBP), which took place on November 14-17 in Providence, Rhode Island. This is the largest academic meeting of minority physicists in the United States and Carl was one of the 200 student attendees sponsored by the National Science Foundation (NSF).

Carl E. Fields,
Michigan State University

Carl is currently a Ph.D. candidate in Astrophysics at Michigan State University working with Professor Sean Couch, and he's also a Graduate Research NSF Fellow. Carl's talk "Multi-Dimensional Hydrodynamic Simulations of Massive Stars" included his team's latest results of 3D hydrodynamic simulations of stellar core-collapse and the implications their models have for core-collapse supernovae.

The American Astronomical Society (AAS) and the NSBP support this award in memory of Dr. Beth Brown, who, in 1998, became the first African American woman to earn a PhD from the University of Michigan's astronomy department. She was an exceptional scientist and role model. She worked at the Goddard Space Flight Center and, at the time of her passing at age 39, had been appointed Assistant Director for Science Communication.

As part of the award, Carl will receive complimentary registration and travel expenses to attend a future AAS or AAS Division meeting, plus a free 1-year AAS student membership. The award also includes opportunities for Carl to give seminars at Howard University and the University of Michigan, Dr. Brown's alma maters.

New partnership with NAOJ

NAOJ
National Astronomical Observatory of Japan

We are excited to announce our new international partnership with the National Astronomical Observatory of Japan (NAOJ).

Researchers at NAOJ are experts in observational astronomy and theoretical astrophysics, which are key to understanding the origins of the elements.

A new Memorandum of Understanding (MoU) was signed between NAOJ and JINA-CEE to establish scientific collaborations focused on abundance measurements of stars, follow-up optical observations of gravitational wave events, and theoretical studies of explosive nucleosynthesis and cosmology.

The new MoU will also help connect JINA-CEE with the broader nuclear astrophysics community of Japan.

Welcome to our new collaborators!

JINA-CEE Faces:
Interview with Benoit Côté

Benoit Côté is a Canadian astrophysicist, and an expert on galactic chemical evolution simulations. He felt inspired to study the stars at an early age thanks to countless clear nights by the lake with his dad. He has fond memories of the two of them enjoying the summer meteor showers.

Benoit obtained his PhD from Université Laval in Quebec, Canada. Upon graduation he became a JINA-CEE postdoc, with a joint appointment between Michigan State University in the United States and the University of Victoria in British Columbia, Canada. He is currently a staff scientist at the Konkoly Observatory in Hungary's capital, Budapest. His research has been featured in popular science media several times and he´s a regular contributor of science highlights for the JINA website.

Benoit Cote
Konkoly Observatory,
Budapest, Hungary

How do you interact with JINA-CEE?

JINA-CEE represents a turning point in my career. Before JINA I often felt isolated, and had little interaction with people outside my university. Through JINA I am now part of a community with easy access to expertise in a variety of topics. My research now involves a really multidisciplinary approach. We have developed a chemical evolution pipeline to highlight the impact of nuclear astrophysics in galaxy simulations at cosmological scales. With the help of my collaborators, we incorporate nuclear physics uncertainties and then see how those affect our chemical evolution predictions. We write multidisciplinary papers that involve modelers, nuclear theorists, observers and nucleosynthesis experts. A short term goal will be to also include experimentalists in our projects.

I also take part in the organization of workshops like the Frontiers Meeting, the First Frontiers Summer School, and an upcoming one in collaboration with Brian O'Shea titled *Broadening the impact of JINA-CEE's chemical evolution and semi-analytic modeling investments*, taking place at MIT next year.

What is the focus of your research?

Broadly speaking I study the astrophysical origins of the elements and their isotopes, and I am interested in using chemical elements as tracers to learn about galaxy formation. A unique aspect of my work is to look at the propagation of uncertainties in chemical evolution predictions. It is necessary to identify the most uncertain components of the calculations in order to improve our models. One goal of my current research program is to pin down the astrophysical site of the r-process using chemical evolution as a diagnostics tool while incorporating gravitational wave observations.

What are the main instruments you use in your research?

I use a variety of numerical tools, from simple toy models to complex hydrodynamic simulations. I use the Blue Waters supercomputer (located at the University of Illinois) to run large-scale cosmological simulations of the early Universe with the ENZO code. At MSU I used the High Performance Computer Center (HPCC). I also have a smaller (60 cores) cluster at my disposal in Hungary. I code in Python, C++, and Fortran, and make the codes I develop open source to the community.

What's your favorite part of your job?

I enjoy interacting with people to share knowledge and to bring our expertise together to come up with new ideas. I really enjoy mentoring too. Also outreach is very important to me and I try to do it as often as possible.

What do you know now that you wish you knew before?

Although I would probably do it all over again, I wish I had a better idea about the huge amount of travel required to do my job. I love it but it also has its challenges. I also wish to have been better informed about what people look for in candidates when hiring for faculty positions. In that respect I think the JINA Frontiers Junior Workshop has been very useful for me.

Upcoming JINA-CEE Events

JINA–CEE

17th Rußbach School on Nuclear Astrophysics

Rußbach am Paß Gschütt, southeast of Salzburg, Austria
March 15-21, 2020
The school will bring together specialists from the various sub-fields of astrophysics, astronomy, cosmochemistry and nuclear physics with the aim to raise mutual interest and to teach under- and postgraduate students, young post-docs as well as senior scientists interested to be introduced to nuclear astrophysics. The school will be organized in major topical sessions, with dedicated lecture time for basic introduction, presentations of the various aspects of the topic, and ample time for discussions and out-door activities in the Dachstein West mountain region.
https://indico.ph.tum.de/event/4364/

Frontiers in Nuclear Astrophysics 2020

Hosted by the University of Notre Dame
Venue: Embassy Suites, South Bend, Indiana
Junior Researchers Workshop: May 18-19
Main Conference: May 20-22

This will be the tenth 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.

https://www.jinaweb.org/events/frontiers-nuclear-astrophysics-2020

JINA-CEE Institutions

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.

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

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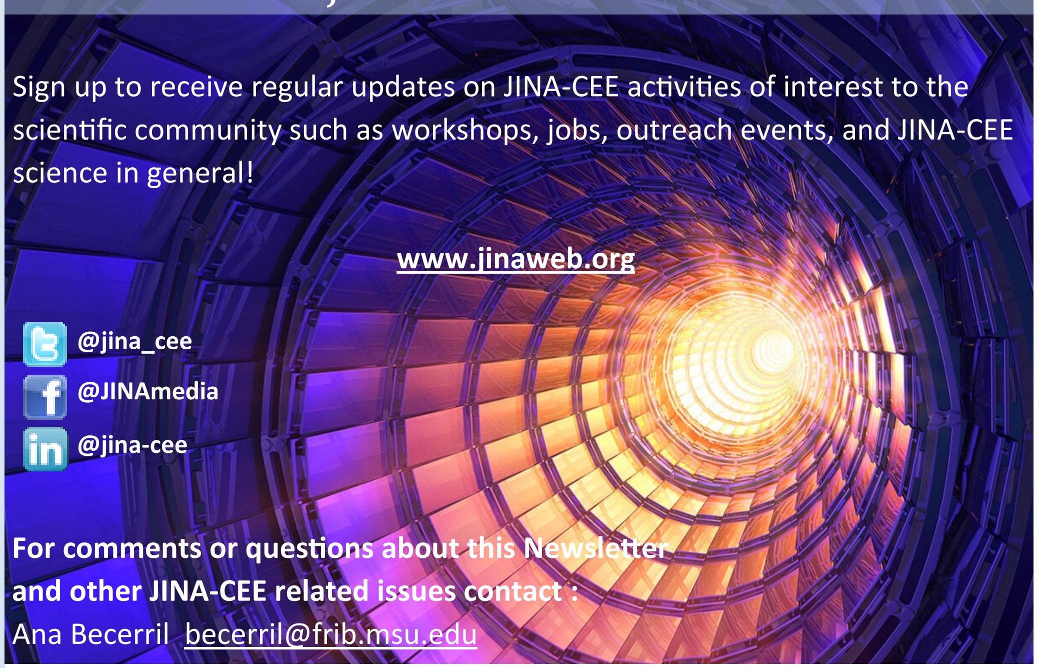

Sign up to receive regular updates on JINA-CEE activities of interest to the scientific community such as workshops, jobs, outreach events, and JINA-CEE science in general!

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