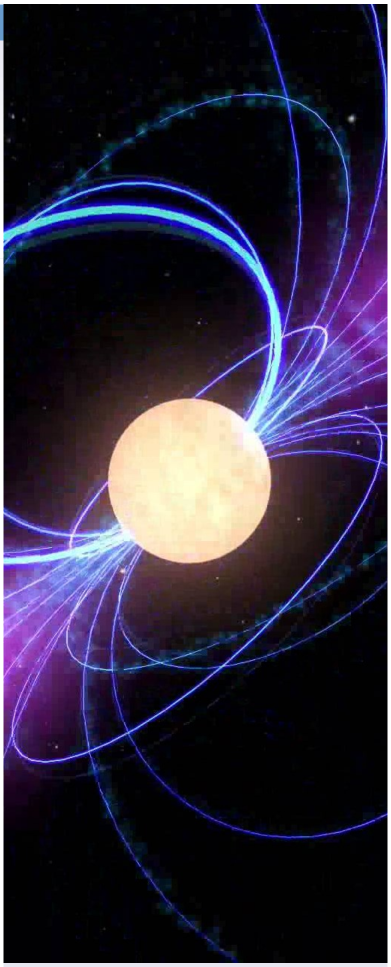
JINA-CEE
Center for the Evolution of the Elements

October 2016



A note from the Director, Hendrik Schatz

Dear JINA-CEE community and friends,

Welcome to the Fall 2016 Newsletter. I hope you will enjoy reading about the exciting science that is happening in JINA-CEE, and about some of the people behind it. The goal of JINA-CEE is to bring together scientists from different fields, and I continue to be amazed at how this happens in JINA-CEE on a daily basis. This newsletter is a great example - you can read about a new approach using telescopes to determine ages of 100,000s of stars so they can be used as a historical record of element formation; you can read about the surprising behavior of some of the nuclear reactions producing elements in the cosmos, discovered through laboratory experiments with rare isotope beams; and you can read about computer simulations that show that exotic states of matter at very high density affect how neutron stars cool.

I am also impressed at how these diverse research activities are coming together within the JINA-CEE collaboration and the broader community to address some of the big scientific questions about the origin of the elements and the role that extreme matter plays in nature. I could see this first hand at the JINA-CEE workshops and conferences that I had the pleasure to attend over Spring and Summer. It is obvious that astronomers, astrophysicists, and nuclear scientists in the US and abroad have formed a strong interdisciplinary nuclear astrophysics community. I encourage everybody, including students and postdocs, to keep thinking about how we can further foster and grow this community, and about the opportunities we have to address together some of the big open scientific questions in the coming years.

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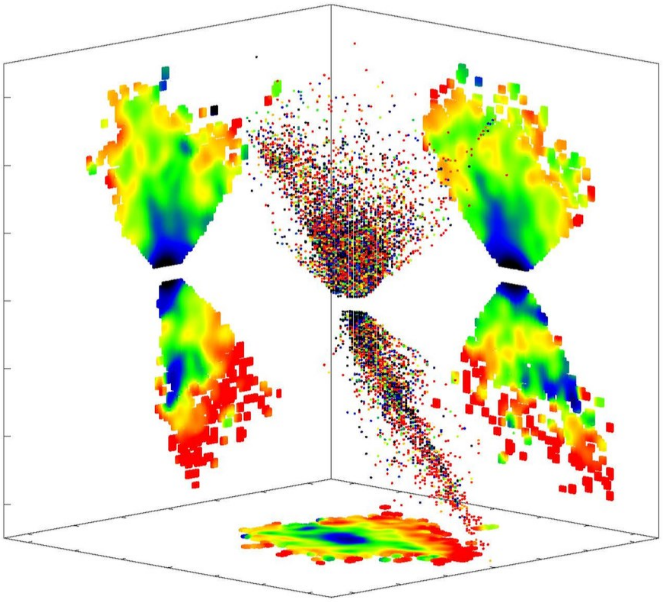
Image Credit:
NASA (artist impression of a neutron star)

Detailed age map shows how Milky Way came together

Contributed by Daniela Carollo (UND)

The halo system of the Milky Way is the locus of the most ancient stars in our Galaxy. By analyzing the motion and chemical composition of stars in the halo system, astronomers can study these ancient stellar populations and shed light on the formation and evolution of the Milky Way and of galaxies in general. However, the halo of the Milky Way is a complex system, since it comprises at least two diffuse components, an inner and an outer region, and several additional structures and extraordinary matter density regions found mainly in its outskirts.

JINA-CEE researchers and their colleagues have recently analyzed the age structure of the Milky Way's halo and produced the clearest picture yet of how our galaxy formed more than 13.5 billion years ago. Using data from the Sloan Digital Sky Survey – of which JINA-CEE is a partner – the scientists identified more than 130,000 blue horizontal-branch stars, which burn helium in their cores, and exhibit different colors based on their ages. The colors, when the stars are at that stage, are directly related to the amount of time that a star has been alive, so the age can be estimated.



Tridimensional chronographic map of the Milky Way's halo system. The three sides of the cube represent projections of the age map on different planes of the Galaxy. More information and a 3D map can be found on http://www3.nd.edu/~vplacco/map/index.html

The researcher's findings are published in the journal Nature Physics and include chronographic maps of our Galaxy. The maps show a concentration of very old stars with ages ranging from 11.5 to 12.5 billion years in the inner region of the Galaxy, including the solar vicinity. Outside of this sphere, the age of the stars decreases and the maps are dominated by numerous resolved younger structures at large distances (beyond 60,000 light years from the center).

JINA-CEE participant Daniela Carollo

These results support the theoretical predictions of structure formation in the presence of so called lambda cold dark matter. According to this theory galaxies formed from hierarchical accretion and mergers of proto-galactic systems. Numerical simulations of this formation process, which is sometimes called the standard model of Big Bang cosmology, predict that the oldest stellar populations are mainly concentrated in tightly bound orbits in the inner regions of the resulting halos. The younger structures that dominate the outskirts of the halo system are expected to have arisen from late-term merging events.

Researchers: D. Carollo (UND), T.C. Beers (UND), V.M. Placco (UND), R. M. Santucci (IAG-USP), P. Denissenkov (UVic), P. B. Tissera (UNAB), G. Lentner (UND), S. Rossi (IAG-USP), Y. S. Lee (CNU) and J. Tumlinson (STScI)

Further Reading: D. Carollo et al., The age structure of the Milky Way's halo, Nature Physics (2016)

Investigating the thermal properties of nuclear pasta with neutron stars

Contributed by Alex Deibel (MSU)

JINA-CEE graduate student Alex Deibel

Cooling neutron star transients provide a unique opportunity to probe the thermal properties of dense matter, in particular, the thermal conductivity of nuclear pasta. Nuclear pasta appears in the deep neutron star crust and consists of nuclei distorted into complex structures by the high density environment. A project led by MSU astronomy graduate student Alex Deibel has modeled the cooling of the neutron star MXB 1659-29 to investigate the effect of nuclear pasta on the long-term cooling behavior of this source [1]. This neutron star had been accreting gas from a companion star for about 2.5 years before accretion halted. Since then, the neutron star has been steadily cooling for over 10 years in quiescence. The surface temperature of the neutron star has been monitored over this time by the X-ray satellites Chandra, XMM-Newton, and Swift.

Crust cooling models of MXB 1659-29 predict that the neutron star's crust will cool entirely in approximately 1000 days. Recent observations of MXB 1659-29, however, show that cooling continued for over 2500 days after accretion halted. Because the cooling light curve reveals successively deeper layers of the crust, the observed late time cooling behavior of MXB 1659-29 is consistent with a low thermal conductivity pasta layer deep in the crust. A nuclear pasta layer remains hotter than the surrounding crust during quiescence. As a result, the crust temperature may be above the critical temperature for neutron superfluidity and a layer of normal neutrons forms alongside the pasta. Cooling models that include heat release from a normal neutron layer in the inner crust are consistent with the late time cooling of MXB 1659-29. The late time cooling of another transient KS 1731-260 was also modeled and is also consistent with late time heat release from a normal neutron layer.

The authors also find that the cooling magnetar SGR 1627-41 may indicate the presence of nuclear pasta. Although many uncertainties remain in the thermal relaxation of magnetars, cooling magnetars are useful in that multiple outbursts may observed in the same source on a shorter timescale than in accreting neutron star transients. In the case of SGR 1627-41, the observed cooling following its 2008 outburst shows some evidence for late time cooling from a normal neutron layer. Further cooling observations of this source are needed to delineate between model predictions of the inner crust thermal properties.

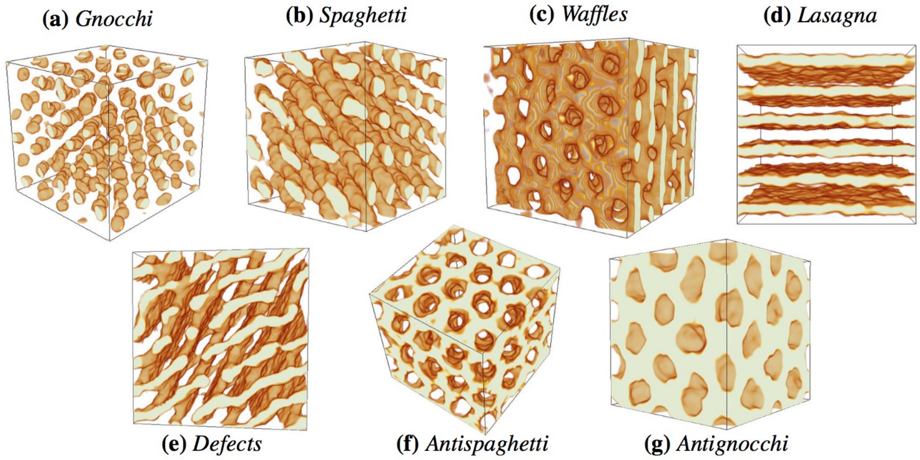
Researchers: A. Deibel (MSU), A. Cumming (McGill U.), E. F. Brown (MSU), and S. Reddy (UW)

Further Reading:

[1] Deibel, A., Cumming, A., Brown, E. F., and Reddy, S. 2016, submitted to ApJ, arXiv: 1609.07155

[2] Caplan, M E and Horowitz, C. J. 2016, arXiv: 1606.03646

[3] Horowitz, C. J. et al. 2015, Physical Review Letters, 114, 031102

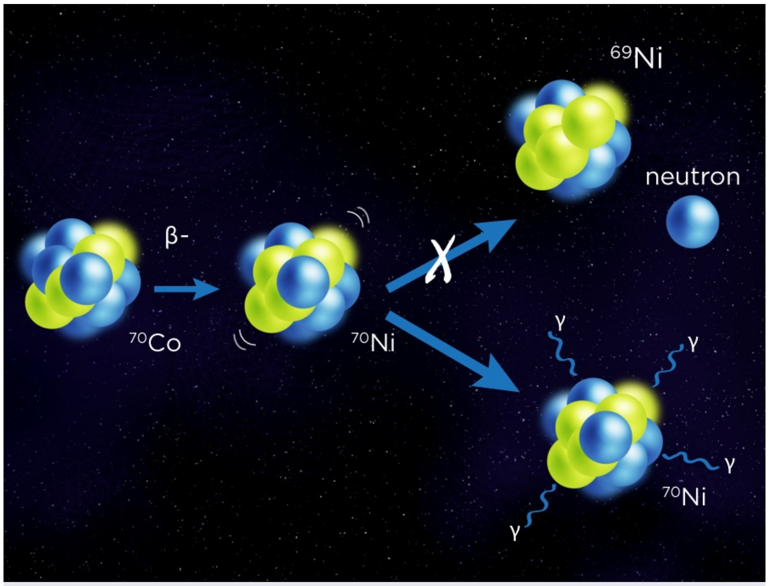


Molecular dynamics simulations of nuclear pasta from [2]. Nuclear pasta may have a low thermal conductivity due to presence of topological defects [3]; see panel (e) of the figure.

Broken neutron link in the sky

In stellar explosions, such as supernovae, chemical elements are produced in complex networks of nuclear reactions and decays, involving a large number of unstable nuclei that exist only for a tiny fraction of a second. These reaction chains produce characteristic patterns of element abundances.

To understand how the elemental composition of the Universe came about, many properties of associated short-lived nuclei, such as their masses, decays, and reaction rates, have to be characterized. While those isotopes are nonexistent on Earth, particle accelerators at nuclear facilities, such as the National Superconducting Cyclotron Laboratory and the future Facility for Rare Isotope Beams at MSU, allow to create and study unstable nuclei in laboratory conditions.



During the process of beta- decay in ^{70}Co one neutron is converted into a proton, populating ^{70}Ni at highly excited states. While the highest excitations are expected to decay by neutron emission populating ^{69}Ni, this was surprisingly not observed in the recent NSCL experiment. Instead, the experiment showed that γ-ray emission is preferred. Picture credit: Erin O'Donnel

Often, surprises are encountered. A case in point is a recent experiment executed by a collaboration of scientists from MSU, the University of Oslo, Central Michigan University, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory. When they studied the radioactive decay of the exotic nucleus of ^{70}Co leading to excited states of ^{70}Ni that are unbound to neutron decay, it was observed that ^{70}Ni subsequently preferentially emits energetic photons – or gamma rays – instead of the expected neutron. An explanation was found in the mismatch in the structure of excited states of ^{70}Ni and ^{69}Ni, the two nuclei that would have been connected by the expected emission of a neutron. This anomaly in the decay properties may have an impact on the synthesis of the elements as the hindered neutron emission is likely to divert the reaction network from the projected path.

Contributed by: A. Spyrou (MSU), S. N. Liddick (MSU), A. Gade (MSU), and W. Nazarewicz (MSU)

Publication: A. Spyrou et al. 2016, Physical Review Letters, 117, 142701

JINA-CEE Virtual Journals

The JINA-CEE Virtual Journal of Nuclear Astrophysics and the SEGUE Virtual Journal provide an up-to-date access to articles of interest to our community, whereas the SEGUE journal focuses on articles of particular interest for observers. Our editors select articles on a weekly basis from more than 30 journals — sign up for a free weekly notification now!

http://jinaweb.org/html/vj.html

XII Torino workshop on Asymptotic Giant Branch Stars

A workshop recap contributed by Maria Lugaro (Konkoly Observatory, Hungary)

The XII Torino Workshop on Asymptotic Giant Branch Stars: Evolution, Nucleosynthesis, Observations, and the Impact on Cosmochemistry together with the IV CSFK Astromineralogy Workshop supported by JINA-CEE was held in Budapest in the first week of August. The workshop was attended by 75 experts ranging from nuclear physicists, astronomers, and astrophysicists, to cosmochemists. This allowed excellent interaction between all the participants and between all the different fields at the very frontier of nuclear astrophysics. People came from many parts of the world, from Europe and the USA to Australia, New Zealand, India, Russia, and China. Some of the highlights reported at the workshop relate to new models of the intermediate neutron capture process in post-AGB stars and in old halo stars, and brand new data on oxygen isotopic ratios in evolved stars, that can now for the first time be directly compared to meteoritic stardust grain data. We enjoyed lovely weather in Budapest and were able to travel to the Buda hills for a visit to the Konkoly Observatory, including observing the Sun on the roof, a taste of local food, a walk in the forest, and return by chairlift. A few of the most resilient finished the excursion day on the Castle hill right on time to see the sunset on the Danube, the perfect end of a day in Budapest.

Upcoming JINA-CEE events

JINA-CEE/TRIUMF Satellite Workshop on Recoil Separators for Nuclear Astrophysics October 11—12, Vancouver, Canada

Luncheon Workshop on Leadership and Diversity @DNP meeting
October 13, Vancouver, Canada

Physics and Astrophysics of Neutron Star Crusts
November 7 — 11, Seattle, Washington

Joint Winter School of JINA-CEE for USA-Chinese Young Scientists
December 12 — 18, Shanghai, China

JINA-CEE Frontiers in Nuclear Astrophysics
February 5 — 9 2017, Lansing, Michigan

Forging Connections: From Nuclei to the Cosmic Web
June 25 — 29 2017, East Lansing, Michigan

P-process Workshop 2017
June 29 — July 1, University of Notre Dame, Indiana

A Celebration of CEMP and Gala of GALAH
November 13 — 17, Monash University, Australia

JINA-CEE faces: Interview with Postdoc MacKenzie Warren

JINA-CEE Postdoc MacKenzie Warren (MSU)

Education:

I received my BA in Physics from Reed College in Portland, Oregon and my PhD in Physics from University of Notre Dame, where my dissertation was titled "Neutrinos in core-collapse supernovae."

When you were young, what did you want to be when you grew up?

A poet! I didn't become interested in science until college.

When did you decide to pursue astrophysics/physics?

It wasn't until my sophomore year of college that I decided to study physics. I had an amazing experience as an REU student, which solidified my interest in physics and fundamental science research.

What is your research focus?

I work on computational modeling of core-collapse supernovae. Most of my work has focused on understanding the explosion mechanism of core-collapse supernovae, but I am also interested in constraining heavy element nucleosynthesis in this environment. In my work, I enjoy exploring extreme neutrino and nuclear physics phenomena, such as neutrino oscillations, which may appear in the supernova environment, but are difficult to access with terrestrial experiments.

With whom and where will you work within JINA-CEE?

I am working with Sean Couch at Michigan State University, utilizing both multidimensional and spherically-symmetric supernova simulations to gain a better understanding of the explosion mechanism and uncertainties that arise from components of the model, such as the nuclear equation of state.

Where do you see yourself in 5 years?

Hopefully as a faculty member, where I can continue my research and have the opportunity to teach and mentor the next generation.

And what about 20 years?

I don't know if I have ever thought that far ahead. I am looking forward to contributing throughout my career to computational modeling of astrophysics and helping make physics more inclusive for marginalized groups.

Is there anything else you'd like to share?

I am chairing the organizing committee for the **2017 JINA-CEE Frontiers Meeting**. It is my goal to make this year's conference the most accessible and inclusive to date and provide space to foster discussions on how to make our collaboration and member institutions more inclusive. We are also looking forward to highlighting the new and innovative research of JINA-CEE members. See you all there!

The JINA-CEE Frontiers in Nuclear Astrophysics meeting will take place from February 5 to 9 2017 in Lansing, Michigan. The main meeting is going to start on 2/7 and will be preceded by a junior researcher workshop.

JINA-CEE publications

D. Carollo et al., *The age structure of the Milky Way's halo*, Nature Physics (2016)

A. Spyrou et al., *Strong Neutron-γ Competition above the Neutron Threshold in the Decay of ^{70}Co,* Phys. Rev. Lett. **117**, 142701 (2016)

V. M. Placco et al., *G64-12 and G64-37 Are Carbon-enhanced Metal-poor Stars*, ApJ **829**, L24 (2016)

C. M. Sakari et al., *Infrared High-resolution Integrated Light Spectral Analyses of M31 Globular Clusters from APOGEE*, ApJ **829**, 116 (2016)

B. Mueller, *The Status of Multi-Dimensional Core-Collapse Supernova Models*, Publ. Astron. Soc. Aust. **33**, e048 (2016)

B. Côté et al., *Mass and Metallicity Requirement in Stellar Models for Galactic Chemical Evolution Applications*, MNRAS (2016)

M. L. Warren et al., *Impact of sterile neutrino dark matter on core-collapse supernovae* , Int. J. Mod. Phys. A, **31**, 1650137 (2016)

C. Siqueira-Mello et al., *Looking for imprints of the first stellar generations in metal-poor bulge field stars,* Astron. Astrophys. **593**, A79 (2016)

G. M. Tveten et al., *Completing the nuclear reaction puzzle of the nucleosynthesis of* ^{92}Mo , Phys. Rev. C **94**, 025804 (2016)

Z. Meisel et al., *Exploratory investigation of the HIPPO gas-jet target fluid dynamic properties*, Nucl. Instr. Meth. Phys. Res. **828**, 8 (2016)

J. Marganiec et al., *Coulomb and nuclear excitations of narrow resonances in ^{17}Ne ,* Phys. Lett. B **759**, 200 (2016)

M. Pignatari et al., *NuGrid Stellar Data Set. I.Stellar Yields from H to Bi for Stars with Metallicities $Z = 0.02$ and $Z = 0.01$* , ApJS **225**, 24 (2016)

U. Battino et al., *Application of a Theory and Simulation-based Convective Boundary Mixing Model for AGB Star Evolution and Nucleosynthesis* , Nucl. Instr. Meth. ApJ **827**, 30 (2016)

A. Frebel et al., The *Chemical Evolution of the Bootes I Ultra-faint Dwarf Galaxy ,* ApJ **826**, 110 (2016)

R. Caballero-Folch et al., *First Measurement of Several β-Delayed Neutron Emitting Isotopes Beyond $N = 126$,* Phys. Rev. Lett. **117**, 012501 (2016)

D. M. Townsley et al., *A Tracer Method for Computing Type Ia Supernova Yields: Burning Model Calibration, Reconstruction of Thickened Flames, and Verification for Planar Detonations,* ApJS **225**, 3 (2016)

R.P. Schiavon et al., *Chemical tagging with APOGEE: Discovery of a large population of N-rich stars in the inner Galaxy,* MNRAS (2016)

E. Fernández-Alvar et al., *Deep SDSS optical spectroscopy of distant halo stars. III. Chemical analysis of extremely metal-poor stars,* Astron. Astrophys. **593**, A28 (2016)

C. Loelius et al., *Lifetime measurement of the 4_1^+ state of ^{58}Ni with the recoil distance method,* Phys. Rev. C. **94**, 024340 (2016)

JINA-CEE Co-PI Tim Beers and 3 Senior Investigators named APS Fellows

JINA-CEE Co-PI Tim Beers (UND), and Senior Investigators Rebecca Surman (UND), Brian O'Shea (MSU), and Alan Wuosmaa (UCONN) have been elected as 2016 fellows of the American Physical Society (APS).

The fellowship is a distinct honor signifying recognition by one's professional peers for exceptional contributions to the physics enterprise–outstanding physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. In a given year, only 0.5 percent of APS members are elected fellows.

Tim Beers, Rebecca Surman, and Alan Wuosmaa were elected through the Division of Nuclear Physics, whereas Brian O'Shea was elected through the Division of Computational Physics. Congratulations to all!

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

JINA-CEE institutions

JINA-CEE Core Institutions:

Michigan State University, Department of Physics and Astronomy, NSCL
University of Notre Dame, Department of Physics, ISNAP
Arizona State University, SESE
University of Washington, INT

JINA-CEE Associated and Participating Institutions:

CCAP Ohio State University, 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 Chicago, University of Minnesota, University of Sao Paulo Brazil, University of Victoria Canada, Western Michigan University, Ball State University, Hope College, Indiana University South Bend, SUNY Geneso

JINA-CEE also has participants from:

California Institute of Technology, Central Michigan University, Gonzaga University, Al-Balqa Applied University Jordan, Lawrence Berkeley National Laboratory, Louisiana State University, Massachusetts Institute of Technology, MPI for Extraterrestrial Physics Germany, UNAM Mexico, Ohio State University, Shanghai Jiao Tong University China, Stony Brook University, TU Darmstadt Germany, University of Hull UK, University of Illinois, University of Michigan, Wayne State University

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