February 2017

JINA-CEE

Center for the Evolution of the Elements

A note from the Director, Hendrik Schatz

Dear Friends of JINA-CEE,

Spring is a busy time for JINA-CEE: we hold our annual collaboration meeting - the "Frontiers in Nuclear Astrophysics" conference, we meet with our international advisory committee, and we make plans for JINA-CEE workshops and schools in the coming year. So it's a good time to take a step back, look at the big picture, and think about innovative approaches to advance science at the intersection of astrophysics and nuclear physics towards our goals to understand the origin of the elements and dense matter environments in the Cosmos. I invite the entire nuclear astrophysics community to participate in these discussions that take place at the many JINA-CEE sponsored workshops and conferences, in the JINA-CEE working groups and the biweekly online seminar, and of course in the various collaborations and discussions among individual scientists. In particular I would like to point out the March 18 deadline for JINA-CEE members to propose workshops.

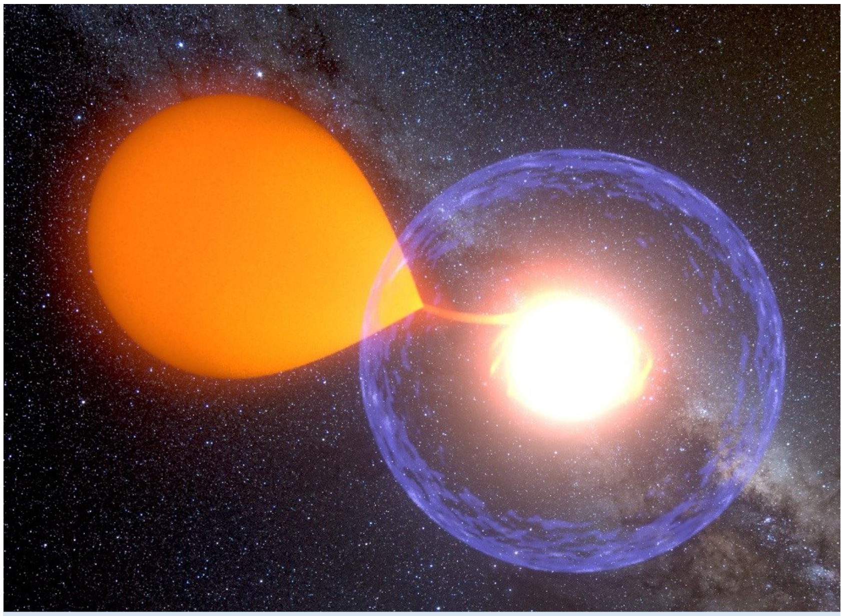
I hope you will enjoy reading this newsletter. It highlights the breadth of research and experimental equipment development within the JINA-CEE network. It also includes an obituary for JINA-CEE researcher Mary Beard from the University of Notre Dame, who sadly passed away last year after a long fight with cancer. I had the great pleasure myself to work closely with Mary on numerous projects, and we all miss her greatly.

Inside this issue

Image Credit: NASA, ESA, HEIC, and the Hubble Heritage Team (STScI/AURA)

Radioactive Beam Experiment Sheds Light on Nova Explosions

Contributed by Filomena Nunes & Hendrik Schatz (NSCL)



An artist's depiction of an accreting white dwarf exploding in a Nova
Image Credit: K. Ulaczyk / Warsaw University Observatory

Theoretical efforts together with an experiment at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University shed new light on the speed of a nuclear reaction that is thought to be critical in determining the elements created in stellar explosions known as novae. Novae are observed as new stars that seem to appear rather suddenly and fade again over weeks or months. They are powered by thermonuclear explosions on the surface of an otherwise rather dim, compact White Dwarf star. The explosions ensue when the White Dwarf star syphons hydrogen rich material from a close-by companion star over 100,000s of years until a sufficiently thick layer ignites and burns via nuclear reactions.

The rate of proton capture on a neutron deficient unstable isotope of Phosphorous, so called ^{30}P, has been identified as a critical bottle-neck in creating elements such as silicon, sulfur, or even calcium during the explosion. The rate must be known to use observations of these elements - either through spectroscopic analysis with telescopes or through laboratory analysis of meteoritic grains thought to have formed in nova explosions - as a probe to understand the nova explosion. Unfortunately, current technology does not allow for the direct measurement of this nuclear reaction rate.

The innards of Gamma-Ray Energy Tracking Array GRETINA, Image Credit: Shumpei Noji (NSCL)

A collaboration of scientists from the University of Edinburgh, UPC Barcelona, and the JINA Center for the Evolution of the Elements at Michigan State University, Central Michigan University, and Argonne National Laboratory has developed an alternative approach to better determine the rate of proton capture on ^{30}P. They studied the transfer of a proton from a deuterium target onto a beam of radioactive ^{30}P nuclei produced at NSCL, into several excited nuclear states in the resulting ^{31}S nucleus. From the emitted gamma-radiation, which could be detected with GRETINA, the largest gamma-ray detection system currently available in the US, the rate of transfer into one of the final states could be deduced. Nuclear theorists at Michigan State University were able to relate this to the rate of proton capture in a stellar environment. The results indicate that the reaction rate is smaller than expected by about a factor of 10. More work will be needed to measure transitions to other final states.

The results will appear in Physics Letters B as **Kankainen et al.**

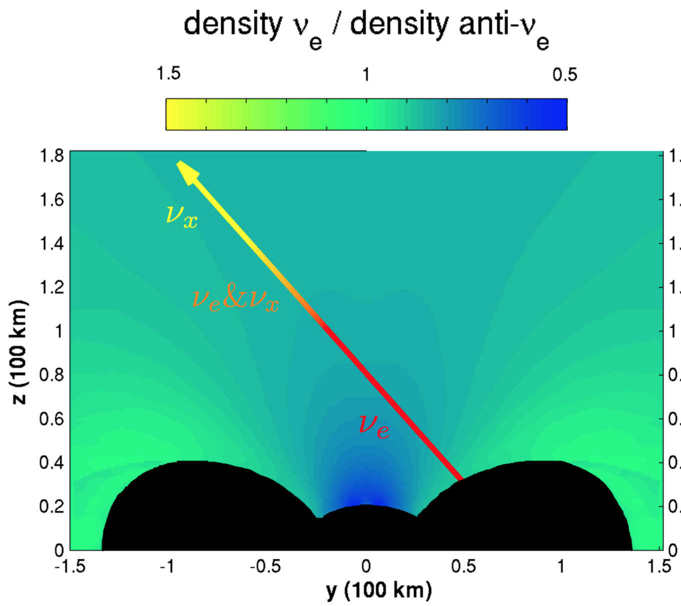
Researchers: A. Kankainen, D. Doherty , G. Lotay, P.J. Woods, H. Schatz, T. Poxon-Pearson, V. Bader, T. Baugher, D. Bazin, B.A. Brown, J. Browne, A. Gade, A. Kontos, C. Langer, Z. Meisel, F. Montes, S. Noji, F. Nunes, J. Pereira, F. Recchia, R. Stroberg, M. Scott, J. Stevens, D. Weisshaar, R. Zegers, D. Seweryniak, J. Jose, A. Estrade, G. Perdikakis, T. Redpath

Matter Neutrino Resonance in Neutron Star Merger Remnants

Contributed by Yong-Lin Zhu (NCSU)

Neutrinos are a necessary component of the physics of several phenomena associated with neutron star merger remnants, examples include nucleosynthesis and jet production in gamma ray bursts. Many essential neutrino interactions are dependent on neutrino flavor, so that an understanding of the flavor content of the neutrinos is critical for providing an accurate picture of merger phenomena.

Once neutrinos are emitted from hot, dense astrophysical objects, they can change their flavor through neutrino oscillations. In the last few years, it has become apparent that many interesting oscillation effects occur in environments with large numbers of neutrinos. In particular, neutrinos may experience collective neutrino oscillations in supernovae [1], and possibly in compact binary mergers. In merger remnant environments, it has been suggested that neutrinos can undergo not only the same type of flavor transformations as in supernova scenarios but also a novel type of transition called matter-neutrino resonance (MNR) transitions [2].



Matter-Neutrino Resonances alter neutrino flavor content, potentially influencing the neutrino dynamics and electromagnetic emission from the remnants, and could have broad ramifications in diverse fields, including high energy astrophysics.

A collaboration led by NC State graduate student Yong-Lin Zhu along with TU Darmstadt researcher Albino Perego and JINA-CEE member Gail McLaughlin performed a study of MNR transitions using the results of a dynamically evolved, detailed three-dimensional, Newtonian simulation of the aftermath of a binary neutron star merger under the influence of neutrino cooling and heating. This is the first calculation that has used self-consistent neutrino and matter distributions from the same dynamical simulation.

They found that neutrinos typically pass through a resonance location at the edge of the low-density funnel above the massive neutron star where the neutrino and matter potentials have approximately the same magnitude. Thus many neutrinos emitted from the massive neutron star have the opportunity to encounter an MNR. The type of MNR transition varies between neutrino trajectories, but in most cases, at the end of the MNR transition(s), the electron neutrinos have completely converted to μ or τ-type neutrinos, whereas the electron antineutrinos experience an oscillation but then return to their original configuration.

Future studies of MNR transitions in binary neutron star merger remnants are needed to elucidate the consequences of these transitions, as well as to further probe the efficacy of the MNR transition itself. These results have implications for various nucleosynthesis scenarios as from collisionally heated material as well as neutrino-driven winds. Additionally, if a merger were to occur within the range of current or future neutrino detectors, the flavor dependent neutrino signal will provide a wealth of information about these objects.

Researchers: Yong-Lin Zhu (NCSU), Albino Perego (TU Darmstadt), Gail C. McLaughlin (NCSU)

Further reading:

[1] Duan, H., Fuller, G.M. and Qian, Y.Z., 2006. Physical Review D, 74(12), p.123004.
[2] Malkus, A., Kneller, J.P., McLaughlin, G.C. and Surman, R., 2012. Physical Review D, 86(8), p.085015.

This work was published (highlighted as editor's suggestion) as:

Zhu, Y.L., Perego, A. and McLaughlin, G.C., 2016. Physical Review D, 94(10), p.105006.

Michael Wiescher receives 2017 Heraeus Visiting Professor Award

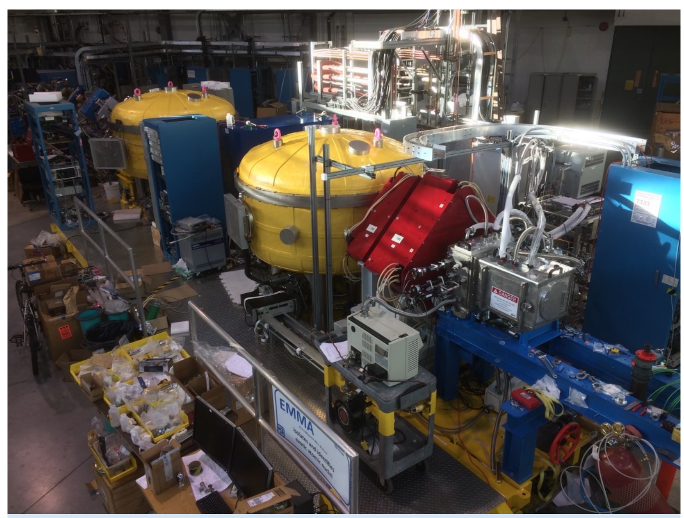
Michael Wiescher, Co-PI of JINA-CEE and Director of the Nuclear Science Laboratory at the University of Notre Dame, is the recipient of the 2017 Heraeus Visiting Professor Award of the Johann Wolfgang von Goethe University of Frankfurt, Germany. He is awarded for his "contribution in the field of Nuclear Astrophysics, especially the synthesis of the elements in the universe". The Goethe University awards the title of Wilhelm Heraeus Visiting Professor for the entire achievement to date of scientists whose fundamental discoveries, insights, or new theories have had a lasting impact on their own scientific discipline and who are expected to continue their outstanding performance in the future. The award is sponsored by funds from the German Wilhelm and Else Heraeus Foundation, established in 1963, which promotes research and training in the natural sciences. Congratulations Michael!

JINA-CEE Co-PI Michael Wiescher (UND)

Successful First Test of EMMA @TRIUMF

Contributed by Barry Davids (TRIUMF)

At TRIUMF, one of the many JINA-CEE associated institutions, EMMA was tested successfully for the first time. The Electromagnetic Mass Analyzer (EMMA) is a recoil mass spectrometer designed to spatially separate the products of nuclear reactions from the beams that induce them. It disperses the reaction products in a focal plane according to their mass/charge ratios and isolates them for further study. EMMA is anticipated to play a major role in the nuclear astrophysics effort at TRIUMF's ISAC-II facility, where it will be used in both direct and indirect studies of nuclear reactions of astrophysical interest. In December 2016 EMMA was tested for the first time with a heavy ion beam. A thick gold foil was bombarded with an 80 MeV ^{36}Ar beam and elastically scattered ^{36}Ar ions were transmitted through the spectrometer to the focal plane. Ions were dispersed according to their mass/charge ratios and ^{36}Ar ions in the 13+ and 14+ charge states were detected in a position-sensitive parallel grid avalanche counter before stopping in a Si detector. The measured mass/charge dispersion and resolving power were found to agree precisely with ion optical calculations. Subsequently we set the spectrometer for ^{197}Au in the 9+ charge state and observed a single peak in the focal plane with no background during an hour long measurement with a billion Ar ions per second incident on the target, demonstrating a hardware beam suppression factor of at least 10^{12} for this reaction. Following this encouraging initial test we intend to complete commissioning EMMA in 2017 and aim to perform its first radioactive beam experiments in 2018.



EMMA in the ISAC-II experimental hall of TRIUMF, Image Credit: Barry Davids

27th TRIUMF Summer Institute (TSI 2017)

The JINA-CEE sponsored 27th TRIUMF Summer Institute (TSI 2017) will be held from July 24th to August 4th, 2017 at TRIUMF in Vancouver, Canada. The topic will be “Modern Tools for Nuclear Astrophysics” and focus on the three research pillars of nuclear astrophysics: experiments, observations, and astrophysical modelling.

The school will host 40 graduate students and young researchers from all over the globe, and is designed to be very interactive with ample time for questions and discussions. During the two weeks of the TSI, the afternoons will be dedicated to hands-on problem solving to help digest the content of the lectures.

TSI 2017 is designed to be accessible to students working in nuclear physics and nuclear astrophysics, providing them with a solid foundation in modern methods and tools in all three areas of research, as well as our current understanding of the astrophysical events under study.

The application for the TSI2017 is open until March 1st, 2017 at https://mis.triumf.ca/events/event.jsf?confcode=TSI2017 . As part of the application process, interested students and postdocs are asked to submit a letter of reference. This letter should not be older than 6 months and must be from the present supervisor under which the student/ postdoc is working. Please fill out the application form and ask your supervisor to send a reference letter in PDF format to tsi@triumf.ca by March 1st.

More upcoming JINA-CEE events

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

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

Microphysics in Computational Relativistic Astrophysics (MICRA) 2017
July 17—21 2017, NSCL, East Lansing

TRIUMF Summer Institute 2017
July 24— August 4 2017, TRIUMF, Vancouver, Canada

A Celebration of CEMP and Gala of GALAH
November 13 — 17 2017, Monash University, Australia

In memoriam: Mary Beard

Mary Beard at the University of Notre Dame

The JINA-CEE community joins our colleagues at the University of Notre Dame in mourning the loss of Mary Beard (1980-2016) who passed away after a long and hard-fought battle with cancer. Mary joined JINA at the University of Notre Dame in 2003 as an MPhys student from the University of Surrey, and she has not left us. Her MPhys Master degree was on the topic of pycnonuclear reactions in the deep crust of neutron stars. Despite her love for England and her desire to live and work there, she came to Notre Dame for a PhD, not without branching out first for an excursion to the favelas of Sao Paulo to learn about nuclear potentials from Brazilian reaction theorists. This excursion provided her with an unlimited source of entertaining stories from Brazil. During her PhD she worked with Dima Yakovlev of St. Petersburg, Russia and his student Peter, which complemented her repertoire of stories from the southern hemisphere with a new set of entertaining tales from the cold most northern part of Europe.

Mary was a sharp observer of the human condition with amazing incites, enormous patience and nearly infinite tolerance for everyone. She was understanding and full of compassion for people, their strengths as well as their weaknesses. For her PhD project she calculated a large set of pycnonuclear fusion and neutron capture reaction rates and their impact on the ashes of X-ray bursts in neutron star crusts. After her PhD, she held postdoctoral positions with the JINA associated ExtreMe Matter Institute EMMI at GSI Darmstadt working closely with research groups in Rossendorf, at Michigan State University and the University of Basel on a number of projects before she returned as a Research Professor to Notre Dame.

Mary built a broad international network of collaborations. She was liked by all of them for her wit and humor, as well as her highly sought after scientific expertise. She kept up her scientific work and enthusiasm through the very end, she never despaired, optimistic to leap frog from one type of treatment to another until a cure could be found. She remained full of hope until the very end. Through all these years Mary became the spirit and strength of the nuclear group at the University of Notre Dame, she mentored graduate and undergraduate students alike, she was a source of support and ideas for faculty and a friend to all. We miss her and we will keep missing her, but we will never forget her.

JINA-CEE publications

F. Anders et al., *Galactic archaeology with asteroseismology and spectroscopy: Red giants observed by CoRoT and APOGEE,* A&A **597**, A30 (2017)

T.C. Beers et al., *Bright Metal-Poor Stars from the Hamburg/ESO Survey. II. A Chemodynamical Analysis,* ApJ **835**, 81 (2017)

D. Bettoni et al., *Low-redshift quasars in the SDSS Stripe 82: associated companion galaxies and signature of star formation*, MNRAS **466**, 3600 (2017)

S. Bisterzo et al., *Galactic Chemical Evolution: The Impact of the 13C-pocket Structure on the s-process Distribution*, ApJ **835**, 97 (2017)

B. Cervantes Sodi, *Low-redshift quasars in the SDSS Stripe 82: associated companion galaxies and signature of star formation*, ApJ **835**, 80 (2017)

B. Côté et al., *The Impact of Modeling Assumptions in Galactic Chemical Evolution Models*, ApJ **835**, 128 (2017)

P. A. Denissenkov et al., *i-process Nucleosynthesis and Mass Retention Efficiency in He-shell Flash Evolution of Rapidly Accreting White Dwarfs*, ApJL **834**, L10 (2017)

E. Fernández-Alvar et al., *Chemical trends in the Galactic halo from APOGEE data,* MNRAS **465**, 1586 (2017)

S. Jones et al., *Idealized hydrodynamic simulations of turbulent oxygen-burning shell convection in 4pi geometry*, MNRAS **465**, 2991 (2017)

Z. Meisel, *β-particle energy-summing correction for beta-delayed proton emission measurements*, NIMPA **844**, 45 (2017)

I. U. Roederer, *The Origin of the Heaviest Metals in Most Ultra-faint Dwarf Galaxies*, ApJ **835**, 23 (2017)

R. Sarmento et al., *Following the Cosmic Evolution of Pristine Gas. I. Implications for Milky Way Halo Stars*, ApJ **834**, 23 (2017)

R. P. Schiavon et al., *APOGEE chemical abundances of globular cluster giants in the inner Galaxy,* MNRAS **466**, 1010 (2017)

B. D. Smith et al., *GRACKLE: a chemistry and cooling library for astrophysics,* MNRAS **466**, 2217 (2017)

S. Stierwalt et al., *Direct evidence of hierarchical assembly at low masses from isolated dwarf galaxy groups*, Nat. Astron. **1**, 25 (2017)

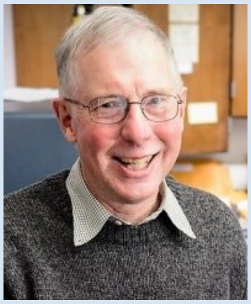
I. Tews, *Spectrum of shear modes in the neutron-star crust: Estimating the nuclear-physics uncertainties,* Phys. Rev.C **95**, 015803 (2017)

T. Tsujimoto et al., *Chemical evolution of 244Pu in the solar vicinity and its implications for the properties of r-process production*, ApJL **835**, L3 (2017)

R. J.van Weeren et al., *The case for electron re-acceleration at galaxy cluster shocks*, Nat. Astron. **1**, (2017)

Vini Placco's work is featured on the cover of the inaugural edition of Nature Astronomy

Nuclear Astrophysics News: 2017 LAD Laboratory Astrophysics Prize Goes to James E. Lawler (UW)



James E. Lawler,
University of Wisconsin
Image Credit: Jeff Miller (UW)

The Laboratory Astrophysics Division (LAD) of the American Astronomical Society (AAS) awarded the 2017 Laboratory Astrophysics Prize to James E. (Jim) Lawler (University of Wisconsin, Madison) for "his contributions in atomic physics to advance our understanding of galactic nucleosynthesis and chemical evolution. His spectroscopic work has opened a new era of stellar chemistry by advancing our ability to compare nucleosynthesis predictions with accurate relative elemental abundances". Over the decades, his work has helped astrophysicists from JINA-CEE and throughout the world measure elemental abundances in stars as well as the interstellar medium, helping match theoretical predictions with accurate relative elemental abundances.

The prize is given each year to an individual "who has made significant contributions to laboratory astrophysics over an extended period of time."

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:

CCAPP 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

For comments or questions about:	**Contact:**
Outreach and Education	Micha Kilburn: mkilburn@nd.edu
Newsletter and other JINA-CEE related issues	Lena Simon: simonl@nscl.msu.edu