

## A note from the Director, Hendrik Schatz

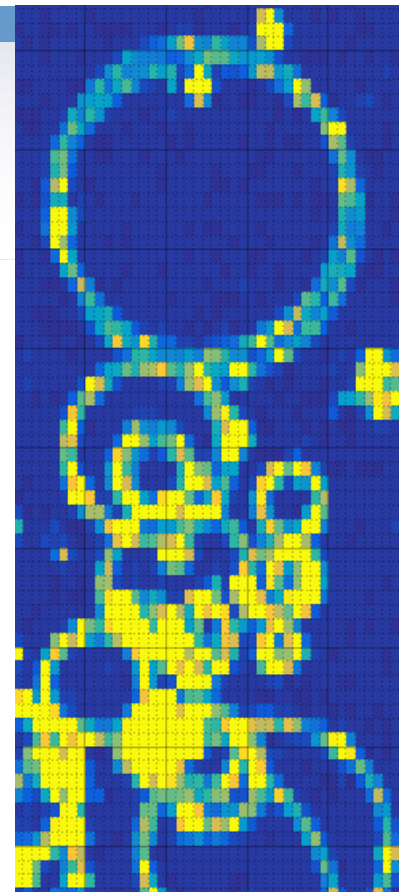
Dear Participants and Friends of JINA-CEE,

As the year comes to a close, JINA-CEE is in full swing, about half-way through its third funding period. This is a good time to reflect about progress achieved so far, and discuss directions for the coming years. And of course there is no better way to do this than by attending our annual JINA-CEE Frontiers in Nuclear Astrophysics meeting, to be held in Lansing on February 7-9. As every year we invite US and international researchers working in nuclear astrophysics - be it as observers, theoretical astrophysicists, nuclear theorists or nuclear experimentalists - to join us to discuss the forefront of the field, exchange the latest results, and evolve and form new collaborations. Abstract submission and early registration ends December 22, so there is still time to sign up and get a discount.

The advancement of research and career opportunities for young researchers is an important goal of JINA-CEE. This year's Frontiers in Nuclear Astrophysics meeting will be preceded by a 2 day workshop exclusively for students and postdocs that will feature educational overviews, career development discussions, and opportunities to share results, ask questions, meet future peers, and discuss collaborations.

JINA-CEE also offers training opportunities for graduate students and postdocs through its schools, which are announced on the JINA-CEE website and are open to all interested young researchers. This Fall we held the 3rd astrophysical reaction network school as part of a successful series that had been started in JINA at the University of Notre Dame, and we just completed an international nuclear astrophysics winter school. New schools for the coming JINA-CEE year will be announced in Spring. I would like to encourage all students and postdocs working in nuclear astrophysics and related fields to take advantage of all these opportunities.

I hope you enjoy reading this newsletter, and I wish you all peaceful holidays and a successful 2017 with more exciting nuclear astrophysics.



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# Low-mass supernova triggered the formation of our solar system

Contributed by Yong-Zhong Qian (UM)

A research team led by JINA-CEE member Yong-Zhong Qian (University of Minnesota) uses new models and evidence from meteorites to show that a low-mass supernova triggered the formation of our solar system. The findings are published in the most recent issue of [Nature Communications](#).

About 4.6 billion years ago, a cloud of gas and dust that eventually formed our solar system was disturbed. The ensuing gravitational collapse formed the proto-Sun with a surrounding disc where the planets were born. A supernova would have enough energy to compress such a gas cloud, yet there was no conclusive evidence to support this theory. In addition, the nature of the triggering supernova remained elusive.

Qian and his collaborators decided to focus on short-lived nuclei present in the early solar system. Due to their short lifetimes, these nuclei could only have come from the triggering supernova. Their abundances in the early solar system have been inferred from their decay products in meteorites. As the debris from the formation of the solar system, meteorites are comparable to the leftover bricks and mortar in a construction site. They tell us what the solar system is made of and in particular, what short-lived nuclei the triggering supernova provided.

Previous efforts in studying the formation of the solar system were focused on a high-mass supernova trigger, which would have left behind a set of nuclear fingerprints that are not present in the meteoric record. Hence, Qian and his collaborators decided to test whether a low-mass supernova, about 12 times heavier than our sun, could explain the meteoritic record. They began their research by examining Beryllium-10, a short-lived nucleus that is widely distributed in meteorites.

In fact the ubiquity of Beryllium-10 was something of a mystery in and of itself. Many researchers had theorized that spallation—a process where high-energy particles strip away protons or neutrons from a nucleus to form new nuclei—by cosmic rays was responsible for the Beryllium-10 found in meteorites. However, this hypothesis involves uncertain inputs and presumes that Beryllium-10 cannot be made in supernovae. Using new models of supernovae, the researchers have shown that Beryllium-10 can be produced by neutrino spallation in supernovae of both low and high masses. However, only a low-mass supernova triggering the formation of the solar system is consistent with the overall meteoritic record.

In addition to explaining the abundance of Beryllium-10, this low-mass supernova model would also explain the short-lived nuclei Calcium-41, Palladium-107, and a few others found in meteorites. What it cannot explain must then be attributed to other sources that require detailed study. The next step is to further corroborate the theory by looking at Lithium-7 and Boron-11 that are produced along with Beryllium-10 by neutrino spallation in supernovae. Qian said they may examine this in a future paper and urged researchers studying meteorites to look at the correlations among these three nuclei with precise measurements.

**Researchers:** P. Banerjee (UM & JINA-CEE), Yong-Zhong Qian (UM & JINA-CEE), Alexander Heger (Monash U. & JINA-CEE), and W. C. Haxton (UC & LBNL)

**Further Reading:** P. Banerjee et al., *Nature Communications* **7**, 13639 (2016)

This article was rewritten from a [news release](#) from the University of Minnesota.



About 4.6 billion years ago, a cloud of gas and dust that eventually formed our solar system was disturbed. The ensuing gravitational collapse formed the proto-Sun with a surrounding disc where the planets were born. That cloud might be similar to a region in this much larger complex of gas and dust about 4,500 light-years away in the constellation Cygnus observed by NASA's Spitzer Telescope.

Image credit: NASA/JPL-Caltech/Harvard-Smithsonian CfA

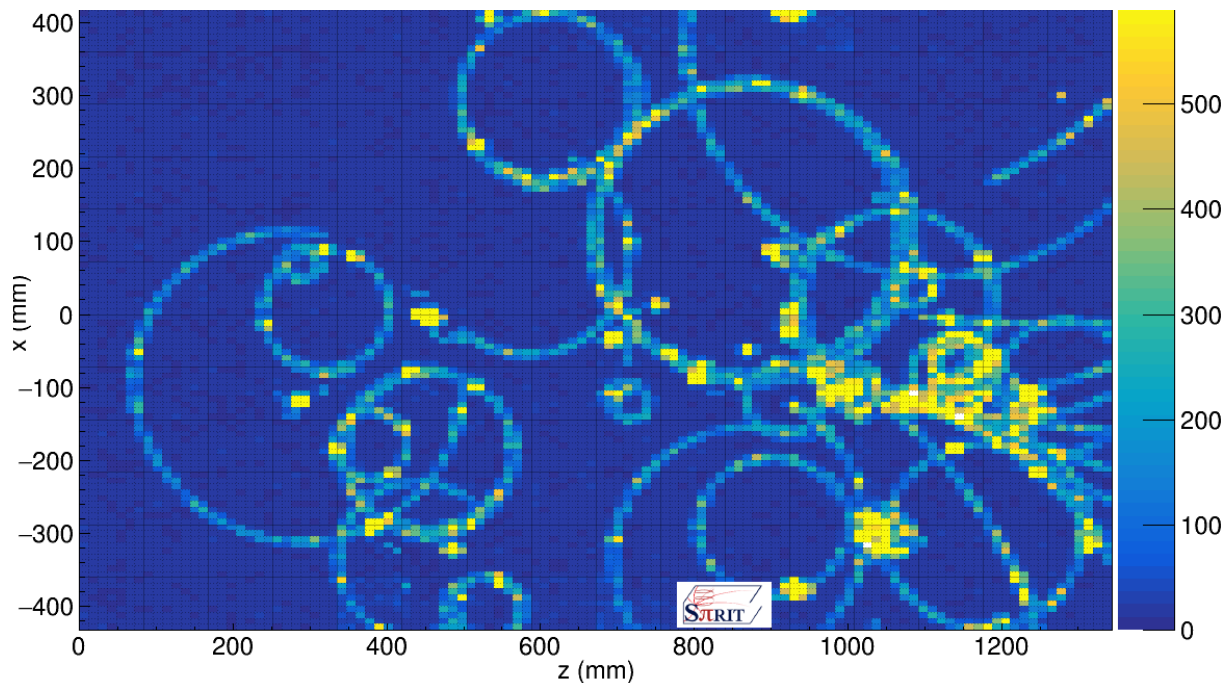
# Art from outer space

Contributed by Betty Tsang (MSU)

JINA-CEE members Betty Tsang and Bill Lynch, are leading a team that recently completed the construction of a Time Projection Chamber (TPC), called the  $S\pi$ RIT (SAMURAI pion Reconstruction Ion Tracker) TPC, which can be used to visualize nuclear collisions in three dimensions by utilizing a two dimensional readout plane and time of detection.  $S\pi$ RIT is an international collaboration aiming to constrain the symmetry-energy term in the nuclear Equation of State (EoS) of the high density matter inside neutron stars. The Equation of State establishes a relationship between density, pressure, temperature, and energy of a neutron star, and is still not very well known. Several equations of state have been proposed and current nuclear astrophysics research in JINA-CEE will constrain the underlying theories to make predictions, for example for the size of neutron stars.

After it was completed, the  $S\pi$ RIT TPC was shipped to RIKEN, Japan in 2014, where it is used in conjunction with a large dipole magnet called SAMURAI magnet. Since beams from large accelerators are expensive to use and limited in availability, the  $S\pi$ RIT group used natural accelerated beams from outer space, also known as cosmic rays, to test and check the TPC before and during the experiments.

Cosmic rays are atomic nuclei that have been accelerated in the cosmos by processes that are not completely understood. Even though most (~80%) of cosmic rays are protons, some are heavier nuclei. The percentage of cosmic rays that are heavier nuclei decreases with mass. Accordingly, nuclei as heavy as iron constitute a small (<0.02%) part of the cosmic ray flux. Many cosmic rays appear as single tracks in the TPC. Occasionally, the interaction of cosmic rays with the atmosphere or other materials produces a cosmic ray shower which contains many fast particles. In the presence of a magnetic field, the charged particles in the cosmic rays will curve, and for these low energy particles, a spiral may form. The multi-tracks of the cosmic showers as observed in the TPC with circles and curved lines can be quite beautiful, as can be seen from the example shown in the picture. Currently, there are plans to use some of these pictures with the JINA-CEE art to science outreach projects for K-12 students. More images of the cosmic rays are available here: [groups.nsl.msu.edu/hira/cosmic/](https://groups.nsl.msu.edu/hira/cosmic/)



The pad-plane view of a cosmic shower inside the  $S\pi$ RIT TPC. The closest analogy of the pad plane is a TV screen with 12096 electronic channels (pixels).

# On Variations Of Pre-Supernova Model Properties

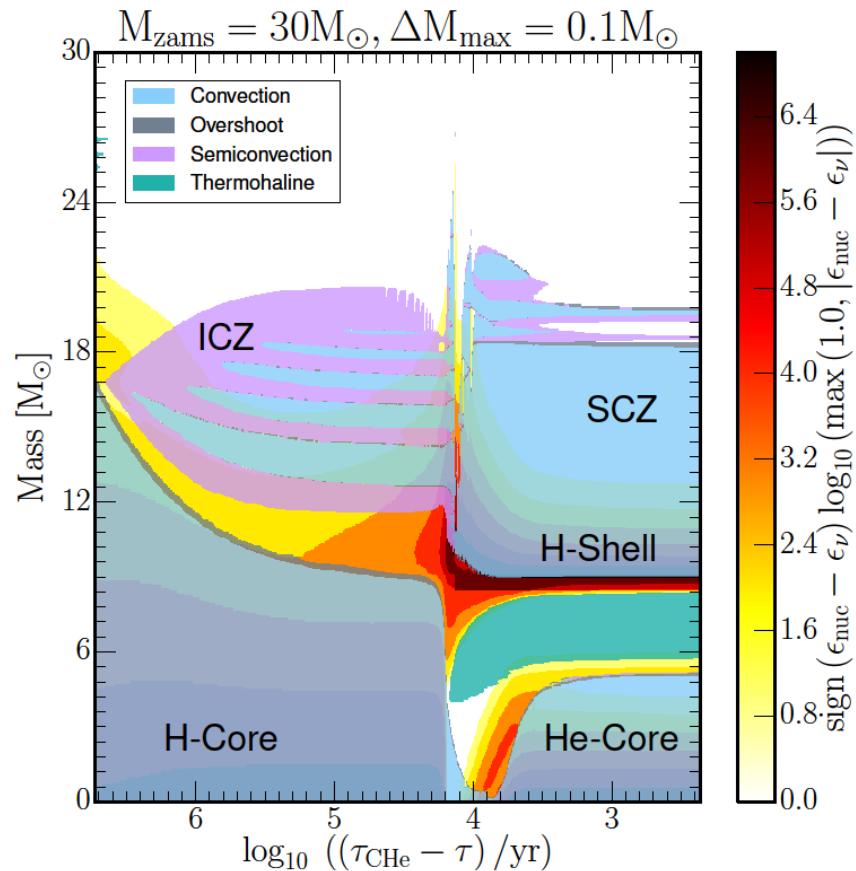
Contributed by Frank Timmes (ASU)

Modeling the nuclear reactions that create elements in stars is one of the primary objectives of JINA-CEE. A long standing challenge is that limited computational power requires to limit the number of nuclear reactions and nuclear isotopes included in the calculation to a small subset. Similarly, the spatial resolution of the calculation has to be coarser than one would want. The question is then to which degree these limitations would affect the results of the model calculations; for example, the predicted structure of the star prior to the supernova explosion at the end of its life, and what the optimum tradeoff would be between number of isotopes and resolution. This problem is addressed by a new theory project conducted at Arizona State University, Michigan State University, and the University of California. The project explores the variation in single star 15-30 solar mass pre-supernova MESA models due to changes in the number of isotopes in a fully-coupled nuclear reaction network and adjustments in the mass resolution. Within this two-dimensional PARAMETER plane we assess the range of core masses at various stages of evolution, mass locations of the main nuclear burning shells, electron fraction profiles, mass fraction profiles, burning lifetimes, stellar lifetimes, and compactness parameter at core-collapse for models with and without mass loss. Up to carbon burning we generally find mass resolution has a larger impact on the variations than the number of isotopes, while the number of isotopes plays a more significant role in determining the span of the variations for neon, oxygen and silicon burning.

## Further Reading:

R. Farmer et al., *On Variations Of Pre-Supernova Model Properties*, Accepted ApJS, (2016)

Spacetime diagram of a 30 solar mass model evolved with a 79 isotope nuclear reaction network. The age shown on the x-axis is time until convection begins in core helium burning. Yellow to red regions denote logarithmic increases in the net nuclear energy generation rate. Blue marks convective regions, grey identifies overshoot regions, purple designates semiconvective regions and green labels thermohaline mixing regions. Labeled are the intermediate convection zone (ICZ), secondary convection zone (SCZ), hydrogen-core, hydrogen-shell, and helium-core.

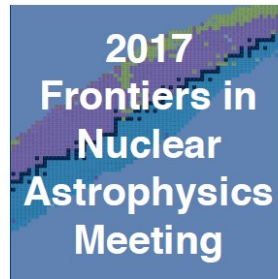


# Frontiers in Nuclear Astrophysics 2017

Our annual collaboration meeting, the JINA-CEE Frontiers in Nuclear Astrophysics 2017 conference, will take place February 7-9 in the Radisson Hotel in Lansing, preceded by a two-day meeting for students and post-docs on February 5 and 6. This is the seventh in a series of meetings to bring 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 neutron stars and the origin of the elements. It is comprised of oral presentations, a poster session, and a participant-organized breakout session, the 'unconference'. Get the conversation started for the unconference on the [meeting wiki](#).

The junior researcher workshop will take place at NSCL and will consist of science sessions that begin with an overview talk given by a postdoc or senior graduate student. On the second day, the workshop will feature presentations on professional development topics and opportunities to build collaborations and connections with other young researchers in the field. One goal of the workshop is to encourage students and postdocs to share their research in a positive and supportive, yet constructive, environment.

Early registration and abstract submission is open until December 22! For more information, see the meeting website: <http://indico.fnal.gov/event/frontiers2017>



# JINA-CEE

## Upcoming JINA-CEE events

### Joint Winter School of JINA-CEE for USA-Chinese Young Scientists

December 12 — 18 2016, 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 2017, University of Notre Dame, Indiana

### 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



## JINA-CEE faces: Interview with Postdoc Ilka Petermann

### Education:

My diploma thesis was concerned with a nuclear physics topic (Shell model calculations of giant resonances; Technical University Darmstadt), then I moved to the area of nuclear astrophysics for my PhD (Influence of fission processes on nucleosynthesis in the r-Process; GSI Helmholtz Centre for Heavy Ion Research, TU Darmstadt)

### When did you decide to pursue astrophysics/physics?

It was a racing duel between biology and physics. During high school we had the possibility to attend a couple of university lectures as a guest auditor and it was then that I decided that I wanted to learn more about some of the largest (stars) and the smallest (nuclei) constituents of the universe - so 'nuclear astrophysics' won the gold medal!

### What is your research focus?

I am working on the evolution of massive stars, in particular the pre-supernova stage and what we can learn from the influence of various parameters such as magnetic fields, binary interaction or numerical resolution on the final phases of massive stars.

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

I am working with Frank Timmes at Arizona State University on massive star evolution.

### Where do you see yourself in 5 years?

I hope that in five years I will be able to throw away the outworn moving boxes that were necessary the last years and have found a permanent position to do research and teaching—high school guest auditors are welcome!

### And what about 20 years?

I bit more than 20 years ago, I thought that 'dinosaur scientist' is a great career and although I have matured a bit since then, I am not sure my predictions of the future have become any better... Hopefully I will still enjoy working as an astrophysicist and have a large group of happy students who can substitute me in my lectures once in a while when I have to go to a dinosaur exhibition.



JINA-CEE Postdoc Ilka Petermann (ASU)

## JINA-CEE bi-weekly online seminar



Zoom into our bi-weekly JINA-CEE online seminar every second Friday at 2pm ET. The seminar is hosted by our postdoc Ingo Tews (University of Washington) and is supposed to support coordinate and initiate projects and research, and to help junior researchers establish collaborations. The current program can be found on the website [jinaweb.org/html/seminarrecordings.html](http://jinaweb.org/html/seminarrecordings.html)

The seminar is accessible via zoom and the recordings of past seminars can be found on the [JINA-CEE YouTube channel](#).

## JINA-CEE publications

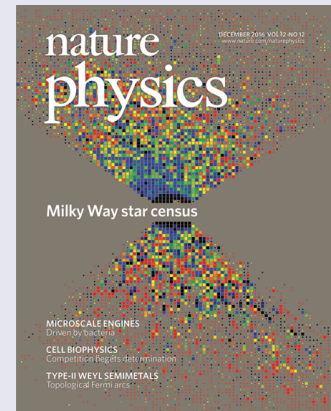
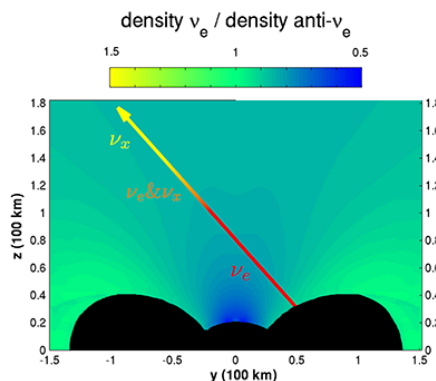
- P. Banerjee** et al., *Evidence from stable isotopes and  $^{10}\text{Be}$  for solar system formation triggered by a low-mass supernova*, Nat. Commun. **7**, 13639 (2016)
- K. Belczynski** et al., *The effect of pair-instability mass loss on black-hole mergers*, A&A **594**, A97 (2016)
- R. H. Cyburt** et al., *Dependence of X-Ray Burst Models on Nuclear Reaction Rates*, ApJ **830**, 55 (2016)
- A. Deibel**, *Ocean g-modes on Transient Neutron Stars*, ApJ **832**, 44 (2016)
- A. Deibel** et al., *Urca Cooling Pairs in the Neutron Star Ocean and Their Effect on Superbursts*, ApJ **831**, 13 (2016)
- C. Iliadis** et al., *Bayesian Estimation of Thermonuclear Reaction Rates*, ApJ **831**, 107 (2016)
- A. Ji** et al., *Complete Element Abundances of Nine Stars in the r-process Galaxy Reticulum II*, ApJ **830**, 93 (2016)
- A. Ji** et al., *Chemical Diversity in the Ultra-faint Dwarf Galaxy Tucana II*, ApJL **832**, L3 (2016)
- A. Kozyreva** et al., *Fast evolving pair-instability supernova models: evolution, explosion, light curves*, MNRAS **464**, 2854 (2017)
- A.L. Mashburn** et al., *Neutron-capture Element Abundances in Magellanic Cloud Planetary Nebulae*, ApJL **831**, L3 (2016)
- L. F. Roberts** et al., *The influence of neutrinos on r-process nucleosynthesis in the ejecta of black hole-neutron star mergers*, MNRAS **464**, 3907 (2017)
- M. E. Weston** et al., *Incidence of WISE -selected obscured AGNs in major mergers and interactions from the SDSS*, MNRAS **464**, 3882 (2017)
- D.E. Willcox** et al., *Type Ia Supernova Explosions from Hybrid Carbon-Oxygen-Neon White Dwarf Progenitors*, ApJ **832**, 13 (2016)

### Physical Review D Editor's Suggestion:

#### *Matter-neutrino resonance transitions above a neutron star merger remnant*

This paper performs a study of the matter neutrino resonance (MNR) phenomenon in neutron star mergers based on a model employing three dimensional merger simulations. MNRs alter the 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.

**Y.L. Zhu** et al., Phys. Rev. D **94**, 105006 (2016)



Tim Beers' work is featured on the cover of the December issue of Nature Physics



## Team led by Sean Couch (MSU) receives DOE INCITE award

Congratulations to our participants Sean Couch (MSU), Almudena Arcones (TU Darmstadt), Carla Froehlich (NCSU) and their collaborators for winning 0.1 billion processor hours through the Department of Energy's "Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program".

The INCITE program is the primary means of accessing the DOE Leadership Computing Facilities at Argonne and Oak Ridge National Laboratories, and is jointly managed by the two centers. Researchers from academia, government research facilities, and industry submit INCITE project proposals, which are awarded on a competitive basis.

The team is going to use the processor hours to perform 3D simulations to investigate the mechanisms of core-collapse supernovae.



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 Geneseo

#### 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:

Outreach and Education  
Newsletter and other JINA-CEE related issues

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