JINA-CEE

Center for the Evolution of the Elements

August 2016

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

A note from the Director, Hendrik Schatz

Dear JINA-CEE community and friends,

I hope you will enjoy reading our summer newsletter. Others may slow down during the summer months, but many activities in JINA-CEE are actually ramping up. While of course exciting science keeps happening, this is particularly true for our public outreach programs that reach 100s of K-12 students and teachers. These programs not only get participants excited about science, but also promote inclusion and diversity in the sciences. You can read about some of the innovative programs and activities in the JINA-CEE Outreach News section. These outreach activities rely heavily on the active participation of graduate students, postdocs, and faculty, and I would like to take the opportunity here to thank everybody who contributed significant time and effort this summer.

We also had a series of very successful workshops this summer, as summarized in the JINA-CEE workshop summer article. I believe this was our busiest workshop summer yet, and it was impressive to see how different communities and subfields communicated and interacted with each other, and how new ideas and collaborations emerged. The workshop program will continue into the late Summer/Fall with a reaction network school in Germany, a recoil separator workshop in Vancouver, and a Joint Winter School for USA-Chinese Young Scientists in China. JINA-CEE will also organize a Luncheon Workshop on Leadership and Diversity at the APS/DNP meeting on October 13, in Vancouver, Canada. If you plan to attend the APS/DNP meeting I encourage you register for this event.

Inside this issue

Evidence for Multiple Progenitors of CEMP-no Stars

Contributed by Jinmi Yoon (JINA-CEE & UND)

CEMP-no stars, very old stars in the Galactic halo with large amounts of carbon, but no enhancement of heavy elements as well as very low iron content, are thought to have formed from the nucleosynthetic by-products of first generation stars born in a few million years after the Big Bang. The chemical compositions of today's CEMP-no stars are therefore thought to provide unique clues about the nature of the very first stars in the universe. JINA-CEE researchers and their colleagues have now found the first evidence that CEMP-no stars have multiple astrophysical origins, which need to be disentangled. These were likely the first stars with different masses.

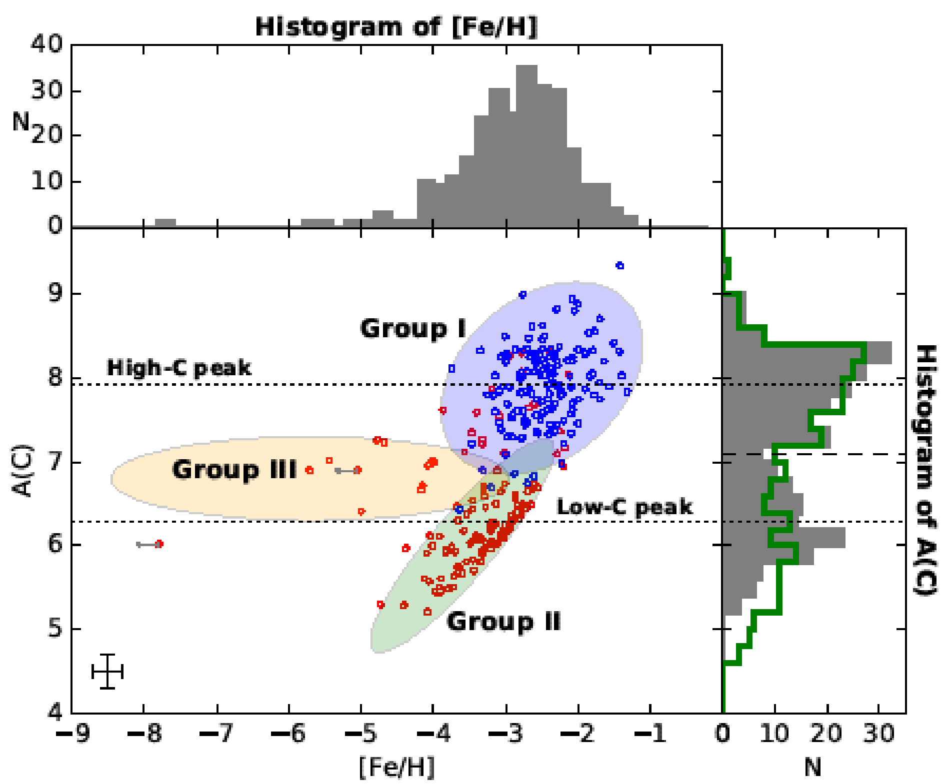
In addition, they have demonstrated that it is possible to quickly and efficiently distinguish CEMP-no stars from the far more frequently occurring CEMP-s (carbon-enhanced stars showing strong over-abundances of neutron-capture elements associated with the s-process) stars. This new approach is based on the absolute carbon abundances of CEMP stars alone, rather than the time-consuming task of determining their Ba abundances (which demands high-resolution spectroscopy), the technique formerly used. This opens the possibility to apply this method to a much larger number of stellar spectra with resolving power as low as R ~ 1000-2000, including those (thousands of stars) taken as part of the Sloan Digital Sky Survey .

With this result, CEMP-no star data can now be used to shed light on the long-sought nature of the distribution of the masses of the very first stars, which are predicted to be much more massive than most of today's stars.

Researchers: J. Yoon (UND), T.C. Beers (UND), V.M. Placco (UND), K.C. Rasmussen (UND), C. Carollo (UND), S. He (XJTU), T.T. Hansen (OCIW), I.U. Roederer (UM) Further Reading

Further Reading: J. Yoon et al., *Observational Constraints on First-Star Nucleosynthesis. I. Evidence for Multiple Progenitors*

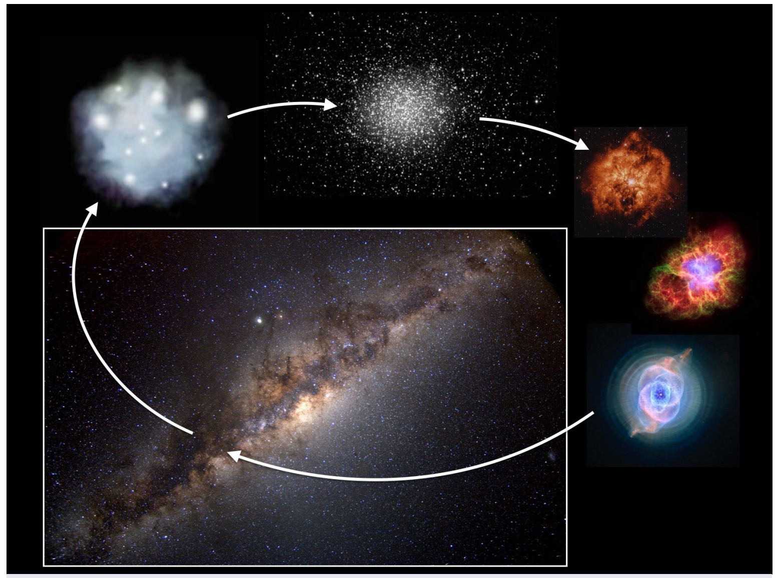
Distribution of absolute carbon abundance A(C) of the CEMP stars as a function of metallicity ([Fe/H]). The most CEMP-no (red circles in Group II and Group III) belong to the low-C region and the majority of CEMP-s/rs (blue circles in Group I) stars reside in the high-C region, as clearly seen in the marginal histogram of the corrected carbon abundance (gray shaded histogram on the right). The corrected carbon abundance is the estimated value of "original" carbon abundances based on each star's evolutionary state, over-plotted with the observed carbon value (the green histogram). While there is a bi-modality in the A(C) distribution, there exists a complexity which indicates that the three different groups likely have different astrophysical origins.



Uncertainties in Galactic Chemical Evolution Models

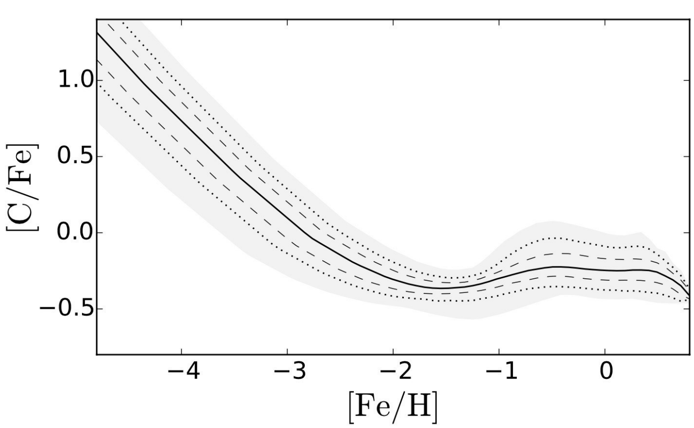
Contributed by Benoit Côté (JINA-CEE & MSU & UVic)

Galactic chemical evolution is a field that aims to understand the formation and evolution of the elements from the early Universe to present time. Reproducing the evolution of the elements inside a galaxy with numerical models requires different areas of expertise and offers the possibility to connect various fields of research such as nuclear physics, stellar evolution, observation, galaxy evolution, and cosmology. But each field has uncertainties that can affect the reliability of numerical predictions when compared with the chemical signatures observed in stars. To this day, it is still difficult to define the real amount of uncertainties inherent in chemical evolution models.



Simplified representation of the life cycle of stars. Images credits: S. Brunier, J. Schmidt, J. Hester, A. Loll, R. Gehrz, Pearson Education, 2MASS project, NASA, STScI, ESA, CXC, ASU, HEIC, Hubble/Chandra/Spitzer Space Telescopes, JPL Caltech, U. of Minnesota.

This study [1] is a first step in JINA-CEE's effort to establish a numerical pipeline that connects nuclear astrophysics research with galactic chemical evolution. We compiled several observational studies to constrain the value and uncertainties of fundamental input parameters, including the stellar initial mass function (the number of stars with a certain mass that form in stellar clusters) and the rate of supernova explosions. We ran hundreds of simulations, using a Monte Carlo approach, to quantify how the uncertainties in these parameters propagate and affect our numerical predictions.



Predicted evolution of the carbon-to-iron ratio. Solid – most plausible prediction. Dashed and dotted –69% and 95% confidence levels. Grey shaded area – plausible range.

The figure below shows the resulting uncertainty in the evolution of the carbon-to-iron ratio as a function of the iron-to-hydrogen ratio (a proxy for galactic age) for a galaxy with properties similar to the Milky Way. The level of uncertainty, which are lower limits, depends on the galactic age and on the targeted elemental ratio (see [1] for more elements). For this work, we used NuGrid stellar models and the SYGMA and OMEGA codes, which are available online [2] and part of the JINA-CEE chemical evolution pipeline.

Researchers: B. Côté (MSU & UVic), C. Ritter (UVic), B.W. O'Shea (MSU), F. Herwig (UVic), M. Pignatari (U. of Hull), S. Jones (HITS), C.L. Fryer (LANL)

[1] B. Côté et al., *Uncertainties in Galactic Chemical Evolution Models*, ApJ **824** 82 (2016).
[2] NuGrid Python Chemical Evolution Environment http://nugrid.github.io/NUPYCEE/

JINA-CEE Outreach News

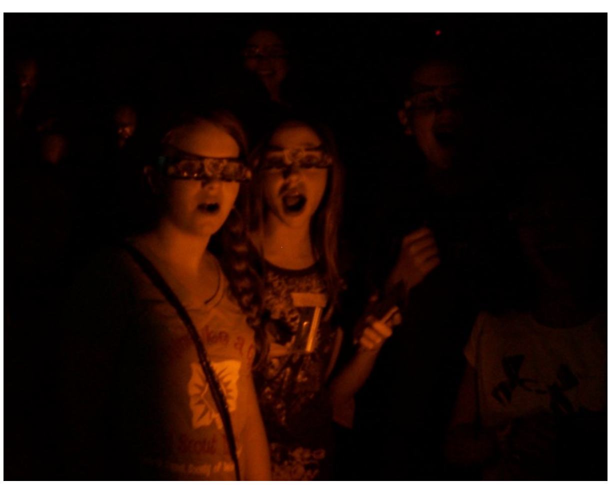
Contributed by Micha Kilburn

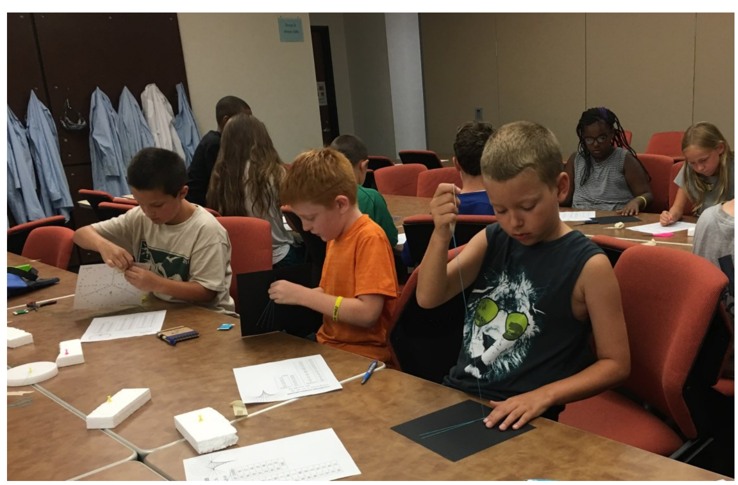
Summer is a great time to do research without course obligations. It's also a great time for outreach since parents are searching for ways to keep their children engaged outside of the school year. JINA-CEE has 6 summer camps this year to satisfy eager minds.

We kicked off the season with Physics of Atomic Nuclei (PAN) for 20 high achieving high school students at the University of Notre Dame. PAN is a free residential summer camp that introduces participants to the fundamentals of the extremely small domain of atomic nuclei and its connection to the extremely large domain of astrophysics and cosmology through a combination of lectures and experiments. We end the summer with a week of PAN for middle and high school physical science teachers followed by a week for HS students at Michigan State University.

In between, we participate in two external programs. We offer a course on nuclear astrophysics for middle school students through MSU's Math, Science and Technology two week program for gifted students in grades 7-9 which is a direct feeder for applications to the PAN program. We also co-sponsor Art Week at St. Patrick's Park in South Bend by adding astronomy instruction and art projects to complement their nature program.

Our largest program of the year was Art 2 Science Camp at Notre Dame for 160 students ages 8-12. The camp is an extension of our after-school program which seeks to ignite stellar imaginations through an integrated STEAM approach to learning. Participants learned about math, science, and engineering through creative hands-on projects including experiments and art projects. The primary goal is to stimulate children's interest in science and boosts their creativity at the same time. According to parents, it's the best camp in town that children talk about year round and some families even plan their summer vacations around it!





JINA-CEE workshop summer

Contributed by James DeBoer & Lena Simon

Each spring we solicit proposals from the JINA-CEE community for JINA-CEE sponsored scientific meetings in order to bring together scientists at the very frontier of nuclear astrophysics. This year, JINA-CEE organized an exciting workshop program, where every event cut across disciplines in its own way.

Participants of the symposium on neutron stars

The summer season was kicked off by the International Symposium on Neutron Stars in May, which was organized by Madappa Prakash at Ohio University. The meeting brought together theorists, observers, and experimentalists from very diverse areas of neutron star physics that are not typically meeting otherwise. The goal was to assess the current state of knowledge and to identify areas in which more work is needed to enable interpretation and extraction of information from observations. As a highlight, Laura Nuttall, both from Syracuse University and a member of the LIGO collaboration, announced a second detected black hole merger event.

The Symposium was preceded by a Satellite Workshop on Experiments for X-ray Burst Nucleosynthesis, organized by Catherine Deibel (Louisiana State University). During the informal one day workshop, a strategy was developed for the next few years in order to measure the most relevant reaction rates for X-ray bursts.


Discussions at the r-process workshop

In June, about 60 astronomers, astrophysicists, nuclear theorists and nuclear experimentalists attended a broad program on r-Process Nucleosynthesis held at MSU. Organized by Charles Horowitz (Indiana University) and funded by the ICNT and JINA-CEE, the workshop followed an entirely different format to cut across disciplines. With only a few regular scheduled presentations there was plenty of time for informal and vivid discussions, where many new ideas were developed and will be published as a review article. The historic gravitational wave observation was just one of the highlights discussed.

Later in June, JINA co-sponsored the 2016 R-Matrix Workshop on Methods and Applications together with Los Alamos National Laboratory and the Institute for Nuclear and Particle Physics at Ohio University. The workshop was organized by our post doc James DeBoer (University of Notre Dame) and held in Santa Fe, NM. About 50 researchers gathered from different areas of nuclear physics, all of whom utilized R-matrix theory but may not regularly communicate with (or even be aware of) each other. Additionally, the organizers strived for a mix of participants with experimental and theoretical backgrounds. The first day of the workshop set the tone with theoretical introductory talks describing basic R-matrix theory and then moved to applied talks and demonstrations of R-matrix codes. The remainder of the workshop featured groups of talks on related topics followed by 45-minute discussion sessions. Some of the highlights included alternate parameterizations, mathematical descriptions of three body and fission reactions, the $^{12}C(\alpha,\gamma)^{16}O$ and $^{13}C(\alpha,n)^{16}O$ reactions, and uncertainty quantification and more complete and standardized descriptions of them. JINA has developed the R-matrix code AZURE2, which has become one of the most widely used, and was well represented in several talks.

We thank all the organizers and participants for an exciting and productive workshop summer!

New JINA-CEE faces: Postdoc Duane Lee

New JINA-CEE Postdoc Duane Lee (Vanderbilt University)

Education: BA w/ Honors in Astrophysics for thesis titled "Quantifying Entanglement" from Williams College. MA in Astronomy with thesis titled "Investigation of Environmental Influence on Galaxian Activity Using KISS and SDSS" from Wesleyan University. Ph.D. in Astronomy with dissertation titled "Understanding the Nature of Stellar Chemical Abundance Distributions in Nearby Stellar Systems" from Columbia University.

When you were young, what did you want to be when you grew up?
I always wanted to become an astronomer or R&B singer. When I got to college that choice changed to one between continuing in astrophysics or changing my studies to quantum mechanics.

When did you decide to pursue astrophysics/physics?

Starting from graduating from elementary school to my junior year in college and then again a few years later after taking a breaking from academia between college and graduate school.

What is your research focus?

Galactic Archeology and near-field cosmology, i.e., origin of stellar populations in the Milky Way, dwarf galaxies and the assembly of the Galactic halo, chemical tagging and tracing of multiple stellar generations, galactic chemical evolution modeling. I work on developing novel ways to model and analyze stellar chemical abundance data in dwarf galaxies and the Halo to model star formation and assembly histories. I'm also interested in constraining nucleosynthetic yields and the originating sites for neutron-capture yields. I accomplish this task by modeling chemical abundance ratio distributions (CARDs) in dwarf galaxies and the Galactic halo to decipher stellar (and merger) mass-dependent elemental yields.

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

I plan on working with Anna Frebel, Ian Roederer, Tim Beers & others on constraining NSM rates in UFDs and the stellar origin of neutron capture element yields in VMP stars. I'm currently at Vanderbilt University and I plan on visiting my collaborators' institutions to get this work done.

Where do you see yourself in 5 years?

Hopefully, I'll be in a permanent position to do scientific research, teach, and mentor students (especially those of color).

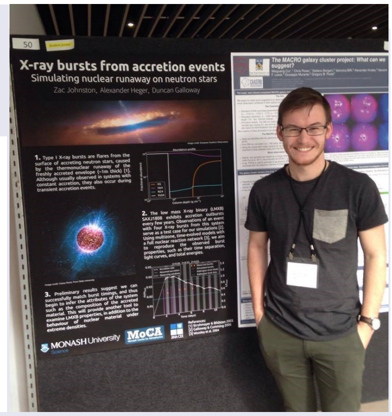
And what about 20 years?

I hope to be in a position to look back at my long and windy career path and survey a number of significant and profound contributions to science ranging from scientific discoveries, theoretical and data-driven predictions, teaching and mentorship, and fostering broader science-informed laws and governmental policies.

Is there anything else you'd like to share?

I would like to applaud JINA-CEE members' initiatives in making their respective institutions more inclusive. Of course there is more work to be done but I look forward to participating in these efforts while we vigorously pursue the data, models, and theory needed to reveal the detailed origin of the elements.

Grad student wins poster prize



JINA-CEE-funded Monash graduate student Zac Johnston won the poster prize at the General Scientific Meeting of the Astronomical Society of Australia in Sydney in July.

He won both the best student poster and best overall poster prize jointly with Monash graduate student David Liptai.
Congratulations!

JINA-CEE publications

A.C. Dombos et. al, *Total absorption spectroscopy of the β decay of ^{76}Ga*, PRC **93**, 064317 (2016)

D. Pérez-Loureiro et al., *β-delayed γ decay of , ^{26}P: Possible evidence of a proton halo*, PRC **93**, 064320 (2016)

M. Munch et al., *Independent measurement of the Hoyle state β feeding from ^{12}B using Gammasphere*, PRC **93**, 065803 (2016)

S.N. Liddick et al., *Experimental Neutron Capture Rate Constraint Far from Stability*, PRL **116**, 242502 (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)

B. Mueller et al., *A simple approach to the supernova progenitor-explosion connection*, MNRAS **460**, 742 (2016)

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

J.B. Miles et al., *On Measuring the Metallicity of a Type Ia Supernova's Progenitor*, ApJ **824**, 59 (2016)

I.U. Roederer et al., *Detection of Phosphorus, Sulphur, and Zinc in the Carbon-enhanced Metal-poor Star BD+44 493*, ApJL **824**, 19 (2016)

H. Schatz, *Trends in nuclear astrophysics,* J. Phys. G **43**, 064001 (2016)

G.P.A. Berg et al., *A recoil separator for nuclear astrophysics SECAR*, Nucl. Instr. Meth. Phys. Res. B **376**, 165 (2016)

T.Y. Hirsh et al., *First operation and mass separation with the CARIBU MR-TOF*, Nucl. Instr. Meth. Phys. Res. B **376**, 229 (2016)

D.W. Bardayan et al., *The new JENSA gas-jet target for astrophysical radioactive beam experiments*, Nucl. Instr. Meth. Phys. Res. B **376**, 326 (2016)

M.B. Bennett et al., *Isobaric multiplet mass equation in the A =31 ,T =3 /2 quartets,* PRC **93**, 064310 (2016)

Upcoming JINA-CEE events

3rd Astrophysical Nuclear Reaction Network School
August 19 — 26, Schmitten, Germany

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

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

JINA–CEE

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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

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