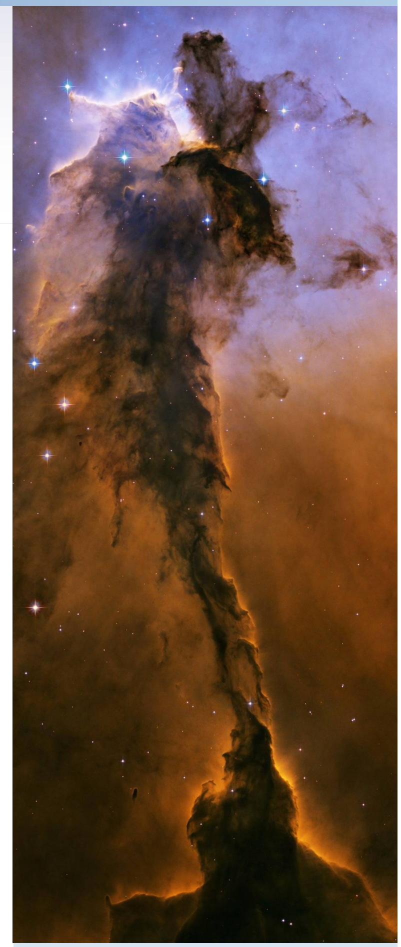
June 2017

JINA-CEE

Center for the Evolution of the Elements



A note from the Director, Hendrik Schatz

Dear Friends of JINA-CEE.

JINA-CEE had a busy Spring, with various committees and site visits, and of course lots of exciting science, some of which you can read about in this newsletter. I am also pleased to welcome two new member institutions joining JINA-CEE: the E.A. Milne Centre for Astrophysics at the University of Hull, UK, and the Anton Pannekoek Institute at the University of Amsterdam, Netherlands. The new partners further strengthen JINA-CEE's international connections and bring in critical expertise related to chemical evolution, element synthesis, x-ray observations, and neutron star phenomena.

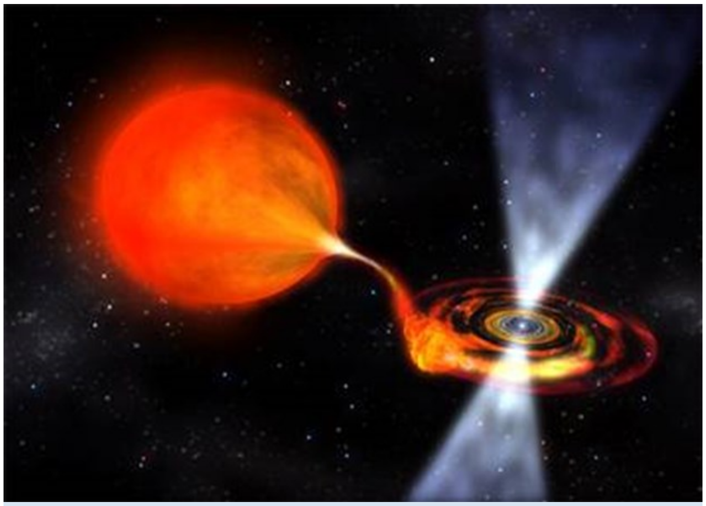
Looking forward, summer is the time of the year when most of JINA-CEE's extensive public outreach happens. Reaching out to the public, including present and future decision makers, is now more important than ever. I therefore encourage you to actively support these outreach activities where possible, they do rely heavily on scientific volunteers including students, postdocs, and faculty.

As a reader of this newsletter you are probably a scientist, or a member of the public interested in science. In either role I would like to encourage you to take every opportunity to promote science and articulate its value to society. Science not only produces an exciting new understanding of nature that will inform generations to come. Science directly improves our lives and forms the basis of our prosperity and future economic growth. Science does not have all the answers, but it brings a unique way of thinking and problem solving to the table that are invaluable for a modern society. The future is bright - progress in nuclear astrophysics and other scientific areas has been stunning, and past and ongoing investments set us on a path for major discoveries. It is important though to get the message out that these are worthwhile investments with significant short and long term returns.

Inside this issue

Image Credit: NASA

Fingerprinting Neutron Stars through Thermonuclear Bursts



An artists depiction of an accreting neutron star burster. Image Credit: NASA/Dana Barry

Neutron stars are the remnants of supernova explosions in medium-sized stars, and when accompanied by a binary companion, show a variety of high-energy phenomena. One example is thermonuclear bursts, where the nuclear fuel (mainly hydrogen and helium) accumulated on the surface of the star ignites and burns to heavier elements. Observers have been working for decades to gather observations of these events, detectable by satellite-based X-ray telescopes. At the same time, theorists have built increasingly more detailed numerical models predicting burst behavior, and including thousands of nuclear masses and reaction rates measured in terrestrial laboratories.

To date, efforts to match the burst properties with models --- and hence infer the system parameters --- have been limited, for several reasons. First, the observed behavior of many bursting neutron stars is frequently at odds with models, with irregular, inefficient bursts. Second, even for the "well-behaved" sources, there is substantial degeneracy in the model parameters, such that very different input parameters can produce similar burst lightcurves and recurrence times in numerical models.

This degeneracy is best illustrated by the case of GS 1826-24, nicknamed the "Clocked burster" for its highly regular and consistent bursts. An early study of the bursting behavior suggested that the lack of variability in the burst profiles over a range of accretion rates required unusually low fraction of Carbon-Nitrogen-Oxygen (CNO) nuclei in the accreted fuel [1]. On the other hand, a comparison of numerical models with the observations suggested instead that the profiles could have arisen from burst fuel with CNO mass fraction up to twenty times higher, consistent with the solar value [2].

To address this ambiguity, it is clear that comparisons of observations and models need to be made over the widest possible range of accretion rates, and incorporating all the available observational data. To this end, we have recently released a sample of observational data for four bursting neutron stars, representing four distinct cases of nuclear ignition, and covering a range of accretion rates [3]. There are three key applications of the sample. First, each example can serve as a test case for different numerical models, to measure the intrinsic uncertainty of different codes. This fundamental uncertainty has not been quantified before. Second, each case can be used to determine the key nuclear reactions which have the most influence on the shape of the burst lightcurve.

Third, each set of data will be used to identify the required input parameters to the models to match in detail the observed bursts with those predicted. This "fingerprinting" of burst sources has the potential to reveal the composition of the accreted fuel, and hence the evolutionary state of the mass donor. The comparison is also sensitive to the neutron star mass and radius, which may allow constraints on the poorly understood nuclear equation of state. Ultimately this effort is also hoped to constrain the nuclear physics input to the models. Further work is under way to fully exploit the new sample of burst observations.

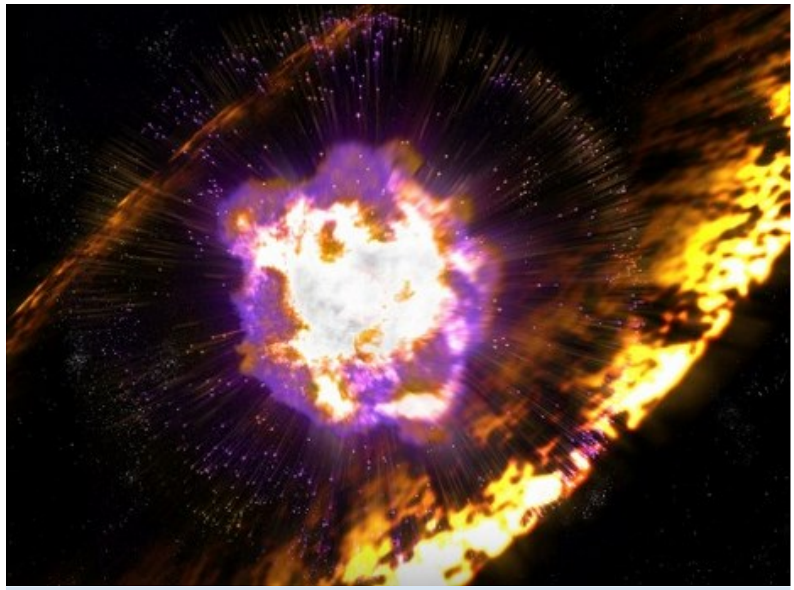
Contributed by Duncan Galloway and Adelle Goodwin

Researchers: Duncan Galloway (Monash), Adelle Goodwin (Monash), Laurens Keek (NASA/GFSC)

[1] Galloway et al. 2004, ApJ 601, 466
[2] Heger et al. 2007, ApJ 671, L141
[3] Galloway et al. 2017, accepted by PASA, arXiv:1703.07485

Impact of (α, n) Reactions on Weak r-process in Neutrino-driven Winds

The origin of the heavier elements from germanium to silver is not yet fully understood even though it is currently assumed that nature may produce those elements in multiple nucleosynthesis processes and scenarios. A suitable process to create those elements is the weak rapid neutron capture process (r-process) in neutrino driven winds. These winds emerge from newly born neutron stars in the first seconds after a supernova explosion and happen frequently enough to explain the relatively large number of stars with enhanced germanium to silver abundances (Z = 32-47).



An artist's illustration of a supernova explosion.
Credit: Greg Stewart/SLAC National Accelerator Laboratory

Once the wind has cooled down after a few seconds, charged particle reactions are key in the production of the heavy elements. In particular, reactions where a heavy nucleus captures an alpha particle and emits a neutron (so called (α,n) reactions) play an important role. None of the most relevant (α,n) reactions have been measured in the energy (temperature) range relevant for weak r-process astrophysical conditions. So far modelers have to rely on theoretical predictions of those rates. However, the theoretical uncertainties of the calculated reaction rates can be as high as 2 orders of magnitude [1] and abundance network calculations are highly sensitive within the expected theoretical uncertainties of these rates [2]. So in order to get a step closer to reliably predict the rates of the reactions that control the production of the heavier elements, we have begun a systematic study searching for the critical reaction rates that influence the most the final abundances in weak r-process scenarios [2,3].

This sensitivity study allows to identify the most impactful reaction rates, which can then be pinned down experimentally by measurements at radioactive beam facilities. Most of the reaction rates responsible for the production of elements Z=32-47 in neutrino driven winds are either viable with current beam intensities at existing nuclear physics facilities or will be in the near future. The direct measurement of some of the relevant (α, n) reaction rates has already started at the ReA facility at MSU's National Superconducting Cyclotron Laboratory and more measurements are planned in the next few years. These measurements combined with stellar abundance observations will help us understand how the heavier elements are produced in our Galaxy.

Contributed by Fernando Montes

Researchers: Fernando Montes (MSU), Jorge Pereira (MSU), Almudena Arcones (TU Darmstadt) , Julia Bliss (TU Darmstadt), Tony Ahn (MSU), Z. Meisel (OU), Hendrik Schatz (MSU)

Further Reading:

[1] J. Pereira and F. Montes, Phys. Rev. C 93, 034611 (2016).
[2] J. Bliss, A. Arcones, F. Montes, J. Pereira, accepted for publication J. Phys. G.
[3] J. Bliss, A. Arcones, F. Montes, J. Pereira, in preparation.

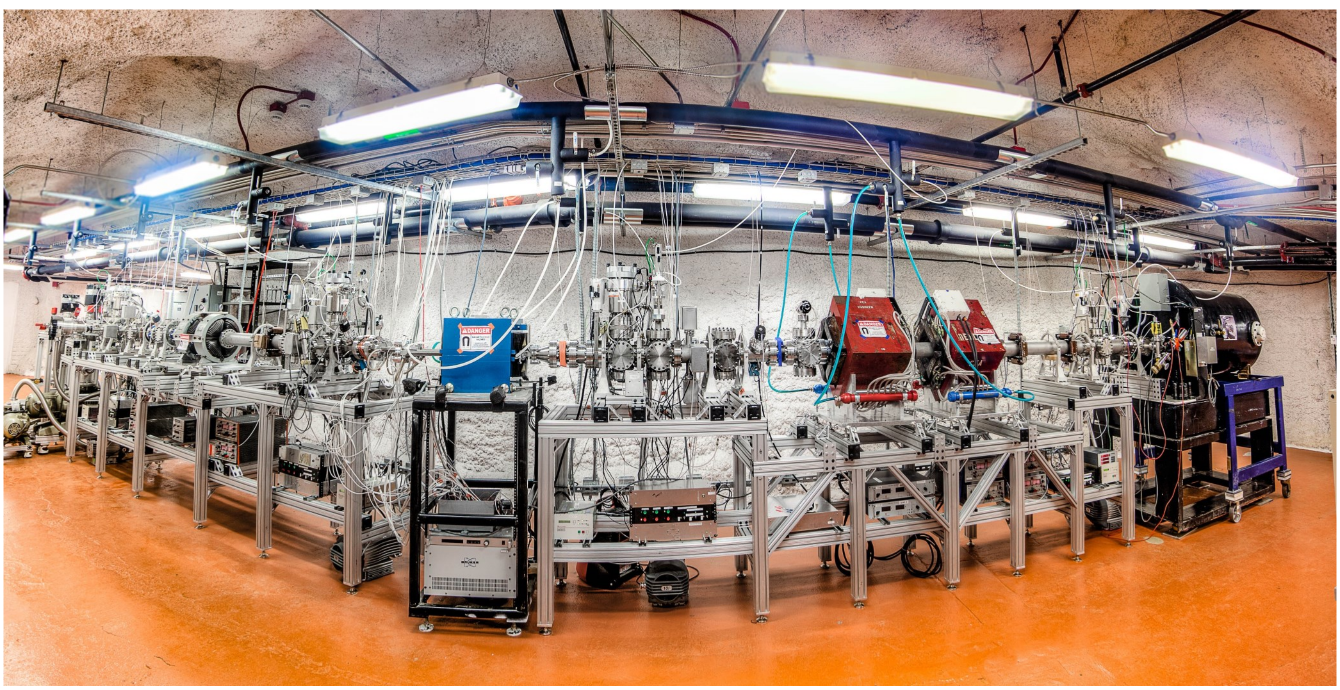
First CASPAR Beam on the Horizon

CASPAR the Compact Accelerator System for Performing Astrophysical Research is a low-energy nuclear astrophysics lab located underground at the 4850 ft level of the Sanford Underground Research Facility (SURF). The 1MV accelerator system saw its first stage of commissioning completed in early March, with the first ignition underground of the RF ion source, and Hydrogen and Helium plasma creation. The accelerator system is a collaboration between the University of Notre Dame, the South Dakota School of Mines and Technology, and the Colorado School of Mines. In a push to see beam delivered to target during the summer of 2017, the CASPAR team has sealed the system, made ready the accelerator with the introduction of its insulating gas, and is prepped for first voltage and beam tests.

Contributed by
Dan Robertson

A final safety review has recently been completed paving the way forward for initial ion beam delivery. System commissioning and characterization will shortly follow, making CASPAR one of only two underground nuclear astrophysics accelerator labs in the world, and the only one in the US. The bringing online of the CASPAR facility, adds a powerful new tool in the investigation of low-energy cross-section measurements of astrophysical interest. A main concentration of the facility will be the reactions important for the production of neutrons as seeds for the s-process, $^{13}C(\alpha,n)$ and $^{22}Ne(\alpha,n)$, pushing current measurements into the astrophysical burning window. This much needed data seeks to help constrain current astrophysical models.

Researchers:
Daniel Robertson (ND), Manoel Couder (ND), Uwe Greife (CSM), Ed Stech (ND),
Frank Strieder (SDSMT), and Michael Wiescher (ND)



The complete CASPAR system in the underground cavity. Beam transport is from the 1 MV accelerator at the right, to the current gas target system at the left. (Picture provided by Matt Kapust)

New International Partner: University of Hull

The Joint Institute for Nuclear Astrophysics, Center for the Evolution of the Elements (JINA-CEE) has a new partner in its effort to foster scientific collaboration across nuclear astrophysics at institutions around the world. Recently, a memorandum of understanding (MOU) was signed with the E. A. Milne Centre for Astrophysics at the University of Hull, UK.

The E. A. Milne Centre for Astrophysics and JINA-CEE will collaborate with senior collaborator Brad Gibson on galactic chemical evolution and nucleosynthesis model calculations.

With Marco Pignatari (University of Hull) being the PI of the NuGrid collaboration, another focus of the MOU is the coordination of NuGrid related activities in JINA-CEE and the organization of joint workshops and schools.

LAMPADA FERENS

UNIVERSITY OF Hull

New International Partner: University of Amsterdam

The Anton Pannekoek Institute for Astronomy (API) at the University of Amsterdam has joined the JINA-CEE collaboration as well.
API faculty members Anna Watts and Rudy Wijnands, and Vidi Fellow Nathalie Degenaar, will be working with their JINA-CEE colleagues on nuclear reactions and supranuclear density matter in neutron stars. Welcome to the collaboration!

UNIVERSITY OF AMSTERDAM

Upcoming JINA-CEE Events

NuGrid Collaboration Meeting
June 19-25, NSCL, East Lansing, Michigan

Forging Connections—From Nuclei to the Cosmic Web
June 26—29 2017, East Lansing, Michigan

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

Microphysics in Computational Relativistic Astrophysics 2017
July 17—21 2017, NSCL, East Lansing, Michigan

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 Jinmi Yoon

JINA-CEE Postdoc Jinmi Yoon (UND)

Education:

I obtained my master's degree from Seoul National University in South Korea in with theoretical high energy physics. Later, my Ph. D. research at Stony Brook University (SUNY at Stony Brook) was about rotation and evolution of A and F stars, which are early-type stars. Unlike late-type stars such as our Sun, these stars rotate rapidly. Since rotation obscures the interpretation of the observed data, my main work was to decouple rotational effects from the physical properties such as temperature, radius, and mass and to measure the rotational velocity more accurately by using both high angular resolution interferometry and high-resolution spectroscopy.

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

I had a wide spectrum of what I wanted to be: an astronomer, an archaeologist (Egyptology), an artist, a comic book illustrator, a fashion designer, a hair stylist, and a teacher.

When did you decide to pursue astrophysics/physics?

Unlike many people in physics, I started thinking about being a physicist pretty late in my life, not until I was a sophomore in my college. When I first took physics classes such as quantum mechanics, relativity, and math classes, I was pretty fascinated by the physical concepts of those subjects, especially that physics can be described by simple mathematical equations. So I first focused on theoretical high energy physics as I wanted to study and understand the Universe, its origin and evolution from a physical point of view. I finally came to pursue further studies in the US after a year and a half of teaching physics at a university.

What is your research focus and with whom are you working?

I am working with Professor Timothy C. Beers in the Galactic Archeology group in the Department of Physics and JINA-CEE at the University of Notre Dame. Galactic archaeology is a study of uncovering the history of the early Universe through stellar fossil records, an ancient star’s chemical content and its kinematics. My current research focus is on understanding how first stars were formed, evolved and enriched the next generations of stars by studying second generation stars. To pursue these goals, on the one hand we are searching for the oldest, metal-poor stars in general, and for carbon-enhanced ultra metal-poor stars in the Galactic halo in particular. On the other hand, I am studying the kinematics of these ancient stars to understand how our Galactic halo was formed and evolved.

Where do you see yourself in 5 years?

I'd like to be an expert on Galactic archeology in 5 years. I am excited by the future access to new data such as high precision astrometric data (kinematics) from GAIA and high-resolution spectroscopic surveys such as GALAH — the chemo-dynamical studies will be revolutionized by these data in 5 years!

And what about 20 years?

Near-field cosmology requires understanding the theoretical aspect of early galactic formation and evolution in addition to chemistry and kinematics. So I would branch out into cosmological simulations to better understand the chemo-dynamical history of our Galaxy and further the Universe.

Recent JINA-CEE Publications

C. Abia et al., *The puzzle of the CNO isotope ratios in asymptotic giant branch carbon stars*, A&A 599, A39 (2017)

A. Arcones et al., *White paper on nuclear astrophysics and low energy nuclear physics Part 1: Nuclear astrophysics*, PPNP 94, 1 (2017)

S. Austin et al., *Reducing Uncertainties in the Production of the Gamma-emitting Nuclei ^{26}Al, ^{44}Ti, and ^{60}Fe in Core-collapse Supernovae by Using Effective Helium Burning Rates,* ApJL 839, L9 (2017)

J. Bliss et al., *Impact of (α,n) reactions on weak r-process in neutrino-driven winds*, J. Phys. G. 44, 054003 (2017)

K.-J. Chen et al., *Low-energy Population III supernovae and the origin of extremely metal-poor stars*, MNRAS 467, 4731 (2017)

B. Côté et al., *Advanced LIGO Constraints on Neutron Star Mergers and r-process Sites*, ApJ 836, 230 (2017)

A. Cumming et al., *Lower limit on the heat capacity of the neutron star core*, PRC 95, 025806 (2017)

A. Deibel et al., *Late-time Cooling of Neutron Star Transients and the Physics of the Inner Crust*, ApJ 839, 95 (2017)

L. Keek et al., *X-Ray Reflection and an Exceptionally Long Thermonuclear Helium Burst from IGR J17062-6143*, ApJ 836, 111 (2017)

Y. S. Lee et al., *Chemical Cartography. I. A Carbonicity Map of the Galactic Halo*, ApJ 836, 91 (2017)

C. Massimi et al., *Neutron spectroscopy of ^{26}Mg states: Constraining the stellar neutron source ^{22}Ne(α,n)^{25}Mg,* Phys. Lett. B 768, 1 (2017)

Z. Meisel et al., *Energy acceptance of the St. George recoil separator*, NIMPA 850, 48 (2017)

Z. Meisel and A. Deibel, *Constraints on Bygone Nucleosynthesis of Accreting Neutron Stars*, ApJ 837, 73 (2017)

M. R. Mumpower et al., *Reverse engineering nuclear properties from rare earth abundances in the r process*, J. Phys. G. 44, 034003 (2017)

S. Richers et al., *Equation of state effects on gravitational waves from rotating core collapse*, PRD 95, 063019 (2017)

A. Spyrou et al., *Neutron-capture rates for explosive nucleosynthesis: the case of ^{68}Ni(n, γ)^{69}Ni*, J. Phys. G. 44, 044002 (2017)

A. Tarifeno-Saldivia et al., *Conceptual design of a hybrid neutron-gamma detector for study of β-delayed neutrons at the RIB facility of RIKEN*, J. Instrum. 12, P04006 (2017)

E. Uberseder et al., *Stellar (n, γ) cross sections of ^{23}Na,* PRC 95, 025803 (2017)

Timmes' Open-source "Library of Stars" Receives NSF Grant

JINA-CEE Co-PI
Frank Timmes

JINA-CEE Co-PI Frank Timmes (ASU) receives a new $2.3 million grant from the National Science Foundation to upgrade the open-source libraries "Modules for Experiments in Stellar Astrophysics (MESA)", designed to gather data from a variety of space missions and in turn drive significant innovation in the nuclear astrophysics, stellar, gravitational wave, exoplanet, galactic and cosmological communities.

An essential tool in the vast discovery of space, MESA is helping to continuously monitor more than 100,000 stars. The discoveries resulting from MESA-based surveys include revelations about the dynamic impact of waves and magnetic fields, unusual explosive outcomes, and remarkably complex binary star systems.

With this new NSF funding, researchers are looking to use MESA to enhance science on supernova light curves, develop new computational modes and enable observational breakthroughs.

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, 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, 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 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

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, Stony Brook University, TU Darmstadt Germany, University of Illinois, University of Michigan, Wayne State University

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