The 1st IReNA-Ukakuren Joint Workshop "Advancing Professional Development in Nuclear Astrophysics and Beyond"

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NAOJ (National Astronomical Observatory of Japan)

Book of Abstracts

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Exploring the neutron-rich actinide region via ion-trap techniques for nuclear astrophysics applications

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The neutron-rich actinide region is of interest as it is thought to be related to the endpoint of the nucleosynthesis via the rapid neutron-capture process (r-process), where the actinide elements such as uranium are formed by beta-decays and middle-mass nuclei are served by nuclear fissions. To explore this region and measure fundamental nuclei properties related to the nucleosynthesis including nuclear mass, half-life, decay scheme, and fission patterns, we are employing ion-trap techniques to develop experimental apparatus. This presentation will outline our recent achievements and developments and future prospects.

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Exploring Shell Structure at N=32, 34: Mass Measurements of Sc, Ti, and V Isotopes

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In this contribution, we report on mass measurements of ^{55}Sc, $^{55-58}$Ti, and $^{55-59}$V isotopes obtained during the first commissioning campaign of the ZD-MRTOF system at the RIBF/RIKEN. We discuss the implications of these masses in the shell structure at $N = 32, 34$ in the context of deformation toward $N = 40$. The newly installed experimental system, located downstream of the ZeroDegree (ZD) spectrometer at the BigRIPS facility (RIBF/RIKEN), comprises a radiofrequency (RF) carpet-type He gas cell combined with a multi-reflection time-of-flight mass spectrograph (MRTOF). In the first low-energy experiment at BigRIPS, high-energy products were captured and decelerated in helium gas, and subsequently extracted through an aperture via an RF microstructure into a Paul trap ion guide structure. The cooled and thermalized ions were injected into the MRTOF system as a high-quality beam for high-precision mass measurements. We describe the details of the new cryogenic gas cell and the mass analysis methods employed in this experiment. Additionally, we present our future plans for mass measurements, particularly in the $N = 126$ region, which is close to waiting point nuclei relevant to the third peak of the r-process.

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Quantified Nuclear Mass Model for r-process simulations using Bayesian Machine Learning Techniques

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Bayesian approach to fission products yields of 235U by data augmentation

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Fission yield is an important physical quantity for nuclear systems and the origin of heavy elements. In recent years, the energy dependence of fission yield has attracted particular attention. In this presentation, we present our first results for fission products yields (FPY) predicted by Bayesian neural network (BNN) model.

In the BNN model, we divided the FPY data in the JENDL-5.0 library into 80% for training data and 20% for validation. To enhance the accuracy of predictions of FPY data by BNN model, we discussed data augmentation by integrating 80% of JENDL-5 FPY data, cumulative fission yields (CFY) data from experiments, and theoretical calculation results as a whole set of training data. Finally, we show the Bayesian estimation of 235U(n,f) FPY data in the induced-energy range (0.5 MeV ~ 14 MeV) with data augmentation. The prediction results from BNN model with data augmentation reproduce the fine structure of the heavy fission product peaks.

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Study of the contribution of the 7Be(d, p) reaction to the 7Li problem in the Big-Bang Nucleosynthesis

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Our research goal is to measure the cross-section of the 7Be(d, p) reaction in search of a solution/key to the cosmological 7Li problem (CLP). The CLP is the overestimation of primordial 7Li abundance in the standard Big Bang nucleosynthesis (BBN) model compared to observed abundances, a major unresolved problem in modern astrophysics. A recent theoretical BBN model emphasized that the primordial 7Li abundance is about three times larger than the recent precise observation [1], [2]. 7Li nuclei were produced predominantly by the electron capture decay of 7Be after the termination of nucleosynthesis in the standard BBN model. We focus on the 7Be(d, p) reaction since it is considered one of the contributors to 7Be destruction in the BBN [3]. Our experiment means that we reproduce the nuclear reactions that occurred in BBN are reproduced in the modern world. We developed a method to produce 7Be (half-life = 53.22 days) target to measure the reaction cross-section in normal kinematics. The experiment was performed at the Tandem Electrostatic Accelerator Kobe University [4]. A 2.36 MeV proton beam irradiated a natural-Li target to transmute 7Li particles to 7Be particles via the 7Li(p, n)7Be reaction [5]. We produced 3.03×10^13 7Be particles in the target after two days of proton irradiation. After the target production, the beam ion was changed to deuterons, and the 7Be(d, p) reaction was measured at energies 0.6, 0.86, 1.0, and 1.6 MeV. Layered silicon telescopes measured the outgoing protons at 30 and 45 degrees. In this talk, we will talk about the experimental setup and preliminary results of this study, including the 7Be(d, p) cross-section and its impact on the solution of the CLP.

[1] R. H. Cyburt et al., J. Cosmol. Astropart. Phys. 11, 012 (2008).
[2] Brian D. Fields et al., J. Cosmol. Astropart. Phys. 03(2020)010.
[3] S. Q. Hou et al., Phys. Rev. C 91, 055802 (2015).
[4] "Kobe University Tandem Electrostatic Accelerator"https://www.maritime.kobe-u.ac.jp/en/study/tandem_e.html

(Accessed 4th August 2022)
[5] K. K. Sekharan et al., Nucl. Instr. Meth. 133, 253-257 (1976).

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Feasibility study for measuring the gamma-decay probability of the 3-1 state in 12C with deuteron inelastic scattering

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The triple alpha (3α) reaction, which produces ^{12}C from ^{4}He, is one of the most important reactions in nucleosynthesis in the universe. In this reaction, resonance states of three α particles are generated as excited states of ^{12}C. In most cases, these states decay back into three α particles, but a tiny fraction of them undergo radiative decay, leading them to the ground state of ^{12}C. Thus, the branching ratio of α-decay and radiative decay in the 3α resonance states is a crucial physical quantity that determines the ^{12}C production rate. At normal stellar temperatures lower than 10^8 K, the 3α reaction mainly proceeds via the 0_2^+ state (Hoyle state), and its radiative-decay probability has been already measured. However, at high temperatures above 10^9 K, high-lying excited states e.g., 3_1^- and 2_2^+ states play an important role. Despite their importance, the radiative-decay probabilities of these high-lying states still remain unmeasured due to the extremely small expected values ranging from 10^{-8} to 10^{-6}. Although we previously measured the radiative-decay probability of the 3_1^- state in ^{12}C by means of proton inelastic scattering with a solid hydrogen target [1], we could not achieve sufficient precision due to significant systematic uncertainty due to background events.
Therefore, we conceived an idea to employ a deuterium target instead of the hydrogen target. Generally, deuterons possess higher separation energies from nuclei than protons. That should be an advantage to kinematically distinguish background events from true events. In this study, we aim to precisely determine the radiative-decay probability of the 3_1^- state in ^{12}C through simultaneous measurement of the scattered ^{12}C and the recoil deuteron, which are emitted from the inelastic deuteron scattering under inverse kinematics conditions. We have already conducted simulation studies to search for optimum experimental conditions. We considered utilizing TiD_2 (deuterated titanium) or solid deuterium as a deuteron target. TiD_2 is much easier to handle than the solid deuterium because it is stable at room temperature and resistant to heating from the beam. However, it was not unclear whether the TiD_2 target was useful for the proposed measurement because its signal-to-noise ratio in the inelastic deuteron scattering was unknown. Therefore, we measured the background rate due to Ti in the TiD_2 target as well as the reaction cross section to excite the 3_1^- state using a 218-MeV ^{12}C beam at CYRIC, Tohoku University. In this talk, we will report the result of the test experiment at CYRIC and our present status.
[1] M. Tsumura et al., Phys. Lett. B 817,136283 (2021).

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Impact of the isospin symmetry breaking on the nuclear equation of state

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TBA

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Prompt decay calculation using primary fission yield and TKE obtained from 4-D Langevin model

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For the fission reaction, the Langevin model simulates the fission process from nuclear deformation after forming a compound nucleus up to scission. We have developed 4-dimensional Langevin model and succeeded in describing the fission fragment yield and total kinetic energy (TKE) as a function of fragment mass number over a wide mass range from actinide to superheavy nuclei. We performed Hauser-Feshbach statistical decay calculation for evaluating fission observables using the fission fragment yield and TKE obtained from our 4-dimensional Langevin model.

Multi-Messenger Astronomy and Astrophysics / 57

Signatures of r-process elements in optical-infrared spectra of neutron star mergers

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Binary neutron star (NS) merger is a promising site for the rapid neutron capture nucleosynthesis (r-process). The radioactive decay of newly synthesized elements powers electromagnetic radiation, as called kilonova. The detection of gravitational wave from a NS merger GW170817 and the observation of the associated kilonova AT2017gfo have provided with us the evidence that r-process happens in the NS merger. However, the abundance pattern synthesized in this event is not yet clear. In this talk, I will focus on the spectra of kilonova to extract information of elements synthesized in neutron star mergers. Based on our recent findings, I will discuss elemental features in kilonova spectra, and identification of elements in AT2017gfo.

Multi-Messenger Astronomy and Astrophysics / 8

Light curve of electron capture and Fe core collapse supernova: The diagnostic method of electron capture supernova

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Stars of 8-10 M⊠ are theoretically considered to become Super Asymptotic Giant Branch (SAGB), and explode as electron capture supernovae (ECSNe). However, there are no observation which is clearly identified as an ECSN. Although SN1054 (Crab Nebula) is considered to be an ECSN, we could hardly know its explosion as detail as modern observation. SN2018zd is a controversial object. Although it is recently proposed as an ECSN from its observational features (Hiramatsu et al. 2021), it is also proposed as an FeCCSN (Callis et al. 2021) at the same time. The reasons why we could hardly identify ECSN clearly are that observational characteristics of ECSNe comparing to Fe core collapse supernovae (FeCCSNe) of Red Super Giant (RSG) are not understood sufficiently, and the diagnostic method of ECSNe is not established yet. Although Kozyreva et al. (2021) shows that ECSN has blue plateau, they don't include circumstellar material (CSM) interaction. However, CSM interaction is quite important to understand the light curve because it might change the light curve significantly (Moriya et al. 2018), and SAGB is expected to experience large mass loss (Poelarends et al. 2008). Understanding the observational characteristics of ECSN including CSM interaction and observing it are highly demanded because it would be a clue to understand not only the stellar evolution of 8-10 M⊠ stars but also its nucleosynthesis, explosion mechanism, mass loss, and contribution to galactic chemical evolution.
We synthesized the multicolor light curves of ECSNe and low-mass FeCCSNe including CSM interaction not only based on the physically motivated properties (e.g. explosion energy estimated by first principles simulation) but also based on the wide range of parameters. The calculation is conducted using the multi-group radiation hydrodynamics code, STELLA (Blinnikov et al. 2000). The progenitor models of SAGB and RSG are obtained from Tominaga et al. (2013) and Sukhbold et al. (2016) respectively.
As a result, it is shown that ECSN has bluer plateau in multicolor light curve even if it has reasonably dense CSM although the bolometric light curve could be degenerate with FeCCSN for some parameter sets. The bluer color of ECSN is explained by tenuous and extended envelope structure of SAGB. Using this characteristic, we propose a new diagnostic method of ECSN in which the transition time from plateau to tail phase (tPT) and the color index B-V at tPT/2 are used. Moreover, we applied the method to SN2018zd, which arises discussion whether it is an ECSN or an FeCCSN (Hiramatsu et al. 2021; Callis et al. 2021) and found that it is likely to be an ECSN.
In the talk, we will show the calculated light curves of ECSN and low-mass FeCCSN and discuss their characteristics. In addition, we will propose a new diagnostic method of ECSN. Also, we will mention our future work in which we will try to find an ECSN and reveal its nature.

Multi-Messenger Astronomy and Astrophysics / 26

Supernova neutrino signals as indicators of neutrino mass ordering

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Supernovae events are one the most powerful cosmic sources of neutrinos with energies of several MeV. The emission of neutrinos and antineutrinos of all flavors carries away the gravitational binding energy of the compact remnant and drives its evolution from the hot initial to the cold final state. I will briefly describe how to detect these neutrinos from Earth, and how to use these data to address the neutrino mass ordering problem. The main goal of this work is to develop a model-independent analysis strategy by comparing different detection channels at large underground detectors that allow looking for indicators of mass ordering in the neutrino sector.
In addition, we performed a statistical study on the expected signals for both mass ordering to determine if the expected signals can be distinguished.

Career Development Session / 49

On the oldest stars in the Milky Way (Online talk)

Author: Anna Frebel[None]

Nuclear Matter / 5

Kaons in nuclei: theoretical calculations of the anti-kaon-nucleus interaction and the implications

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The interaction between the anti-kaon ($\bar{K}$) and the nucleus is one of the hot topics in recent hadron physics. Since the $\bar{K}N$ interaction is attractive enough to produce a bound state as the $\Lambda(1405)$ baryon, the $\bar{K}$-nucleus interaction is expected to be attractive as well, providing an important clue to understanding the behavior of strange quarks in dense matter such as neutron stars. Recently, we have been able to access information about the $\bar{K}$-nucleus interaction via the hadronic reactions using anti-kaon beams, for example at J-PARC. In particular, precise data are available for the kaonic atoms, the Coulomb-assisted K^--nucleus bound states, and the kaonic nuclei, the Kbar-nucleus bound states with the strong interactions. In the present talk I would like to present our theoretical work on the evaluation of the $\bar{K}$-nucleus potentials which reproduce the experimental data on the kaonic atoms and kaonic nuclei.

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Self-Consistent Superfluid Band Calculations for Neutron Star Inner Crust

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Neutron star is a remnant of supernova, and viewed as the resource of plenty of physical properties, associated with subnuclear, nuclear and quark matter.

At the bottom layer of subnuclear area(so-called "crust"), neutrons are dripped from excessively neutron-rich nuclei, and moreover nuclei form various non-uniform crystalline structures which are totally called "pasta" phases.
It becomes clear that properties of pasta nuclei are intimately related with dripped neutrons and their conduction. In particular "entrainment" effect may interrupt the interpretation of pulsar's "glitch" phenomenon and bring about a big controversy, that's why a naively microscopic calculation is strongly desired.

Under such a situation, we formalized the time-dependent Hartree-Fock-Bogoliubov (TDHFB) calculations combined with Band theory, and performed them for 1 dimensional crystalline (slab) phases, imposing Beta equilibrium condition. At the same time, we extended those calculations into finite-temperature and magnetic field systems, investigating the diverse properties of subnuclear matter.

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Dark matter effect on the neutron star equation of state

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This talk explores the effect of dark matter, captured by the strong gravity and high density of neutron stars, on the equation of state (EoS) of neutron stars.
We establish a theoretical framework incorporating dark matter interactions and demonstrate potential modifications in the neutron star EoS.
These theoretical modifications allow us to explore potential constraints on the properties of dark matter by comparing them to observational data.
In particular, we would like to discuss whether they can provide unique insights into the characteristics of the dark sector.
The presentation concludes with a discussion on future prospects.

Accreting Neutron Stars / 63

Constraints on Neutron Star Structure from Clocked Burster 1RXS J180408.9-342058

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Type-I X-ray bursts are rapidly brightening phenomena triggered by the nuclear burning of light elements near the surface of accreting neutron stars. Observed light curves are sensitive to many model parameters. We focus on the uncertainties of the nuclear equation of states, which determines the mass and radius of neutron stars. Regarding the observations, we focus on one of the regular bursters, 1RXS J180408.9-342058, where two series of X-ray bursts have been detected by NuStar. Based on our numerical models covering whole areas of neutron stars, we will discuss the possibility of constraining the equation of states and the mass from the observed recurrence time and persistent flux.

Accreting Neutron Stars / 10

Do Accreting Neutron Stars All Have Identical Crusts?

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Accretion onto a neutron star induces nuclear reactions which heat the crust. By fitting crust models to the observed thermal evolution of the neutron star after accretion halts and the neutron star enters quiescence, we obtain constraints on the composition and heating of the neutron star crust, notably the crust impurity concentration and the amount of heat deposited per accreted nucleon. Heat deposition in the shallowest layers of the crust is required to fit the early-time cooling as well as to explain the observed recurrence time of superbursts, but the physical mechanism that causes this heating is unknown. It is also unknown whether this shallow heating is constant among different accretion outbursts and different neutron stars and whether different neutron stars have the same crust composition.

We model the thermal evolution of seven neutron stars in which crustal cooling has been observed using the crust cooling code dStar. We estimate the model parameters by performing Markov Chain Monte Carlo fits to the observational data. To test whether model parameters are constant across different outbursts and neutron stars, we perform our analysis first for each neutron star independently, then perform joint fits in which the heat deposition or crust impurity are shared among all neutron stars. We find that models in which the shallow heating is shared across neutron stars fit the data significantly more poorly than those in which it is not shared. This suggests that the shallow heating is indeed different for different neutron stars.

Career Development Session / 48

Academia: Thinking outside the tenure-track box

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There is more to life in academia than the traditional tenure-track career path. Plenty of exciting -and often overlooked- opportunities exist for science PhDs to contribute their expertise and passion within the academic world. In this session I will briefly describe my own career path and those of other scientists with non-traditional academic careers, while emphasizing the importance of interdisciplinary collaboration, effective communication, leadership, and innovation. We will discuss strategies to help participants explore how they can forge a rewarding and impactful academic career that aligns with their interests, strengths, and aspirations. Participants will also learn about networking opportunities, and professional development resources available to them within the IReNA network.

Career Development Session / 47

Navigating the intertwined paths of a nuclear physics career

Author: Alfredo Estrade[None]

Nuclear physics is a fascinating discipline with clearly defined objectives: understanding the properties and behavior of atomic nuclei and their connection to the fundamental laws of physics and the nuclear processes that affect the evolution of the cosmos, and finding way to apply this knowledge to the benefit of society. As in other fields of science, the work required to achieve these goals requires a surprising breadth of tasks and skills, often distributed among members of research teams with specialized roles. Thus, the nuclear physics workforce includes a group of scientists with a diverse set of interests and expertise. There are many alternatives for those interested in a research career in nuclear physics, but navigating the various available career paths can be a daunting prospect since the formal coursework of a physics degree often does not cover aspects of the day-to-day life of a working physicist. In this presentation we will discuss strategies and alternatives to forge research career paths in nuclear physics and related fields of science.

Chemical Evolution and SNR / 39

Chemical Evolution of Galaxies in the Local Group

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Chemical Evolution and SNR / 13

Molecule formation in core-collapse supernova ejecta: the impact of effective matter mixing based on 3D hydrodynamical models of SN 1987A

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It is considered that molecules and dust are formed in the ejecta of core-collapse supernovae (CCSNe); how molecules are formed in CCSN ejecta, however, has not been elucidated yet. SN 1987A found at Large Magellanic Cloud entered a phase of a young supernova remnant more than 30 years after the discovery. Recent ALMA observations (Abellán et al. 2017) have, actually, revealed 3D distributions of carbon monoxide (CO) and silicon monoxide (SiO), which are rather non-spherical and lumpy. The distribution of seed atoms in CCSN ejecta, which is affected by matter mixing before the molecule formation, may play a role in the formation of molecules. Hence, to investigate the impact of matter mixing on the formation of molecules in the CCSN ejecta, time-dependent rate equations for chemical reactions are solved (arXiv:2305.02550) for one-zone and one-dimensional ejecta models of SN 1987A based on three-dimensional hydrodynamical models (Ono et al. 2020). It is found that the mixing of ^{56}Ni could play a non-negligible role in both the formation and destruction of molecules, in particular CO and SiO, through several reaction sequences. Some of the results and how ^{56}Ni, practically ^{56}Co, affects the formation and destruction of molecules are presented.

Multi-Messenger Astronomy and Astrophysics / 40

Heavy Element Nucleosynthesis in the Multi-Messenger Era

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Neutron star mergers (NSMs) have been confirmed as one of the production sites of the heaviest elements. Studying post-NSM signals in the electromagnetic spectrum is invaluable for understanding

the production of these elements, especially with the LIGO Scientific Collaboration having begun its next observing run. However, with the current low detection rates of post-merger light curves, we invoke a different kind of resource for observational data: metal-poor stars. Long after merger, metal-poor stars can host in their spectra signatures of the historical events that produced the heavy elements, which can in turn be used as additional sources to study ancient NSM sites. This talk will discuss the overlap between observations of metal-poor stars and NSM signals and how their joint study can help constrain the cosmic evolution of the elements and the fundamental nature of dense matter.

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Long term simulation of supernovae for multi-messenger astronomy

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A star more than eight times the mass of the sun undergoes a massive explosion called a supernova at the end of its life. Supernova explosions, including the emission of neutrinos, gravitational waves, and beyond SM particles, are ideal targets for multi-messenger astronomy. One issue in the study of supernova explosions is that research has mainly focused on the first second of the explosion. Based on observations of SN 1987A, it is known that neutrinos with durations of over 10 seconds are detected when a supernova explosion occurs in the Milky Way. Therefore, it is not possible to compare theory and observation in the next case of a supernova explosion within our galaxy. In the presentation, the calculation of supernova explosions for future galactic events in the context of multi-messenger astronomy is reported, including the calculation of neutrinos from multiple progenitors and the estimation of gravitational wave frequencies based on neutron star asteroseismology.

Light Nuclei / 55

Studying the nucleosynthesis in explosive stellar environments

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Understanding the nucleosynthesis processes in various astrophysical scenarios such as x-ray bursts and supernovae involve the study of numerous capture reactions. A Type-I x-ray burst (XRB) is an explosion in a binary system of an accreting neutron star and a companion star. The dominant (p, γ) nucleosynthesis flow in XRBs is halted at several waiting point nuclei such as ^{22}Mg, $^{24-26}$Si, $^{28-30}$S and ^{34}Ar due to (p, γ)-(γ, p) equilibrium. It has been suggested that the flow can be bypassed by alpha-capture reactions on these waiting point nuclei (αp-process). However, the present uncertainties in the relevant alpha-capture reaction rates at these waiting points hinder the ability to accurately predict the light curve and ash composition of XRBs. Core-collapse supernovae (CCSNe) occur when massive stars exhaust their core fuel, resulting in the gravitational collapse of the iron core leading to an outward shock wave that results in one of the strongest explosions in the universe, ejecting a variety of chemical elements into the interstellar medium. Properties of CCSNe can be obtained by studying the signatures from prominent remnants such as ^{44}Ti and ^{56}Ni, of which the observed abundances are affected by proton, alpha and neutron captures.

A large number of nuclear reactions affect the nucleosynthesis in these two environments, and precise knowledge of these nuclear reaction rates are needed to constrain astrophysical models to better understand the underlying explosion mechanisms. Constraining many of these reaction rates using direct techniques is experimentally difficult due to low reaction cross sections and the need for sufficiently intense radioactive beams. Sensitivity studies that have been performed for these two astrophysical scenarios, as well as several experimental techniques currently utilized to constrain a few of these reaction rates affecting the nucleosynthesis in XRB and CCSNe environments will be presented.

Light Nuclei / **25**

Cross section evaluation of the dependence of the mean field model on antisymmetrized molecular dynamics

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^{12}C-induced reactions at MeV order energy are of great importance not only in astronomical contexts but also in applications such as cancer treatment, thanks to recent advances in accelerator technology. However, there is no established standard calculation method for reactions involving heavy ions with higher mass numbers than alpha particles. Various computational codes employ a wide range of models.
Antisymmetrized molecular dynamics (AMD) is a valuable model for this study because it not only allows for fragment formation but also incorporates mean-field effects and the effects of NN collisions. In particular, AMD can effectively reproduce fragment production in collisions of stable nuclei.
In this research, we use the ^{12}C+^{27}Al and ^{12}C+^{16}O reactions as examples to assess the differences in particle production predictions among different mean-field models by comparing them with experimental data through reaction cross-sections.

Light Nuclei / **32**

Unraveling the role of carbon-alpha reaction rate for radioactive nickel synthesis in pair-instability supernovae

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Pair-instability supernovae (PISNe) are phenomena that are the final fates of very massive stars with an initial mass ranging from 140 to 260 $M_{\odot}$. Unlike other supernovae, PISNe do not leave behind compact objects. Stellar evolution theory predicts that there is a gap in the distribution of black hole masses due to PISNe. Recent works suggested that the location of this gap may be influenced by the uncertainty in the $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ reaction rate. In our study, we investigate how the $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ reaction rate affects PISNe profiles, particularly in terms of nucleosynthesis and

explosion energy. We find a correlation between the $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ reaction rate and the amount of radioactive $^{56}\mathrm{Ni}$, which determines the peak luminosity of supernovae. This correlation is attributed to the intensity of burning during the carbon burning phase, which changes the structure of the star. In this presentation, I will provide a detailed report of our findings.

Poster Session / 29

Feasibility studies to detect r-process nuclear emissions from the binary-neutron-star merger remnants with the HEX-P satellite

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The r-process nucleosynthesis site in the Universe is one of the important astrophysical questions. The r-process site should be a neutron-rich environment, and the binary neutron-star mergers (NSMs) are considered to be the most promising site. Nuclear gamma rays through the decay of unstable nuclei will provide direct evidence of r-process synthesis. However, the gamma-ray radiation is extremely weak (Hotokezaka et al., 2016), and the sensitivity of the near future MeV missions is limited to detect gamma-rays from NSMs at Mpc distances or NSM remnants in our Galaxy (Terada et al., 2022).

In this study, we focus on the hard X-ray band, which enables us to detect K X-rays emitted through the decay chain of r-process nuclei. Here, we performed the feasibility study to detect NSMs with the next-generation US-lead hard-X-ray mission, HEX-P. The mission is proposed to have the large effective area (4400 cm^2) in the soft to hard X-ray bands (2-200 keV). As demonstrated in Terada et al. (2022), the NSM is expected to have a unique spectral shape compared with other high-energy sources. Therefore, we examined the slope of the energy spectra simulated for NSMs in the 2-200 keV band. Accordingly, we performed an observation simulation with the exposure of 1 Ms to investigate the ratio of (25-70 keV)/(2-25 keV) and (70-200 keV)/(25-70 keV) fluxes. We used the same nuclear model in Terada et al. (2022), but with X-ray irradiation data from the daughter nuclei of r-process nuclei. As a result, the NSM can be distinguished from other sources with at least 3σ significance for the age of up to 10^4 years within a distance of 100 pc. In this presentation, we will discuss the feasibility to detect nuclear gamma-rays lines with the HEX-P for gamma-ray diagnostics in the neutron environment.

Poster Session / 28

Search for r-process nuclear gamma-rays from binary neutron-star merger remnants with the gamma-ray satellite INTEGRAL/SPI

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One of the most promising candidates in the universe for the r-process r-process, which is the only sites that can provide elements heavier than ^{209}Bi are the binary neutron-star mergers (NSMs).The post-merger remnant becomes optically thin in a few weeks to months, and gamma-rays from the decay of r-process elements are observable in the MeV energy band. The presence of r-process nuclei in NSMs was already shown by the infrared observation of the first NSM gravitational event GW170817 (e.g.,Kasen et al.2017;Roswog et al.2018;Domoto et al.2022), and such MeV gamma-rays are expected carry more direct information on the r-process nuclei especially for Lanthanoids.In fact,however ,nuclear gamma-rays from NSMs are so dim that they are below sensitivity in the MeV missions. (Hotokezaka et al. 2016).
According to numerical estimation of gamma-rays from NSMs (Terada et al 2022), they have unique gamma-ray spectra compared with other high energy objects and thus the spectral shape can be used to identify NSMs.Numerically, Terada et al.(2022) provides a new method to identify of NSMs using color-color diagram both in the hard Xray (10-500 keV) and gamma-ray (70-3000 keV) bands. In this study, we searched for NSM remnants at the galactic center region ($-15° < l < 15°$,$-20° < b < 20°$).The search was conducted using archived data from the INTEGRAL/SPI gamma-ray observatory, which currently has the best sensitivity in the MeV energy band. Adopting the method described above, we searched for NSMs using the color-color diagram using the five energy bands; 10-25 keV,25-70 keV, 70-500 keV, 500-1000 keV, and 1000-3000 keV, including the hard X-ray bands. As a result, one and seven candidates of NSM remnants are identified in the hard X-ray and gamma-ray bands,respectively. In this presentation, we will present a detailed analysis of the candidate sources and discuss their validity as NSM remnant candidates.

Poster Session / 18

Direct measurement of the cross section for 102Pd(p,g)103Ag reaction in the p-process

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The study of the p-process is of paramount importance in unraveling the origin of heavy elements in the universe. To describe the entire p-nuclei nucleosynthesis process, a comprehensive reaction network involving over ten thousand nuclear reactions is required, and accurate measurements of some key reaction cross sections are essential for determining reaction rates. 102Pd is one of the more than 30 p-nuclei, and the 102Pd(p,g)103Ag reaction is one of its significant destruction reactions. Experimental studies for the p-nucleus 102Pd indicate that the reaction rate for 102Pd(p,g)103Ag is significantly higher than HF predictions. There are significant discrepancies in the available data on the 102Pd(p,g)103Ag reaction cross section in the low-energy regime relevant to nuclear astrophysics. In light of these discrepancies, a direct measurement was carried out to determine the reaction cross section of 102Pd(p,g)103Ag within the energy range of 1.9-2.8 MeV. The measurement was conducted utilizing the 2*1.7 MV tandem accelerator at China Institute of Atomic Energy (CIAE). The latest cross section data were obtained using offline activation measurement technique based on the low background anti-muon and anti-Compton spectrometer in CIAE.
The latest results have extended the cross section of 102Pd(p,g)103Ag to the lowest energy range of proton down to 1.9 MeV. The newly measured cross section data provide valuable experimental references for the calculation of statistical models, particularly in the low-energy regime of interest in nuclear astrophysics. These results contribute to a better understanding of the p-process and its implications for the nucleosynthesis of heavy elements in the universe.

Poster Session / 21

Direct measurement of the ^{26}Si(α, p)^{29}P reaction for the nucleosynthesis in the X-ray bursts

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In the X-ray bursts, the αp-process, that consists of alternating (α, p) and (p, γ) reactions, is considered to have a great impact on the light curve. However, most of the important reactions have not been understood experimentally because of technical difficulties. The ^{26}Si(α, p)^{29}P reaction rate is one of the αp-process reactions and it is considered that the reaction rate has high sensitivity to the X-ray burst light curve. Therefore, a direct measurement of the reaction was performed at the CNS RI beam separator (CRIB). CRIB produced a ^{26}Si beam with a typical intensity of 3.2×10^4 pps and a purity of 29%, which bombarded the ^{4}He gas target. We measured the reaction particles using five telescopes consisting of three and four silicon detectors. The ^{26}Si(α, p)^{29}P reaction was measured up to the center-of-mass energy of about 7.5 MeV, corresponding to about 3 GK of Gamow energy, using the thick gas target method. Because of insufficient statistics, the statistical error became large but an upper limit on the cross section was obtained, which was 0.134 times that of the NON-SMOKER statistical model. The results are useful for comparing experimental and theoretical values at higher temperatures and for constraining the ^{26}Si(α, p)^{29}P reaction rate.
The analysis method and the results will be discussed.

Poster Session / 20

Direct measurement of astrophysical S(E) for the 9Be(p,a)6Li and 9Be(p,d)8Be reactions at low energy

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The p-9Be reactions play a key role in accurate prediction of primordial abundance of beryllium, and its abundance can be used to exquisitely probe the nucleosynthesis and mixing mechanism of stars. In the present work, astrophysical S(E) factors of the 9Be(p,d)8Be and 9Be(p,α)6Li reactions have been obtained from thick-target yield Yield(Ei) for proton energies from 18 to 100 keV. A full Rmatrix analysis was performed to fit both the 9Be(p,d)8Be and 9Be(p,α)6Li reactions, simultaneously. The resulting astrophysical S(E) factors agree well with direct measurements, leading to S(0) = 17.3 ± 2.1 and 13.9 ± 1.8 MeV·b for the 9Be(p,d)8Be and 9Be(p,α)6Li reactions, respectively. The reaction

rates were also calculated in the temperature range from 0.01 to 1 T9, which improve the precision of standard database NACRE and NACRE II.

Poster Session / **16**

High-dispersion spectroscopic observations of r-process elements including thorium in solar metallicity and mildly-metal-poor stars

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The origin of the r-process was unknown for many years, but in 2017, neutron-star merger (NSM) was observed by gravitational waves (Abbott et al., 2017). The NSM is found to be the origin of the r-process by photometric and spectroscopic observation. However, NSM alone is unable to explain the origin of the r-process. For example, investigation of stellar abundances has found stars with high [Th/Eu] value (Actinide-Boost stars), but the origin of Actinide-Boost stars is unclear. The existence of such stars suggests that the r-process has more than one origin (Holmbeck et al., 2018, Yong et al., 2021). Although it is important to determine the Th abundance in many stars to clarify the origin of the r-process, there have been few observations of Th in [Fe/H] > -1.5 (Mishenina et al., 2022). Therefore, we observed such stars with Nayuta/MALLS and obtained Subaru/HDS archive data. We obtained a number of r-process abundances including Th, over ten objects in [Fe/H] > -1.5. As a result, the value of [Th/Eu] is constant and independent of the metallicity, there is no Actinide-boost stars in [Fe/H] > -1.5. These results are important to clarify the origin of Actinide-boost stars. Identifying the origins of Actinide-boost stars is to investigate the origins of the r-process.

Poster Session / **12**

Follow-up of bright very metal-poor star candidates discovered by narrow-band survey

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Chemical abundance of metal-poor stars is a clue to understand the chemical evolution of the early Universe. However, the metal-poor stars discovered by previous surveys are faint and it is difficult to measure their abundance of many elements with high precision. Therefore, we performed a photometric survey using the wide-field CMOS camera (Tomo-e Gozen Camera) on the Kiso Schmidt telescope with narrow-band filters sensitive to stellar metallicity to search for bright metal-poor stars. Very metal-poor star candidates with [Fe/H] < -2 were selected for follow-up medium-resolution spectroscopy with the Nayuta telescope. We establish a method for analyzing medium-dispersion spectra using 43 stars with metallicity measurements and determine the metallicity and abundance of alpha-elements of ~300 metal-poor star candidates that we have followed up so far. As a result,

nine new very metal-poor stars and two low-alpha stars were discovered. In this talk, we present the results of the follow-up and the metal-poor star candidate selection methods.

Poster Session / 30

Understanding nucleosynthesis by Gamma-Ray and AntiMatter Survey (GRAMS)

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The r-process plays a crucial role in understanding the origin of heavy elements. The gravitational wave event GW170817, resulting from a neutron star (NS) merger, is believed to be the source of heavy elements through the r-process (Tanaka et al., 2017). However, direct evidence for the r-process has not been observed yet, which enables us to make a quantitative study of nucleosynthesis, such as the fraction of each element. Although nuclear gamma rays from r-process elements are the ideal tool, the present sensitivity of MeV gamma-ray observations is quite limited for such a purpose. Gamma-Ray and AntiMatter Survey (GRAMS) is a Japan-US mission for next-generation MeV gamma-ray observation with an enhanced effective area by two orders of magnitude compared to the previous MeV gamma-ray observatory, COMPTEL (Aramaki et al., 2020). Our plan includes a science Pathfinder flight in a few years and a balloon-borne observation in the 2030s, and we finally aim for a satellite mission in the late 2030s. The energy and orientation of the MeV gamma-ray are estimated from the scintillation light and the ionized electron produced by Compton scattering with argon atoms in the detector. The use of liquid argon will enable us to easily increase the effective area of the detector, and the detector will provide all-sky monitoring. Therefore, GRAMS is suitable to obtain direct evidence of the r-process in NS merger.
Now the GRAMS project is in the concept verification stage. A compact detector (about 5 cm $\times$ 5 cm $\times$ 10 cm) is being developed at Osaka University, with functional testing slated to commence this year. Simultaneously, a simplified detector will be launched on a balloon this summer to investigate the safe handling of liquid argon in a balloon-borne setting and assess detector performance. In this presentation, we will introduce the power and status of the GRAMS project.

Poster Session / 31

Cryogenic hydrogen gas target for a measurement of neutron inelastic scattering in ^{12}C

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The triple alpha process is an essential reaction in nucleosynthesis. In a hot and dense environment, the reaction rate can be enhanced by neutron upscattering process. In that process, the Hoyle state in ^{12}C decays into the bound states by giving the excitation energy to neutrons instead of radiation decay. We plan to measure a cross section of the inverse reaction in order to determine the

enhancement factor. For the measurement, we developed a cryogenic hydrogen gas target to produce a high-intensity monoenergetic neutron beam. The hydrogen gas is cooled to below 77 K by a GM refrigerator and approximately 10 MeV neutron beam is produced by $^{1}\mathrm{H}(^{13}\mathrm{C},\mathrm{n})^{13}\mathrm{N}$ reaction at $E_{^{13}C} = 72.7$ MeV. We performed a thermal test of the cryogenic target with heaters to simulate the primary beam energy loss. In addition, we also conduct a performance test of the target using an actual beam. I will report the development of the gas target and results of two performance tests.

Poster Session / 51

CHARGE-EXCHANGE REACTIONS IN CONJUNCTION WITH THE OSLO METHOD

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Charge-Exchange (CE) reactions are an important tool for studying the spin-isopin response of nuclei. They can be utilized to obtain information about interactions mediated by the weak nuclear force, such as β and electron capture decay. Using the proportionality between Gamow-Teller strength (B(GT)) and the CE differential cross section, B(GT) strength distributions can be extracted indirectly. Since CE reactions are not limited to a narrow Q value window, they provide information that is complementary to information obtained from β and electron capture decay. Such data are necessary for constraining reaction rates that happen in dense and hot astrophysical environments. In the near future, it is planned to combine measurements in which GT strengths are extracted with g decay measurements. One of the goals is to use the Oslo method to extract level densities and g-ray strength functions, which are also important for constraining astrophysical reaction rates.

Poster Session / 52

An Update on the Commissioning of SECAR

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The Separator for Capture Reactions (SECAR) located in Reaccelerator Hall 3 (ReA3) at the Facility for Rare Isotope Beams (FRIB) is a recoil separator designed to study the direct reaction rates of capture reactions in inverse kinematics. Such reactions are crucial to the understanding of many stellar phenomena such as type I X-ray bursts and supernovae. This poster presentation will be an update on the commissioning of SECAR and will provide an overview of the detection apparti along the beam line, focusing on the BGO Array, and the alignment procedure of the isotope beam. Additionally, I will show some results from experiments with stable beams and outline the future developments and plans for SECAR.

Poster Session / 60

Measurement of the gamma Decay Probability of the Hoyle State

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Measurement of neutron inelastic scattering of the Hoyle state to estimate the triple-alpha reaction rate in high-density environments

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Poster Session / 64

Supernova Nucleosynthesis: Radioactive Nuclear Reactions and Neutrino-Mass Hierarchy

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Poster Session / 65

Developing ”1D+” simulation of Core-collapse supernovae

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Open Poster Session

Core-Collapse Supernova Explosions / 44

Neutrino physics in massive star evolution and core collapse supernova

Author: Chinami Kato[None]

Core-Collapse Supernova Explosions / 7

Progenitor dependence of neutrino-driven supernova explosions with the aid of heavy axion-like particles

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Core-collapse supernova is an explosion event of a dying massive star at the end of its lifetime. The explosion mechanism has not been well-understood due to large numerical and physical complexity. Now that KAGRA project and Hyper-Kamiokande project are launched in Japan, we need to construct a precise supernova model to capture all possible astrophysical information from a nearby supernova in the future. In this work, we have conducted spherically symmetric core-collapse supernova simulations with the aid of heavy axion-like particles (ALPs), which possibly interact with photons and deposit energy behind a shock wave. As a result, we found that two of the ALP parameters, ALP mass and ALP-photon coupling constant, have the following relationships with the shock wave. First, heavy ALPs with high coupling constant are favorable for the shock wave to expand. However, when ALP mass exceeds a certain value (for example, m_a=600 MeV in the case of 20M_sun star), ALP emission rate decreases and the shock wave is less likely to turn into an expansion. This is because the temperature achieved inside the supernova core is not high enough to produce heavy ALPs sufficiently. In general, the maximum temperature depends on the progenitor structure. We have demonstrated such simulations for three progenitors and found that the ALP assist of explosion is effective in massive progenitors even in the case of heavy ALPs with m_a>600 MeV.

Core-Collapse Supernova Explosions / 6

Core-collapse supernovae: 3D MHD simulations and multi-messenger signals

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Systematic studies of core-collapse supernovae have been conducted based on hundreds of one-dimensional artificial models (O'Connor & Ott 2011,2013; Ugliano et al. 2013, Ertl et al. 2015) and two-dimensional self-consistent simulations (Nakamura et al. 2015;2019, Burrows & Vartanyan 2020). We have performed three-dimensional core-collapse simulations for 16 progenitor models covering ZAMS mass between 9 and 24 solar masses. Our models show a wide variety of shock evolution and explosion energy, as well as multi-messenger signals including neutrinos and gravitational waves. We present the dependence of these explosion properties on the progenitor structure.

High Energy Astrophysics / 22

Nuclear reactions related to very high and ultra-high energy cosmic rays

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The composition of very high-energy (VHE) and ultra-high energy (UHE) cosmic rays (CRs) was recently measured with higher statistics than before. The results implied that the composition of VHECRs becomes heavier up to $\sim 10^{17.2}$ eV and lighter above the energy, and the composition of UHECRs becomes lighter up to $\sim 10^{18.3}$ eV and heavier above the energy. The experimental evidence induces motivation to study the nuclear reactions of cosmic ray nuclei at the cosmic ray sources, in their propagation, and in the atmosphere of Earth. In this presentation, I will begin with an overview of the observations of very high and ultra-high energy cosmic rays and the nuclear reactions. After that, I will talk about our recent activities related to this topic.

High Energy Astrophysics / 14

Revealing the journey of cosmic rays with petaelectronvolt energies through the observation of sub-PeV gamma rays by the upcoming experiment ALPACA

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The ALPACA experiment is an international project between Bolivia, Mexico, and Japan, the prototype of which started data-taking in Bolivia in September 2022. One of the motivations of the experiment is to explore the southern sky in the sub-PeV (E > 10^14 eV) gamma-ray sky to locate astrophysical accelerators of Galactic cosmic rays in the PeV (E > 10^15 eV) range, so-called PeVatrons. The experiment has two types of detectors: a surface air shower array consisting of scintillation detectors which reconstruct the energies and directions of gamma rays by observing extensive air showers, and an underground water-Cherenkov-type muon detector array which effectively discriminates between gamma rays and background cosmic rays. In addition to the principal motivation of the PeVatron search, transient gamma-ray sources such as gamma-ray bursts (GRBs) should be interesting targets to be observed by the experiment taking advantage of its wide field of view and high duty cycle. Gamma rays of several hundreds of GeV to multi-TeV energies can be detected by densely arranging the scintillation detectors covering the surface over several thousand square meters above one of the muon detectors. The lower-energy extension of observation would help improve our understanding of prompt and afterglow emission from GRBs, some of which could be closely related to the merger of neutron stars synthesizing heavy elements through the r-process. The presentation gives a design of such a dense air shower array, which should be called the ALPACA high-density array, and a simulation-based study of its performance for GRBs.

Poster Session / 4

Machine Learning Refinements to Metallicity-Dependent Isotopic Abundances

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The project aims to use machine learning algorithms to fit the free parameters of an isotopic scaling model to elemental observations. The processes considered are massive star nucleosynthesis, Type Ia SNe, the s-process, the r-process, and p-isotope production. The analysis on the successful fits seeks to minimize the reduced chi squared between the model and the data. Based upon the successful refinement of the isotopic parameterized scaling model, a table providing the 287 stable isotopic abundances as a function of metallicity, separated into astrophysical processes, is useful for identifying the chemical history of them. The table provides a complete averaged chemical history for the Galaxy, subject to the underlying model constraints.

Poster Session / 62

GENSOGAKUSHO×GENSOGOUSEI: Illustrations of nucleosynthesis by personification characters

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