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Search for Supernova 60Fe in Biologically Produced Magnetofossils: A New Discovery

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Between 2 and 3 Myr before the present, the Earth was subjected to the debris of a supernova explosion. First evidence for this was the presence of a concentration spike of live atoms of 60Fe in a Pacific ocean ferromanganese crust. This signal was found using accelerator mass spectrometry (AMS). The known cosmic site for the production of 60Fe is core collapse supernova. Subsequent searches in marine sediments for this signal failed.
We now report on a new detection of live 60Fe found in a new terrestrial reservoir; namely, biogenically produced magnetite crystals, that are now fossilized -- so-called magnetofossils. The occurance in the geological record is ~2.5 Myr before the present. This contribution will explain the motivation to search in magnetofossils for this signature, and show our preliminary results of the 60Fe signal.

Experimental studies of charged-particle induced reactions for nucleosynthesis of p nuclei

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The p nuclei are to a large extent produced by photodisintegration reaction on s- and r- process seeds within the so-called gamma process [1]. Most of the reaction rates within this huge network are calculated using the Hauser-Feshbach statistical model. Major uncertainties entering these calculations stem from the nuclear physics ingredients, such as optical-model potentials, gamma-strength functions, and nuclear level densities. Measured cross sections of charged-particle induced reactions can in some cases be used to directly calculate the stellar reaction rate. Otherwise, a determination of cross sections can be used to indirectly improve the description of the aforementioned input parameters which, in turn, allows a more reliable prediction of the stellar reaction rate.

Cross sections of the reaction 141Pr(alpha,n) have been measured by the activation method using the gamma-gamma-coincidence technique close to the astrophysically relevant energy range [2]. Therefore, this reaction allowed to study the validity of alpha+nucleus optical-model potentials at low energies. A local potential was constructed in order to improve the description of the experimental data. Additionally, experimental results of alpha-induced reactions on the p nucleus 168Yb, i.e. 168Yb(alpha,n) and 168Yb(alpha,gamma), are presented which were also measured using the activation method. The reaction 168(alpha,gamma)172Hf is of direct astrophysical importance, since a branching point in the gamma-process flow is predicted to be located at 172Hf [3].

The in-beam technique with high-resolution HPGe detectors was used to measure cross sections of the reaction 74Ge(p,gamma) [4]. The measured energy range significantly overlaps with the astrophysically relevant energy range, where the cross section is dominantly sensitive to the proton+nucleus optical-model potential and thus allows an improvement . The astrophysical conclusions which can be drawn from this measurement are important to understand the production route to the lightest p nucleus 74Se.

Recently, a dedicated setup for in-beam measurements relevant for nuclear astrophysics was developed at the Institute for Nuclear Physics in Cologne. A first measurement was performed on the reaction 89Y(p,gamma) of which preliminary results are presented. For this measurement, the high-efficiency HPGe detector array HORUS, which consists of up to 14 HPGe detectors, partially equipped with active BGO shielding, was used. This measurement embodies effectively the first measurement relevant for nuclear astrophysics using this setup.

[1] M. Rayet et al., Astron. Astrophys. 298, 517 (1995).
[2] A. Sauerwein et al., Phys. Rev. C 84, 045808 (2011).
[3] T. Rauscher, Phys. Rev. C 73, 015804 (2006).
[4] A. Sauerwein et al., Phys. Rev. C 86, 035802 (2012).

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Activation measurement of the 187Re(?,n) reaction at the Cologne Clover counting-setup

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The reaction network of thep-process includes about 20000 reactions on 2000 nuclei. Since not all of them are accessable by experimental studies, theoretical predictions of reaction rates,e.g., through Hauser-Feshbach calculations, are inevitable.
The accuracy of these predictions is mainly based on nuclear-physics input like ?-strength functions, nuclear-level densities and optical-model potentials.
But experimental data for ?-induced reactions at low energies are rare, especially for heavy nuclei in mass regions above A ? 160. In particular, the construction of a global ? optical potential is difficult. In order to improve theoretical predictions experimental data is essential. Thus, an activation measurement of the 187Re(?,n) reaction was recently performed.
The activated targets were counted offline with two clover detectors in a very close face-to-face geometry. Each of the detectors provide a relative efficiency of 100 % in comparison to a standard NaI. Additionally, the granularity of the clovers facilitates an analysation with the so called ??-coincidence method [1].
The offline counting setup at the Institute for Nuclear Physics in Cologne as well as experimental results are presented.
Supported under the DFG contracts (ZI 510/5-1, INST 216/544-1). P.S, J.M. and A.S. are member of the Bonn-Cologne Graduate School of Physics and Astronomy.

[1] A. Sauerweinet al., Phys. Rev. C 84, 045808 (2011)

In-beam Experiments for Nuclear Astrophysics at HORUS

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The p process involves a large network consisting of about 20000 reactions on approximately 2000 nuclei. As only few experimental data are available, network calculations are based almost completely on reaction rates predicted by theoretical models. Accurate predictions depend on nuclear physics input, e.g., optical-model potentials.
In-beam experiments aim at reactions resulting in stable as well as unstable nuclei which are mostly not accessible in activation measurements and, therefore, provide an important method to improve theoretical models. Additional information, e.g. partial cross sections, can also be obtained.
Located at the 10 MV Van de Graaf tandem accelerator of the University of Cologne, the high-efficiency HORUS Gamma-ray spectrometer provides excellent opportunities to improve the experimental situation on charged particle induced reactions relevant for the p process. The experimental setup features a reaction chamber equipped with multiple current readouts, a cooling trap, and a detector for Rutherford-Backscattering Spectrometry.
In this talk, the spectrometer and first results of recently performed experiments are presented.

Cross section measurements for the p-process

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An accurate description of the nucleosynthesis of heavy, neutron-deficient stable isotopes known as p-nuclei remains a mystery. The current best models describing the production of the p-nuclei via the p-process, which consists of photodisintegrations of existing heavier seed nuclei, fail to explain the observed abundances of all the p-nuclei. As these models rely heavily on theoretical reaction rates, it is necessary to develop new experimental techniques to measure p-process reactions in an effort to constrain and verify the theory. The Summing NaI(Tl) (SuN) detector has recently been developed at Michigan State University to measure (p,g) and (a,g) reactions relevant to p-process nucleosynthesis utilizing the summing technique. Reaction cross sections at astrophysically relevant energies resulting from a successful experimental campaign at the University of Notre Dame will be presented and compared with theoretical calculations.

Light elements depletion in view of the recent THM measurements: focus on the lithium problem

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Light elements lithium, beryllium and boron (LiBeB) constitute an unique benchmark for understanding
stellar structure and mixing phenomena, being they gradually destroyed at different depths of the stellar interior mainly via (p,) reactions induced at temperature of 106K. For such a reason several experiment have been performed in the last years by using the Trojan Horse Method (THM), an indirect
experimental technique particularly suitable for measuring the S(E)-factor overcoming the extrapolation
procedures typical of direct measurements. Here, in view of the recent measurements, the 6;7Li and
11B burning S(E)-factor and the corresponding Ue values will be discussed by applying the THM to the
corresponding quasi-free reactions. Astrophysical implications will be also discussed.

nuclear fission in r-process nucleosynthesis

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Half of heavy elements are considered to be produced by the rapid neutron-capture process, which is called the r-process. It is still unknown where the r-process occurs although core collapse supernovae, neutron star mergers, and gamma-ray bursts are proposed to be viable candidate sites for the r-process. One of the reasons is that explosive conditions of these astrophysical sites are poorly understood despite recent progress in numerical simulations for the lack of precise observational data. Another reason is that we need many unknown nuclear data on extremely neutron-rich unstable nuclei, such as nuclear masses, beta half-lives, neutron-capture cross sections, nuclear fission modes, etc., for the theoretical calculations of r-process nucleosynthesis. These nuclear input data are still far to reach in laboratory experiments. Theoretical calculations of the r-process nucleosynthesis therefore are largely subject to nuclear physics uncertainties.
In this talk, I would like to discuss the effects of nuclear fission of very neutron-rich actinide elements on the r-process nucleosynthesis [1]. The r-process path would eventually reach very neutron-rich actinides that are heavy enough to be fissile and the nuclear fission affects the final abundance pattern of the r-process elements. Nuclear fission is expected to account for smoothed abundance pattern along with the universality of the r-process elements discovered among metal-deficient halo stars and the solar system. Our model of nuclear fission is based on phenomenological theoretical studies of the formation of super-heavy elements [2] where both fusion and fission modes are theoretically calculated in Langevin equation of motion for predicting realistic fission fragment distributions.
We carry out r-process nucleosynthesis for various candidate sites of the core collapse supernovae (both neutrino-driven winds and magneto-hydrodynamic jets), the neutron star mergers, and the gamma-ray bursts with realistic fission fragment distributions. We investigate how strongly the fission affects the final r-process yields depending on the environmental conditions of these astrophysical sites. We also discuss physical conditions for the operation of fission cycles in order to clarify how they work for smoothing the abundance pattern and satisfy the universality.

[1] S. Shibagaki, T. Kajino, K. Nakamura, S. Nishimura, M. Famiano, G. J. Mathews, T. Tachibana, H. Koura and S. Chiba, in preparation for submittal to ApJ (2013).
[2] S. Chiba, H. Koura, T. Tachibana, Y. Aritomo and M. Ohta, in preparation (2013).

Probing stellar evolution with the surface abundance patterns of stars in globular clusters

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The chemical composition of the stellar atmosphere is not a perfect reflection of the gas cloud in which the star was born. Already on the main sequence can subtle diffusion effects slowly alter the surface composition of elements, while the later giant phases exhibit the effects of dredge-up processes. In a metal-poor globular cluster, our best proxy for an old, single stellar population, these effects can be directly traced by comparing stars in different evolutionary phases. In addition to verifying the predictions from standard stellar evolution theory, this can give us important clues on yet unknown physical processes in the stellar interior. The light and fragile element Li is extra sensitive to internal mixing event and can shed light even on problems of cosmological nature.

Europium abundances in the Milky Way thick disk and stellar halos

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In the solar-system material, more than 90% of europium (Eu) is considered to be synthesized in the rapid neutron-capture process (r-process). Consequently, europium is one of the key elements, which gives us clues to unveil the astrophysical sites of the r-process as well as the chemical evolution of neutron-capture elements in the Milky Way (MW) Galaxy.
We studied abundances of elements including europium in 97 nearby metal-poor stars belonging to the MW thick disk, inner and outer stellar halo components. The high-resolution spectra taken with the High Dispersion Spectrograph (HDS) mounted on the Subaru Telescope were used to estimate the chemical abundances of the sample stars under the assumption of the Local Thermodynamic Equilibrium (LTE). We show that, in the sample stars with metallicity ([Fe/H]= logX_Fe ? logX_Fe, sun, where X_Fe=N_Fe/N_H) above about -1.5, relative abundance ratios of the alpha-elements (Mg and Si) and the europium in the inner and outer halo subsamples show different trends with [Fe/H] from those seen in the thick disk subsample. We present highlight results of our data and the possible implications to the origin and evolution of the r-process elements in our Galaxy

Stellar electron-capture rates on nuclei based on a microscopic Skyrme functional

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Weak interaction processes play a pivotal role in the life of a star, especially during the late stages of the evolution of massive stars. In particular, during the supernova core-collapse, electron capture on free protons and on exotic nuclei controls the neutronization phase, until the formation of an almost deleptonized central compact object, the neutron star.
In this work, electron-capture rates on nuclei for stellar conditions are calculated for ^{54,56}Fe and Ge isotopes, using a self-consistent microscopic approach. The single-nucleon basis and the occupation factors in the target nucleus are calculated in the finite-temperature Skyrme Hartree-Fock model, and the charge-exchange transitions are determined in the finite-temperature random-phase approximation (RPA). The scheme is self-consistent, i.e. both the Hartree-Fock and the RPA equations are based on the same Skyrme functional. Several Skyrme interactions are used in order to provide a theoretical uncertainty on the electron-capture rates for different astrophysical conditions.
The results of the calculations show that, comparing electron-capture rates obtained either with different Skyrme sets or with different available models, differences up to one-two orders of magnitude can arise.

Does proton ingestion lead to unusual neutron caputre nucleosynthesis?

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At low metallicity, low-mass stars behave very differently from their high-metallicity cousins. During episodes of intense helium burning (both core and shell flashes), convection can lead to protons being drawn down into hot, carbon-rich regions. These so-called 'proton ingestion episodes' are not well modelled by the current generation of stellar evolution codes, but we may appeal to hydrodynamic simulations to help improve the situation. The results of these simulations suggest that a substantial supply of carbon-13 (and hence a supply of neutrons) can readily be produced in these episodes. I will discuss how these episodes can affect the standard picture of s-process nucleosynthesis and whether proton ingestion episodes may explain the enhancements of both s- and r-process elements observed in a large fraction of the carbon-enhanced metal-poor stars.

Measurement of the -3 keV resonance in the 13C(?,n)16O reaction and its in?uence on the synthesis of A > 90 nuclei

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The 13C(?, n)16O reaction is the neutron source for the main component of the s-process, responsible of the production of most nuclei in the mass range 90

Surprising pairing pairing properties around the drip line and in the crust of neutron stars

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Based on a microscopic description of superfluidity in overflowing nuclear systems, it is shown that continuum coupling plays an important role in the suppression, the persistence and the reentrance of pairing. In such systems, the structure of the drip-line nucleus determines the suppression and the persistence of superfluidity. The reentrance of pairing with increasing temperature leads to additional critical temperatures between the normal and superfluid phases. Consequences for the crust of neutron stars will also be discussed.

Doppler Shift Attenuation Method: The new setup and the commissioning experiment at the Maier-Leibnitz-Laboratory

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Resonant (p, gamma) capture reaction rates are relevant for the production of intermediate mass elements in classical nova events. The resonant reaction rate is inversely proportional to the lifetime of the resonance state formed by the (p,gamma) reaction. Thus, if the rates cannot be determined in a direct measurement, lifetime measurements of those resonant states, in the Gamow window, provide an important constraint/ingredient for eventually determining these rates indirectly.
A new setup has been built to measure the lifetimes of excited states in nuclei in the range of fs up to a few ps. It is located at the Maier-Leibnitz-Laboratory in Garching, where a tandem accelerator with terminal voltages up to 13 MV provides heavy ion beams.
In the commissioning experiment in 2011, the first excited state in 31S has been observed, being populated via the 32S(3He,4He) reaction and its lifetime has been determined. The experimental method, data and the analysis will be presented and the result will be discussed.

Role Be7 in enhancement of formation of heavy elements

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Among the light particle group Li7 and Be7 have almost equal masses but their importance in formation of heavy ion chain is not same. Li7 is very stable and having long half life period with +ve reaction Q-values like Be7 but the later one nuclei has unstable shape which makes it so useful and important, even with very small half life period, in the process of heavy elements in the nucleosynthesis. Be7 has very igh affinity with Li6,7 and alpha particles. Few experimental result with analytical approach can be discussed in the talk

Neutron induced reactions and Trojan Horse Method

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Indirect methods in studying nuclear reactions of astrophysical interest received much attention over the last two decades. Among them, the Trojan Horse Method has been applied to study a number of reactions induced by charged particles relevant for Nuclear Astrophysics. The method allows to measure the reaction cross-section directly in the energy region of astrophysical interest avoiding the suppression effects due to the Coulomb and centrifugal barrier and the electron screening effect.
Quasi-free reactions can also be exploited to study processes induced by neutrons. This technique is particularly interesting when applied to reaction involving unstable short-lived nuclei. Such processes are very important in the nucleosynthesis of elements in the s- and r-processes scenarios and this technique can give hints for solving key questions in Nuclear Astrophysics, where direct measurements are practically non feasable.
Recent experimental results on neutron induced reactions studied by THM will be presented.

X-ray source variability study of the M 31 central field using Chandra HRC-I

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The central field of the Andromeda galaxy (M 31) has been monitored, using the Chandra HRC-I detector during the years 2006 to 2012 with the main aim to detect X-rays from optical novae. We present a systematic analysis of all X-ray sources found in the 41 nova monitoring observations, along with 23 M 31 central field HRC-I observations available from the Chandra data archive starting in December 1999.
Based on these observations, we studied the X-ray long-term variability of the source population and especially of X-ray binaries in M 31.
We created a catalogue of sources, detected in the 64 available observations, which add up to a total exposure of about 1 Ms. To study the variability, we developed a processing pipeline to derive long-term Chandra HRC-I light curves for each source over the 13 years of observations. In the merged images we also searched for extended X-ray sources.
We present a point-source catalogue, containing 318 X-ray sources with detailed long-term variability information. 28 of which are published for the first time. The spatial and temporal resolution of the catalogue allows us to classify 115 X-ray binary candidates showing high X-ray variability or even outbursts in addition to 14 globular cluster X-ray binary candidates showing no significant variability. The analysis may suggest, that outburst sources are less frequent in globular clusters than in the field of M 31. We detected 7 supernova remnants, one of which is a new candidate and in addition resolved the first X-rays from a known radio supernova remnant. Besides 33 known optical nova/X-ray source correlations, we also discovered one previously unknown super-soft X-ray outburst and several new nova candidates.
The catalogue contains a large sample of detailed long-term X-ray light curves in the M 31 central field, which helps to understand the X-ray population of our neighbouring spiral galaxy M 31.

Cross section measurements of capture reactions relevant to Nuclear Astrophysics

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The origin in the cosmos of the so-calledpnuclei is one of the most puzzling problems to be solved by any model of heavy-element nucleosynthesis. In order to contribute to a cross-section database relevant to the modelling of thepprocess and to obtain global input parameters for HF calculations, several cross sections measurements of capture reactions have been performed. Various aspects of the experiments performed so far, as well as plans for additional measurements, are presented.

TROJAN HORSE METHOD: A PRIMER WITH APPLICATION.

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The Trojan Horse Method has been developed in order to overcome some of the problems inherent in measurements of nuclear reactions of astrophysical interest.
The background of the method will be presented from a phenomenological point of view and some applications will be also shown.

The Origin of Zr Isotope Variations in the Early Solar System

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High precision isotope analyses on meteorites can be used to place constraints on early solar system evolution and stellar nucleosynthesis. Nucleosynthetic, isotope variations in Mo were reported for primitive and differentiated meteorites, relative to the Earth and Moon [1-3]. The observed isotopic pattern is consistent with different accretionary regions of the solar system that received variable amounts of s-process material, most likely from a low mass AGB star. The precise nature of s-process material, and the process(es) responsible for the heterogeneous distribution in our solar system requires further understanding.

Zirconium isotopes are ideal for addressing this issue as they are mainly neutron capture isotopes, on the first s-process peak. As such, they are synthesized in multiple s-process sources, including the main (low mass and intermediate mass AGB stars) and weak (massive stars) s-process. In this study, we compare Zr isotope data from [4] with updated stellar model predictions of the s-process [5] to further constrain the sources of the heterogeneously distributed s-process material. The bulk rock Zr data are consistent with an s-process component that encompasses contributions from multiple s-process production sites (stars). This excludes the possibility of the heterogeneous distribution of material from the injection of a single star into the solar system. As such, nebular processes - such as selective thermal processing of dust, or grain-size sorting - are considered a likely mechanism for the bulk heterogeneity.

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[4] Akram W. (2012) PhD Thesis, The University of Manchester.
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