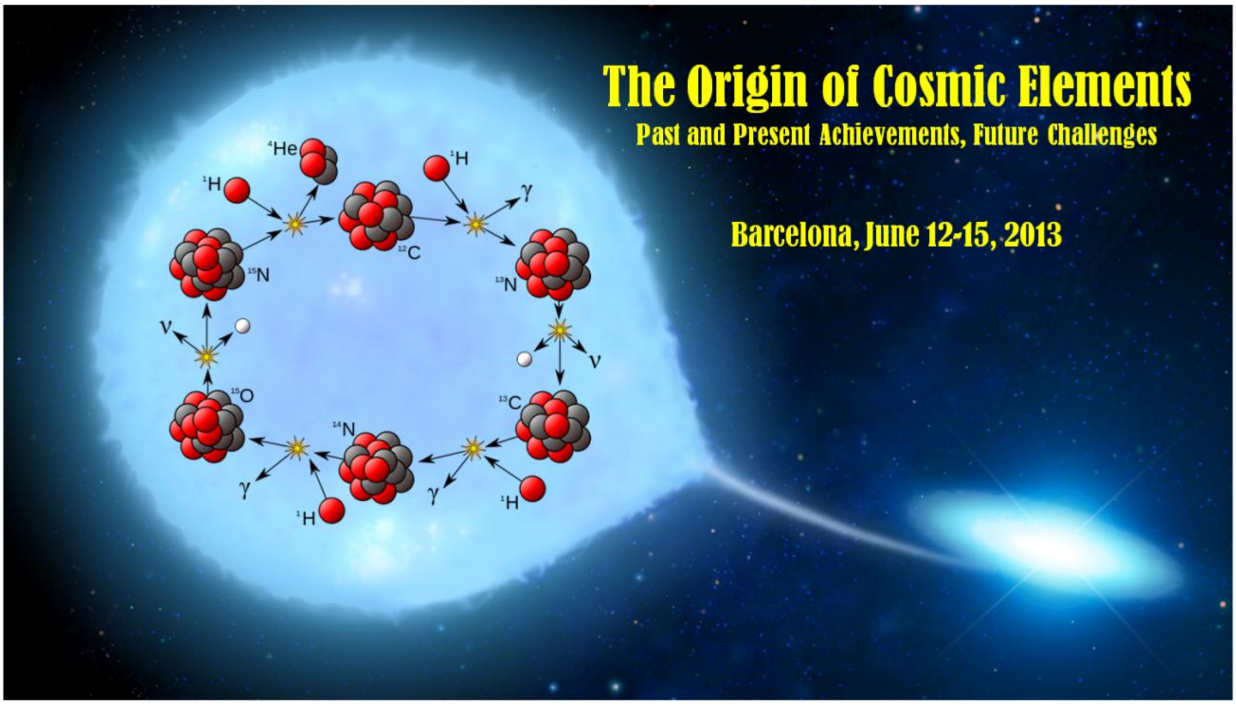

Book of abstracts

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EUROGENESIS CONFERENCE ABSTRACTS

Abia, C.
Universidad de Granada

Carbon, nitrogen and oxygen isotope ratios in AGB carbon stars: constraints for stellar nucleosynthesis and mixing

We report the first (coherent) high-resolution spectroscopic measurements of 12C/13C, 14N/15N, 17O/16O and 18O/16O ratios in Galactic carbon stars of different spectral types.
The 14N/15N ratio is derived for the first time in these evolved stars. We show that J- and some SC-type stars might produce A+B grains, even for 15N enrichments previously attributed to novae. We also show that most mainstream (MS) grains are compatible with the composition of N-type stars, but might also descend, in some cases, from SC stars. On the other hand, the O isotope ratios derived in most of the stars can only be explained if an extra-mixing process is occurring during the AGB phase however, this is at odd with the figure revealed by the measured 12C/13C ratios and with the fact that these stars are C-rich (C/O>1). We conclude that from the theoretical point of view, no astrophysical scenario can interpret the C, N and O isotopic ratios of SC, J and N-type carbon stars together, as well as those of many grains produced by them. This poses urgent questions to stellar physics.

Badenes, C., Bravo, E., Park, S., Piro, T.
University of Pittsburgh

Burning Chrome, or how secondary Fe-peak elements in supernova remnants can shed light on Type Ia supernova progenitors.

The exceptional capabilities of the Suzaku satellite have allowed the detection of K-shell emission lines from secondary elements in the Fe peak (Cr, Mn, and Ni) in the X-ray spectra of young Type Ia supernova remnants (SNRs). These lines provide a direct window onto the ill-understood processes that take place just before and during Type Ia SN explosions. In particular, the Mn/Cr line flux ratio is a sensitive indicator of the neutron excess present in the progenitor before the explosion, and the Ni/Fe line flux ratio can be used to determine the type of nuclear burning that took place during the SN itself. Together, these measurements can be used to constrain key properties of the Type Ia SN progenitors, like the metallicity and the length of the \'simmering\' phase that precedes the thermonuclear runaway, which are extremely difficult or impossible to probe in any other way.

Bemmerer, D.
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Precise study of the supernova reaction 40Ca(α,γ)44Ti by activation in the Dresden Felsenkeller

The radioactive nuclide 44Ti is believed to be produced in the α-rich freeze out preceding super- nova explosions. The γ-rays from its decay have been observed in space-based γ-observatories for the Cassiopeia A and very recently also SN 1987A supernova remnants. The rates of the nuclear reactions governing the production and destruction of 44Ti should therefore be known with high precision. Over the last years there have been various studies of the 40Ca(α,γ)44Ti reaction, which is dominating the 44Ti production in supernovae. Those studies have been performed using in-beam γ-spectroscopy, activation, accelerator mass spectrometry (AMS), and recoil mass spectrometry via inverse kinematics. However, there are still discrepancies in the resulting reaction rates. Using an α-beam of 1-2 μA intensity the strengths of the strongest 40Ca(α,γ)44Ti resonances from 3.5 to 4.5 MeV laboratory α-energy have been studied by in-beam γ-counting and activation. The samples have been analyzed in the ultra-low-background underground γ-counting facility "Felsenkeller Dresden". The target stoichiometry has been determined by nuclear reactions and by elastic recoil detection analysis (ERDA). An AMS measurement of the activated samples is in preparation.

Biscaro, Ch., Cherchneff I.
Basel University

Molecule reprocessing by shocks in the supernova remnant Cas A

Dust and molecules are observed in various supernovae (SNe) and their remnants, but their formation and evolution in these hostile, shocked environments are still unclear. Recently, transitions of warm CO have been detected with the Spitzer, Akari and Herschel telescopes in the 330 years-old SN remnant Cas A. In particular, CO lines were detected with Herschel in a small O-rich clump, and a high CO column density and temperature, compatible with shocked gas, were derived from line modelling. These observations thus show that fair quantities of CO reform after the passage of the reverse shock. The Cas A remnant results from the explosion of a 19 Msun star as a supernova. We first model the SN ejecta chemistry to identify the molecules and dust clusters that form after the explosion. We then model the impact of the reverse shock on a O-rich ejecta clump, using a chemical kinetic approach. The reverse shock slows down while crossing the high-density gas of the clump to reach a speed of 200 km/s. We investigate the post-shock chemistry, considering the destruction of molecules and dust clusters by the shock and their reformation. We consider the impact of X-rays coming from the hot post-shock region on the ionization fraction of the post-shock gas. We found that the reverse shock destroys the molecules and dust clusters present in the O-rich clump. CO reforms in the post shock gas with abundances that concur with the latest Herschel observations, confirming a post-shock origin for the submm CO lines. Small dust clusters do not efficiently reform in the shocked gas, indicating that once destroyed by the reverse shock, the SN ejecta dust won't be able to reform in the remnant.

Busso, M. M.
Department of Physics, University of Perugia

Nucleosynthesis and mixing in low-mass stars

We outline the activity done by IP5 of CoDustMas during the period of the Eurogenesis collaboration. The activity was aimed at generating the nuclear inputs and the nucleosynthesis models necessary to understand the composition of cosmic dust (and in particular of presolar grains whose origin is attributed to Low Mass Stars). These results range from new nuclear reaction rate measurements, to new stellar and nucleosynthesis models in red giants (in presence of deep mixing phenomena), to estiamtes for the chemical evolution of Galaxies.

Caballero-Folch, R., Domingo-Pardo, C.
DFEN- UPC

Measurements of b-delayed neutrons for the third r-process peak

Beta-decay and beta-delayed neutron emission measurements of neutron rich nuclei along N=50 and N=82 have been measured so far at several RIB facilities. Such experiments yielded valuable nuclear physics input for r-process model calculations aiming at reproducing the 1st and 2nd abundance maxima. However, no experimental information exists in the r-path region which yields the heaviest abundance peak at A=195. This contribution will summarize recent experimental efforts made at the RIB facility of GSi, aiming at the measurment of several nuclei in the neighbourhood of the third r-process peak, in particular beyond N=126. A summary of preliminary half-lives and neutron branchings will be presented together with an outlook for future experiments aiming at getting closer to the r-path.

Charbonnel, C.
Geneve Observatory and CNRS

The nucleosynthetic role of intermediate-mass and massive stars during the turbulent infancy of globular clusters

A major paradigm shift has recently revolutionized our picture of globular clusters (GC) that were long thought to be simple systems of coeval stars born out of homogeneous material. Indeed, detailed abundance studies of GC long-lived low-mass stars performed with 8-10m class telescopes, together with high-precision photometry of Galactic GCs obtained with HST, have brought compelling clues on the presence of multiple stellar populations in individual GCs. These stellar subgroups can be recognized thanks to their different chemical properties (more precisely by abundance differences in light elements from carbon to aluminium) and by the appearance of multimodal sequences in the colour-magnitude diagrams. This has a severe impact on our understanding of the formation and early evolution of GCs, and more generally of the role that massive stars may play in shaping the intra-cluster medium and in inducing secondary star formation in massive star clusters. In this talk I will summarize the observational status. I will discuss the possible role of massive and intermediate-mass stars, and present the detailed timeline we have recently proposed for the first 40 Myrs in the lifetime of a typical massive protocluster following the general ideas of our so-called \"Fast Rotating Massive stars scenario\" and taking into account the dynamics of interstellar bubbles produced by stellar winds and supernovae.

Cherchneff, I.
Basel University

A study of dust synthesis and evolution in supernovae

For the last three years, members of the CoDusMas network have been investigating new research lines related to the production and evolution of cosmic dust in supernovae and their remnant. I will report on the scientific achievements of the CoDustMas network.

Dervisoglu, A., Pavlovski K., Kolbas V., Southworth, J.
Erciyes University Astronomy & Space Science Department

Disentangling Binary Spectra as a trace of CNO exposed layers of Algols: Case υ Her

The evolution of the stars in binary systems is affected by the presence of their companion. Only a limited space is allowed due to limitation with its gravitational potential, the Roche lobe, and the more massive component of the system will be the first to reach this limiting radius. At this point, a rapid phase of mass transfer happens and the more massive component is accreted by its companion, hence, an Algol-type binary system is formed. The previous more massive star is now a low-mass subgiant filling its Roche lobe, and its companion is now the hotter and more massive component. This mass-transfer scenario is the well-established solution to the "Algol paradox\'\' (c.f. Hilditch 2001). A significant fraction of the mass may be lost to interstellar space, affecting the chemical evolution of galaxies (Batten 1989). This evolutionary scenario causes many effects (changes in orbital period, erratic light variability, distorted radial velocity curves etc.), but one is particularly important. Up to 80% of the mass of the originally more massive star can be lost, exposing layers which were originally deep within the star and have been altered by thermonuclear fusion during the star\'s main sequence evolution. Some of the material transferred to the companion star is similarly altered. The surface chemical compositions of both stars are therefore a precious diagnostic of the nucleosynthetic processes that occur deep within stars. We have performed definitive analyses of the abundances of a sample of Algol system υ Her. Using satellite photometry and series of spectra, we managed to disentangle components spectra. Despite of the high rotation rates of components, we carefully made abundance analyses of CNO elements and found indications on Nitrogen enrichment and Carbon deficiency.

de Sereville, N., Benamara, S., Laird, A. et al.
Institut de Physique Nucleaire d'Orsay (IPNO)

Experimental study of the 26Al(n,p)26Mg and 26Al(n,a)23Na reactions using the 27Al(p,p\')27Al inelastic scattering reaction

Observations of 26Al are relevant for several astrophysical studies: i) characteristic gamma-ray lines of 26Al decay are observed in our galaxy confirming nucleosynthesis processes are still active nowdays, and (ii) observation of 26Al in presolar grains is used to constraint the astrophysical environment of solar system formation. However the interpretation of these observations rely on 26Al yields, presently very uncertain, obtained from stellar models. It has been recently shown that key reactions for 26Al nucleosynthesis in massive stars are 26Al(n,p)26Mg, 26Al(n,a)23Na and 23Na(a,p)26Mg for which the spectroscopy information is limited (level position, branching ratio) in the compound nucleus 27Al. We report here on the study of 27Al spectroscopy using the 27Al(p,p\')27Al inelastic scattering reaction performed at the TANDEM-ALTO facility at Orsay. Protons were detected and identified using the high-resolution Split-Pole spectrometer. All known 27Al levels were populated and new resonances above the neutron threshold (Sn = 13 MeV) are observed for the first time. Comparison of the measured level density with the compound nucleus calculation will be presented and impact on the reaction rates will be discussed.

Feige, J., Wallner, A., Fifield, L.K., Korschinek, G., Merchel, S., Rugel, G, Steier, P., Winkler, S.R.
University of Vienna - VERA Laboratory

Long-lived radionuclides as indications of a close-by supernova explosion in deep-sea sediment cores

The first evidence of a SN close-by to the solar system was given by Knie et al. in 2004. Examinations of a ferromanganese crust from the Pacific Ocean showed an excess of 60Fe corresponding to a time some 2 Myr ago. We have obtained two deep-sea sediment cores from the Indian Ocean, which provide a better time resolution due to higher accumulation rates. We use Accelerator Mass Spectrometry (AMS) for measuring concentrations of the long-lived radionuclides 26Al, 53Mn and 60Fe in these marine sediments. All three radionuclides, with half-lives between 0.7 and 3.7 Myr, are produced in the late burning phases and during a supernova explosion of a massive star and are ejected into the interstellar medium in the explosion. To overcome the solar wind and the interplanetary magnetic field they will have to enter the solar system within dust particles. In contrast to 60Fe, which is not produced in-situ on Earth, cosmogenic production of 26Al and 53Mn in the atmosphere and in-situ adds to a potential extraterrestrial signal. The cosmogenic isotope 10Be, produced from cosmic rays in the Earth’s atmosphere, is analysed for dating purposes. We will present and discuss our first measurement results for 10Be and 26Al.

García-Berro, E., Aznar-Siguán, G.,Lorén-Aguilar, P, José, J., Isern, J.
Universitat Politècnica de Catalunya

Nucleosynthesis in white dwarf close encounters and collisions

In old, dense stellar systems collisions of white dwarfs are a rather frequent phenomenon. We present the results of a comprehensive set of Smoothed Particle Hydrodynamics simulations of close encounters of white dwarfs aimed to explore the outcome of the interaction and the resulting nucleosynthetic patterns for different initial conditions. Depending on the initial conditions and the white dwarf masses, three different outcomes are possible. Specifically, the outcome of the interaction can be either a direct or a lateral collision or the interaction can result in the formation of an eccentric binary system. In those cases in which a collision occurs, the infalling material is compressed and heated and the physical conditions for a detonation are reached during the most violent phases of the merger in a significant number of simulations, whereas in some other, although some nuclear processing occurs in the region where the material of the disrupted less massive star hits the surface of the more massive one, the temperature increase in the shocked region rapidly lifts degeneracy, and the burning is quenched. We thus characterize under which circumstances a detonation is likely to occur as a result of the impact of the disrupted star on the surface of the more massive white dwarf. Finally, we also study which interactions result in bound systems, and in which ones the more massive white dwarf is also disrupted as a consequence of the dynamical interaction.

Gruyters, P., Korn,A., Barklem, P.
Uppsala University

Atomic Diffusion in NGC6752

Atomic diffusion in stars can create systematic trends of surface abundances with evolutionary stage. Globular clusters offer useful laboratories to put observational constraints on this theory as one needs to compare abundances in unevolved and evolved stars, all drawn from the same stellar population. I will show the results of an abundance study of stars in the globular cluster NGC6752 which shows weak but systematic abundances trends with evolutionary phase for Fe, Sc, Ti and Ca. The trends are best explained by a stellar structure model including atomic diffusion with efficient additional mixing. The model allows to correct for sub-primordial stellar lithium abundances of the stars on Spite plateau, and to match it to the WMAP-calibrated Big-Bang nucleosynthesis predictions to within the mutual 1-sigma errors.

Güray, R. T., Özkan, N., Yalçın, C., Gyürky, G., Farkas, J., Fülöp, Z., Halász, Z., Somorjai, E.
Kocaeli University

Experimental cross sections of proton-induced reactions on 152Gd for the astrophysical p process

The p-process is a nucleosynthesis mechanism in explosive environments in the temperature range of 2–3 GK, such as the O/Ne layers of Type-II supernovae. The p-process is responsible for the production of about 35 proton rich stable isotopes (p nuclei) between 74Se and 196Hg shielded by stable nuclei from the production via the slow and rapid neutron capture processes. Because experimental studies are relatively few in the heavier mass region, where 152Gd (p nucleus) is located, the cross sections of 152Gd(p,g)153Tb and 152Gd(p,n)152Tb reactions have been measured by the activation technique in order to extend the experimental database for the astrophysical p-process and to test the reliability of statistical model predictions. The experiments were carried out in the energies from 3.5 to 8 MeV, close to the astrophysically relevant energy range. The targets were prepared by evaporating 30.6 % isotopically enriched 152Gd oxide on Aluminum backing foils, and bombarded with proton beams provided by the cyclotron accelerator of the Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI). Preliminary results are presented and compared with the Hauser-Feshbach statistical model predictions.

Halabi, G.
American University of Beirut

The Effect of Key Nuclear Reaction Rates on The Properties of Cepheids

We investigate the effects of a modification of the $^{14}N(p,\gamma)^{15}O$ reaction rate, as suggested by recent evaluations, on the formation and extension of the blue loops encountered during the evolution of the stars in the mass range 5M☉ to 12M☉. We show that the blue loops of stars in the mass range 5M☉ to 8M☉, that is the range of super ABG stars, are severely affected by a modification of the important $^{14}N(p,\gamma)^{15}O$ reaction rate. We also show the effect of different mixing mechanisms on restoring the blue loops, which is necessary to explain the observations of the Cepheid stars.

Hernanz, M.
CSIC-IEEC

High Energy emission during nova explosions

Accreting white dwarfs in binary systems can explode as classical novae. We\'ll review how gamma-rays (in the MeV range) trace the nucleosynthesis in such explosions. We\'ll also show how shocks in the ejecta and with circumstellar matter produce emission both in the X-ray range and in the GeV range, as recently detected by the Fermi satellite.

Hu, J., He, J.J., Xu,S.W., Yamaguchi, H., Ma, P., David, K., Su, J., Wang, J.H.
Institute of Modern Physics, Chinese Academy of Sciences

Study of the crucial nuclear reaction 14O(a, p)17F in X-ray burst

The stellar 14O(a, p)17F reaction is thought to be one of the most important breakout reactions from the Hot CNO cycles into the rp-process in Type I X-ray bursters. In the present work, the properties of proton resonances in 18Ne have been investigated efficiently by utilizing a technique of proton resonant scattering with a 17F radioactive-ion (RI) beam and a thick Hydrogen gas target. Several proton resonances in 18Ne were observed, and their resonant parameters have been determined by an R-matrix analysis of the differential cross-sections. An improved 14O(a, p)17F reaction rate has been determined.

Imbriani, G. for LUNA collaboration
Department of Physics, University of Naples Federico II

Reaction rates for nucleosynthesys of ligh and intermediate-mass isotopes

The main difficulty of direct measurements of nuclear cross section of astrophysical interest is determined by the background, which, together with the low cross sections, set a limit on the energy range that can be investigated with a simple setup on the earth's surface. The best solution so far was to install an accelerator facility in a deep underground laboratory, in a similar way to solar neutrino detectors. This has been the approach of LUNA (Laboratory for Underground Nuclear Astrophysics) experiment. I will report about some recent experiments perfomed in this experiment, in particular, I will discuss the present status of knowledge of 15N(p,g)16O, 17O(p,g)18 and 25Mg(p,g)26Al cross sections, discussing their impact on stellar evolution and nucleosynthesis modeling will be reviewed.

Isern, J.
Institut de Ciències de l'Espai (CSIC) & Institut d'Estudis Espacials de Catalunya (IEEC)

SNIa: wonders and mysteries

There is a wide consensus that Type Ia supernovae are the outcome of the thermonuclear explosion of a carbon--oxygen white dwarf in a binary system, but the nature of this system, the process of ignition itself and the development of the explosion continue to be a mystery. Nevertheless, important improvements on both, theory and observations, have started to provide insight into this phenomenon, challenging the classical scenario and forcing the exploration of new issues or, at least, the reconsideration of scenarios that were previously rejected.

José, J.
Univ. Politècnica de Catalunya (UPC BarcelonaTech) & Inst. Estudis Espacials de Catalunya (IEEC)

<u>Stellar beacons: classical novae, type Ia supernovae, X-ray bursts and stellar mergers</u>

Many stars form binary or multiple systems, with a fraction hosting one or two degenerate objects (white dwarfs and/or neutron stars) in short-period orbits, such that mass transfer episodes onto the degenerate component ensue. This scenario is the framework for a suite of violent stellar events, such as type Ia supernovae, classical novae, X-ray bursts, or stellar mergers (WD+WD, WD+NS, NS+NS). The expected nucleosynthesis accompanying these cataclysmic events is very rich: classical novae are driven by proton-capture reactions in competition with beta-decays, proceeding close to the valley of stability, up to Ca. Type I X-ray are powered by a suite of nuclear processes, including the rp-process (rapid p-captures and beta-decays), the 3alpha-reaction, and the alpha-p-process (a sequence of (alpha,p) and (p,gamma) reactions); here, the nuclear flow proceeds far away from the valley of stability, merging with the proton drip-line beyond A = 38, and reaching eventually the SnSbTe-mass region, or beyond. In type Ia supernovae, the detailed abundances of the freshly synthesized elements depend on the peak temperature reached and on the excess of neutrons and protons (which depend in turn on the metallicity of the white dwarf progenitor as well as on the density at which the thermonuclear runaway occurs); they constitute the major factory of Fe-peak elements in the Galaxy, and roughly speaking, the abundance pattern of their ejecta is the result of four different burning regimes: NSE and incomplete Si-, O-, and C-Ne-burning. A suite of different nuclear processes are expected to occur during stellar mergers (indeed, neutron star mergers have been suggested as a possible site for the r-process).
In this talk, I will highlight recent progress achieved in this broad research area, with emphasis on the results obtained by different EuroGENESIS groups.

Kobayashi, C.
University of Hertfordshire

<u>Future challenges of Galactic chemical evolution</u>

I will summarize the current understanding of stellar yields (Nomoto, Kobayashi, Tominaga, 2013 ARAA, in press) and the predictions of chemodynamical simulations for future Galactic archaeology surveys. Then I will discuss future challenges of Galactic chemical evolution.

La Cognata, M., Spitaleri12, C ., Mukhamedzhanov, M., Indelicato, I., Trippella, O, Kiss, G.G., Rogachev, G.V., Aliotta, M., Avila, M., Burjan, V., Coc, A., Guardo, G.L., Hons, Z., Koshchiy, E., Kroha, V., Kuchera, A., Lamia2, L., Mrazek, J., Piskor, S., Puglia, S.M.R., Romano, S., Santiago, D., Spartà, R.
INFN-LNS

<u>Application of the THM to resonance reactions and implications for stellar nucleosynthesis</u>

Resonance reactions play a very important role in astrophysics as resonances may dramatically change cross sections of relevant reactions at low energies. Since astrophysical energies can be as low as ~10-100 keV during quiescent burning, they can be hardly achieved with standard approaches and astrophysical models usually rely on extrapolations. However, at these energies the effect of atomic electrons cannot be neglected, also determining an increase of the astrophysical factor at low energies, resembling the effect of a sub threshold resonance, for instance. The Trojan Horse Method (THM) has proved very useful to measure cross sections at very low energies, allowing us to reduce systematic uncertainties associated with the extrapolation procedure. It has been modified to investigate resonance reactions, both in the case of low energy resonances and of sub threshold resonances. For these it has been possible to extract the asymptotic normalization coefficient, with important consequences in the development of indirect methods. We will show some recent results, about the 19F(p,a)16O and 13C(a,n)16O reactions to illustrate the resonance THM for two important astrophysical processes, with possible consequence on fluorine and s-process nucleosynthesis.

Leeb, H., Warjri, D.M., Srdinko, Th.
TU Wien, Atominstitut

<u>Microscopic Approaches for Alpha-Nucleus Optical Potentials for Nucleosynthesis</u>

Nuclear reactions involving alpha-particles play an important role in astrophysics, e.g. in the nucleosynthesis of p-nuclei and as neutron sources. Especially at medium and heavy nuclei elastic alpha-nucleus scattering cross sections at astrophysically relevant energies are experimentally not accessible and corresponding optical potentials have to rely on extrapolations of questionable accuracy. In this contribution we consider two microscopic approaches to alpha-optical potentials; (i) within a coupled-channel approach to rotational states and (ii) within the nuclear structure approach using RPA to describe intermediate states. Both approaches are suited for low energies, albeit they cannot account for the full absorption. However, they give a glance on their energy dependence and thus allowing a relation to available experimental data. In addition transmission coefficients required by statistical model calculations can be determined. Work supported by the Fonds zur Foerderung der wissenschaftlichen Forschung (FWF), Austria under the project number I426-N16.

Longland, R., Lorén-Aguilar, P., José, J., García-Berro, E., Althaus, L.G., Isern, J.
Universitat Politècnica de Catalunya

Nucleosynthesis in R Coronae Borealis stars

R Corona Borealis (RCrB) stars and their hydrogen deficient cousins have surface abundance patterns that cannot be explained by invoking standard stellar evolution. Rather, their formation requires a mechanism for removing hydrogen from their atmospheres while enriching them in carbon, oxygen, lithium, fluorine, and s-process elements. In this presentation, we will highlight a number of studies funded under the EuroGENESIS grant to model nucleosynthesis in white dwarf mergers. The studies show that these systems can, indeed, reproduce the observed surface abundances of RCrB stars. The signature of such mergers in stellar dust will also be discussed.

Lucatello, S.
INAF Osservatorio Astronomico di Padova

Chemical compositions of multiple stellar populations in Globular Clusters

The series of events that results in the formation of Globular Clusters (GC) and in their multiple populations is currently of high interest, also given the growing evidence that a considerable fraction of Milky Way halo stars were indeed bornin GC and successively lost to the field. However, such formation process is far from being fully understood yet. In particular, the class(es) of object responsible for the chemical self enrichment of GC, a signature of the multiple populations, have not yet been ascertained. Spectroscopic studies leading to the measurements of a large set of elemental abundances for large samples of stars in GC allow to provide crucial constraints on the nucleosynthetic sites and time-scales involved. I will present the latest results from our on going Galactic GC spectroscopic survey (the largest to date), discussing the implications on our understanding of the their formation and of nucleosynthetic processes responsible for the self enrichment.

Martinez-Pinedo, G.
TU Darmstadt

Neutrinos In supernova Evolution and Nucleosynthesis

In this talk, I will discuss different aspects related to the role of neutrinos in core-collapse supernova evolution and nucleosynthesis. Recent results about oscillations of neutrinos produced on nuclear reactors suggest that the standard neutrino mixing scenario needs to be extended to consider a light sterile neutrino with a mass in the eV range. Based on Mikheyev-Smirnov-Wolfenstein mechanism that describes neutrino oscillations on matter, I will show that the current values of sterile neutrino mass and mixing angle imply the presence of a resonance in the supernova core in the region outside the protoneutron star where the electron-to-nucleon ratio reaches a value of 1/3. As electron neutrino and antineutrino cross this resonance they will oscillate to sterile neutrinos and will not interact anymore with the surrounding matter. This process is particularly efficient during the first hundreds of milliseconds after bounce when neutrinos are expected to revive the stalled shock and launch the supernova explosion. One can use the fact that supernova do in fact explode to constrain the neutrino oscillation parameter space. However, if sterile neutrinos do exist, they will impact the supernova dynamics and nucleosynthesis. If time allows I will further discuss the role of neutrino matter interactions at high densities in determining the neutron richness of neutrino wind ejecta.

Matteucci, F.
Department of Physics, University of Trieste (Italy)

<u>The production of Europium: supernovae versus merging neutron stars</u>

We discuss the evolution of Europium abundance in the Milky Way under different assumptions!

i) Eu is produced only in SNeII
ii) Eu is produced only in merging neutron stars and
iii) Eu is produced – both SneII and merging neutrons tars. We show that each one of these assumptions is possible, after comparison with observational data.

Mikolajewska, J.
Copernicus Astronomiacl Center

<u>Chemical abundance analysis of symbiotic giants</u>

Symbiotic stars are strongly interacting binaries with a cool red giant primary and a hot white dwarf secondary. Here we will present results of a detailed abundance analysis of some red symbiotic stars. In particular, we have derived photospheric abundances of CNO and of iron peak (Ti, Fe, and Ni) elements. We will also present preliminary results of search for s-process and carbon enhancements from previous accretion.

Özkan, N., R. T. Güray, R.T., Durkaya, B., Yalçın, C., Tan, W., Aprahamian, A., Battaglia, A., Beard, M., Best, A., Bucher, B., DeBoer, R.J., Calderon, S., Couder, M., Falahat, S., Görres, J., Stech, E., Stranberg, E., Uberseder, E., Kontos, A., Li, Q., Sonnabend, K., Sauerwein, A., Wiescher, M., Fülöp, Z., Gyürky, G., Somorjai, E., Greene, J., Lee, H.
Kocaeli University

<u>Proton and Alpha induced reaction cross sections on erbium isotopes for the astrophysical γ-process</u>

The gamma-process, i.e., a sequence of photo-disintegration reactions, (gamma,neutron), (gamma,proton), and (gamma,alpha) on heavy nuclei at temperatures of 2-3 GK is the favored mechanism responsible for the production of p-nuclei with masses larger than 100. Most of the involved reaction rates are experimentally unknown and typically calculated with the statistical Hauser-Feshbach (HF) model. Since not only the experimental data for charged-particle induced reaction cross sections especially on heavier p-process nuclei are nearly absent, but also p-process nucleosynthesis have problems in the mass regions A less than 124 and between150 and 165, the systematic p and α capture reaction measurements have been carried out by Kocaeli University. The proton and alpha capture reaction cross sections of the erbium isotopes with A=162 and 164, which are p-nuclei, have been measured using activation technique in the beam energy range changing depending on the reaction between 4 and 17 MeV. The evaporated enriched erbium isotopes on Al and C backings were irradiated at the Notre Dame FN tandem accelerator with the beam intensities of 50-600 nA. The reaction yields have been determined by the observed activity of produced radioactive isotopes, which was detected off-line by a HpGe-detector in a low background counting setup. The obtained total cross section results for (proton,gamma), (alpha,gamma) and (proton,neutron), (alpha,neutron) reactions on Er-162 and Er-164 are presented and compared with the Hauser-Feshbach statistical theory predictions. In this talk, the details of the measurements, the status of activation measurements, advantages and restrictions, and future projects will also be discussed.

Palmerini, S.
Universidad de Granada

<u>Challenges and solutions from Oxygen and Aluminum isotopic ratios in grains of AGB origin</u>

The explanation of the Oxygen isotopic abundances shown by the whole population of group 2 oxide grains, and the identification of very low mass AGB stars ($M \leq 1.2M$□) as their progenitor belong to the main results of the studies about nucleosythesis coupled with extra-mixing phenomena. Moreover, the 17O abundances observed in two bright K giants (α Boo and α Tau) have allowed to derive constraints on the elusive physics of non-convective mixing in RGB stars. We find that very slow mixing, like that associated to diffusive processes, are incapable of explaining grains data, which require a fast transport. In the same way, circulation mechanisms with speeds intermediate between those typical of diffusive and convective mixing are necessary for giant stars. Despite this promising results, a challenge arises from 26Al/27Al ratios higher than 10-2 detected in a part of group 2 grains and that require high temperature mixing to be accounted for. Indeed, the feedback of energy of such a deep mixing should affect the stellar equilibrium and more massive stellar progenitors would worsen the fit to the 17O/16O ratios. Furthermore, the recent measurement of the 25Mg(p,γ)26Al cross section excludes an higher efficiency of this channel for the 26Al production, which was suggested as a possible solution of this problem. We present the results of a re-analysis of 26Al nucleosynthesis in low mass evolved stars assuming different non-convective mixing models, with velocity profiles, and different enrichments in Al isotopes from the third dredge-up.

Prantzos, N.
Institut d'Astrophysique de Paris

Nuclear Astrophysics: Past and Present Achievements

I will prsent an - obviously subjective and biased - overview of the field of Nuclear Astrophysics, in the light of recent theoretical, observational and experimental developments

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Dust formation in the ejecta of type II-P supernovae

Observations in the infrared (IR) and sub-millimeter (submm) both indicate the presence of molecules and dust in the ejecta of Type II-P supernova (SNe) and their remnants. The mass of dust formed in the ejecta of SNe is still uncertain and highly debated: IR observations indicate small dust mass (10-5 to 10-3 Msun) before 500 days post-explosion, when submm observations with Herschel reveal large reservoirs of cool dust (10-2 to 0.7 Msun) in supernova remnants. We study the ejecta of various Type II-P SNe using a chemical kinetic approach, and consider the synthesis of molecules and small clusters (e.g., silicates, carbon, metal oxides, metallic clusters etc) in the ejected material until 4 years after explosion. We find that the dust clusters form gradually over time in different ejecta zones, resulting in small dust masses produced before ~ 600 days (~ 10-4 solar mass), that gradually increase up to ~ 0.1 Msun at 1500 days post-explosion. These small clusters undergo coagulation processes to form dust grains. We model the contribution of these grains to the IR flux at ~ 500 days post-explosion in SNe, and to the submm flux of SN remnants (e.g., SN87A, the Crab Nebula) measured with Herschel. Both clumped and unclumped ejecta are considered. Our small dust mass can reproduce the IR fluxes of SNe at early post-explosion time, when our larger dust mass at late time (10-2 to 0.1Msun) can reproduce the submm fluxes of SNe remnants. The gradual dust growth in SN ejecta with time therefore reconciles IR and submm data. We conclude that Type II-P supernovae are moderate dust producers to galaxies.

Sengupta, S.,Izzard, G.,Lau, H.H.B.,Stancliffe, R.J.
Argelander-Institut für Astronomie

Nova reaccretion model for J-type carbon stars

The J-type carbon stars are a significant fraction (10-15%) of the observed carbon stars in our Galaxy and the Large Magellanic Cloud (LMC). They are characterized by their low 12C/13C ratios signifying enhancement of 13C, along with other peculiar chemical signatures like the lack of s-process enhancement unlike normal carbon (N-type) stars. There are also surveys estimating luminosities of these objects (eg. Morgan et al. 2003 in the LMC) which show that most of them are dimmer than typical AGB stars, indicating they are low-mass less evolved objects -- contrary to single star models with hot bottom burning (HBB). As an new approach to understanding the observed peculiarities in these mysterious objects, a binary model involving classical novae (CNe) is investigated, where the white dwarf (WD) companion (secondary) can evolve with such anomalous features, due to re-accretion of the nova ejecta that are predicted to be enhanced in isotopes like 13C significantly produced in CNe (Jose & Hernanz 1998). A detailed population synthesis study is performed to estimate the number of systems in which such nova pollution can cause enough 13C enhancement to evolve the WD companion with the peculiar features observed for the J-type carbon stars.

Simpson, J., Cottrell, P.,Clare Worley, C., Ridden-Harper, A.
University of Canterbury

Spectral Matching for Elemental Abundances of Evolved Stars of Globular Clusters

In order to understand the origin of globular clusters, large samples of their stars need to be observed and analyzed for their chemical composition. This is especially true for the complex, multimetallic cluster omega Centauri, with its large range of iron, carbon, nitrogen, oxygen, sodium and barium abundances. In order to accomplish this, an automated spectral matching pipeline was developed to determine these abundances. This talk will present these results as well as previewing results from the Southern African Large Telescope of omega Centauri and monometallic clusters NGC6752, NGC362 and 47 Tuc.

Soic, N., Blagus, S., Grassi, L., Jelavic Malenica, D., Mijatovic, T., Miljanic, D., Prepolec, L., Szilner, S., Tokic, V., Uroic, M., Milin, M., Corradi, L., Stefanini, A.M., Montagnoli, G., Montanari, D., Scarlassara, F., Di Pietro, A., Figuera, P., Fisichella, M., Lattuada, M., Scuderi, V., Torresi, D., Acosta, L., Martel, I., Sanchez-Benitez, A., Bailey, S., Curtis, N., Freer, M., Kokalova, Tz., Walshe, J., Wheldon, C., Ziman,V.
Rudjer Boskovic Institute

Search for 24Mg resonances inside Gamow window for 12C+12C fusion

The 12C+12C fusion plays a crucial role in many stellar environments and the current uncertainties in its rate affect modeling of many astrophysical phenomena. The most relevant quantity for astrophysical purposes is the total fusion reaction cross-section, but the reaction 12C+12C into channels 20Ne+alpha and 23Na+p are importantly contributing to the C-C burning rate and to the nucleosynthesis of the heavier nuclei. The most important energy range is ECM=1.5-3.3 MeV, but for explosive phenomena the relevant energy extends up to 5.7 MeV. The existing direct measurement data for the 12C+12C fusion extend down to 2.1 MeV above the reaction threshold. Considering that resonances exist in 12C+12C system throughout the entirely measured higher relative energy range, it is likely that resonances exist also inside Gamow window. Such sub-barrier low spin resonances may dramatically enhance cross-section at astrophysically relevant energy. Two experiments have been performed in search for 24Mg resonances just above the 12C+12C decay threshold with large contribution of one-particle (23Na+p) and alpha-cluster (alpha+20Ne) structure which may enhance 12C+12C burning. These indirect technique measurements provide essential information on the states needed to determine astrophysical factor of the carbon-carbon fusion inside Gamow window. In the first experiment the 12C(16O,alphaX)Y reaction, where X=12C, 8Be, alpha, p and Y=12C, 16O, 20Ne, 23Na respectively, was measured at the INFN-LNS Tandem accelerator. The second experiment, scheduled at INFN-LNL for May/June 2013, includes the measurements of the excitation functions of the 4He+20Ne resonant scattering and the 4He+20Ne into 1H+23Na reaction at astrophysically relevant energies, by use of the 20Ne beams delivered by the PIAVE-ALPI facility and a thick 4He gas target which stops the beam. Preliminary results of these measurements will be presented.

Spite, M., Caffau E., Bonifacio P., Spite F., Ludwig H.-G., Plez B., Christlieb N.
Observatoire de Paris

<u>Are there 2 plateaux of the C abundance in CEMP turnoff stars?</u>

I will show that it seems that in the interval Fe/H=-6 to Fe/H=-2 the C abundance in CEMP turnoff stars is equal to about A(C)=8.2 (for A(H)=12) of A(C)=6.5 at the lowest metallicity. To confirm the existence of this possible \"second plateau\" it is necessary to observe CEMP dwarfs with a temperature lower than 6000K.

Spitoni E., Matteucci, F.
Department of Physics, Section of Astronomy, University of Trieste (Italy)

<u>Effects of the radial inflow of gas and galactic fountains on the chemical evolution of the Milky Way and M31</u>

Galactic fountains and radial gas flows are very important ingredients for modelling the chemical evolution of galactic disks. We adopt a ballistic method to study the effects of galactic fountains on the chemical enrichment of the galactic disks by analyzing the landing coordinate of the fountains and the time delay in the pollution of the interstellar gas. We also implement radial flows of gas in models for the chemical evolution of the Milky Way and M31.

Strieder, F. on behalf of the LUNA Collaboration
Ruhr-Universität Bochum

LUNA-MV – The next underground accelerator facility

It is in the nature of astrophysics that many of the processes and objects one tries to understand are physically inaccessible. Thus, it is important that those aspects that can be studied in the laboratory are rather well understood. Nuclear fusion reactions are such important quantities that can be partly measured in the laboratory. These reactions sensitively influence the nucleosynthesis of the elements in the earliest stages of the universe and in all the objects formed thereafter, and control the associated energy generation and evolution of stars. Since 20 years the LUNA (Laboratory for Underground Nuclear Astrophysics) Collaboration has been directly measuring cross sections of the Hydrogen burning in the underground laboratories of Laboratori Nazionali del Gran Sasso (LNGS). The work of LUNA demonstrated the research potential of an underground laboratory for the field of nuclear astrophysics. Several key reactions could be studied at LUNA, some directly at the Gamow peak for the solar hydrogen burning. This presentation will focus on an outlook to the LUNA– MV project at LNGS, which aims for the installation of a new and larger accelerator capable to deliver intense proton and alpha beams with a projectile energy of up to 3.5 MeV on gas and solid state targets. The LUNA MV project will focus on the measurement of the key astrophysical reactions 3He(a,g)7Be, 12C(a,g)16O, 13C(a,n)16O and 22Ne(a,n)25Mg using this MV machine. In particular the reaction 12C(a,g)16O, the Holy Grail of Nuclear Astrophysics, will be studied towards very low energies by means of angular distribution measurements. The goals and limits of the experiments will be presented.

Wallner, A.
University of Vienna and Australian National University

^{60}Fe, 244Pu and nanodiamonds

Accelerator mass spectrometry (AMS) represents the most sensitive technique for studying long-lived radionuclides through ultra-low isotope ratio measurements. Within Eurogenesis we have applied AMS for the search of extraterrestrial radionuclides (single supernova-produced and also the abundance in the interstellar medium). We also measured stable isotope ratios in nanodiamonds and applied AMS for nucleosynthesis studies leading to long-lived reaction products. Here, I will highlight

(i) the search for live supernova(SN)-produced radionuclides in terrestrial archives: such studies probe directly specific nucleosynthesis sites and will help understanding heavy element nucleosynthesis in massive stars. Our new data on a deep-sea crust sample suggest a very low abundance of interstellar 244Pu (t1/2 = 81 Ma) - a perfect nuclide to study r process nucleosynthesis that serves also as a probe for r process sites.

(ii) the status of the 60Fe (t1/2 = 2.6 Ma) sensitivity at the ANU, Canberra, using a gas-filled magnet setup with the goal to identify SN-produced live 60Fe in deep-sea sediments. I will also detail a new approach to determine its disputed half-life value.

(iii) the measurement of trace element isotope ratios in presolar nanodiamonds isolated from the Allende meteorite, e.g. isotope ratios of Pt to extract r-process nucleosynthesis signatures and to confirm or exclude models that predict simultaneous enhancements in 198Pt/195Pt & 194Pt/195Pt ratios.

Wallström, Sofia
Chalmers University of Technology, Onsala Space Observatory

CO in the supernova remmant Cas A

Supernovae play a key role in the dust budgets of galaxies, both producing dust in their ejecta and processing ISM dust in their strong shocks. In order to quantify the net dust production of supernovae, we must study the effect of the reverse shock processing of gas and dust in supernova remnants. The supernova remnant Cas A, being both young (~300yrs) and nearby (3.4kpc), is the perfect object for studying the effects of the reverse shock which is just starting to process the ejecta. The CoDustMas IP2 project has observed CO lines with Herschel in a small region of the remnant, in order to determine the gas characteristics and relation to the reverse shock. The gas we see appears to be very warm (~2000 K) and dense (~10^6 cm^-3), and most likely in the post-shock region of the reverse shock.

Zhang, L., He, J.J., Xu, S.W.,Yamaguchi, H., Kubono, S., Wakabayashi, Y., Chen, S.Z.., Hu, J., Ma, P., Togano, Y., Hashimoto, T., Kahl, D., Teranishi, T., Chen, R.F., Wang, H.W., Tian, W.D., Guo, B., Hayakawa, S., Iwasa, N.,Yamada, T., Komatsubara, T.
Institute of Modern Physics Chinese Academy of Sciences

Experimental Study Of The Key Astrophysical 18Ne(a p)21Na reaction

The 18Ne(a, p)21Na reaction is thought to be one of the key breakout reaction from the hot CNO cycle to the rp-process in X-ray bursts. We investigated the resonant properties of the compound nucleus 22Mg by measuring the resonant elastic scattering of 21Na+p. An 89 MeV 21Na radioactive beam was produced by CRIB and then bombarded a thick polyethylenetarget. The 21Na beam intensity was about 2*1E5 pps, with a purity of about 70% on the target.The recoiled protons were measured by three sets of ΔE-E telescope respectively. A wide excitation energy range of 5.5-9.2 MeV in 22Mg was scanned with a thick-target method. Some preliminary results are shown.