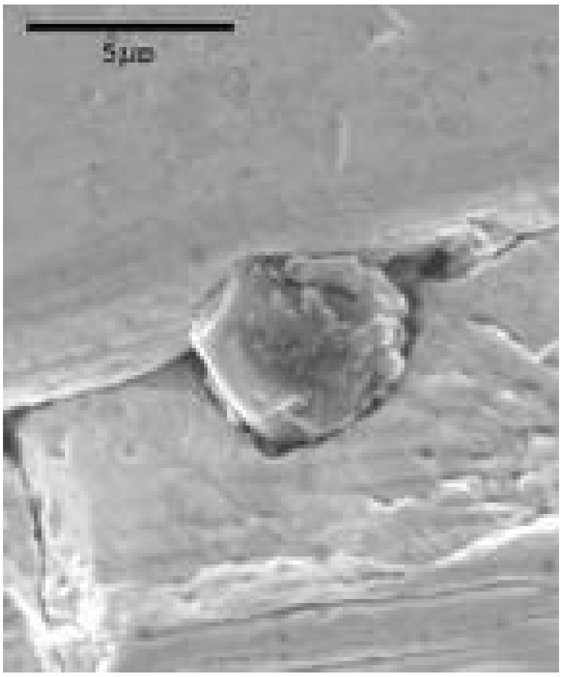
# The XII Torino workshop and IV CSFK Astromineralogy workshop

Sunday 31 July 2016 - Friday 5 August 2016

Budapest




# Book of Abstracts

**Dear Participant,**

JINA-CEE workshops and conferences are community events intended for networking and collaboration as well as learning. We value the participation of every attendee and want all attendees to have an enjoyable and productive experience. Accordingly, all attendees are expected to show respect and courtesy to other attendees throughout the workshop and to abide by the following Code of Conduct. Any participant who wishes to report a violation of this policy is encouraged to speak to Maria Lugaro or Christopher Tout, as they have agreed to serve as a point of contact (or if desired, to another member of the organizing team).

## Code of Conduct

JINA-CEE workshops and conferences are committed to providing a harassment-free environment for everyone, regardless of gender, sexual orientation, disability, physical appearance, body size, race, nationality, or religion. Harassment includes offensive verbal comments or jokes related to gender, sexual orientation, disability, physical appearance, body size, race, religion, sexual images in public spaces, deliberate intimidation, stalking, following, harassing photography or recording, sustained disruption of talks or other events, inappropriate physical contact, and unwelcome sexual attention. All communication should be appropriate for a professional audience including people of many different backgrounds. Be kind to others. Do not insult or put down other attendees. Behave professionally. Participants asked to stop any harassing behavior are expected to comply immediately. Attendees violating these rules may be asked to leave the event at the sole discretion of the conference organizers.

**Thank you for helping make this a welcoming, friendly event for all!**

# Contents

**15**

## The origin of CEMP-r/s stars: Can we learn anything about AGB nucleosynthesis?

**Author:** Carlo Abate[1]

[1] *Argelander-Institute for Astronomy*

**Corresponding Author:** cabate@uni-bonn.de

CEMP-*r/s* stars are metal-poor stars with enhanced abundances of carbon and heavy elements associated with the slow and rapid neutron-capture process (*s*- and *r*-elements, respectively). It is believed that carbon and *s*-elements were accreted in the past from the wind of a primary star in the asymptotic giant branch (AGB) phase of evolution, a scenario that is generally accepted to explain the formation of CEMP stars that are only enhanced in *s*-elements (CEMP-*s* stars). The origin of *r*-element-enrichment in CEMP-*r/s* stars is currently debated. Many formation scenarios have been put forward, for example: (*i*) pre-pollution of the gas cloud, in which the stars were born, in heavy elements produced by the explosions of previous-generation stars; (*ii*) multiple mass-transfer episodes in binaries or hierarchical triple systems; (*iii*) radiative levitation of the neutron-capture elements in the stellar atmospheres or self-enrichment during the AGB phase of evolution.

In my talk I will review the main scenarios proposed to explain the formation of CEMP-*r/s* stars, and I will show that most of them are implausible because they predict too few CEMP-*r/s* stars compared to the observations. I will argue that the "*intermediate* process", which is supposedly active in some circumstances during the AGB phase, could provide an explanation of the origin of CEMP-*r/s* stars, similar to that of CEMP-*s* stars, in the context of wind mass accretion in binary systems. I will discuss, within this formation scenario, what constraints can be put on AGB-nucleosynthetis models by the observed population of CEMP-*r/s* stars.

**16**

## The puzzle of the CNO isotopic ratios in AGB carbon stars

**Author:** Carlos A. Abia Ladrón de Guevera[1]

[1] *Universidad de Granada*

**Corresponding Author:** cabia@ugr.es

We present carbon, nitrogen and oxygen isotopic ratios for a sample of 56 galactic AGB carbon stars of N, J and SC spectral types. Models for solar composition (or slightly below) AGB stars of different initial masses are used to interpret our results. Similar to previous works, we find that a number of stars have 12C/13C ratios below about 40, which might be explained if an extramixing mechanism is acting during both the RGB and AGB phases. Most of the 14N/15N derived are in agreement with theoretical expectations from low mass AGB models although a few stars (mostly of SC and J-types) show very low 14N/15N ratios for which currently there is no explanation in any stellar scenario. These carbon stars might be alternative progenitors to SiC grains of AB type.
Our stars show a large spread in the 16O/17O/18O ratios similar to that observed in M, MS and S-type O-rich AGB stars and to that of group 1 of presolar oxide grains.
A few of them show very high 16O/18O (similar to that of group 2 of oxide grains), which might be also explained by the operation of an extramixing mechanism. Nevertheless, the 12C/13C and 14N/15N derived in these stars are at odd with this hypothesis. In addition, we find a few stars with 18O excesses that, when compared with oxide presolar grains from AGB stars, might reveal variations in the interstellar medium chemical composition. Interestingly, many N-type stars show 16O/17O > 1000. These large ratios have not an easy explanation according to the standard low mass AGB models. The most simple explanation for that, together with their observed 12C/13C and 14N/15N ratios, would be to admit that these carbon stars have masses below 1.5 Mo, which

would decrease the currently theoretical accepted lower mass-limit for a star to become an intrinsic carbon stars at near solar metallicity.
Finally, for the only eight stars where we derive the four isotopic ratios, we
do not find any astrophysical scenario able to explain them simultaneously. This poses a challenge to the current theory on the evolution and nucleosynthesis of low mass stars.

**12**

# Alloys-rich Extraterrestrial Debris in Ferruginous Palaeosol from the Libyan Desert Glass Strewnfield, SW Egypt: Evidence of a Quirky Comet Origin

**Authors:** Jan Kramers[1]; Marco Andreoli[2]; Mario Di Martino[3]

**Co-authors:** Alexander Ziegler [4]; George Belyanin [1]; Hassina Mouri [5]; Ingrid Stengel [6]; Karl Rumbold [7]; Lesley Chown [8]; Marion Bamford [9]; Roger Gibson [10]; Romano Serra [11]; Simo Huotari [12]; Vittoria Pischedda [13]; Zubair Jinnah [2]

[1] *Department of Geology, University of Johannesburg, Johannesburg, South Africa*

[2] *School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa*

[3] *INAF –Osservatorio Astrofisico di Torino, Pino Torinese, Italy*

[4] *Microscopy and Microanalysis Unit, University of the Witwatersrand, Johannesburg, South Africa*

[5] *3 Department of Geology, University of Johannesburg, Johannesburg, South Africa*

[6] *Polytechnic of Namibia, Windhoek, Namibia*

[7] *School of Molecular and Cell Biology, University of the Witwatersrand, Johannesburg, South Africa*

[8] *School of Chemical and Metallurgical Engineering, University of the Witwatersrand; DST-NRF Centre of Excellence in Strong Materials, hosted by University of the Witwatersrand, Johannesburg, South Africa Johannesburg, South Africa*

[9] *Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[10] *School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa,*

[11] *Dipartimento di Fisica e Astronomia, Università di Bologna, Italy*

[12] *University of Helsinki, Helsinki, Finland*

[13] *ILM, Université de Lyon 1, Villeurbanne, France*

**Corresponding Author:** marco.andreoli@wits.ac.za

The discovery of a diamond-bearing carbonaceous pebble in the Libyan Desert Glass (LDG) area of SW Egypt was made in 1996 by A. Barakat, an Egyptian geologist. Subsequent investigations have demonstrated its extraterrestrial origin, either as a shocked comet relic [Kramers et al., EPSL 382 (2013), 21-31; Andreoli et al., Nuclear Instruments and Methods B 363 (2015), 79-85] or an unusual meteorite [Avice et al., EPSL 432 (2015), 243-253].

An expedition to the area by some of the authors (MDM, RS) failed to recover similar material, but returned with samples of goethite-cemented, pebbly sandstones of speculated Cenozoic age and the pedogenic characteristics widely represented in the region. One of these samples, less than 1 kg in mass, was crushed and digested in acids (aqua regia ± HF), followed by bromoform separation, to test for nanodiamonds in the heavy minerals fraction. This investigation is ongoing and involves several micro-analytical techniques, including scanning electron microscopy with energy dispersive X-ray spectroscopy and electron probe micro-analysis, synchrotron tomography and Laser Raman spectroscopy. In addition to aluminosilicates, pyrite, ilmenite, zircon and rutile, a large number of unusual metallic and carbonaceous grains have been identified. These grains have been divided into various Classes on the basis of their distinctive morphology and chemistry:

I) Individual flakes/rods of partially oxidized aluminium (with Si ± Bi or Fe; size: ˜50 µm x ˜80 µm), titanium with a laminar structure (0.76 mm x 0.23 mm x 0.18 mm [**not** typing errors!]), or Sn ± Ca with traces of Cu (˜ 1.0 mm x 0.2 mm).

II) Clusters of sintered spherules, filaments and grains of (almost) pure metals, or alloys and ceramics. Most prominent are two clusters of titanium with 0.7 wt. % Al, quenched gas cavities, and chondritic isotope ratios (E. Zinner, unpublished data). These clusters are up to 1.27 mm x 0.73 mm in size and include rare grains of aluminium oxycarbonitride (up to 28 µm x 6 µm), titanium aluminide, non-stoichiometric titanium nitrides and pure silver. A 260 µm x 180 µm cluster of Pb grains, each ˜2 µm in length, was also identified.

III) Single, spherical to ovoid particles (partly oxidized in places) consisting of metallic Ti, Ag, Si (± Al, Ca, S) compounds in variable proportions (size range: <1 µm up to 20 µm).

IV) Glassy, pale green spherical to ovoid spherules of P-Si compounds with near-equiatomic P:Si and minor, variable amounts of O ± Al, up to 100 µm x 130 µm in size.

V) Tiny (sub-micron to ≤ 20 µm) grains of Sn-Pb and Zr-Pb alloys, or Zr, Zn and Ag, with the latter being occasionally found also attached to the surface of Class II titanium clusters.

VI) Hard grains of carbon nitrides (CxNy» O, S, Cl) up to 67 µm x 46 µm in size.

VII) Carbonaceous to sub-graphitic thin films and delicate filaments (the latter up to ˜300 µm long) coating/protruding over sections of the Class-I and -II grains.

Purely on the basis of morphologically visible textural relationships and published phase diagram data for titanium and the abovementioned alloys, the Class-I aluminium alloy and almost pure titanium grains have been tentatively interpreted as being the oldest, least altered of all the Classes identified to date. The Class-II and -III grains and spherules have thus been interpreted as deriving from the Class I grains due to heating at temperatures in excess of 1668 ℃, the melting point of titanium [M.J. Donachie, Titanium: a Technical Guide, 2nd Ed., ASM Int.(2000)].

It is very difficult to interpret these sediment-derived metallic and carbonaceous grains on the basis of anthropogenic or geological/meteorite source models such as fulgurites, typical cosmic spherules, metal-rich meteorites, GEMS, or impact-related melts/carbonaceous matter. Instead, the presence of grains of nearly pure Ag and Al metal and ˜1 mm long filaments of nearly pure titanium within the Hypatia stone [Andreoli et al., 2015 (see above); G. Belyanin, unpublished data] support the stone' s common origin with the grains described above. If this conjecture were to be proved correct, the carbonaceous grains, films and filaments (Class-VI and -VII) possibly formed on the metals after the inclusion of the latter in cold, thermally unprocessed carbonaceous dust represented by the Hypatia stone [Andreoli et al., op. cit.]. The authors conclude that the LDG area may be underlain by the partly eroded remnants of a regional strewnfield with minerals from the airburst/impact of a comet. However, our finds show that such a comet may represent a type so far unrecognized either from remote spectral analyses, or from sampling missions by space probes and IDP-sampling flights.

**22**

## Stellar Ages in the Kepler Era

**Author:** George Angelou[1]

**Co-authors:** Earl Bellinger [2]; Elisabeth Guggenberger [1]; Sarbani Basu [3]; Saskia Hekker [4]; Warrick Ball [5]

[1] *Max Planck Institute fur Sonnensytemforschung*

[2] *Max Planck Insitute fur Sonnensystemforschung*

[3] *Yale University*

[4] *Max Planck Institute fur Sonnensystemforschung*

[5] *Georg-August-University*

**Corresponding Author:** george.angelou@gmail.com

Asteroseismology provides the opportunity to constrain the ages of stars through accurate inferences of their interior structures. This in turn drives a wide range of applications in astrophysics, such as characterising extrasolar planetary systems, assessing galactic chemical evolution, and performing

ensemble studies of the Galaxy. Obtaining accurate ages, however, is not without its difficulties. For the most part stellar ages are model dependent and subject to the uncertainties therein. We summarize the different methods available to determine the ages of stars.

We have recently developed machine learning methods for instantly estimating fundamental stellar parameters such as the age, mass, and chemical composition of main-sequence solar-like stars from classical and asteroseismic observations. We demonstrate our method on the Sun, 16 Cyg A \& B, twenty-two \emph{Kepler} planet hosting stars, as well as recover the results from 10 SpaceInn Hare \& Hound simulation exercises. We find that our estimates and their associated uncertainties are comparable to the results of other methods, but with the additional benefit of needing practically zero computation time. In the case of 16 cyg A and B our prediction and uncertainties for the stellar radii match that currently provided by interferometry.

**53**

# Gd and Dy isotopic compositions in presolar SiC grains from AGB stars

**Author:** Janaina Avila[1]

**Co-authors:** Amanda Karakas [2]; Ernst Zinner [3]; Frank Gyngard [3]; Maria Lugaro [4]; Trevor Ireland [1]

[1] *Australian National University*

[2] *Monash University*

[3] *Washington University*

[4] *Konkoly Observatory*

**Corresponding Author:** janaina.avila@anu.edu.au

The *s*-process nucleosynthesis in the Eu-Gd-Tb-Dy path is strongly sensitive to neutron density and temperature during thermal pulses in AGB stars, being affected by several branching points (e.g. $^{152,154,155}$Eu, $^{153,159}$Gd, $^{163}$Dy). New neutron capture cross sections for several isotopes in this mass range have been recently reported, helping to better constrain the *s*-process abundances obtained by astrophysical models. Here we report the results of Gd and Dy isotopic analyses performed on a SiC-enriched bulk sample (KJB fraction) and on large presolar SiC grains extracted from the Murchison carbonaceous chondrite. We have compared the SiC data with theoretical predictions of the evolution of Gd and Dy isotopic ratios in the envelopes of low-mass AGB stars with a range of stellar masses and metallicities. There is an overall match between the SiC data and the theoretical predictions. The SiC grains appear to be depleted in $^{155,156,157,160}$Gd relative to $^{158}$Gd and depleted in $^{161,162,163}$Dy relative to $^{164}$Dy, as expected for *s*-process nucleosynthesis in AGB stars.

**52**

# Galactic chemical evolution: the impact of AGB stars

**Author:** Sara Bisterzo[1]

**Co-authors:** Alexander Heger [2]; Benoit Cote [3]; Claudia Travaglio [4]; Franz Karl Kaeppeler [5]; Marco Pignatari [6]; Michael Wiescher [7]

[1] *INAF - Astrophysical Observatory Turin*

[2] *Monash Centre for Astrophysics, Monash University, Melbourne, Australia*

[3] *Department of Physics and Astronomy, University of Victoria, Canada*

[4] *INAF - Astrophysical Observatory of Turin, Italy*

[5] *Forschungszentrum Karlsruhe GmbH (FZK)-Karlsruhe Institute of Te*

[6] *Department of Physics & Mathematics, University of Hull, UK*

[7] *University of Notre Dame*

**Corresponding Author:** sarabisterzo@gmail.com

The last generation of telescopes has revolutionized our understanding of the chemical evolution and star formation histories of the Milky Way and its satellites. Several elements have been detected with high resolution spectroscopy, and has provided powerful instruments to understand the contribution coming from different stellar generations.

Stars have different lifetimes (depending on their initial mass and metallicity) and, at the end of their evolutionary phases, they lose mass through stellar winds polluting the interstellar medium with newly synthesized elements (see e.g., Prantzos 2008, Nomoto et al. 2013).
Short-lived massive stars ($M \geq 8$ $M_o$) explode as Supernovae of Type II (SNeII), efficiently producing alpha elements like O and Mg (see e.g., Rauscher et al. 2002). They are also the main site for the weak s process, which synthesizes most of the s-process abundances in the solar system between iron and strontium (Pignatari et al. 2013).
Despite a clear scenario is not available, the origin of the rapid neutron capture process (r-process), like Eu, is ascribed to Supernovae events or neutron mergers (see review by Thielemann et al. 2011, and references therein). A multiplicity of r-process components has been discovered to operate in the early Galaxy (Roederer et al. 2010), and an additional primary contribution is being explored to account for a complementary light r contributions of nuclei with A ˜ 80 to 120 (Travaglio et al. 2004; Arcones & Thielemann 2013 and references therein).
Long-lived low-mass stars ($M \sim 1$ to 8 $M_o$) during their asymptotic giant branch (AGB) phase synthesize C and slow neutron capture (s-process) elements (like Sr, Y, Zr, Ba, La, Pb), and then extinguish as white dwarfs (Kaeppeler et al. 2011 and references therein).
Binary systems formed by stars of low mass, after accretion of material from the companion, violently explode as Supernovae of Type Ia (SNeIa), mainly ejecting Fe and other elements belonging to the iron group (see e.g., Travaglio et al. 2011, and references therein).

Self-consistent information can only be obtained through a comprehensive chemical analysis of the alpha-, s- and r-process elements available in literature.
Specifically, the ratio of a given element to iron reflects the details of the star formation history. Given that Fe is largely produced by long-lived SNeIa, while O and Mg are almost totally produced by short-lived SNeII, the behavior of the [O,Mg/Fe] ratio versus metallicity [Fe/H] is a commonly used chronometer of the star formation history. Similarly, the analysis of s-process elements, e.g., [Ba,La/Fe], provides information about the contribution by long-lived low-mass AGB stars, while [Eu/Fe] indicates the contribution by the r-process.
An eventual scattering in [El/Fe] at low metallicity (corresponding to the early evolutionary –metal-free –phases of a galaxy having seen the contribution by few short-lived SNeII) indicates inhomogeneous mixing of the interstellar medium.

AGB stars with low initial mass ($M < 4$ $M_o$) are the major responsible for the nucleosynthesis of the solar s-process isotopes with A $>$ 90 in our Galaxy. We study the solar abundances of heavy s isotopes at the epoch of the formation of the solar system as the outcome of nucleosynthesis occurring in AGB stars of various masses and metallicities. At present, one of the major uncertainties of AGB stellar model is the formation of the $^{13}$C pocket, a thin layer at the top of the He-intershell where the major neutron source of low-mass AGB stars, the $^{13}C(\alpha, n)^{16}O$ reaction, is activated (see e.g., Herwig 2005, Straniero et al. 2006). The internal structure of the $^{13}$C pocket may depend on the initial mass and metallicity of the AGB and on the physical mechanisms that may compete inside the star itself.

We present a revised GCE model, which accounts for an improved interpretation of the thick and thin disk stars behavior observed in the solar neighborhood.

The model includes two infall events that reproduce halo, thick- and thin-disc phases. Star formation rate (SFR) and major GCE inputs (e.g., initial mass function, treatment of SNIa, and stellar yields) have been tested and revised accordingly. GCE uncertainties are constrained by the several observables in the solar neighborhood (e.g., solar abundances, metallicity distribution functions and age-metallicity relation in the thick- and thin-disc components, present ratio of SNII over SNIa rates, observed chemical abundances of several indicative chemical elements and their ratios).

We investigate the impact of different AGB yields available in literature (see e.g., Set-1 NuGrid models, Pignatari et al. 2016; as well as STARS and Monash/Mount Stromlo models, Lugaro et al. 2012; Karakas, Marino, & Nataf 2014; FUNS, Cristallo et al. 2015).
The implications of updated yields of super-AGB stars, Electron-Capture SNe, Core-Collapse SNe, Jet-SNe on heavy elements are discussed (e.g., Frischknecht et al. 2016; Nishimura et al. 2015; Doherty et al. 2015)
and possible indications on the origin of elements characteristic of the weak- and main-r processes are examined.
Elements particularly sensitive to improved 3D calculations of SNIa in an extended range of metallicities are highlighted.

References:
Arcones & Thielemann, 2013, J. Phys. G: Nucl. Part. Phys., 40, 013201;
Doherty, C. L. et al. 2015, MNRAS, 446, 2599;
Frischknecht, U. et al. 2016, MNRAS, 45, 1803;
Herwig, F. 2005, ARA&A, 43, 435;
Kaeppeler, F. et al. 2011, Rev. Mod. Phys., 2011, 83, 157;
Karakas, A. I. & Lattanzio, J. C. 2014, PASA, 31, 30;
Karakas, A. I., et al. 2014, ApJ, 784, 32;
Nishimura, N. et al. 2015, ApJ, 810, 109;
Nomoto, K., Kobayashi, C., Tominaga, N. 2013, ARA&A, 51, 457;
Pignatari, M. et al. 2013, ApJ, 762, 31;
Prantzos, N. 2008, EAS Publications Series, 32, 311;
Rauscher, T. et al. 2002, ApJ, 576, 323;
Roederer, I. et al. 2010, ApJ, 724, 975;
Straniero, O. et al. 2006, NuPhA, 777, 311;
Thielemann et al. 2011, Progress in Particle and Nuclear Physics, 66, 346;
Travaglio, C. et al. 2004, ApJ, 601, 864;
Travaglio, C. et al. 2011, ApJ, 739, 93.

**13**

## Toward a non-parametric coupling of nucleosynthesis and mixing in evolved low mass stars.

**Author:** Maurizio Maria Busso[1]

**Co-author:** Sara Palmerini [2]

[1] *University of Perugia*

[2] *Università degli Studi di Perugia - INFN sez. Perugia*

**Corresponding Author:** maurizio.busso@unipg.it

Mechanisms for inducing the circulation of matter below the convective envelopes of evolved red giants and AGB stars, permitted by the peculiar properties of plasma physics there valid, are found to answer a number of so far open questions on the coupling of nucleosynthesis and deep mixing in low mass stars. Applications of these mechanisms in phases where p-, alpha. and n-capture nucleosynthesis modify the envelope composition is discussed and encouraging comparisons with observations are illustrated.

**44**

## The Case of the Missing AGB Stars in Globular Clusters

**Author:** Simon Campbell[1]

[1] *Max-Planck-Institut für Astrophysik (MPA)*

**Corresponding Author:** simwcampbell@gmail.com

Galactic Globular clusters (GCs) are not as simple as once thought - they all consist of two or more stellar populations that are chemically distinct in light element abundances. Although this makes GCs more complex it also opens up the possibility of making differential comparisons between stellar populations that are otherwise very similar in age, distance, and heavy element composition. Stellar evolution can be 'tracked' by the chemical tagging of each subpopulation at each evolutionary phase.

Doing this shows that the multiple populations in GCs show no variation in relative proportions for all phases of evolution - except the AGB. In some cases the proportion of the field-star-like population (eg. low Na, high O) becomes 100% on the AGB. This appears to indicate that the other population(s) avoid the AGB phase completely.

In this talk I will review observational efforts to identify this phenomenon which in the past year has been confirmed in a range of GCs by various groups. I will also review the theoretical efforts to explain it.

**63**

## The structure, formation and nucleosynthesis of THorne-Zytkow objects

**Author:** Ross Church[1]

**Co-authors:** Anna Zytkow [2]; Carolyn Doherty ; Christopher Tout [3]; Claire Worley [2]; Rob Izzard

[1] *Lund University, Sweden*

[2] *Institute of Astronomy, University of Cambridge*

[3] *University of Cambridge*

**Corresponding Author:** ross@astro.lu.se

In light of the discovery of HV 2112, a Thorne-Zytkow object candidate in the SMC, I discuss the structure, formation and nucleosynthesis of TZOs. I will show that the predicted formation rate is consistent with HV 2112 being a TZO, albeit with very large error bars, and explain why we think that theoretical concerns mean that it is likely not an SAGB star that has been polluted by a supernova. Finally I will briefly describe our work to calculate updated TZO models.

**34**

## AGB stars: interior vs exterior

**Author:** Sergio Cristallo[1]

**Co-authors:** David Gobrecht [1]; Luciano Piersanti [1]

[1] *INAF - Osservatorio Astronomico di Teramo*

**Corresponding Author:** sergio.cristallo@inaf.it

Asymptotic Giant Branch stars are among the most important polluters of the interstellar medium. Their rich nucleosynthesis occurs in a wide range of temperatures and densities. Atoms are produced in their interiors, via charged particle reactions and thanks to the slow neutron capture process (the s-process). In their atmospheres, when the temperature drops below 5000 K, oxygen and carbon bearing molecules form, depending on the local C/O ratio. Further away from the central star, in their cool and expanded circumstellar envelopes, molecules cluster, leading to the formation of dust grains. Currently, the latter are the most promising candidates to drive the mass loss of these stellar objects. To date, the above listed type of nucleosynthesis (atoms-molecules-grains) are a sort of "watertight compartments".
Therefore, we started a project aimed at theoretically reproducing the nucleation path of chemical species, starting from single atoms up to the formation of dust grains. In order to do that, we wrote "ab initio"and we are currently implementing the VULCAN code. VULCAN is a 1D hydrodinamic code, working in OpenMP architecture, coupled to a kinetic non-equilibrium network which includes about 100 molecules. The initial atomic composition and the physical internal boundary conditions are taken from the FUNS code, which follows the evolution and nucleosynthesis of AGB internal layers. In this talk, I will present the status of the project, highlighting pro and cons of our new approach to the problem.

**5**

## Barium abundances as diagnostics of stellar youth

**Author:** Valentina D'Orazi[1]

[1] *National Institute for Astrophysics - INAF*

**Corresponding Author:** valentina.dorazi@oapd.inaf.it

High-resolution spectroscopic studies focussing on abundance determination for slow n-capture process elements in open cluster stars, moving groups and young associations have revealed the presence of an anti-correlation between the barium abundance and the stellar/cluster age. The younger the cluster, the higher the Ba content. The reason of such a peculiar trend is yet to be understood and several aspects need to be deeply investigate; for instance we cannot ascertain whether the Ba enhancement is accompanied by a similar behaviour in the other slow n-capture elements (e.g., Y, Zr, La), that might imply a revision of the input physics in stellar evolution models. Regardless of the origin of this phenomenon, we can take advantage of the increasing trend in Ba abundance to provide an independent information on the star's youthfulness and on its (possible) membership to stellar clusters and associations.
The age determination is particularly critical for planet-host stars because it severely affects the calibration of the age-luminosity relationship for sub-stellar objects and is crucial to our understanding of how planets have formed (see e.g., the well known case of HR 8799).
We present in this contribution our results for barium abundance determination in open clusters, young associations as well as isolated, field stars known to host planetary companions and discuss the scientific implications.

**14**

## 7Be(n,$\alpha$) and 7Be(n,p) cross section measurement for the Cosmological Lithium Problem at the n_TOF facility at CERN

**Author:** Lucia Anna Damone[1]

[1] *Universita e INFN, Bari (IT)*

**Corresponding Author:** lucia.anna.damone@cern.ch

The primordial abundance of $^{7}$Li as predicted by Big Bang Nucleosynthesis (BBN) is more than a factor 2 larger than what has been observed in metal-poor halo stars. The abundance of $^{7}$Li is essentially linked to the production and destruction of $^{7}$Be. While the main reaction of the $^{7}$Be production is relatively well known, the same can not be said about the reactions responsible for its destruction.
The measurements of the reactions induced by charged particles on the $^{7}$Be excluded that those one induced by protons, deuterons or $^{3}$He could be responsible for the destruction of the $^{7}$Be. Instead the reactions induced by neutrons on the $^{7}$Be, in particular the (n,$\alpha$) and (n,p) reactions, could play an important role. Despite of the importance that these reactions could have in the BBN, there is a lack on the cross section data.
Based on the characteristic features of the second experimental area of n_TOF facility at CERN, e.g. the very high instantaneous neutron flux, the high resolution, and the low background conditions, accurate measurements of the (n,$\alpha$), (n,p) cross sections have been performed for $^{7}$Be isotope with the aim to improve the evaluations reliability on the BBN.
The results obtained so far, and future plans for improving the accuracy of the $^{7}$Be(n,p) cross-section, will be here presented.

**49**

# Iron and nickel isotopes in presolar SiC grains

**Author:** Andrew Davis[1]

**Co-authors:** Detlef Rost [1]; Frank Gyngard [2]; Michael Pellin [3]; Michael Savina [4]; Nicolas Dauphas [1]; Reto Trappitsch [1]; Thomas Stephan [1]

[1] *University of Chicago*

[2] *Washington University in St Louis*

[3] *Argonne National Laboratory*

[4] *Lawrence Livermore National Laboratory*

**Corresponding Author:** a-davis@uchicago.edu

We report the first measurements of all iron and all nickel isotopes, measured in 74 presolar SiC grains. The measurements were made using laser desorption with a 351 nm laser focused to <1 µm and laser resonance ionization with six tunable Ti:sapphire lasers with CHILI (the CHicago Instrument for Laser Ionization). The isobaric interference at mass 58 was resolved by delaying the firing of nickel ionization lasers by 200 ns relative to the iron ionization lasers. The SiC grains were analyzed for carbon and silicon isotopes by NanoSIMS prior to the CHILI analyses. Most of the SiC grains are mainstream grains, likely made in AGB stars of near-solar metallicity. These grains show a range of isotopic compositions that are in accord with models of AGB star nucleosynthesis, with the largest excesses in the most neutron-rich isotopes, 58Fe/56Fe (–100 to +400 permil) and 64Ni/58Ni (+100 to +1400 permil). There are also correlations of 54Fe/56Fe and 60Fe/58Fe with 29Si/28Si that are in qualitative agreement with galactic chemical evolution models. One Type X grain, likely from a core collapse supernova, has large excesses in 61Ni/58Ni and 64Ni/58Ni of ˜1300 permil. Several grains of Types AB, Y and Z have patterns similar to those of mainstream grains. One Type Z grain has large excesses in 60Ni, 61Ni, 62Ni, and 64Ni of 1200, 600, 600, and 1500, respectively, all with respect to 58Ni, and may be from a Type II supernova. Both of the likely supernova grains have near-normal iron isotopic compositions. The iron and nickel isotopic compositions of presolar SiC grains provide a rich record with implications for galactic chemical evolution and stellar nucleosynthesis.

**20**

## AGB stars in the Local Group galaxies: evolution and dust production

**Author:** Flavia Dell'Agli[1]

[1] *INAF-Observatory of Rome*

**Corresponding Author:** flaviadellagli@gmail.com

Asymptotic giant branch stars are among the most important gas and dust polluters of the Universe. Based on updated AGB models, which account for dust formation in the circumstellar evelope, we characterised the AGB population of the Magellanic Clouds in terms of initial mass, age and metallicity of the individual stars observed. We extended the comparison to near- and mid- infrared observations of dwarf galaxies in the Local Group, providing useful constrains on the modelling and the star formation history of these galaxies.

**31**

## Impact of rotation and convective boundary mixing in low mass AGB stars

**Author:** Jacqueline Den Hartogh[1]

[1] *Keele University*

**Corresponding Author:** j.den.hartogh@keele.ac.uk

After the central He burning in exhausted, stars with an initial mass of 1.5-3 solar masses start the AGB phase. In this phase, the s-process takes place, which is producing about half of all elements heavier than iron. Our non-rotating AGB stellar models calculated with MESA (see Battino et al., submitted) include a treatment of convective
boundary mixing based on the results of hydrodynamic simulations and on the theory of mixing due to gravity waves in the vicinity of convective boundaries. We show examples of how the models compare with spectroscopic abundance observations and presolar grains measurements. In particular, our models reproduce the highest observed values of the s-process index [hs/ls]. On the other hand, the full range of the observed [hs/ls] as well as the laboratory measurement of Zr isotopic-ratios were not properly reproduced. A spread of initial rotational velocity in AGB stars might help to improve this. We are calculating stellar evolution models including both rotation and the above described ingredients, enabling us to analyse their interplay and the impact on s-process efficiencies.

**24**

## The i-process nucleosynthesis in post-AGB and rapidly-accreting white dwarf stars

**Author:** Pavel Denisenkov[1]

[1] *University of Victoria*

**Corresponding Author:** pavel.denisenkov@gmail.com

The H-rich material rapidly accreted by a carbon-oxygen white dwarf in a close binary system burns under stationary conditions, which results in an accumulation of a He shell. Later on, when the He shell experiences a thermal flash, convection driven by the flash may penetrate the H-rich envelope, ingesting H into the He convective shell. This may trigger the i process of neutron capture by heavy isotopes with a density of neutrons intermediate between those characteristic for the s and r processes. The resulting nucleosynthesis goes along the path that is 4 or 5 neutrons away from the valley of stability. The i process may also occur in a single post-AGB star if its He shell experiences a very late thermal pulse. I will present and discuss the new results of our recent analysis of nuclear and stellar physics uncertainties that can affect theoretical predictions of the i-process nucleosynthesis yields from these stars.

**2**

# Low-Energy resonances in the $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction directly observed at LUNA

**Author:** Rosanna Depalo[1]

[1] *University of Padova and INFN Padova*

**Corresponding Author:** rosanna.depalo@pd.infn.it

The NeNa cycle of hydrogen burning influences the synthesis of the elements between $^{20}$Ne and $^{27}$Al in AGB stars and classical novae explosions.
Among the reactions of the NeNa cycle, the $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction rate is the most uncertain because of a large number of unobserved resonances lying in the Gamow window.
A new direct study of the $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction has been performed at the Laboratory for Underground Nuclear Astrophysics (LUNA) using a windowless gas target and two HPGe detectors.
Three resonances have been observed for the first time in a direct experiment. Moreover, improved upper limits are provided for the unobserved resonances.
The experimental method and results will be discussed. The updated $^{22}$Ne(p,$\gamma$)$^{23}$Na reaction rate calculated including the new LUNA results will also be shown.

**28**

# Bye-bye KADoNiS: The Final Act!

**Author:** Iris Dillmann[1]

**Co-authors:** Alberto Mengoni [2]; Franz Kaeppeler [3]; Ralf Plag [4]; Thomas Rauscher [5]

[1] *TRIUMF*

[2] *ENEA Bologna*

[3] *Karlsruhe Institute of Technology, Campus Nord*

[4] *Uni Frankfurt and GSI Darmstadt*

[5] *University of Basel / University of Hertfordshire*

**Corresponding Author:** dillmann@triumf.ca

The "Karlsruhe Astrophysical Database of Nucleosynthesis in Stars" project has been launched 12 years ago by two brave, highly motivated and maybe a little crazy PhD students, supported by a team of exceptional scientists. After 3 intermediate updates it is time for the final act: KADoNiS v1.0 will be the last version provided by the original team and published in paper form like its precursors.

In this talk I will summarize what has been achieved, show the latest recommended MACS and some major changes compared to earlier versions, and give some advice where new measurements should be carried out.
And finally I will solve the most important question every user might have: why the hell do you have a yellow pyramid in the logo???

**55**

## Monash Chemical Yields Project (Monχey) - Element production in low- and intermediate-mass stars of metallicities Z = 0 to 0.04

**Author:** Carolyn Doherty[1]

**Co-authors:** Amanda Karakas [2]; George Angelou [3]; John Lattanzio [2]; Maria Lugaro [4]; Pilar Gil-Pons [5]; Richard Stancliffe [6]; Ross Church [7]; Sergio Cristallo [8]; Simon Campbell [9]; Thomas Constantino [10]

[1] *Konkoly Observatory MTA CSFK*

[2] *Monash University*

[3] *Max Planck Institute fur Sonnensytemforschung*

[4] *Konkoly Observatory, MTA CSFK*

[5] *Departament de Física, Univ. Politècnica de Catalunya*

[6] *Argelander-Institut für Astronomie, Bonn, Germany*

[7] *Department of Astronomy and Theoretical Physics, Lund University*

[8] *National Institute for Astrophysics - INAF*

[9] *MPA Garching*

[10] *University of Exeter*

**Corresponding Author:** carolyn.doherty@csfk.mta.hu

The Monχey project will provide a large and homogeneous set of stellar yields from H to Bi for the low- and intermediate- mass stars. I present preliminary results from our grid of stellar evolutionary models and corresponding nucleosynthetic yields. When complete this detailed grid will contain over 800 stars of initial mass 0.8 $M_\odot$ up to the limit for core collapse supernova ≈ 10 $M_\odot$ and cover a broad range of metallicities, ranging from the first, primordial stars (Z=0) to those of super-solar metallicity (Z=0.04). I briefly introduce our easy to use web-based database which provides the evolutionary tracks, structural properties, internal/surface nucleosynthetic compositions and stellar yields.

**18**

## The connection between thermonuclear SNe and previous evolutionary phases

**Author:** Inma Dominguez[1]

**Co-authors:** Amedeo Tornambé [2]; Eduardo Bravo [3]; Luciano Piersanti [4]; Oscar Straniero [4]; Sergio Cristallo [5]

[1] *Universidad de Granada*

[2] *INAF-OAR*

[3] *UPC*

[4] *INAF-OAT*

[5] *INA-OAT*

**Corresponding Author:** inma@ugr.es

Thermonuclear explosions of CO WDs (SNIa) are important tools for cosmology. Based on their observations, the recent acceleration and previous deceleration of the expansion rate of the Universe have been measured, in agreement with a 70% of the energy-matter content of the Universe in form of an exotic component, called dark energy. To constrain the nature of the dark energy, based on SNe Ia Hubble diagrams, it is necessary to decrease the current dispersion in the SNIa calibration relation. Observational data show a link between SNe Ia and their host galaxies: galaxies

with on-going star formation host brighert SNIa and show higher SNIa rates. Models and observations agree that brighter SNIa require more 56Ni synthesized during the explosions. However, Why CO WD explosions associated with young enviroments should produce more 56Ni ? This question challenges our understanding. In this talk, we will discuss the physical properties of the progenitor systems which may influence the observed properties of SNe Ia. In particular, we will present recent numerical stellar evolution simulations of low and intermediate mass stars, including the accretion and hydrostatic carbon burning phases. Does this last phase emphasize or delete the hints of the previous evolution ?

**47**

## Chemically-Deduced Star Formation Histories of Dwarf Galaxies

**Author:** Gina Duggan[1]

**Co-author:** Evan Kirby [1]

[1] *California Institute of Technology*

**Corresponding Author:** gduggan@caltech.edu

Dwarf galaxies provide a relatively simple test case where individual stellar spectra can produce precise star formation histories. Knowledge gained in these systems will inform the details of early star formation in galaxies and how it is affected by various physical processes and other galaxies. I will be presenting barium abundance measurements of hundreds of red giant stars in several satellite dwarf spheroidal galaxies and globular clusters. Spectra obtained with Keck/DEIMOS medium-resolution spectroscopy were fitted with synthetic spectra generated around six strong barium absorption lines available in the optical. Iron predominantly traces Type Ia supernovae, and barium predominant traces asymptotic giant branch stars. The different timescales of these two nucleosynthetic sources can be used to measure a finely resolved chemically-deduced star formation history, especially when combined with existing [alpha/Fe] measurements.

**21**

## Presolar Silicate Grains: What Have We Learned?

**Author:** Christine Floss[1]

[1] *Washington University, Physics Dept.*

**Corresponding Author:** floss@wustl.edu

In the inventory of presolar grains, silicates represent a special case. Although astronomical observations suggested the presence of abundant silicates in the circumstellar outflows of evolved O-rich stars, they were the last major type of presolar grain to be identified. Their enhanced susceptibility to destruction, compared to other more refractory presolar phases, means that they are only found in the most primitive extraterrestrial samples, those that have largely escaped aqueous alteration and thermal metamorphism. Moreover, unlike most other presolar grain types, presolar silicates cannot be isolated by acid dissolution techniques because they are dissolved during this process along with the solar system silicates that dominate the meteorites in which presolar grains are found.

I will discuss (briefly) the technical developments that led to the discovery of presolar silicate grains, including the contributions of Ernst Zinner, and review what we have learned about these grains and their stellar sources in the last ten years.

**51**

## What do observations in CEMP-s stars tell us about the 13C-pocket srtucture in AGB stars?

**Author:** Sara Bisterzo[1]

**Co-authors:** Claudia Travaglio [2]; Franz Karl Kaeppeler [3]; Michael Wiescher [4]; Oscar Straniero [5]; Roberto Gallino [6]; Sergio Cristallo [5]

[1] *INAF - Astrophysical Observatory Turin*

[2] *INAF - Astrophysical Observatory of Turin, Italy*

[3] *Forschungszentrum Karlsruhe GmbH (FZK)-Karlsruhe Institute of Te*

[4] *University of Notre Dame*

[5] *INAF - Osservatorio Astronomico di Collurania, Teramo, Italy*

[6] *University of Torino*

**Corresponding Authors:** gallino@ph.unito.it, sarabisterzo@gmail.com

We provide an updated discussion of the sample of CEMP-s (and CEMP-s/r) stars, collected from the literature. Observations are compared with theoretical nucleosynthesis models of asymptotic giant branch (AGB) stars in the light of the most recent spectroscopic results.
The high enhancement in carbon and s-process elements observed in CEMP-s stars is currently produced by the primary star during the AGB phase, and subsequently transferred by stellar winds onto the low-mass companion, which is the star observed today.
The origin of CEMP-s/r stars is largely debated (Jonsell et al. 2006; Bisterzo et al. 2011; Lugaro et al. 2012); recent studies attribute the peculiar pattern observed in these objects to an intermediate astrophysical process, the i-process (Dardelet et al. 2015; Abate et al. 2016), with very promising preliminary results.

Starting from our post-process AGB models, we investigate the impact of different internal structures of the 13C-pocket on Carbon and the three s-process peaks, and compare the results with updated observational hints from CEMP-s (and CEMP-s/r) stars.
This systematic study provides significant constraints on theoretical models at low metallicities, and help in guiding future computing efforts (supported by a more realistic physical inputs).
Main results and possible physical scenarios are discussed.

References:
Abate, C. et al. 2016, A&A 587, A50;
Bisterzo, S. et al. 2011, MNRAS, 418, 284;
Dardelet, L. et al. 2014, PoS, XIII Nuclei in the Cosmos, 7-11 July, Debrecen, Hungary;
Jonsell, K. et al. 2006, A&A 451, 651;
Lugaro, M. et al. 2012, ApJ, 747, 2.

**58**

## The impact of the discovery of presolar grains on theoretical studies of the s-process: a two decades of fabulous interaction with Ernst Zinner

**Author:** Roberto Gallino[1]

[1] *Universita' di Torino*

**Corresponding Author:** gallino@ph.unito.it

The discovery of presolar grains carrying the isotopic signature of the s-process in abundant trace heavy elements and in light and heavy nobel gases boosted a unique opportunity of stellar nucleosynthesis studies of the s-process in low mass Asymptotic Giant branch stars as well as of the presupernova nucleosynthesis in massive stars in the last phases of core He burning and in the following convective shell Carbon burning
phases. The incredible precision in the measurement in the lab of isotopic ratios measured in trace elements carried by presolar grains was an incomparable advancement in the study of the stellar origin of the s process, given that the spectroscopic analysis of stars of various spectral classes typically provide information on the heavy elements abundances, not on their isotopic distribution. The synergy between the "washu" group leaded by Ernst Zinner and the so-called "Torino group" gave rise to around 50 publications present
in the NASA ADS collection. I will briefly point out the scientific excursus of these studies.

**10**

# GK Car and GZ Nor: Two depleted stars with different IR-excess properties

**Author:** Ilknur Gezer[1]

**Co-authors:** Hans Van Winckel [2]; Zeynep Bozkurt [3]

[1] *Astronomy and Space Science Department, Ege University*

[2] *Instituut voor Sterrenkunde, KU Leuven*

[3] *Ege University Astronomy and Space Science Department*

**Corresponding Author:** gezer.ilknur@gmail.com

We present a chemical abundance analysis of two post AGB stars GK Car and GZ Nor, on the basis of high-resolution optical spectra which are obtained with UVES high-resolution optical spectrograph of the VLT located at the UT2. GK Car is a RV Tauri pulsator with 27.6 day period. Thanks to period-luminosity relation given by Alcock et al. 1998, we defined luminosity and also we determined distance calculating total flux of the Kurucz model for GK Car. GZ Nor is a quite faint W Virginis variable hence there is not enough photometric data to define accurate period therefore luminosity for GZ Nor. Both stars are member of population II Cepheid variables. The selection criterion for the stars are their different IR properties hence their positions in our recently defined WISE colour-colur diagram (Gezer et al. 2015). Both stars have IR-excess starting at 2MASS K. While SED of GK Car shows a broad IR-excess indicating for the presence of a stable compact dusty disc, GZ Nor displays an unclear IR-excess in its SED. With an [Fe/H]=-1.32 and [Zn/Ti]=+1.24 for GK Car and a [Fe/H]=-1.76 and [Zn/Ti]=+0.71 for GZ Nor, both stars display depletion of refractory elements in their photospheres. With our results we show that depletion extends to W Vir stars.

**25**

# Silicon Carbide stardust formation

**Author:** David Gobrecht[1]

**Co-authors:** Luciano Piersanti [2]; Sergio Cristallo [2]; Steafan Bromley [3]

[1] *National Institute for Astrophysics - INAF*

[2] *INAF*

[3] *IQTCUB, ICREA*

**Corresponding Author:** gobrecht@oa-teramo.inaf.it

SiC grains are considered as one of the major AGB wind-driving species, owing to their opacity to stellar radiation and their thermal stability. However, their nucleation path is not yet fully understood. Experimental as well as theoretical rates for the gas phase, cluster and grain formation are lacking. In particular, the transition from small molecular clusters to the well-ordered crystalline β-SiC with alternating Si-C bonds is unknown.

We develop a bottom-up approach for SiC nucleation reflecting the growth of these clusters and accounting for the various thermodynamic conditions prevailing in the circumstellar envelope and the inner wind. Moreover, we assess SiC nucleation pathways and rates by structural and energetic inspection and eventually include them in a chemical-kinetic network following the molecule and dust formation in AGB stars.

Finally, we present new results on small SiC clusters ((SiC)n, n=1-20) with sizes of 2-20 Angstroems. The energetically most favourable isomers are characterised by planar and cage-like structures as well as atom-segregated 5-and 6 member C-rings. Some of these clusters are found for the first time by means of molecular dynamics simulations and subsequent refinement on the quantum level of theory. The resulting vibrational modes and its corresponding infrared spectra are compared to observations and allows us to concretely identify structures.

**27**

## 22Ne(a,n) revisited

**Authors:** Joachim Goerres[1]; Rashi Talwar[2]

[1] *University of Notre Dame*

[2] *Argonne National Laboratory*

**Corresponding Author:** joachim.goerres.1@nd.edu

The 22Ne(a,n)25Mg reaction is the main neutron source for the weak s-process in massive stars. Despite large efforts to measure this reaction directly, large uncertainties remain. In addition one also needs to know the reaction rate of the directly competing reaction 22Ne(a,g). To improve the situation we have measured the nuclear structure in 26Mg above the alpha-threshold to find natural parity states using the 22Ne(a,a') reaction and to locate alpha-cluster states with the help of the alpha-transfer reaction 22Ne(6Li,d). These measurements were performed at the Research Center of Nuclear Physics at Osaka University and the results indicate a reduction of the neutron production.

**62**

## Experimental study of hydrogen burning reactions in wide energy ranges

**Author:** György Gyürky[1]

[1] *Institute for Nuclear Research (Atomki) Hungary*

**Corresponding Author:** gyurky@atomki.mta.hu

In various processes of hydrogen burning - from the pp chains to advanced CNO cycles - many nuclear reactions play important roles in the energy generation and nucleosynthesis of stars. Cross section data of these reactions are certainly needed in order to provide input for stellar models. Experimental studies of these reactions typically concentrate to the lowest possible energies, but extrapolations to stellar energies still cannot be avoided. Measurements at higher energies, on the

other hand, are often neglected, although theory-based extrapolations require data in wide energy ranges.

An experimental program is therefore in progress at the Institute for Nuclear Research with the aim of studying some hydrogen burning reactions in wide energy ranges using the activation method. Reactions such as 3He(a,g)7Be, 17O(p,g)18F and 14N(p,g)15O are being studied. Details of the investigations as well as some preliminary results will be presented.

**23**

## First in-situ laboratory identification of a CO Nova Graphite and a Presolar Iron Sulfide

**Author:** Pierre Haenecour[1]

**Co-authors:** Alian Wang [1]; Christine Floss [1]; Frank Gyngard [1]; Jordi José [2]; Katharina Lodders [1]; Manavi Jadhav [3]; Sachiko Amari [1]

[1] *Washington University in St. Louis*

[2] *Universitat Politècnica de Catalunya*

[3] *University of Louisiana at Lafayette*

**Corresponding Author:** haenecour@wustl.edu

Presolar grains constitute remnants of stars that existed before the formation of the solar system. In addition to providing direct information on the materials from which the solar system formed, these grains provide ground-truth information for models of stellar evolution and nucleosynthesis. Here we report the in-situ identification of two unique presolar graphite grains from the primitive meteorite LaPaz Icefield 031117. Based on these two graphite grains, we estimate a bulk presolar graphite abundance of ˜5 ppm in this meteorite. One of the grains (LAP-141) is characterized by an enrichment in 12C and depletions in 33,34S, and contains a small iron sulfide subgrain, representing the first unambiguous identification of presolar iron sulfide. The other grain (LAP-149) is extremely 13C-rich and 15N-poor, with one of the lowest 12C/13C ratios observed among presolar grains. Comparison of its isotopic compositions with new stellar nucleosynthesis and dust condensation models indicates an origin in the ejecta of a low-mass CO nova. Grain LAP-149 is the first putative nova grain that quantitatively best matches nova model predictions, providing the first strong evidence for graphite condensation in nova ejecta. Our discovery confirms that CO nova graphite and presolar iron sulfide contributed to the original building blocks of the solar system.

**50**

## Classical Novae: A Case for 2D Stellar Evolution

**Author:** Ghina Halabi[1]

**Co-authors:** Christopher Tout [1]; Jordi Jose [2]; Rob Izzard [1]

[1] *University of Cambridge*

[2] *UPC, Barcelona*

**Corresponding Author:** gmh@ast.cam.ac.uk

In this contribution a series of nova models will be presented. The models are calculated with state-of-the-art chemical profiles based on new evolutionary sequences of intermediate-mass stars that lead to the formation of carbon-oxygen white dwarfs [1]. I will discuss the impact of the abundance profiles of the underlying white dwarf on the nucleosynthesis accompanying classical nova outbursts, and the implications these calculations draw on explaining infrared observations of classical novae.

I will then present preliminary results of our Two-Dimensional Stellar Evolution code [2] which combines stellar evolution with essential physics such as rotation and binary interaction, and will thus provide a novel and physically consistent framework to study the effects of mass-transfer and binarity on such calculations.

[1] Jose, J., Halabi, G. M. & El Eid, M. (2016) in prep.
[2] Halabi, G. M., Izzard R., Jermyn, A., Tout, C. & Cannon, R. (2016) in progress.

**11**

# Extinct Silicon-32 in Presolar Silicon Carbide Grains

**Author:** Peter Hoppe[1]

**Co-authors:** Falk Herwig [2]; Marco Pignatari [3]; Wataru Fujiya [4]

[1] *MPI for Chemistry, Mainz, Germany*

[2] *University of Victoria, Canada*

[3] *University of Hull, UK*

[4] *Ibaraki University, Japan*

**Corresponding Author:** peter.hoppe@mpic.de

Primitive Solar System materials contain small quantities of nanometer- to micrometer-sized presolar grains [1]. Presolar grains are older than our Solar System and formed in the winds of evolved stars and in the ejecta of stellar explosions, as evidenced from large isotopic abundance anomalies. Among the identified presolar minerals are graphite, silicon carbide (SiC), silicon nitride, oxides, and silicates.

Silicon carbide is the best studied presolar mineral and a wealth of information exists on the isotopic compositions of the major, minor, and trace elements in individual grains. Most SiC grains, the mainstream grains, originate from 1-3 Msun AGB stars of about solar metallicity. Important subpopulations are the Type X and C grains, which formed in the ejecta of supernova explosions, and the Type AB grains, some of which might originate from born-again AGB stars.

Radioactive nuclei, e.g., aluminum-26 and titanium-44, were important constituents of presolar SiC grains at the time of grain formation. These now extinct radioactive nuclei are detected in SiC grains by large isotopic overabundances of their daughter isotopes. The recent finding of large sulfur-32 excesses in C grains [2-4], and of moderate sulfur-32 excesses in AB grains [5] is best explained by the decay of radioactive silicon-32 (half-life 153 yr). In supernovae silicon-32 is predicted to be produced by neutron-capture reactions in C-rich He-shell material [6], while in born-again AGB stars it may be produced by the so-called i-process, which is characterized by neutron-capture reactions at neutron densities intermediate between the s- and r-process [7].

Unlike born-again AGB stars, common AGB stars are not expected to produce significant amounts of silicon-32 [8]. This is compatible with the essentially normal (i.e. solar) S-isotopic compositions of mainstream grains [9]. The low sulfur abundances in mainstream grains lend support to the view that the significantly higher abundances of excess sulfur-32 in some AB grains are the result of the in-situ decay of radioactive silicon-32.

[1] Zinner E. (2014) In Treatise on Geochemistry, Vol. 1.4, 181
[2] Gyngard F. et al. (2010) MAPS, 45, A72
[3] Hoppe P. et al. (2012) ApJL, 745, L26
[4] Xu Y. et al. (2015) ApJ, 799, 156
[5] Fujiya W. et al. (2013) ApJL, 776, L29
[6] Pignatari M. et al. (2013) ApJL, 771, L7
[7] Herwig F. et al. (2011) ApJ, 727, 89
[8] Cristallo S. et al. (2009) ApJ, 696, 797
[9] Hoppe P. et al. (2015) MAPS, 50, 1122

**32**

## Carbon-rich AGB stars in the L- and M-band: from CRIRES to MATISSE

**Author:** Josef Hron[1]

**Co-authors:** Bernhard Aringer [2]; Claudia Paladini [3]; Thomas Lebzelter [1]

[1] *University of Vienna, Institut für Astrophysik*

[2] *Osservatorio Astronomico di Padova –INAF*

[3] *Université Libre de Bruxelles, Institute of Astronomy and Astrophysics*

**Corresponding Author:** josef.hron@univie.ac.at

The region between 3 and 5$\mu$m contains several important molecular features for C-rich AGB stars. We present CRIRES spectroscopy and spectro-astrometry in the L- and M-band of a few such stars. The irregular variable TX Psc is of particular interest as it shows clear evidence for a complex environment from a few out to several thousand stellar radii. We show how this affects the determination of the photospheric 12C/13C ratio from CO fundamental lines. We also touch upon the high potential of MATISSE, the second generation VLTI instrument in the L-,M- and N-band, for the study of C-rich cool giants.

**68**

## s-Process nucleosynthetic profile through heavy elements

**Author:** Trevor Ireland[1]

**Co-authors:** Janaina Avila [1]; Maria Lugaro

[1] *Australian National University*

**Corresponding Author:** trevor.ireland@anu.edu.au

Trace-element abundances and isotopic compositions of heavy elements (Ba through Pb) have been measured in stardust grains believed to have condensed in the outflows of low-mass carbon-rich asymptotic giant branch (AGB) stars. The grain data have provided detailed information on the nucleosynthesis of heavy elements produced by the slow neutron capture process (the s-process). In this talk, I will review the current status of s-process nucleosynthetic signatures of heavy elements from stardust grains and how we can use the data available to address issues concerning how the protosolar nebula formed and evolved.

**9**

## Post-AGB Binary Discs

**Authors:** Adam Jermyn[1]; Rob Izzard[1]

[1] *University of Cambridge*

**Corresponding Author:** rob.izzard@gmail.com

Circumbinary discs are ubiquitous around binary post-AGB stars. We report on our efforts to implement models of such discs in our binary stellar populations. We use Green's function solutions to the viscous disc equation to model the evolution circumbinary discs quickly and efficiently in model populations of model binaries. Our aim is to model realistic discs to determine the feedback

on the stellar orbits, e.g. eccentricity pumping, the chemical abundances in the discs and whether they are viable planet-forming regions. The first population of this type will be presented, including a comparison with observed discs.

**59**

## Constraining AGB nucleosynthesis with observations from post-AGB stars

**Author:** Devika Kamath[1]

**Co-authors:** Amanda Karakas [2]; Hans Van Winckel [1]; Kenneth De Smedt [3]; Peter Wood [4]

[1] *Institute of Astronomy, KU Leuven, Leuven*

[2] *Monash Centre for Astrophysics, Melbourne*

[3] *nstitute of Astronomy, KU Leuven, Leuven*

[4] *Research School of Astronomy and Astrophysics, ANU, Canberra*

**Corresponding Author:** devika.kamath@ster.kuleuven.be

We have carried out several detailed chemical abundance studies using post-AGB stars (in the Galaxy as well as the Magellanic Clouds). We find that these objects display a large chemical diversity. This implies that the nucleosynthesis that occurs during and prior to the AGB phase is in-fact more complicated than expected. Our observations provide excellent constraints (as a function of mass and metallicity) for the third dredge-up, mass-loss and the s-process nucleosynthesis that governs the AGB phase. Our chemical abundances studies also revealed several intriguing results, a few of which are: the discovery of luminous, metal-poor stars that fail the third dredge-up, stars with an under-abundance of Pb compared to the predictions from AGB nucleosynthesis models, extremely s-process enriched intrinsically-metal-poor stars, and extremely depleted stars. In this talk, I will present an overview of this observed chemical diversity and its implications on AGB (especially s-process) nucleosynthesis, and the observational constraints provided by these exotic post-AGB stars for AGB (single and binary) models.

**61**

## R Coronae Borealis Stars as Viable Factories of Pre-solar Grains

**Author:** Amanda Karakas[1]

**Co-authors:** Ashley Ruiter [2]; Athira Menon [1]; Melanie Hampel [3]

[1] *Monash University*

[2] *ANU*

[3] *University of Heidelberg*

**Corresponding Author:** amanda.karakas@monash.edu

We present a new theoretical estimate for the birthrate of R Coronae Borealis (RCB) stars
that is in agreement with recent observational data. We find the current Galactic birthrate of RCB stars to be ≈ 25\% of the Galactic rate of Type Ia supernovae, assuming that RCB stars are formed through the merger of carbon-oxygen and helium-rich white dwarfs.
Our new RCB birthrate ($1.8 \times 10^{-3}$ yr$^{-1}$) is a factor of 10 lower than previous theoretical estimates. This results in roughly 180–540 RCB stars in the Galaxy, depending on the RCB lifetime. From the theoretical and observational estimates, we calculate the total dust production from RCB stars and compare this rate to dust production from novae and born-again asymptotic giant branch (AGB) stars. We find that the amount of dust produced by RCB stars is comparable to the amounts

produced by novae or born-again post-AGB stars, indicating that these merger objects are a viable source of carbonaceous pre-solar grains in the Galaxy. There are graphite grains with carbon and oxygen isotopic ratios consistent with the observed composition of RCB stars, adding weight to the suggestion that these rare objects are a source of stardust grains. Nucleosynthesis models of RCB mergers will be used to predict an isotopic signature of RCB stars, which can be compared to the pre-solar grain database.

**29**

## Meteorite research at CSFK

**Author:** Ákos Kerészturi[1]

**Co-authors:** Ildiko Gyollai [1]; Mate Szabó [1]; Mária Pető [1]; Zsolt Benkó [2]

[1] *CSFK*

[2] *Atomki*

**Corresponding Author:** kereszturiakos@gmail.com

This presentation is to overview the research activity in meteoritics, which has been started four years ago at CSFK, Hungary. The local, classical Earth science related instrument heritage was applied for cosmic material analysis, and completed with new FTIR, Raman, Micro-XRD facilities. Durign the last years the work focused on the identification and analysis of accretional rims of chondrules and some related early Solar System processes, later alterations including shock driven fragmentation, shock p-T estimation, heterogeneous structure production in meteorites, metasomatic alteration especailly Fe-Mg diffusion analysis by EPMA plus FTIR-ATR methods, correlation of FTIR and Raman data for meteroite mineral analysis, and recently isotope analysis in collaboration with ATOMKI's rejuvenated noble gas analyzer. The research work also aims to identify parallel processes in distant forming disks observed by telescopes and inside carbonaceous chondrites analyzed in laboratories.

**66**

## Overshoot Below the Intershell Convective Zone

**Author:** John C. Lattanzio[1]

**Co-author:** Amanda Karakas

[1] *Monash University*

**Corresponding Author:** john.lattanzio@monash.edu

Convection remains one of the most uncertain mechanisms in stellar models. In particular, the mixing behaviour around the borders of convection, as well as the location of the borders, is particularly uncertain. In this work we investigate the effects of prescribing some overshoot inward, at the bottom of the intershell convective zone. We will report on evolutionary as well as nucleosynthesis consequences.

**17**

## Carbon and oxygen isotopic rations for nearby Miras

**Author:** Thomas Lebzelter[1]

**Co-authors:** Kenneth Hinkle [2]; Oscar Straniero [3]

[1] *University of Vienna*

[2] *NOAO*

[3] *INAF*

**Corresponding Author:** thomas.lebzelter@univie.ac.at

Carbon and oxygen isotopic ratios are reported for a sample of more than 40 Mira and SRa-type variable AGB stars. Vibration-rotation first and second overtone CO lines in 1.5 to 2.5 $\mu$m spectra were measured to derive isotopic ratios for $^{12}$C/$^{13}$C, $^{16}$O/$^{17}$O, and $^{16}$O/$^{18}$O. The ratios are compared to available literature values for the individual stars and the ratios are compared to isotopic ratios for various samples of evolved stars. Models for solar composition AGB stars of different initial masses are compared to the results. We find that the majority of the M stars had main sequence masses between 1.5 and 2.0\,$M_\odot$ and have not experienced the third dredge-up. The progenitors of the S and C Miras in the sample were more massive but no stars in the sample show evidence of hot bottom burning. AGB star wind is a significant source of material in the ISM. The Mira abundances are compared to solar and ISM isotopic abundances. The role of Miras in the chemical evolution of the galaxy is discussed.

**7**

# The $\beta$-decay rates of $^{59}$Fe isotope in shell burning environments and their influences on the production of $^{60}$Fe in massive star

**Author:** Kuoang Li[1]

**Co-authors:** Chong Qi [2]; Ningtao Zhang [3]; Xiaodong Tang [3]; Yi Hua Lam [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *KTH*

[3] *Institute of Modern Physics, CAS*

**Corresponding Author:** tupolev95@gmail.com

The experimental $B$(GT) strengths of the $^{59}$Fe excited states are employed to determine the transition strengthes which greatly contribute $^{59}$Fe stellar $\beta-$decay at typical carbon shell burning temperature. The result has been compared with the theoretical rates FFN (Fuller-Fowler-Newman) and LMP (Langanke&Martinez-Pinedo). Impact of the newly determined rate on the synthesis of cosmic $\gamma$ emitter $^{60}$Fe has also been studied using one-zone model calculation. Our results show $^{59}$Fe stellar $\beta-$decay rate plays an important role in the $^{60}$Fe nucleosynthesis. However the uncertainty of the decay rate is rather large due to the error of $B$(GT) strength that requires further studies.

**37**

# Coexistence of Explosive H-Burning and Neutron Capture Isotopic Signatures in Presolar SiC Grains

**Author:** Nan Liu[1]

**Co-authors:** Conel Alexander [2]; Jianhua Wang [2]; Larry Nittler [2]

[1] *Carnegie Institution for Science*

[2] *DTM, Carnegie Institution for Science*

**Corresponding Author:** nliu@carnegiescience.edu

Although excesses of 13C and 15N in rare presolar SiC grains cannot be used to distinguish between origins in either classical novae or core-collapse supernovae (CCSNe) [1], they are diagnostic of explosive hydrogen burning in stars in general. We report multi-element isotopic data for eight new 13C- and 15N-enriched presolar SiC grains (12C/13C<˜10 and 14N/15N<˜400) to further investigate explosive hydrogen burning in different stellar environments. Seven of the eight grains are of type AB with Si isotopic ratios resembling those of mainstream grains; the other grain is enriched in 30Si relative to 29Si (δ29Si =37±17‰, δ30Si =157±15‰) and is classified as a putative nova grain. The putative nova grain shows a high initial 26Al/27Al ratio (0.07), enrichment in 32S (δ33S = −833±167‰, δ34S = −435±131‰) and normal Ti isotopic compositions, which are incompatible with nova nucleosynthesis, and instead can be explained by local mixing of materials that experienced explosive hydrogen burning in CCSNe [1].

Three AB grains show large excesses in 50Ti relative to 49Ti, e.g., Δ50Ti >200‰ (Δ50Ti =δ50Ti−δ49Ti), with correlated 32S excesses in two of the grains, which are isotopic signatures of neutron capture nucleosynthesis (assuming that the 32S excess is due to decay of 32Si). The independent coexistence of proton- and neutron-capture isotopic signatures in these grains further confirms heterogeneous H ingestion into the He-shell in at least some pre-supernova massive stars as previously suggested by type C2 grains [1]. Also, the N isotopic ratios of AB grains are tightly correlated with their 26Al/27Al ratios. Since three of the 10 AB grains (including three AB grains from [1]) are likely to have come from CCSNe, their correlated 14N/15N and 26Al/27Al ratios imply that the explosive hydrogen burning environments in the parent stars of these 15N-enriched grains are astonishingly similar in both the amount of ingested hydrogen and stellar temperature [2], pointing towards either a single parent CCSN or multiple parent CCSNe with quite similar explosive hydrogen burning environments.

[1] N. Liu et al., ApJ 820, 140 (2016);
[2] M. Pignatari et al., ApJ 808, L43 (2015).

**19**

## On the chemical enrichemt of the ISM by AGB stars

**Author:** Arturo Manchado[1]

**Co-authors:** Amanda Karakas [2]; Anibal Garcia-Hernandez [1]; Eva Villaver [3]; Guillermo Garcia-Segura [4]

[1] *IAC*

[2] *Mt Stromlo Observatory, Australia*

[3] *UAM*

[4] *UNAM*

**Corresponding Author:** amt@iac.es

During the last thermal pulses in the asymptotic giant branch (AGB) phase, several dredge-up episodes occur, bringing highly processed material to the stellar surface. Low-mass star will be enriched in carbon (to a lower extent in oxygen, especially at low metallicity), while high-mass stars will overproduce helium and nitrogen. As the AGB atmosphere expands, it will create a circumstellar shell than eventually will interact with the interstellar medium (ISM).In the process, the stellar chemically modified ejecta mixes with the ISM affecting the chemical composition of the circumstellar envelope. We present hydrodynamical simulations of evolving AGB stars for different progenitor masses (1 and 3.5 Msun), relative velocities (10-100 km s-1) and ISM densities (between 0.01 and 1

cm-3). We will show how and when bow shocks and cometary-like structures form and how instabilities lead to the penetration of the ISM material into the AGB envelope modifying the expected chemical yields of AGB stars in the measured envelopes.

**64**

## Cr isotopic composition in individual Presolar AGB grains

**Author:** Kuljeet Kaur Marhas[1]

**Co-authors:** Sachiko Amari [2]; Scott Messenger [3]

[1] *Planetary Science Division, Physical Research Laboratory, Ahmedabad*

[2] *Laboratory for Space Sciences and the Physics Department, Washington University, St. Louis*

[3] *Center for Isotope Cosmochemistry and Geochronology, ARES division, NASA-Johnson Space Center, Houston*

**Corresponding Author:** kkmarhas@prl.res.in

Inherited chromium isotopes can be further s-processed in various RGB/AGB stars. The s-process nucleosynthetic calculations suggest significant overproduction of 54Cr isotope (δ54Cr values ˜ +200‰) with limited variations in rest of the isotopes of Cr. Here, we report Cr isotopic data along with C & N isotopic data abundances for ˜15 individual presolar grains (KJG series) from Murchison meteorite using JSC-nanoSIMS 50L. Identification and classification of presolar grains were based on C, N isotopic composition using a Cs+ source of ˜1pA. Followed by rastered O- primary beam of ˜ 50 pA to analyze 28Si, 52Cr, 53Cr, 54Cr, 55Mn and 56Fe in multicollection mode. All grains measured are Mainstream grains, with their carbon isotope ranging from 29 < 12C/13C < 108 and N isotopes ranging from 259< 14N/15N< 7800. An expected mainstream Cr- pattern is observed with negligible enrichment/depletion in 53Cr with average δ 53Cr ˜ 4 ‰. Though the statistical errors for 54Cr are quite large, the average value for δ 54Cr centers ˜ 107‰ indicating enrichment as per nucleosynthetic calculations.

**56**

## Sodium ejecta from AGB stars: the impact of the new LUNA rate for 22Ne(p,gamma)23Na

**Author:** Paola Marigo[1]

**Co-authors:** - LUNA Collaboration [2]; Alessandra Slemer [3]; Denise Piatti [1]

[1] *(1) University of Padova, (2) INFN Padova*

[2] -

[3] *University of Padova*

**Corresponding Author:** paola.marigo@unipd.it

I will report on a recent investigation aimed at analysing the impact of the new LUNA rate for the nuclear reaction 22Ne(p,gamma)23Na on the chemical ejecta of intermediate-mass stars, with particular focus on the thermally-pulsing asymptotic giant branch (TP-AGB) stars that experience hot-bottom burning. To this aim, we computed the complete evolution, from the pre-main sequence up to the termination of the TP-AGB phase, for a few sets of stellar models with initial masses in the range 3.0 Msun - 6.0 Msun and three values of metallicity, Zi=0.0005, Zi=0.006, and Zi=0.014. We compare the results of the Ne-Na nucleosynthesis obtained with the new LUNA rate and others available in the literature. We find that the improvement in the astrophysical S-factor obtained with LUNA has remarkably reduced the nuclear uncertainties in the 22Ne and 23Na AGB yields, which drop from factors of ˜ 10 to just a few for the lowest metallicity models. The uncertainties that still affect the 22Ne and 23Na AGB ejecta are now dominated by evolutionary aspects (efficiency of mass-loss, dredge-up events, convection). Finally, I will discuss how the LUNA results may impact on the hypothesis that invokes primordial massive AGB and super-AGB stars as the main agents of the observed O-Na anticorrelation in Galactic globular clusters.

**54**

## Mixing processes in carbon-enhanced metal-poor stars with s-process enrichment

**Author:** Elvijs Matrozis[1]

**Co-author:** Richard Stancliffe [1]

[1] *Argelander-Institut für Astronomie, Bonn, Germany*

**Corresponding Author:** roxfan93@gmail.com

Most if not all carbon-enhanced metal-poor (CEMP) stars showing s-process enrichment (CEMP-s stars) are the products of mass transfer from a binary asymptotic giant branch (AGB) companion. The surface abundances of CEMP-s stars are therefore usually assumed to be representative of the relative abundances in the material ejected by the AGB star, allowing us to probe the nucleosynthesis output of low-metallicity AGB stars from observations of CEMP-s stars. In this talk I will show that this assumption should not hold in CEMP dwarfs because atomic diffusion, in particular radiative levitation, should lead to relative abundance variations during the main sequence such that the surface composition is no longer representative of the transferred material. However, in a typical CEMP-s star, which has a very superficial convective envelope (containing 10<sup>-5</sup> M<sub>9737;</sub> of material or less), these variations should lead to, e.g. [Fe/H] > -1 and [C/Fe] < -1 around the main-sequence turn-off because of the efficient levitation of iron. Such abundance variations are in contradiction with observations. Hence, in real CEMP-s stars diffusion must be strongly inhibited by mass loss and/or some additional, turbulent mixing process operating at the base of the convective envelope, which extends the mixed region down to about 10<sup>-4</sup> M<sub>9737;</sub> from the surface. Finally, I will discuss whether such turbulence could be caused by rotational mixing.

**65**

## The Apache Point Observatory Galactic Evolution Experiment

**Author:** Szabolcs Meszaros[1]

[1] *Gothard Astrophysical Observatory*

**Corresponding Author:** meszi@gothard.hu

The Apache Point Observatory Galactic Evolution Experiment was a three-year, near-infrared (15090–16990 A), high-resolution spectroscopic survey of about 100,000 red giant stars included as part of the third Sloan Digital Sky Survey (SDSS-III Eisenstein et al. 2011). With a nominal resolving power of 22,500, APOGEE is deriving abundances of up to 15 elements besides the main astrophysical parameters. APOGEE-2 will continue observations from APO, but with the addition of a twin spectrograph on the 2.5-m du Pont telescope at the Las Campanas Observatory, the survey is expected to increase the

sample by at least a factor of five to 500,000 stars. The Southern Hemisphere provides more exceptional scientific payoff, because the survey will be able to measure radial velocities and elemental abundances covering the full sky and accessing the entire Milky Way. In this talk we will discuss the survey's current status, how to access its data and its first scientific results.

**46**

## Barium and heavier elements in silicon carbide, and the case of the refractory metal nuggets

**Author:** Ulrich Ott[1]

**Co-author:** Karl-Ludwig Kratz [2]

[1] *University of West Hungary*

[2] *Max-Planck-Institut für Chemie*

**Corresponding Author:** uli.ott@mpic.de

Barium has been the first of the neutron capture elements (besides the noble gases) shown to be present in presolar SiC grains with characteristic isotopic abundance patterns [1, 2]. Mainstream SiC grains show the signature of the s-process and put constraints on models of s-process nucleosynthesis (e.g., [3, 4]). The Rare Earth Elements between Ba and Hf show not only isotopic signatures but also an elemental abundance pattern dominated by the s-process [5].

Signatures of Ba in SiC-X grains have been more difficult to understand. Marhas et al. (2007) [4] have tried to interpret the few available data from their as well as previous work in terms of mixtures between isotopically solar Ba and either r-process-Ba, Ba produced in a neutron burst or by the weak s-process, but did not find any convincing solution. Based on the position of data points in a plot of 135Ba/137Ba vs. 136Ba/137Ba (their Fig. 11) we suggest a different explanation: mixing of either r-process or neutron burst Ba with a "normal"component that contains a larger (on the order of 50% higher) share of s-process Ba than the solar composition. The high abundance of 138Ba in the X grains of [4] can then be due either due to unusually high 138Ba in the "extra-s"Ba or, more likely, serve as a measure of the time of grain formation, since freshly synthesized "long-lived"135Ba and 137Ba from r-process or neutron burst nucleosynthesis will still be largely present as isotopes of volatile Cs at the time the grains formed.

Refractory metal nuggets (RMNs) consisting largely of Pt group elements are also found in primitive meteorites and can be isolated using chemical procedures similar to those used for the isolation of SiC grains. While the majority has a Solar System origin [6, 7], a small fraction may be presolar [8]. As we have shown in [9], elemental compositions can serve for screening a large number of RMNs for stardust candidate grains. Grains possibly derived from AGB stars should be easily detectable, while such dominated by r-process patterns will be more difficult to distinguish from solar system RMNs.

References: [1] Ott U. and Begemann F. (1990) ApJL 353, L57. [2] Zinner E. et al. (1991) ApJL 382, L47. [3] Savina M.R. et al. (2003) GCA 67, 3201. [4] Marhas K.K. et al. (2007) MAPS 42, 1077. [5] Yin Q.-Z. et al. (2006) ApJ 647, 676. [6] Berg T. et al. (2009) ApJL 702, L172. [7] Schwander D. et al. (2014) MAPS 49, 1888. [8] Croat T.K. et al. (2013) MAPS 48, 686. [9] Schwander D. et al. (2014) ApJ 793, 20.

**3**

## Composition of Oxide Grains of AGB Origin: a Puzzle Solved by Stellar MHD and Nuclear Physics

**Author:** Sara Palmerini[1]

**Co-authors:** Maurizio Busso [2]; Oscar Trippella [3]

[1] *Università degli Studi di Perugia - INFN sez. Perugia*

[2] *University of Perugia - INFN sez. Perugia*

[3] *Università degli Studi di Perugia- INFN sez. Perugia*

**Corresponding Author:** sara.palmerini@gmail.com

Oxide grains, enclosed in meteorites, give us very precise information about the stars in which they formed. Grains that belong to group 1 and 2 are characterized by values of $^{17}O/^{16}O$ and $^{17}O/^{16}O$, inconsistent with explosive nucleosynthesis scenarios, and are then believed to form in red giant stars [1]. The measurements of the $^{14}N(p,\gamma)^{15}O$ and the $^{16}O(p,\gamma)^{17}F$ cross sections remarked that these grains condensate in the envelope of stars less massive than $2M_\odot$ [2,3]. Nevertheless, the high $^{18}O$ dilution and the large $^{26}Al$ abundance found in several grains remained unexplained, unless in precence of very deep mixing mechanisms coupled with nuclear burning [4,5]. The fine tuning of extra-mixing parameters and a new measurement of the $^{17}O$+p reaction rates significantly improved the agreement between the grain oxygen isotopic mix and the model predictions. AGB stars with $M \leq 1.5M_\odot$ were proved tobeprogenitors of group 2 grains [6,7]. However, two challenges remained to be addressed: the physical origin of the extra-mixing mechanisms and high amount of 26Al found in some grains ($^{26}Al/^{27}Al$0.02). Recently, [8] have shown that the MHD equations allow for exact analytical solutions in the relevant layers of AGB stars. Applying this model of mixing driven by the buoyancy of magnetized materials, we find that the $^{17}O/^{16}O$, $^{17}O/^{16}O$ and $^{26}Al/^{27}Al$ ratios shown by group 1 and 2 grains are perfectly reproduced by a $1.2M_\odot$ AGB stars, without encountering any relevant energy feedback.

1. L. R. Nittler, et al., The Astrophysical J. 483, 475 (1997)
2. G. Imbriani, G., et al., Eur. Phys. J. A. 25, 455 (2005)
3. C. Iliadis, et al., Phys. Rev. C 77, 045802 (2008).
4. G. J. Wasserburg, et al., The Astrophysical J. 447, L37 (1995)
5. K. M. Nollett, et al., The Astrophysical J. 582, 1036 (2003)
6. S. Palmerini, et al., The Astrophysical J. 729, 3 (2011)
7. S. Palmerini, et al., The Astrophysical J. 764, 128 (2013) and references therein
8. M. C. Nucci, M. & M. Busso, The Astrophysical J. 787, 141 (2014)
9. O. Trippella O., et al., The Astrophysical J., 818, 125 (2016)

**67**

# Binary probes of AGB nucleosynthesis

**Author:** Onno Pols[1]

[1] *Radboud University, Nijmegen, The Netherlands*

**Corresponding Author:** o.pols@astro.ru.nl

Binary systems in which one star has been polluted by mass transfer from a former asymptotic red giant companion star, are excellent probes of some of the uncertainties in AGB nucleosynthesis. Examples include post-AGB binaries, barium stars and (at low metallicity) carbon-enhanced metal-poor stars. A proper interpretation of their observed abundance patterns also requires a good understanding of their binary evolution history.

Binary mass transfer occurs by Roche-lobe overflow (RLOF) in relatively close systems, and by wind accretion in systems that are too wide for either star to fill its Roche lobe. In the case of red giant primaries, RLOF is often (though not always) unstable and results in a highly non-conservative

common envelope event that shrinks the orbit. On the other hand, wind mass loss tends to widen the orbit. This divergent orbital evolution is expected to produce a gap in the period distribution of mass-transfer remnant systems. However, the observed remnant systems are plentiful in this period range (roughly 100 days to a few years) and their properties are at odds with the predictions of standard binary evolution models. In this contribution I will explore some of the processes that may be at work here.

**33**

## Rb and Zr content in massive Milky Way AGB stars revisited

**Author:** Víctor Pérez-Mesa[1]

**Co-authors:** Amanda Karakas [2]; Aníbal García-Hernández [1]; Arturo Manchado [3]; Bertrand Plez [4]; Maria Lugaro [5]; Olga Zamora [1]

[1] *Instituto de Astrofísica de Canarias; Universidad de La Laguna*

[2] *Research School of Astronomy & Astrophysics, Australian National University*

[3] *Instituto de Astrofísica de Canarias; Universidad de La Laguna; Consejo Superior de Investigaciones Científicas*

[4] *Laboratoire Univers et Particules de Montpellier, Université Montpellier2*

[5] *Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences; Monash Centre for Astrophysics, Monash University*

**Corresponding Author:** vperezme@iac.es

We report new abundances of Rb and Zr in a sample of massive Galactic asymptotic giant branch (AGB) stars, previously studied with hydrostatic models, by using more realistic dynamical model atmospheres. We use a modified version of the spectral synthesis code Turbospectrum and consider the presence of a gaseous circumstellar envelope and radial wind in these massive Galactic AGB stars. The Rb and Zr abundances are determined from the 7800 A Rb I resonant line and the 6474 A ZrO bandhead, respectively, and they are compared with the AGB nucleosynthesis theoretical predictions. The derived Rb abundances are much lower with the new dynamical models, while the Zr abundances, however, are closer to the hydrostatic values. The new model atmospheres can help to resolve the problem of the mismatch between the observations and the nucleosynthesis theoretical predictions of massive AGB stars.

**45**

## Probing AGB nucleosynthesis via detailed abundance studies of S-stars.

**Author:** Shreeya Shetye[1]

[1] *Universite Libre De Bruxelles and KU Leuven*

**Corresponding Author:** shreeya.shetye@ulb.ac.be

The S stars are late-type giants whose spectra show distinctive molecular band with as most noticeable characteristic the appearance of ZrO bands. Intrinsic S stars are considered as transition objects between normal M giants and carbon stars during the evolution along the Asymptotic Giant Branch (AGB). Their overabundance patterns show signature of s-process nucleosynthesis, while the C/O ratio is still such as to keep them intermediate objects between normal M giants and carbon stars. These features add to the complexity of deriving their stellar parameters. In this contribution I present the S4U code [S Stars SEDs Fitting Utility] aiming at deriving automatically parameters of large samples of S stars. S4U uses dedicated MARCS model atmospheres for S-type stars covering a range in effetive temperature, surface gravity, metallicity, [s/Fe] and C/O. It calculates the synthetic

fluxes from the model spectral energy distribution (SED) hence allowing a comparison between observed and synthetic photometry, and ultimately constraining the stellar parameters. The parameter study along with the luminosity of intrinsic S stars in the HR diagram will help
us marking the onset of the third dredge-up in the HR diagram. The ultimate goal is to gain insight in the AGB nucleosynthesis and third dredge-up episodes.

**38**

## Xenon implantation in nanodiamonds: in situ study in TEM and Molecular Dynamics simulations

**Author:** Andrey Shiryaev[1]

**Co-authors:** Graeme Greaves [2]; Jonathan Hinks [2]; Nigel Marks [3]; Stephen Donnelly [4]

[1] *Institute of physical chemistry and electrochemistry, Moscow, Russia*

[2] *Huddersfield Univ, UK*

[3] *Curtin Univ, Australia*

[4] *Huddersfield Univ., UK*

**Corresponding Author:** a_shiryaev@mail.ru

Xenon in nanodiamonds from meteorites is a remarkable impurity. At least two isotopically different components of Xe are known: P3 and Xe-HL. The P3 component might represent adsorbed Xe; whereas the component enriched in heavy and light isotopes (Xe-HL) is likely related to explosions of Supernovae of types I (Jorgensen 1988) or II (Lewis et al., 1987). Formation mechanism of nanodiamonds and their astrophysical sources remain debatable. It is widely accepted that the HL component was implanted. However, experimental data on radiation resistance of nanoparticles are scarce and contradictory results were obtained. We present here results of the first investigation of the Xe implantation process into nanodiamonds of various sizes studied in situ in Transmission Electron Microscope (TEM), complemented by advanced Molecular Dynamics simulations.

Several types of nanodiamonds (ND) were studied: NDs extracted from meteorites (log-normal size distribution from ˜1 to 10 nm with median size around 2.6 nm); synthetic NDs with sizes 4-5 nm with occasional presence of larger particles; synthetic NDs 30-40 nm in diameter. The in situ implantation study was performed at MIAMI facility (Huddersfield Univ, UK, Hinks et al., 2011). Xe ion energies of 6 and 40 keV were employed. The ion energies allowed to study various rates of defects introduction by the transmitted ions. Molecular dynamics calculations are performed using the environmental dependent interaction potential (EDIP) for carbon in combination with the Ziegler-Biersack-Littmark (ZBL) potential to describe close approaches. The carbon EDIP methodology accurately models the behaviour of disordered and amorphous carbons.

The most important result of the experiment is that contrary to expectations that nanodiamond grains will gradually amorphise or graphitise, we have observed gradual disappearance of small nanodiamond particles (meteoritic NDs and 4-5 nm synthetic grains) under the beam. The larger grains (>10 nm) were almost unaffected by the ion beam. Such behavior points to existence of a size effect on radiation resistance of carbon nanoparticles. Molecular dynamics explains the experimental observations. It is shown that the 6 keV Xe ion leads to extreme raise of temperature of a nanodiamond grain, resembling stochastic heating phenomenon usually discussed for UV photons. For the grains ≤2 nm in size the temperature excursions exceed 10000 K which effectively "explodes" the particle. For particles 2-5 nm in size the heating converts the grain to carbon onion-like cluster. At larger ND grain sizes only points defects are created and size diamond is notoriously resistant to radiation damage (Fairchild et al., 2012) the effect of the implantation is not strongly pronounced at fluences employed in the current work. Modeling shows that for the Xe ions the energy of 5-6 keV leads to the most pronounced devastation effect on the smallest particles, at lower energies the ions are implanted with formation of some point defects; at higher energies ions are transmitted leaving some damage behind.

Preliminary Monte-Carlo simulations show that qualitatively similar effects could be produced by Kr ions. However, damage levels from light ions such as Si and N which are relevant to studies of meteoritic NDs and for technological applications are always too low to induce such dramatic effects.

Implications of the present work for problem of dust survival in astrophysical environments are discussed.

References. 1) Jorgensen U. G. 1988. Nature 332:702–705. 2) Lewis R. S. et al., 1987. Nature 326: 160–162. 3) J.A. Hinks et al., 2011 J. Vac. Sci. Technol. A 29(2) 021003, 4)
Fairchild et al., Advanced Materials, 2012 DOI: 10.1002/adma.201104511.

**26**

## Spectroscopic study of meteoritic nanodiamonds: implications for formation mechanism and detection in space

**Author:** Andrey Shiryaev[1]

[1] *Institute of physical chemistry and electrochemistry, Moscow, Russia*

**Corresponding Author:** a_shiryaev@mail.ru

Nanodiamonds in meteorites were discovered in 1987 (Lewis et al., 1987), but remain an enigmatic substance. Their abundance may reach 2000 ppm, thus constituting up to 3% of total carbon inventory of a given meteorite. Despite long history of active research the formation process(es) and astrophysical source(s) of meteoritic nanodiamonds (MND) remain highly debatable. Whereas isotopic composition of noble gazes indicates that a fraction of MND might be related to SN explosions (both types I and II were considered), isotopic composition of matrix C and N are less conclusive and support hypothesis of MND formation in the Solar system. According to theoretical modeling and laboratory experiments diamond phase is fairly stable at sizes less than few nanometers. In laboratory nanodiamonds were synthesized by very different ways, showing that several independent mechanisms may be responsible for formation of nanodiamonds in astrophysical environments. Combined analysis of information about structure and chemical impurities (Shiryaev et al., 2011) suggests that the growth process of (at least) N-containing nanodiamond grains should be very fast. The CVD-like (Chemical Vapour Deposition) process, possibly triggered by a shock wave, looks plausible, but other processes cannot be excluded.
Numerous attempts to observe nanodiamond features in astrophysical spectra are known, but very few of them can be (relatively) unambiguously assigned to diamonds. Studies of diamonds of various sizes show that extrapolation of spectroscopic results obtained for mAcroscopic diamond crystals or powders is often unjustified and may lead to totally incorrect conclusions (e.g., Shiryaev et al., 2011, Vlasov et al., 2012). Detailed knowledge of spectroscopic properties of real meteoritic nanodiamonds is important for eventual detection of this form of carbon in astrophysical spectra.
Recently we have reported observation of an important point defect a silicon ion in a divacancy in diamond lattice (often called a silicon-vacancy defect or SiV) in nanodiamonds from chondrites of different classes (Shiryaev et al., 2011, 2015). This defect is observed both in emission and in absorption and is manifested by a line at 7370 A with several secondary features. Subsequent studies (Vlasov et al., 2014) demonstrated that the SiV luminescence is confined to the smallest grains (≤2 nm); the unusual stability of this defect is also proved by state-of-the-art DFT calculations. Up to three defects could be present in a single grain, thus opening potential for isotopic studies if severe problem of surface contamination of ND grains by Si could be solved. Note that the spectroscopic observations of the SiV defect are robust and is totally not sensitive to the surface contamination.
We summarise here results of examination of the SiV defects in nanodiamonds from meteorites of various chemical classes and groups performed in broad temperature range. The luminescence of the SiV defect may assist in search of astrophysical sources of nanodiamonds with grain sizes comparable with those observed in meteorites. The SiV defect is characterized by very strong sero-phonon line remains rather narrow even in nanodiamonds. Strong temperature dependence of the SiV luminescence permits its observation from cold particles only. However, this defect is also visible in absorption, thus complementing IR observations of C-H bands pronounced in IR emission spectra

of hot particles (>400-500 ℃).
A summary of experimental investigation of nanodiamonds from different meteorites at different temperatures will be given. Implications of these observations for astrospectroscopy are discussed.

References
1) Lewis R. S., et al., 1987. Nature 326: 160; 2) Shiryaev A. et al., 2011, Geochim. Cosmochim. Acta, 75, 3155; 3) Shiryaev A.A., et al., 2015 Meteoritics and Planetary Science, 50: 1005; 4) Vlasov I.I. et al., In: Ultrananocrystalline Diamond, Elsevier, 2012, p.291-326; 5) Vlasov I., et al., 2014, Nature Nanotechnology, 9: 54.

**60**

# Silicon isotopic variation within Enstatite Chondrite

**Author:** Jinia Sikdar[1]

**Co-author:** Vinai K. Rai [1]

[1] *Physical Research Laboratory, Ahmedabad*

**Corresponding Author:** jinia@prl.res.in

Introduction: Enstatite chondrites are unique amongst the primitive meteorites since they have formed under extremely reducing conditions with C/O ratio >1. In such a reducing environment, Si becomes siderophilic and a set of new minerals are formed which are typically not stable on Earth, such as Fe–Ni metal with ˜3% Si, a suite of Mg, Ca and Mn bearing sulphides, TiN and Si2N2O etc. Striking similarity of Enstatite chondrites with Bulk Silicate Earth (BSE) for a number of isotope systems such as O, Cr, N, Mo, Ni, Ti, and Os has led to its consideration as a major building block of Earth. However, there appears to be resolvable isotopic differences between E-chondrites and BSE with respect to Silicon isotope. This difference is postulated to be due to preferential enrichment of light Si in metallic phase with implications towards presence of Si in Earth's core. Moreover, E-chondrites appear to have undergone significant refractory lithophile element fractionation, as evinced by their low Mg/Si and Al/Si ratios, compared to other meteorites. Such a substantial fractionation must invoke kinetic fractionation during its early nebular evolution either due to preferential loss of more volatile Si relative to Mg, equilibrium isotopic fractionation between gaseous SiO and solid forsterite or due to any giant impact. Hence it is crucial to re-asses the exact cause of Si isotope fractionation in Enstatite chondrites before concluding its origin due to any parent body process.

Experiment: Various phases of two EH3 chondrites such as silicate bearing clasts, matrices, metals and chondrules were micromilled after their characterization using EPMA. Si was purified from these phases using cation exchange resin (Bio-Rad AG 50W-X8, 200-400 mesh) in H+ form. Si isotopic analyses were carried out by Thermo Neptune Plus MC-ICPMS at PRL.

Results: Terrestrial rocks that represent BSE display negligible variation in Silicon isotopic values (δ 30Si=-0.29 to -0.26‰). In contrast, various phases of Enstatite chondrite define a broad range of isotopic values (δ 30Si=-0.28 to -6.8‰). Si in the metal phase of E-chondrites is significantly lighter than that of silicates. The intrinsic heterogeneity among its different phases calls off the use of Si isotope value of bulk Enstatite chondrite to constrain the amount of Si in the core of Earth. Rather it indicates complex mixing of different components of Enstatite meteorites in different space and time over a wide range of nebular composition.

References: Armytage, R. M. G. et al., Geochim. Cosmochim. Acta, 2011, 75: 3662–3676.
Dauphas, N. et al., Earth Planet. Sci. Lett., 2015, 427: 236-248. Fitoussi, C. et al., Earth Planet. Sci. Lett., 2009, 287: 77-85. Fitoussi, C. et al., Earth Planet. Sci. Lett., 2010, 295: 139–146. Georg, R. B. et al., Science, 2007, 447: 1102–1106. Savage et al., Earth Planet. Sci. Lett., 2013, 487-496. Zambardi et al., Geochim. Cosmochim. Acta, 2013, 67-83. Ziegler, K. et al., Earth Planet. Sci. Lett., 2010, 295: 487–496.

**35**

## The intermediate neutron capture process and carbon-enhanced metal-poor stars

**Author:** Richard Stancliffe[1]

**Co-authors:** Brad S. Meyer [2]; Maria Lugaro [3]; Melanie Hampel [4]

[1] *University of Bonn*

[2] *Clemson University*

[3] *Konkoly Observatory, MTA CSFK*

[4] *University of Heidelberg*

**Corresponding Author:** rstancli@uni-bonn.de

Carbon-enhanced metal-poor stars are often classified into four sub-groups based on their presence or absence of barium and europium. The origin of the so-called CEMP-r/s stars, which display high abundances of barium and europium, is currently unclear. Most of the proposed formation scenarios simply cannot work. In this contribution, we examine whether the abundance patterns of CEMP-r/s can arise from neutron capture nucleosynthesis. While low neutron densities give rise to the s process, and extremely high densities characterise the r process, intermediate neutron densities of around 10ˆ15 cm-3 give rise to their own signatures —the so-called i process. Using a one-zone nucleosynthesis code, we show that an i process can explain the abundances patterns in a sample of 20 CEMP-r/s stars that could not be explained by s process nucleosynthesis. Some thoughts on possible sites for the i process will be given.

**40**

## Stellar structure studies in the era of precision asteroseismology

**Author:** Róbert Szabó[1]

[1] *CSFK MTA*

**Corresponding Author:** rszabo@konkoly.hu

Recent years witnessed the triumph of asteroseismology thanks to the ultra-precise photometric measurements from space. CoRoT and especially Kepler provided stellar oscillation data for hundreds of main sequence and thousands of red giants stars. In this talk I briefly highlight the most important results concerning stellar structure and evolution, such as precise radius and age determination, pinning down the evolutionary phase of red giants, derivation of the inner rotation profile of evolved stars, assessing the magnitude of magnetic field in the core of red giants, just to name a few. Finally I review the status of future asteroseismic missions.

**1**

## Recent results in Nuclear Astrophysics of n_TOF facility at CERN

**Author:** Giuseppe Tagliente[1]

**Co-author:** collaboration n_TOF [2]

[1] *INFN sezione di Bari*

[2] *CERN*

**Corresponding Author:** giuseppe.tagliente@ba.infn.it

Neutron capture reactions in stars are responsible for about 99% of the elemental abundances heavier than Fe. Two processes contribute about equally to the overall abundance pattern: the slow neutron capture process (s process) where neutron densities are small and therefore radioactive decay is generally faster than neutron capture, and the rapid neutron capture process (r process) which takes place in environments of high neutron densities, driving the reaction path towards the neutron rich side. The key nuclear physics input for s process studies are stellar neutron capture cross sections, called MACS (Maxwellian-averaged cross section). In this context, accurate cross sections are particularly important between Fe and Zr and for the light neutron poisons. The uncertainty of a single cross section propagates to the abundances of the heavier isotopes on the s-process path, or over the complete s-process distribution in the case of neutron poisons.
In this framework the n_TOF collaboration has been carrying out an ambitious experimental program on nuclear capture reactions with the aim of reducing the respective cross section uncertainties, and to improve the reliability of astrophysical models.
The innovative feature of the n_TOF facility at CERN, in the two experimental areas, (20 m and 200 m flight paths), i.e. the high instantaneous flux, the high energy resolution and low background, allow for an accurate determination of the neutron capture cross section for radioactive samples or for isotopes with small neutron capture cross section, which are of interest for Nuclear Astrophysics The recent results obtained, and the implication of the astrophysical program of the n_TOF collaboration will be presented in this talk

**8**

## Direct measurement of the $^{13}$C($\alpha$,n)$^{16}$O reaction at stellar energies

**Author:** Xiaodong Tang[1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

**Corresponding Author:** guoxt2k11@gmail.com

The $^{13}$C($\alpha$,n)$^{16}$O reaction is a key neutron source for the stellar s-process nucleosynthesis. Due to the existence of sub-threshold resonances, there is a rather large uncertainty in this important reaction rate which limits our understanding to the nucleosynthesis of heavy elements. We will take the advantage of the ultra-low background in Jinping underground lab, the underground high current accelerator based on an ECR source and highly sensitive neutron detector to study directly this important reaction for the first time within its relevant stellar energy range. Our result will be crucially important for testing and calibrating the predictive power of extrapolating model, providing a reliable astrophysical reaction rate, and eliminating the uncertainty incurred by the $^{13}$C($\alpha$,n)$^{16}$O reaction rate in stellar nucleosynthesis model.

This work is supported by NSFC, CAS and CNNC. It is being performed by the JUNA collaboration.

**36**

## Investigating the Milky Way halo enrichment with Mg isotopes

**Author:** Anders Thygesen[1]

**Co-authors:** Evan Kirby [1]; Luca Sbordone [2]

[1] *California Institute of Technology*

[2] *Pontificia Universidad Catolica de Chile*

**Corresponding Author:** thygesen@caltech.edu

The observed behaviour of s-process elements in metal poor stars in the Milky Way halo is not easily interpreted. These elements are synthesized in AGB stars on a long timescale, compared to the r-process neutron capture elements. The abundance ratios of different elements provide conflicting answers to the onset of significant AGB contribution. For instance [La/Eu] suggests an AGB contribution already at metallicities below [Fe/H]$= -2.0$ (Simmerer+ 2004), whereas the observed [Pb/Eu] indicate that this happens only at a significantly higher metallicity of around $-1.4$ (Roederer+ 2010). Determining the onset of the AGB pollution the Halo chemistry would represent a key observation to enhance our understanding of the MW chemical evolution.

Intermediate-to-massive AGB stars also produce a variety of other elemental species. Of particular interest is the production of the heavy Mg isotopes, $^{25,26}$Mg. At metallicities below [Fe/H]$= -1.0$ AGB stars are the only known producers. A clear detection of these isotopes at low metallicity, would be an unambiguous sign of an AGB contribution.

Earlier claims of heavy Mg detection (or lack thereof) in stars of metallicities below [Fe/H]$= -2.0$ hinges on very few data points (Yong+ 2003, Melendez+ 2007), and no clear conclusion can be been drawn. In this talk I will present early results from an investigation of the heavy Mg content in a large sample of Halo stars at $-3.0 <$ [Fe/H] $< -1.0$, from high resolution optical spectra. Our analysis benefits from a significantly larger stellar sample, as well as an updated and improved analysis method. We use both standard 1D model atmospheres, as well as state-of-the-art 3D hydrodynamical models to derive the isotopic ratios. This has not previously been attempted for dwarf stars, and should improve the robustness of the results, to firmly settle the question when AGB stars become important for the Halo chemistry.

**30**

## The Origin of High-field Magnetic White Dwarfs

**Author:** Christopher Tout[1]

[1] *University of Cambridge*

**Corresponding Author:** cat@ast.cam.ac.uk

White dwarfs with surface magnetic fields in excess of 1MG are found as isolated single stars and relatively more often in magnetic cataclysmic variables. Some 1,253 white dwarfs with a detached low-mass main-sequence companion are identified in the Sloan Digital Sky Survey but none of these is observed to show evidence for Zeeman splitting of hydrogen lines associated with a magnetic field in excess of 1MG. If such high magnetic fields on white dwarfs result from the isolated evolution of a single star then there should be the same fraction of high field white dwarfs among this SDSS binary sample as among single stars. Thus we deduce that the origin of such high magnetic fields must be intimately tied to the formation of cataclysmic variables. The formation of a CV must involve orbital shrinkage from giant star to main-sequence star dimensions. It is believed that this shrinkage occurs as the low-mass companion and the white dwarf spiral together inside a common envelope. CVs emerge as very close but detached binary stars that are then brought together by magnetic braking or gravitational radiation. We propose that the smaller the orbital separation at the end of the common envelope phase, the stronger the magnetic field.

**48**

# The $^{13}$C-pocket formation and the $^{13}$C($\alpha$,$n$)$^{16}$O reaction rate.

**Author:** Oscar Trippella[1]

**Co-authors:** Marco La Cognata [2]; Maurizio Busso [3]; sara palmerini [4]

[1] *Universita' degli Studi di Perugia*

[2] *Laboratori Nazionali del Sud - Catania*

[3] *University of Perugia, Department of Physics*

[4] *Università degli Studi di Perugia - INFN sez. Perugia*

**Corresponding Author:** oscartrippella@gmail.com

The $s$-process, which involves a series of slow neutron captures and $\beta$-decays, is responsable of the production of about 50% of elements heavier than iron during the asymptotic giant branch (AGB) phase of low-mass stars (LMS, with M<3 $M_{\odot}$). In radiative conditions (at around 8 keV) during the quiet phases between two subsequent thermal instabilities from the He shell, the main neutron source is considered to be the $^{13}$C($\alpha$,$n$)$^{16}$O. In this scenario, the main open problems concerning its operation as a driver for the slow neutron captures are two.

(i) From a nuclear point of view, the astrophysical factor of the $^{13}$C($\alpha$,$n$)$^{16}$O reaction, recently determined also using the Trojan Horse Method (THM), still remains matter of debate because of the contribution of a broad resonance located near the reaction threshold. A recent paper show that the 1/2$^{+}$ $^{17}$O excited state, strongly influencing the most important energy region for astrophysics and so far assumed to be centered at a few keV below the $^{13}$C-$\alpha$ threshold, is now a resonance located at positive E$_{c.m.}$ values (about 0.0047 MeV). In this context, we are proposing a re-analysis of the THM measurements in order to quantify possible variations of the asympotic normalization coefficient (ANC), whose values by several works in literature show a spread, that could affect the neutron production in AGB-LMS.

(ii) Contemporarily, in stellar models, the mechanism to produce $^{13}$C in the He-rich region of an AGB star, after a proton penetration occurs during third dredge-up, was so far treated as a free parameter. Our group presents the first self-consistent physical, analytical, and exact model for the $^{13}$C formation, based on magnetic buoyancy in a dynamo mechanism in both 2D and 3D. The resulting pocket shows a flat distribution of $^{13}$C and only a limited production of $^{14}$N, while is more extended than those so far assumed in literature. This pocket allows us to reproduce the solar abundances in high-metallicity AGB stars and to account for the ensuing chemical evolution of $s$-elements. Moreover, the so far unexplained s/(C/O) ratios in certain low-metallicity post-AGB stars togheter with the abundance and isotope ratios of $s$-elements in presolar SiC grains are also explained.

**6**

# LX Cyg: A carbon star is born

**Author:** Stefan Uttenthaler[1]

**Co-authors:** B. Aringer [2]; K. Hinkle [3]; L. Guzman-Ramirez [4]; R. Greimel [5]; R. R. Joyce [3]; T. Lebzelter [1]; s. Meingast [1]

[1] *University of Vienna*

[2] *University of Padova*

[3] *National Optical Astronomy Observatory*

[4] *European Southern Observatory*

[5] *Universitat Graz*

**Corresponding Author:** stefan.uttenthaler@univie.ac.at

For low-mass stars on the AGB, theory predicts an evolution along the spectral sequence M-S-C as a result of dredge-uo of carbon to the atmosphere. Observational evidence is in full agreement with

this prediction. Yet, due to the long time scales of stellar evolution, no star has been observed to take a step in this sequence. We identified the Mira LX Cyg, which was of spectral type S/SC until the 1970ies, but is clearly of type C now. We became aware of this star because its pulsation period increased from 460 to 580d within only 20 years, in parallel to its spectral type change. In the talk, the observed bahaviour is explained as a result of a recent 3DUP event that caused a genuine change in C/O. Also alternative explanations are discussed.

**39**

## The temperature and chronology of heavy-element synthesis in low-mass stars

**Author:** Sophie Van Eck[1]

**Co-authors:** Alain Jorissen [1]; Bertrand Plez [2]; Lionel Siess [1]; Pieter Neyskens [1]; Stéphane Goriely [1]

[1] *ULB*

[2] *Université de Montpellier II*

**Corresponding Author:** svaneck@astro.ulb.ac.be

Two neutron sources, activated at distinct temperatures, have been proposed for the s-process of nucleosynthesis in low- and intermediate-mass stars: 13C and 22Ne, each releasing one neutron per alpha-particle captured. To explain the measured stellar abundances, stellar evolution models invoking the 13C neutron source (which operates at temperatures of about one hundred million kelvin) are favoured. Isotopic ratios in primitive meteorites, however, reflecting nucleosynthesis in the previous generations of stars that contributed material to the Solar System, point to higher temperatures (more than three hundred million kelvin), requiring at least a late activation of 22Ne. Here we report a determination of the s-process temperature directly in evolved low-mass giant stars, using zirconium and niobium abundances, independently of stellar evolution models. The derived temperature supports 13C as the s-process neutron source. The radioactive pair 93Zr–93Nb used to estimate the s-process temperature also provides, together with the pair 99Tc–99Ru, chronometric information on the time elapsed since the start of the s-process, which we determine to be one million to three million years (Neyskens et al. Nature, 517, 174, 2015).

**43**

## Influence of the Outer Boundary Condition on models of AGB stars

**Author:** Graham Wagstaff[1]

[1] *Max Planck Institute for Astrophysics*

**Corresponding Author:** wagstaff@mpa-garching.mpg.de

Current implementations of the stellar atmosphere typically derive boundary conditions for the interior model from either grey plane-parallel atmospheres or scaled solar atmospheres, neither of which can be considered to have appropriate underlying assumptions for the Thermally Pulsing Asymptotic Giant Branch (TP-AGB). I will discuss the treatment and influence of the outer boundary condition within stellar evolution codes, and the resulting effects on the AGB evolution. The complex interaction of processes, such as the third dredge up and mass loss, governing the TP-AGB can be affected by varying the treatment of this boundary condition. In my study so far I have altered the geometry, opacities and implemented the use of a grid of MARCS/COMARCS model atmospheres in order to improve this treatment. I will discuss the resultant changes to the TP-AGB evolution and necessary steps which should be considered in the future.

**57**

## Interstellar Medium near Earth –mapped through live Fe-60, Al-26 and Pu-244 on Earth

**Author:** Anton Wallner[1]

[1] *Australian National University*

**Corresponding Author:** anton.wallner@anu.edu.au

The Interstellar Medium (ISM) is continuously fed with new nucleosynthetic products. Presence of radionuclides live in the ISM is evidenced by space-born γ-ray telescopes. The solar system moves through the ISM and collects dust particles. Therefore, direct detection of freshly produced radionuclides 'live'on Earth, i.e. before decaying, would provide insight into recent and nearby nucleosynthetic activities. A pioneering work at TU Munich [1] of an ocean crust-sample showed an enhanced $^{60}$Fe signal of extraterrestrial origin –does it originate from a close-by supernova about 2-3 Myr ago?

Within an international collaboration [2,3] we continued to search for ISM radionuclides incorporated into terrestrial archives via ultra-low single atom measurements using accelerator mass spectrometry (AMS). Here, we report on new experimental results of radionuclide concentrations in the interstellar medium.

We have analyzed several deep-sea sediments, crusts and nodules for extraterrestrial $^{60}$Fe ($t_{1/2}$=2.6 Myr), $^{26}$Al ($t_{1/2}$=0.7 Myr) and $^{244}$Pu ($t_{1/2}$=81 Myr) [2,3] complemented by independent work at TU Munich [4,5]. I will present a new approach to determine $^{60}$Fe's half-life value. Our new data using AMS suggest an unexpected low abundance of interstellar $^{244}$Pu. I will also present new results on $^{60}$Fe and $^{26}$Al and will relate them to potential exposure of Earth to recent supernova explosions.

[1] K. Knie et al., Phys. Rev. Lett. 93, 171103 (2004).
[2] A. Wallner et al., Nature Comm. 6:5956 (2015).
[3] A. Wallner et al., Nature 532, 69 (2016).
[4] L. Fimiani, Phys. Rev. Lett. 116, 151104 (2016).
[5] P. Ludwig et al., submitted, 2016.

**42**

## HV2112, an elusive TZO or a super-AGB star?

**Author:** Claire Worley[1]

**Co-authors:** Anna Zytkow [1]; Christopher Tout [2]; Morgan Fraser [1]; Rob Izzard ; Ross Church [3]

[1] *Institute of Astronomy, University of Cambridge*

[2] *University of Cambridge*

[3] *Department of Astronomy and Theoretical Physics, Lund University*

**Corresponding Author:** ccworley@ast.cam.ac.uk

HV2112 has become a source of much scientific debate as to whether or not it is the first detection of the elusive Thorne-Zytkow object. We have obtained XShooter observations across the full spectral range, and high resolution UVES observations for regions of key element spectral features. We present here a preliminary analysis of these data and some more clues as to the origins of this enigmatic star.

**41**

# Second-generation asymptotic giant branch stars in metal-poor galactic globular clusters

**Author:** Olga Zamora[1]

**Co-authors:** Cassisi Santi [2]; Garcia Hernandez Domingo Anibal [1]; Lucatello Sara [3]; Meszaros Szabolcs [4]; Monelli Matteo [1]; Shetrone Matthew [5]; Stetson Peter B. [6]

[1] *Instituto de Astrofísica de Canarias*

[2] *INAF–Osservatorio Astronomico di Teramo*

[3] *Osservatorio Astronomico di Padova*

[4] *ELTE Gothard Astrophysical Observatory*

[5] *University of Texas at Austin*

[6] *Herzberg Inst of Astrophysics*

**Corresponding Author:** omzamora@gmail.com

Galactic globular clusters (GCs) are known to host multiple stellar populations: a first generation (FG) with a chemical pattern typical of halo field stars and a second generation (SG) enriched in Na and Al and depleted in O and Mg. Both stellar generations are found at different evolutionary stages (e.g., the main-sequence turnoff, the subgiant branch, and the red giant branch (RGB)). The non-detection of SG asymptotic giant branch (AGB) stars in several metal-poor ([Fe/H] < -1) GCs suggests that not all SG stars ascend the AGB phase, and that failed AGB stars may be very common in metal-poor GCs. This observation represents a serious problem for stellar evolution and GC formation/evolution theories. We have detected seventeen SG-AGB stars in four metal-poor GCs (M13, M5, M3, M2, and M92) with different observational properties: horizontal branch (HB) morphology, metallicity, and age. By combining the H-band Al abundances obtained by the Apache Point Observatory Galactic Evolution Experiment (APOGEE) survey with ground-based optical photometry, we identify SG Al-rich AGB stars in these four GCs and show that Al-rich RGB/AGB GC stars should be Na-rich. Our observations resolve the apparent problem for stellar evolution, supporting the canonical models of horizontal branch stars.