THE AGB NEWSLETTER

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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

Happy New Year! It is our pleasure to present you the 222$^{\text{nd}}$ issue of the AGB Newsletter. It is a voluminous edition containing much of interest and inspiration – including determinations of masses and ages of red giant stars, high angular resolution images of the circumstellar environments of cool evolved stars, the properties of the circumstellar dust grains, the abundances of *s*-process (and other) elements; novæ, planetary nebulæ and other post-AGB objects.

The next issue is planned to be distributed around the 1$^{\text{st}}$ of February.

Editorially Yours,
Jacco van Loon, Ambra Nanni and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

What happens to the Kuiper Belt and Oort Cloud when the Sun becomes an AGB star?

Reactions to this statement or suggestions for next month's statement can be e-mailed to astro.agbnews@keele.ac.uk (please state whether you wish to remain anonymous)

Refereed Journal Papers

Revisiting the role of the Thermally-Pulsating Asymptotic Giant Branch phase in high-redshift galaxies

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We study the debated contribution from thermally pulsing asymptotic giant branch (TP-AGB) stars in evolutionary population synthesis models. We investigate the Spectral Energy Distributions (SEDs) of a sample of 51 spectroscopically confirmed, high-z ($1.3 < z_{\rm spec} < 2.7$), galaxies using three evolutionary population synthesis models with strong, mild and light TP-AGB. Our sample is the largest of spectroscopically confirmed galaxies on which such models are tested so far. Galaxies were selected as passive, but we model them using a variety of star formation histories in order not to be dependent on this pre-selection.

We find that the observed SEDs are best fitted with a significant contribution of TP-AGB stars or with substantial dust attenuation. Without including reddening, TP-AGB-strong models perform better and deliver solutions consistent within 1σ from the best-fit ones in the vast majority of cases. Including reddening, all models perform similarly. Using independent constraints from observations in the mid- and far-IR, we show that low/negligible dust attenuation, i.e. $E(B-V)\lesssim 0.05$ mag, should be preferred for the SEDs of passively-selected galaxies. Given that TP-AGB-light models give systematically older ages for passive galaxies, we suggest number counts of passive galaxies at higher redshifts as a further test to discriminate among stellar population models.

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Available from arXiv:1511.05573

An excess of mid-infrared emission from the Type Iax SN 2014dt

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Supernovæ Type Iax (SNe Iax) are less energetic and less luminous than typical thermonuclear explosions. A suggested explanation for the observed characteristics of this subclass is a binary progenitor system consisting of a CO white dwarf primary accreting from a helium star companion. A single-degenerate explosion channel might be expected to result in a dense circumstellar medium (CSM), although no evidence for such a CSM has yet been observed for this subclass. Here we present recent *Spitzer* observations of the Iax SN 2014dt obtained by the SPIRITS program nearly one year post-explosion that reveal a strong mid-IR excess over the expected fluxes of more normal SNe Ia. This excess is consistent with 10^{-5} $M_\odot$ of newly formed dust, which would be the first time that newly formed dust has been observed to form in a Type Ia. The excess, however, is also consistent with a dusty CSM that was likely formed in pre-explosion mass-loss, thereby suggesting a single degenerate progenitor system. Compared to other SNe Ia that show significant shock interaction (SNe Ia–CSM) and interacting core-collapse events (SNe IIn), this dust shell in SN 2014dt is less massive. We consider the implications that such a pre-existing dust shell has for the progenitor system, including a binary system with a mass donor that is a red giant, a red supergiant, and an asymptotic giant branch star.

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Available from arXiv:1510.08070

Spectroscopic determination of masses (and implied ages) for red giants

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The mass of a star is arguably its most fundamental parameter. For red giant stars, tracers luminous enough to be observed across the Galaxy, mass implies a stellar evolution age. It has proven to be extremely difficult to infer ages and masses directly from red giant spectra using existing methods. From the *Kepler* and APOGEE surveys, samples of several thousand stars exist with high-quality spectra and asteroseismic masses. Here we show that from these data we can build a data-driven spectral model using The Cannon, which can determine stellar masses to ~ 0.07 dex from APOGEE DR12 spectra of red giants; these imply age estimates accurate to ~ 0.2 dex (40 per cent). We show that The Cannon constrains these ages foremost from spectral regions with CN absorption lines, elements whose surface abundances reflect mass-dependent dredge-up. We deliver an unprecedented catalog of 80,000 giants (including 20,000 red-clump stars) with mass and age estimates, spanning the entire disk (from the Galactic center to $R \sim 20$ kpc). We show that the age information in the spectra is not simply a corollary of the birth-material abundances [Fe/H] and [α/Fe], and that even within a mono-abundance population of stars, there are age variations that vary sensibly with Galactic position. Such stellar age constraints across the Milky Way open up new avenues in Galactic archaeology.

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Evidence for gas from a disintegrating extrasolar asteroid

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We report high-resolution spectroscopic observations of WD 1145+017 – a white dwarf that recently has been found to be transitted by multiple asteroid-sized objects within its tidal radius. We have discovered numerous circumstellar absorption lines with linewidths of ~ 300 km s^{-1} from Mg, Ca, Ti, Cr, Mn, Fe and Ni, possibly from several gas streams produced by collisions among the actively disintegrating objects. The atmosphere of WD 1145+017 is polluted

with 11 heavy elements, including O, Mg, Al, Si, Ca, Ti, V:, Cr, Mn, Fe and Ni. Evidently, we are witnessing the active disintegration and subsequent accretion of an extrasolar asteroid.

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Red giant masses and ages derived from carbon and nitrogen abundances

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We show that the masses of red giant stars can be well predicted from their photospheric carbon and nitrogen abundances, in conjunction with their spectroscopic stellar labels $\log g$, $T_{\rm eff}$, and [Fe/H]. This is qualitatively expected from mass-dependent post main sequence evolution. We here establish an empirical relation between these quantities by drawing on 1,475 red giants with asteroseismic mass estimates from *Kepler* that also have spectroscopic labels from APOGEE DR12. We assess the accuracy of our model, and find that it predicts stellar masses with fractional r.m.s. errors of about 14% (typically 0.2 $M_{\odot}$). From these masses, we derive ages with r.m.s. errors of 40%. This empirical model allows us for the first time to make age determinations (in the range 1–13 Gyr) for vast numbers of giant stars across the Galaxy. We apply our model to $\sim 52,000$ stars in APOGEE DR12, for which no direct mass and age information was previously available. We find that these estimates highlight the vertical age structure of the Milky Way disk, and that the relation of age with [α/M] and metallicity is broadly consistent with established expectations based on detailed studies of the solar neighbourhood.

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Polycyclic aromatic hydrocarbons and molecular hydrogen in oxygen-rich planetary nebulæ: the case of NGC 6720

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Evolved stars are primary sources for the formation of polycyclic aromatic hydrocarbons (PAHs) and dust grains. Their circumstellar chemistry is usually designated as either oxygen-rich or carbon-rich, although dual-dust chemistry objects, whose infrared spectra reveal both silicate- and carbon-dust features, are also known. The exact origin and nature of this dual-dust chemistry is not yet understood. *Spitzer*-IRS mid-infrared spectroscopic imaging of the nearby, oxygen-rich planetary nebula NGC 6720 reveals the presence of the 11.3-μm aromatic (PAH) emission band. It is attributed to emission from neutral PAHs, since no band is observed in the 7–8 μm range. The spatial distribution of PAHs is found to closely follow that of the warm clumpy molecular hydrogen emission. Emission from both neutral

PAHs and warm H_2 is likely to arise from photo-dissociation regions associated with dense knots that are located within the main ring. The presence of PAHs together with the previously derived high abundance of free carbon (relative to CO) suggest that the local conditions in an oxygen-rich environment can also become conducive to in-situ formation of large carbonaceous molecules, such as PAHs, via a bottom-up chemical pathway. In this scenario, the same stellar source can enrich the interstellar medium with both oxygen-rich dust and large carbonaceous molecules.

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Large dust grains in the wind of VY Canis Majoris

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Massive stars live short lives, losing large amounts of mass through their stellar wind. Their mass is a key factor determining how and when they explode as supernovae, enriching the interstellar medium with heavy elements and dust. During the red supergiant phase, mass-loss rates increase prodigiously, but the driving mechanism has proven elusive. Here we present high-contrast optical polarimetric-imaging observations of the extreme red supergiant VY Canis Majoris and its clumpy, dusty, mass-loss envelope, using the new extreme-adaptive-optics instrument SPHERE at the VLT. These observations allow us to make the first direct and unambiguous detection of submicron dust grains in the ejecta; we derive an average grain radius ~ 0.5 μm, 50 times larger than in the diffuse ISM, large enough to receive significant radiation pressure by photon scattering. We find evidence for varying grain sizes throughout the ejecta, highlighting the dynamical nature of the envelope. Grains with 0.5 μm sizes are likely to reach a safe distance from the eventual explosion of VY Canis Majoris; hence it may inject upwards of 10^{-2} $M_\odot$ of dust into the ISM.

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Quantum calculation of inelastic CO collisions with H. III. Rate coefficients for ro-vibrational transitions

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We present calculated rate coefficients for ro-vibrational transitions of CO in collisions with H atoms for a gas temperature range of 10 K $\leq T \leq$ 3000 K, based on the recent three-dimensional ab initio H–CO interaction potential of Song et al. (2013). Rate coefficients for ro-vibrational $v = 1$, $j =$ 0–30 $\rightarrow v' = 0, j'$ transitions were obtained from scattering

cross sections previously computed with the close-coupling method by Song et al. (2015). Combining these with the rate coefficients for vibrational $v = 1$–$5 \rightarrow v' < v$ quenching obtained with the infinite-order sudden approximation, we propose a new extrapolation scheme that yields the rate coefficients for ro-vibrational $v = 2$–$5, j = 0$–$30 \rightarrow v', j'$ de-excitation. Cross sections and rate coefficients for ro-vibrational $v = 2, j = 0$–$30 \rightarrow v' = 1, j'$ transitions calculated with the close-coupling method confirm the effectiveness of this extrapolation scheme. Our calculated and extrapolated rates are very different from those that have been adopted in the modeling of many astrophysical environments. The current work provides the most comprehensive and accurate set of ro-vibrational de-excitation rate coefficients for the astrophysical modeling of the H–CO collision system. Application of the previously available and new data sets in astrophysical slab models shows that the line fluxes typically change by 20–70% in high temperature environments (800 K) with an H/H_2 ratio of 1; larger changes occur for lower temperatures.

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The variable V381 Lac and its possible connection with the R CrB phenomenon

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We have performed new medium resolution spectroscopy, optical and near infrared photometry to monitor the variability of the AGB carbon star V381 Lac. Our observations revealed rapid and deep changes in the spectrum and extreme variability in the optical and near infrared bands. Most notably we observed the change of Na I D lines from deep absorption to emission, and the progressive growing of the [N II] doublet 6548–6584 Å emission, strongly related to the simultaneous photometric fading. V381 Lac occupies regions of 2MASS and WISE colour–colour diagrams typical of stars with dust formation in the envelope. The general framework emerging from the observations of V381 Lac is that of a cool AGB carbon star undergoing episodes of high mass ejection and severe occultation of the stellar photosphere reminiscent of those characterising the RCB phenomenon. Comparing the Spectral Energy Distribution obtained with the theoretical model for AGB evolution with dust in the circumstellar envelope, we can identify V381 Lac as the descendant of a star of initial mass $\sim 2\ M_\odot$, in the final AGB phases, evolved into a carbon star by repeated Third Dredge Up episodes. According to our model the star is moderately obscured ($\tau_{10} \sim 0.22$) by dust, mainly formed by amorphous carbon ($\sim 80\%$) and SiC ($\sim 20\%$), with dust grain dimensions around $\sim 0.2\ \mu$m and $\sim 0.08\ \mu$m respectively.

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A detailed view of the gas shell around R Sculptoris with ALMA

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During the asymptotic giant branch (AGB) phase, stars undergo thermal pulses – short-lived phases of explosive helium burning in a shell around the stellar core. Thermal pulses lead to the formation and mixing-up of new elements to the stellar surface. They are hence fundamental to the chemical evolution of the star and its circumstellar envelope. A further consequence of thermal pulses is the formation of detached shells of gas and dust around the star, several of which have been observed around carbon-rich AGB stars. We aim to determine the physical properties of the detached gas shell around R Sculptoris, in particular the shell mass and temperature, and to constrain the evolution of the mass-loss rate during and after a thermal pulse. We analyse CO(1–0), CO(2–1), and CO(3–2) emission, observed with the Atacama Large Millimeter/submillimeter Array (ALMA) during Cycle 0 and complemented by single-dish observations. The spatial resolution of the ALMA data allows us to separate the detached shell emission from the extended emission inside the shell. We perform radiative transfer modelling of both components to determine the shell properties and the post-pulse mass-loss properties. The ALMA data show a gas shell with a radius of 19.″5 expanding at 14.3 km s^{-1}. The different scales probed by the ALMA Cycle 0 array show that the shell must be entirely filled with gas, contrary to the idea of a detached shell. The comparison to single-dish spectra and radiative transfer modelling confirms this. We derive a shell mass of 4.5×10^{-3} $M_\odot$ with a temperature of 50 K. Typical timescales for thermal pulses imply a pulse mass-loss rate of 2.3×10^{-5} $M_\odot$ yr^{-1}. For the post-pulse mass-loss rate, we find evidence for a gradual decline of the mass-loss rate, with an average value of 1.6×10^{-5} $M_\odot$ yr^{-1}. The total amount of mass lost since the last thermal pulse is 0.03 $M_\odot$, a factor four higher compared to classical models, with a sharp decline in mass-loss rate immediately after the pulse. We find that the mass-loss rate after a thermal pulse has to decline more slowly than generally expected from models of thermal pulses. This may cause the star to lose significantly more mass during a thermal pulse cycle, which affects the lifetime on the AGB and the chemical evolution of the star, its circumstellar envelope, and the interstellar medium.

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On the non-thermal κ-distributed electrons in planetary nebulae and H II regions: the κ index and its correlations with other nebular properties

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Recently, a suspicion arose that the free electrons in planetary nebulæ (PNe) and H II regions might have non-thermal energy distributions. In this scenario, a κ index is introduced to characterize the electron energy distributions, with smaller κ values indicating larger deviations from Maxwell–Boltzmann distributions. Assuming that this is the case, we determine the κ values for a sample of PNe and H II regions by comparing the intensities of [O III] collisionally excited lines and the hydrogen Balmer jump. We find the average κ indices of PNe and H II regions to be 27 and 32, respectively. Correlations between the resultant κ values and various physical properties of the nebulæ are examined to explore the potential origin of non-thermal electrons in photoionized gaseous nebulæ. However, no positive result is obtained. Thus the current analysis does not lend to support to the idea that κ-distributed electrons are present in PNe and H II regions.

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The close circumstellar environment of Betelgeuse – III. SPHERE/ZIMPOL imaging polarimetry in the visible

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The physical mechanism through which the outgoing material of massive RSGs is accelerated above the escape velocity is unclear. Thanks to the transparency of its circumstellar envelope, the nearby red supergiant Betelgeuse gives the opportunity to probe the innermost layers of the envelope of a typical red supergiant down to the photosphere, i.e. where the acceleration of the wind is expected to occur. We took advantage of the SPHERE/ZIMPOL adaptive optics imaging polarimeter to resolve the visible photosphere and close envelope of Betelgeuse. We detect an asymmetric gaseous envelope inside a radius of 2 to 3 times the near-infrared photospheric radius of the star ($R_\star$), and a significant Hα emission mostly contained within 3 $R_\star$. From the polarimetric signal, we also identify the signature of dust scattering in an asymmetric and incomplete dust shell located at a similar radius. The presence of dust so close to the star may have a significant impact on the wind acceleration through radiative pressure on the grains. The 3 $R_\star$ radius emerges as a major interface between the hot gaseous and dusty envelopes. The detected asymmetries strengthen previous indications that the mass loss of Betelgeuse is likely tied to the vigorous convective motions in its atmosphere.

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The dust disk and companion of the nearby AGB star L_2 Puppis – SPHERE/ZIMPOL polarimetric imaging at visible wavelengths

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The bright southern star L_2 Pup is a particularly prominent asymptotic giant branch (AGB) star, as its distance of 64 pc makes it the nearest of its type. We report new adaptive optics observations of L_2 Pup at visible wavelengths with the SPHERE/ZIMPOL instrument of the VLT that confirm the presence of the circumstellar dust disk at high inclination discovered recently by Kervella et al. (2014b). The signature of the three-dimensional structure of the disk is clearly observed in the map of the degree of linear polarization p_L. We identify the inner rim of the disk through its polarimetric signature at a radius of 6 au from the AGB star. The ZIMPOL intensity images in the V and R bands also reveal a close-in secondary source at a projected separation of 2 au from the primary. The identification of the spectral type of this companion is uncertain due to the strong reddening from the disk, but its photometry suggests that it is a late K giant, of comparable mass to the AGB star. We present refined physical parameters for the dust disk derived using the RADMC-3D radiative transfer code. We also interpret the p_L map using a simple polarization model to infer the three-dimensional structure of the envelope. Interactions between the inner binary system and the disk apparently form spiral structures that propagate along the orthogonal axis to the disk to form streamers. Two dust plumes propagating orthogonally to the disk are also detected. They originate in the inner stellar system, and are possibly related to the interaction of the wind of the two stars with the material in the disk. Based on the morphology of the envelope of L_2 Pup, we propose that this star is at an early stage of the formation of a bipolar planetary nebula.

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Unusual shock-excited OH maser emission in a young Planetary Nebula

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We report on OH maser emission toward G 336.644−0.695 (IRAS 16333−4807), which is a H_2O maser-emitting Planetary Nebula (PN). We have detected 1612, 1667 and 1720 MHz OH masers at two epochs using the Australia Telescope Compact Array (ATCA), hereby confirming it as the seventh known case of an OH-maser-emitting PN. This is only the second known PN showing 1720 MHz OH masers after K 3-35 and the only evolved stellar object with 1720 MHz OH masers as the strongest transition. This PN is one of a group of very young PNe. The 1612 MHz and 1667 MHz masers are at a similar velocity to the 22 GHz H_2O masers, whereas the 1720 MHz masers show a variable spectrum, with several components spread over a higher velocity range (up to 36 km s^{-1}). We also detect Zeeman splitting in the 1720 MHz transition at two epochs (with field strengths of $\sim$ 2 to $\sim$ 10 mG), which suggests the OH emission at 1720 MHz is formed in a magnetized environment. These 1720 MHz OH masers may trace short-lived equatorial ejections during the formation of the PN.

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CK Vul: a smorgasbord of hydrocarbons rules out a 1670 nova (and much else besides)

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We present observations of CK Vul obtained with the *Spitzer* Space Telescope. The infrared spectrum reveals a warm dust continuum with nebular, molecular hydrogen and HCN lines superimposed, together with the "Unidentified Infrared" (UIR) features. The nebular lines are consistent with emission by a low density gas. We conclude that the *Spitzer* data, combined with other information, are incompatible with CK Vul being a classical nova remnant in "hibernation" after the event of 1670, a "Very Late Thermal Pulse", a "Luminous Red Variable" such as V838 Mon, or a "Diffusion-induced nova". The true nature of CK Vul remains a mystery.

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Electron-capture and β-decay rates for *sd*-shell nuclei in stellar environments relevant to high-density O–Ne–Mg cores

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Electron-capture and β-decay rates for nuclear pairs in the *sd*-shell are evaluated at high densities and high temperatures relevant to the final evolution of electron-degenerate O–Ne–Mg cores of stars with the initial masses of 8–10 $M_\odot$. Electron capture induces a rapid contraction of the electron-degenerate O–Ne–Mg core. The outcome of rapid contraction depends on the evolutionary changes in the central density and temperature, which are determined by the competing processes of contraction, cooling, and heating. The fate of the stars is determined by these competitions, whether they end up with electron-capture supernovæ or Fe core-collapse supernovæ. Since the competing processes are induced by electron capture and β-decay, the accurate weak rates are crucially important. The rates are obtained for pairs with $A = 20$, 23, 24, 25, and 27 by shell-model calculations in the *sd*-shell with the USDB Hamiltonian. Effects of Coulomb corrections on the rates are evaluated. The rates for pairs with $A = 23$ and 25 are important for nuclear Urca processes that determine the cooling rate of the O–Ne–Mg core, while those for pairs with $A = 20$ and 24 are important for the core contraction and heat generation rates in the core. We provide these nuclear rates at stellar environments in tables with fine enough meshes at various densities and temperatures for the studies of astrophysical processes sensitive to the rates. In particular, the accurate rate tables are crucially important for the final fates of not only O–Ne–Mg cores but also a wider range of stars, such as C–O cores of lower-mass stars.

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Discovery of collimated bipolar outflows in the planetary nebula Th 2-A

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We present a comprehensive set of spatially resolved, integral field spectroscopic mapping of the Wolf–Rayet planetary nebula Th 2-A, obtained using the Wide Field Spectrograph on the Australian National University 2.3-m telescope. Velocity-resolved Hα channel maps with a resolution of 20 km s^{-1} allow us to identify different kinematic components within the nebula. This information is used to develop a three-dimensional morpho-kinematic model of the nebula using the interactive kinematic modeling tool SHAPE. These results suggest that Th 2-A has a thick toroidal shell with an expansion velocity of 40 ± 10 km s^{-1}, and a thin prolate ellipsoid with collimated bipolar outflows toward its axis reaching velocities in the range of 70–110 km s^{-1}, with respect to the central star. The relationship between its morpho-kinematic structure and *peculiar* [WO]-type stellar characteristics deserves further investigation.

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A luminous yellow post-AGB star in the Galactic globular cluster M 79

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We report discovery of a luminous F-type post-asymptotic-giant-branch (PAGB) star in the Galactic globular cluster (GC) M 79 (NGC 1904). At visual apparent and absolute magnitudes of $V = 12.20$ and $M_V = -3.46$ mag, this "yellow" PAGB star is by a small margin the visually brightest star known in any GC. It was identified using CCD observations in the $uBVI$ photometric system, which is optimized to detect stars with large Balmer discontinuities, indicative of very low surface gravities. Follow-up observations with the SMARTS 1.3- and 1.5-m telescopes show that the star is not variable in light or radial velocity, and that its velocity is consistent with cluster membership. Near- and mid-infrared observations with 2MASS and WISE show no evidence for circumstellar dust. We argue that a sharp upper limit to the luminosity function exists for yellow PAGB stars in old populations, making them excellent candidates for Population II standard candles, which are four magnitudes brighter than RR Lyræ variables. Their luminosities are consistent with the stars being in a PAGB evolutionary phase, with core masses of ~ 0.53 M$_\odot$.
We also detected four very hot stars lying above the horizontal branch ("AGB-manqué" stars); along with the PAGB star, they are the brightest objects in M 79 in the near ultraviolet. In an Appendix, we give periods and light curves for five variables in M 79: three RR Lyræ stars, a Type II Cepheid, and a semi-regular variable.

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New models for the evolution of post-asymptotic giant branch stars and central stars of planetary nebulæ

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The post Asymptotic Giant Branch (AGB) phase is arguably one of the least understood phases of the evolution of

low- and intermediate- mass stars. The two grids of models presently available are based on outdated micro- and macro-physics and do not agree with each other. We study the timescales of post-AGB and CSPNe in the context of our present understanding of the micro- and macro-physics of stars. We want to assess whether new post-AGB models, based on the latter improvements in TP-AGB modeling, can help to understand the discrepancies between observation and theory and within theory itself. We compute a grid of post-AGB full evolutionary sequences that include all previous evolutionary stages from the Zero Age Main Sequence to the White Dwarf phase. Models are computed for initial masses between 0.8 and 4 $M_\odot$ and for a wide range of initial metallicities (Z_0 = 0.02, 0.01, 0.001, 0.0001); this allow us to provide post-AGB timescales and properties for H-burning post-AGB objects with masses in the relevant range for the formation of planetary nebulæ ($\sim$ 0.5–0.8 $M_\odot$). We find post-AGB timescales that are at least $\sim$ 3 to $\sim$ 10 times shorter than those of old post-AGB stellar evolution models. This is true for the whole mass and metallicity range. The new models are also $\sim$ 0.1–0.3 dex brighter than the previous models with similar remnant masses. Post-AGB timescales show only a mild dependence on metallicity. The shorter post-AGB timescales derived in the present work are in agreement with recent semiempirical determinations of the post-AGB timescales from the CSPNe in the Galactic Bulge. Due to the very different post-AGB crossing times, initial–final mass relation and luminosities of the present models, they will have a significant impact in the predictions for the formation of planetary nebulæ and the planetary nebulæ luminosity function.

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Concurrent formation of carbon and silicate dust in nova V1280 Sco

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We present infrared multi-epoch observations of the dust forming nova V1280 Sco over $\sim$ 2000 days from the outburst. The temporal evolution of the infrared spectral energy distributions at 1272, 1616 and 1947 days can be explained by the emissions produced by amorphous carbon dust of mass (6.6–8.7)$\times 10^{-8}$ $M_\odot$ with a representative grain size of 0.01 μm and astronomical silicate dust of mass (3.4–4.3)$\times 10^{-7}$ $M_\odot$ with a representative grain size of 0.3–0.5 μm. Both of these dust species travel farther away from the white dwarf without an apparent mass evolution throughout those later epochs. The dust formation scenario around V1280 Sco suggested from our analyses is that the amorphous carbon dust is formed in the nova ejecta followed by the formation of silicate dust in the expanding nova ejecta or as a result of the interaction between the nova wind and the circumstellar medium.

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Detailed homogeneous abundance studies of 14 Galactic s-process enriched post-AGB stars: In search of lead (Pb)

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Context: This paper is part of a larger project in which we systematically study the chemical abundances of Galactic and extragalactic post-asymptotic giant branch (post-AGB) stars. The goal at large is to provide improved observational constraints to the models of the complex interplay between the AGB s-process nucleosynthesis and the associated mixing processes.
Aims: Lead (Pb) is the final product of the s-process nucleosynthesis and is predicted to have large overabundances with respect to other s-process elements in AGB stars of low metallicities. However, Pb abundance studies of s-process enriched post-AGB stars in the Magellanic Clouds show a discrepancy between observed and predicted Pb abundances. The determined upper limits based on spectral studies are much lower than what is predicted. In this paper, we focus specifically on the Pb abundance of 14 Galactic s-process enhanced post-AGB stars to check whether the same discrepancy is present in the Galaxy as well. Among these 14 objects, two were not yet subject to a detailed abundance study in the literature. We apply the same method to obtain accurate abundances for the 12 others. Our homogeneous abundance results provide the input of detailed spectral synthesis computations in the spectral regions where Pb lines are located.
Methods: We used high-resolution UVES and HERMES spectra for detailed spectral abundance studies of our sample of Galactic post-AGB stars. None of the sample stars display clear Pb lines, and we only deduced upper limits of the Pb abundance by using spectrum synthesis in the spectral ranges of the strongest Pb lines.
Results: We do not find any clear evidence of Pb overabundances in our sample. The derived upper limits are strongly correlated with the effective temperature of the stars with increasing upper limits for increasing effective temperatures. We obtain stronger Pb constraints on the cooler objects. Moreover, we confirm the s-process enrichment and carbon enhancement of two unstudied 21-μm sources IRAS 13245−6428 and IRAS 14429−4539. The mildly s-process enhanced post-AGB star IRAS 17279−1119 is part of a binary system and may be the long sought precursor of extrinsic Ba stars.
Conclusion: Stars with $T_{\rm eff} > 7500$ K do not provide strong constraints on the Pb abundance as the strongest line in the optical spectrum is only detectable at unrealistically high Pb atmospheric abundances. Combining the Pb abundance results from this study with abundances from our previous studies, we conclude that the discrepancy between theory and observation increases towards lower metallicities. The model predictions are consistent with the deduced upper limits on the Pb abundances for all stars with [Fe/H] > -0.7 dex. For stars with [Fe/H] < -0.7 dex, however, the model predictions overestimate the Pb abundances with respect to the other s-process elements. All objects, except IRAS 17279−1119, confirm the relation between neutron exposure $[hs/ls]$ and third dredge-up efficiency $[s/\mathrm{Fe}]$, whereas no relation between metallicity and neutron exposure is detected within the metallicity range of our total sample ($-1.4 <$ [Fe/H] < -0.2). The mild enrichment of IRAS 17279−1119 can probably be attributed to a cut-off of the AGB evolution due to binary interactions. To our knowledge, IRAS 17279−1119 is the first s-process enhanced Galactic post-AGB star known in a binary system and is a possible precursor of the extrinsic Ba dwarf stars. We corroborate the finding that the variety in abundance profiles shows that a large spread of neutron irradiation is needed for a given metallicity. Lead-rich stars are yet to be found in post-AGB stars.

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EU Del: exploring the onset of pulsation-driven winds in giant stars

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We explore the wind-driving mechanism of giant stars through the nearby (117 pc), intermediate-luminosity ($L \sim 1600$ $L_\odot$) star EU Del (HIP 101810, HD 196610). APEX observations of the CO (3–2) and (2–1) transitions are used to derive a wind velocity of 9.51 ± 0.02 km s^{-1}, a ^{12}C/^{13}C ratio of 14^{+9}_{-4} and a mass-loss rate of a few $\times 10^{-8}$ $M_\odot$ yr^{-1}. From published spectra, we estimate that the star has a metallicity of [Fe/H] $= -0.27 \pm 0.30$ dex. The star's dusty envelope lacks a clear 10-μm silicate feature, despite the star's oxygen-rich nature. Radiative transfer modelling cannot fit a wind acceleration model which relies solely on radiation pressure on condensing dust. We compare our results to VY Leo (HIP 53449), a star with similar temperature and luminosity, but different pulsation properties. We suggest the much stronger mass loss from EU Del may be driven by long-period stellar pulsations, due to its potentially lower mass. We explore the implications for the mass-loss rate and wind velocities of other stars.

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Hot bubbles of planetary nebulæ with hydrogen-deficient winds I. Heat conduction in a chemically stratified plasma

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Heat conduction has been found a plausible solution to explain discrepancies between expected and measured temperatures in hot bubbles of planetary nebulæ (PNe). While the heat conduction process depends on the chemical composition, to date it has been exclusively studied for pure hydrogen plasmas in PNe. A smaller population of PNe show hydrogen-deficient and helium- and carbon-enriched surfaces surrounded by bubbles of the same composition; considerable differences are expected in physical properties of these objects in comparison to the pure hydrogen case. The aim of this study is to explore how a chemistry-dependent formulation of the heat conduction affects physical properties and how it affects the X-ray emission from PN bubbles of hydrogen-deficient stars. We extend the description of heat conduction in our radiation hydrodynamics code to work with any chemical composition. We then compare the bubble-formation process with a representative PN model using both the new and the old descriptions. We also compare differences in the resulting X-ray temperature and luminosity observables of the two descriptions. The improved equations show that the heat conduction in our representative model of a hydrogen-deficient PN is nearly as efficient with the chemistry-dependent description; a lower value on the diffusion coefficient is compensated by a slightly steeper temperature gradient. The bubble becomes somewhat hotter with the improved equations, but differences are otherwise minute. The observable properties of the bubble in terms of the X-ray temperature and luminosity are seemingly unaffected.

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The bright symbiotic Mira EF Aquilæ

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An incidental spectrum of the poorly studied long period variable EF Aquilæ shows [O III] emission indicative of a symbiotic star. Strong GALEX detections in the UV reinforce this classification, providing overt evidence for the presence of the hot subluminous companion. Recent compilations of the photometric behavior strongly suggest that the cool component is a Mira variable. Thus EF Aql appears to be a member of the rare symbiotic Mira subgroup.

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On the progenitors of Local Group novæ. II. The red giant nova rate of M 31

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In our preceding paper, Liverpool Telescope data of M 31 novæ in eruption were used to facilitate a search for their progenitor systems within archival *Hubble* Space Telescope (HST) data, with the aim of detecting systems with red giant secondaries (RG-novæ) or luminous accretion disks. From an input catalog of 38 spectroscopically confirmed novæ with archival quiescent observations, likely progenitors were recovered for eleven systems. Here we present the results of the subsequent statistical analysis of the original survey, including possible biases associated with the survey and the M 31 nova population in general. As part of this analysis we examine the distribution of optical decline times (t_2) of M 31 novæ, how the likely bulge and disk nova distributions compare, and how the M 31 t_2 distribution compares to that of the Milky Way. Using a detailed Monte Carlo simulation, we determine that 30^{+13}_{-10} per cent of all M 31 nova eruptions can be attributed to RG-nova systems, and at the 99 per cent confidence level, > 10 per cent of all M 31 novæ are RG-novæ. This is the first estimate of a RG-nova rate of an entire galaxy. Our results also imply that RG-novæ in M 31 are more likely to be associated with the M 31 disk population than the bulge, indeed the results are consistent with all RG-novæ residing in the disk. If this result is confirmed in other galaxies, it suggests any Type Ia supernovæ that originate from RG-nova systems are more likely to be associated with younger populations, and may be rare in old stellar populations, such as early-type galaxies.

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The Fe/Ni ratio in ionized nebulæ: clues on dust depletion patterns

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We perform a homogeneous analysis of the Fe/Ni abundance ratio in eight Galactic planetary nebulæ (PNe) and three Galactic H II regions that include the Orion nebula, where we study four nebular zones and one shocked region. We

use [Fe II], [Fe III], and [Ni III] lines, and ionization correction factors (ICFs) that account for the unobserved ions. We derive an ICF for nickel from an extensive grid of photoionization models. We compare our results with those derived by other authors for 16 neutral clouds in the solar neighbourhood with available Fe/Ni ratios in the literature.
We find an excellent agreement between the ionized nebulæ and the diffuse clouds, with both types of regions showing a clear correlation between the Fe/Ni ratios and the iron and nickel depletion factors. The trend shows that the objects with a relatively low depletion have near solar Fe/Ni ratios whereas at higher depletions the Fe/Ni ratio increases with the depletion. Our results confirm that, compared to iron atoms, nickel ones are more efficiently stuck to the dust grains in ambients where dust formation or growth have been more efficient.

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Evolution of long-lived globular cluster stars. II. Sodium abundance variations on the asymptotic giant branch as a function of globular cluster age and metallicity

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Long-lived stars in globular clusters exhibit chemical peculiarities with respect to their halo counterparts. In particular, sodium-enriched stars are identified as belonging to a second stellar population born from cluster material contaminated by the hydrogen-burning ashes of a first stellar population. Their presence and numbers in different locations of the colour-magnitude diagram provide important constraints on the self-enrichment scenarios. In particular, the ratio of Na-poor to Na-rich stars on the asymptotic giant branch (AGB) has recently been found to vary strongly from cluster to cluster (NGC 6752, 47 Tuc, and NGC 2808), while it is relatively constant on the red giant branch (RGB). We investigate the impact of both age and metallicity on the theoretical sodium spread along the AGB within the framework of the fast rotating massive star (FRMS) scenario for globular cluster self-enrichment. We computed evolution models of low-mass stars for four different metallicities ([Fe/H] = -2.2, -1.75, -1.15, -0.5) assuming the initial helium-sodium abundance correlation for second population stars derived from the FRMS models and using mass loss prescriptions on the RGB with two realistic values of the free parameter in the Reimers formula. Based on this grid of models we derive the theoretical critical initial mass for a star born with a given helium, sodium, and metal content that determines whether that star will climb or not the AGB. This allows us to predict the maximum sodium content expected on the AGB for globular clusters as a function of both their metallicity and age. We find that (1) at a given metallicity, younger clusters are expected to host AGB stars exhibiting a larger sodium spread than older clusters and (2) at a given age, higher sodium dispersion along the AGB is predicted in the most metal-poor globular clusters than in the metal-rich ones. We also confirm the strong impact of the mass loss rate in the earlier evolution phases on the Na cut on the AGB: the higher the mass loss, the stronger the trends with age and metallicity. The theoretical trends we obtain provide, in principle, an elegant qualitative explanation to the different sodium spreads that are observed along the AGB in the Galactic globular clusters of different ages and [Fe/H] values. Although it is real, the slope with both age and metallicity is relatively flat, although it steepens when accounting for mass loss variations. Therefore, additional parameters may play a role in inducing cluster to cluster variations, that are difficult to disentangle from existing data.

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s-Processing in AGB stars revisited. II. Enhanced ^{13}C production through MHD-induced mixing

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Slow neutron captures are responsible for the production of about 50% of elements heavier than iron, mainly, occurring during the asymptotic giant branch phase of low-mass stars ($1 \lesssim M/\mathrm{M}_\odot \lesssim 3$), where the main neutron source is the ^{13}C(α,n)^{16}O reaction. This last is activated from locally-produced ^{13}C, formed by partial mixing of hydrogen into the He-rich layers. We present here the first attempt at describing a physical mechanism for the formation of the ^{13}C reservoir, studying the mass circulation induced by magnetic buoyancy and without adding new free parameters to those already involved in stellar modelling. Our approach represents the application, to the stellar layers relevant for s-processing, of recent exact, analytical 2D and 3D models for magneto-hydrodynamic processes at the base of convective envelopes in evolved stars in order to promote downflows of envelope material for mass conservation, during the occurrence of a dredge-up phenomenon. We find that the proton penetration is characterized by small concentrations, but extended over a large fractional mass of the He-layers, thus producing ^{13}C reservoirs of several 10^{-3} M$_\odot$. The ensuing ^{13}C-enriched zone has an almost flat profile, while only a limited production of ^{14}N occurs. In order to verify the effects of our new findings we show how the abundances of the main s-component nuclei can be accounted for in solar proportions and how our large ^{13}C-reservoir allows us to solve a few so far unexplained features in the abundance distribution of post-AGB objects.

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Abundances in normal and C-enhanced metal-poor stars

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An increasing fraction of carbon-enhanced metal-poor (CEMP) stars is found as their iron abundance, [Fe/H], decreases below [Fe/H] $= -2.0$. The CEMP-s stars have the highest absolute carbon abundances, [C/H], and are thought to owe their enrichment in carbon and the slow neutron-capture (s-process) elements to mass transfer from a former asymptotic giant branch (AGB) binary companion. The most Fe-poor CEMP stars are normally single, exhibit somewhat lower [C/H] than CEMP-s stars, but show no s-process element enhancement (CEMP-no stars). Abundance determinations of CNO offer clues to their formation sites.
Our aim is to use the medium-resolution spectrograph X-shooter/VLT to determine stellar parameters and abundances for C, N, Sr, and Ba in several classes of CEMP stars in order to further classify and constrain the astrophysical formation sites of these stars.
Atmospheric parameters for our programme stars were estimated from a combination of $V - K$ photometry, model isochrone fits, and estimates from a modified version of the SDSS/SEGUE spectroscopic pipeline. We then used X-shooter spectra in conjunction with the 1D LTE spectrum synthesis code MOOG, 1D ATLAS9 atmosphere models to

derive stellar abundances, and, where possible, isotopic $^{12}C/^{13}C$ ratios.
Abundances (or limits) of C, N, Sr, and Ba are derived for a sample of 27 faint metal-poor stars for which the X-shooter spectra have sufficient signal-to-noise ratios. These moderate resolution, low S/N ($\sim$ 10–40) spectra prove sufficient to perform limited chemical tagging and enable assignment of these stars into the CEMP subclasses (CEMP-*s* and CEMP-no). According to the derived abundances, 17 of our sample stars are CEMP-*s* and 3 are CEMP-no, while the remaining 7 are carbon-normal. For four CEMP stars, the subclassification remains uncertain, and two of them may be pulsating AGB stars.
The derived stellar abundances trace the formation processes and sites of our sample stars. The [C/N] abundance ratio is useful for identifying stars with chemical compositions unaffected by internal mixing, and the [Sr/Ba] abundance ratio allows us to distinguish between CEMP-*s* stars with AGB progenitors and the CEMP-no stars. Suggested formation sites for the latter include faint supernovae with mixing and fallback and/or primordial, rapidly-rotating, massive stars (spinstars). X-shooter spectra have thus proved to be valuable tools in the continued search for their origin.

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Conference Papers

Dust and molecules in extra-galactic planetary nebulæ

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Extra-galactic planetary nebulæ (PNe) permit the study of dust and molecules in metallicity environments other than the Galaxy. Their known distances lower the number of free parameters in the observations vs. models comparison, providing strong constraints on the gas-phase and solid-state astrochemistry models. Observations of PNe in the Galaxy and other Local Group galaxies such as the Magellanic Clouds (MC) provide evidence that metallicity affects the production of dust as well as the formation of complex organic molecules and inorganic solid-state compounds in their circumstellar envelopes. In particular, the lower metallicity MC environments seem to be less favorable to dust production and the frequency of carbonaceous dust features and complex fullerene molecules is generally higher with decreasing metallicity. Here, I present an observational review of the dust and molecular content in extra-galactic PNe as compared to their higher metallicity Galactic counterparts. A special attention is given to the level of dust processing and the formation of complex organic molecules (e.g., polycyclic aromatic hydrocarbons, fullerenes, and graphene precursors) depending on metallicity.

Oral contribution, published in IAU General Assembly XXIX, Focus Meeting 4 "Planetary Nebulæ as Probes of Galactic Structure and Evolution"; To appear in "Focus on Astronomy", eds. Méndez, Stanghellini & Peña, Cambridge University Press (Invited Talk)
Available from arXiv:1511.06165

Pathways for observing stellar surfaces using 3D hydrodynamical simulations of evolved stars

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Evolved stars are among the largest and brightest stars and they are ideal targets for the new generation of sensitive, high resolution instrumentation that provides spectrophotometric, interferometric, astrometric, and imaging observables. The interpretation of the complex stellar surface images requires numerical simulations of stellar convection

that take into account multi-dimensional time-dependent radiation hydrodynamics with realistic input physics. We show how the evolved star simulations are obtained using the radiative hydrodynamics code CO5BOLD and how the accurate observables are computed with the post-processing radiative transfer code OPTIM3D. The synergy between observations and theoretical work is supported by a proper and quantitative analysis using these simulations, and by strong constraints from the observational side.

Oral contribution, published in EAS Publications Series, Volume 71–72, p.237 (2015)
Available from arXiv:1512.03590
and from http://adsabs.harvard.edu/abs/2015EAS....71..237C

The nearby AGB star L_2 Puppis: the birth of a planetary nebula?

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Adaptive optics observations in the infrared (VLT/NACO, Kervella et al. 2014) and visible (VLT/SPHERE, Kervella et al. 2015) domains revealed that the nearby AGB star L_2 Pup ($d = 64$ pc) is surrounded by a dust disk seen almost edge-on. Thermal emission from a large dust "loop" is detected at 4 μm up to more than 10 au from the star. We also detect a secondary source at a separation of 32 mas, whose nature is uncertain. L_2 Pup is currently a relatively "young" AGB star, so we may witness the formation of a planetary nebula. The mechanism that breaks the spherical symmetry of mass loss is currently uncertain, but we propose that the dust disk and companion are key elements in the shaping of the bipolar structure. L_2 Pup emerges as an important system to test this hypothesis.

Oral contribution, published in "Physics of Evolved Stars", 8–12 June 2015, Nice, EAS Publications Series, Volume 71–72, p.211 (2015)
Available from arXiv:1512.03459
and from http://poe2015.sciencesconf.org/resource/page/id/16

Evolved stars as donors in symbiotic binaries

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This contribution is focused on the role of cool giants in symbiotic binaries. Especially, we pay attention to their mass-loss rates and the mass-transfer onto their compact accretors.

Oral contribution, published in EAS Publications Series, Volume 71–72, p.189 (2015)
Available from arXiv:1512.08803

Announcement

IAU Symposium 323 – Planetary nebulæ: Multi-wavelength probes of stellar and galactic evolution Second announcement

Dear Colleague,

This is the 2nd announcement for the IAU Symposium 323 – Planetary nebulæ: Multi-wavelength probes of stellar and galactic evolution to be held on October 10–14, 2016, in Beijing, China. The Symposium will encompass all aspects of the impact and importance of planetary nebulæ (PNe) on stellar and galactic evolution. In particular, we will cover the following topics:

- New challenges to surveys of PNe in the Local Group
- PNe as a versatile laboratory of dust and molecular studies
- From the asymptotic giant branch to the white dwarf stellar phases
- The connection between binary evolution and the PN phenomena
- PNe as probes of galactic chemical evolution and dynamics
- PNe outside of the local group
- PNe and forefront instrumentation

Invited speakers: F. Bresolin, L. Coccato, G. Delgado-Inglada, F. Dell'Agli, X. Fang, D. Frew, D. Jones, J. Kalirai, H. Kim, S. Kwok, E. Lagadec, A. Longobardi, M. Lugaro, M. Manteiga, R. Méndez, B. Miszalski, M. Molla, R. Montez, C. Morrisset, J. Nordhaus, S. Ramstedt, L. Sabin, G. Sloan, R. Stancliffe, N. Sterling, K.-W. Suh, S. Torres-Peimbert, G. van de Steene, Y. Zhang.

Contributed talks will be selected from the submitted titles and abstracts. Two discussion sessions, one on modeling and data and another on PNe and forefront instrumentation, will be arranged, as well as splash sessions for posters.

The IAU is offering a limited number of grants to support non-Chinese participants without other means. Priority will be given to under-represented and disadvantaged groups (all according to the IAU rules). Grant applications should be sent to iaus323@pku.edu.cn no later than May 31, 2016. The results will be notified by June 30, 2016.

Important dates:

1. April 1, 2016: Opening of early registration, as well as submission of oral and poster contributions;
2. May 31, 2016: Deadline for oral contributions and grant applications;
3. June 30, 2016: Deadline for poster contributions; Grant application results notified;
4. July 31, 2016: Closing of early registration.

More information will be found on the conference's home page http://iaus323.pku.edu.cn/

We hope to see a broad participation to this Symposium!

Xiaowei Liu, Letizia Stanghellini, and Amanda Karakas (SOC co-Chairs)

NB: The IAU follows the regulations of the International Council for Science (ICSU) and concurs with the actions undertaken by their Standing Committee on Freedom in the Conduct of Science on non-discrimination and universality of science.

See also http://iaus323.pku.edu.cn/