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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 141st issue of the AGB Newsletter. Besides a variety of topics covered by recently accepted or submitted refereed journal papers, there are three very nice conference review papers for you to look at.

Congratulations to Olga Zamora, for having successfully defended her Ph.D. thesis on R-type stars!

Also don't forget to check out the update on SHAPE, the 3D morpho-kinematic modelling tool.

The next issue will be distributed on the 2nd of May 2009; the deadline for contributions is the 1st of May.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Which of the chemical peculiarities of globular cluster stars are also found in the field?

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

The global gas and dust budget of the Large Magellanic Cloud: AGB stars and supernovae, and the impact on the ISM evolution

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We report on an analysis of the gas and dust budget in the the interstellar medium (ISM) of the Large Magellanic Cloud (LMC). Recent observations from the *Spitzer Space Telescope* enable us to study the mid-infrared dust excess of asymptotic giant branch (AGB) stars in the LMC. This is the first time we can quantitatively assess the gas and dust input from AGB stars over a complete galaxy, fully based on observations. The integrated mass-loss rate over all intermediate and high mass-loss rate carbon-rich AGB candidates in the LMC is 8.5×10^{-3} $M_{\odot}$ yr^{-1}, up to 2.1×10^{-2} $M_{\odot}$ yr^{-1}. This number could be increased up to 2.7×10^{-2} $M_{\odot}$ yr^{-1}, if oxygen-rich stars are included. This is overall consistent with theoretical expectations, considering the star formation rate when these low- and intermediate-mass stars where formed, and the initial mass functions.
AGB stars are one of the most important gas sources in the LMC, with supernovae (SNe), which produces about 2–4$\times 10^{-2}$ $M_{\odot}$ yr^{-1}. At the moment, the star formation rate exceeds the gas feedback from AGB stars and SNe in the LMC, and the current star formation depends on gas already present in the ISM. This suggests that as the gas in the ISM is exhausted, the star formation rate will eventually decline in the LMC, unless gas is supplied externally.
Our estimates suggest 'a missing dust-mass problem' in the LMC, which is similarly found in high-z galaxies: the accumulated dust mass from AGB stars and possibly SNe over the dust life time (400–800 Myrs) is significant less than the dust mass in the ISM. Another dust source is required, possibly related to star-forming regions.

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Available from arXiv:0903.1123

Massive AGB models of low metallicity: the implications for the self-enrichment scenario in metal poor Globular Clusters

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We present the physical and chemical properties of intermediate-mass stars models of low metallicity, evolved along the thermal pulse phase. The target of this work is to extend to low metallicities, $Z = 1, 2$ and 6×10^{-4}, the models previously computed for chemistries typical of Globular Clusters of an intermediate metallicity ($Z = 0.001$), and for the most metal-rich clusters found in our Galaxy ($Z = 0.004$); the main goal is to test the self-enrichment scenario also for metal poor Globular Clusters We calculated three grids of intermediate-mass models with metallicities $Z = 10^{-4}$, 2×10^{-4}, and 6×10^{-4}; the evolutionary sequences are followed from the pre-main sequence throughout the AGB

phase, almost until the ejection of the whole envelope. We discuss the chemistry of the ejecta, and in particular the mass fractions of those elements that have been investigated during the many, deep, spectrocopic surveys of Globular Clusters Although the data for oxygen and sodium are scarce for low metallicity Globular Clusters, the few data for the unevolved stars in NGC 6397 are compatible with the models. Further, we find good agreement with the C–N anticorrelation of unevolved stars in the cluster M 15. In this cluster, however, no stars having low oxygen ([O/Fe] = −1) have been detected. The most massive, very metal poor clusters, should contain such stars, according to the present models. At the lowest metallicity $Z = 10^{-4}$, the ejecta of the most massive AGBs have C/O > 1, due to the dramatic decrease of the oxygen abundance. We discuss the possible implications of this prediction.

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A large stellar evolution database for population synthesis studies. V. Stellar models and isochrones with CNONa abundance anticorrelation

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We present a new grid of stellar models and isochrones for old stellar populations, covering a large range of [Fe/H] values, for an heavy element mixture characterized by CNONa abundance anticorrelations as observed in Galactic globular cluster stars. The effect of this metal abundance pattern on the evolutionary properties of low mass stars, from the main sequence to the horizontal branch phase is analyzed. We perform comparisons between these new models, and our reference α-enhanced calculations, and discuss briefly implications for CMDs showing multiple main sequence or subgiant branches. A brief qualitative discussion of the effect of CN abundances on color–$T_{\rm eff}$ transformations is also presented, highlighting the need to determine theoretical color transformations for the appropriate metal mixture, if one wants to interpret observations in the Strömgren system, or broadband filters blueward of the Johnson V-band.

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Chemical Abundances of the S star GZ Peg

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The chemical compositions of stars from the Asymptotic Giant Branch are still poorly known due to the low temperatures of their atmospheres and therefore the presence of many molecular transitions hampering the analysis of atomic lines. One way to overcome this difficulty is by the study of lines in regions free from molecular contamination. We have chosen some of those regions to study the chemical abundance of the S-type star GZ Peg. Stellar parameters are derived from spectroscopic analysis and a metallicity of −0.77 dex is found. Chemical abundances of 8 elements are reported and an enhancement of s-process elements is inferred, typical to that of an S-type star.

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Available from arXiv:0903.1053

A massive white dwarf member of the Coma Berenices Open Cluster

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We report the identification, from a photometric, astrometric and spectroscopic study, of a massive white dwarf member of the nearby, approximately solar metalicity, Coma Berenices open star cluster (Melotte 111). We find the optical to near-IR energy distribution of WD 1216+260 to be entirely consistent with that of an isolated DA and determine the effective temperature and surface gravity of this object to be $T_{\rm eff} = 15739^{+197}_{-196}$ K and $\log g = 8.46^{+0.03}_{-0.02}$. We set tight limits on the mass of a putative cool companion, $M \gtrsim 0.036$ M$_\odot$ (spatially unresolved) and $M \gtrsim 0.034$ M$_\odot$, (spatially resolved and $a \lesssim 2500$ AU). Based on the predictions of CO core, thick-H layer evolutionary models we determine the mass and cooling time of WD 1216+260 to be $M_{\rm WD} = 0.90 \pm 0.04$ M$_\odot$ and $\tau_{\rm cool} = 363^{+46}_{-41}$ Myrs respectively. For an adopted cluster age of $\tau = 500 \pm 100$ Myrs we infer the mass of its progenitor star to be $M_{\rm init} = 4.77^{+5.37}_{-0.97}$ M$_\odot$. We briefly discuss this result in the context of the form of the stellar initial mass–final mass relation.

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A new detailed examination of white dwarfs in NGC 3532 and NGC 2287

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We present the results of a photometric and spectroscopic study of the white dwarf candidate members of the intermediate age open clusters NGC 3532 and NGC 2287. Of the nine objects investigated, it is determined that six are probable members of the clusters, four in NGC 3532 and two in NGC 2287. For these six white dwarfs we use our estimates of their cooling times together with the cluster ages to constrain the lifetimes and masses of their progenitor stars. We examine the location of these objects in initial mass–final mass space and find that they now provide no evidence for substantial scatter in initial mass–final mass relation as suggested by previous investigations. Instead, we demonstrate that, when combined with current data from other solar metalicity open clusters and the Sirius binary system, they hint at an IFMR that is steeper in the initial mass range 3 M$_\odot \lesssim M_{\rm init} \lesssim 4$ M$_\odot$ than at progenitor masses immediately lower and higher than this. This form is generally consistent with the predictions of stellar evolutionary models and can aid population synthesis models in reproducing the relatively sharp drop observed at the high mass end of the main peak in the mass distribution of white dwarfs.

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Potassium abundances in red giants of mildly to very metal-poor globular clusters

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A non-LTE analysis of K I resonance lines at 7664.91 and 7698.97 Å was carried out for 15 red giants belonging to three globular clusters of different metallicity (M 4, M 13, and M 15) along with two reference early-K giants (ρ Boo and α Boo), in order to check whether the K abundances are uniform within a cluster and to investigate the behavior

of [K/Fe] ratio at the relevant metallicity range of $-2.5 < \mathrm{[Fe/H]} < -1$. We confirmed that [K/H] (as well as [Fe/H]) is almost homogeneous within each cluster to a precision of $\lesssim 0.1$ dex, though dubiously large deviations are exceptionally seen for two peculiar stars showing signs of considerably increased turbulence in the upper atmosphere. The resulting [K/Fe] ratios are mildly supersolar by a few tenths of dex for three clusters, tending to gradually increase from $\sim +0.1$–0.2 at $\mathrm{[Fe/H]} \sim -1$ to $\sim +0.3$ at $\mathrm{[Fe/H]} \sim -2.5$. This result connects reasonably well with the [K/Fe] trend of disk stars ($-1 < \mathrm{[Fe/H]}$) and that of extremely metal-poor stars ($-4 < \mathrm{[Fe/H]} < -2.5$). That is, [K/Fe] appears to continue a gradual increase from $\mathrm{[Fe/H]} \sim 0$ toward a lower metallicity regime down to $\mathrm{[Fe/H]} \sim -3$, where a broad maximum of $\mathrm{[K/Fe]} \sim +0.3$–$0.4$ is attained, possibly followed by a slight downturn at $\mathrm{[Fe/H]} \lesssim -3$.

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Density-enhanced gas and dust shells in a new chemical model for IRC +10 216

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A new chemical model is presented for the carbon-rich circumstellar envelope of the AGB star IRC +10 216. The model includes shells of matter with densities that are enhanced relative to the surrounding circumstellar medium. The chemical model uses an updated reaction network including reactions from the RATE06 database and a more detailed anion chemistry. In particular, new mechanisms are considered for the formation of CN^-, C_3N^- and C_2H^-, and for the reactions of hydrocarbon anions with atomic nitrogen and with the most abundant cations in the circumstellar envelope. New reactions involving H^- are included which result in the production of significant amounts of C_2H^- and CN^- in the inner envelope. The calculated radial molecular abundance profiles for the hydrocarbons C_2H, C_4H and C_6H and the cyanopolyynes HC_3N and HC_5N show narrow peaks which are in better agreement with observations than previous models. Thus, the narrow rings observed in molecular microwave emission surrounding IRC +10 216 are interpreted as arising in regions of the envelope where the gas and dust densities are greater than the surrounding circumstellar medium. Our models show that CN^- and C_2H^- may be detectable in IRC +10 216 despite the very low theorised radiative electron attachment rates of their parent neutral species. We also show that magnesium isocyanide (MgNC) can be formed in the outer envelope through radiative association involving Mg^+ and the cyanopolyyne species.

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Searching Heavily Obscured Post-AGB Stars and Planetary Nebulae. I. IRAS Candidates with 2MASS PSC Counterparts

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Context. The transition from the Asymptotic Giant Branch (AGB) to the planetary nebula (PN) phase is critical in the shaping of PNe. It is suggested that the most asymmetric PNe are the descendant of massive AGB stars. Since these AGB stars are believed to evolve into heavily obscured post-AGB stars and PNe, the compilation of a sample of bona fide obscured post-AGB stars and PNe is important to help understand the formation of asymmetric PNe. Aims. We aim to identify and characterize in the IR a large number of post-AGB stars and PNe and to assess their degree of optical obscuration. The improved positions will enable future detailed studies to determine their true nature, whereas the optical and IR properties can be used to investigate their spectral behaviour.
Methods. We have used 2MASS, Spitzer GLIMPSE, MSX, and IRAS data in search of the near-IR counterparts of a sample of 165 presumably obscured IRAS post-AGB and PN candidates, and DSS red images to identify the optical counterparts among the objects detected in the near-IR. The IR spectral energy distributions (SEDs) in the

wavelength range from 1 μm to 100 μm of the sources with unambiguous near-IR counterparts have been analyzed using appropriate colour-colour diagrams.
Results. We have identified the near-IR counterparts of 119 sources out of the 165 IRAS post-AGB and PN candidates in our sample. The improved astrometric coordinates of these sources have allowed us to find optical counterparts for 59 of them, yielding a reduced sample of 60 optically obscured post-AGB star and PN candidates. Among the 119 sources with near-IR counterparts, only 80 have unambiguous identifications in the 2MASS Point Source Catalogue. For these sources, we find that objects with and without optical counterpart, while having similar mid- and far-IR colours, are segregated in colour–colour diagrams that use the near-IR J band to compute one of the colours.

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The evolution of low-metallicity asymptotic giant branch stars and the formation of carbon-enhanced metal-poor stars

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We investigate the behaviour of asymptotic giant branch (AGB) stars between metallicities $Z = 10^{-4}$ and $Z = 10^{-8}$. We determine which stars undergo an episode of flash-driven mixing, where protons are ingested into the intershell convection zone, as they enter the thermally pulsing AGB phase and which undergo third dredge-up. We find that flash-driven mixing does not occur above a metallicity of $Z = 10^{-5}$ for any mass of star and that stars above 2 $M_\odot$ do not experience this phenomenon at any metallicity. We find carbon ingestion (CI), the mixing of carbon into the tail of hydrogen burning region, occurs in the mass range 2 $M_\odot$ to around 4 $M_\odot$. We suggest that CI may be a weak version of the flash-driven mechanism. We also investigate the effects of convective overshooting on the behaviour of these objects. Our models struggle to explain the frequency of CEMP stars that have both significant carbon and nitrogen enhancement. Carbon can be enhanced through flash-driven mixing, CI or just third dredge up. Nitrogen can be enhanced through hot bottom burning and the occurrence of hot dredge-up also converts carbon into nitrogen. The C/N ratio may be a good indicator of the mass of the primary AGB stars.

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The Mass-Loss Return From Evolved Stars to the LMC: Empirical Relations for Excess Emission at 8 and 24 μm

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We present empirical relations describing excess emission from evolved stars in the Large Magellanic Cloud (LMC)

using data from the Spitzer Space Telescope SAGE (Surveying the Agents of a Galaxy's Evolution) survey which includes the IRAC 3.6, 4.5, 5.8 and 8.0 μm and MIPS 24, 70 and 160 μm bands. We combine the SAGE data with the Two Micron All Sky Survey (2MASS; J, H and K_s) and the optical Magellanic Cloud Photometric Survey (MCPS; U, B, V and I) point source catalogs in order to create complete spectral energy distributions (SEDs) of the asymptotic giant branch (AGB) star candidates in the LMC. AGB star outflows are among the main producers of dust in a galaxy, and this mass loss results in an excess in the fluxes observed in the 8 and 24 μm bands. The aim of this work is to investigate the mass-loss return by AGB stars to the interstellar medium of the LMC by studying the dependence of the infrared excess flux on the total luminosity. We identify oxygen-rich, carbon-rich and extreme AGB star populations in our sample based on their 2MASS and IRAC colors. The SEDs of oxygen- and carbon-rich AGB stars are compared with appropriate stellar photosphere models to obtain the excess flux in all the IRAC bands and the MIPS 24 μm band. Extreme AGB stars are dominated by circumstellar emission at 8 and 24 μm thus we approximate their excesses with the flux observed in these bands. We find about 16,000 O-rich, 6300 C-rich and 1000 extreme sources with reliable 8 μm excesses, and about 4500 O-rich, 5300 C-rich and 960 extreme sources with reliable 24 μm excesses. The excesses are in the range 0.1 mJy–5 Jy. The 8 and 24 μm excesses for all three types of AGB candidates show a general increasing trend with luminosity. The color temperature of the circumstellar dust derived from the ratio of the 8 and 24 μm excesses decreases with an increase in excess, while the 24 μm optical depth increases with excess. The extreme AGB candidates are the major contributors to the mass loss, and we estimate the total AGB mass-loss return to the LMC to be $(5.9\text{–}13)\times10^{-3}$ $M_\odot$ yr^{-1}.

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An alternative symbiotic channel to Type Ia supernovae

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By assuming an aspherical stellar wind with an equatorial disk from a red giant, we investigate the production of Type Ia supernovae (SNe Ia) via symbiotic channel. We estimate that the Galactic birthrate of SNe Ia via symbiotic channel is between 1.03×10^{-3} and 2.27×10^{-5} yr^{-1}, the delay time of SNe Ia has wide range from ~ 0.07 to 5 Gyr. The results are greatly affected by the outflow velocity and mass-loss rate of the equatorial disk. Using our model, we discuss the progenitors of SN 2002ic and SN 2006X.

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A high-speed bi-polar outflow from the archetypical pulsating star Mira A

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Optical images and high–dispersion spectra have been obtained of the ejected material surrounding the pulsating AGB star Mira A. The two streams of knots on either side of the star, found in far ultra-violet (FUV) GALEX images, have now been imaged clearly in the light of Hα. Spatially resolved profiles of the same line reveal that the bulk of these knots form a bi-polar outflow with radial velocity extremes of $\pm$ 150 km s^{-1} with respect to the central star. The South stream is approaching and the North stream receding from the observer. A displacement away from Mira A between the position of one of the South stream knots in the new Hα image and its position in the previous Palomar

Observatory Sky Survey (POSS I) red plate has been noted. If interpreted as a consequence of expansion proper motions the bipolar outflow is tilted at $69^\circ \pm 2^\circ$ to the plane of the sky, has an outflow velocity of 160 ± 10 km s^{-1} and is ≈ 1000 y old.

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A long trail behind the planetary nebula HFG 1 (PK 136+05) and its precataclysmic binary central star V664 Cas

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A deep wide–field image in the light of the Hα+ [N II] emission lines, of the planetary nebula HFG 1 which surrounds the precataclysmic binary system V664 Cas, has revealed a tail of emission at least $20'$ long, at a position angle of 316°. Evidence is presented which suggests that this is an $\approx 10^5$ y old trail of shocked material, left behind V664 Cas as it ejects matter whilst ploughing through its local interstellar media at anywhere between 29 and 59 km s^{-1} depending on its distance from the Sun.

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SN 2008S: an electron capture SN from a super-AGB progenitor?

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We present comprehensive photometric and spectroscopic observations of the faint transient SN 2008S discovered in the nearby galaxy NGC 6946. SN 2008S exhibited slow photometric evolution and almost no spectral variability during

the first nine months, implying a long photon diffusion time and a high density circumstellar medium. Its bolometric luminosity ($\simeq 10^{41}$ erg s^{-1} at peak) is low with respect to most core collapse supernovae but is comparable to the faintest type II-P events. Our quasi-bolometric lightcurve extends to 300 days and shows a tail phase decay rate consistent with that of ^{56}Co. We propose that this is evidence for an explosion and formation of ^{56}Ni. The mass of ^{56}Ni synthesized by SN 2008S is 0.0014 ± 0.0003 M$_\odot$. Spectra of SN 2008S show intense emission lines of Hα, [Ca II] doublet and Ca II NIR triplet, all without obvious P-Cygni absorption troughs. The large mid-infrared (MIR) flux detected shortly after explosion can be explained by a light echo from pre-exisiting dust. The late near-infrared (NIR) flux excess is plausibly due to a combination of warm newly-formed ejecta dust together with shock-heated dust in the circumstellar environment. We reassess the progenitor object detected previously in Spitzer archive images, supplementing this discussion with a model of the MIR spectral energy distribution. This supports the idea of a dusty, optically thick shell around SN 2008S with an inner radius of nearly 90 AU and outer radius of 450 AU, and an inferred heating source of 3000 K. The luminosity of the central star is $L \simeq 10^{4.6}$ L$_\odot$. All the nearby progenitor dust was likely evaporated in the explosion leaving only the much older dust lying further out in the circumstellar environment. The combination of our long term multi-wavelength monitoring data and the evidence from the progenitor analysis leads us to support the scenario of a weak electron capture supernova explosion in a super-AGB progenitor star (of initial mass 6–8 M$_\odot$) embedded within a thick circumstellar gaseous envelope. We suggest that all of main properties of the electron capture SN phenomenon are observed in SN 2008S and future observations may allow a definitive answer.

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New Asymptotic Giant Branch models for a range of metallicities

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We present a new grid of stellar model calculations for stars on the Asymptotic Giant Branch between 1.0 and 6.0 M$_\odot$. Our grid consists of 5 chemical mixtures between $Z = 0.0005$ and $Z = 0.04$, with both solar-like and α-element enhanced metal ratios. We treat consistently the carbon-enhancement of the stellar envelopes by using opacity tables with varying C/O-ratio and by employing theoretical mass loss rates for carbon stars. The low temperature opacities have been calculated specifically for this project. For oxygen stars we use an empirical mass loss formalism. The third dredge-up is naturally obtained by including convective overshooting. Our models reach effective temperatures in agreement with earlier synthetic models, which included approximative carbon-enriched molecular opacities and show good agreement with empirically determined carbon-star lifetimes. A fraction of the models could be followed into the post-AGB phase, for which we provide models in a mass range supplementing previous post-AGB calculations. Our grid constitutes the most extensive set of AGB-models, calculated with the latest physical input data and treating carbon-enhancement due to the third dredge-up most consistently.

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Properties of the 5-state at 839 keV in ^{176}Lu and the s-process branching at $A = 176$

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The s-process branching at mass number $A = 176$ depends on the coupling between the high-K ground state and a low-lying low-K isomer in ^{176}Lu. This coupling is based on electromagnetic transitions via intermediate states at higher energies. The properties of the lowest experimentally confirmed intermediate state at 839 keV are reviewed, and the transition rate between low-K and high-K states under stellar conditions is calculated on the basis of new experimental data for the 839 keV state. Properties of further candidates for intermediate states are briefly analyzed. It is found that the coupling between the high-K ground state and the low-K isomer in ^{176}Lu is at least one order of magnitude stronger than previously assumed leading to crucial consequences for the interpretation of the ^{176}Lu/^{176}Hf pair as an s-process thermometer.

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A *Spitzer* Study of Asymptotic Giant Branch Stars. III. Dust Production and Gas Return in Local Group Dwarf Irregular Galaxies

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We present the third and final part of a census of Asymptotic Giant Branch (AGB) stars in Local Group dwarf irregular galaxies. Papers I and II presented the results for WLM and IC 1613. Included here are Phoenix, LGS 3, DDO 210, Leo A, Pegasus dIrr, and Sextans A. *Spitzer* photometry at 3.6, 4.5, 5.8, and 8 μm are presented, along with a more thorough treatment of background galaxy contamination than was presented in papers I and II. We find that at least a small population of completely optically obscured AGB stars exists in each galaxy, regardless of the galaxy's metallicity, but that higher-metallicity galaxies tend to harbor more stars with slight IR excesses. The optical incompleteness increases for the redder AGB stars, in line with the expectation that some AGB stars are not detected in the optical due to large amounts of extinction associated with in situ dust production. Overall, there is an underrepresentation of $30\% - 40\%$ in the optical AGB within the 1-σ errors for all of the galaxies in our sample. This undetected population is large enough to affect star formation histories derived from optical color–magnitude diagrams. As measured from the $[3.6] - [4.5]$ color excesses, we find average stellar mass-loss rates ranging from 3.1×10^{-7}–6.6×10^{-6} M$_\odot$ yr^{-1}, and integrated galaxy mass-loss rates ranging from 4.4×10^{-5}–1.4×10^{-3} M$_\odot$ yr^{-1}. The integrated mass-loss rate is sufficient to sustain the current star formation rate in only LGS 3 and DDO 210, requiring either significant non-dusty mass loss or gas accretion in Phoenix, Leo A, Pegasus dIrr, Sextans A, WLM, and IC 1613 if they are to maintain their status as gas-rich galaxies.

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Detection of a tertiary brown dwarf companion in the sdB-type eclipsing binary HS 0705+6700

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HS 0705+6700 is a short-period ($P = 2.3$ hours), close binary containing a hot sdB-type primary and a fully convective secondary. We have monitored this eclipsing binary for more than 2 years and as a result, 32 times of light minimum were obtained. Based on our new eclipse times together with these compiled from the literature, it is discovered that

the O–C curve of HS 0705+6700 shows a cyclic variation with a period of 7.15 years and a semiamplitude of 92.4 s. The periodic change was analyzed for the light-travel time effect that may be due to the presence of a tertiary companion. The mass of the third body is determined to be $M_3 \sin i = 0.0377 \pm 0.0043$ $M_\odot$ when a total mass of 0.617 $M_\odot$ for HS 0705+6700 is adopted. For orbital inclinations $i \geq 32.8°$, the mass of the tertiary component would be below the stable hydrogen-burning limit of $M_3 \sim 0.072$ $M_\odot$, and thus it would be a brown dwarf. The third body is orbiting the sdB-type binary at a distance shorter than 3.6 astronomical units (AU). HS 0705+6700 was formed through the evolution of a common envelope after the primary becomes a red giant. The detection of a sub-stellar companion in HS 0705+6700 system at this distance from the binary could give some constraints on stellar evolution in such systems and the interactions between red giants and their companions.

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Probing the mass loss history of the yellow hypergiant IRC +10 420

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We have used the sub-millimeter array to image the molecular envelope around IRC +10 420. Our observations reveal a large and clumpy expanding envelope aro und the star. The molecular envelope shows a clear asymmetry in ^{12}CO J=2–1 emission in the South-West direction. The elongation of the envelope is found even more pronounced in the emission of ^{13}CO J=2–1 and SO $J_K=6_5–5_4$. A small positiona l velocity gradient across velocity channels is seen in these lines, suggesting the presence of a weak bipolar outflow in the envel ope of IRC +10 420. In the higher resolution ^{12}CO J=2–1 map, we find that the envelope has two components: (1) an inner shell (shell I) located between radiu s of about 1″–2″; (2) an outer shell (shell II) located between 3″ to 6″ in radius. These shells represent two previous mass-loss episodes from IRC +10 420. We attempt to derive in self-consistent manner the physical conditions inside the envelope by modelling the dust properties, and the heating and cooling of molecular gas. We estimate a mass loss rate of $\sim$9 10^{-4} $M_\odot$ yr^{-1} for shell I and 7 10^{-4} $M_\odot$ yr^{-1} for shell II. The gas temperature is found to be unusually high in IRC +10 420 in compar ison with other oxygen-rich envelopes. The elevated gas temperature is mainly due to higher heating rate, which results from the large luminosity of the central star. We also derive an isotopic ratio ^{12}C/^{13}C = 6.

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Composite Grains: Effects of Porosity and Inclusions on the 10 μm Silicate Feature

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We calculate the absorption efficiency of the composite grains, made up of host silicate spheroids and inclusions of ices/graphites/or voids, in the spectral region 7.0–14.0 μm The absorption efficiencies of the composite spheroidal grains for three axial ratios are computed using the discrete dipole approximation (DDA) as well as using the effective medium approximation & T-Matrix (EMT-Tmatrix) approach. We study the absorption as a function of the volume fraction of the inclusions and porosity. In particular, we study the variation in the 10.0 μm feature with the volume fraction of the inclusions and porosity. We then calculate the infrared fluxes for these composite grains and compare the model curves with the average observed IRAS-LRS curve, obtained for several circumstellar dust shells around stars.

These results on the composite grains show that the wavelength of the peak absorption shifts and the width of the 10.0 μm feature varies with the variation in the volume fraction of the inclusions. The model curves for composite grains with axial ratios not very large ($AR \sim 1.3$) and volume fractions of inclusions with $f = 0.20$, and dust temperature of about 250–300 K , fit the observed emission curves reasonably well.

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Asteroseismology of hot pre-white dwarf stars: the case of the DOV stars PG 2131+066 and PG 1707+427, and the PNNV star NGC 1501

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We present an asteroseismological study on the two high-gravity pulsating PG 1159 (GW Vir or DOV) stars, PG 2131+066 and PG 1707+427, and on the pulsating [WCE] star NGC 1501. All of these stars have been intensively scrutinized through multi-site observations, so they have well resolved pulsation spectra. We compute adiabatic g-mode pulsation periods on PG 1159 evolutionary models with stellar masses ranging from 0.530 to 0.741 $M_{\odot}$. These models take into account the complete evolution of progenitor stars, through the thermally pulsing AGB phase, and born-again episode. We constrain the stellar mass of PG 2131+066, PG 1707+427, and NGC 1501 by comparing the observed period spacing with the asymptotic period spacing and with the average of the computed period spacings. We also employ the individual observed periods in search of representative seismological models for each star. We derive a stellar mass of 0.627 $M_{\odot}$ for PG 2131+066, 0.597 $M_{\odot}$ for PG 1707+427, and 0.571 $M_{\odot}$ for NGC 1501 from a comparison between the observed period spacings and the computed asymptotic period spacings, and a stellar mass of 0.578 $M_{\odot}$ for PG 2131+066, 0.566 $M_{\odot}$ for PG 1707+427, and 0.576 $M_{\odot}$ for NGC 1501 by comparing the observed period spacings with the average of the computed period spacings. We also find, on the basis of a period-fit procedure, asteroseismological models representatives of PG 2131+066 and PG 1707+427. These best-fit models are able to reproduce the observed period patterns of these stars with an average of the period differences of $\overline{\delta\Pi_i} = 1.57$ s and $\overline{\delta\Pi_i} = 1.75$ s, respectively. The best-fit model for PG 2131+066 has an effective temperature $T_{\rm eff} = 102\,100$ K, a stellar mass $M_\star = 0.589\ M_{\odot}$, a surface gravity $\log g = 7.63$, a stellar luminosity and radius of $\log(L_\star/L_{\odot}) = 1.57$ and $\log(R_\star/R_{\odot}) = -1.71$, respectively, and a He-rich envelope thickness of $M_{\rm env} = 1.6 \times 10^{-2}\ M_{\odot}$. We derive a seismic distance $d \sim 830$ pc and a parallax $\pi \sim 1.2$ mas. The best-fit model for PG 1707+427, on the other hand, has $T_{\rm eff} = 89\,500$ K, $M_\star = 0.542\ M_{\odot}$, $\log g = 7.53$, $\log(L_\star/L_{\odot}) = 1.40$, $\log(R_\star/R_{\odot}) = -1.68$, and $M_{\rm env} = 2.5 \times 10^{-2}$ $M_{\odot}$, and the seismic distance and parallax are $d \sim 730$ pc and $\pi \sim 1.4$ mas. Finally, we have been unable to find an unambiguous best-fit model for NGC 1501 on the basis of a period-fit procedure. This work closes our short series of asteroseismological studies on pulsating pre-white dwarf stars. Our results demonstrate the usefulness of asteroseismology for probing the internal structure and evolutionary status of pre-white dwarf stars. In particular, asteroseismology is able to determine stellar masses of PG 1159 stars with an accuracy comparable or even better than spectroscopy.

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Shock fronts in the symbiotic system BI Crucis

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We investigate the symbiotic star BI Crucis through a comprehensive and self-consistent analysis of the spectra emitted in three different epochs: 60's, 70's, and late 80's. In particular, we would like to find out the physical conditions in

the shocked nebula and in the dust shells, as well as their location within the symbiotic system, by exploiting both photometric and spectroscopic data from radio to UV. We suggest a model which, on the basis of optical imaging, emission line ratios and spectral energy distribution profile, is able to account for collision of the winds, formation of lobes and jets by accretion onto the WD, as well as for the interaction of the blast wave from a past, unrecorded outburst with the ISM. We have found that the spectra observed throughout the years show the marks of the different processes at work within BI Cru, perhaps signatures of a post-outburst evolution. We then call for new infrared and millimeter observations, potentially able to resolve the inner structure of the symbiotic nebula.

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On the Carriers of the 21 μm Emission Feature in Post-Asymptotic Giant Branch Stars

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The mysterious 21μm emission feature seen in sixteen C-rich proto-planetary nebulae (PPNe) remains unidentified since its discovery in 1989. Over a dozen of materials are suggested as the carrier candidates. In this work we quantitatively investigate eight inorganic and one organic carrier candidates in terms of elemental abundance constraints, while previous studies mostly focus on their spectral profiles (which could be largely affected by grain size, shape and clustering effects). It is found that: (1) five candidates (TiC nanoclusters, fullerenes coordinated with Ti atoms, SiS_2, doped-SiC, and SiO_2-coated SiC dust) violate the abundance constraints (i.e. they require too much Ti, S or Si to account for the emission power of the 21μm band, (2) three candidates (carbon and silicon mixtures, Fe_2O_3, and Fe_3O_4),while satisfying the abundance constraints, exhibit secondary features which are not detected in the 21μm sources, and (3) nano FeO, neither exceeding the abundance budget nor producing undetected secondary features, seems to be a viable candidate, supporting the suggestions of Posch et al. (2004).

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Discovery of the 1.80 hr Spin Period of the White Dwarf of the Symbiotic System BF Cyg

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We report on the discovery of a coherent periodicity in the B light curve of the symbiotic star BF Cyg. The signal was detected in some sections of the light curve of the star recorded in the year 2003 as double hump periodic variations with an amplitude of $\sim$ 7 mmag. In the year 2004 the signal was also present in only a subsection of the light curve. In that year, the system was about twice as bright and the amplitude of the oscillations was about half of what it was in 2003. In 2004 the cycle structure was of a single hump, the phase of which coincided with the phase of one of the humps in the 2003 cycle. No periodic signal was detected in a third, short series of observations performed in the year 2007, when the star was three magnitudes brighter than in 2003. We interpret the periodicity as the spin period of the white dwarf component of this interacting binary system. We suggest that the signal in 2003 originated in two hot spots on or near the surface of the white dwarf, most likely around the two antipodes of an oblique dipole magnetic field of this star. Magnetic field lines funneled accreted matter from the wind of the cool component to the pole areas, where the falling material created the hot spots. This process is apparently intermittent in its nature. In 2004, the activity near only one pole was enhanced enough to raise the signal above the threshold of our detection ability.

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Very Late Thermal Pulses Influenced by Accretion in Planetary Nebulae

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We consider the possibility that a mass of $\sim 10^{-5} - 10^{-3}$ M$_\odot$ flows back from the dense shell of planetary nebulae and is accreted by the central star during the planetary nebula phase. This backflowing mass is expected to have a significant specific angular momentum even in (rare) spherical planetary nebulae, such that a transient accretion disk might be formed. This mass might influence the occurrence and properties of a very late thermal pulse (VLTP), and might even trigger it. For example, the rapidly rotating outer layer, and the disk if still exist, might lead to axisymmetrical mass ejection by the VLTP. Unstable burning of accreted hydrogen might result in a mild flash of the hydrogen shell, also accompanied by axisymmetrical ejection.

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Metal-rich carbon stars in the Sagittarius Dwarf Spheroidal galaxy

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We present spectroscopic observations from the *Spitzer Space Telescope* of six carbon-rich AGB stars in the Sagittarius Dwarf Spheroidal Galaxy (Sgr dSph) and two foreground Galactic carbon stars. The band strengths of the observed C_2H_2 and SiC features are very similar to those observed in Galactic AGB stars. The metallicities are estimated from an empirical relation between the acetylene optical depth and the strength of the SiC feature. The metallicities are higher than those of the LMC, and close to Galactic values. While the high metallicity could imply an age of around 1 Gyr, for the dusty AGB stars, the pulsation periods suggest ages in excess of 2 or 3 Gyr. We fit the spectra of the observed stars using the DUSTY radiative transfer model and determine their dust mass-loss rates to be in the range 1.0–3.3$\times 10^{-8}$ M$_\odot$ yr^{-1}. The two Galactic foreground carbon-rich AGB stars are located at the far side of the solar circle, beyond the Galactic Centre. One of these two stars show the strongest SiC feature in our present Local Group sample.

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Conference Paper

The Cycle of Dust in the Milky Way: Clues from the High-Redshift and Local Universe

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Models for the evolution of dust can be used to predict global evolutionary trends of dust abundances with metallicity and examine the relative importance of dust production and destruction mechanisms. Using these models, we show that the trend of the abundance of polycyclic aromatic hydrocarbons (PAHs) with metallicity is the result of the delayed injection of carbon dust that formed in low mass asymptotic giant branch (AGB) stars into the interstellar medium. The evolution of dust composition with time will have important consequences for determining the opacity of galaxies and their reradiated thermal infrared (IR) emission. Dust evolution models must therefore be an integral part of population synthesis models, providing a self-consistent link between the stellar and dust emission components of the spectral energy distribution (SED) of galaxies. We also use our dust evolution models to examine the origin of dust at redshifts > 6, when only supernovae and their remnants could have been, respectively, their sources of production and destruction. Our results show that unless an average supernova (or its progenitor) produces between 0.1 and 1 $M_\odot$ of dust, alternative sources will need to be invoked to account for the massive amount of dust observed at these redshifts.

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Review Papers

Model atmospheres for cool massive stars

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In this review given at the Hot and Cool: Bridging Gaps in Massive Star Evolution conference, I present the state of the art in red supergiant star atmosphere modelling. The last generation of hydrostatic 1D LTE MARCS models publicly released in 2008 have allowed great achievements in the past years, like the calibration of effective temperature scales. I rapidly describe this release, and then I discuss in some length the impact of the opacity sampling approximation on the thermal structure of models and on their emergent spectra. I also insist on limitations inherent to these models. Estimates of collisional and radiative time scales for electronic transitions in e.g. TiO suggest that non-LTE effects are important, and should be further investigated. Classical 1D models are not capable either to provide the large and non-gaussian velocity fields we know exist in red supergiants atmospheres. I therefore also present current efforts in 3D radiative hydrodynamical simulation of RSGs. I show that line profiles and shifts are predicted by these simulations, without the need for fudge micro- and macroturbulence velocities. This is a great progress, although line depths and widths are slightly too shallow. This is probably caused by the simplified grey radiative transfer used in these heavy simulations. Future non-grey 3D simulations should provide a better fit to observations in terms of line strengths and widths.

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Dust Formation and Winds around Evolved Stars: The Good, the Bad and the Ugly Cases

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Cool luminous giants, in particular asymptotic giant branch stars, are among the most important sources of cosmic dust. Their extended dynamical atmospheres are places where grains form and initiate outflows driven by radiation pressure, leading to considerable stellar mass loss and the enrichment of the interstellar medium with newly-produced elements. This review summarizes the current understanding of dust formation and winds in such stars, sketching a system of criteria for identifying crucial types of dust grains in the range of possible condensates. Starting with an overview of the specific conditions for dust formation in cool dynamic atmospheres, the role of grains as wind drivers, as well as their influence on observable properties of cool giants and the circumstellar environment is discussed in some detail. Regarding the literature, special attention is given to current developments, e.g., the debate concerning the Fe-content and size of silicate grains in M-type AGB stars which are critical issues for the wind mechanism, or recent advances in spatially resolved observations and 3D modeling of giants and their dusty envelopes.

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Thesis

The chemical composition and evolutionary status of the R-type stars

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In this work we have performed a detailed study of 23 galactic early and late-type R carbon stars. The sample was selected from the *Hipparcos* catalogue of cool stars with reprocessed parallaxes according to Knapp et al. (2001). We have analysed their kinematics, photometric and chemical properties, this later based on high-resolution ($R \sim 20,000$–40,000), high signal-to-noise ratio spectra. For the chemical analysis we use the spectral synthesis technique in the one-dimensional LTE approximation and the state of the art of carbon-rich spherical model atmospheres. Their location in the Galaxy and kinematics properties show that the late-type R stars belong to the galactic thin disk, while the early-type to the thick disk. This implies that the two types of R stars constitute different stellar populations, the late-type being typically more massive and younger than the early-type ones. In the chemical analysis, we derive the C/O and ^{12}C/^{13}C ratios, average metallicity, lithium and $s-$element abundances (including technetium) and, in some stars, the absolute carbon, nitrogen and oxygen abundances, independently. From the abundance patterns obtained, kinematics and photometric characteristics we conclude that i) the late-type R stars are identical to the normal (N-type) AGB carbon stars, ii) a significant number of the early-type R stars are misclassified K giants or carbon stars of CH-type and, iii) for the remaining *true* early-type R stars, our chemical analysis confirms the previous by Dominy (1984), i.e.: they have near solar metallicity, N enhanced, C/O ratios slightly larger than one, low ^{12}C/^{13}C ratios and no $s-$element enhancements. We suggest, despite that our stellar sample is small, that the fraction of the real R-type stars among all giant carbon stars types seems to be significantly lower than previously thought and, thus, that they do not constitute a frequent stage during the evolution of low mass stars. The observed characteristics of the early-type R are discussed in the framework of the proposed scenarios for their formation: pollution of primordial origin and non-standard carbon mixing triggered by an anomalous He-flash, whether as single stars or as a consequence of the coalescence of two degenerate He cores in a binary system. While the observational evidence clearly discard the former scenario, our preliminary smooth particle hydrodynamic simulations of the merging and one dimension hydrostatic calculations, do not result in such carbon mixing. This still keeps the origin of the early-type R stars both a mystery and a challenge for modern stellar evolution.

Complementary, we study the chemical composition of three galactic carbon stars of SC-type. We find a good agreement with previous chemical analysis by Abia (1998) except in the average metallicity, which is ~ 0.4 dex lower on average in the present analysis. For the stars in the sample with some *s*-element enhancements (late-R and the reclassified stars as CH-type), the abundance patterns nicely agree with the theoretical *s*-process nucleosynthesis predictions in low-mass AGB stars where the $^{13}C(\alpha,n)^{16}O$ reaction is the main source of neutrons. Nevertheless, the *s*-process abundance pattern derived in the SC stars put some doubts on their location in the spectral sequence M→MS→S→SC→C(N) along the AGB phase. We suggest that SC stars are intermediate-mass stars ($M > 3$ M$_\odot$) in the later stages of the AGB phase that become carbon rich for a short period of time. Detailed nucleosynthesis calculations in intermediate-mass stars are needed to confirm such hypothesis.

Defended on 27$^{\rm th}$ March 2009 at the University of Granada

Announcement

Shape Version 3.0 released

The third mayor public release of the morpho-kinematic 3D modeling software Shape is out now.

Significant structural and conceptual improvements have been implemented. A semi-automatic optimizer module helps to fine tune multiple parameters simultaneously. The most important addition is the ability to physically model wavelength dependent light scattering and absorption from, e.g., dust. Furthermore, a basic implementation of spectral radiation transfer allows the modeling of wavelength dependent absorption due to Doppler shifts like in P-Cygni profiles. More detailed information can be found on the ShapeSite (http://www.astrosen.unam.mx/shape) that comes with this release.

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ShapeMasters

See also http://www.astrosen.unam.mx/shape