THE AGB NEWSLETTER

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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 118$^{\rm th}$ issue of the AGB Newsletter. A large number of contributions present new work on elemental abundances, in particular in metal-poor stars, whilst several others discuss the driving of cool stellar winds or the morphology of the circumstellar medium.

Last month's Food for Thought statement on the link between rotation and magnetic activity of AGB stars generated some reaction. Renada Konstantinova-Antova kindly pointed out that X-ray emission has been detected from some M giants, and that there is at least one active M giant that seems to be a single star which is rotating relatively fast (Hünsch et al., in IAU Symposium 219). More reactions are always welcome.

And don't miss the advertisement for a PhD studentship in Brussels.

The next issue will be distributed on the 1$^{\rm st}$ of April; the deadline for contributions is the 31$^{\rm st}$ of March.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Oxygen-rich stars cannot drive a wind through radiation pressure on silicate grains

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)

Refereed Journal Papers

Time variation of radial gradients in the galactic disk: electron temperatures and abundances

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We investigate the electron temperature gradient in the galactic disk as measured by young H II regions on the basis of radio recombination lines and the corresponding gradient in planetary nebulae (PN) based on [O III] electron temperatures. The main goal is to investigate the time evolution of the electron temperature gradient and of the radial abundance gradient, which is essentially a mirror image of the temperature gradient. The recently derived electron temperature gradient from radio recombination lines in H II regions is compared with a new determination of the corresponding gradient from planetary nebulae for which the progenitor star ages have been determined. The newly derived electron temperature gradient for PN with progenitor stars with ages in the 4-5 Gyr range is much steeper than the corresponding gradient for H II regions. These electron temperature gradients are converted into O/H gradients in order to make comparisons with previous estimates of the flattening rate of the abundance gradient. It is concluded that the O/H gradient has flattened out in the past 5 Gyr at a rate of about 0.0094 dex kpc^{-1} Gyr^{-1}, in good agreement with our previous estimates.

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Available from astro-ph/0701337
and from http://www.astro.iag.usp.br/∼maciel

Off-center burnt carbon-oxygen stars as supernova progenitors

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Exploring stellar models which ignite carbon off-center (in the mass range of about 1.05 - 1.18 $M_\odot$, depending on the carbon mass fraction) we find that they may present an interesting SN I progenitor scenario, since whereas in the standard scenario runaway always takes place at the same density of about 2×10^9 gr/cm^3, in our case, due to the small amount of carbon ignited, we get a whole range of densities from 1×10^9 up to 6×10^9 gr/cm^3. These results could contribute in resolving the emerging recognition that at least some diversity among SNe I exists, since runaway at various central densities is expected to yield various outcomes in terms of the velocities and composition of the ejecta, which should be modeled and compared to observations.

Submitted to Astropysical Journal
Available from astro-ph/0701892

NLTE determination of the sodium abundance in a homogeneous sample of extremely metal-poor stars

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Abundance ratios in extremely metal-poor (EMP) stars are a good indication of the chemical composition of the gas

in the earliest phases of the Galaxy evolution. It had been found from an LTE analysis that at low metallicity, and in contrast with most of the other elements, the scatter of [Na/Fe] versus [Fe/H] was surprisingly large and that, in giants, [Na/Fe] decreased with metallicity. Since it is well known that the formation of sodium lines is very sensitive to non-LTE effects, to firmly establish the behaviour of the sodium abundance in the early Galaxy, we have used high quality observations of a sample of EMP stars obtained with UVES at the VLT, and we have taken into account the non-LTE line formation of sodium. The profiles of the two resonant sodium D lines (only these sodium lines are detectable in the spectra of EMP stars) have been computed in a sample of 54 EMP giants and turn-off stars (33 of them with [Fe/H]< -3.0) with a modified version of the code MULTI, and compared to the observed spectra. With these new determinations in the range $-4 <$[Fe/H]< -2.5, both [Na/Fe] and [Na/Mg] are almost constant with a low scatter. In the turn-off stars and "unmixed" giants (located in the low RGB): [Na/Fe]$= -0.21 \pm 0.13$ or [Na/Mg]$= -0.45 \pm 0.16$. These values are in good agreement with the recent determinations of [Na/Fe] and [Na/Mg] in nearby metal-poor stars. Moreover we confirm that all the sodium-rich stars are "mixed" stars (i.e., giants located after the bump, which have undergone an extra mixing). None of the turn-off stars is sodium-rich. As a consequence it is probable that the sodium enhancement observed in some mixed giants is the result of a deep mixing.

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Carbon-enhanced metal-poor stars and thermohaline mixing

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One possible scenario for the formation of carbon-enhanced metal-poor stars is the accretion of carbon-rich material from a binary companion which may no longer visible. It is generally assumed that the accreted material remains on the surface of the star and does not mix with the interior until first dredge-up. However, thermohaline mixing should mix the accreted material with the original stellar material as it has a higher mean molecular weight. We investigate the effect that this has on the surface abundances by modelling a binary system of metallicity $Z = 0.0001$ with a 2 $M_\odot$ primary star and a 0.74 $M_\odot$ secondary star in an initial orbit of 4000 days. The accretion of material from the wind of the primary leads to the formation of a carbon-rich secondary. We find that the accreted material mixes fairly rapidly throughout 90% of the star, with important consequences for the surface composition. Models with thermohaline mixing predict very different surface abundances after first dredge-up compared to canonical models of stellar evolution.

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A critical test of empirical mass loss formulas applied to individual giants and supergiants

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To test our new, improved Reimers-type mass-loss relation (which applies to ordinary cool winds, i.e., NOT dust-driven), given by Schröder & Cuntz in 2005 (ApJL 630, L73), we take a look at the best studied galactic giants and supergiants - particularly those with spatially resolved circumstellar shells and winds, obtained directly or by means of a companion acting as a probing light source. Together with well-known physical parameters, the selected stars provide the most powerful and critical observational venues for assessing the validity of parameterized mass-loss relations for cool winds not driven by molecules or dust. In this study, star by star, we compare our previously published relation

with the original Reimers relation (1975), the Lamers relation (1981), and the two relations by de Jager and his group (1988, 1990). The input data, especially the stellar masses, have been constrained using detailed stellar evolution models. We find that only the relationship by Schröder & Cuntz agrees, within the error bars, with the observed mass-loss rates for all giants and supergiants.

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Arcsecond-resolution ^{12}CO mapping of the yellow hypergiants IRC +10420 and AFGL 2343

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IRC +10420 and AFGL 2343 are the unique, known yellow hypergiants (YHGs) presenting a heavy circumstellar envelope (CSE). We aim to study the morphology, exceptional kinematics, and excitation conditions of their CSEs, and the implications for mass-loss processes. We have mapped the ^{12}CO J=2−1 and 1−0 emission in these YHGs with the IRAM Plateau de Bure interferometer and the 30m telescope. We developed LVG models in order to analyze their circumstellar characteristics. The maps show that the overall shape of both CSEs is approximately spherical, although they also reveal several aspherical features. The CSE around IRC +10420 shows a rounded extended halo surrounding a bright inner region, with both components presenting aspherical characteristics. It presents a brightness minimum at the center. The envelope around AFGL 2343 is a detached shell, showing spherical symmetry and clumpiness at a level of $\sim$ 15% of the maximum brightness. The envelopes expand isotropically at $\sim$ 35 km s^{-1}, about two or three times faster than typical CSEs around AGB stars. High temperatures ($\sim$ 200 K) are derived for the innermost regions in IRC +10420, while denser and cooler ($\sim$ 30 K) gas is found in AFGL 2343. The mass-loss processes in these YHGs have been found to be similar. The deduced mass-loss rates ($\sim$ 10^{-4}–10^{-3} M$_\odot$ yr^{-1}) are much higher than those obtained in AGB stars, and they present significant variations on time scales of $\sim$ 1000 yr.

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Abundance analysis of barium and mild barium stars

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High signal to noise, high resolution spectra were obtained for a sample of normal, mild barium, and barium giants. Atmospheric parameters were determined from the Fe I and Fe II lines. Abundances for Na, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, Y, Zr, Ba, La, Ce, Nd, Sm, Eu, and Gd, were determined from equivalent widths and model atmospheres in a differential analysis, with the red giant ϵ Vir as the standard star. The different levels of s-process overabundances of barium and mild barium stars were earlier suggested to be related to the stellar metallicity. Contrary to this suggestion, we found in this work no evidence for barium and mild barium to have a different range in metallicity. However, comparing the ratio of abundances of heavy to light s-process elements, we found some evidence that they do not share the same neutron exposure parameter. The exact mechanism controlling this difference is still not clear. As a by-product of this analysis we identify two normal red giants misclassified as mild barium stars. The relevance of this finding is discussed. Concerning the suggested nucleosynthetic effects possibly related to the s-process, for elements like Cu, Mn, V and Sc, we found no evidence for an anomalous behavior in any

of the s-process enriched stars here analyzed. However, we stress that further work is still needed since a clear [Cu/Fe] vs. [Ba/H] anticorrelation exists for other s-process enriched objects.

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A Debris Disk around the Central Star of the Helix Nebula?

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Excess emission from a point-like source coincident with the central star of the Helix Nebula is detected with Spitzer at 8, 24, and 70 μm. At 24 μm, the central source is superposed on an extended diffuse emission region. While the [O IV] 25.89 μm line contributes to the diffuse emission, a 10-35 μmm spectrum of the central source shows a strong thermal continuum. The excess emission from the star most likely originates from a dust disk with blackbody temperatures of 90–130 K. Assuming a simple optically thin debris disk model, the dust is distributed in a ring between $\sim$35 and $\sim$150 AU from the central star, possibly arising from collisions of Kuiper-Belt-like Objects or the break-up of comets from an Oort-like cloud that have survived from the post-main-sequence evolution of the central star.

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A compact dust shell in the symbiotic system HM Sge

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We present high spatial resolution observations of the mid-infrared core of the dusty symbiotic system HM Sge. The MIDI interferometer was used with the VLT UTs and ATs providing baselines oriented from PA=42° to 105°. The MIDI visibilities are compared with the ones predicted in the frame of various spherical dust shells published in the literature involving single or double dusty shells. The mid-IR environment is unresolved by a 8m telescope and the MIDI spectrum exhibits a level similar to the ISO spectra recorded 10 yr ago. The estimated Gaussian HWHM of the shell of 12AU in the 8-9 μm range, and 18AU in the 11-12 μm range, are much smaller than the angular separation between the Mira and the White Dwarf of 60AU. The discrepancies between the HWHM at different angle orientations suggest an increasing level of asymmetry from 13 to 8 μm. The observations are well fitted by the densest and smallest model published in the literature based on the ISO data, although such a model does not account for the variations of near-IR photometry due to the Mira pulsation cycle suggesting a much smaller optical thickness. These observations also discard the two shells models, developed to take into account the effect of the WD illumination onto the dusty wind of the Mira. These observations show that a high rate of dust formation is occurring in the vicinity of the Mira which seems to be not highly perturbed by the hot companion.

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Origin of Abundance Inhomogeneity in Globular Clusters

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We numerically investigate abundance properties of the Galactic globular clusters (GCs) by adopting a new "external pollution" scenario. In this framework, GCs are assumed to originate in forming low-mass dwarfs embedded in dark matter subhalos at very high redshifts (z) and thus be chemically influenced by field AGB stars of the dwarfs during early GC formation processes. In this external pollution scenario, the ratio of the total mass of infalling gas to that of AGB ejecta during GC formation in a dwarf (s) and the time scale of gas infall (σ_I) are the most important key parameters that can determine abundance properties of GCs. We mainly investigate the abundance inhomogeneity among light elements (e.g., C, N, O, Na, and Al) of stars in GCs by using the latest stellar yield models of metal-poor AGB stars *with and without third dredge-up*. Our principal results for the models with no third dredge-up, which are more consistent with observations, are as follows.
(1) Both [N/Fe] and [C/Fe] can be diverse among stars within a GC owing to chemical pollution from field AGB stars. [N/Fe] distributions in some GCs can clearly show bimodality whereas [C/Fe] is monomodal in most models. [N/Fe] distributions depend on s such that models with smaller s (i.e., larger mass fraction of AGB ejecta used for GC formation) show the [N/Fe] bimodality more clearly.
(2) N-rich, C-poor stars in GCs also have higher He abundances owing to pollution from massive AGB stars with He-rich ejecta. The number fraction of He-rich stars ($Y > 0.30$) is higher for the models with smaller s and shorter σ_I for $3 < s < 24$ and $10^5 < \sigma_I < 10^7$ yr. He abundances of stars correlate with [N/Fe] and [Al/Fe] and anticorrelate with [C/Fe], [O/Fe], and [Na/Fe] within GCs in our models.
(3) Although our model can much better explain the observed C-N and Mg-Al anticorrelations than previous theoretical models, it is in strong disagreement with the observed O-Na anticorrelation.
(4) This model naturally provides an explanation for the large fraction of CN-strong stars without recourse to an implausible IMF.
Based on these results for the above external pollution scenario, we discuss the long-standing problem of the CN-bimodality prevalent in the Galactic GCs, the possible helium abundance inhomogeneity in these systems, and their horizontal branch morphologies.

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Multisite campaign on the open cluster M67. II. Evidence for solar-like oscillations in red giant stars

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Measuring solar-like oscillations in an ensemble of stars in a cluster, holds promise for testing stellar structure and

evolution more stringently than just fitting parameters to single field stars. The most ambitious attempt to pursue these prospects was by (Gilliland 1993) who targeted 11 turn-off stars in the open cluster M67 (NGC 2682), but the oscillation amplitudes were too small (< 20 μmag) to obtain unambiguous detections. Like Gilliland (1993) we also aim at detecting solar-like oscillations in M67, but we target red giant stars with expected amplitudes in the range 50-500 μmag and periods of 1 to 8 hours. We analyse our recently published photometry measurements, obtained during a six-week multisite campaign using nine telescopes around the world. The observations are compared with simulations and with estimated properties of the stellar oscillations. Noise levels in the Fourier spectra as low as 27 μmag are obtained for single sites, while the combined data reach 19 μmag, making this the best photometric time series of an ensemble of red giant stars. These data enable us to make the first test of the scaling relations (used to estimate frequency and amplitude) with an homogeneous ensemble of stars. The detected excess power is consistent with the expected signal from stellar oscillations, both in terms of its frequency range and amplitude. However, our results are limited by apparent high levels of non-white noise, which cannot be clearly separated from the stellar signal.

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Discovery of photospheric argon in very hot central stars of planetary nebulae and white dwarfs

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We report the first discovery of argon in hot evolved stars and white dwarfs. We have identified the Ar VII 1063.55 Å line in some of the hottest known ($T_{\rm eff} = 95,000 - 110,000$ K) central stars of planetary nebulae and (pre-) white dwarfs of various spectral type. We determine the argon abundance and compare it to theoretical predictions from stellar evolution theory as well as from diffusion calculations. We analyze high-resolution spectra taken with the Far Ultraviolet Spectroscopic Explorer. We use non-LTE line-blanketed model atmospheres and perform line-formation calculations to compute synthetic argon line profiles. We find a solar argon abundance in the H-rich central star NGC1360 and in the H-deficient PG1159 star PG1424+535. This confirms stellar evolution modeling that predicts that the argon abundance remains almost unaffected by nucleosynthesis. For the DAO-type central star NGC7293 and the hot DA white dwarfs PG0948+534 and REJ1738+669 we find argon abundances that are up to three orders of magnitude smaller than predictions of calculations assuming equilibrium of radiative levitation and gravitational settling. For the hot DO white dwarf PG1034+001 the theoretical overprediction amounts to one dex. Our results confirm predictions from stellar nucleosynthesis calculations for the argon abundance in AGB stars. The argon abundance found in hot white dwarfs, however, is another drastic example that the current state of equilibrium theory for trace elements fails to explain the observations quantitatively.

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Self-consistent treatment of dynamics and chemistry in the winds from carbon-rich AGB stars. I. Tests of the equilibrium and kinetic chemical codes.

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The main aim of the paper was performing test of our (chemical and kinetic) codes, which will be used during self-consistent modelling of dynamics and chemistry in the winds from C-rich AGB stars. We use the thermodynamical

equilibrium code to test the different databases of dissociation constants. We also calculate the equilibrium content of the gas using the kinetic code, which includes the chemical network of neutral-neutral reactions studied by Willacy & Cherchneff (1998). The influence of reaction rates updated using the UMIST database for Astrochemistry 2005 (UDFA05), was tested.
The local thermodynamical equilibrium calculations have shown that the NIST database reproduce fairly well equilibrium concentrations of Willacy & Cherchneff (1998), while agreement in case of Tsuji (1973) dissociation constants is much worse. The most important finding is that the steady state solution obtained with the kinetic code for reaction network of Willacy & Cherchneff (1998) is different from the thermodynamical equilibrium solution. In particular, CN and C_2, which are important opacity sources are underabundant relative to thermodynamical equilibrium, while O-bearing molecules (like SiO, H_2O, and OH) are overabundant. After updating the reaction rates by data from the UDFA05 database consistency in O-bearing species becomes much better, however the disagreement in C-bearing species is still present.

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Temporal variations of the outer atmosphere and the dust shell of the carbon-rich Mira variable V Oph probed with VLTI/MIDI

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We present the first multi-epoch N-band spectro-interferometric observations of the carbon-rich Mira variable V Oph using MIDI at the ESO's Very Large Telescope Interferometer. Our MIDI observations were carried out at three different phases 0.18, 0.49, and 0.65, using three different baselines configurations (UT2-UT4, UT1-UT4, and UT2-UT3) with projected baseline lengths of 42–124 m. The wavelength dependence of the uniform-disk diameters obtained at all epochs is characterized by a roughly constant region between 8 and 10 μm with a slight dip centered at $\sim$9.5 μm and a gradual increase longward of 10 μm. These N-band angular sizes are significantly larger than the estimated photospheric size of V Oph. The angular sizes observed at different epochs reveal that the object appears smaller at phase 0.49 (minimum light) with uniform-disk diameters of $\sim$5–12 mas than at phases 0.18 ($\sim$12–20 mas) and 0.65 ($\sim$9–15 mas). We interpret these results with a model consisting of optically thick C_2H_2 layers and an optically thin dust shell. Our modeling suggests that the C_2H_2 layers around V Oph are more extended ($\sim$1.7–1.8 $R_\star$) at phases 0.18 and 0.65 than at phase 0.49 ($\sim$1.4 $R_\star$) and that the C_2H_2 column densities appear to be the smallest at phase 0.49. We also find that the dust shell consists of amorphous carbon and SiC with an inner radius of $\sim$2.5 $R_\star$, and the total optical depths at phases 0.18 and 0.65 are higher than that at phase 0.49. Our MIDI observations and modeling indicate that carbon-rich Miras also have extended layers of polyatomic molecules as previously confirmed in oxygen-rich Miras.

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Magnesium Isotopes in Metal-Poor Dwarfs, the Rise of AGB Stars and the Formation Timescale of the Galactic Halo

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We have determined magnesium isotopic ratios (^{25,26}Mg/Mg) in metal-poor ($-2.6 <$[Fe/H]< -1.3) halo dwarfs employing high S/N (90-280) high spectral resolution ($R = 10^5$) Keck HIRES spectra. Unlike previous claims of an

important contribution from intermediate-mass AGB stars at low metallicities, we find that the rise of the AGB contribution in the Galactic halo did not occur until intermediate metallicities ([Fe/H]$\gtrsim -1.5$).

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Investigation for the puzzling abundance pattern of the neutron-capture elements in the ultra metal-poor star: CS 30322−023

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The s-enhanced and very metal-poor star CS 30322−023 shows a puzzling abundance pattern of the neutron-capture elements, i.e. several neutron-capture elements such as Ba, Pb etc. show enhancement, but other neutron-capture elements such as Sr, Eu etc. exhibit deficient with respect to iron. The study to this sample star could make people gain a better understanding of s- and r-process nucleosynthesis at low metallicity. Using a parametric model, we find that the abundance pattern of the neutron-capture elements could be best explained by a star that was polluted by an AGB star and the CS 30322−023 binary system formed in a molecular cloud which had never been polluted by r-process material. The lack of r-process material also indicates that the AGB companion cannot have undergone a type-1.5 supernova, and thus must have had an initial mass below 4.0 $M_\odot$, while the strong N overabundance and the absence of a strong C overabundance indicate that the companion's initial mass was larger than 2.0 $M_\odot$. The smaller s-process component coefficient of this star illustrates that there is less accreted material of this star from the AGB companion, and the sample star should be formed in the binary system with larger initial orbital separation where the accretion-induced collapse (AIC) mechanism can not work.

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Investigation of the single neutron exposure model for the s-process: the primary nature of the neutron source

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The primary nature of the ^{13}C neutron source is very significant for the studies of the s-process nucleosynthesis. In this paper we present an attempt to fit the element abundances observed in 16 s-rich stars using parametric model of the single neutron exposure. The calculated results indicate that almost all s-elements were made in a single neutron exposure for 9 sample stars. Although a large spread of neutron exposure is obtained, the maximum value of the neutron exposure will reach about 7.0 mbarn^{-1}, which is close to the theoretical predictions by the AGB model. The calculated result is a significant evidence for the primary nature of the neutron source. Combining the result obtained in this work and the neutron exposure-initial mass relations, a large spread of neutron exposure can be explained by the different initial stellar mass and their time evolution. The possibility that the rotationally induced mixing process can lead to a spread of the neutron exposure in AGB stars is also existent.

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Continuum emission around AGB stars at 1.2 mm

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It is generally acknowledged that the mass loss of Asymptotic Giant Branch (AGB) stars undergoes variations on different time scales. We constructed models for the dust envelopes for a sample of AGB stars to assess whether mass-loss variations influence the spectral energy distribution (SED). To constrain the variability, extra observations at millimetre wavelengths 1.2 mm were acquired. From the analysis of the dust models, two indications for the presence of mass-loss variations can be found, being (1) a dust temperature at the inner boundary of the dust envelope that is far below the dust condensation temperature and (2) an altered density distribution with respect to $\rho(r) \propto r^{-2}$ resulting from a constant mass-loss rate. For 5 out of the 18 studied sources a two-component model of the envelope is required, consisting of an inner region with a constant mass-loss rate and an outer region with a less steep density distribution. For one source an outer region with a steeper density distribution was found. Moreover, in a search for time variability in our data set at 1.2 mm, we found that WX Psc shows a large relative time variation of 34% which might partially be caused by variable molecular line emission.

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The Dynamical Implications of Multiple Stellar Formation Events in Galactic Globular Clusters

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Various galactic globular clusters display abundance anomalies that affect the morphology of their colour-magnitude diagrams. In this paper we consider the possibility of helium enhancement in the anomalous horizontal branch of NGC 2808. We examine the dynamics of a self-enrichment scenario in which an initial generation of stars with a top-heavy initial mass function enriches the interstellar medium with helium via the low-velocity ejecta of its asymptotic giant branch stars. This enriched medium then produces a second generation of stars which are themselves helium-enriched. We use a direct N-body approach to perform five simulations and conclude that such two-generation clusters are both possible and would not differ significantly from their single-generation counterparts on the basis of dynamics. We find, however, that the stellar populations of such clusters would differ from single-generation clusters with a standard initial mass function and in particular would be enhanced in white dwarf stars. We conclude, at least from the standpoint of dynamics, that two-generation globular clusters are feasible.

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Can the third dredge-up extinguish hot-bottom burning in massive AGB stars?

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Marigo (2002) has highlighted the crucial importance of molecular opacities in modelling the evolution of AGB stars at varying surface C/O ratio. In particular, it has been shown the large inadequacy of solar-scaled opacities when applied to models of carbon stars, and hence the need for correctly coupling the molecular opacities to the current

surface chemical composition of AGB stars. The aim of the present follow-up study is to investigate the effects of variable molecular opacities on the evolutionary properties of luminous AGB stars with massive envelopes, i.e. with initial masses from $\sim$3.5 $M_{\odot}$ up to 5-8 $M_{\odot}$, which are predicted to experience both the third dredge-up and hot-bottom burning. It is found that if the dredge-up of carbon is efficient enough to lead to an early transition from C/O$<$ 1 to C/O$>$ 1, then hot-bottom burning may be weakened, extinguished, or even prevented. The physical conditions for this occurrence are analysed and a few theoretical and observational implications are discussed. Importantly, it is found that the inclusion of variable molecular opacities could significantly change the current predictions for the chemical yields contributed by intermediate-mass AGB stars, with M$\sim$3.5 - 4.0 $M_{\odot}$ that make as much as $\sim$30-50% of all stars expected to undergo hot-bottom burning.

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The 3D Morphology of VY Canis Majoris II: Polarimetry and the Line-of-Sight Distribution of the Ejecta

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We use imaging polarimetry taken with the HST/ACS/HRC to explore the three dimensional structure of the circumstellar dust distribution around the red supergiant VY Canis Majoris. The polarization vectors of the nebulosity surrounding VY CMa show a strong centro-symmetric pattern in all directions except directly East and range from 10% - 80% in fractional polarization. In regions that are optically thin, and therefore likely have only single scattering, we use the fractional polarization and photometric color to locate the physical position of the dust along the line-of-sight. Most of the individual arc-like features and clumps seen in the intensity image are also features in the fractioanl polarization map. These features must be distinct geometric objects. If they were just local density enhancements, the fractional polarization would not change so abruptly at the edge of the feature. The location of these features in the ejecta of VY CMa using polarimetry provides a determination of their 3D geometry independent of, but in close agreement with, the results from our study of their kinematics (Paper I).

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Winds of M- and S-type AGB stars: an unorthodox suggestion for the driving mechanism

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Current knowledge suggests that the dust-driven wind scenario provides a realistic framework for understanding mass loss from C-rich AGB stars. For M-type objects, however, recent detailed models demonstrate that radiation pressure on silicate grains is not sufficient to drive the observed winds, contrary to previous expectations. In this paper, we suggest an alternative mechanism for the mass-loss of M-type AGB stars, involving the formation of both carbon and silicate grains due to non-equilibrium effects, and we study the viability of this scenario. We model the dynamical atmospheres and winds of AGB stars by solving the coupled system of frequency-dependent radiation hydrodynamics and time-dependent dust formation, using a parameterized description of non-equilibrium effects in the gas phase. This approach allows us to assess under which circumstances it is possible to drive winds with small amounts of carbon dust and to get silicate grains forming in these outflows at the same time. The properties of the resulting

wind models, such as mass loss rates and outflow velocities, are well within the observed limits for M-type AGB stars. Furthermore, according to our results, it is quite unlikely that significant amounts of silicate grains will condense in a wind driven by a force totally unrelated to dust formation, as the conditions in the upper atmosphere and wind acceleration region put strong constraints on grain growth. The proposed scenario provides a natural explanation for the observed similarities in wind properties of M-type and C-type AGB stars and implies a smooth transition for stars with increasing carbon abundance, from solar-composition to C-rich AGB stars, possibly solving the long-standing problem of the driving mechanism for stars with C/O close to one.

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The 3D Morphology of VY Canis Majoris. I The Kinematics

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Images of the complex circumstellar nebula associated with the famous red supergiant VY CMa show evidence for multiple and asymmetric mass loss events over the past 1000 yrs. Doppler velocities of the arcs and knots in the ejecta showed that they are not only spatially distinct but also kinematically separate from the surrounding diffuse material. In this paper we describe second epoch HST/WFPC2 images to measure the transverse motions which when combined with the radial motions provide a complete picture of the kinematics of the ejecta including the total space motions and directions of the outflows. Our results show that the arcs and clumps of knots are moving at different velocities, in different directions, and at different angles relative to the plane of the sky and to the star, confirming their origin from eruptions at different times and from physically separate regions on the star. We conclude that the morphology and kinematics of the arcs and knots are consistent with a history of mass ejections not aligned with any presumed axis of symmetry. The arcs and clumps represent relatively massive outflows and ejections of gas very likely associated with large – scale convective activity and magnetic fields.

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Conference Papers

The Impact of LSST on Asymptotic Giant Branch Star Research

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The Large Synoptic Survey Telescope (LSST) is currently by far the most ambitious proposed ground-based optical survey. The main science themes that drive the LSST system design are Dark Energy and Matter, the Solar System Inventory, Transient Optical Sky and the Milky Way Mapping. The LSST system, with its 8.4m telescope and 3,200 Megapixel camera, will be sited at Cerro Pachon in northern Chile, with the first light scheduled for 2013. In a continuous observing campaign, LSST will cover the entire available sky every three nights in two photometric bands to a depth of V=25 per visit (two 15 second exposures), with exquisitely accurate astrometry and photometry. Over the proposed survey lifetime of 10 years, each sky location would be observed about 1000 times, with the total exposure time of 8 hours distributed over six broad photometric bandpasses (ugrizY). This campaign will open a movie-like window on objects that change brightness, or move, on timescales ranging from 10 seconds to 10 years. The survey will have a data rate of about 30 TB/night, and will collect over 60 PB of data over its lifetime, resulting in an incredibly

rich and extensive public archive that will be a treasure trove for breakthroughs in many areas of astronomy. I describe how this archive will impact the AGB star research and speculate how the system could be further optimized by utilizing narrow-band TiO and CN filters.

Oral contribution, published in "Why do galaxies care about AGB stars", Vienna, August 7-11, 2006
Available from astro-ph/0701507

Stellar Populations: High Spectral Resolution Libraries. Improved TP-AGB Treatment

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I present a short description of the STELIB, HNGSL, IndoUS, MILES, ELODIE, UVES-POP, and IRTF libraries of empirical stellar spectra and show some applications of their use in population synthesis models. When new calculations of the TP-AGB evolutionary phase for stars of different mass and metallicity are included in population synthesis models, the stellar mass in galaxies at z from 1 to 3 determined from spectro-photometric data can be up to 50% lower than the mass determined from the BC03 models. The ages inferred for these populations are considerably lower than the BC03 estimates.

Oral contribution, published in "From Stars to Galaxies: Building the Pieces to Build Up the Universe", eds. A. Vallenari, R. Tantalo, L. Portinari, & A. Moretti, ASP Conf. Ser.
Available from astro-ph/0702091

Understanding the Chemical Complexity in Circumstellar Envelopes of C-rich AGB stars: The case of IRC +10216

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The circumstellar envelopes of carbon-rich AGB stars show a chemical complexity that is exemplified by the prototypical object IRC +10216, in which about 60 different molecules have been detected to date. Most of these species are carbon chains of the type C_nH, C_nH_2, C_nN, HC_nN. We present the detection of new species (CH_2CHCN, CH_2CN, H_2CS, CH_3CCH and C_3O) achieved thanks to the systematic observation of the full 3 mm window with the IRAM 30m telescope plus some ARO 12m observations. All these species, known to exist in the interstellar medium, are detected for the first time in a circumstellar envelope around an AGB star. These five molecules are most likely formed in the outer expanding envelope rather than in the stellar photosphere. A pure gas phase chemical model of the circumstellar envelope is reasonably successful in explaining the derived abundances, and additionally allows to elucidate the chemical formation routes and to predict the spatial distribution of the detected species.

Oral contribution, published in ALMA: A New Era for Astrophysics
Available from astro-ph/0702491

Dust from AGB stars

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Dust is formed in the expanding atmosphere during late stages of stellar evolution. Dust influences the dynamics and thermodynamics of the stellar atmosphere by its opacity. The dust opacity depends both on the optical properties of the grain material as well as on the amount of dust present. A rich source of information on some mineral phases of dust in AGB stars comes from the study of presolar grains from meteorites. This paper presents a short overview of presolar grains studies and describes how the optical properties of dust grains are obtained in the laboratory.

Oral contribution, published in "Why Galaxies Care About AGB Stars", eds. Kerschbaum F., Charbonnel C., Wing R., ASP Conf. Ser.
Available from astro-ph/0702618

A First Study of Giant Stars in the Galactic Bulge based on Crires Spectra

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We present our on-going work on the determination of elemental abundances of giants in the Galactic Bulge by means of infrared spectroscopy. We show a preliminarily reduced spectrum and a synthetic spectrum fit of the Bulge giant Arp 4203 recorded with the near-infrared, high-resolution Crires spectrograph mounted on the VLT during its science verification run in August 2006. Abundances derived from this spectrum are discussed.

Poster contribution, published in IAUS 241
Available from astro-ph/0701916

Review Papers

Binary post-AGB stars

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The specific characteristic of the SED of serendipitously discovered post-AGB binaries, allowed us to launch a very extensive multi-wavelength study of evolved objects, selected on the basis of very specific selection criteria. Those criteria were tuned to discover more stars with circumstellar dusty discs. The observational study includes radial velocity monitoring, high spectral resolution optical studies, infrared spectral dust studies, sub-mm bolometric observations and high spatial resolution interferometric experiments with the VLTI. In this contribution, we will review the preliminary results of this program showing that the binary rate is indeed very high. We argue that the formation of a stable circumbinary disc must play a lead role in the evolution of the systems.

Published in Baltic Astronomy, "Evolution and chemistry of symbiotic stars, binary post-AGB and related objects", held in Wierzba, Poland, 28-30 August 2006, Eds.: R. Szczerba, J. Mikołajewska
Available from astro-ph/0702245

Headwind: Modelling Mass Loss of AGB Stars, Against All Odds

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The intricate interplay of atmospheric shock waves and a complex, variable radiation field with non-equilibrium dust formation presents a considerable challenge to self-consistent modelling of atmospheres and winds of AGB stars. Nevertheless it is clear that realistic models predicting mass loss rates and synthetic spectra are crucial for our understanding of this important phase of stellar evolution. While a number of questions are still open, significant progress has been achieved in recent years. In particular, self-consistent models for atmospheres and winds of C-stars have reached a level of sophistication which allows direct quantitative comparison with observations. In the case of stars with C/O < 1, however, recent work points to serious problems with the dust-driven wind scenario. This contribution analyzes the basic ingredients of this scenario with analytical estimates, focusing on dust formation, non-grey effects, and differences between C-rich and O-rich environments, as well as discussing the status of detailed dynamical wind models and current trends in this field.

Published in "Why Galaxies Care About AGB Stars", eds. Kerschbaum F., Charbonnel C., Wing R., ASP Conf. Ser.
Available from astro-ph/0702444

Job Advert

Institut d'astronomie et d'astrophysique, Université libre de Bruxelles, Belgium PhD student in physics

The ELSA network (European Leadership in Space Astrometry, ELSA is a Marie Curie Research Training Network supported by the European Community's Sixth Framework Programme - FP6) invites applications for 1 PhD study position related to the astrometry of AGB stars.

The thesis will explore the possible impact of the surface brightness asymmetries present at the surface of AGB and supergiant stars on their parallax accuracy, as derived by Gaia.

Candidates must fulfill the special conditions described at
http://www.astro.lu.se/ELSA/pages/vacancies_phd.html#Who_can_apply

Deadline for applications: March 22, 2007
Thesis supervisors: A. Jorissen & D. Pourbaix

See also http://www.astro.lu.se/ELSA/pages/vacancies_phd.html#Pos_03