THE AGB NEWSLETTER

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Editorial

Dear Colleagues,

It is our pleasure to present you the 145th issue of the AGB Newsletter. Many of you may be enjoying the company of your colleagues and friends at the General Assembly in Rio de Janeiro. Timely therefore, this issue of the newsletter features the first two items on behalf of the IAU Working Group on Abundances in Red Giants, for which the AGB Newsletter acts as an official communication. One proposition put forward by the working group is the establishment of IAU Schools, to make sure that what we learn will not be forgotten. Having attended a particularly inspiring and pleasant Winter school himself, one of the editors fondly remembers the experience, knowledge gained and friendships made. Few conferences come close to matching that.

Our congratulations go to Lars Mattsson, who defended his very interesting Philosopher's Degree thesis on dust-driven winds of carbon stars.

In these times of recession, it is nice to see job openings — such as the one in Leuven. It sounds very exciting, so if you are looking for a postdoctoral position please consider this forefront research in a vibrant place.

The next issue will be distributed on the 1st of September 2009; the deadline for contributions is the 31st of August.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

The mantles, atmospheres and circumstellar environments of red supergiants are simply scaled-up versions of those of asymptotic and first-ascent red giant branch stars

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)

Welcome to the Working Group on Abundances in Red Giants

The AGB Newsletter recently became an official newsletter of the IAU Working Group on Abundances in Red Giants (WGARG). Although the remit of the Newsletter extends well beyond that of WGARG, it does cover all aspects of it. Here we briefly introduce WGARG, as the first item of a new section in the AGB Newsletter devoted to communications by WGARG.

WGARG is the reincarnation of the Working Group on Peculiar Red Giants, that was established as an IAU Working Group at the 1985 General Assembly in New Delhi. It had wanted to encourage communication and collaboration between astronomers trying to understand the peculiar chemical abundance patterns found in many cool evolved stars. As it was realised that these "peculiarities" were perhaps more a reflection of our ignorance rather than these stars doing something they weren't ought to be doing, "peculiar" was replaced by "abundances". This also emphasized the general importance of red giants for the fabrication of chemical elements. Rather than inconsequential oddities, red giants in actual fact play a pivotal role in the chemical enrichment of the Universe.

The working group has traditionally concentrated on AGB stars and low-mass RGB stars. However, it does not exclude in principle the study of abundance patterns in their massive siblings, the red supergiants. The issue of surface elemental enrichment of metal-poor red supergiants and their progenitors has in fact enjoyed considerable interest in recent times. Synergies between studies of massive and low-/intermediate-mass cool giants could help advance both fields of research, under the motto "$1 + 1 > 2$". In a similar vein, the spectrum of chemical abundances inside and at the surface of red giants has important implications for their appearance in unresolved stellar populations, their use as witnesses of early, long-gone generations of stars, the behaviour of their mass loss and dust production and hence our ability to read our past in meteoritic material, to name but a few topics that rely on, as well as inform, the nucleosynthesis and dynamical processes inside red giants. Likewise, WGARG advocates a concerted approach of theory and simulation on the one hand, and observational and laboratory studies on the other.

WGARG falls under the auspices of IAU Division IV ("Stars"). It has an Organizing Committee of its own, chaired by John Lattanzio, and maintains its own website (see below). WGARG is asked to support many proposals for IAU Symposia (and it often does!), and it also endorses many non-IAU conferences and workshops. This is testimony of the awareness among our colleagues that in many cases red giants are either the actors or probes (to borrow a Viennese conference's subtitle) of some relevant astrophysical phenomenon.

There are two orders of magnitude more astronomers working in this field than serve on the WGARG organizing committee, which means a huge workforce and pool of intellect. WGARG would be delighted to help coordinate your many ideas to enhance scientific quality: please feel welcome to approach any of its organizing committee members if you have a suggestion or a query.

More information: http://web.maths.monash.edu.au/~johnl/wgarg/index.shtml

A proposal for the founding of IAU Schools

Recent discussions within the WGARG organizing committee identified a danger that much knowledge and wisdom gained over many years may be wasted if it is not passed-on effectively to new generations of researchers. Likewise, talented astronomers may be wasting effort if they are unaware of previous successes and failures. Furthermore, it is not uncommon for astronomers to move into a new field, or for other reasons to realize that they would benefit from expert instruction within certain topics.

To help secure that key areas in the education of astronomers are made available for those who did not perhaps get it as part of their previous training, WGARG wishes to propose, at the IAU General Assembly in Rio de Janeiro, that the IAU supports not only symposia, but also schools at which world experts lecture motivated, talented novices in the field. WGARG would of course wish to suggest that the first such IAU School be on a stellar astrophysics topic, and it would offer its support to help organize it. If this necessitates a reduction in the number of symposia the IAU can support each year, then WGARG feels that this is a price worth paying for the unique benefits that could arise from IAU Schools.

We welcome debate on this topic, for instance during the IAU General Assembly, or via replies to the WGARG organizing committee or the AGB newsletter.

Mass outflow from red giant stars in M 13, M 15, and M 92

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Chromospheric model calculations of the Hα line for selected red giant branch (RGB) and asymptotic giant branch (AGB) stars in the globular clusters M 13, M 15, and M 92 are constructed to derive mass loss rates. The model spectra are compared to the observations obtained with the Hectochelle on the MMT telescope. These stars show strong Hα emissions and blue-shifted Hα cores signaling that mass outflow is present in all stars. Outflow velocities of 3–19 km s^{-1}, larger than indicated by Hα profiles, are needed in the upper chromosphere to achieve good agreement between the model spectra and the observations. The resulting mass loss rates range from 0.6×10^{-9} to 5×10^{-9} M$_\odot$ yr^{-1}, which are about an order of magnitude lower than predicted from "Reimers' law" or inferred from the infrared excess of similar stars. The mass loss rate increases slightly with luminosity and with decreasing effective temperature. Stars in the more metal-rich M 13 have higher mass loss rates by a factor of ~ 2 than in the metal-poor clusters M 15 and M 92. A fit to the mass loss rates is given by: $\dot{M}[\mathrm{M}_\odot \ \mathrm{yr}^{-1}] = 0.092 \ L^{0.16} T_{\mathrm{eff}}^{-2.02} A^{0.37}$ where $A = 10^{[\mathrm{Fe/H}]}$. Multiple observations of stars revealed one object in M 15, K 757, in which the mass outflow increased by a factor of 6 between two observations separated by 18 months. Other stars showed changes in mass loss rate by a factor of 1.5 or less.

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Candidate planetary nebulae in the IPHAS photometric catalogue

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Context. We have carried out a semi-automated search for planetary nebulae (PNe) in the INT Photometric H-Alpha Survey (IPHAS) catalogue. We present the PN search and the list of selected candidates. We cross correlate the selected candidates with a number of existing infrared galactic surveys in order to gain further insight into the nature of the candidates. Spectroscopy of a subset of objects is used to estimate the number of PNe present in the entire candidate list.

Aims. The overall aim of the IPHAS PN project is to carry out a deep census of PNe in the northern Galactic plane, an area where PN detections are clearly lacking.

Methods. The PN search is carried out on the IPHAS photometric catalogues. The candidate selection is based on the IPHAS and 2MASS/UKIDSS colours of the objects and the final candidate selection is made visually.

Results. From the original list of ~ 600 million IPHAS detections we have selected a total of 1005 objects. Of these, 224 are known objects, leaving us with 781 PN candidates. Based on the initial follow-up spectroscopy, we expect the

list to include very young and proto-PNe in addition to genuine, normal PNe ($\sim 16\%$) and emission line objects other than PNe. We present additional criteria to select the most probable PN candidates from our candidate list.

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The destruction and survival of dust in the shell around SN 2008S

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SN 2008S erupted in early 2008 in the grand design spiral galaxy NGC 6946. The progenitor was detected by Prieto et al. in *Spitzer Space Telescope* images taken over the four years prior to the explosion, but was not detected in deep optical images, from which they inferred a self-obscured object with a mass of about 10 $M_{\odot}$. We obtained *Spitzer* observations of SN 2008S five days after its discovery, as well as coordinated *Gemini* and *Spitzer* optical and infrared observations six months after its outburst.
We have constructed radiative transfer dust models for the object before and after the outburst, using the same r^{-2} density distribution of pre-existing amorphous carbon grains for all epochs and taking light-travel time effects into account for the early post-outburst epoch. We rule out silicate grains as a significant component of the dust around SN 2008S. The inner radius of the dust shell moved outwards from its pre-outburst value of 85 AU to a post-outburst value of 1250 AU, attributable to grain vaporisation by the light flash from SN 2008S. Although this caused the circumstellar extinction to decrease from $A_{\rm V} = 15$ mag before the outburst to 0.8 mag after the outburst, we estimate that less than 2% of the overall circumstellar dust mass was destroyed.
The total mass-loss rate from the progenitor star is estimated to have been $(0.5\text{–}1.0)\times10^{-4}$ $M_{\odot}$ yr^{-1}. The derived dust mass-loss rate of 5×10^{-7} $M_{\odot}$ yr^{-1} implies a total dust injection into the ISM of up to 0.01 $M_{\odot}$ over the suggested duration of the self-obscured phase. If objects like this are common, as has recently been proposed, they could be significant contributors to the dust observed in distant galaxies.

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Spatially resolving the inhomogeneous structure of the dynamical atmosphere of Betelgeuse with VLTI/AMBER

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We present spatially resolved high-spectral resolution K-band observations of the red supergiant Betelgeuse (α Ori) using AMBER at the Very Large Telescope Interferometer (VLTI). Betelgeuse was observed between 2.28 and 2.31

μm using baselines of 16, 32, and 48 m with spectral resolutions of 4800–12000. Spectrally dispersed interferograms have been obtained in the 2[nd], 3[rd], and 5[th] lobes, which represents the highest spatial resolution (9 mas) achieved for Betelgeuse, corresponding to 5 resolution elements over its stellar disk. The AMBER data in the continuum can be reasonably fitted by a uniform disk with a diameter of 43.19 ± 0.03 mas or a limb-darkening disk with 43.56 ± 0.06 mas. The K-band interferometric data taken at various epochs suggest that Betelgeuse seen in the continuum shows much smaller deviations from the above uniform/limb-darkened disk than predicted by 3-D convection simulations. On the other hand, our AMBER data in the CO lines reveal that the blue and red wings of the CO lines originate in spatially distinct regions over the stellar disk, indicating an inhomogeneous velocity field. Our AMBER data in the CO lines can be roughly explained by a simple model, in which a patch of CO gas is moving outward or inward at velocities of 10–15 km s^{-1}, while the CO gas in the remaining region in the atmosphere is moving in the opposite direction at the same velocities. The AMBER data are also consistent with the presence of warm molecular layers at ~ 1.4–$1.5\ R_\star$ with a CO column density of $\sim 1 \times 10^{20}$ cm^{-2}. Our AMBER observations of Betelgeuse are the first spatially resolved study of the so-called macroturbulence in a stellar atmosphere other than the Sun. The spatially resolved CO gas motion is likely to be related to convective motion or intermittent mass ejections in clumps or arcs.

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Characteristics of solar-like oscillations in red giants observed in the CoRoT exoplanet field

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Context: Observations during the first long run (~ 150 days) in the exo-planet field of CoRoT increase the number of G–K giant stars for which solar-like oscillations are observed by a factor of 100. This opens the possibility to study the characteristics of their oscillations in a statistical sense.
Aims: We aim to understand the statistical distribution of the frequencies of maximum oscillation power ($\nu_{\rm max}$) in red giants and to search for a possible correlation between $\nu_{\rm max}$ and the large separation (Δ_ν).
Methods: Red giants with detectable solar-like oscillations are identified using both semi-automatic and manual procedures. For these stars, we determine $\nu_{\rm max}$ as the centre of a Gaussian fit to the oscillation power excess. For the determination of Δ_ν, we use the autocorrelation of the Fourier spectra, the comb response function and the power spectrum of the power spectrum.
Results: The resulting $\nu_{\rm max}$ distribution shows a pronounced peak between 20–40 μHz. For about half of the stars we obtain Δ_ν with at least two methods. The correlation between $\nu_{\rm max}$ and Δ_ν follows the same scaling relation as inferred for solar-like stars.
Conclusions: The shape of the $\nu_{\rm max}$ distribution can partly be explained by granulation at low frequencies and by white noise at high frequencies, but the population density of the observed stars turns out to be also an important factor. From the fact that the correlation between Δ_ν and $\nu_{\rm max}$ for red giants follows the same scaling relation as obtained for sun-like stars, we conclude that the sound travel time over the pressure scale height of the atmosphere scales with the sound travel time through the whole star irrespective of evolution. The fraction of stars for which we determine Δ_ν does not correlate with $\nu_{\rm max}$ in the investigated frequency range, which confirms theoretical predictions.

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Spitzer 24 μm images of Planetary Nebulae

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Spitzer MIPS 24 μm images were obtained for 36 Galactic planetary nebulae (PNe) whose central stars are hot white dwarfs (WDs) or pre-WDs with effective temperatures of ~100,000 K or higher. Diffuse 24 μm emission is detected in 28 of these PNe. The eight non-detections are angularly large PNe with very low Hα surface brightnesses. We find three types of correspondence between the 24 μm emission and Hα line emission of these PNe: six show 24 μm emission more extended than Hα emission, nine have a similar extent at 24 μm and Hα, and 13 show diffuse 24 μm emission near the center of the Hα shell. The sizes and surface brightnesses of these three groups of PNe and the non-detections suggest an evolutionary sequence, with the youngest ones being brightest and the most evolved ones undetected. The 24 μm band emission from these PNe is attributed to [O IV] 25.9 μm and [Ne V] 24.3 μm line emission and dust continuum emission, but the relative contributions of these three components depend on the temperature of the central star and the distribution of gas and dust in the nebula.

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TEXES observations of M Supergiants: Dynamics and thermodynamics of wind acceleration

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We have detected [Fe II] 17.94 μm and 24.52 μm emission from a sample of M supergiants using TEXES on the IRTF. These low opacity emission lines are resolved at $R = 50,000$ and provide new diagnostics of the dynamics and thermodynamics of the stellar wind acceleration zone. The [Fe II] lines, from the first excited term, are sensitive to the warm plasma where energy is deposited into the extended atmosphere to form the chromosphere and wind outflow. These diagnostics complement previous KAO and ISO observations which were sensitive to the cooler and more extended circumstellar envelopes. The turbulent velocities, $v_{\rm turb} \sim$ 12–13 km s^{-1}, observed in the [Fe II] forbidden lines are found to be a common property of our sample, and are less than that derived from the hotter chromospheric C II] 2325 Å lines observed in α Ori, where $v_{\rm turb} \sim$ 17–19 km s^{-1}. For the first time, we have dynamically resolved the motions of the dominant cool atmospheric component discovered in α Ori from multi-wavelength radio interferometry by Lim et al. (1998). Surprisingly, the emission centroids are quite Gaussian and at rest with respect to the M supergiants. These constraints combined with model calculations of the infrared emission line fluxes for α Ori imply that the warm material has a low outflow velocity and is located close to the star. We have also detected narrow [Fe I] 24.04 μm emission that confirms that Fe II is the dominant ionization state in α Ori's extended atmosphere.

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A new analysis of the O VI emitting nebula around KPD 0005+5106

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We present observations of O VI λ1032 emission around the helium white dwarf KPD 0005+5106 obtained with the *Far Ultraviolet Spectroscopic Explorer*. Previously published data, reprocessed with an updated version of the calibration pipeline, are included along with new observations. The recent upward revision of the white dwarf's effective temperature to 200,000 K has motivated us to re-analyze all the data. We compare observations with photoionization models and find that the density of the O VI nebula is about 10 cm^{-3}, and that the stellar flux must be attenuated by about 90% by the time it impinges on the inner face of the nebula. We infer that this attenuation is due to circumstellar material ejected by KPD 0005+5106 earlier in its evolution.

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On magnesium sulfide as the carrier of the 30 μm emission feature

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A large number of carbon-rich evolved objects (asymptotic giant branch stars, protoplanetary nebulae, and planetary nebulae) in both the Milky Way galaxy and the Magellanic Clouds exhibit an enigmatic broad emission feature at ~ 30 μm This feature, extending from ~ 24 μm to ~ 45 μm, is very strong and accounts for up to 30% of the total infrared luminosity of the object. In literature it is tentatively attributed to magnesium sulfide (MgS) dust. Using the prototypical protoplanetary nebula around HD 56126 for illustrative purpose, however, in this work we show that in order for MgS to be responsible for the 30 μm feature, one would require an amount of MgS mass substantially exceeding what would be available in this source. We therefore argue that MgS is unlikely the carrier of the 30 μm feature seen in this source and in other sources as well.

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The K giant star Arcturus: the hybrid nature of its infrared spectrum

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We investigate infrared spectrum of Arcturus to clarify the nature of the cool component of its atmosphere, referred to as the CO-mosphere. For this purpose, we apply the IR spectral atlas by Hinkle, Wallace, and Livingston (1995). It is found that the nature of CO lines shows an abrupt change at $\log(W/\nu) \approx -4.75$, and the lines stronger than this limit can no longer be analyzed with the classical line-formation theory, while the weaker lines can and provide some information on the photosphere (e.g., $\log A_{\rm C} = 7.97$ / $\log A_{\rm H} = 12.00$, $\xi_{\rm micro} = 1.87$ km s^{-1}, and $\xi_{\rm macro} = 3.47$ km s^{-1}). A more simple manifestation of this fact is that the curves-of-growth of CO lines show an unpredictable upturn in their flat part at $\log(W/\nu) \approx -4.75$. Similar unusual behaviors of empirical curves-of-growth are confirmed in other cool luminous stars including M giants, red supergiants, and Mira variables. In all these cases, it looks as if the curves-of-growth are composite of at least two components of different origins. We think it difficult to understand such empirical data as due to the classical photosphere alone, and infrared spectra of cool luminous stars including Arcturus should be hybrid in nature. Although strong lines of the CO fundamentals observed in Arcturus show strengthening compared to the predicted photospheric spectrum, the weaker lines show slight weakening, and we propose that these

results are due to absorption/emission in the molecular clouds formed within the extended atmosphere. Now, do clouds exist in stellar atmospheres? It is certainly not easy to answer this question by spectroscopic observations alone, but we find several arguments in favor of such a possibility in Arcturus by analyzing the CO lines. In cooler (super)giant stars in which CO lines show similar unusual behaviors as in Arcturus, the presence of molecular clouds (referred to as MOLsphere for convenience in modeling) in the outer atmospheres has been demonstrated by direct observations with spatial interferometry. We suggest that the formation of molecular clouds is a general feature in the outer atmospheres of cool luminous stars from early K to late M (super)giant stars.

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A *Spitzer*/IRS spectrum of the 2008 luminous transient in NGC 300: Connection to proto-Planetary Nebulae

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We present a *Spitzer*/IRS low-resolution mid-infrared spectrum (5–14 μm) of the luminous transient discovered in the nearby galaxy NGC 300 in May 2008. This transient had peak luminosity $M_{\rm V} \simeq -13$ mag, showed an optical spectrum dominated by relatively narrow Balmer and Ca II lines in emission, and its progenitor was identified in pre-explosion images as a dust-enshrouded ~ 10 $M_{\odot}$ star, characteristics that make it a twin of SN 2008S. The *Spitzer* spectrum, obtained three months after discovery, shows that the transient is very luminous in the mid-IR. Furthermore, the spectrum shows strong, broad emission features at 8 μm and 12 μm that are observed in Galactic carbon-rich proto-planetary nebulae. Combining these data with published optical and near-IR photometry obtained at the same epoch, we find that the mid-IR excess traced by the *Spitzer* spectrum accounts for $\sim 20\%$ of the total energy output. This component can be well explained by emission from $\sim 10^{-4}$ $M_{\odot}$ of pre-existing progenitor dust at temperature $T \sim 500$ K. The spectral energy distribution of the transient also shows a near-IR excess that can be explained by emission from newly-formed dust in the ejecta. Alternatively, both the near-IR and mid-IR excesses can together be explained by a single pre-existing geometrically thick dust shell. In light of the new observations obtained with *Spitzer*, we revisit the analysis of the optical spectra and kinematics, which were compared to the massive yellow-hypergiant IRC +10420 in previous studies. We show that proto-planetary nebulae share many properties with the NGC 300 transient and SN 2008S. We conclude that even though the explosion of a massive star ($M \gtrsim 10$ $M_{\odot}$) cannot be ruled out, an explosive event on a massive ($M \sim 6$–10 $M_{\odot}$) carbon-rich AGB/super-AGB or post-AGB star is consistent with all observations of the transients and their progenitors presented thus far.

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Radiative hydrodynamics simulations of red supergiant stars: I. interpretation of interferometric observations

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Context. It has been suggested that convection in Red Supergiant (RSG) stars gives rise to large-scale granules causing observable surface inhomogeneities. This convection is also extremely vigorous, and suspected to be one of the causes of mass loss in RSGs. It must thus be understood in details. Evidence has been accumulated that there are asymmetries in the photospheres of RSGs, but detailed studies of granulation are still lacking. Interferometric observations offer an exciting possibility to tackle this question, but they are still often interpreted using smooth symmetrical limb-darkened intensity distributions, or very simple spotted ad hoc models. Aims. We explore the impact of the granulation on visibility curves and closure phases using the radiative transfer code OPTIM3D. We simultaneously assess how 3D simulations of convection in RSG with CO5BOLD can be tested against these observations. Methods. We use 3D radiative-hydrodynamics (RHD) simulations of convection to compute intensity maps at various wavelengths and time, from which we derive interferometric visibility amplitudes and phases. We study their behaviour with time, position angle, and wavelength, and compare them to observations of the RSG α Ori Results. We provide average limb-darkening coefficients for RSGs. We detail the prospects for the detection and characterization of granulation (contrast, size) on RSGs. We demonstrate that our RHD simulations provide an excellent fit to existing interferometric observation of α Ori, contrary to limb darkened disks. This confirms the existence of large convective cells on the surface of Betelgeuse.

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An analysis of a spectrum of V838 Monocerotis in October 2005

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V838 Mon erupted at the beginning of 2002 becoming an extremely luminous star with $L = 10^6$ $L_\odot$. Among various scenarios proposed to explain the nature of the outburst, the most promising is a stellar merger event. We attempt to obtain information about the structure and evolution of the object in the decline from the 2002 eruption. The results of spectroscopic observations of the object obtained in October 2005 with the Keck/HIRES instrument, presented in detail in Paper I, are analysed and discussed. Modelling of the observed line profiles has been used to constrain the physical parameters of the system. The kinematics of the atmosphere of V838 Mon is very complex. Our analysis of the molecular bands and the P-Cyg profiles of atomic lines shows that the object loses matter with a velocity of up to 215 km s^{-1} and a rate of 10^{-6}–10^{-5} $M_\odot$ yr^{-1}. In the profiles of some atomic lines, we have, however, found evidence of matter infall. Moreover, a narrow absorption component, which is particularly strong in some P-Cyg profiles, may indicate that a jet-like outflow has also been formed.

We show that the observed emission in the [Fe II] lines and an eclipse-like event observed in November/December 2006 was probably caused by interactions of the expanding matter, ejected by V838 Mon in 2002, with radiation from the B3 V companion. In particular, the observed profiles of the [Fe II] lines can be easily modelled in this scenario and allow us to estimate parameters of the system, such as the position of the B3 V companion relative to V838 Mon and the line of sight, density in the outflowing matter, and mass lost in the 2002 eruption. The observed appearance of strong Hα emission, just before and during the eclipse-like event, can be interpreted as a result of the accretion of the outflowing matter onto the B3 V companion: the accreted matter, shocked above the stellar surface, can be a source of extreme-UV and soft X-ray radiation capable of ionizing and exciting H in the outflow.

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Spectroscopy of the symbiotic star CH Cygni from 1996 to 2007

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We monitored a set of emission lines in the optical spectra of CH Cyg using the 1.5-m telescope at the Tartu Observatory, Estonia. Most of the spectra were registered in the Hα region, but other Balmer lines and lines of He, N, O, and

Fe were also investigated in terms of their equivalent widths, radial velocities, and absolute fluxes. The spectra indicate different stages that CH Cyg has been through in the course of our observations. During quiescence, the strength of the line profiles changes in opposite phase with the star's luminosity. The Hα profile becomes double-peaked at times, which may point to the temporary presence of some disk-like structure, but also to absorption in neutral gas surrounding the area of the formation of the emission component. In 1999, when a periastron passage is assumed according to the 5700-day model, the Balmer lines strengthen considerably, as might be expected due to an increase in the accretion rate. The eclipse in 2001, however, is not noticed. At certain episodes, the controversial 756-day period of CH Cyg is seen in our data.

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Variable sodium absorption in a low-extinction type Ia supernova

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Recent observations have revealed that some Type Ia supernovae exhibit narrow, time-variable Na I D absorption features. The origin of the absorbing material is controversial, but it may suggest the presence of circumstellar gas in the progenitor system prior to the explosion, with significant implications for the nature of the supernova progenitors. We present the third detection of such variable absorption, based on six epochs of high-resolution spectroscopy of the Type Ia supernova SN 2007le from the Keck I telescope and the Hobby-Eberly Telescope. The data span a time frame of approximately three months, from 5 days before maximum light to 90 days after maximum. We find that one component of the Na I D absorption lines strengthened significantly with time, indicating a total column density increase of $\sim 2.5 \times 10^{12}$ cm^{-2}. The data limit the typical timescale for the variability to be more than 2 days but less than 10 days. The changes appear to be most prominent after maximum light rather than at earlier times when the ultraviolet flux from the supernova peaks. As with SN 2006X, we detect no change in the Ca II H and K absorption lines over the same time period, rendering line-of-sight effects improbable and suggesting a circumstellar origin for the absorbing material. Unlike the previous two supernovae exhibiting variable absorption, SN 2007le is not highly reddened ($E_{B-V} = 0.27$ mag), also pointing toward circumstellar rather than interstellar absorption. Photoionization calculations show that the data are consistent with a dense (10^7 cm^{-3}) cloud or clouds of gas located $\sim$ 0.1 pc (3×10^{17} cm) from the explosion. These results broadly support the single-degenerate scenario previously proposed to explain the variable absorption, with mass loss from a nondegenerate companion star responsible for providing the circumstellar gas. We also present possible evidence for narrow Hα emission associated with the supernova, which will require deep imaging and spectroscopy at late times to confirm.

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A near-infrared survey of Miras and the distance to the Galactic Centre

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We report the results of a near-infrared survey for long-period variables in a field of view of 20′ by 30′ towards the Galactic Centre (GC). We have detected 1364 variables, of which 348 are identified with those reported in Glass et al. (2001). We present a catalogue and photometric measurements for the detected variables and discuss their nature. We also establish a method for the simultaneous estimation of distances and extinctions using the period–luminosity relations for the JHK_s bands. Our method is applicable to Miras with periods in the range 100–350 d and mean magnitudes available in two or more filter bands. While J-band means are often unavailable for our objects because of the large extinction, we estimated distances and extinctions for 143 Miras whose H- and K_s-band mean magnitudes are obtained. We find that most are located at the same distance to within our accuracy. Assuming that the barycentre of these Miras corresponds to the GC, we estimate its distance modulus to be 14.58 ± 0.02(stat.)± 0.11(syst.) mag, corresponding to 8.24 ± 0.08(stat.)± 0.42(syst.) kpc. We have assumed the distance modulus to the LMC to be 18.45 mag, and the uncertainty in this quantity is included in the systematic error above. We also discuss the large and highly variable extinction. Its value ranges from 1.5 mag to larger than 4 mag in $A(K_s)$ except towards the thicker dark nebulae and it varies in a complicated way with the line of sight. We have identified mid-infrared counterparts in the *Spitzer*/IRAC catalogue of Ramírez et al. (2008) for most of our variables and find that they follow rather narrow period-luminosity relations in the 3.6 to 8.0 μm wavelength range.

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The close circumstellar environment of Betelgeuse — Adaptive optics spectro-imaging in the near-IR with VLT/NACO

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Context: Betelgeuse is one the largest stars in the sky in terms of angular diameter. Structures on the stellar photosphere have been detected in the visible and near-infrared as well as a compact molecular environment called the MOLsphere. Mid-infrared observations have revealed the nature of some of the molecules in the MOLsphere, some being the precursor of dust.
Aims: Betelgeuse is an excellent candidate to understand the process of mass loss in red supergiants. Using diffraction-limited adaptive optics (AO) in the near-infrared, we probe the photosphere and close environment of Betelgeuse to study the wavelength dependence of its extension, and to search for asymmetries.
Methods: We obtained AO images with the VLT/NACO instrument, taking advantage of the "cube" mode of the CONICA camera to record separately a large number of short-exposure frames. This allowed us to adopt a "lucky imaging" approach for the data reduction, and obtain diffraction-limited images over the spectral range 1.04–2.17 μm in 10 narrow-band filters.
Results: In all filters, the photosphere of Betelgeuse appears partly resolved. We identify an asymmetric envelope around the star, with in particular a relatively bright "plume" extending in the southwestern quadrant up to a radius of approximately six times the photosphere. The CN molecule provides an excellent match to the 1.09 μm bandhead

in absorption in front of the stellar photosphere, but the emission spectrum of the plume is more difficult to interpret. Conclusions: Our AO images show that the envelope surrounding Betelgeuse has a complex and irregular structure. We propose that the southwestern plume is linked either to the presence of a convective hot spot on the photosphere, or to the rotation of the star.

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Joint analysis of near-infrared properties and surface brightness fluctuations of LMC star clusters

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Surface brightness fluctuations have been proved to be a very powerful technique to determine the distance and characterize the stellar content in extragalactic systems. Nevertheless, before facing the problem of stellar content in distant galaxies, we need to calibrate the method onto nearby well-known systems. In this paper we analyze the properties at J and K_s bands of a sample of 19 star clusters in the Large Magellanic Cloud (LMC), for which accurate near-infrared (NIR) resolved star photometry, and integrated photometry are available. For the same sample, we derive the SBF measurements in J and K_s-bands. We use the multi-purpose stellar population code SPoT (Stellar POpulations Tools) to simulate the color–magnitude diagram, stellar counts, integrated magnitudes, colors, and surface brightness fluctuations of each cluster. The present procedure allows us to estimate the age and metallicity of the clusters in a consistent way, and provides a new calibration of the empirical s-parameter. We take advantage of the high sensitivity of NIR surface brightness fluctuations to thermally pulsing asymptotic (TP-AGB) stars to test different mass-loss rates affecting the evolution of such stars. We argue that NIR-SBFs can contribute to the disentangling of the observable properties of TP-AGB stars, especially in galaxies, where a large number of these stars are present.

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Binary planetary nebulae nuclei towards the Galactic bulge. II. A penchant for bipolarity and low-ionisation structures

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Considerable effort has been applied towards understanding the precise shaping mechanisms responsible for the diverse range of morphologies exhibited by planetary nebulae (PNe). At least 10–20% of PNe have central stars (CSPN) with a close binary companion thought responsible for heavily shaping the ejected PN during common-envelope (CE) evolution, however morphological studies of the few available examples show no clear distinction between PNe and post-CE PNe. The discovery of several new binary central stars (CSPN) from the OGLE-III photometric variability survey has significantly increased the number of post-CE PNe available for morphological analysis to 30 PNe. High-quality Gemini South narrow-band images are presented for most of the OGLE sample, while some previously known post-CE nebulae are reanalysed with images from the literature. Nearly 30% of nebulae have canonical bipolar morphologies, however this could be as high as 60% once inclination effects are incorporated with the aid of geometric models. This is the strongest observational evidence yet linking CE evolution to bipolar morphologies. A higher than average proportion of the sample shows low-ionisation knots, filaments or jets suggesting they have a binary origin.

These features are also common in nebulae around emission-line nuclei which may be explained by speculative binary formation scenarios for H-deficient CSPN.

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Evolution and chemical yields of AGB stars: effects of low-temperature opacities

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The studies focused on the Thermally-Pulsing Asymptotic Giant Branch phase experienced by low- and intermediate-mass stars are extremely important in many astrophysical contexts. In particular, a detailed computation of their chemical yields is essential for several issues, ranging from the chemical evolution of galaxies, to the mechanisms behind the formation of globular clusters. Among all the uncertainties affecting the theoretical modelling of this phase, and described in the literature, it remains to be fully clarified which results are severely affected by the use of inadequate low-temperature opacities, that are in most cases calculated on the basis of the original chemical composition of the stars, and do not consider the changes in the surface chemistry due to the occurrence of the third dredge-up and hot-bottom burning. Our investigation is aimed at investigating this point. By means of full evolutionary models including new set of molecular opacities computed specifically with the AESOPUS tool, we highlight which stellar models, among those present in the literature, need a substantial revision, mainly in relation to the predicted chemical yields. The interplay among convection, hot bottom burning and the low-temperature opacity treatment is also discussed.

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The color excesses of type Ia supernovae from single-degenerate channel model

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Single Degenerate model is the most widely accepted progenitor model of type Ia supernovae (SNe Ia), in which a carbon-oxygen white dwarf (CO WD) accretes hydrogen-rich material from a main sequence or a slightly evolved star (WD+MS) to increase its mass, and explodes when its mass approaches the Chandrasekhar mass limit. During the mass transfer phase between the two components, an optically thick wind may occur and the material lost as the wind may exist as circumstellar material (CSM). Searching the CSM around progenitor star is helpful to discriminate different progenitor models of SNe Ia. Meanwhile, the CSM is a source of color excess.The purpose of this paper is to study the color excess produced from the single-degenerate progenitor model with optically thick wind, and reproduce the distribution of color excesses of SNe Ia. Meng et al. (2009) systemically carried out binary evolution calculation of the WD+MS systems for various metallicities and showed the parameters of the systems before Roche lobe overflow and at the moment of supernova explosion in Meng & Yang (2009). With the results of Meng et al. (2009), we calculate the color excesses of SNe Ia at maximum light via a simple analytic method. We reproduces the distribution of color excesses of SNe Ia by our binary population synthesis approach if the velocity of the optically thick wind is taken to be of order of magnitude of 10 km s^{-1}. However, if the wind velocity is larger than 100 km s^{-1}, the reproduction is bad.

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Long secondary periods in variable red giants

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We present a study of a sample of LMC red giants exhibiting Long Secondary Periods (LSPs). We use radial velocities obtained from VLT spectral observations and MACHO and OGLE light curves to examine properties of the stars and to evaluate models for the cause of LSPs. This sample is much larger than the combined previous studies of Hinkle et al. (2002) and Wood, Olivier & Kawaler (2004).
Binary and pulsation models have enjoyed much support in recent years. Assuming stellar pulsation, we calculate from the velocity curves that the typical fractional radius change over an LSP cycle is greater than 30 per cent. This should lead to large changes in $T_{\rm eff}$ that are not observed. Also, the small light amplitude of these stars seems inconsistent with the radius amplitude. We conclude that pulsation is not a likely explanation for the LSPs. The main alternative, physical movement of the star — binary motion — also has severe problems. If the velocity variations are due to binary motion, the distribution of the angle of periastron in our large sample of stars has a probability of 1.4×10^{-3} that it comes from randomly aligned binary orbits. In addition, we calculate a typical companion mass of 0.09 $M_\odot$. Less than 1 per cent of low mass main sequence stars have companions near this mass (0.06 to 0.12 $M_\odot$) whereas ~ 25 to 50 per cent of low mass red giants end up with LSPs. We are unable to find a suitable model for the LSPs and conclude by listing their known properties.

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Low-temperature gas opacity — AESOPUS: a versatile and quick computational tool

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We introduce a new tool — AESOPUS: Accurate Equation of State and OPacity Utility Software — for computing the equation of state and the Rosseland mean (RM) opacities of matter in the ideal gas phase. Results are given as a function of one pair of state variables, (i.e. temperature T in the range $3.2 \leq \log(T) \leq 4.5$, and parameter $R = \rho/(T/10^6\,{\rm K})^3$ in the range $-8 \leq \log(R) \leq 1$), and arbitrary chemical mixture. The chemistry is presently solved for about 800 species, consisting of almost 300 atomic and 500 molecular species. The gas opacities account for many continuum and discrete sources, including atomic opacities, molecular absorption bands, and collision-induced absorption. Several tests made on AESOPUS have proved that the new opacity tool is accurate in the results, flexible in the management of the input prescriptions, and agile in terms of computational time requirement. We set up a web-interface (http://stev.oapd.inaf.it/aesopus) which enables the user to compute and shortly retrieve RM opacity tables according to his/her specific needs, allowing a full degree of freedom in specifying the chemical composition of the gas. Useful applications may regard RM opacities of gas mixtures with i) scaled-solar abundances of metals, choosing among various solar mixture compilations available in the literature; ii) varying CNO abundances, suitable for evolutionary models of red and asymptotic giant branch stars and massive stars in the Wolf-Rayet stages; iii) various degrees of enhancement in alpha-elements, and C-N, Na-O and Mg-Al abundance anti-correlations, necessary to properly describe the properties of stars in early-type galaxies and Galactic globular clusters; iv) zero-metal abundances appropriate for studies of gas opacity in primordial conditions.

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Red supergiants in the Andromeda galaxy (M 31)

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Red supergiants (RSGs) are a short-lived stage in the evolution of moderately massive stars (10–25 $M_\odot$), and as such their location in the H–R diagram provides an exacting test of stellar evolutionary models. Since massive star evolution is strongly affected by the amount of mass-loss a star suffers, and since the mass-loss rates depend upon metallicity, it is highly desirable to study the physical properties of these stars in galaxies of various metallicities. Here we identify a sample of red supergiants in M 31, the most metal-rich of the Local Group galaxies. We determine the physical properties of these stars using both moderate resolution spectroscopy and broad-band V–K photometry. We find that on average the RSGs are our sample are variable in V by 0.5 mag, smaller but comparable to the 0.9 mag found for Magellanic Cloud (MC) RSGs. No such variability is seen at K , also in accord with what we know of Galactic and MC RSGs. We find that there is a saturation effect in the model TiO band strengths with metallicities higher than solar. The physical properties we derive for the RSGs from our analysis with stellar atmosphere models agree well with the current evolutionary tracks, a truly remarkable achievement given the complex physics involved in each. We do not confirm an earlier result that the upper luminosities of RSGs depend upon metallicity; instead, the most luminous RSGs have $\log L/L_\odot \sim 5.2$–5.3, broadly consistent but slightly larger than that recently observed by Smartt et al. as the upper luminosity limit to Type II-P supernovae, believed to have come from RSGs. We find that, on average, the RSGs are considerably more reddened than O and B stars, suggesting thatcircumstellar dust is adding a significant amount of extra extinction, about 0.5 mag, on average. This is in accord with our earlier findings on Milky Way and Magellanic Cloud stars. Finally, we call attention to a peculiar star whose spectrum appears to be heavily veiled, possibly due to scattering by an expanding dust shell.

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Hot C-rich white dwarfs: testing the DB–DQ transition through pulsations

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Hot DQ white dwarfs constitute a new class of white dwarf stars, uncovered recently within the framework of the SDSS project. There exist nine of them, out of a total of several thousands white dwarfs spectroscopically identified. Recently, three hot DQ white dwarfs have been reported to exhibit photometric variability with periods compatible with pulsation g-modes. Here, we present a nonadiabatic pulsation analysis of the recently discovered carbon-rich hot DQ white dwarf stars. One of our main aims is to test the convective-mixing picture for the origin of hot DQs through the pulsational properties. Our study relies on the full evolutionary models of hot DQ white dwarfs recently developed by Althaus et al. (2009), that consistently cover the whole evolution from the born-again stage to the white dwarf cooling track. Specifically, we present a stability analysis of white dwarf models from stages before the blue

edge of the DBV instability strip ($T_{\rm eff} \approx 30\,000$ K) until the domain of the hot DQ white dwarfs ($18\,000 - 24\,000$ K), including the transition DB→hot DQ white dwarf. We explore evolutionary models with $M_\star = 0.585$ M$_\odot$ and $M_\star = 0.87$ M$_\odot$, and two values of the thickness of the He-rich envelope ($M_{\rm He} = 2 \times 10^{-7} M_\star$ and $M_{\rm He} = 10^{-8} M_\star$). These envelopes are 4–5 orders of magnitude thinner than those of standard DB white dwarf models resulting from canonical stellar evolution computations. We found that at evolutionary phases in which the models are characterized by He-dominated atmospheres, they exhibit unstable g-mode pulsations typical of DBV stars, and when the models become DQ white dwarfs with carbon-dominated atmospheres, they continue being pulsationally unstable with similar characteristics than DB models, and in agreement with the periods detected in variable hot DQ white dwarfs. In particular, for models with $M_{\rm He} = 10^{-8} M_\star$ there exists a narrow gap separating the DB and DQ instability domains. Our calculations provide strong support to the convective-mixing picture for the formation of hot DQs. In particular, our results point to the existence of pulsating DB white dwarfs with very thin He-rich envelopes, which after passing the DBV instability strip become variable hot DQ stars. The existence of these DB stars with very thin envelopes could be investigated through asteroseismology.

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CNO enrichment by rotating AGB stars in globular clusters

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AGB stars have long been held responsible for the important star-to-star variations in light elements observed in Galactic globular clusters. We analyse the main impacts of a first generation of rotating intermediate-mass stars on the chemical properties of second-generation globular cluster stars. The rotating models were computed without magnetic fields and without the effects of internal gravity waves. They account for the transports by meridional currents and turbulence. We computed the evolution of both standard and rotating stellar models with initial masses between 2.5 and 8 M$_\odot$ within the metallicity range covered by Galactic globular clusters. During central He-burning, rotational mixing transports fresh CO-rich material from the core towards the hydrogen-burning shell, leading to the production of primary ^{14}N. In stars more massive than $M > 4$ M$_\odot$, the convective envelope reaches this reservoir during the second dredge-up episode, resulting in a large increase in the total C+N+O content at the stellar surface and in the stellar wind. The corresponding pollution depends on the initial metallicity. At low- and intermediate-metallicity (i.e., [Fe/H] $\lesssim -1.2$), it is at odds with the constancy of C+N+O observed among globular cluster low-mass stars. With the given input physics, our models suggest that massive (i.e., > 4 M$_\odot$) rotating AGB stars have not shaped the abundance patterns observed in low- and intermediate-metallicity globular clusters. Our non-rotating models, on the other hands, do not predict surface C+N+O enhancements, hence are in a better position as sources of the chemical anomalies in globular clusters showing the constancy of the C+N+O. However at the moment, there is no reason to think that intermediate mass stars were not rotating. On the contrary there is observational evidence that stars in clusters have higher rotational velocities than in the field.

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The effects of red supergiant mass loss on supernova ejecta and the circumburst medium

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Massive stars becoming red supergiants lose a significant amount of their mass during that brief evolutionary phase. They then either explode as a hydrogen-rich supernova (SN Type II), or continue to evolve as a hotter supergiant (before exploding). The slow, dusty ejecta of the red supergiant will be over-run by the hot star wind and/or SN ejecta. I will present estimates of the conditions for this interaction and discuss some of the implications.

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Galactic C and S stars as guidelines for magellanic cloud AGB stars

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The study of the evolutionary properties of Asymptotic Giant Branch stars still presents unresolved topics. Progress in the theoretical understanding of their evolution is hampered by the difficulty to empirically explain key physical parameters like their luminosity, mass loss rate and chemical abundances. We are performing an analysis of Galactic AGB stars trying to find constraints for these parameters. Our aim is of extending this analysis to the AGB stars of the Magellanic Clouds and of the Dwarf Spheroidal Galaxies using also mid-infrared observations from the Antarctic telescope IRAIT. AGB sources from the Magellanic Clouds will be fundamental in our understanding of the AGB evolution because they are all at a well defined distance (differently from the Galactic AGBs). Moreover, these sources present different values of metallicity: this fact should permit us of examining in a better way their evolutionary properties comparing their behaviour with the one from Galactic sources.

Poster contribution, published in IAU Symposium 256: The Magellanic System: Stars, Gas, and Galaxies
Available from arXiv:0906.5377
and from http://www.astro.keele.ac.uk/iaus256/proceedings/p4.ps

Miras around the Galactic Center

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We report results of our near-IR survey for variables in a field of view of $20'$ by $30'$ towards the Galactic Center (GC), where we detected 1364 long-period variables. We have established a method for the simultaneous estimation of distances and extinctions using the period-luminosity relations for the JHK_s bands. Our method is applicable to Miras with periods in the range 100–350 days and mean magnitudes available in two or more filters. Here we discuss 143 Miras whose distances and extinctions were obtained based on their periods and H- and K_s-band magnitudes. We find that almost all of them are located at the same distance to within our accuracy, and the distance modulus of the GC is estimated to be $14.58 \pm 0.02 \pm 0.11$ mag. The former error corresponds to the statistical error and the latter to the systematic one which includes the uncertainty of our assumed distance modulus of the LMC (18.45 ± 0.05 mag). We also discuss the large and highly variable extinction towards the GC.

Poster contribution, published in "Stellar Pulsation: Challenges for Theory and Observations"
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Stochastic processes in yellow and red pulsating variables

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Random changes in pulsation period are well established in cool pulsating stars, in particular the red giant variables: Miras, semi-regulars of types A and B, and RV Tau variables. Such effects are also observed in a handful of Cepheids, the SX Phe variable XX Cyg, and, most recently, the red supergiant variable, BC Cyg, a type C semi-regular. The nature of such fluctuations is seemingly random over a few pulsation cycles of the stars, yet the regularity of the primary pulsation mechanism dominates over the long term. The degree of stochasticity is linked to the dimensions of the stars, the randomness parameter e appearing to correlate closely with mean stellar radius through the period P, with an average value of $e/P = 0.0136 \pm 0.0005$. The physical processes responsible for such fluctuations are uncertain, but presumably originate in temporal modifications of envelope convection in such stars.

Poster contribution, published in "Stellar Pulsation: Challenges for Theory and Observation", AIP Conference Series
Available from arXiv:0907.2818

Thesis

On the winds of carbon stars and the origin of carbon: A theoretical study

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Carbon is the basis for life, as we know it, but its origin is still largely unclear. Carbon-rich Asymptotic Giant Branch (AGB) stars (carbon stars) play an important rôle in the cosmic matter cycle and may contribute most of the carbon in the Galaxy.

In this thesis it is explored how the dust-driven mass loss of these stars depends on the basic stellar parameters by computing a large grid of wind models. The existence of a critical wind regime and mass-loss thresholds for dust-driven winds are confirmed. Furthermore, a steep dependence of mass loss on carbon excess is found. Exploratory work on the effects of different stellar metallicities and the sizes of dust grains shows that strong dust-driven winds develop also at moderately low metallicities, and that typical sizes of dust grains affect the wind properties near a mass-loss threshold.

It is demonstrated that the mass-loss rates obtained with the wind models have dramatic consequences when used in models of carbon-star evolution. A pronounced superwind develops soon after the star becomes carbon rich, and it

therefore experiences only a few thermal pulses as a carbon star before the envelope is lost. The number of dredge-up events and the thermal pulses is limited by a self-regulating mechanism: each thermal pulse dredges up carbon, which increases the carbon excess and hence also the mass-loss rate. In turn, this limits the number of thermal pulses.

The mass-loss evolution during a thermal pulse (He-shell flash) is considered as an explanation of the observations of so-called detached shells around carbon stars. By combining models of dust-driven winds with a stellar evolution model, and a simple hydrodynamic model of the circumstellar envelope, it is shown that wind properties change character during a He-shell flash such that a thin detached gas shell can form by wind-wind interaction.

Finally, it is suggested that carbon stars are responsible for much of the carbon in the interstellar medium, but a scenario where high-mass stars are major carbon producers cannot be excluded. In either case, however, the carbon abundances of the outer Galactic disc are relatively low, and most of the carbon has been released quite recently. Thus, there may neither be enough carbon, nor enough time, for more advanced carbon-based life to emerge in the outer Galaxy. This lends some support to the idea that only the mid-part of the Galactic disc can be a "Galactic habitable zone", since the inner parts of the Galaxy are plagued by frequent supernova events that are presumably harmful to all forms of life.

Opponent: Groenewegen, Martin, Dr. (Royal Observatory of Belgium)
Available from http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-99593

Job Advert

Instituut voor Sterrenkunde, KULeuven, Belgium Post-doctoral researcher in Infrared Astronomy

The Institute of Astronomy of the University of Leuven is a young research team of some 45 scientists and engineers. Its main science themes are in the very broad context of stellar evolution, including star formation and young stars, evolved stars, galactic structure, and asteroseismology.

Field of research:
Analysis and modeling of far-infrared imaging and integral-field spectroscopy of circumstellar media of evolved stars. The prime resource of observational data for this research is the Herschel guaranteed time Key Programme on Mass Loss around Evolved Stars (MESS). The programme consists of several hundreds of hours of Herschel imaging and spectroscopy in the PACS and SPIRE bands of post-main sequence stars. The main aim of this Key Program is threefold:
(1) to study the time-dependence of the mass-loss process and total mass in the circumstellar envelopes,
(2) to study the dust-, gas- and molecular chemistry as a function of progenitor mass, and,
(3) to study the asymmetries in circumstellar envelopes, in evolved stars, both from low- and intermediate mass, and massive progenitors. To this end, a sample of Asymptotic Giant Branch and Red Super Giants, post-AGB and Planetary Nebulae, Luminous Blue Variables and Wolf-Rayet stars, and a few Supernovae remnants will be imaged with PACS at 70+110 μm, and a sub-set of 32 stars will be imaged at all 3 wavelengths with SPIRE. In spectroscopy, a sample of 55 stars will be observed over the full wavelength range of PACS and, 23 stars will be observed with the SPIRE FTS. Based on the results obtained in this large key programme, we anticipate initiating follow-up open time programmes. The successful candidate will be encouraged to take an active role in these proposals. Besides our leading role in the MESS programme our research group is responsible for important parts of the guaranteed time Key Programmes on Stellar Disk Evolution; HIFISTARS: The physical and chemical properties of circumstellar environments around evolved stars; Water and related chemistry in the Solar system; Probing the origin of the stellar initial mass function (a wide-field Herschel photometeric survey of nearby star-forming cloud complexes), and the Open Time key programmes on Gas in Protoplanetary systems (GASP); Dust, Ice and Gas in Time (DIGIT) and Hi-GAL: the Herschel infrared Galactic Plane Survey. We anticipate important synergies between the MESS programme and these

other Herschel programmes and the stellar evolution research legacy of our research group.

Profile
— PhD in Astrophysics
— A relevant research record in infrared observational astrophysics
— Familiarity with the study of late stages of stellar evolution
— Experience with the use of map reconstruction algorithms and (far-) infrared imaging
— expertise in radiative-transfer modelling of dusty environments.
— Capable to work in an international research team Employment conditions
— Duty station is the Institute of Astronomy, K.U.Leuven, Belgium
— Starting date : depending on availability candidate; target October / November
— Fixed-term contract in the service of K.U.Leuven, Two year contract. Extension possible.
— The salary will be according to the university salary scales of post-doctoral researcher depending on the level of experience.

Applications
Application deadline is 31-August-2009.
Applications, including CV and publication list, can be sent electronically to Prof. Dr. Christoffel Waelkens
— christoffel.waelkens@ster.kuleuven.be.
Three letters of recommendation are required — these can be sent separately to the same address

See also http://www.ster.kuleuven.be/vacancies/index_en.html