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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 189$^{\rm th}$ issue of the AGB Newsletter. A variety of work is presented, on elemental abundances, masers, post-AGB objects, et cetera, as well as some results presented at the Betelgeuse workshop with relevance to the study of AGB stars.

Prospective PhD students may wish to consider the positions opened in Uppsala, Sweden.

The 6$^{\rm th}$ Asymmetrical Planetary Nebulæ conference will be held in México.

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

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Experiences in youth shape adulthood – AGB stars keep memory of their past

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

Two beyond-primitive extrasolar planetesimals

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Using the Cosmic Origins Spectrograph onboard the *Hubble* Space Telescope, we have obtained high-resolution ultraviolet observations of GD 362 and PG 1225−079, two helium-dominated, externally-polluted white dwarfs. We determined or placed useful upper limits on the abundances of two key volatile elements, carbon and sulfur, in both stars; we also constrained the zinc abundance in PG 1225−079. In combination with previous optical data, we find strong evidence that each of these two white dwarfs has accreted a parent body that has evolved beyond primitive nebular condensation. The planetesimal accreted onto GD 362 had a bulk composition roughly similar to that of a mesosiderite meteorite based on a reduced χ^2 comparison with solar system objects; however, additional material is required to fully reproduce the observed mid-infrared spectrum for GD 362. No single meteorite can reproduce the unique abundance pattern observed in PG 1225−079; the best fit model requires a blend of ureilite and mesosiderite material. From a compiled sample of 9 well-studied polluted white dwarfs, we find evidence for both primitive planetesimals, which are a direct product from nebular condensation, as well as beyond-primitive planetesimals, whose final compositions were mainly determined by post-nebular processing.

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Convective overshoot mixing in stellar interior models

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The convective overshoot mixing plays an important role in stellar structure and evolution. However, the overshoot mixing is a long standing problem. The uncertainty of the overshoot mixing is one of the most uncertain factors in stellar physics. As it is well known, the convective and overshoot mixing is determined by the radial chemical component flux. In this paper, a local model of the radial chemical component flux is established based on the hydrodynamic equations and some model assumptions. The model is tested in stellar models. The main conclusions are as follows. (i) The local model shows that the convective and overshoot mixing could be regarded as a diffusion process, and the diffusion coefficient for different chemical element is the same. However, if the non-local terms, i.e., the turbulent convective transport of radial chemical component flux, are taken into account, the diffusion coefficient for each chemical element should be in general different. (ii) The diffusion coefficient of convective / overshoot mixing shows different behaviors in convection zone and in overshoot region because the characteristic length scale of the mixing is large in the convection zone and small in the overshoot region. The overshoot mixing should be regarded as a weak mixing process. (iii) The result of the diffusion coefficient of mixing is tested in stellar models. It is found that a single choice of our central mixing parameter leads to consistent results for a solar convective envelope model as well as for core convection models of stars with mass from 2 $M_\odot$ to 10 $M_\odot$.

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Is the sulphur anomaly in planetary nebulæ caused by the s-process?

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Motivated by unexplained observations of low sulphur abundances in planetary nebulæ (PNe) and the PG 1159 class of post asymptotic giant branch (AGB) stars, we investigate the possibility that sulphur may be destroyed by nucleosynthetic processes in low-to-intermediate mass stars during stellar evolution. We use a 3 $M_\odot$, $Z = 0.01$ evolutionary sequence to examine the consequences of high and low reaction rate estimates of neutron captures onto sulphur and neighbouring elements. In addition we have also tested high and low rates for the neutron producing reactions $^{13}C(\alpha,n)^{16}O$ and $^{22}Ne(\alpha,n)^{25}Mg$. We vary the mass width of a partially mixed zone (PMZ), which is responsible for the formation of a ^{13}C pocket and is the site of the $^{13}C(\alpha,n)^{16}O$ neutron source. We test PMZ masses from zero up to an extreme upper limit of the entire He-intershell mass at 10^{-2} $M_\odot$. We find that the alternative reaction rates and variations to the partially mixed zone have almost no effect on surface sulphur abundances and do not reproduce the anomaly. To understand the effect of initial mass on our conclusions, 1.8 $M_\odot$ and 6 $M_\odot$ evolutionary sequences are also tested with similar results for sulphur abundances. We are able to set a constraint on the size of the PMZ, as PMZ sizes that are greater than half of the He-intershell mass (in the 3 $M_\odot$ model) are excluded by comparison with neon abundances in planetary nebulæ. We compare the 1.8 $M_\odot$ model's intershell abundances with observations of PG 1159−035, whose surface abundances are thought to reflect the intershell composition of a progenitor AGB star. We find general agreement between the patterns of F, Ne, Si, P, and Fe abundances and a very large discrepancy for sulphur where our model predicts abundances that are 30–40 times higher than is observed in the star.

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NGC 7419 as a template for red supergiant clusters

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The open cluster NGC 7419 is known to contain five red supergiants and a very high number of Be stars. However, there are conflicting reports about its age and distance that prevent a useful comparison with other clusters. We intend to obtain more accurate parameters for NGC 7419, using techniques different from those of previous authors, so that it may be used as a calibrator for more obscured clusters. We obtained Strömgren photometry of the open cluster NGC 7419, as well as classification spectroscopy of $\sim$ 20 stars in the area. We then applied standard analysis and classification techniques. We find a distance of 4 ± 0.4 kpc and an age of 14 ± 2 Myr for NGC 7419. The main-sequence turn-off is found at spectral type B1, in excellent agreement. We identify 179 B-type members, implying that there are more than 1200 $M_\odot$ in B stars at present. Extrapolating this to lower masses indicates an initial cluster mass of between 7000 and 10,000 $M_\odot$, depending on the shape of the initial mass function. We find a very high fraction ($\sim$ 40%) of Be stars around the turn-off, but very few Be stars at lower masses. We also report for the first time a strong variability in the emission characteristics of Be stars. We verified that the parameters of the red supergiant members can be used to obtain accurate cluster parameters. NGC 7419 is sufficiently massive to serve as a testbed for theoretical predictions and as a template to compare more obscured clusters. The distribution of stars above the main-sequence turn-off is difficult to accommodate with current evolutionary tracks. Though the presence of five red supergiants is marginally consistent with theoretical expectations, the high number of Be stars and very low number of luminous evolved B stars hint at some unknown physical factor that is not considered in current synthesis models.

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Water maser survey on AKARI and IRAS sources: A search for "low-velocity" water fountains

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We present the results of a 22-GHz H_2O maser survey toward a new sample of AGB and post-AGB star candidates. Most of the objects are selected for the first time based on the AKARI data, which have high flux sensitivity in the mid-infrared ranges. We aim at finding H_2O maser sources in the transient phase between the AGB and post-AGB stage of evolution, where the envelopes start to develop large deviations from spherical symmetry. The observations were carried out with the Effelsberg 100-m radio telescope. Among 204 observed objects, 63 detections (36 new) were obtained. We found 4 objects which may be "water fountain" sources (IRAS 15193+3132, IRAS 18056−1514, OH 16.3−3.0, and IRAS 18455+0448). They possess an H_2O maser velocity coverage much smaller than those in other known water fountains. However, the coverage is still larger than that of the 1612-MHz OH maser. It implies that there is an outflow with a higher velocity than the envelope expansion velocity (typically ≤ 25 km s^{-1}), meeting the criterion of the water fountain class. We suggest that these candidates are possibly oxygen-rich late AGB or early post-AGB stars in a stage of evolution immediately after the spherically symmetric AGB mass-loss has ceased.

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Non-aqueous formation of the calcium carbonate polymorph vaterite: astrophysical implications

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We study the formation of calcium carbonate, through the solid-gas interaction of amorphous Ca-silicate with gaseous CO_2, at elevated pressures, and link this to the possible presence of calcium carbonate in a number of circumstellar and planetary environments. We use in-situ synchrotron X-Ray powder diffraction to obtain detailed structural data pertaining to the formation of the crystalline calcium carbonate phase vaterite and its evolution with temperature. We found that the metastable calcium carbonate phase vaterite was formed alongside calcite, at elevated CO_2 pressure, at room temperature and subsequently remained stable over a large range of temperature and pressure. We report the formation of the calcium carbonate mineral vaterite whilst attempting to simulate carbonate dust grain formation in astrophysical environments. This suggests that vaterite could be a mineral component of carbonate dust and also presents a possible method of formation for vaterite and its polymorphs on planetary surfaces.

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e-MERLIN resolves Betelgeuse at wavelength 5 cm

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Convection, pulsation and magnetic fields have all been suggested as mechanisms for the transport of mass and energy from the optical photosphere of red supergiants, out to the region where the stellar wind is launched. We imaged the red supergiant Betelgeuse at 0.″06–0.″18 resolution, using e-MERLIN at 5.5–6.0 GHz, with a sensitivity of ~ 0.01 mJy beam^{-1}. Most of the radio emission comes from within an ellipse 0.235×0.218 arcsec^2 ($\sim 5\times$ the optical radius), with a flux density of 1.62 mJy, giving an average brightness temperature ~ 1250 K. This radio photosphere contains two hotspots of 0.53 and 0.79 mJy beam^{-1}, separated by 90 milli-arcsec, with brightness temperatures 5400 ± 600 K and 3800 ± 500 K. Similar hotspots, at more than double the distance from the photosphere of those seen in any other regime, were detected by the less-sensitive 'old' MERLIN in 1992, 1995 and 1996 and many exceed the photospheric temperature of 3600 K. Such brightness temperatures are high enough to emanate from pockets of chromospheric plasma. Other possibilities include local shock heating, the convective dredge-up of hot material or exceptionally cool, low density regions, transparent down to the hottest layer at ~ 40 milliarcsec radius. We also detect an arc 0.″2–0.″3 to the SW, brightness temperature ~ 150 K, in a similar direction to extensions seen on both smaller and larger scales in the infra-red and in CO at mm wavelengths. These preliminary results will be followed by further e-MERLIN, VLA and ALMA observations to help resolve the problem of mass elevation from 1 to 10 $R_\star$ in red supergiants.

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Transition of the stellar initial mass function explored with binary population synthesis

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The stellar initial mass function (IMF) plays a crucial rôle in determining the number of surviving stars in galaxies, the chemical composition of the interstellar medium, and the distribution of light in galaxies. A key unsolved question is whether the IMF is universal in time and space. Here we use state-of-the-art results of stellar evolution to show that the IMF of our Galaxy made a transition from an IMF dominated by massive stars to the present-day IMF at an early phase of the Galaxy formation. Updated results from stellar evolution in a wide range of metallicities have been implemented in a binary population synthesis code, and compared with the observations of carbon-enhanced metal-poor (CEMP) stars in our Galaxy. We find that applying the present-day IMF to Galactic halo stars causes serious contradictions with four observable quantities connected with the evolution of AGB stars. Furthermore, a comparison between our calculations and the observations of CEMP stars may help us to constrain the transition metallicity for the IMF which we tentatively set at [Fe/H] $= -2$. A novelty of the current study is the inclusion of mass loss suppression in intermediate-mass AGB stars at low-metallicity. This significantly reduces the overproduction of nitrogen-enhanced stars that was a major problem in using the high-mass star dominated IMF in previous studies.

Our results also demonstrate that the use of the present day IMF for all time in chemical evolution models results in the overproduction of Type I.5 supernovæ. More data on stellar abundances will help to understand how the IMF has changed and what caused such a transition.

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Analysis of far-UV data of central stars of planetary nebulæ: Occurrence and variability of stellar winds

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The occurrence of stellar wind in the central star of a planetary nebula (CSPN) can be revealed by the presence of P-Cygni profiles of high-excitation lines overimposed on its stellar continuum. We examined the entire Far-Ultraviolet Spectroscopic Explorer *FUSE* archive and merged all useful spectroscopic observations of CSPNe to produce the highest quality spectra that can be used to assess the frequency of stellar winds. Furthermore, the individual spectra of each CSPN were compared to search for variability in the P-Cygni profile. P-Cygni profiles of high-excitation lines have been found in 44 CSPNe, with a clear correlation between the ionization potential of the lines and the effective temperature of the star. We introduce a prescription to derive the terminal wind velocity (v_∞) from saturated and unsaturated P-Cygni profiles and provide new values of v_∞ for these stars. Another 23 CSPNe do not show P-Cygni profiles, or else their data in the FUSE archive are not conclusive enough to determine the occurrence of P-Cygni profiles. Variability in the P-Cygni profile of high-excitation, far-UV lines is found for the first time in six CSPNe, namely Hen 2-131, NGC 40, NGC 1535, NGC 2392, Sp 3, and SwSt 1. This increases up to 13 the number of CSPNe with variable P-Cygni profiles in the UV, including those previously reported using IUE or FUSE observations. Variability is seen primarily in the unsaturated P V and Si IV lines, but also in saturated C III and O VI lines. The CSPNe with variable P-Cygni profiles have similar stellar properties (relatively low $\log g$ and $T_{\rm eff}$) that suggest they are less evolved CSPNe. Some of the CSPNe with variable P-Cygni profiles show O VI lines, while their effective temperature is insufficient to produce this ion. We suggest that this ion is produced by Auger ionization from X-rays associated to shocks in their stellar winds, as is the case in massive OB stars of high ionization potential ions that cannot be abundantly produced by photo-ionizations.

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Populations of rotating stars. I. Models from 1.7 $M_\odot$ to 15 $M_\odot$ at $Z = 0.014$, 0.006, and 0.002 with $\Omega/\Omega_{\rm crit}$ between 0 and 1

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Context: B-type stars are known to rotate at various velocities, including very fast rotators near the critical velocity as the Be stars.
Aims: In this paper, we provide stellar models covering the mass range between 1.7 to 15 $M_\odot$, which includes the typical mass of known Be stars, at $Z = 0.014$, 0.006, and 0.002 and for an extended range of initial velocities on the zero-age main sequence.
Methods: We used the Geneva stellar-evolution code, including the effects of shellular rotation, with a numerical treatment that has been improved so the code can precisely track the variation in the angular momentum content of the star as it changes under the influence of radiative winds and/or mechanical mass loss.
Results: We discuss the impact of the initial rotation rate on the tracks in the Hertzsprung–Russell diagram, the

main-sequence (MS) lifetimes, the evolution of the surface rotation and abundances, as well as on the ejected masses of various isotopes. Among the new results obtained from the present grid we find that 1) fast-rotating stars with initial masses around 1.7 $M_\odot$ present at the beginning of the core hydrogen-burning phase quite small convective cores with respect to their slowly rotating counterparts. This fact may be interesting to keep in mind in the framework of the asteroseismic studies of such stars. 2) The contrast between the core and surface angular velocity is higher in slower rotating stars. Our results are in agreement with the very few values obtained for B-type stars from asteroseismology. 3) At $Z = 0.002$, the stars in the mass range of 1.7 to 3 $M_\odot$ with a mean velocity on the MS of the order of 150 km s^{-1} show N/H enhancement superior to 0.2 dex at mid-MS, and superior to 0.4 dex at the end of the MS phase. At solar metallicity the corresponding values are below 0.2 dex at any time in the MS.
Conclusions: An extended database of stellar models containing 270 evolutionary tracks is provided to the community.

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What determines the grain size distribution in galaxies?

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We construct a dust evolution model taking into account the grain size distribution, and investigate what kind of dust processes determine the grain size distribution at each stage of galaxy evolution. In addition to the dust production by type II supernovæ (SNeII) and asymptotic giant branch (AGB) stars, we consider three processes in the ISM: (i) dust destruction by SN shocks, (ii) metal accretion onto the surface of preexisting grains in the cold neutral medium (CNM) (called grain growth), and (iii) grain–grain collisions (shattering and coagulation) in the warm neutral medium (WNM) and CNM. We found that the grain size distribution in galaxies is controlled by stellar sources in the early stage of galaxy evolution, and that afterwards the main processes that govern the size distribution changes to those in the ISM. Since shattering produces a large abundance of small grains (consequently, the surface-to-volume ratio of grains increases), it enhances the efficiency of grain growth, contributing to the significant increase of the total dust mass. Grain growth creates a large bump in the grain size distribution around a ~ 0.01 μm. Coagulation occurs effectively after the number of small grains is enhanced by shattering, and the grain size distribution is deformed to have a bump at $a \sim 0.03$–0.05 μm at $t \sim 10$ Gyr. We conclude that the evolutions of the total dust mass and the grain size distribution in galaxies are closely related to each other, and the grain size distribution changes considerably through the galaxy evolution because the dominant dust processes which regulate the grain size distribution change.

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The outer halo of the nearest giant elliptical: A VLT/VIMOS survey of the resolved stellar populations in Centaurus A to 85 kpc

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We present the first survey of resolved stellar populations in the remote outer halo of our nearest giant elliptical (gE), Centaurus A ($d = 3.8$ Mpc). Using the VIMOS/VLT optical camera, we obtained deep photometry for four fields

along the major and minor axes at projected elliptical radii of $\sim$ 30–85 kpc (corresponding to $\sim$ 5–14 $R_{\rm eff}$). We use resolved star counts to map the spatial and colour distribution of red giant branch (RGB) stars down to $\sim$ 2 magnitudes below the RGB tip. We detect an extended halo out to the furthermost elliptical radius probed ($\sim$ 85 kpc or $\sim$ 14 $R_{\rm eff}$), demonstrating the vast extent of this system. We detect localised substructure in these parts, visible in both (old) RGB and (intermediate-age) luminous asymptotic giant branch stars, and there is some evidence that the outer halo becomes more elliptical and has a shallower surface brightness profile. We derive photometric metallicity distribution functions for halo RGB stars and find relatively high median metallicity values ($\langle$[Fe/H]$\rangle_{\rm med} \sim -0.9$ to -1.0 dex) that change very little with radius over the extent of our survey. Radial metallicity gradients are measured to be ≈ -0.002–0.004 dex kpc^{-1} and the fraction of metal-poor stars (defined as [Fe/H] < -1.0) is $\approx$ 40–50% at all radii. We discuss these findings in the context of galaxy formation models for the build-up of gE haloes.

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^{3}He: Does the problem persist?

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To understand the chemical evolution of the Galaxy, we need to understand the contribution of PNe in the ^{3}He abundance. ^{3}He abundances have been detected only in a couple of PNe, their abundances are consistent with the standard models, in which ^{3}He is produced in significant quantities by stars of 1–2 $M_\odot$. However, for all the other PNe observed to date there have been no detections, therefore only upper limits in their abundance can be calculated. Observations of the ^{3}He$^+$ emission line using the VLA towards the PNe IC 418, NGC 6572 and NGC 7009 were used to obtain upper limits for their ^{3}He abundance. Because the abundance of ^{3}He in H II regions, the ISM and the proto-solar system is much lower than what is predicted, new chemical models were proposed. The resulting evolution of ^{3}He, based on stellar evolution models, can be consistent with the values determined in pre-solar material and the ISM if 96% of the population of stars with mass below ~ 2.5 $M_\odot$ has undergone enhanced ^{3}He depletion. This implies that unless the combined sample of PNe that has been observed so far is very atypical, the solution to the "The ^{3}He Problem" lies elsewhere. However, the results presented here suggest that more observations are needed in order to make a strong conclusion about the stellar evolution models.

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Red giants in eclipsing binary and multiple-star systems: modeling and asteroseismic analysis of 70 candidates from *Kepler* data

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Red-giant stars are proving to be an incredible source of information for testing models of stellar evolution, as asteroseismology has opened up a window into their interiors. Such insights are a direct result of the unprecedented data from space missions CoRoT and *Kepler* as well as recent theoretical advances. Eclipsing binaries are also fundamental astrophysical objects, and when coupled with asteroseismology, binaries provide two independent methods to obtain masses and radii and exciting opportunities to develop highly constrained stellar models. The possibility of discovering pulsating red giants in eclipsing binary systems is therefore an important goal that could potentially offer very robust

characterization of these systems. Until recently, only one case has been discovered with *Kepler*. We cross-correlate the detected red-giant and eclipsing-binary catalogs from *Kepler* data to find possible candidate systems. Light-curve modeling and mean properties measured from asteroseismology are combined to yield specific measurements of periods, masses, radii, temperatures, eclipse timing variations, core rotation rates, and red-giant evolutionary state. After using three different techniques to eliminate false positives, out of the 70 systems common to the red-giant and eclipsing-binary catalogs we find 13 strong candidates (12 previously unknown) to be eclipsing binaries, one to be an non-eclipsing binary with tidally induced oscillations, and 10 more to be hierarchical triple systems, all of which include a pulsating red giant. The systems span a range of orbital eccentricities, periods, and spectral types F, G, K, and M for the companion of the red giant. One case even suggests an eclipsing binary composed of two red-giant stars and another of a red giant with a δ-Scuti star. The discovery of multiple pulsating red giants in eclipsing binaries provides an exciting test bed for precise astrophysical modeling, and follow-up spectroscopic observations of many of the candidate systems are encouraged. The resulting highly constrained stellar parameters will allow, for example, the exploration of how binary tidal interactions affect pulsations when compared to the single-star case.

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R Coronæ Borealis stars in M 31 from the Palomar Transient Factory

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We report the discovery of R Coronæ Borealis (RCB) stars in the Andromeda galaxy (M 31) using the Palomar Transient Factory (PTF). RCB stars are rare hydrogen-deficient, carbon-rich supergiant variables, most likely the merger products of two white dwarfs. These new RCBs, including two confirmed ones and two candidates, are the first to be found beyond the Milky Way and the Magellanic Clouds. All of M 31 RCBs showed > 1.5 mag irregular declines over timescales of weeks to months. Due to the limiting magnitude of our data ($R \sim 21$–22 mag), these RCB stars have $R \sim 19.5$ to 20.5 mag at maximum light, corresponding to $M_R = -4$ to -5, making them some of the most luminous RCBs known. Spectra of two objects show that they are warm RCBs, similar to the Milky Way RCBs RY Sgr and V854 Cen. We consider these results, derived from a pilot study of M 31 variables, as an important proof-of-concept for the study of rare bright variables in nearby galaxies with the PTF or other synoptic surveys.

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Evolution of planetary systems with time dependent stellar mass loss

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Observations indicate that intermediate-mass stars, binary stars, and stellar remnants often host planets; a complete explanation of these systems requires an understanding of how planetary orbits evolve as their central stars lose mass. Motivated by these dynamical systems, this paper generalizes in two directions previous studies of orbital evolution in planetary systems with stellar mass-loss: [1] Many previous treatments focus on constant mass-loss rates and much of this work is carried out numerically. Here we study a class of single planet systems where the stellar mass-loss rate is time dependent. The mass-loss rate can be increasing or decreasing, but the stellar mass always decreases monotonically. For this class of models, we develop analytic approximations to specify the final orbital elements for

planets that remain bound after the epoch of mass loss, and find the conditions required for the planets to become unbound. We also show that for some mass-loss functions, planets become unbound only in the asymptotic limit where the stellar mass vanishes. [2] We consider the chaotic evolution for two planet systems with stellar mass-loss. Here we focus on a model consisting of analogs of Jupiter, Saturn, and the Sun. By monitoring the divergence of initially similar trajectories through time, we calculate the Lyapunov exponents of the system. This analog solar system is chaotic in the absence of mass loss with Lyapunov time in the range 5–10 Myr; we find that the Lyapunov time decreases with increasing stellar mass-loss rate, with a nearly linear relationship between the two time scales. Taken together, the results of this paper help provide an explanation for a wide range of dynamical evolution that occurs in solar systems with stellar mass-loss.

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Available from arXiv:1303.3841

The color dependent morphology of the post-AGB star HD 161796

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Context: Many proto-planetary nebulæ show strong asymmetries in their surrounding shells, pointing to asymmetries during the mass-loss phase. Questions concerning the origin and the onset of deviations from spherical symmetry are important for our understanding of the evolution of these objects. Here we focus on the circumstellar shell of the post-AGB star HD 161796.
Aims: We aim to detect signatures of an aspherical outflow, and to derive its properties. Methods: We used the imaging polarimeter ExPo (the Extreme Polarimeter), a visitor instrument at the *William Herschel* Telescope, to accurately image the dust shell surrounding HD 161796 in various wavelength filters. Imaging polarimetry allows us to separate the faint, polarized, light that comes from circumstellar material from the bright, unpolarized, light from the central star.
Results: The shell around HD 161796 is highly aspherical. A clear signature of an equatorial density enhancement can be seen. This structure is optically thick at short wavelengths and changes its appearance to optically thin at longer wavelengths. In the classification of the two different appearances of planetary nebulae from HST images it changes from being classified as DUst-Prominent Longitudinally-EXtended (DUPLEX) at short wavelengths to Star-Obvious Low-level-Elongated (SOLE) at longer wavelengths. This strengthens the interpretation that these two appearances are manifestations of the same physical structure. Furthermore, we find that the central star is hotter than often assumed and the relatively high observed reddening is a consequence of circumstellar rather than interstellar extinction.

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Available from arXiv:1303.1704

Nitrogen isotopes in AGB carbon stars and pre-solar SiC grains: a challenge for stellar nucleosynthesis

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Isotopic ratios of C, N, Si, and trace heavy elements in presolar SiC grains from meteorites provide crucial constraints

to nucleo-synthesis. A long-debated issue is the origin of the so-called A+B grains, as for them no stellar progenitor has so far been clearly identified on observational grounds. We report the first spectroscopic measurements of $^{14}N/^{15}N$ ratios in Galactic carbon stars of different spectral types and show that J- and some SC-type stars might produce A+B grains, even for ^{15}N enrichments previously attributed to novæ. We also show that most mainstream (MS) grains are compatible with the composition of N-type stars, but might also descend, in some cases, from SC stars. From the theoretical point of view, no astrophysical scenario can explain the C and N isotopic ratios of SC, J and N-type carbon stars together, as well as those of many grains produced by them. This poses urgent questions to stellar physics.

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A new extensive library of PHOENIX stellar atmospheres and synthetic spectra

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We present a new library of high-resolution synthetic spectra based on the stellar atmosphere code PHOENIX that can be used for a wide range of applications of spectral analysis and stellar parameter synthesis. The spherical mode of PHOENIX was used to create model atmospheres and to derive detailed synthetic stellar spectra from them. We present a new self-consistent way of describing micro-turbulence for our model atmospheres. The synthetic spectra cover the wavelength range from 500 Å to 50 000 Å with resolutions of $R = 500\,000$ in the optical and near IR, $R = 100\,000$ in the IR and a step size of 0.1 Å in the UV. The parameter space covers $2\,300\ \mathrm{K} \leq T_{\mathrm{eff}} \leq 12\,000\ \mathrm{K}$, $0.0 \leq \log g \leq +6.0$, $-4.0 \leq [\mathrm{Fe/H}] \leq +1.0$, and $-0.2 \leq [\alpha/\mathrm{Fe}] \leq +1.2$. The library is a work in progress and we expect to extend it up to $T_{\mathrm{eff}} = 25\,000$ K.

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A comparison of the velocity parameters of SiO $v = 1$, $J = 1$–**0 and** $J = 2$–**1 maser emission in long period variables**

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We present an analysis of velocity parameters derived from multi-epoch observations of the SiO maser spectra of 47 long period variables (LPVs). The velocity parameters are important to inform and constrain theoretical models of SiO maser emission and to extract information on binary orbits. Mira and R Aquarii (R Aqr) are two known binaries included in the program. The 47 LPVs are among 121 sources of the Australia Telescope National Facility (ATNF) Mopra telescope's monitoring program. Observations were carried out several times a year between 2008 and 2012 and are continuing. The SiO spectra are from the $v = 1$, $J = 1$–0 (43.122 GHz; hereafter J10) and the $v = 1$, $J = 2$–1 (86.2434 GHz; hereafter J21) transitions. For 41 of the 47 LPVs we observed both transitions nearly simultaneously in 457 observations. We have determined and compared the velocity centroids (VCs) and velocity ranges of emission (VRs) suffixed as above (10 and 21) for the two transitions – VC10, VC21, VR10, and VR21. The VCs of the two transitions are, on average, within 0.13 km s^{-1} of each other but are sometimes separated by a few km s^{-1}. The VC10s are, on average, slightly more positive than the VC21s. The values of the VCs in the two transitions have been compared to justify using both of these transitions to extract binary star orbital parameters. The arithmetic mean VR10 derived from 635 observations of 47 sources is 6.4 km s^{-1} with a standard deviation of 3.4 km s^{-1} while the

mean VR21 derived from 485 observations of 41 sources is 4.2 km s^{-1} with a standard deviation of 2.8 km s^{-1}. The number of occurrences of VR10 and VR21versus velocity range have different distributions. The differences in the VRs indicate that the J21 and J10 emissions arise from dynamically different regions of the circumstellar environment.

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A massive parsec-scale dust ring nebula around the yellow hypergiant Hen 3-1379

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On the basis of far-infrared images obtained by the *Herschel* Space Observatory, we report the discovery of a large and massive dust shell around the yellow hypergiant Hen 3-1379 . The nebula appears as a detached ring of 1 pc diameter which contains 0.17 $M_\odot$ of dust. We estimate the total gas mass to be 7 $M_\odot$, ejected some 16 000 years ago. The ring nebula is very similar to nebulæ found around luminous blue variables (LBVs) except it is not photo-ionized. We argued that Hen 3-1379 is in a pre-LBV stage, providing direct evidence that massive LBV ring nebulæ can be ejected during the red supergiant phase.

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Spatially resolved, high-spectral resolution observation of the K giant Aldebaran in the CO first overtone lines with VLTI/AMBER

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Aims: We present a high-spatial and high-spectral resolution observation of the well-studied K giant Aldebaran with AMBER at the Very Large Telescope Interferometer (VLTI). Our aim is to spatially resolve the outer atmosphere (so-called MOLsphere) in individual CO first overtone lines and derive its physical properties, which are important for understanding the mass-loss mechanism in normal (i.e., non-Mira) K–M giants.
Methods: Aldebaran was observed between 2.28 and 2.31 μm with a projected baseline length of 10.4 m and a spectral resolution of 12 000.
Results: The uniform-disk diameter observed in the CO first overtone lines is 20–35% larger than is measured in the continuum. We have also detected a signature of inhomogeneities in the CO-line-forming region on a spatial scale of $\sim$ 45 mas, which is more than twice as large as the angular diameter of the star itself. While the MARCS photospheric model reproduces the observed spectrum well, the angular size in the CO lines predicted by the MARCS model is significantly smaller than observed. This is because the MARCS model with the parameters of Aldebaran has a geometrical extension of only $\sim$ 2% (with respect to the stellar radius). The observed spectrum and interferometric data in the CO lines can be simultaneously reproduced by placing an additional CO layer above the MARCS photosphere. This CO layer is extended to 2.5 ± 0.3 $R_\star$ with CO column densities of 5×10^{19}–2×10^{20} cm^{-2} and a temperature of 1500 ± 200 K.
Conclusions: The high spectral resolution of AMBER has enabled us to spatially resolve the inhomogeneous, extended outer atmosphere (MOLsphere) in the individual CO lines for the first time in a K giant. Our modeling of the MOLsphere of Aldebaran suggests a rather small gradient in the temperature distribution above the photosphere up to 2–3 $R_\star$.

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Available from arXiv:1303.4763

Individual α elements, C, N, and Ba in early-type galaxies

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Spectral data on early-type galaxies is analyzed for chemical abundance with an emphasis on obtaining detailed abundances for the elements O and Si in addition to C, N, Na, Mg, Ca, Fe, and Ba. The abundance trends with velocity dispersion fit preconceptions based upon previous Mg conclusions, namely that larger galaxies have a higher α element to iron peak ratio indicative of a higher ratio of Type II to Type Ia supernova products. The heaviest α elements, Ca and Ti, do not participate in this trend, although this fact does not necessarily alter the basic picture given the uncertainties in nucleosynthetic yields. Elements that likely have significant contributions from intermediate-mass stars, namely C, N, and Ba, also gain ground relative to Fe in massive galaxies at a modest level, with the Ba conclusion uncertain from our data alone.

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Studies of variability in proto-planetary nebulæ: II. Light and velocity curve analyses of IRAS 22272+5435 and 22223+4327

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We have carried out a detailed observational study of the light, color, and velocity variations of two bright, carbon-rich proto-planetary nebulæ, IRAS 22223+4327 and 22272+5435. The light curves are based upon our observations from 1994 to 2011, together with published data by Arkhipova and collaborators. They each display four significant periods, with primary periods for IRAS 22223+4327 and 22272+5435 being 90 and 132 days, respectively. For each of them, the ratio of secondary to primary period is 0.95, a value much different from that found in Cepheids, but which may be characteristic of post-AGB stars. Fewer significant periods are found in the smaller radial velocity data sets, but they agree with those of the light curves. The color curves generally mimic the light curves, with the objects reddest when faintest. A comparison in seasons when there exist contemporaneous light, color, and velocity curves reveals that the light and color curves are in phase, while the radial velocity curves are $\sim 0.25P$ out of phase with the light curves. Thus they differ from what is seen in Cepheids, in which the radial velocity curve is $0.50P$ out of phase with the light curve. Comparison of the observed periods and amplitudes with those of post-AGB pulsation models shows poor agreement, especially for the periods, which are much longer than predicted. These observational data, particularly the contemporaneous light, color, and velocity curves, provide an excellent benchmark for new pulsation models of cool stars in the post-AGB, proto-planetary nebula phase.

Published in Astrophys. J., 766, 116 (2013)

A lithium-rich red giant below the clump in the *Kepler* cluster, NGC 6819

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WIYN/HYDRA spectra in the Li 6708 Å region have been obtained for 332 probable members of the old open cluster,

NGC 6819. Preliminary analysis shows a pattern of Li depletion from the top of the turn-off to the base of the giant branch. Starting one magnitude below the level of the clump, all brighter giants have $A(\mathrm{Li}) < 1.0$, with most having upper limits below 0.5. Star W007017, located *below* the first-ascent red giant bump is Li-rich with $A(\mathrm{Li}) = 2.3$. As a highly probable single-star astrometric and radial-velocity cluster member, its discrepant asteroseismic membership could be a by-product of the processes that triggered Li-enhancement. Its color–magnitude diagram location is consistent with only one proposed enhanced mixing process among first-ascent red giants.

Accepted for publication in Astrophysical Journal Letters
Available from arXiv:1303.2984

Conference Papers

Dust-forming molecules in VY Canis Majoris (and Betelgeuse)

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The formation of inorganic dust in circumstellar environments of evolved stars is poorly understood. Spectra of molecules thought to be most important for the nucleation, i.e. AlO, TiO, and TiO_2, have been recently detected in the red supergiant VY CMa. These molecules are effectively formed in VY CMa and the observations suggest that non-equilibrium chemistry must be involved in their formation and nucleation into dust. In addition to exploring the recent observations of VY CMa, we briefly discuss the possibility of detecting these molecules in the dust-poor circumstellar environment of Betelgeuse.

Oral contribution, published in proceedings of the Betelgeuse Workshop 2012: The physics of Red Supergiants: recent advances and open questions, 2012 Paris
Available from arXiv:1302.6922

Numerical models for the circumstellar medium around Betelgeuse

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The nearby red supergiant (RSG) Betelgeuse has a complex circumstellar medium out to at least 0.5 parsecs from its surface, shaped by its mass-loss history within the past 0.1 Myr, its environment, and its motion through the interstellar medium (ISM). In principle its mass-loss history can be constrained by comparing hydrodynamic models with observations. Observations and numerical simulations indicate that Betelgeuse has a very young bow shock, hence the star may have only recently become a RSG. To test this possibility we calculated a stellar evolution model for a single star with properties consistent with Betelgeuse. We incorporated the resulting evolving stellar wind into 2D hydrodynamic simulations to model a runaway blue supergiant (BSG) undergoing the transition to a RSG near the end of its life. The collapsing BSG wind bubble induces a bow shock-shaped inner shell which at least superficially

resembles Betelgeuse's bow shock, and has a similar mass. Surrounding this is the larger-scale retreating bow shock generated by the now defunct BSG wind's interaction with the ISM. We investigate whether this outer shell could explain the bar feature located (at least in projection) just in front of Betelgeuse's bow shock.

Oral contribution, published in proceedings of the Betelgeuse 2012 Workshop, Paris, Nov. 2012, eds. P. Kervella, T. Le Bertre & G. Perrin
Available from arXiv:1303.2064

3D smoothed particle hydrodynamics models of Betelgeuse's bow shock

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Betelgeuse, the bright red supergiant (RSG) in Orion, is a runaway star. Its supersonic motion through the interstellar medium has resulted in the formation of a bow shock, a cometary structure pointing in the direction of motion. We present the first 3D hydrodynamic simulations of the formation and evolution of Betelgeuse's bow shock. We show that the bow shock morphology depends substantially on the growth timescale for Rayleigh–Taylor versus Kelvin–Helmholtz instabilities. We discuss our models in light of the recent *Herschel*, GALEX and VLA observations. If the mass in the bow shock shell is low (∼few $\times 0.001$ $M_\odot$), as seems to be implied by the AKARI and *Herschel* observations, then Betelgeuse's bow shock is very young and is unlikely to have reached a steady state. The circular, smooth bow shock shell is consistent with this conclusion. We further discuss the implications of our results, in particular, the possibility that Betelgeuse may have only recently entered the RSG phase.

Oral contribution, published in proceedings of the Betelgeuse workshop, November 2012, Paris, European Astronomical Society Publications Series, eds. Pierre Kervella, Thibaut Le Bertre & Guy Perrin
Available from arXiv:1303.4200

The population of M-type supergiants in the starburst cluster Stephenson 2

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The open cluster Stephenson 2 contains the largest collection of red supergiants known in the Galaxy, and at present is the second most massive young cluster known in the MilkyWay. We have obtained multi-epoch, intermediate-resolution spectra around the Ca II triplet for more than 30 red supergiants in Stephenson 2 and its surroundings. We find a clear separation between a majority of RSGs having spectral types M0–M2 and the brightest members in the NIR, which have very late spectral types and show strong evidence for heavy mass loss. The distribution of spectral types is similar to that of RSGs in other clusters, such as NGC 7419, or associations, like Per OB1. The cluster data strongly support the idea that heavy mass loss and maser emission is preferentially associated with late-M spectral types, suggesting that they represent an evolutionary phase.

Oral contribution, published in proceedings of the Betelgeuse Workshop, November 2012, Paris, European Astronomical Society Publications Series, eds. Pierre Kervella, Thibaut Le Bertre & Guy Perrin
Available from arXiv:1303.1837

Review Papers

Betelgeuse and the red supergiants

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Betelgeuse is one of the most magnificent stars in the sky, and one of the nearest red supergiants. Astronomers gathered in Paris in the Autumn of 2012 to decide what we know about its structure, behaviour, and past and future evolution, and how to place this in the general context of the class of red supergiants. Here I reflect on the discussions and propose a synthesis of the presented evidence. I believe that, in those four days, we have achieved to solve a few riddles.

Published in proceedings of the Betelgeuse workshop, November 2012, Paris. European Astronomical Society Publications Series, editors: Pierre Kervella, Thibaut Le Bertre & Guy Perrin
Available from arXiv:1303.0321

Asteroseismology of solar-type and red-giant stars

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We are entering a golden era for stellar physics driven by satellite and telescope observations of unprecedented quality and scope. New insights on stellar evolution and stellar interiors physics are being made possible by asteroseismology, the study of stars by the observation of natural, resonant oscillations. Asteroseismology is proving to be particularly significant for the study of solar-type and red-giant stars. These stars show rich spectra of solar-like oscillations, which are excited and intrinsically damped by turbulence in the outermost layers of the convective envelopes. In this review we discuss the current state of the field, with a particular emphasis on recent advances provided by the Kepler and CoRoT space missions and the wider significance to astronomy of the results from asteroseismology, such as stellar populations studies and exoplanet studies.

Published in Annual Reviews of Astronomy and Astrophysics (2013)
Available from arXiv:1303.1957

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See also http://www.uu.se/jobb/phd-students/annonsvisning?tarContentId=239016

Announcement

Asymmetrical Planetary Nebulæ VI

We are happy to announce the 6th edition of "Asymmetrical Planetary Nebulæ". Most – if not all – planetary nebulæ exhibit a complex structure, far from the spherical shape. The reasons for this dramatic change in symmetry, that occurs in early stage of the development of the nebula, remain controversial. The same physics operates in a variety of stars, from young (winds from young stars and/or high mass stars) to old (novæ, symbiotic stars). The aim of the APN series of conferences has been to offer the opportunity to anyone involved in the study of asymmetric planetary nebulæ (and related objects) to discuss the latest results obtained in this field.

The conference scheduled for 4–8 November 2013, will be held in an all-inclusive hotel, close to Playa del Carmen (Riviera Maya, Quintana Roo, México), 50 km south Cancun International Airport.

Conference topics

- Asymmetry:
  - Planetary nebula phase
  - Pre-PN phase
  - On the AGB
- Shaping mechanisms:
  - Magnetic fields
  - Binarity of the central star
  - Jets and accretion disks
  - What else
- Related objects:
  - Novæ and cataclysmic variables
  - Symbiotic stars
  - Nebulæ around massive stars

Important Deadlines

Pre-registration: 1 August

Submission of abstract: 15 August

SOC results on talks/posters distribution: 25 August

Fees early payment: US$ 250 until 30 August, US$ 300 later

Hotel group price: through the conference code (to be announced later) until 20 September

On behalf of the Scientific Organizing Committee
Miriam Peña

Contact: http://www.astroscu.unam.mx/apn6/
apn6@astro.unam.mx

See also http://www.astroscu.unam.mx/apn6/