THE AGB NEWSLETTER

An electronic publication dedicated to Asymptotic Giant Branch stars and related phenomena

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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Figure 1: The Cat's Eye Planetary Nebula imaged by Mark Hanson at Stan Watson Observatory with a 24″ f6.7 teelescope. It includes 23 hours worth of [O III]. The best known part, the "eye" is just the small object in the middle, while the messy halo extends much further. Notice also the bowshock on the right. (Suggestion by Sakib Rasool.)

Editorial

Dear Colleagues,

It is a pleasure to present you the 276th issue of the AGB Newsletter.

Note that IAU Symposium 366 ("The Origin of Outflows in Evolved Stars") has been postponed until November next year, while in June 2021 there will be a 4-week programme of workshops on stellar astrophysics in the Gaia era, in Munich (Germany). See the announcements for both meetings at the end of the newsletter.

Unfortunately our proposal for a Focus Meeting at next year's IAU General Assembly was not successful. One of the reasons given was: "Some evaluators commented that Most of the topics in this proposal could have been made 10 or 20 years ago. It is not at the very forefront of most exciting topics for this point in time of the 21st century." The topics we proposed were:

- Internal structure, mixing processes, and evolution
- Nucleosynthesis and meteoritic evidence
- Atmospheric and circumstellar structure including dust formation
- Instabilities; feedback (mass loss)
- End products (white dwarfs, neutron stars, black holes; planetary nebulæ)
- Interaction with stellar and planetary companions
- Importance for interstellar chemistry and the role of laboratory astrophysics
- Diagnostics in nearby and distant galaxies
- How to make progress

The meeting aimed to be highly audience-driven, and its goal was to formulate the most pressing issues to resolve in the coming years with suggestions for how to achieve that. One of the other comments was that "This is more of a workshop than a FM" – exactly. So we are now considering hosting a non-IAU meeting in 2021, likely a combination of face-to-face (in situ) and remote participation.

The next issue is planned to be distributed around the 1st of August.

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

Food for Thought

This month's thought-provoking statement is:

Convection causes apparent luminosity variations but not bolometric luminosity variations.

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

Refereed Journal Papers

Discovery of a complex spiral-shell structure around the oxygen-rich AGB star GX Monocerotis

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The circumstellar envelopes of asymptotic giant branch (AGB) stars exhibit a wide range of morphologies and chemical compositions that can be exploited to unravel their mass-loss history as well as binary status. Here, we present ALMA Band 6 observations centred upon the oxygen-rich, high mass-loss rate AGB star GX Mon. The resulting CO (2–1) map reveals an intricate, complex circumstellar spiral-arc structure consistent with hydrodynamical models for an AGB experiencing mass loss in a highly eccentric, close binary system with an orbital period of around 140 years. Several other transitions (including SiO, SiS, SO_2, and CS) are detected in the data, however only the SO (5–4) map shows a similar – although much weaker – distribution as imaged for the CO.

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Available from https://ui.adsabs.harvard.edu/abs/2020A%26A...636A.123R/abstract

The K supergiant runaway star HD 137071

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Extensive work exists on runaway massive stars with peculiar motions that are much higher than those typical of the extreme Population I to which they belong. Work on runaways has focused almost exclusively on O and B stars, most of which undergo a red supergiant phase before ending their lives as supernovæ. Very few examples are known of red supergiant runaways, all of which descend from the more massive O-type precursors, but none from the lower mass B-type precursors, although runaway statistics of B-type stars suggest that K-type runaways must be relatively numerous. We study HD 137071, a star that has so far been considered to be a normal K-type red giant. Its parallax measured by Gaia and the derived luminosity suggest that it is a supergiant, whereas its derived distance to the Galactic plane and its spatial velocity of 54.1 km s^{-1} with respect to the local standard of rest suggest that it is also a runaway star. However, intrinsic limitations in determining the trigonometric parallaxes of cool supergiants, even in the Gaia era, require accurate spectral classifications for confirmation. We present visible spectroscopy obtained with the 2.2m telescope at Calar Alto Observatory and compare it with the spectra of MK standard stars to produce an accurate spectral classification, including the determination of its luminosity class. We complement this information with astrometric data from the Gaia DR2 catalog. We reliably classify HD 137071 as a K4 II star and establish its membership to the extreme Population I. This agrees with the luminosity derived using the Gaia DR2 parallax measurement. Kinematical data from the Gaia DR2 catalog confirm its high spatial velocity and runaway nature. By combining the spectral classification with astrometric information, recent Galactic potential models, and evolutionary models for high-mass stars, we trace the motion of HD 137071 back to the proximities of the Galactic plane and speculate which of the two proposed mechanisms for the production of runaway stars may be responsible for the high velocity of HD 137071. The available data favor the formation of HD 137071 in a massive binary system where the more massive companion underwent a supernova explosion about 32 Myr ago.

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Available from https://arxiv.org/abs/2004.12622

On the paradoxical impact of blending by red clump giants

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The impact of blending by RCGs (red clump giants, or relatively metal-rich red horizontal branch stars) is discussed as it relates to RRab and classical Cepheids, and invariably establishing an improved distance scale. An analysis of OGLE Magellanic Cloud variables reaffirms that blending with RCGs may advantageously thrust remote extragalactic stars into the range of detectability. Specifically, simulations of Magellanic Cloud RRab and RCG blends partly reproduce bright non-canonical trends readily observed in amplitude-magnitude space (I_c vs. A_{I_c}). Conversely, the larger magnitude offset between classical Cepheids and RCGs causes the latter's influence to be challenging to address. The relative invariance of a Wesenheit function's slope to metallicity (e.g., W_{VI_c}) implies that a deviation from the trend could reveal blending and photometric inaccuracies (e.g., standardization), as blending by RCGs (a proxy of an evolved red stellar demographic) can flatten period–Wesenheit relations owing to the increased impact on less-luminous shorter-period Cepheids. That could partly explain both a shallower inferred Wesenheit function and over-estimated H_0 values. A consensus framework to identify and exploit blending is desirable, as presently H_0 estimates from diverse teams are unwittingly leveraged without homogenizing the disparate approaches (e.g., no blending correction to a sizable $\simeq 0^{\rm m}_{\cdot}3$).

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ALMA and VLA reveal the lukewarm chromospheres of the nearby red supergiants Antares and Betelgeuse

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We first present spatially resolved ALMA and VLA continuum observations of the early-M red supergiant Antares to search for the presence of a chromsophere at radio wavelengths. We resolve the free-free emission of the Antares atmosphere at 11 unique wavelengths between 0.7 mm (ALMA band 8) and 10 cm (VLA S band). The projected angular diameter is found to continually increase with increasing wavelength, from a low of 50.7 mas at 0.7 mm up to a diameter of 431 mas at 10 cm, which corresponds to 1.35 and 11.6 times the photospheric angular diameter, respectively. All four ALMA measurements show that the shape of the atmosphere is elongated, with a flattening of 15% at a similar position angle. The disk-averaged gas temperature of the atmosphere initially rises from a value of 2700 K at 1.35 $R_\star$ (i.e. 0.35 $R_\star$ above the photosphere) to a peak value of 3800 K at $\sim 2.5\ R_\star$, after which it then more gradually decreases to 1650 K at 11.6 $R_\star$. The rise in gas temperature between 1.35 $R_\star$ and $\sim 2.5\ R_\star$ is evidence for a chromospheric temperature rise above the photosphere of a red supergiant. We detect a clear change in the spectral index across the sampled wavelength range, with the flux density $S_\nu \propto \nu^{1.42}$ between 0.7 mm and 1.4 cm, which we associate with chromosphere-dominated emission, while the flux density $S_\nu \propto \nu^{0.8}$ between 4.3 cm and 10 cm, which we associate with wind-dominated emission. We show that the Antares MOLsphere is transparent at our observed wavelengths, and the *lukewarm* chromosphere that we detect is therefore real and not just an average of the cool MOLsphere and hot ultraviolet emitting gas. We then perform nonlocal thermal equilibrium modeling of the far-ultraviolet radiation field of another early-M red supergiant, Betelgeuse, and find that an additional hot (i.e. > 7000 K) chromospheric photoionization component with a much smaller filling factor must also exist throughout the chromospheres of these stars.

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A survey for C II emission-line stars in the Large Magellanic Cloud

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We present a narrow-band imaging survey of the Large Magellanic Cloud, designed to isolate the C II $\lambda\lambda$7231,7236 emission lines in objects as faint as $m_{\lambda 7400} \sim 18$ mag. The work is motivated by the recent serendipitous discovery in the LMC of the first confirmed extragalactic [WC11] star, whose spectrum is dominated by C II emission, and the realization that the number of such objects is currently largely unconstrained. The survey, which imaged ~ 50 deg^2 using on-band and off-band filters, will significantly increase the total census of these rare stars. In addition, each new LMC [WC] star has a known luminosity, a quantity quite uncertain in the Galactic sample. Multiple known C II emitters were easily recovered, validating the survey design. We find 38 new C II emission candidates; spectroscopy of the complete sample will be needed to ascertain their nature. In a preliminary spectroscopic reconnaissance, we observed three candidates, finding C II emission in each. One is a new [WC11]. Another shows both the narrow C II emission lines characteristic of a [WC11], but also broad emission of C IV, O V, and He II characteristic of a much hotter [WC4] star; we speculate that this is a binary [WC]. The third object shows weak C II emission, but the spectrum is dominated by a dense thicket of strong absorption lines, including numerous O II transitions. We conclude it is likely an unusual hot, hydrogen-poor post-AGB star, possibly in transition from [WC] to white dwarf. Even lacking a complete spectroscopic program, we can infer that late [WC] stars do not dominate the central stars of LMC planetary nebulæ, and that the detected C II emitters are largely of an old population.

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On granulation and irregular variation of red supergiants

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The mechanism and characteristics of the irregular variations of red supergiants (RSGs) are studied based on the RSG samples in Small Magellanic Cloud (SMC), Large Magellanic Cloud (LMC) and M 31. With the time-series data from All-Sky Automated Survey for SuperNovæ (ASAS-SN) and Intermediate Palomar Transient Factory survey, we use the continuous time autoregressive moving average model to estimate the variability features of the light curves and their power spectral density. The characteristic evolution timescale and amplitude of granulations are further derived from fitting the posterior power spectral density with the COR function, which is a Harvey-like granulation model. The consistency of theoretical predictions and results is checked to verify the correctness of the assumption that granulations on RSGs contribute to irregular variation. The relations between granulation and stellar parameters are obtained and compared with the results of red giant branch stars and Betelgeuse. It is found that the relations are in agreement with predictions from basic physical process of granulation and fall close to the extrapolated relations of RGB stars. The granulations in most of the RSGs evolve at a timescale of several days to a year with the characteristic amplitude of 10–1000 mmag. The results imply that the irregular variations of RSGs can be attributed to the evolution of granulations. When comparing the results from SMC, LMC and M 31, the timescale and amplitude of granulation seem to increase with metallicity. The analytical relations of the granulation parameters with stellar parameters are

derived for the RSG sample of each galaxy.

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Galactic extinction laws: I. A global NIR analysis with 2MASS photometry

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We have started an ambitious program to determine if the full diversity of extinction laws is real or if some of it is due to calibration or methodological issues. Here we start by analyzing the information on NIR extinction in a 2MASS stellar sample with good quality photometry and very red colors. We calculate the extinction at 1 μm, A_1, and the power-law exponent, α ($A_\lambda = A_1\lambda^{-\alpha}$), for the 2MASS stars located in the extinction trajectory in the H–K vs. J–H plane expected for red giants with $A_1 > 5$ mag. We test the validity of the assumption about the nature of those stars, whether a single or multiple values of α are needed, and the spatial variations of the results. Most ($\sim$ 83%) of those stars can indeed be explained by high-extinction red giants and the rest is composed of extinguished AGB stars (mostly O-rich) and smaller numbers of other objects, a contaminant fraction that can be reduced with the help of Gaia DR2 data. Galactic red giants experience a NIR extinction with $\alpha \sim 2.27$ and an uncertainty of a few hundredths of a magnitude. There is no significant spread in α values even though our sample is widely distributed and has a broad range of extinctions. Differences with previous results are ascribed to the treatment of non-linear photometric effects and/or the contaminant correction. Future research should concentrate in finding the correct functional form for the NIR extinction law. In the appendix we detail the treatment of non-linear photometric effects in the 2MASS bands.

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Optical interferometry and Gaia measurement uncertainties reveal the physics of asymptotic giant branch stars

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Context: Asymptotic giant branch stars are cool luminous evolved stars that are well observable across the Galaxy and populating Gaia data. They have complex stellar surface dynamics.

Aims: On the AGB star CL Lac, it has been shown that the convection-related variability accounts for a substantial part of the Gaia DR2 parallax error. We observed this star with the MIRC-X beam combiner installed at the CHARA interferometer to detect the presence of stellar surface inhomogeneities.
Methods: We performed the reconstruction of aperture synthesis images from the interferometric observations at different wavelengths. Then, we used 3D radiative hydrodynamics simulations of stellar convection with CO5BOLD and the post-processing radiative transfer code OPTIM3D to compute intensity maps in the spectral channels of MIRC-X observations. Then, we determined the stellar radius and compared the 3D synthetic maps to the reconstructed ones focusing on matching the intensity contrast, the morphology of stellar surface structures, and the photocentre position at two different spectral channels, 1.52 and 1.70 μm, simultaneously.
Results: We measured the apparent diameter of CL Lac at two wavelengths and recovered the radius using a Gaia parallax. In addition to this, the reconstructed images are characterised by the presence of a brighter area that largely affects the position of the photocentre. The comparison with 3D simulation shows good agreement with the observations both in terms of contrast and surface structure morphology, meaning that our model is adequate for explaining the observed inhomogenities.
Conclusions: This work confirms the presence of convection-related surface structures on an AGB star of Gaia DR2. Our result will help us to take a step forward in exploiting Gaia measurement uncertainties to extract the fundamental properties of AGB stars using appropriate RHD simulations.

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Betelgeuse fainter in the sub-millimetre too: an analysis of JCMT and APEX monitoring during the recent optical minimum

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Betelgeuse, the nearest red supergiant star to us underwent an unusually deep minimum at optical wavelengths during its most recent pulsation cycle. We present submillimetre observations taken by the *James Clerk Maxwell* Telescope and Atacama Pathfinder Experiment over a time span of 13 years including the optical dimming. We find that Betelgeuse has also dimmed by $\sim 20\%$ at these longer wavelengths during this optical minimum. Using radiative-transfer models, we show that this is likely due to changes in the photosphere (luminosity) of the star as opposed to the surrounding dust as was previously suggested in the literature.

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Origin of large meteoritic SiC stardust grains in metal-rich AGB stars

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Stardust grains that originated in ancient stars and supernovæ are recovered from meteorites and carry the detailed composition of their astronomical sites of origin. We present evidence that the majority of large (μm-sized) meteoritic silicon carbide (SiC) grains formed in C-rich asymptotic giant branch (AGB) stars that were more metal-rich than the Sun. In the framework of the slow neutron-captures (the s process) that occurs in AGB stars the lower-than-solar ^{88}Sr/^{86}Sr isotopic ratios measured in the large SiC grains can only be accompanied by Ce/Y elemental ratios that are also lower than solar, and predominately observed in metal-rich barium stars – the binary companions of AGB stars. Such an origin suggests that these large grains represent the material from high-metallicity AGB stars needed to explain the s-process nucleosynthesis variations observed in bulk meteorites (Ek et al. 2020). In the outflows of metal-rich, C-rich AGB stars SiC grains are predicted to be small ($\simeq 0.2$ μm-sized); large ($\simeq$ μm-sized) SiC grains can grow if the number of dust seeds is two to three orders of magnitude lower than the standard value of 10^{-13} times the number of H atoms. We therefore predict that with increasing metallicity the number of dust seeds might decrease, resulting in the production of larger SiC grains.

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Effect of a strong magnetic field on gravity-mode period spacings in red giant stars

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When a star evolves into a red giant, the enhanced coupling between core-based gravity modes and envelope-based pressure modes forms mixed modes, allowing its deep interior to be probed by asteroseismology. The ability to obtain information about stellar interiors is important for constraining theories of stellar structure and evolution, for which the origin of various discrepancies between prediction and observation are still under debate. Ongoing speculation surrounds the possibility that some red giant stars may harbour strong (dynamically significant) magnetic fields in their cores, but interpretation of the observational data remains controversial. In part, this is tied to shortfalls in our understanding of the effects of strong fields on the seismic properties of gravity modes, which lies beyond the regime of standard perturbative methods. Here we seek to investigate the effect of a strong magnetic field on the asymptotic period spacings of gravity modes. We use a Hamiltonian ray approach to measure the volume of phase space occupied by mode-forming rays, this being roughly proportional to the average density of modes (number of modes per unit frequency interval). A strong field appears to systematically increase this by about 10%, which predicts a $\sim 10\%$ smaller period spacing. Evidence of near integrability in the ray dynamics hints that the gravity-mode spectrum may still exhibit pseudo-regularities under a strong field.

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Magnetic-buoyancy induced mixing in AGB stars: presolar SiC grains

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Isotope ratios can be measured in presolar SiC grains from ancient Asymptotic Giant Branch (AGB) stars at permil-level (0.1%) precision. Such precise grain data permit derivation of more stringent constraints and calibrations on mixing efficiency in AGB models than traditional spectroscopic observations. In this paper we compare SiC heavy-element isotope ratios to a new series of FRUITY models that include the effects of mixing triggered by magnetic fields. Based on 2D and 3D simulations available in the literature, we propose a new formulation, upon which the general features of mixing induced by magnetic fields can be derived. The efficiency of such a mixing, on the other hand, relies on physical quantities whose values are poorly constrained. We present here our calibration by comparing our model results with the heavy-element isotope data of presolar SiC grains from AGB stars. We demonstrate that the isotopic compositions of all measured elements (Ni, Sr, Zr, Mo, Ba) can be simultaneously fitted by adopting a single magnetic field configuration in our new FRUITY models.

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An in-depth reanalysis of the alleged type Ia supernova progenitor Henize 2-428

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Context: The nucleus of the planetary nebula Hen 2-428 is a short orbital-period (4.2 h), double-lined spectroscopic binary, whose status as a potential supernova type Ia progenitor has raised some controversy in the literature.
Aims: With the aim of resolving this debate, we carried out an in-depth reanalysis of the system.
Methods: Our approach combines a refined wavelength calibration, thorough line-identifications, improved radial-velocity measurements, non-LTE spectral modeling, as well as multi-band light-curve fitting. Our results are then

discussed in view of state-of-the-art stellar evolutionary models.
Results: Besides systematic zero-point shifts in the wavelength calibration of the OSIRIS spectra which were also used in the previous analysis of the system, we found that the spectra are contaminated with diffuse interstellar bands. Our Voigt-profile radial velocity fitting method, which considers the additional absorption of these diffuse interstellar bands, reveals significantly lower masses ($M_1 = 0.66 \pm 0.11$ M$_\odot$ and $M_2 = 0.42 \pm 0.07$ M$_\odot$) than previously reported and a mass ratio that is clearly below unity. Our spectral and light curve analyses lead to consistent results, however, we find higher effective temperatures and smaller radii than previously reported. Moreover, we find that the red-excess that was reported before to prove to be a mere artifact of an outdated reddening law that was applied.
Conclusions: Our work shows that blends of He II λ5412Å with diffuse interstellar bands have led to an overestimation of the previously reported dynamical masses of Hen 2-428. The merging event of Hen 2-428 will not be recognised as a supernova type Ia, but most likely leads to the formation of a H-deficient star. We suggest that the system was formed via a first stable mass transfer episode, followed by common envelope evolution, and it is now composed of a post-early asymptotic giant branch star and a reheated He-core white dwarf.

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The chemistry of cosmic dust analogues from C, C_2, and C_2H_2 in C-rich circumstellar envelopes

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Interstellar dust is mainly formed in the innermost regions of circumstellar envelopes of asymptotic giant branch (AGB) stars. In these highly chemically stratified regions, atomic and diatomic carbon, along with acetylene are the most abundant species after H_2 and CO. Thus, C, C_2 and C_2H_2 are expected to play an important role in the formation of carbonaceous dust grains. In particular, acetylene is responsible for the formation of linear polyacetylenic chains, mainly in the external layers of the envelope where photons from the Galaxy penetrate and can therefore produce the photodissociation of molecules formed near the star photosphere. In the dust formation zone, and under the potential presence of shocks, acetylene could lead the formation of benzene and polycyclic aromatic hydrocarbons (PAHs). However, till now, no experiments have simulated the chemistry in the dust formation region involving the most abundant carbon precursors, i.e. C, C_2,and C_2H_2.
Here, we study in ultra-high vacuum (UHV) the gas-phase chemistry of acetylene by analyzing the products of its reaction with atomic and diatomic carbon. We show that these reactions produce linear polyacetylenic chains, benzene and other PAHs. More importantly, we have found a non-negligible amount of pure and hydrogenated carbon clusters as well as aromatics with aliphatic substitutions, both being a direct consequence of the addition of atomic carbon. The incorporation of alkyl substituents into aromatics is rationalized by a Hydrogen Abstraction–Methyl Addition (HAMA) mechanism. All the species detected in gas phase are incorporated into the nanometric sized dust analogues, which consist of a complex mixture of sp, sp^2 and sp^3 hydrocarbons with amorphous morphology.

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Asteroseismic signatures of the helium-core flash

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All evolved stars with masses $M_\star \lesssim 2$ M$_\odot$ undergo a helium(He)-core flash at the end of their first stage as a giant star. Although theoretically predicted more than 50 years ago, this core-flash phase has yet to be observationally probed. We show here that gravity modes (g modes) stochastically excited by He-flash driven convection are able to reach the stellar surface, and induce periodic photometric variabilities in hot-subdwarf stars with amplitudes of the order of a few mmag. As such they can now be detected by space-based photometry with the Transiting Exoplanet Survey Satellite (TESS) in relatively bright stars (e.g. magnitudes $I_c \lesssim 13$). The range of predicted periods spans from a few thousand seconds to tens of thousand seconds, depending on the details of the excitation region. In addition, we find that stochastically excited pulsations reproduce the pulsations observed in a couple of He-rich hot subdwarf stars. These stars, and in particular the future TESS target Feige 46, are the most promising candidates to probe the He-core flash for the first time.

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Re-evaluation of the 22Ne$(\alpha,\gamma)^{26}$Mg and ^{22}Ne$(\alpha,n)^{25}$Mg reaction rates

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Background: The competing ^{22}Ne$(\alpha,\gamma)^{26}$Mg and ^{22}Ne$(\alpha,n)^{25}$Mg reactions control the production of neutrons for the weak *s*-process in massive and AGB stars. In both systems, the ratio between the corresponding reaction rates strongly impacts the total neutron budget and strongly influences the final nucleosynthesis.

Purpose: The ^{22}Ne(α,γ)^{26}Mg and ^{22}Ne(α,n)^{25}Mg reaction rates must be re-evaluated by using newly available information on ^{26}Mg given by various recent experimental studies. Evaluations of the reaction rates following the collection of new nuclear data presently show differences of up to a factor of 500 resulting in considerable uncertainty in the resulting nucleosynthesis.
Methods: The new nuclear data are evaluated and, where possible, correspondence between states observed in different experiments are made. With updated spin and parity assignments, the levels which can contribute to the reaction rates are identified. The reaction rates are computed using a Monte-Carlo method which has been used for previous evaluations of the reaction rates in order to focus solely on the changes due to modified nuclear data.
Results: The evaluated ^{22}Ne(α,γ)^{26}Mg reaction rate remains substantially similar to that of Longland et al. but, including recent results from Texas A&M, the ^{22}Ne(α,n)^{25}Mg reaction rate is lower at a range of astrophysically important temperatures. Stellar models computed with NEWTON and MESA predict decreased production of the weak branch s-process due to the decreased efficiency of ^{22}Ne as a neutron source. Using the new reaction rates in the MESA model results in ^{96}Zr/^{94}Zr and ^{135}Ba/^{136}Ba ratios in much better agreement with the measured ratios from presolar SiC grains.
Conclusion: The ^{22}Ne+α reaction rates ^{22}Ne(α,γ)^{26}Mg and ^{22}Ne($\alpha.n$)^{25}Mg have been recalculated based on more recent nuclear data. The ^{22}Ne(α,γ)^{26}Mg reaction rate remains substantially unchanged since the previous evaluation but the ^{22}Ne($\alpha.n$)^{25}Mg reaction rate is substantially decreased due to updated nuclear data. This results in significant changes to the nucleosynthesis in the weak branch of the s-process.

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The 100 pc white dwarf sample in the SDSS footprint

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We present follow-up spectroscopy of 711 white dwarfs within 100 pc, and present a detailed model atmosphere analysis of the 100 pc white dwarf sample in the SDSS footprint. Our spectroscopic follow-up is complete for 83% of the white dwarfs hotter than 6000 K, where the atmospheric composition can be constrained reliably. We identify 1508 DA white dwarfs with pure hydrogen atmospheres. The DA mass distribution has an extremely narrow peak at 0.59 $M_\odot$, and reveals a shoulder from relatively massive white dwarfs with $M = 0.7$–0.9 $M_\odot$. Comparing this distribution with binary population synthesis models, we find that the contribution from single stars that form through mergers cannot explain the over-abundance of massive white dwarfs. In addition, the mass distribution of cool DAs shows a near absence of $M > 1$ $M_\odot$ white dwarfs. The pile-up of 0.7–0.9 $M_\odot$ and the disappearance of $M > 1$ $M_\odot$ white dwarfs is consistent with the effects of core crystallization. Even though the evolutionary models predict the location of the pile-up correctly, the delay from the latent heat of crystallization by itself is insufficient to create a significant pile-up, and additional cooling delays from related effects like phase separation are necessary. We also discuss the population of infrared-faint (ultracool) white dwarfs, and demonstrate for the first time the existence of a well defined sequence in color and magnitude. Curiously, this sequence is connected to a region in the color–magnitude diagrams where the number of helium-dominated atmosphere white dwarfs is low. This suggests that the infrared-faint white dwarfs likely have mixed H/He atmospheres.

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Is Betelgeuse the outcome of a past merger?

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We explore the possibility that the star α Orionis (Betelgeuse) is the outcome of a merger that occurred in a low mass-ratio ($q = M_2/M_1 = 0.07$–0.25) binary system some time in the past hundreds of thousands of years. To that goal, we present a simple analytical model to approximate the perturbed internal structure of a post-merger object following the coalescence of a secondary in the mass range 1–4 $M_\odot$ into the envelope of a 15–17 $M_\odot$ primary. We then compute the long-term evolution of post-merger objects for a grid of initial conditions and make predictions about their surface properties for evolutionary stages that are consistent with the observed location of Betelgeuse in the Hertzsprung–Russell diagram. We find that if a merger occurred after the end of the primary's main-sequence phase, while it was expanding toward becoming a red supergiant star and typically with radius $\sim$ 200–300 $R_\odot$, then its envelope is spun up to values that remain in a range consistent with Betelgeuse observations for thousands of years of evolution. We argue that the best scenario that can explain both the fast rotation of Betelgeuse and its observed large space velocity is one where a binary was dynamically ejected by its parent cluster a few million years ago and then subsequently merged. An alternative scenario in which the progenitor of Betelgeuse was spun up by accretion in a binary and released by the supernova explosion of the companion requires a finely tuned set of conditions but cannot be ruled out.

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Astrophysical distance scale II. Application of the JAGB method: a nearby galaxy sample

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We apply the near-infrared J-region Asymptotic Giant Branch (JAGB) method, recently introduced by Madore & Freedman (2020), to measure the distances to 14 nearby galaxies out to 4 Mpc. We use the geometric detached eclipsing binary (DEB) distances to the LMC and SMC as independent zero-point calibrators. We find excellent agreement with previously published distances based on the Tip of the Red Giant Branch (TRGB): the JAGB distance determinations (including the LMC and SMC) agree in the mean to within Δ(JAGB–TRGB) $= +0.025 \pm 0.013$ mag, just over 1%, where the TRGB I-band zero point is $M_I = -4.05$ mag. With further development and testing, the JAGB method has the potential to provide an independent calibration of Type Ia supernovæ (SNe Ia), especially with JWST. The JAGB stars (with $M_J = -6.20$ mag) can be detected farther than the fainter TRGB stars, allowing greater numbers of calibrating galaxies for the determination of H_0. Along with the TRGB and Cepheids, JAGB stars are amenable to theoretical understanding and further refined empirical calibration. A preliminary test shows little dependence, if any, of the JAGB magnitude with metallicity of the parent galaxy. These early results suggest that the JAGB method has considerable promise for providing high-precision distances to galaxies in the local universe that are independent of distances derived from the Leavitt Law and/or the TRGB method; and it has numerous and demonstrable advantages over the possible use of Mira variables.

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Astrophysical distance scale. The AGB J-band method: I. Calibration and a first application

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A near-infrared, color-selected subset of carbon-rich asymptotic giant branch (C-AGB) are found to have tightly-constrained luminosities in the NIR J band. Based on JK photometry of some 3,300 C-AGB stars in the bar of the Large Magellanic Cloud (LMC) we find that these stars have a constant absolute magnitude of $\langle M_J \rangle = -6.22$ mag, adopting the Detached Eclipsing Binary (DEB) distance to the LMC of 18.477 ± 0.004 (stat) ± 0.026 (sys). Undertaking a second, independent calibration in the SMC, which also has a DEB geometric distance, we find $\angle M_J \rangle = -6.18 \pm 0.01$ (stat) ± 0.05 (sys) mag. For the LMC the scatter is ± 0.27 mag for single-epoch observations, (falling to ± 0.15 mag for multiple observations averaged over a window of more than one year). We provisionally adopt $\langle M_J \rangle = -6.20$ mag ± 0.01 (stat) ± 0.04 (sys) mag for the mean absolute magnitude of these stars. Applying this calibration to stars recently observed in the galaxy NGC 253, we determine a distance modulus of 27.66 ± 0.01 (stat) ± 0.04 mag (syst), corresponding to a distance of 3.40 ± 0.06 Mpc (stat). This is in excellent agreement with the average TRGB distance modulus of 27.68 ± 0.05 mag, assuming $M_I = -4.05$ mag for the TRGB zero point.

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The thermal equilibrium mass-loss model and its applications in binary evolution

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Binary evolution is indispensable in stellar evolution to understand the formation and evolution of most peculiar and energetic objects, such as binary compact objects, Type Ia supernovæ, X-ray binaries, cataclysmic variables, blue stragglers, hot subdwarfs, and central binaries in planetary nebulae. Mass transfer in binary stars can change the evolutionary path and fate of the components compared to what is expected from single stellar evolution. The critical mass ratio at which unstable mass transfer occurs is an unsolved fundamental problem in binary evolution. To resolve this issue, we construct the thermal equilibrium mass-loss model and derive critical mass ratios for both thermal-timescale mass transfer and unstable mass transfer, the latter of which occurs when the outer Lagrangian point, L_2, is overfilled. Using several 3.2 $M_\odot$ stellar models as examples, we study the stellar response to thermal equilibrium mass loss and present the thresholds for thermal-timescale mass transfer. We study the possible mass transfer channels of binary systems containing a 3.2 $M_\odot$ donor star, considering thermal-timescale mass transfer, unstable mass transfer through L_2, and dynamical-timescale mass transfer. We repeat this simulation for a grid of donor stars with different masses (from 0.1 to 100 $M_\odot$ with $Z = 0.02$) and at different evolutionary stages and present our results. The results show that unstable mass transfer due to the overfilling of the outer Lagrangian point may also play an essential role in the formation of common envelopes for late red giant branch and asymptotic giant branch donors.

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The Zwicky Transient Facility catalog of periodic variable stars

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The number of known periodic variables has grown rapidly in recent years. Thanks to its large field of view and faint limiting magnitude, the Zwicky Transient Facility (ZTF) offers a unique opportunity to detect variable stars in the northern sky. Here, we exploit ZTF Data Release 2 (DR2) to search for and classify variables down to $r \sim 20.6$ mag. We classify 781,602 periodic variables into 11 main types using an improved classification method. Comparison with previously published catalogs shows that 621,702 objects (79.5%) are newly discovered or newly classified, including ~ 700 Cepheids, ~ 5000 RR Lyræ stars, $\sim 15,000$ δ Scuti variables, $\sim 350,000$ eclipsing binaries, $\sim 100,000$ long-period variables, and about 150,000 rotational variables. The typical misclassification rate and period accuracy are on the order of 2% and 99%, respectively. 74% of our variables are located at Galactic latitudes, $|b| < 10°$. This large sample of Cepheids, RR Lyræ, δ Scuti stars, and contact (EW-type) eclipsing binaries is helpful to investigate the Galaxy's disk structure and evolution with an improved completeness, areal coverage, and age resolution. Specifically, the northern warp and the disk's edge at distances of 15–20 kpc are significantly better covered than previously. Among rotational variables, RS Canum Venaticorum and BY Draconis-type variables can be separated easily. Our knowledge of stellar chromospheric activity would benefit greatly from a statistical analysis of these types of variables.

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Helium enhancement in the metal-rich red giants of ω Centauri

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The helium-enriched (He-enriched) metal-rich red giants of ω Centauri, discovered by Hema and Pandey using the low-resolution spectra from the Vainu Bappu Telescope (VBT) and confirmed by the analyses of the high-resolution spectra obtained from the HRS-South African Large Telescope (SALT) for LEID 34225 and LEID 39048, are reanalysed here to determine their degree of He-enhancement/hydrogen-deficiency (H-deficiency). The observed MgH band combined with model atmospheres with differing He/H ratios are used for the analyses. The He/H ratios of these two giants are determined by enforcing the fact that the derived Mg abundances from the Mg I lines and from the subordinate lines of the MgH band must be same for the adopted model atmosphere. The estimated He/H ratios for LEID 34225 and LEID 39048 are 0.15 ± 0.04 and 0.20 ± 0.04, respectively, whereas the normal He/H ratio is 0.10. Following the same criteria for the analyses of the other two comparison stars (LEID 61067 and LEID 32169), a normal He/H ratio of 0.10 is obtained. The He/H ratio of 0.15–0.20 corresponds to a mass fraction of helium ($Z(\mathrm{He}) = Y$) of about 0.375–0.445. The range of helium enhancement and the derived metallicity of the program stars are in line with those determined for ω Cen blue main-sequence stars. Hence, our study provides the missing link for the evolutionary track of the metal-rich helium-enhanced population of ω Centuari. This research work is the very first spectroscopic determination of the amount of He-enhancement in the metal-rich red giants of ω Centauri using the Mg I and MgH lines.

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Gaia white dwarfs within 40 pc. I: spectroscopic observations of new candidates

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We present a spectroscopic survey of 230 white dwarf candidates within 40 pc of the Sun from the *William Herschel* Telescope and Gran Telescopio Canarias. All candidates were selected from Gaia Data Release 2 (DR2) and in almost all cases had no prior spectroscopic classifications. We find a total of 191 confirmed white dwarfs and 39 main-sequence star contaminants. The majority of stellar remnants in the sample are relatively cool (average $T_{\rm eff} = 6200$ K), showing either hydrogen Balmer lines or a featureless spectrum, corresponding to 89 DA and 76 DC white dwarfs, respectively. We also recover two DBA white dwarfs and 9 to 10 magnetic remnants. We find two carbon-bearing DQ stars and 14 new metal-rich white dwarfs. This includes the possible detection of the first ultra-cool white dwarf with metal lines. We describe three DZ stars for which we find at least four different metal species, including one which is strongly Fe- and Ni-rich, indicative of the accretion of a planetesimal with core-Earth composition. We find one extremely massive (1.31 ± 0.01 M$_\odot$) DA white dwarf showing weak Balmer lines, possibly indicating stellar magnetism. Another white dwarf shows strong Balmer line emission but no infrared excess, suggesting a low-mass sub-stellar companion. High spectroscopic completeness ($> 99\%$) has now been reached for Gaia DR2 sources within 40 pc sample, in the northern hemisphere (dec $> 0°$) and located on the white dwarf cooling track in the Hertzsprung–Russell diagram. A statistical study of the full northern sample is presented in a companion paper.

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Binary evolution along the red giant branch with BINSTAR: the barium star perspective

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Barium (Ba), CH and extrinsic or Tc-poor S-type stars are evolved low- and intermediate-mass stars that show enhancement of slow-neutron-capture-process elements on their surface, an indication of mass accretion from a former asymptotic giant branch (AGB) companion, which is now a white dwarf (WD). Ba and CH stars can be found in the main-sequence (MS), the sub-giant, and the giant phase, while extrinsic S-type stars populate the giant branches only. As these polluted stars evolve, they might be involved in a second phase of interaction with their now white dwarf companion. In this paper, we consider systems composed of a main-sequence Ba star and a WD companion when the former evolves along the Red Giant Branch (RGB). We want to determine if the orbital properties of the known population of Ba, CH, and S giants can be inferred from the evolution of their suspected dwarf progenitors. For this purpose, we use the BINSTAR binary evolution code and model MS+WD binary systems, considering different binary interaction mechanisms, such as a tidally-enhanced wind mass-loss and a reduced circularisation efficiency. To explore their impact on the second RGB ascent, we compare the modelled orbits with the observed period and eccentricity distributions of Ba and related giants. We show that, independently of the considered mechanism, there is a strong period cut off below which core-He burning stars should not be found in binary systems with a WD companion. This limit is shorter for more massive RGB stars and for more metal-poor systems. However, we still find a few low-mass short-period giant systems that are difficult to explain with our models as well as two systems with very high eccentricities.

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Review Paper

White-dwarf asteroseismology with the *Kepler* space telescope

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In the course of their evolution, white-dwarf stars go through at least one phase of variability in which the global pulsations they undergo allow astronomers to peer into their interiors, this way making possible to shed light on their deep inner structure and evolutionary stage by means of asteroseismology. The study of pulsating white dwarfs has witnessed substantial progress in the last decade, and this has been so largely thanks to the arrival of continuous observations of unprecedented quality from space, like those of the CoRoT, *Kepler*, and TESS missions. This, along with the advent of new detailed theoretical models and the development of improved asteroseismological techniques, has helped to unravel the internal chemical structure of many pulsating white dwarfs, and, at the same time, has opened new questions that challenge theoreticians. In particular, uninterrupted monitoring of white-dwarf stars for months has allowed discovering phenomena impossible to detect with ground-based observations, despite admirable previous efforts like the Whole Earth Telescope (WET). Here, we start by reviewing the essential properties of white-dwarf and pre-white dwarf stars and their pulsations, and then, we go through the different families of pulsating objects known to date. Finally, we review the most outstanding findings about pulsating white dwarfs and pre-white dwarfs made possible with the unprecedented-quality observations of the *Kepler* space telescope, although we envisage that future analyzes of space data from this mission that still await to be examined may reveal new secrets of these extremely interesting variable stars.

Published in "Asteroseismology in the *Kepler* Era", eds. Andrzej S. Baran, Anthony Eugene Lynas-Gray & Karen Kinemuchi, Frontiers in Astronomy and Space Sciences
Available from https://arxiv.org/abs/2006.04955

Announcements

Postponed to 2021 – IAU Symposium 366 "The Origin of Outflows in Evolved Stars"

Due to the COVID-19 pandemic, and after a detailed investigation of the situation and an extended discussion with the SOC/LOC and other partners involved, we have to take the difficult but inevitable decision to postpone the IAU Symposium 366: "The Origin of Outflows in Evolved Stars". A provisional new date is November 1–5 2021. More information will follow in the coming weeks and can be found on the conference website.

See also www.iaus366.be

Stellar astrophysics in the era of Gaia, spectroscopic, and asteroseismic surveys

We are pleased to announce the forthcoming program to be held at MIAPP (Munich Institute for Astro and Particle Physics) from 31 May to 25 June 2021.

The program will bring together experts on different aspects of stellar astrophysics: radiative transfer and spectroscopy, stellar structure and evolution, fundamental stellar parameters, asteroseismology, interferometry, multiplicity, hydrodynamics and stellar atmospheres, and, of course, modern observational facilities and surveys, such as Gaia, GALAH, 4MOST, SDSS, among others. The detailed science case and some information about MIAPP are appended below.

The registration form and further information can be found at https://intern.universe-cluster.de/form/view.php?id=28814

Please note that the registration deadline is August 31, 2020 and that MIAPP requires attendance for at least two weeks. MIAPP provides financial support to cover part of the local expenses for all external participants. Additional support for families and for graduate students is available, the details are can be found on the MIAPP webpage.

See also http://www.munich-iapp.de/stellar-astrophysics2021