THE AGB NEWSLETTER

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

Official publication of the IAU Working Group on Abundances in Red Giants

No. 251 — 5 June 2018

http://www.astro.keele.ac.uk/AGBnews

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Editorial

Dear Colleagues,

It is a pleasure to present you the 251st issue of the AGB Newsletter.

No fewer than 35 publications cover topics ranging from novæ – with this month's favourite object Z And – and other (post-AGB) binaries, clusters, variability, abundances, physical processes, et cetera... and of course planetary nebulæ!

Last month's Food for Thought item provoked two reactions. One reader agreed that models are never wrong, but doubted whether theoreticians are ever right. On the other hand, Roberto Nesci suggested that "Really I think that models are always wrong, meaning that they are simplified approximations of the real world. But our aim is to build models of the world, otherwise it would be impossible for us to interact, in any sense, with the world." – this inspired this month's food for Thought (see below).

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

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

Food for Thought

This month's thought-provoking statement is:

Observations need models just as much as models need observations

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

The temporal development of dust formation and destruction in Nova Sagittarii 2015 #2 (V5668 Sgr) : a panchromatic study

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We present 5–28 μm SOFIA FORECAST spectroscopy complemented by panchromatic X-ray through infrared observations of the CO nova V5668 Sgr documenting the formation and destruction of dust during ~ 500 days following outburst. Dust condensation commenced by 82 days after outburst at a temperature of ~ 1090 K. The condensation temperature indicates that the condensate was amorphous carbon. There was a gradual decrease of the grain size and dust mass during the recovery phase. Absolute parameter values given here are for an assumed distance of 1.2 kpc. We conclude that the maximum mass of dust produced was 1.2×10^{-7} M$_\odot$ if the dust was amorphous carbon. The average grain radius grew to a maximum of ~ 2.9 μm at a temperature of ~ 720 K around day 113 when the shell visual optical depth was $\tau_v \sim 5.4$. Maximum grain growth was followed by followed by a period of grain destruction. X-rays were detected with *Swift* from day 95 to beyond day 500. The *Swift* X-ray count rate due to the hot white dwarf peaked around day 220, when its spectrum was that of a $kT = 35$ eV blackbody. The temperature, together with the super-soft X-ray turn-on and turn-off times, suggests a WD mass of ~ 1.1 M$_\odot$. We show that the X-ray fluence was sufficient to destroy the dust. Our data show that the post-dust event X-ray brightening is not due to dust destruction, which certainly occurred, as the dust is optically thin to X-rays.

Accepted for publication in The Astrophysical Journal
Available from https://arxiv.org/abs/1804.00575

Galactic or extragalactic chemical tagging for NGC 3201? Discovery of an anomalous CN–CH relation

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(ABRIDGED) The origin of the globular cluster (GC) NGC 3201 is under debate. Its retrograde orbit points to an extragalactic origin, but no further chemical evidence supports this idea. Light-element chemical abundances are useful to tag GCs and can be used to shed light on this discussion. We aim to derive CN and CH band strengths for red giant stars in NGC 3201 and compare these with photometric indices and high-resolution spectroscopy and discuss in the context of GC chemical tagging. We found three groups in the CN–CH distribution. A main sequence (S1), a secondary less-populated sequence (S2), and a group of peculiar (pec) CN-weak and CH-weak stars, one of which was previously known. The three groups seem to have different C+N+O and/or *s*-process element abundances, to be confirmed by high-resolution spectroscopy. These are typical characteristics of anomalous GCs. The CN distribution of NGC 3201 is quadrimodal, which is more common in anomalous clusters. However, NGC 3201 does not belong to the trend of anomalous GCs in the mass–size relation. Three scenarios are postulated here: (i) if the sequence pec–S1–S2 has increasing C+N+O and *s*-process element abundances, NGC 3201 would be the first anomalous GC outside of the mass–size relation; (ii) if the abundances are almost constant, NGC 3201 would be the first non-anomalous GC with multiple CN–CH anti-correlation groups; or (iii) it would be the first anomalous GC without variations in C+N+O and *s*-process element abundances. In all cases, the definition of anomalous clusters and the scenario in which they have an extragalactic origin must be revised.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1803.05124
and from https://doi.org/10.1051/0004-6361/201731957

NGC 3105: a young open cluster with low metallicity

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NGC 3105 is a young open cluster hosting blue, yellow and red supergiants. This rare combination makes it an excellent laboratory to constrain evolutionary models of high-mass stars. It is poorly studied and fundamental parameters such as its age or distance are not well defined. We intend to characterize in an accurate way the cluster as well as its evolved stars, for which we derive for the first time atmospheric parameters and chemical abundances. We identify 126 B-type likely members within a radius of 2.7 ± 0.6 arcmin, which implies an initial mass, $M_{\rm cl} \approx 4100$ M$_\odot$. We find a distance of 7.2 ± 0.7 kpc for NGC 3105, placing it at $R_{\rm GC} = 10.0 \pm 1.2$ kpc. Isochrone fitting supports an age of 28 ± 6 Ma, implying masses around 9.5 M$_\odot$ for the supergiants. A high fraction of Be stars ($\approx 25\%$) is found at the top of the main sequence down to spectral type B3. From the spectral analysis we estimate for the cluster a $v_{\rm rad} = +46.9 \pm 0.9$ km s^{-1} and a low metallicity, [Fe/H] $= -0.29 \pm 0.22$. We also have determined, for the first time, chemical abundances for Li, O, Na, Mg, Si, Ca, Ti, Ni, Rb, Y, and Ba for the evolved stars. The chemical composition of the cluster is consistent with that of the Galactic thin disc. An overabundance of Ba is found, supporting the enhanced s-process. NGC 3105 has a low metallicity for its Galactocentric distance, comparable to typical LMC stars. It is a valuable spiral tracer in a very distant region of the Carina–Sagittarius spiral arm, a poorly known part of the Galaxy. As one of the few Galactic clusters containing blue, yellow and red supergiants, it is massive enough to serve as a testbed for theoretical evolutionary models close to the boundary between intermediate and high-mass stars.

Accepted for publication in Astronomy and Astrophysics
Available from https://arxiv.org/abs/1805.00507

Variability search in M 31 using Principal Component Analysis and the *Hubble* Source Catalog

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Principal Component Analysis (PCA) is being extensively used in Astronomy but not yet exhaustively exploited for variability search. The aim of this work is to investigate the effectiveness of using the PCA as a method to search for variable stars in large photometric data sets. We apply PCA to variability indices computed for light curves of 18152 stars in three fields in M 31 extracted from the *Hubble* Source Catalogue. The projection of the data into the principal components is used as a stellar variability detection and classification tool, capable of distinguishing between RR Lyræ stars, long period variables (LPVs) and non-variables. This projection recovered more than 90% of the known variables and revealed 38 previously unknown variable stars (about 30% more), all LPVs except for one object of uncertain variability type. We conclude that this methodology can indeed successfully identify candidate variable stars.

Published in MNRAS
Available from https://arxiv.org/abs/1803.09782
and from https://doi.org/10.1093/mnras/sty758

Red supergiant stars in the Large Magellanic Cloud. II. Infrared properties and mid-infrared variability

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The characteristics of infrared properties and mid-infrared (MIR) variability of red supergiant (RSG) stars in the Large Magellanic Cloud (LMC) are analyzed based on 12 bands of near-infrared (NIR) to MIR co-added data from 2MASS, *Spitzer* and WISE, and $\sim$ 6.6 years of MIR time-series data collected by the ALLWISE and NEOWISE-R projects. 773 RSGs candidates were compiled from the literature and verified by using the color–magnitude diagram (CMD), spectral energy distribution (SED) and MIR variability. About 15% of valid targets in the IRAC1–IRAC2/IRAC2–IRAC3 diagram may show polycyclic aromatic hydrocarbon (PAH) emission. We show that arbitrary dereddening Q parameters related to the IRAC4, S9W, WISE3, WISE4, and MIPS24 bands could be constructed based on a precise measurement of MIR interstellar extinction law. Several peculiar outliers in our sample are discussed, in which one outlier might be a RSG right before the explosion or an extreme asymptotic giant branch (AGB) star in the very late evolutionary stage based on the MIR spectrum and photometry. There are 744 identified RSGs in the final sample having both the WISE1- and WISE2-band time-series data. The results show that the MIR variability is increasing along with the increasing of brightness. There is a relatively tight correlation between the MIR variability, mass loss rate (MLR; in terms of $K_{\rm s}$–WISE3 color), and the warm dust or continuum (in terms of WISE4 magnitude/flux), where the MIR variability is evident for the targets with $K_{\rm s}$ − WISE3 > 1.0 mag and WISE4 < 6.5 mag, while the rest of the targets show much smaller MIR variability. The MIR variability is also correlated with the MLR for which targets with larger variability also show larger MLR with an approximate upper limit of $\log \dot{M} = -6.1$ M$_\odot$ yr^{-1}. Both the variability and the luminosity may be important for the MLR since the WISE4-band flux is increasing exponentially along with the degeneracy of luminosity and variability. The identified RSG sample has been compared with the theoretical evolutionary models and shown that the discrepancy between observation and evolutionary models can be mitigated by considering both variability and extinction.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1805.03290

The perturbed sublimation rim of the dust disk around the post-AGB binary IRAS 08544−4431

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Context: Post-Asymptotic Giant Branch (AGB) binaries are surrounded by stable dusty and gaseous disks similar to the ones around young stellar objects. Whereas significant effort is spent on modeling observations of disks around young stellar objects, the disks around post-AGB binaries receive significantly less attention, even though they pose significant constraints on theories of disk physics and binary evolution.
Aims: We want to examine the structure of and phenomena at play in circumbinary disks around post-AGB stars. We continue the analysis of our near-infrared interferometric image of the inner rim of the circumbinary disk around IRAS 08544−4431. We want to understand the physics governing this inner disk rim.
Methods: We use a radiative transfer model of a dusty disk to reproduce simultaneously the photometry as well as the near-infrared interferometric dataset on IRAS 08544−4431. The model assumes hydrostatic equilibrium and takes dust settling self-consistently into account.
Results: The best-fit radiative transfer model shows excellent agreement with the spectral energy distribution up to mm wavelengths as well as with the PIONIER visibility data. It requires a rounded inner rim structure, starting at a radius of 8.25 au. However, the model does not fully reproduce the detected over-resolved flux nor the azimuthal flux distribution of the inner rim. While the asymmetric inner disk rim structure is likely to be the consequence of disk-binary interactions, the origin of the additional over-resolved flux remains unclear.
Conclusions: As in young stellar objects, the disk inner rim of IRAS 08544−4431 is ruled by dust sublimation physics. Additional observations are needed to understand the origin of the extended flux and the azimuthal perturbation at the inner rim of the disk.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1805.04501

Gone with the wind: the impact of wind mass transfer on the orbital evolution of AGB binary systems

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In low-mass binary systems, mass transfer is likely to occur via a slow and dense stellar wind when one of the stars is in the asymptotic giant branch (AGB) phase. Observations show that many binaries that have undergone AGB mass transfer have orbital periods of 1–10 yr, at odds with the predictions of binary population synthesis models. In this paper we investigate the mass-accretion efficiency and angular-momentum loss via wind mass transfer in AGB binary systems and we use these quantities to predict the evolution of the orbit. To do so, we perform 3D hydrodynamical simulations of the stellar wind lost by an AGB star in the time-dependent gravitational potential of a binary system, using the AMUSE framework. We approximate the thermal evolution of the gas by imposing a simple effective cooling balance and we vary the orbital separation and the velocity of the stellar wind. We find that for wind velocities higher than the relative orbital velocity of the system the flow is described by the Bondi–Hoyle–Lyttleton approximation and the angular-momentum loss is modest, which leads to an expansion of the orbit. On the other hand, for low wind velocities an accretion disk is formed around the companion and the accretion efficiency as well as the angular-momentum loss are enhanced, implying that the orbit will shrink. We find that the transfer of angular momentum from the binary orbit to the outflowing gas occurs within a few orbital separations from the centre of mass of the binary. Our results suggest that the orbital evolution of AGB binaries can be predicted as a function of the ratio of the terminal wind velocity to the relative orbital velocity of the system, $v_\infty/v_{\rm orb}$. Our results can provide insight into the puzzling orbital periods of post-AGB binaries. The results also suggest that the number of stars entering into the common-envelope phase will increase, which can have significant implications for the expected formation rates of the end products of low-mass binary evolution, such as cataclysmic binaries, type Ia supernovæ, and double white-dwarf mergers.

Accepted for publication in Astronomy & Astrophysics

Available from https://arxiv.org/abs/1805.03208

The ExoMol atlas of molecular opacities

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The ExoMol project is dedicated to providing molecular line lists for exoplanet and other hot atmospheres. The ExoMol procedure uses a mixture of ab initio calculations and available laboratory data. The actual line lists are generated using variational nuclear motion calculations. These line lists form the input for opacity models for cool stars and brown dwarfs as well as for radiative transport models involving exoplanets. This paper is a collection of molecular opacities for 52 molecules (130 isotopologues) at two reference temperatures, 300 K and 2000 K, using line lists from the ExoMol database. So far, ExoMol line lists have been generated for about 30 key molecular species. Other line lists are taken from external sources or from our work predating the ExoMol project. An overview of the line lists generated by ExoMol thus far is presented and used to evaluate further molecular data needs. Other line lists are also considered. The requirement for completeness within a line list is emphasized and needs for further line lists discussed.

Published in Atoms

Available from https://arxiv.org/abs/1805.03711

and from http://www.mdpi.com/2218-2004/6/2/26

Disc instabilities and nova eruptions in symbiotic systems: RS Ophiuchi and Z Andromedæ

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Using the disc instability model we investigate the stability of accretion discs in long-period binary systems. We simulate outbursts due to the thermal-viscous instabilities for two symbiotic systems, RS Ophiuchi and Z Andromedæ. The outbursts properties deduced from our simulations suggest that although the recurrent nova events observed in RS Oph are due to a thermonuclear runaway at the white dwarf surface, these runaways are triggered by accretion disc instabilities. In quiescence, the disc builds up its mass and it is only during the disc-instability outburst that mass is accreted onto the white dwarf at rates comparable to or larger than the mass-transfer rate. If the mass transfer rate is in the range 10^{-8}–10^{-7} $M_\odot$ yr^{-1}, the accretion rate and the mass accreted are sufficient to lead to a thermonuclear runaway during one of a series of a few dwarf nova outbursts, barely visible in the optical, but easily detectable in X-rays. In the case of Z And, persistent irradiation of the disc by the very hot white-dwarf surface strongly modifies the dwarf-nova outbursts properties, making them significant only for very high mass transfer rates, of the order of 10^{-6} $M_\odot$ yr^{-1}, much higher than the expected secular mean in this system. It is thus likely that the so-called "recombination nova" (Sokoloski et al. 2006b) outburst observed in years 2000–2002 was triggered not by a dwarf-nova instability but by a mass-transfer enhancement from the giant companion, leading to an increase of nuclear burning at the accreting white-dwarf surface.

Submitted to MNRAS
Available from https://arxiv.org/abs/1804.07916

Precise radial velocities of giant stars. X. Bayesian stellar parameters and evolutionary stages for 372 giant stars from the Lick planet search

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The determination of accurate stellar parameters of giant stars is essential for our understanding of such stars in general and as exoplanet host stars in particular. Precise stellar masses are vital for determining the lower mass limit of potential substellar companions with the radial velocity method, but also for dynamical modeling of multiplanetary systems and the analysis of planetary evolution. Our goal is to determine stellar parameters, including mass, radius, age, surface gravity, effective temperature and luminosity, for the sample of giants observed by the Lick planet search. Furthermore, we want to derive the probability of these stars being on the horizontal branch (HB) or red giant branch (RGB), respectively. We compare spectroscopic, photometric and astrometric observables to grids of stellar evolutionary models using Bayesian inference. We provide tables of stellar parameters, probabilities for the current post-main sequence evolutionary stage, and probability density functions for 372 giants from the Lick planet search. We find that 81% of the stars in our sample are more probably on the HB. In particular, this is the case for 15 of the 16 planet host stars in the sample. We tested the reliability of our methodology by comparing our stellar parameters to literature values and find very good agreement. Furthermore, we created a small test sample of 26 giants with available asteroseismic masses and evolutionary stages and compared these to our estimates. The mean difference of the stellar masses for the 24 stars with the same evolutionary stages by both methods is only $\langle \Delta M \rangle = 0.01 \pm 0.20$ $M_\odot$. We do not find any evidence for large systematic differences between our results and estimates of stellar parameters based on other methods. In particular we find no significant systematic offset between stellar masses provided by asteroseismology to our Bayesian estimates based on evolutionary models.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1805.04094

OH^+ emission from cometary knots in planetary nebulæ

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We model the molecular emission from cometary knots in planetary nebulæ (PNe) using a combination of photoionization and photodissociation region (PDR) codes, for a range of central star properties and gas densities. Without the inclusion of ionizing extreme ultraviolet (EUV) radiation, our models require central star temperatures $T_\star$ to be near the upper limit of the range investigated in order to match observed H_2 and OH^+ surface brightnesses consistent with observations - with the addition of EUV flux, our models reproduce observed OH^+ surface brightnesses for $T_\star \geq 100$ kK. For $T_\star < 80$ kK, the predicted OH^+ surface brightness is much lower, consistent with the non-detection of this molecule in PNe with such central star temperatures. Our predicted level of H_2 emission is somewhat weaker than commonly observed in PNe, which may be resolved by the inclusion of shock heating or fluorescence due to UV photons. Some of our models also predict ArH^+ and HeH^+ rotational line emission above detection thresholds, despite neither molecule having been detected in PNe, although the inclusion of photodissociation by EUV photons, which is neglected by our models, would be expected to reduce their detectability.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1804.10528

Light element abundances and multiple populations in M 10

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We present CN and CH band measurements for 137 RGB and AGB stars in the Galactic globular cluster M 10. Our measurements come from low resolution spectroscopy taken with the Hydra spectrograph on the WIYN-3.5m telescope. We use these measurements to identify two populations of stars within the cluster, a CN-normal and CN-enhanced, and find that in our sample 60% of stars are CN-enhanced. Our large sample allows us to conduct a detailed analysis on the carbon and nitrogen abundances and the radial distribution of each population separately. Our analysis of the radial dependence shows that each population has the same radial distribution in the cluster, which is likely due to the cluster being dynamically evolved. We also compare our results to other methods of classifying multiple populations in globular clusters such as the Na–O anti-correlation and the HST pseudo-color magnitude diagrams. We find that these three methods of identifying multiple populations are in good agreement with each other for M 10 and all lead to an estimate of the fraction of second generation stars approximately equal to 60%. Among AGB stars, when classified by the CN band, there appears to be a lack of second generation stars when compared to the RGB stars. However, when classified by [N/Fe], we find a similar 60% of AGB stars in the second generation. Finally, we use the measured carbon and nitrogen abundances in RGB stars to study the change of each element with magnitude as stars evolve up the RGB, comparing the results to globular clusters of similar metallicity, M 3 and M 13.

Accepted for publication in The Astronomical Journal
Available from https://arxiv.org/abs/1805.01529

On the X-ray temperature of hot gas in diffuse nebulæ

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X-ray emitting diffuse nebulæ around hot stars are observed to have soft-band temperatures in the narrow range (1–3)$\times 10^6$ K, independent of the stellar wind parameters and the evolutionary stage of the central star. We discuss the origin of this X-ray temperature for planetary nebulæ (PNe), Wolf–Rayet nebulæ (WR) and interstellar wind bubbles around hot young stars in our Galaxy and the Magellanic Clouds. We calculate the differential emission measure (DEM) distributions as a function of temperature from previously published simulations and combine these with the X-ray emission coefficient for the 0.3–2.0 keV band to estimate the X-ray temperatures. We find that all simulated nebulæ have DEM distributions with steep negative slopes, which is due to turbulent mixing at the interface between the hot shocked stellar wind and the warm photoionized gas. Sharply peaked emission coefficients act as temperature filters and emphasize the contribution of gas with temperatures close to the peak position, which coincides with the observed X-ray temperatures for the chemical abundance sets we consider. Higher metallicity nebulæ have lower temperature and higher luminosity X-ray emission. We show that the second temperature component found from spectral fitting to X-ray observations of WR nebulæ is due to a significant contribution from the hot shocked stellar wind, while the lower temperature principal component is dominated by nebular gas. We suggest that turbulent mixing layers are the origin of the soft X-ray emission in the majority of diffuse nebulæ.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1804.10244
and from http://adsabs.harvard.edu/doi/10.1093/mnras/sty1127

Sparsely-observed pulsating red giants in the AAVSO observing program

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This paper reports on time-series analysis of 156 pulsating red giants (21 SRa, 552 SRb, 33 SR, 50 Lb) in the AAVSO observing program for which there are no more than 150–250 observations in total. Some results were obtained for 68 of these stars: 17 SRa, 14 SRb, 20 SR, and 17 Lb. These results generally include only an average period and amplitude. Many, if not most of the stars are undoubtedly more complex; pulsating red giants are known to have wandering periods, variable amplitudes, and often multiple periods including "long secondary periods" of unknown origin. These results (or lack thereof) raise the question of how the AAVSO should manage the observation of these and other sparsely-observed pulsating red giants.

Submitted to JAAVSO
Available from https://arxiv.org/abs/1804.08578

SiO Masers in the Galactic Bulge and Disk: kinematics from the BAaDE survey

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We present the first results from the BAaDE (Bulge Asymmetries and Dynamic Evolution) survey. Though only a subset of the complete survey (~ 2700 out of $\sim 20\,000$ final sources), our data comprise the largest radio kinematic survey to date of stellar SiO masers observed toward the Galactic bulge and plane from $-15^\circ < l < +12^\circ$ and $-6^\circ < b < +6^\circ$. Our sources include a substantial number of line-of-sight (LoS) velocities in high extinction regions within $\pm 1^\circ$ of the Galactic plane. When matched with 2MASS photometry, our radio-detected sample lies significantly brighter than and red-ward of the first red giant branch tip, reaching extremes of $(J - K_\mathrm{s})0 > 8$ mag, colors consistent with Mira variables and mass losing AGB stars. We see a clean division into two kinematic populations: a kinematically cold ($\sigma \sim 50$ km s^{-1}) population that we propose is in the foreground disk, consisting of giants with 2MASS $K_\mathrm{s} < 5.5$

mag, and a kinematically hot ($\sigma \sim 100$ km s^{-1}) candidate bulge/bar population for most giants with $K_s > 5.5$ mag. Only the kinematically hot giants with $K_s > 5.5$ mag include the reddest stars. Adopting 8.3 kpc to the Galactic Center, and correcting for foreground extinction, we find that most of the sources have $M_{\rm bol} \sim -5$ mag, consistent with their being luminous, and possibly intermediate age, AGB stars. We note some tension between the possibly intermediate age of the kinematically hot population, and its high velocity dispersion compared to the disk.

Accepted for publication in ApJ
Available from https://arxiv.org/abs/1805.04522

Deep secrets of intermediate-mass giants and supergiants: models with rotation seem to overestimate mixing effects on the surface abundances of C, N, and Na

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Recent observational results have demonstrated an increase in the surface Na abundance that correlates with stellar mass for red giants between 2 and 3 $M_\odot$. This trend supports evolutionary mixing processes as the explanation for Na overabundances seen in some red giants. In this same mass range, the surface Al abundance was shown to be constant. Our main aim was to extend the investigation of the Na and Al surface abundances to giants more massive than 3 $M_\odot$. We sought to establish accurately whether the Na abundances keep increasing with stellar mass or a plateau is reached. In addition, we investigated whether mixing can affect the surface abundance of Al in giants more massive than 3 $M_\odot$. We obtained new high-resolution spectra of 20 giants in the field of 10 open clusters; 17 of these stars were found to be members of 9 clusters. The giants have masses between 2.5 $M_\odot$ and 5.6 $M_\odot$. Abundances of C, N, and O were determined using spectrum synthesis. The abundances of Na and Al were corrected for non-local thermodynamic equilibrium effects (non-LTE). Moreover, to extend the mass range of our sample, we collected from the literature high-quality C, N, O, and Na abundances of 32 Galactic Cepheids with accurate masses in the range between 3 $M_\odot$ and 14 $M_\odot$. The surface abundances of C, N, O, Na, and Al were compared to predictions of stellar evolution models with and without the inclusion of rotation-induced mixing. The surface abundances of most giants and Cepheids of the sample can be explained by models without rotation. For giants above $\sim$ 2.5 $M_\odot$, the Na abundances reach a plateau level of about [Na/Fe] $\sim$ 0.20–0.25 dex (in non-LTE). Our results support previous works that found models with rotation to overestimate the mixing effects in intermediate-mass stars. [abridged]

Accepted for publication in A&A
Available from https://arxiv.org/abs/1805.03460

Super lithium-rich K giant with low ^{12}C to ^{13}C ratio

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The lithium abundances in a few percent of giants exceed the value predicted by the standard stellar evolution models, and the mechanisms of Li enhancement are still under debate. The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey has obtained over six million spectra in the past five years, and thus provides a great opportunity to search these rare objects and to more clearly understand the mechanisms of Li enhancement. Based on the high-resolution spectrum we obtained the stellar parameters ($T_{\rm eff}$, $\log g$, [Fe/H]), and determined the elemental abundances of Li, C, N, α, Fe-peak, r-process, s-process elements, and the projected rotational velocity. For a better understanding of the effect of mixing processes, we also derived the ^{12}C to ^{13}C ratio, and constrained the evolutionary status of TYC 3251-581-1 based on the BaSTI stellar isochrones. The super Li-rich giant TYC 3251-581-1 has A(Li) = 3.51, the average abundance of two lithium lines at λ = 6708 Å and 6104 Å based on the non-local thermodynamic equilibrium (NLTE) analysis. The atmospheric parameters show that our target locates on the luminosity function bump. The low carbon isotopic ratio (^{12}C/^{13}C = 9.0), a slow rotational velocity $v \sin i = 2.2$ km s^{-1}, and no sign of IR excess suggest that additional mixing after first dredge up (FDU) should occur to bring internal synthesized Li to the surface. The low carbon ([C/Fe] ~ -0.34) and enhanced nitrogen ([N/Fe] ~ 0.33) are also consistent with the sign of mixing. Given the evolutionary stage of TYC 3251-581-1 with the relatively low ^{12}C/^{13}C, the internal production which replenishes Li in the outer layer is the most likely origin of Li enhancement for this star.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1804.09333

The maser emitting structure and time variability of the SiS lines $J = 14$–13 and 15–14 in IRC +10°216

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We present new high angular resolution interferometer observations of the $v = 0$ $J = 14$–13 and 15–14 SiS lines towards IRC +10°216, carried out with CARMA and ALMA. The maps, with angular resolutions of $\sim 0\farcs25$ and $0\farcs55$, reveal (1) an extended, roughly uniform, and weak emission with a size of $\sim 0\farcs5$, (2) a component elongated approximately along the East–West direction peaking at $\sim 0\farcs13$ and $0\farcs17$ at both sides of the central star, and (3) two blue- and red-shifted compact components peaking around $0\farcs07$ to the NW of the star. We have modeled the emission with a 3D radiation transfer code finding that the observations cannot be explained only by thermal emission. Several maser clumps and one arc-shaped maser feature arranged from 5 to 20 $R_\star$ from the central star, in addition to a thin shell-like maser structure at ~ 13 $R_\star$ are required to explain the observations. This maser emitting set of structures accounts for 75% of the total emission while the other 25% is produced by thermally excited molecules. About 60% of the maser emission comes from the extended emission and the rest from the set of clumps and the arc. The analysis of a time monitoring of these and other SiS and ^{29}SiS lines carried out with the IRAM 30m telescope from 2015 to present suggests that the intensity of some spectral components of the maser emission strongly depends on the stellar pulsation while other components show a mild variability. This monitoring evidences a significant phase lag of ~ 0.2 between the maser and NIR light-curves.

Accepted for publication in ApJ
Available from https://arxiv.org/abs/1805.05218

Herschel Planetary Nebula Survey (HerPlaNS): hydrogen recombination laser lines in Mz 3

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The bipolar nebula Menzel 3 (Mz 3) was observed as part of the *Herschel* Planetary Nebula Survey (HerPlaNS), which used the PACS and SPIRE instruments aboard the *Herschel* Space Observatory to study a sample of planetary nebulæ (PNe). In this paper, one of the series describing HerPlaNS results, we report the detection of H I recombination lines (HRLs) in the spectrum of Mz 3. Inspection of the spectrum reveals the presence of 12 HRLs in the 55 to 680 μm range covered by the PACS and SPIRE instruments (H11α to H21α and H14β). The presence of HRLs in this range is unusual for PNe and has not been reported in Mz 3 before. Our analysis indicates that the HRLs we observed are enhanced by laser effect occurring in the core of Mz 3. Our arguments for this are: (i) the available Mz 3 optical to submillimetre HRL α line intensity ratios are not well reproduced by the spontaneous emission of optically thin ionized gas, as would be typical for nebular gas in PNe; (ii) the compact core of Mz 3 is responsible for a large fraction of the *Herschel* HRLs emission; (iii) the line intensity ratios for Mz 3 are very similar to those in the core emission of the well known star MWC 349A, where laser effect is responsible for the enhancement of HRLs in the *Herschel* wavelength range; (iv) the physical characteristics relevant to cause laser effect in the core of MWC 349A are very similar to those in the core of Mz 3.

ESA News link: http://www.esa.int/Our_Activities/Space_Science/Herschel/A_space_ant_fires_its_lasers

Published in MNRAS
Available from https://arxiv.org/abs/1805.06496
and from https://doi.org/10.1093/mnras/sty966

VLTI-GRAVITY measurements of cool evolved stars. I. Variable photosphere and extended atmosphere of the Mira star R Peg

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Dynamic model atmospheres of Mira stars predict variabilities in the photospheric radius and in atmospheric molecular layers which are not yet strongly constrained by observations. Here we measure the variability of the oxygen-rich Mira star R Peg in near-continuum and molecular bands. We used near-infrared K-band spectro-interferometry with a spectral resolution of about 4000 obtained at four epochs between post-maximum and minimum visual phases employing the newly available GRAVITY beam combiner at the Very Large Telescope Interferometer (VLTI). Our observations show a continuum radius that is anti-correlated with the visual lightcurve. Uniform disc (UD) angular diameters at a near-continuum wavelength of 2.25 μm are steadily increasing with values of 8.7 ± 0.1 mas, 9.4 ± 0.1 mas, 9.8 ± 0.1 mas, and 9.9 ± 0.1 mas at visual phases of 0.15, 0.36, 0,45, 0.53, respectively. UD diameters at a bandpass around 2.05 μm, dominated by water vapour, follow the near-continuum variability at larger UD diameters between 10.7 mas and 11.7 mas. UD diameters at the CO 2–0 bandhead, instead, are correlated with the visual lightcurve and anti-correlated with the near-continuum UD diameters, with values between 12.3 mas and 11.7 mas. The observed anti-correlation between continuum radius and visual lightcurve is consistent with an earlier study of the oxygen-rich Mira S Lac, and with recent 1D CODEX dynamic model atmosphere predictions. The amplitude of the variation is comparable to the earlier observations of S Lac, and smaller than predicted by CODEX models. The wavelength-dependent visibility variations at our epochs can be reproduced by a set of CODEX models at model phases between 0.3 and 0.6. The anti-correlation of water vapour and CO contributions at our epochs suggests that these molecules undergo different processes in the extended atmosphere along the stellar cycle. The newly available GRAVITY instrument is suited to conducting longer time series observations, which are needed to provide strong constraints on the model-predicted intra- and inter-cycle variability.

Accepted for publication in Astronomy and Astrophysics
Available from https://arxiv.org/abs/1805.05333
and from https://doi.org/10.1051/0004-6361/201833029

The importance of the ^{13}C(α,n)^{16}O reaction in Asymptotic Giant Branch stars

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Low mass Asymptotic Giant Branch stars are among the most important polluters of the interstellar medium. In their interiors, the main component ($A \gtrsim 90$) of the slow neutron capture process (the *s*-process) is synthesized, the most important neutron source being the ^{13}C(α,n)^{16}O reaction. In this paper we review its current experimental status, discussing possible future synergies between some experiments currently focused on the determination of its rate. Moreover, in order to determine the level of precision needed to fully characterize this reaction, we present a theoretical sensitivity study, carried out with the FUNS evolutionary stellar code and the NEWTON post-process code. We modify the rate up to a factor of two with respect to a reference case. We find that variations of the ^{13}C(α,n)^{16}O rate do not appreciably affect *s*-process distributions for masses above 3 $M_\odot$ at any metallicity. Apart from a few isotopes, in fact, the differences are always below 5%. The situation is completely different if some ^{13}C burns in a convective environment: this occurs in FUNS models with $M < 3$ $M_\odot$ at solar-like metallicities. In this case, a change of the ^{13}C(α,n)^{16}O reaction rate leads to non-negligible variations of the elements surface distribution (10% on average), with larger peaks for some elements (as rubidium) and for neutron-rich isotopes (as ^{86}Kr and ^{96}Zr). Larger variations are found in low-mass low-metallicity models, if protons are mixed and burnt at very high temperatures. In this case, the surface abundances of the heavier elements may vary by more than a factor 50.

Accepted for publication in The Astrophysical Journal
Available from https://arxiv.org/abs/1804.10751

The onset of low Prandtl number thermal convection in thin spherical shells

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This study considers the onset of stress-free Boussinesq thermal convection in rotating spherical shells with aspect ratio $\eta = r_i/r_o = 0.9$ (r_i and r_o being the inner and outer radius), Prandtl numbers $\mathrm{Pr} \in [10^{-4}, 10^{-1}]$, and Taylor numbers $\mathrm{Ta} \in [10^4, 10^{12}]$. We are particularly interested in the form of the convective cell pattern that develops, and in its time scales, since this may have observational consequences. For a fixed $\mathrm{Ta} < 10^9$ and by decreasing Pr from 0.1 to 10^{-4} a transition between spiralling columnar (SC) and equatorially-attached (EA) modes, and a transition between EA and equatorially antisymmetric or symmetric polar (AP/SP) weakly multicellular modes are found. The latter modes are preferred at very low Pr. Surprisingly, for $\mathrm{Ta} > 3 \times 10^9$ the unicellular polar modes become also preferred at moderate $\mathrm{Pr} \sim 10^{-2}$ because two new transition curves between EA and AP/SP and between AP/SP and SC modes are born at a triple-point bifurcation. The dependence on Pr and Ta of the transitions is studied to estimate the type of modes, and their critical parameters, preferred at different stellar regimes.

Published in Phys. rev. Fluids 3, 024801 (2018)
Available from https://arxiv.org/abs/1802.03071

The lowest metallicity type II supernova from the highest mass red-supergiant progenitor

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Red supergiants have been confirmed as the progenitor stars of the majority of hydrogen-rich type II supernovæ. However, while such stars are observed with masses > 25 M$_\odot$, detections of > 18 M$_\odot$ progenitors remain elusive. Red supergiants are also expected to form at all metallicities, but discoveries of explosions from low-metallicity progenitors are scarce. Here, we report observations of the type II supernova, SN 2015bs, for which we infer a progenitor metallicity of ≤ 0.1 Z$_\odot$ from comparison to photospheric-phase spectral models, and a Zero Age Main-Sequence mass of 17–25 M$_\odot$ through comparison to nebular-phase spectral models. SN 2015bs displays a normal 'plateau' light-curve morphology, and typical spectral properties, implying a red supergiant progenitor. This is the first example of such a high mass progenitor for a 'normal' type II supernova, suggesting a link between high mass red supergiant explosions and low-metallicity progenitors.

Published in Nature Astronomy
Available from https://arxiv.org/abs/1805.04434

Accretion in common envelope evolution

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Common envelope evolution (CEE) is presently a poorly understood, yet critical, process in binary stellar evolution. Characterizing the full 3D dynamics of CEE is difficult in part because simulating CEE is so computationally demanding. Numerical studies have yet to conclusively determine how the envelope ejects and a tight binary results, if only the binary potential energy is used to propel the envelope. Additional power sources might be necessary and accretion onto the inspiraling companion is one such source. Accretion is likely common in post-asymptotic giant branch (AGB) binary interactions but how it operates and how its consequences depend on binary separation remain open questions. Here we use high resolution global 3D hydrodynamic simulations of CEE with the adaptive mesh refinement (AMR) code AstroBEAR, to bracket the range of CEE companion accretion rates by comparing runs that remove mass and pressure via a subgrid accretion model with those that do not. The results show that if a pressure release valve is available, super-Eddington accretion may be common. Jets are a plausible release valve in these environments, and they could also help unbind and shape the envelopes.

Submitted to MNRAS
Available from https://arxiv.org/abs/1805.03607

SALT HRS discovery of the binary nucleus of the Etched Hourglass Nebula MyCn 18

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The shaping of various morphological features of planetary nebulæ (PNe) is increasingly linked to the role of binary

central stars. Identifying a binary within a PN offers a powerful tool with which to directly investigate the formation mechanisms behind these features. The Etched Hourglass Nebula, MyCn 18, is the archetype for several binary-linked morphological features, yet it has no identified binary nucleus. It has the fastest jets seen in a PN of 630 km s^{-1}, a central star position offset from the nebula centre, and a bipolar nebula with a very narrow waist. Here we report on the Southern African Large Telescope (SALT) High Resolution Spectrograph (HRS) detection of radial velocity variability in the nucleus of MyCn 18 with an orbital period of 18.15 ± 0.04 days and a semi-amplitude of 11.0 ± 0.3 km s^{-1}. Adopting an orbital inclination of 38 ± 5 deg and a primary mass of 0.6 ± 0.1 $M_\odot$ yields a secondary mass of 0.19 ± 0.05 $M_\odot$ corresponding to an M5 V companion. The detached nature of the binary rules out a classical nova (CN) as the origin of the jets or the offset central star as hypothesised in the literature. Furthermore, scenarios that produce the offset central star during the AGB and that form narrow waist bipolar nebulae result in orbital separations 80–800 times larger than observed in MyCn 18. The inner hourglass and jets may have formed from part of the common envelope ejecta that remained bound to the binary system in a circumbinary disk, whereas the offset central star position may best be explained by proper motion. Detailed simulations of MyCn 18 are encouraged that are compatible with the binary nucleus to further investigate its complex formation history.

Accepted for publication in PASA
Available from https://arxiv.org/abs/1805.07602

Do meteoritic silicon carbide grains originate from asymptotic giant branch stars of super-solar metallicity?

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We compare literature data for the isotopic ratios of Zr, Sr, and Ba from analysis of single meteoritic stardust silicon car- bide (SiC) grains to new predictions for the slow neutron-capture process (the *s* process) in metal-rich asymptotic giant branch (AGB) stars. The models have initial metallicities $Z = 0.014$ (solar) and $Z = 0.03$ (twice-solar) and initial masses 2–4.5 $M_\odot$, selected such as the condition C/O > 1 for the formation of SiC is achieved. Because of the higher Fe abundance, the twice-solar metallicity models result in a lower number of total free neutrons released by the $^{13}C(\alpha,n)^{16}O$ neutron source. Furthermore, the highest-mass (4–4.5 $M_\odot$) AGB stars of twice-solar metallicity present a milder activation of the $^{22}Ne(\alpha,n)^{25}Mg$ neutron source than their solar metallicity counterparts, due to cooler temperatures resulting from the effect of higher opacities. They also have a lower amount of the ^{13}C neutron source than the lower-mass models, following their smaller He-rich region. The combination of these different effects allows our AGB models of twice-solar metallicity to provide a match to the SiC data without the need to consider large variations in the features of the ^{13}C neutron source nor neutron-capture processes different from the *s* process. This raises the question if the AGB parent stars of meteoritic SiC grains were in fact on average of twice-solar metallicity. The heavier-than-solar Si and Ti isotopic ratios in the same grains are in qualitative agreement with an origin in stars of super-solar metallicity because of the chemical evolution of the Galaxy. Further, the SiC dust mass ejected from C-rich AGB stars is predicted to significantly increase with increasing the metallicity.

Published in Geochimica Cosmochimica Acta
Available from https://arxiv.org/abs/1804.09982
and from https://www.sciencedirect.com/science/article/pii/S001670371730354X?via%3Dihub

AGB candidates in the field of γ Cas

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We report the spectroscopic and photometric monitoring of a sample of 530 candidate AGB stars in a 5° field, selected from the IPHAS catalog: historic light curves were derived from Asiago IR plates taken in the years 1965–1984. We found 10 Miras, 5 stars with long term trends, 3 semiregular and 3 irregular. Spectral types from CCD slit spectra gave 8 M-type, 7 C-type and 6 S-type stars. In the color–color plots made from IPHAS and 2MASS catalogs, the S-type and M-type stars occupy the same regions, while C-type stars are well separated. All C-type stars with IR excess showed long term trends in their light curve. Distances of the Mira stars, estimated from their periods and K magnitudes, gave a median value of 4.9 kpc with a large spread. A comparison with astrometric parallaxes from Gaia DR2 is briefly discussed.

Accepted for publication in Revista Mexicana de Astronomía y Astrofísica
Available from https://arxiv.org/abs/1805.09191

Non-linear seismic scaling relations

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In recent years the global seismic scaling relations for the frequency of maximum power and for the large frequency separation have caught the attention of various fields of astrophysics. With the exquisite photometry of *Kepler*, the uncertainties in the seismic observables are small enough to estimate masses and radii with a precision of only a few per cent. Even though this seems to work quite well for main-sequence stars, there is empirical evidence, mainly from studies of eclipsing binary systems, that the seismic scaling relations overestimate the mass and radius of red giants by about 15 and 5%, respectively. Model-based corrections of the $\Delta\nu$-scaling reduce the problem but do not solve it. We re-examine the global oscillation parameters of the giants in the binary systems in order to determine their seismic fundamental parameters and find them to agree with the dynamic parameters from the literature if we adopt nonlinear scalings. We note that a curvature and glitch corrected $\Delta\nu_{\rm cor}$ should be preferred over a local or average values. We then compare the observed seismic parameters of the cluster giants to those scaled from independent measurements and find the same nonlinear behaviour as for the eclipsing binaries. Our final proposed scaling relations are based on both samples and cover a broad range of evolutionary stages from RGB to RC stars: $g/\sqrt{T_{\rm eff}} = (\nu_{\rm max}/\nu_{{\rm max},\odot})^{1.0075\pm0.0021}$ and $\sqrt{\bar\rho} = (\Delta\nu_{\rm cor}/\Delta\nu_{{\rm cor},\odot})[\eta - (0.0085 \pm 0.0025)\log^2(\Delta\nu_{\rm cor}/\Delta\nu_{{\rm cor},\odot})]^{-1}$, where g, $T_{\rm eff}$, and $\bar\rho$ are in solar units, $\nu_{{\rm max},\odot} = 3140 \pm 5$ μHz and $\Delta\nu_{{\rm cor},\odot} = 135.08 \pm 0.02$ μHz , and η is equal to one in case of RGB stars and 1.04 ± 0.01 for RC stars.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1805.06249

An empirical measurement of the initial–final mass relation with Gaia white dwarfs

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We use data from Gaia DR2 to constrain the initial–final mass relation (IFMR) for field stars with initial masses $0.9 \lesssim m_{\rm in}/{\rm M}_\odot \lesssim 8$. Precise parallaxes have revealed unprecedented substructure in the white dwarf (WD) cooling sequence on the color–magnitude diagram (CMD). Some of this substructure reflects the diversity of WD atmospheric compositions, but the CMD remains bimodal even when only spectroscopically-confirmed DA WDs are considered. We develop a generative model to predict the CMD for DA WDs as a function of the initial mass function (IMF), stellar age distribution, and a flexibly parameterized IFMR. We then fit the CMD of 1100 bright DA WDs within 100 pc, for which spectral types and completeness are well-understood. The resulting best-fit IFMR flattens at $3.5 \lesssim m_{\rm in}/{\rm M}_\odot \lesssim 5.5$, producing a secondary peak in the WD mass distribution at $m_{\rm WD} \sim 0.8$ ${\rm M}_\odot$. Such non-linearity in the IFMR is predicted by stellar evolution models and is broadly consistent with weaker constraints obtained from binaries and star clusters in previous work. A visibly bimodal CMD is only predicted for mixed-age stellar populations: in single-age clusters, more massive WDs reach the bottom of the cooling sequence before the first lower-mass WDs appear. This may explain why bimodal cooling sequences have thus far evaded detection in cluster CMDs.

Submitted to MNRAS
Available from https://arxiv.org/abs/1805.05849

Variability of red supergiants in M 31 from the Palomar Transient Factory

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Most massive stars end their lives as red supergiants (RSGs), a short-lived evolution phase when they are known to pulsate with varying amplitudes. The RSG period–luminosity (PL) relation has been measured in the Milky Way, the Magellanic Clouds and M 33 for about 120 stars in total. Using over 1500 epochs of R band monitoring from the Palomar Transient Factory (PTF) survey over a five-year period, we study the variability of 255 spectroscopically cataloged RSGs in M 31. We find that all RGSs brighter than $M_K \approx -10$ mag ($\log(L/{\rm L}_\odot) > 4.8$) are variable at $\Delta m_R > 0.05$ mag. Our period analysis finds 63 with significant pulsation periods. Using the periods found and the known values of M_K for these stars, we derive the RSG PL relation in M 31 and show that it is consistent with those derived earlier in other galaxies of different metallicities. We also detect, for the first time, a sequence of likely first-overtone pulsations. Comparison to stellar evolution models from MESA confirms the first overtone hypothesis and indicates that the variable stars in this sample have 12 ${\rm M}_\odot < M < 24$ ${\rm M}_\odot$. As these RSGs are the immediate progenitors to Type II-P core-collapse supernovæ (SNe), we also explore the implication of their variability in the initial-mass estimates for SN progenitors based on archival images of the progenitors. We find that this effect is small compared to the present measurement errors.

Published in The Astrophysical Journal
Available from https://arxiv.org/abs/1803.09934
and from http://iopscience.iop.org/article/10.3847/1538-4357/aabc59

The evolving radio photospheres of long-period variable stars

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Observations with the Karl G. Jansky Very Large Array at 46 GHz ($\lambda \approx 7$ mm) have been used to measure the size and shape of the radio photospheres of four long-period variable stars: R Leonis (R Leo), IRC +10°216 (CW Leo), χ Cygni (χ Cyg), and W Hydræ (W Hya). The shapes of the stars range from nearly round to ellipticities of ~ 0.15. Comparisons with observations taken several years earlier show that the photospheric parameters (mean diameter, shape, and/or flux density) of each of the stars have changed over time. Evidence for brightness asymmetries and non-uniformities across the radio surfaces are also seen in the visibility domain and in images obtained using a sparse modeling image reconstruction technique. These trends may be explained as manifestations of large-scale irregular convective flows on the stellar surface, although effects from non-radial pulsations cannot be excluded. Our data also allow a new evaluation of the proper motion of IRC +10°216. Our measurement is in agreement with previous values obtained from radio wavelength measurements, and we find no evidence of statistically significant astrometric perturbations from a binary companion.

Accepted for publication in AJ
Available from https://arxiv.org/abs/1805.05428

Mass loss rates of Li-rich AGB/RGB stars

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A sample of AGB/RGB stars with an excess of Li abundances is considered in order to estimate their mass loss rates. Ourmethod is based on a correlation between the Li abundances and the stellar luminosity, using a modified version of Reimers formula. We have adopted a calibration on the basis of an empirical correlation between the mass loss rate and some stellar parameters.We conclude that most Li-rich stars have lower mass loss rates compared with the majority of AGB/RGB stars, which show no evidence of Li enhancements, so the Li enrichment process is apparently not associated with an increased mass loss rate.

Accepted for publication in Astronomische Nachrichten
Available from https://arxiv.org/abs/1805.05164
and from http://www.astro.iag.usp.br/∼maciel/research/research.html

Radiating the hydrogen recombination energy during common envelope evolution

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By using the stellar evolution code MESA we show that most of the hydrogen recombination energy that is released as the envelope expands during a regular common envelope evolution (CEE), namely, the initial dynamical phase or plunge-in phase, is radiated, and hence increases substantially the stellar luminosity. We show that the key property of energy transport is that when convection becomes inefficient in the outer parts of the envelope, where the ionization degree of hydrogen falls below about 30 per cent, photon diffusion becomes very efficient and removes the recombination energy. The expanding envelope absorbs most of the gravitational energy that is released by the spiraling-in process of the secondary star inside the common envelope, and so it is the hydrogen recombination energy that is behind most of

the luminosity increase of the system. The recombination energy of hydrogen adds only a small fraction of the energy required to remove the common envelope, and hence does not play a significant role in the ejection of the envelope.

Submitted to ApJ Letters
Available from https://arxiv.org/abs/1805.08543

Repeated transient jets from a warped disk in the symbiotic prototype Z And: a Link to the long-lasting active phase

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Active phases of some symbiotic binaries survive for a long time from years to decades. The accretion process onto a white dwarf (WD) sustaining long-lasting activity, and sometimes leading to collimated ejection, is not well understood. We present the repeated emergence of highly collimated outflows (jets) from the symbiotic prototype Z And during its 2008 and 2009–10 outbursts and suggest their link to the current long-lasting (from 2000) active phase. We monitored Z And with the high-resolution spectroscopy, multicolor $UBVR_{\rm C}$ and high-time-resolution photometry. The well-pronounced bipolar jets were ejected again during the 2009–10 outburst together with the simultaneous emergence of the rapid photometric variability ($\Delta m \approx 0.06$ mag) on the timescale of hours, showing similar properties as those during the 2006 outburst. These phenomena and the measured disk-jets connection could be caused by the radiation-induced warping of the inner disk due to a significant increase of the burning WD luminosity. Ejection of transient jets by Z And around outburst maxima signals a transient accretion at rates above the upper limit of the stable hydrogen burning on the WD surface. The enhanced accretion through the disk warping, supplemented by the accretion from the giant's wind, can keep a high luminosity of the WD for a long time, until depletion of the disk. In this way, the jets provide a link to long-lasting active phases of Z And.

Published in The Astrophysical Journal, 858, 120 (2018)
Available from https://arxiv.org/abs/1805.10908

Conference Paper

Clusters rich in red supergiants

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In the past few years, several clusters containing large numbers of red supergiants have been discovered. These clusters are amongst the most massive young clusters known in the Milky Way, with stellar masses reaching a few 10^4 $M_\odot$. They have provided us, for the first time, with large homogeneous samples of red supergiants of a given age. These large populations make them, despite heavy extinction along their sightlines, powerful laboratories to understand the evolutionary status of red supergiants. While some of the clusters, such as the eponymous RSG C1, are so obscured that their members are only observable in the near-IR, some of them are easily accessible, allowing for an excellent characterisation of cluster and stellar properties. The information gleaned so far from these clusters gives strong support to the idea that late-M type supergiants represent a separate class, characterised by very heavy mass loss. It also shows that the spectral-type distribution of red supergiants in the Milky Way is very strongly peaked towards M1, while suggesting a correlation between spectral type and evolutionary stage.

Oral contribution, published in IAU XXIX General Assembly (Honolulu, 2015), Focus Meeting 16 "Stellar Behemoths – Red Supergiants across the local Universe", conveyed by Ben Davies
Available from https://arxiv.org/abs/1803.06018