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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 256$^{\rm th}$ issue of the AGB Newsletter.

Congratulations to José Jairo Díaz-Luis on his Ph.D. thesis! We wish him luck in his career as a postdoc.

Finally, the IAU Working Group "Abundances in Red Giants" has been allowed to change its name to IAU Working Group "Red Giants and Supergiants". We have some exciting plans in mind, and are looking to refresh our Organizing Committee.

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

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

Food for Thought

This month's thought-provoking statement is:

Who should join the Organizing Committee of the IAU Working Group on Red Giants and Supergiants, and why?

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

Understanding the orbital periods of CEMP-s stars

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The chemical enrichments detected in carbon- and s-element-enhanced metal-poor (CEMP-s) stars are believed to be the consequence of a past episode of mass transfer from a now extinct asymptotic-giant-branch primary star. This hypothesis is borne out by the evidence that most CEMP-s stars exhibit radial-velocity variations suggesting that they belong to binary systems in which the companion is not directly visible. We use the orbital-period distribution of an unbiased sample of observed CEMP-s stars to investigate the constraints it imposes on our models of binary evolution and on the properties of the metal-poor binary population in the Galactic halo. We generate synthetic populations of metal-poor binary stars using different assumptions about the initial period distribution and about the physics of the mass-transfer process, and we compare the predicted period distributions of our synthetic CEMP-s stars with the observed one. With a set of default assumptions often made in binary population-synthesis studies, the observed period distribution cannot be reproduced. The percentage of observed CEMP-s systems with periods shorter than about 2,000 days is underestimated by almost a factor of three, and by about a factor of two between 3,000 and 10,000 days. Conversely, about 40% of the simulated systems have periods longer than 10,000 days, which is approximately the longest measured period among CEMP-s stars. Variations in the assumed stability criterion for Roche-lobe overflow and the efficiency of wind mass transfer do not alter the period distribution enough to overcome this discrepancy. To reconcile the results of the models with the orbital properties of observed CEMP-s stars, one or both of the following conditions are necessary: (i) the specific angular momentum carried away by the material that escapes the binary system is approximately two to five times higher than currently predicted by analytical models and hydrodynamical simulations of wind mass transfer, and (ii) the initial period distribution of very metal-poor binary stars is significantly different from that observed in the solar vicinity and weighted towards periods shorter than about ten thousand days. Our simulations show that some, perhaps all, of the observed CEMP-s stars with apparently constant radial velocity could be undetected binaries with periods longer than 10,000 days, but the same simulations also predict that twenty to thirty percent of detectable binaries should have periods above this threshold, much more than are currently observed.

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HST STIS UV spectroscopic observations of the protoplanetary nebula Hen 3-1475

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We present UV spectra of the protoplanetary nebula (pPN) Hen 3-1475 obtained with the Space Telescope Imaging Spectrograph (STIS) on board the *Hubble* Space Telescope (HST). Our deep, low-dispersion spectroscopy enables monochromatic imaging of Hen 3-1475 in UV nebular emission lines, the first of such attempt ever made for a pPN. The high spatial resolution of STIS imaging allows an unprecedentedly sharp view of the S-shaped jet, especially the

inner NW1 knot, which is resolved into four components in the Mg II 2800Å line emission. Through critical comparison with HST optical narrowband images, we found a negative radial velocity gradient in NW1, from -1550 km s^{-1} on its innermost component to about -300 km s^{-1} on the outermost. Despite their high radial velocities, these components of NW1 mostly show no obvious (or very small) proper motions, indicating that they might be quasi-stationary shocks near the tip of the conical flow along the collimated jet of Hen 3-1475.

Accepted for publication in The Astrophysical Journal Letters

Hot bubbles of planetary nebulæ with hydrogen-deficient winds. II. Analytical approximations with application to BD +30° 3639

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The first high-resolution X-ray spectroscopy of a planetary nebula, BD +30° 3639, opened the possibility to study plasma conditions and chemical compositions of X-ray emitting "hot" bubbles of planetary nebulæ in much greater detail than before.
We investigate (i) how diagnostic line ratios are influenced by the bubble's thermal structure and chemical profile, (ii) whether the chemical composition inside the bubble of BD +30° 3639 is consistent with the hydrogen-poor composition of the stellar photosphere/wind, and (iii) whether hydrogen-rich nebular matter has already been added to the bubble of BD +30° 3639 by evaporation.
We applied an analytical 1D model for wind-blown bubbles with temperature and density profiles based on self-similar solutions including thermal conduction. We also constructed heat-conduction bubbles with a chemical stratification. The X-ray emission is computed using the well-documented CHIANTI code. These bubble models are used to re-analyse the high-resolution X-ray spectrum from the hot bubble of BD +30° 3639.
We found that our 1D heat-conducting bubble models reproduce the observed line ratios much better than plasmas with single electron temperatures. In particular, all the temperature- and abundance-sensitive line ratios are consistent with BD +30° 3639. X-ray observations for (i) an intervening column density of neutral hydrogen, $N_{\rm H} = 0.20^{+0.05}_{-0.10} \times 10^{22}$ cm^{-2}, (ii) a characteristic bubble X-ray temperature of $T_{\rm X} = 1.8 \pm 0.1$ MK together with (iii) a very high neon mass fraction of about 0.05, virtually as high as that of oxygen. For lower values of $N_{\rm H}$ we cannot exclude that the hot bubble of BD +30° 3639 contains a small amount of "evaporated" (or mixed) hydrogen-rich nebular matter. Given the possible range of $N_{\rm H}$, the fraction of evaporated hydrogen-rich matter cannot exceed 3% of the bubble mass.
The diffuse X-ray emission from BD +30° 3639 can well be explained by models of wind-blown bubbles with thermal conduction and a chemical composition equal to that of the hydrogen-poor and carbon-, oxygen-, and neon-rich stellar surface.

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Atmospheres and wind properties of non-spherical AGB stars

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The wind-driving mechanism of asymptotic giant branch (AGB) stars is commonly attributed to a two-step process: first, gas in the stellar atmosphere is levitated by shockwaves caused by stellar pulsation, then accelerated outwards by radiative pressure on newly formed dust, inducing a wind. Dynamical modelling of such winds usually assumes a spherically symmetric star. We explore the potential consequences of complex stellar surface structures, as predicted by three-dimensional (3D) star-in-a-box modelling of M-type AGB stars, on the resulting wind properties with the aim to improve the current wind models. Two different modelling approaches are used; the CO^{5}BOLD 3D star-in-a-box code to simulate the convective, pulsating interior and lower atmosphere of the star, and the DARWIN one-dimensional (1D) code to describe the dynamical atmosphere where the wind is accelerated. The gas dynamics of the inner atmosphere region at distances of $R \sim 1$–$2\ R_\star$, which both modelling approaches simulate, are compared. Dynamical properties and luminosity variations derived from CO^{5}BOLD interior models are used as input for the inner boundary in DARWIN wind models in order to emulate the effects of giant convection cells and pulsation, and explore their influence on the dynamical properties. The CO^{5}BOLD models are inherently anisotropic, with non-uniform shock fronts and varying luminosity amplitudes, in contrast to the spherically symmetrical DARWIN wind models. DARWIN wind models with CO^{5}BOLD-derived inner boundary conditions produced wind velocities and mass-loss rates comparable to the standard DARWIN models, however the winds show large density variations on time-scales of 10–20 years. The method outlined in this paper derives pulsation properties from the 3D star-in-a-box CO^{5}BOLD models, to be used in the DARWIN models. If the current grid of CO^{5}BOLD models is extended, it will be possible to construct extensive DARWIN grids with inner boundary conditions derived from 3D interior modelling of convection and pulsation, and avoid the free parameters of the current approach.

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Binary red supergiants: a new method for detecting B-type companions

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With the exception of a few well-known and studied systems, the binary population of red supergiants (RSGs) remains relatively uncharacterized. Famous systems such as VV Cep, 31 Cyg and ζ Aur contain RSG + B star binaries and here we explore whether B stars are the main type of companion we expect from an evolutionary point of view. Using the Geneva evolutionary models we find that this is indeed the case. However, few such systems are known, and we use model spectra to determine how easy such binaries would be to detect observationally. We find that it should be quite difficult to hide a B-type companion given a reasonable signal-to-noise in the optical / blue portion of the spectrum. We next examine spectra of Magellanic Cloud RSGs and newly acquired spectra of Galactic RSGs looking for new systems and refining our conclusions about what types of stars could be hidden in the spectra. Finally, we develop a set of photometric criteria that can help select likely binaries in the future without the overhead of large periodic or spectroscopic surveys.

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The kinematics of the outer halo of M 87 as mapped by planetary nebulæ

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We present a kinematic study of a sample of 298 planetary nebulæ (PNs) in the outer halo of the central Virgo galaxy M 87 (NGC 4486). The line-of-sight velocities of these PNe are used to identify sub-components, to measure the angular momentum content of the smooth M 87 halo, and to constrain the orbital distribution of the stars at these large radii. We find that the surface density profile of the ICPNS at 100 kpc radii has a shallow logarithmic slope, $-\alpha_{\rm ICL} \simeq -0.8$,

dominating the light at the largest radii. The angular momentum-related λ_R profile for the smooth halo remains in the slow rotator regime, out to 135 kpc average ellipse radius. The velocity dispersion profile is measured to decrease sharply to $\sigma_{\rm halo} \sim 100$ km s^{-1} at $R_{\rm avg} = 135$ kpc. Such a steeply decline of the velocity dispersion and the surface density profile of the smooth halo can be reconciled with the circular velocity curve inferred from assuming hydrostatic equilibrium for the hot X-ray gas if the orbit distribution of the smooth M 87 halo changes strongly from approximately isotropic within $R_{\rm avg} \sim 60$ kpc to very radially anisotropic at the largest distances probed. The extended LOSVD of the PNe in the M 87 halo allows the identification of several subcomponents: the ICPNs, the "crown" accretion event, and the smooth M 87 halo. In galaxies like M 87, the presence of these sub-components needs to be taken into account to avoid systematic biases in estimating the total enclosed mass. The dynamical structure inferred from the velocity dispersion profile indicates that the smooth halo of M 87 steepens beyond $R_{\rm avg} = 60$ kpc and becomes strongly radially anisotropic, and that the velocity dispersion profile is consistent with the X-ray circular velocity curve at these radii without non-thermal pressure effects.

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FliPer: a global measure of power density to estimate surface gravities of main-sequence Solar-like stars and red giants

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Asteroseismology provides global stellar parameters such as masses, radii or surface gravities using the mean global seismic parameters as well as the effective temperature for thousands of low-mass stars (0.8 $M_\odot < M < 3$ $M_\odot$). This methodology has been successfully applied to stars in which acoustic modes excited by turbulent convection are measured. Other techniques such as the Flicker can also be used to determine stellar surface gravities, but only works for $\log g$ above 2.5 dex. In this work, we present a new metric called FliPer (the acronym stands for Flicker in spectral power density, in opposition to the standard Flicker measurement which is computed in the time domain) that is able to extend the range for which reliable surface gravities can be obtained ($0.1 < \log g < 4.6$ dex) without performing any seismic analysis for stars brighter than $Kp < 14$ mag. FliPer takes into account the average variability of a star measured in the power density spectrum in a given range of frequencies. However, FliPer values calculated on several ranges of frequency are required to better characterize a star. Using a large set of asteroseismic targets it is possible to calibrate the behavior of surface gravity with FliPer through machine learning. This calibration made with a random forest regressor covers a wide range of surface gravities from main-sequence stars to subgiants and red giants, with very small uncertainties from 0.04 to 0.1 dex. FliPer values can be inserted in automatic global seismic pipelines to either give an estimation of the stellar surface gravity or to assess the quality of the seismic results by detecting any outliers in the obtained $\nu_{\rm max}$ values. FliPer also constrains the surface gravities of main-sequence dwarfs using only long cadence data for which the Nyquist frequency is too low to measure the acoustic-mode properties.

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A global optimisation study of the low-lying isomers of the alumina octomer $(Al_2O_3)_8$

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We employ the Monte-Carlo Basin-Hopping (MC–BH) global optimisation technique with inter-atomic pair potentials to generate low-energy candidates of stoichiometric alumina octomers ($(Al_2O_3)_8$). The candidate structures are subsequently refined with density functional theory calculations employing hybrid functionals (B3LYP and PBE0) and a large basis set (6-311+G(d)) including a vibrational analysis. We report the discovery of a set of energetically low-lying alumina octomer clusters, including a new global minimum candidate, with shapes that are elongated rather than spherical. We find a stability limit for these and smaller-sized clusters at a temperature of $T \simeq 1300$–1450 K corresponding to a phase transition in liquid alumina.

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and from https://www.sciencedirect.com/science/article/abs/pii/S0009261418307474

Asteroseismic age estimates of RGB stars in open clusters. A statistical investigation of different estimation methods

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Open clusters (OCs) provide a classical target to calibrate the age scale and other stellar parameters. Despite their wide use, some issues remain to be explored in detail. We performed a theoretical investigation focused on the age estimate of red giant branch (RGB) stars in OCs based on mixed classical surface ($T_{\rm eff}$ and [Fe/H]) and asteroseismic ($\Delta\nu$ and $\nu_{\rm max}$) parameters. We aimed to evaluate the performances of three widely adopted fitting procedures, that is, a pure geometrical fit, a maximum likelihood approach, and a single stars fit, in recovering stellar parameters. A dense grid of stellar models was computed, covering different chemical compositions and different values of the mixing-length parameter. Artificial OCs were generated from these data by means of a Monte Carlo procedure for two different ages (7.5 and 9.0 Gyr) and two different choices of the number of stars in the RGB evolutionary phase (35 and 80). The cluster age and other fundamental parameters were then recovered by means of the three methods previously mentioned. A Monte Carlo Markov chain approach was adopted for estimating the posterior densities of probability of the estimated parameters. The geometrical approach overestimated the age by about 0.3 and 0.2 Gyr for true ages of 7.5 and 9.0 Gyr, respectively. The value of the initial helium content was recovered unbiased within the large random errors on the estimates. The maximum likelihood approach provided similar biases (0.1 and 0.2 Gyr) but with a variance reduced by a factor of between two and four with respect to geometrical fit. The independent fit of single stars showed a very large variance owing to its neglect of the fact that the stars came from the same cluster. The age of the cluster was recovered with no biases for 7.5 Gyr true age and with a bias of −0.4 Gyr for 9.0 Gyr. The most important difference between geometrical and maximum likelihood approaches was the robustness against observational errors. For the first fitting technique, we found that estimations starting from the same sample but with different Gaussian perturbations on the observables suffer from a variability in the recovered mean of about 0.3 Gyr from one Monte Carlo run to another. This value was as high as 45% of the intrinsic variability due to observational errors. On the other hand, for the maximum likelihood fitting method, this value was about 65%. This larger variability led most simulations – up to 90% – to fail to include the true parameter values in their estimated

1 σ credible interval. Finally, we compared the performance of the three fitting methods for single RGB-star age estimation. The variability owing to the choice of the fitting method was minor, being about 15% of the variability caused by observational uncertainties. Each method has its own merits and drawbacks. The single star fit showed the lowest performances. The higher precision of the maximum likelihood estimates is partially negated by the lower protection that this technique shows against random fluctuations compared to the pure geometrical fit. Ultimately, the choice of the fitting method has to be evaluated in light of the specific sample and evolutionary phases under investigation.

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An XMM–*Newton* observation of the symbiotic star AG Peg: the X-ray emission after the end of its 2015 outburst

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We present an analysis of the XMM–*Newton* observation of the symbiotic star AG Peg, obtained after the end of its 2015 outburst. The X-ray emission of AG Peg is soft and of thermal origin. AG Peg is an X-ray source of class beta of the X-ray sources amongst the symbiotic stars, whose X-ray spectrum is well matched by a two-temperature optically-thin plasma emission ($kT_1 \sim 0.14$ keV and $kT_2 \sim 0.66$ keV). The X-ray emission of the class β sources is believed to originate from colliding stellar winds (CSW) in binary system. If we adopt the CSW picture, the theoretical CSW spectra match well the observed properties of the XMM–*Newton* spectra of AG Peg. However, we need a solid evidence that a massive-enough hot-star wind is present in the post-outburst state of AG Peg to proof the validity of the CSW picture for this symbiotic binary. No short-term X-ray variability is detected while the UV emission of AG Peg shows stochastic variability (flickering) on time-scales of minutes and hours.

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Accurate OH maser positions II. the Galactic Center region

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We present high spatial resolution observations of ground-state OH masers, achieved using the Australia Telescope

Compact Array (ATCA). These observations were conducted towards 171 pointing centres, where OH maser candidates were identified previously in the Southern Parkes Large-Area Survey in Hydroxyl (SPLASH) towards the Galactic Center region, between Galactic longitudes of 355° and 5° and Galactic latitudes of −2° and +2°. We detect maser emission towards 162 target fields and suggest that 6 out of 9 non-detections are due to intrinsic variability. Due to the superior spatial resolution of the follow-up ATCA observations, we have identified 356 OH maser sites in the 162 of the target fields with maser detections. Almost half (161 of 356) of these maser sites have been detected for the first time in these observations. After comparing the positions of these 356 maser sites to the literature, we find that 269 (76%) sites are associated with evolved stars (two of which are planetary nebulae), 31 (9%) are associated with star formation, four are associated with supernova remnants and we were unable to determine the origin of the remaining 52 (15%) sites. Unlike the pilot region (Qiao et al. 2016a), the infrared colors of evolved star sites with symmetric maser profiles in the 1612 MHz transition do not show obvious differences compared with those of evolved star sites with asymmetric maser profiles.

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Tracking down R Coronæ Borealis stars using the WISE All-Sky survey

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R Coronæ Borealis stars (RCBs) are the best candidates to be the products of white dwarf mergers in the intermediate mass range ($0.4 < M_{\rm tot} < 1.1$ M$_{\odot}$). After a merger, a He envelope surrounds a CO core, and a short-lived supergiant phase starts. RCBs correspond to that phase. They are known to be hydrogen-deficient and carbon-rich supergiant stars. They are rare; a hundred are known now in the Galaxy and the Magellanic Clouds. They are also highly diverse in chemical abundances, brightness and photosphere temperature. To understand their evolutionary path, constrain their spatial distribution and test their formation rate in the context of population synthesis results, we aim to increase significantly the number of known RCBs. To do so, we need first to create a list of targets of interest rich in RCB stars, that will be subsequently followed-up spectroscopically to reveal their true nature. Fortunately, RCBs are producing dust and are therefore surrounded by warm circumstellar dust shells. Using the all-sky 2MASS and WISE infrared surveys, our goal is to discriminate RCBs among other dust-producing stars. A series of selection criteria was applied to colour–colour diagrams and to the brightness of all objects catalogued. The criteria were designed using all 102 known RCB stars. RCB spectral energy distribution models were also used to understand the limits of the criteria and the possible bias in terms of shell temperature selected. The analysis was complicated by the unpredictable photometric declines that RCB stars are known to undergo. Those events reddened drastically the photospheres of some RCBs that were in decline at the time of the 2MASS epoch. With a detection efficiency of about 85%, our analysis selected only 2356 targets among the 563 million objects catalogued in the WISE All-Sky survey. These targets were classified in order of priority for further studies. Only 375 targets form the priority #1 group where the highest rate of discovery should be made. We created a short list of targets of interest rich in RCB stars that supersedes a previously published one made from the preliminary WISE data release. This list, published in the CDS Vizier database, will allow us to increase significantly the number of known RCB stars, understand our selection bias and consequently study their origin.

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A plethora of new R Coronæ Borealis stars from a dedicated spectroscopic follow-up survey

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It is increasingly suspected that R Coronæ Borealis (RCB) stars – rare hydrogen-deficient and carbon-rich supergiant stars – are the product of mergers of white-dwarfs in the intermediary mass regime ($0.6 < M_{\rm Tot} < 1.2$ M$_\odot$). They show a wide range of effective temperatures and chemical abundances. Only 78 RCB stars are currently known in our Galaxy while up to 1000 were expected. It is necessary to find more of these peculiar and diverse stars to understand their origin and evolutionary path. We are undertaking such a dedicated search. We plan to follow-up spectroscopically 2356 targets of interest that were carefully selected using the all sky 2MASS and WISE surveys. They have similar brightnesses and shell temperatures to known RCB stars and only a spectrum can reveal their real nature. We have observed nearly 500 of these targets using optical low-resolution spectrographs. These spectra were compared to synthetic spectra from a new grid of MARCS hydrogen-deficient atmospheric models. Classical RCB stars' photospheric temperatures range mostly from 4000 K to about 8500 K, and therefore their spectra look very different showing the presence of carbon molecules C_2 and CN up to $\sim$ 6800 K and solely atomic absorption lines above that. From the study of both observed and synthetic spectra, we have put in place a series of criteria to distinguish RCB stars from other AGB carbon-rich stars, mainly using estimates of the C/N ratio and ^{13}C strength, intensities of potential Balmer lines, and estimates of $T_{\rm eff}$ using the Ca II triplet lines strength. We found 45 new RCB stars, including 30 Cold ($4000 < T_{\rm eff} < 6800$ K), 14 Warm ($6800 < T_{\rm eff} < 8500$ K) and one Hot RCB ($T_{\rm eff} > 10\,000$ K). Forty of these belong to the Milky Way and five are located in the Magellanic Clouds. We also confirmed with the same spectroscopic method that the long lasting candidate KDM 5651 is indeed a new Magellanic RCB star, increasing the total number of Magellanic Cloud RCB stars to 30. Our method is particularly efficient at detecting Warm RCB stars as we have increased their number by a factor 4. We have increased by $\sim$ 50% the total number of RCB stars known, now reaching 147. We also include a list of 14 strong RCB candidates, most certainly observed during a dust obscuration phase. From the detection efficiency and success rate so far, we estimate that there should be no more than 500 RCB stars/HdC stars in the Milky Way.

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Evidence against anomalous compositions for giants in the Galactic nuclear star cluster

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Very strong Sc I lines have recently been found in cool M giants in the Nuclear Star Cluster (NSC) in the Galactic center. Interpreting these as anomalously high scandium abundances in the Galactic center would imply a unique enhancement signature and chemical evolution history for NSCs, and a potential test for models of chemical enrichment in these objects. We present high resolution K-band spectra (NIRSPEC/Keck II) of cool M giants situated in the solar neighborhood and compare them with spectra of Mgiants in the NSC. We clearly identify strong Sc I lines in our solar neighborhood sample as well as in the NSC sample. The strong Sc I lines in Mgiants are therefore not unique to stars in the NSC and we argue that the strong lines are a property of the line formation process that currently escapes accurate theoretical modeling. We further conclude that for giant stars with effective temperatures below approximately 3800 K these Sc I lines should not be used for deriving the scandium abundances in any astrophysical environment until we better understand how these lines are formed. We also discuss the lines of vanadium, titanium, and yttrium identified in the spectra, which demonstrate a similar striking increase in strength below 3500 K effective temperature.

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Red supergiants in the JWST era. I: Near-IR photometric diagnostics

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The Near Infrared Camera (NIRCam) on the *James Webb* Space Telescope (JWST) will be an incredibly powerful instrument for studying red supergiants (RSGs). The high luminosities and red peak wavelengths of these stars make them ideal targets for JWST/NIRCam. With effective photometric diagnostics in place, imaging RSG populations in multiple filters will make it possible to determine these stars' physical properties and, in cases where JWST pre-explosion imaging is available, to identify RSG supernova progenitors. This paper uses observed and model spectra of Galactic RSGs to simulate JWST/NIRCam near-IR photometry and colors, quantify and test potential diagnostics of effective temperature and bolometric magnitude, and present photometric techniques for separating background RSG and foreground dwarf populations. While results are presented for the full suite of near-IR filters, this work shows that (F070W–F200W) is the JWST/NIRCam color index most sensitive to effective temperature, F090W is the best band for determining bolometric magnitude, and the (F070W–F090W) vs. (F090W–F200W) color–color diagram can be used to separate foreground dwarf and background RSG samples. The combination of these three filters is recommended as the best suite of photometric observations to use when studying RSGs with JWST.

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The cosmic evolution of magnesium isotopes

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The abundance of magnesium in the interstellar medium is a powerful probe of star formation processes over cosmological timescales. Magnesium has three stable isotopes, ^{24}Mg, ^{25}Mg, ^{26}Mg, which can be produced both in massive and intermediate-mass (IM) stars with masses between 2 and 8 $M_\odot$. In this work, we use constraints on the cosmic star formation rate density (SFRD) and explore the role and mass range of intermediate mass stars using the observed isotopic ratios. We compare several models of stellar nucleosynthesis with metallicity-dependent yields and also consider the effect of rotation on the yields massive stars and its consequences on the evolution of the Mg isotopes. We use a cosmic evolution model updated with new observational SFRD data and new reionization constraints coming from 2018 *Planck* collaboration determinations. We find that the main contribution of ^{24}Mg comes from massive stars whereas ^{25}Mg and ^{26}Mg come from intermediate mass stars. To fit the observational data on magnesium isotopic ratios, an additional intermediate mass SFRD component is preferred. Moreover, the agreement between model and data is further improved when the range of IM masses is narrowed towards higher masses (5–8 $M_\odot$). While some rotation also improves the fit to data, we can exclude the case where all stars have high rotational velocities due to an over-production of ^{26}Mg.

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Rapidly-evolving episodic outflow in IRAS 18113−2503: clues to the ejection mechanism of the fastest water fountain

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Water fountains are evolved stars showing early stages of collimated mass loss during transition from the asymptotic giant branch, providing valuable insight into the formation of asymmetric planetary nebulæ. We report the results of multi-epoch VLBI observations, which determine the spatial and three-dimensional kinematic structure of H_2O masers associated with the water fountain IRAS 18113−2503. The masers trace three pairs of high-velocity ($\sim$ 150–300 km s^{-1}) bipolar bow shocks on a scale of $0''.18$ ($\sim$ 2000 au). The expansion velocities of the bow shocks exhibit an exponential decrease as a function of distance from the central star, which can be explained by an episodic, jet-driven outflow decelerating due to drag forces in a circumstellar envelope. Using our model, we estimate an initial ejection velocity $\sim$ 840 km s^{-1}, a period for the ejections $\sim$ 10 yr, with the youngest being $\sim$ 12 yr old, and an average envelope density within the H_2O maser region $n_{H_2} \approx 10^6$ cm^{-3}. We hypothesize that IRAS 18113−2503 hosts a binary central star with a separation of $\sim$ 10 au, revealing novel clues about the launching mechanisms of high-velocity collimated outflows in water fountains.

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An imaging spectroscopic survey of the planetary nebula NGC 7009 with MUSE

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The spatial structure of the emission lines and continuum over the 50″ extent of the nearby, O-rich, planetary nebula NGC 7009 (Saturn Nebula) have been observed with the MUSE integral field spectrograph on the ESO Very Large Telescope. Science Verification data, in $< 0\farcs6$ seeing, have been reduced and analysed as images over the wavelength range 4750–9350 Å. Emission line maps over the bright shells are presented, from neutral to the highest ionization available (He II and [Mn V]). For collisionally excited lines (CELs), maps of electron temperature (T_e from [N II] and [S III]) and electron density (N_e from [S II] and [Cl III]) are available and for optical recombination lines (ORLs) temperature (from the Paschen jump and ratio of He I lines) and density (from high Paschen lines). These estimates are compared: for the first time, maps of the differences in CEL and ORL T_e's have been derived, and correspondingly a map of t^2 between a CEL and ORL temperature, showing considerable detail. Total abundances of He and O were formed, the latter using three ionization correction factors. However the map of He/H is not flat, departing by $\sim 2\%$ from a constant value, with remnants corresponding to ionization structures. Ionization correction factor methods are compared for O abundance, but none delivers a flat map. An integrated spectrum over an area of 2340 arcsec^2 was also formed and compared to 1D photoionization models. The spatial variation of a range of nebular parameters illustrates the complexity of the ionized media in NGC 7009. These MUSE data are very rich with detections of many lines over areas of hundreds of square arcseconds and follow-on studies are indicated. (Abridged)

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The *s* process in AGB stars as constrained by a large sample of barium stars

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Context: Barium (Ba) stars are dwarf and giant stars enriched in elements heavier than iron produced by the *slow*

neutron-capture process (s process). These stars belong to binary systems in which the primary star evolved through the asymptotic giant branch (AGB) phase. During this phase the primary star produced s-process elements and transferred them onto the secondary, which is now observed as a Ba star.
Aims: We compare the largest homogeneous set of Ba giant star observations of the s-process elements Y, Zr, La, Ce, and Nd with AGB nucleosynthesis models to reach a better understanding of the s process in AGB stars.
Methods: By considering the light-s (ls: Y and Zr) heavy-s (hs: La, Ce, and Nd) and elements individually, we computed for the first time quantitative error bars for the different hs-element to ls-element abundance ratios, and for each of the sample stars. We compared these ratios to low-mass AGB nucleosynthesis models. We excluded La from our analysis because the strong La lines in some of the sample stars cause an overestimation and unreliable abundance determination, as compared to the other observed hs-type elements.
Results: All the computed hs-type to ls-type element ratios show a clear trend of increasing with decreasing metallicity with a small spread (less than a factor of 3). This trend is predicted by low-mass AGB models in which ^{13}C is the main neutron source. The comparison with rotating AGB models indicates the need for the presence of an angular momentum transport mechanism that should not transport chemical species, but significantly reduces the rotational speed of the core in the advanced stellar evolutionary stages. This is an independent confirmation of asteroseismology observations of the slow down of core rotation in giant stars, and of rotational velocities of white dwarfs lower than predicted by models without an extra angular momentum transport mechanism.

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S stars and s-process in the Gaia era I. Stellar parameters and chemical abundances in a sub-sample of S stars with new MARCS model atmospheres

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Context: S stars are transition objects between M-type giants and carbon stars on the asymptotic giant branch (AGB). They are characterized by overabundances of s-process elements. Roughly half of them are enhanced in technetium (Tc), an s-process element with no stable isotope, while the other half lack technetium. This dichotomy arises from the fact that Tc-rich S stars are intrinsically producing s-process elements and have undergone third dredge-up (TDU) events, while Tc-poor S stars owe their s-process overabundances to a past pollution by a former AGB companion which is now an undetected white dwarf, and since the epoch of the mass transfer, technetium has totally decayed.
Aims: Our aim is to analyse the abundances of S stars and gain insights into their evolutionary status and on the nucleosynthesis of heavy s-process elements taking place in their interior. In particular, the location of extrinsic and intrinsic S stars in the HR diagram will be compared with the theoretical onset of the TDU on the thermally-pulsing AGB.
Methods: A sample of 19 S-type stars was analysed by combining HERMES high-resolution spectra, accurate Gaia Data Release 2 (GDR2) parallaxes, stellar-evolution models, and newly-designed MARCS model atmospheres for S-type stars. Various stellar parameters impact the atmospheric structure of S stars, not only effective temperature, gravity, metallicity and microturbulence, but also C/O and [s/Fe]. We show that photometric data alone are not sufficient to disentangle these parameters. We present a new automatic spectral-fitting method that allows one to constrain the range of possible atmospheric parameters.
Results: Combining the derived parameters with GDR2 parallaxes allows a joint analysis of the location of the stars in the Hertzsprung–Russell diagram and of their surface abundances. For all 19 stars, Zr and Nb abundances are derived, complemented by abundances of other s-process elements for the three Tc-rich S stars. These abundances agree within the uncertainties with nucleosynthesis predictions for stars of corresponding mass, metallicity and evolutionary stage.

The Tc dichotomy between extrinsic and intrinsic S stars is seen as well in the Nb abundances: intrinsic, Tc-rich S stars are Nb-poor, whereas extrinsic, Tc-poor S stars are Nb-rich. Most extrinsic S stars lie close to the tip of the red giant branch (RGB), and a few are located along the early AGB. All appear to be the cooler analogues of barium stars. Barium stars with masses smaller than 2.5 $M_\odot$ turn into extrinsic S stars on the RGB, because only for those masses does the RGB tip extend to temperatures lower than $\sim$ 4200 K, which allows the ZrO bands distinctive of S-type stars to develop. On the contrary, barium stars with masses in excess of $\sim$ 2.5 $M_\odot$ can only turn into extrinsic S stars on the E-AGB, but those are short-lived, and thus rare. The location of intrinsic S stars in the HR diagram is compatible with them being thermally-pulsing AGB stars. Although nucleosynthetic model predictions give a satisfactory distribution of s-process elements, fitting at the same time the carbon and heavy s-element enrichments still remains difficult. Finally, the Tc-rich star V915 Aql is challenging as it points at the occurrence of TDU episodes in stars with masses as low as $M \sim 1$ $M_\odot$.

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Modelling long-period variables – I. A new grid of O-rich and C-rich pulsation models

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We present a new grid of non-adiabatic, linear pulsation models of Long-Period Variables (LPVs), including periods and growth rates for radial modes from the fundamental to the fourth overtone. The models span a wide range in mass, luminosity, metallicity, C/O ratio and helium abundance, effectively covering the whole thermally-pulsing asymptotic giant branch (TP-AGB) evolution, and representing a significant update with respect to previous works. The main improvement is the inclusion of detailed atomic and molecular opacities, consistent with the models chemical mixture, that makes the present set of models the first to systematically account for variability in C-stars. We examine periods and growth rates in the models, and find that, while the fundamental mode is affected by the structure of the envelope, overtones are less sensitive to the interior and largely determined by the global properties. In the models, the frequency of the overtone with the largest degree of excitation is found to scale with the acoustic cut-off frequency at the stellar surface, a behaviour similar to that observed for the frequency of maximum oscillation power for solar-like oscillations in less evolved red giants. This allows us to provide a simple analytic prescription to predict the most-likely dominant mode as a function of stellar parameters. Best-fit relations for periods are also provided. By applying results of pulsation models to evolutionary tracks, we present a general picture of the evolution of long-period variability during the TP-AGB, that we find consistent with observations. Models are made public through a dedicated web interface.

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Planetary nebulæ with UVIT II: Revelations from FUV vision of Butterfly Nebula NGC 6302

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The high excitation planetary nebula, NGC 6302, has been imaged in two far-ultraviolet (FUV) filters, F169M (Sapphire; $\lambda_{\rm eff}$: 1608 Å) and F172M (Silica; $\lambda_{\rm eff}$: 1717 Å) and two NUV filters, N219M (B15; $\lambda_{\rm eff}$: 2196 Å) and N279N (N2; $\lambda_{\rm eff}$: 2792 Å) with the Ultra Violet Imaging Telescope (UVIT). The FUV F169M image shows faint emission

lobes that extend to about 5arcmin on either side of the central source. Faint orthogonal collimated jet-like structures are present on either side of the FUV lobes through the central source. These structures are not present in the two NUV filters nor in the FUV F172M filter. Optical and IR images of NGC 6302 show bright emission bipolar lobes in the East–West direction with a massive torus of molecular gas and dust seen as a dark lane in the North–South direction. The FUV lobes are much more extended and oriented at a position angle of 113°. They and the jet-like structures might be remnants of an earlier evolutionary phase, prior to the dramatic explosive event that triggered the Hubble type bipolar flows approximately 2200years ago. The source of the FUV lobe and jet emission is not known, but is likely due to fluorescent emission from H_2 molecules. The cause of the difference in orientation of optical and FUV lobes is not clear and, we speculate, could be related to two binary interactions.

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ALMA observations of the circumstellar envelope around EP Aqr

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Atacama Large Millimetre/sub-millimetre Array (ALMA) observations of the CO(1–0) and CO(2–1) emissions from the circumstellar envelope of the Asymptotic Giant Branch (AGB) star EP Aqr have been made with four times better spatial resolution than previously available. They are analysed with emphasis on the de-projection in space of the effective emissivity and flux of matter using as input a prescribed configuration of the velocity field, assumed to be radial. The data are found to display an intrinsic axi-symmetry with respect to an axis making a small angle with the line of sight. A broad range of wind configurations, from prolate (bipolar) to oblate (equatorial) has been studied and found to be accompanied by significant equatorial emission. Qualitatively, the effective emissivity is enhanced near the equator to produce the central narrow component observed in the Doppler velocity spectra and its dependence on star latitude generally follows that of the wind velocity with the exception of an omni-present depression near the poles. In particular, large equatorial expansion velocities produce a flared disc or a ring of effective emissivity and mass loss. The effect on the determination of the orientation of the star axis of radial velocity gradients and possibly competing rotation and expansion in the equatorial disc is discussed. In general, the flux of matter is found to reach a broad maximum at distances of the order of 500 au from the star. Arguments are given that may be used to prefer one wind velocity distribution to another. As a result of the improved quality of the data, a deeper understanding of the constraints imposed on morphology and kinematics has been obtained.

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Radio stars: from kHz to THz

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Advances in technology and instrumentation have now opened up virtually the entire radio spectrum to the study of stars. An international workshop – "Radio Stars: from kHz to THz" – was held at the Massachusetts Institute of Technology Haystack Observatory on 2017 November 1–3 to enable the discussion of progress in solar and stellar astrophysics enabled by radio wavelength observations. Topics covered included the Sun as a radio star, radio emission from hot and cool stars (from the pre- to post-main-sequence), ultracool dwarfs, stellar activity, stellar winds and mass loss, planetary nebulæ, cataclysmic variables, classical novae, and the role of radio stars in understanding the Milky Way. This article summarizes meeting highlights along with some contextual background information.

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Physical properties of the fullerene C_{60}-containing planetary nebula SaSt 2-3

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We perform a detailed analysis of the fullerene C_{60}-containing planetary nebula (PN) SaSt 2-3 to investigate the physical properties of the central star (B0–1 II) and nebula based on our own *Subaru*/HDS spectra and multiwavelength archival data. By assessing the stellar absorption, we derive the effective temperature, surface gravity, and photospheric abundances. For the first time, we report time variability of the central star's radial velocity, strongly indicating a binary central star. Comparison between the derived elemental abundances and those predicted values by asymptotic giant branch (AGB) star nucleosynthesis models indicates that the progenitor is a star with initial mass of ~ 1.25 $M_\odot$ and metallicity $Z = 0.001$/α-element/Cl-rich ([α,Cl/Fe]$\sim$ +0.3–0.4). We determine the distance (11.33 kpc) to be consistent with the post-AGB evolution of 1.25 $M_\odot$ initial mass stars with $Z = 0.001$. Using the photoionization model, we fully reproduce the derived quantities by adopting a cylindrically shaped nebula. We derive the mass fraction of the C-atoms present in atomic gas, graphite grain, and C_{60}. The highest mass fraction of C_{60} ($\sim 0.19\%$) indicates that SaSt 2-3 is the C_{60}-richest PN amongst Galactic PNe. From comparison of stellar/nebular properties with other C_{60} PNe, we conclude that the C_{60} formation depends on the central star's properties and its surrounding environment (e.g., binary disc), rather than the amount of C-atoms produced during the AGB phase.

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Orbital properties of binary post-AGB stars

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Binary post-asymptotic giant branch (post-AGB) stars are thought to be the products of a strong but poorly understood interaction during the AGB phase. The aim of this contribution is to update the orbital elements of a sample of galactic post-AGB binaries observed in a long-term radial-velocity monitoring campaign by analysing these systems in a homogeneous way. Radial velocities are computed from high signal-to-noise spectra via a cross-correlation method. The radial-velocity curves are fitted by using both a least-squares algorithm and a Nelder–Mead simplex algorithm. We use a Monte Carlo method to compute uncertainties on the orbital elements. The resulting mass functions are used to derive a companion mass distribution by optimising the predicted to the observed cumulative mass-function distributions, after correcting for observational bias. As a result, we derive and update orbital elements for 33 Galactic post-AGB binaries, among which 3 are new orbits. The orbital periods of the systems range from 100 to about 3000 days. Over 70% (23 out of 33) of our binaries have significant non-zero eccentricities ranging over all periods. Their orbits are non-circular even though the Roche-lobe radii are smaller than the maximum size of a typical AGB star and tidal circularisation should have been strong when the objects were on the AGB. We derive a distribution of companion masses that is peaked around 1.09 $M_\odot$ with a standard deviation of 0.62 $M_\odot$. The large spread in companion masses highlights the diversity of post-AGB binary systems. Post-AGB binaries are often chemically peculiar, showing in their photospheres the result of an accretion process of circumstellar gas devoid of refractory elements. We find that only post-AGB stars with high effective temperatures (> 5500 K) in wide orbits are depleted in refractory elements, suggesting that re-accretion of material from a circumbinary disc is an ongoing process. It appears, however, that depletion is inefficient for the closest orbits irrespective of the actual surface temperature.

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Simultaneous VLBI astrometry of H_2O and SiO masers toward the semiregular variable R Crateris

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We obtained, for the first time, astrometrically registered maps of the 22.2 GHz H_2O and 42.8, 43.1, and 86.2 GHz SiO maser emission toward the semiregular b-type variable (SRb) R Crateris, at three epochs (2015 May 21, and 2016 January 7 and 26) using the Korean Very-long-baseline Interferometry Network. The SiO masers show a ring-like spatial structure, while the H_2O maser shows a very asymmetric one-side outflow structure, which is located at the southern part of the ring-like SiO maser feature. We also found that the 86.2 GHz SiO maser spots are distributed in an inner region, compared to those of the 43.1 GHz SiO maser, which is different from all previously known distributions of the 86.2 GHz SiO masers in variable stars. The different distribution of the 86.2 GHz SiO maser seems to be related to the complex dynamics caused by the overtone pulsation mode of the SRb R Crateris. Furthermore, we estimated the position of the central star based on the ring fitting of the SiO masers, which is essential for interpreting the morphology and kinematics of a circumstellar envelope. The estimated stellar coordinate corresponds well to the position measured by Gaia.

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On the post-common-envelope central star of the planetary nebula NGC 2346

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The common-envelope phase is one of the most poorly understood phases of (binary) stellar evolution, in spite of its importance in the formation of a wide-range of astrophysical phenomena ranging from cataclysmic variables to cosmologically important supernova type Ia, and even recently discovered gravitational wave producing black hole mergers. The central star of the planetary nebula NGC 2346 has long been held as one of the longest period post-common-envelope systems known with a published period of approximately 16 days, however the data presented were also consistent with much shorter periods of around 1 day (a more typical period among the known sample of post-common-envelope binary central stars). Here, using the modern high-stability, high-resolution spectrograph HERMES, we conclusively show the period to, indeed, be 16 days while also revising the surface gravity to a value typical of a sub-giant (rather than main-sequence) resulting in an intrinsic luminosity consistent with the recently published GAIA parallax distance. Intriguingly, the implied mass for the secondary ($\gtrsim 3.5$ $M_{\odot}$) makes it, to our knowledge, the most massive post-common-envelope secondary known, whilst also indicating that the primary may be a post-RGB star.

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AKARI mission program: excavating Mass Loss History in extended dust shells of Evolved Stars (MLHES) I. Far-IR photometry

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We performed a far-IR imaging survey of the circumstellar dust shells of 144 evolved stars as a mission programme of the AKARI infrared astronomical satellite using the Far-Infrared Surveyor (FIS) instrument. With this survey, we deliver far-IR surface brightness distributions of roughly $10' \times 40'$ or $10' \times 20'$ areas of the sky around the target evolved stars in the four FIS bands at 65, 90, 140, and 160 μm. Our objectives are to characterize the far-IR surface brightness distributions of the cold dust component in the circumstellar dust shells, from which we derive the amount of cold dust grains as low as 20 K and empirically establish the history of the early mass loss history. In this first instalment of the series, we introduce the project and its aims, describe the observations, data reduction, and surface brightness correction process, and present the entire data set along with the results of integrated photometry measurements (i.e. the central source and circumstellar dust shell altogether). We find that (1) far-IR emission is detected from all but one object at the spatial resolution about $30''$–$50''$ in the corresponding bands, (2) roughly 60–70% of the target sources show some extension, (3) previously unresolved nearby objects in the far-IR are now resolved around 28 target sources, (4) the results of photometry measurements are reasonable with respect to the entries in the AKARI/FIS Bright Source Catalogue, despite the fact that the targets are assumed to be point-sources when catalogue flux densities were computed, and (5) an IR two-color diagram would place the target sources in a roughly linear distribution that may correlate with the age of the circumstellar dust shell and can potentially be used to identify which targets are

more extended than others.

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Time resolved spectroscopy of dust and gas from extrasolar planetesimals orbiting WD 1145+017

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Multiple long and variable transits caused by dust from possibly disintegrating asteroids were detected in light curves of WD 1145+017. We present time-resolved spectroscopic observations of this target with QUCAM CCDs mounted in the Intermediate dispersion Spectrograph and Imaging System at the 4.2-m *William Herschel* Telescope in two different spectral arms: the blue arm covering 3800–4025 Å, and the red arm covering 7000–7430 Å. When comparing individual transits in both arms, our observations show with 20σ significance an evident colour difference between the in- and out-of-transit data of the order of 0.05–0.1 mag, where transits are deeper in the red arm. We also show with $> 6\sigma$ significance that spectral lines in the blue arm are shallower during transits than out-of-transit. For the circumstellar lines it also appears that during transits the reduction in absorption is larger on the red side of the spectral profiles. Our results confirm previous findings showing the u'-band excess and a decrease in line absorption during transits. Both can be explained by an opaque body blocking a fraction of the gas disc causing the absorption, implying that the absorbing gas is between the white dwarf and the transiting objects. Our results also demonstrate the capability of EMCCDs to perform high-quality time resolved spectroscopy of relatively faint targets.

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Variability in proto-planetary nebulæ: V. Velocity and light curve analyses of IRAS 17436+5003, 18095+2704, and 19473+3119

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We have obtained contemporaneous light, color, and radial velocity data for three proto-planetary nebulæ (PPNe) over the years 2007 to 2015. The light and velocity curves of each show similar periods of pulsation, with photometric periods of 42 and 50 days for IRAS 17436+5003, 102 days for IRAS 18095+2704, and 35 days for IRAS 19475+3119. The light and velocity curves are complex with multiple periods and small, variable amplitudes. Nevertheless, at least over limited time intervals, we were able to identify dominant periods in the light, color, and velocity curves and compare the phasing of each. The color curves appear to peak with or slightly after the light curves while the radial velocity curves peak about a quarter of a cycle before the light curves. Similar results were found previously for two other PPNe, although for them the light and color appeared to be in phase. Thus it appears that PPNe are brightest when smallest and hottest. These phase results differ from those found for classical Cepheid variables, where the light and velocity differ by half a cycle, and are hottest at about average size and expanding. However, they do appear to have similar phasing to the larger amplitude pulsations seen in RV Tauri variables. Presently, few pulsation models exist for PPNe, and these do not fit the observations well, especially the longer periods observed. Model fits to these

new light and velocity curves would allow masses to be determined for these post-AGB objects, and thereby provide important constraints to post-AGB stellar evolution models of low and intermediate-mass stars.

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X-ray, UV, and optical observations of the accretion disk and boundary layer in the symbiotic star RT Crucis

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Compared to mass transfer in cataclysmic variables, the nature of accretion in symbiotic binaries in which red giants transfer material to white dwarfs (WDs) has been difficult to uncover. The accretion flows in a symbiotic binary are most clearly observable, however, when there is no quasi-steady shell burning on the WD to hide them. RT Cru is the prototype of such non-burning symbiotics, with its hard (δ-type) X-ray emission providing a view of its innermost accretion structures. In the past 20 yr, RT Cru has experienced two similar optical brightening events, separated by ~ 4000 days and with amplitudes of $\Delta V \sim 1.5$ mag. After *Swift* became operative, the Burst Alert Telescope (BAT) detector revealed a hard X-ray brightening event almost in coincidence with the second optical peak. Spectral and timing analyses of multi-wavelength observations that we describe here, from NuSTAR, *Suzaku*, *Swift*/X-Ray Telescope (XRT) + BAT + UltraViolet Optical Telescope (UVOT) (photometry) and optical photometry and spectroscopy, indicate that accretion proceeds through a disk that reaches down to the WD surface. The scenario in which a massive, magnetic WD accretes from a magnetically truncated accretion disk is not supported. For example, none of our data show the minute-time-scale periodic modulations (with tight upper limits from X-ray data) expected from a spinning, magnetic WD. Moreover, the similarity of the UV and X-ray fluxes, as well as the approximate constancy of the hardness ratio within the BAT band, indicate that the boundary layer of the accretion disk remained optically thin to its own radiation throughout the brightening event, during which the rate of accretion onto the WD increased to 6.7×10^{-9} M$_\odot$ yr^{-1} $(d/2\ \mathrm{kpc})^2$. For the first time from a WD symbiotic, the NuSTAR spectrum showed a Compton reflection hump at $E > 10$ keV, due to hard X-rays from the boundary layer reflecting off of the surface of the WD; the reflection amplitude was 0.77 ± 0.21. The best fit spectral model, including reflection, gave a maximum post-shock temperature of $kT = 53 \pm 4$ keV, which implies a WD mass of 1.25 ± 0.02 M$_\odot$. Although the long-term optical variability in RT Cru is reminiscent of dwarf-novae-type outbursts, the hard X-ray behavior does not correspond to that observed in well-known dwarf nova. An alternative explanation for the brightening events could be that they are due to an enhancement of the accretion rate as the WD travels through the red giant wind in a wide orbit, with a period of ~ 4000 days. In either case, the constancy of the hard X-ray spectrum while the accretion rate rose suggests that the accretion-rate threshold between a mostly optically thin and thick boundary layer, in this object, may be higher than previously thought.

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Annual parallax measurements of a semiregular variable star SV Pegasus with VERA

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Many studies have shown that there are clear sequences in the period–luminosity relationship (PLR) for Mira variables and semiregular variables (SRVs) in the Large Magellanic Cloud (LMC). To investigate the PLR for SRVs in our galaxy, we examined the annual parallax measurement and conducted K′-band photometric monitoring of an SRV star SV Pegasus (SV Peg). We measured the position change of the associating H_2O maser spots by phase-referencing VLBI observations with VERA at 22 GHz, spanning approximately 3 yr, and detected an annual parallax of $\pi = 3.00 \pm 0.06$ mas, corresponding to a distance of $D = 333 \pm 7$ pc. This result is in good agreement with the *Hipparcos* parallax and improves the accuracy of the distance from 35% to 2%. However, the Gaia DR2 catalog gave a parallax of $\pi = 1.12 \pm 0.28$ mas for SV Peg. This indicates that the Gaia result might be blurred by the effect of the stellar size because the estimated stellar radius was ~ 5 mas, which is comparable to the parallax. We obtained a K′-band mean magnitude of $m_{K'} = -0.48$ mag and a period of $P = 177$ days from our photometric monitoring with a 1-m telescope. Using the trigonometric distance, we derived an absolute magnitude of $M_{K'} = -8.09 \pm 0.05$ mag. This result shows that the position of SV Peg in the PLR falls on the C′ sequence found in the PLR in the LMC, which is similar to other SRVs in our galaxy.

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Conference Papers

Molecular dust precursors in envelopes of oxygen-rich AGB stars and red supergiants

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Condensation of circumstellar dust begins with formation of molecular clusters close to the stellar photosphere. These clusters are predicted to act as condensation cores at lower temperatures and allow efficient dust formation farther away from the star. Recent observations of metal oxides, such as AlO, AlOH, TiO, and TiO_2, whose emission can be traced at high angular resolutions with ALMA, have allowed first observational studies of the condensation process in oxygen-rich stars. We are now in the era when depletion of gas-phase species into dust can be observed directly. I review the most recent observations that allow us to identify gas species involved in the formation of inorganic dust of AGB stars and red supergiants. I also discuss challenges we face in interpreting the observations, especially those related to non-equilibrium gas excitation and the high complexity of stellar atmospheres in the dust-formation zone.

Oral contribution, published in IAU Symposium 343, "Why Galaxies Care About AGB Stars", eds. F. Kerschbaum, M. Groenewegen & H. Olofsson (invited contribution)
Available from https://arxiv.org/abs/1809.10583

Tomography of the red supergiant star μ Cep

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A tomographic method, aiming at probing velocity fields at depth in stellar atmospheres, is applied to the red supergiant star μ Cep and to snapshots of 3D radiative-hydrodynamics simulation in order to constrain atmospheric motions and relate them to photometric variability.

Poster contribution, published in IAU Symposium No. 343: "Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time"
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The binary central stars of planetary nebulæ

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It is now clear that central star binarity plays a key role in the formation and evolution of planetary nebulæ, with a significant fraction playing host to close-binary central stars which have survived one or more common envelope episodes. Recent studies of these systems have revealed many surprises which place important constraints on the common envelope – a critical phase in the formation of a wide variety of astrophysical phenomena, including the cosmologically important supernovæ type Ia and other transient phenomena which will be detected by next-generation facilities, like the Large Synoptic Survey Telescope and the space-based gravitational wave detector the Laser Interferometer Space Antenna.

Oral contribution, published in the XIII Scientific Meeting of the Spanish Astronomical Society, Highlights of Spanish Astrophysics X
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Review Papers

Asymptotic giant branch variables in nearby galaxies

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Certain types of large amplitude AGB variable are proving to be powerful distance indicators that will rival Cepheids in the JWST era of high precision infrared photometry. These are predominantly found in old populations and have low mass progenitors. At the other end of the AGB mass-scale, large amplitude variables, particularly those undergoing hot bottom burning, are the most luminous representatives of their population. These stars are < 1 Gyr old, are often losing mass copiously and are vital to our understanding of the integrated light of distant galaxies as well as to chemical enrichment. However, the evolution of such very luminous AGB variables is rapid and remains poorly understood. Here I discuss recent infrared observations of both low- and intermediate-mass Mira variables in the Local

Group and beyond.

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Angular momentum transport in stellar interiors

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Stars lose a significant amount of angular momentum between birth and death, implying that efficient processes transporting it from the core to the surface are active. Space asteroseismology delivered the interior rotation rates of more than a thousand low- and intermediate-mass stars, revealing that: 1) single stars rotate nearly uniformly during the core hydrogen and core helium burning phases; 2) stellar cores spin up to a factor 10 faster than the envelope during the red giant phase; 3) the angular momentum of the helium-burning core of stars is in agreement with the angular momentum of white dwarfs. Observations reveal a strong decrease of core angular momentum when stars have a convective core. Current theory of angular momentum transport fails to explain this. We propose improving the theory with a data-driven approach, whereby angular momentum prescriptions derived from multi-dimensional (magneto)hydrodynamical simulations and theoretical considerations are continously tested against modern observations. The TESS and PLATO space missions have the potential to derive the interior rotation of large samples of stars, including high-mass and metal-poor stars in binaries and clusters. This will provide the powerful observational constraints needed to improve theory and simulations.

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Science with the ngVLA: planetary nebulæ

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Planetary nebulæ (PNe) represent the near endpoints of evolution for stars of initial mass $\sim$ 1–8 $M_\odot$, wherein the envelope of an asymptotic giant branch (AGB) star becomes photodissociated and ionized by high-energy radiation from a newly emerging white dwarf that was the progenitor star's core. It is increasingly evident that most PNe are descended from binary systems. PNe hence provide unique insight into a diverse range of astrophysical phenomena, including the influence of companion stars on the late stages of stellar evolution; stellar wind interactions and shocks; the physics and chemistry of photoionized plasmas and photon-dominated regions (PDRs); and enrichment of the ISM

in the products of intermediate-mass stellar nucleosynthesis. We describe specific examples of the potential impact of the ngVLA in each of these areas.

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and from http://ngvla.nrao.edu/page/scibook

Science with an ngVLA: evolved stars

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This chapter reviews some of the expected contributions of the ngVLA to the understanding of the late evolutionary stages of low-to-intermediate mass stars, including asymptotic giant branch (AGB) stars, post-AGB stars, and pre-planetary nebulæ. Such objects represent the ultimate fate of stars like the Sun, and the stellar matter they lose to their immediate vicinity contributes significantly to the chemical enrichment of galaxies. Topics addressed in this chapter include continuum imaging of radio photospheres, studies of circumstellar envelopes in both thermal and nonthermal lines, and the investigation of the transition stages from the AGB to planetary nebulæ using radio wavelength diagnostics.

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Primordial to extremely metal-poor AGB and Super-AGB stars: white dwarf or supernova progenitors?

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Getting a better understanding of the evolution and nucleosynthetic yields of the most metal-poor stars ($Z \lesssim 10^{-5}$) is critical because they are part of the big picture of the history of the primitive Universe. Yet many of the remaining unknowns of stellar evolution lie in the birth, life, and death of these objects. We review stellar evolution of intermediate-mass $Z \leq 10^{-5}$ models existing in the literature, with a particular focus on the problem of their final fates. We emphasize the importance of the mixing episodes between the stellar envelope and the nuclearly processed core, which occur after stars exhaust their central He (second dredge-up and dredge-out episodes). The depth and efficiency of these episodes are critical to determine the mass limits for the formation of electron-capture supernovæ (EC-SNe). Our knowledge of these phenomena is not complete because they are strongly affected by the choice of input physics. These uncertainties affect stars in all mass and metallicity ranges. However, difficulties in calibration pose additional challenges in the case of the most metal-poor stars. We also consider the alternative SN $\mathrm{I}\frac{1}{2}$ channel to form supernovæ out of the most metal-poor intermediate mass objects. In this case, it is critical to understand the thermally-pulsing AGB evolution until the late stages. Efficient second dredge-up and, later, third dredge-up episodes could be able to pollute stellar envelopes enough for the stars to undergo thermal pulses in a way very similar to that of higher initial Z objects. Inefficient second and/or third dredge-up may leave an almost pristine envelope, unable

to sustain strong stellar winds. This may allow the H-exhausted core to grow to the Chandrasekhar mass before the envelope is completely lost, and thus let the star explode as a SN I$\frac{1}{2}$. After reviewing the information available on these two possible channels for the formation of supernovæ, we discuss existing nucleosynthetic yields of stars of metallicity $Z \leq 10^{-5}$, and present an example of nucleosynthetic calculations for a thermally-pulsing Super-AGB star of $Z = 10^{-5}$. We compare theoretical predictions with observations of the lowest [Fe/H] objects detected. The review closes by discussing current open questions as well as possible fruitful avenues for future research.

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Thesis

Study of fullerene-based molecular nanostructures in planetary nebulæ

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The main goal of this thesis is to unveil some questions related to the formation of complex fullerene-based molecules in space, with the aim of resolving some key problems in astrophysics. The unexpected detections of fullerenes and graphene (possible C_{24}) in the H-rich circumstellar environments of evolved stars indicate that these complex molecules are not so rare and bring the idea that other forms of carbon such as hydrogenated fullerenes (fulleranes), buckyonions, and carbon nanotubes may be widespread in the Universe, being closely involved in many aspects of circumstellar/interstellar chemistry and physics. We explore this new and fertile field of research by focusing our study on some Galactic planetary nebulæ (PNe) that contain fullerenes. In order to do this, we make use of laboratory spectra of several fullerene-related compounds and compare them with astronomical data. This work is a first step to open up a new field of interdisciplinary research, crossing the boundaries between astronomers, chemists, and physicists, and understand the significant presence of fullerene structures in circumstellar/interstellar environments.

PASP (Dissertation Summary)
Available from https://arxiv.org/abs/1810.09688

Announcements

Fizeau exchange visitors program – call for applications

The Fizeau exchange visitors program in optical interferometry funds (travel and accommodation) visits of researchers to an institute of his/her choice (within the European Community) to perform collaborative work and training on one of the active topics of the European Interferometry Initiative. The visits will typically last for one month, and strengthen the network of astronomers engaged in technical, scientific and training work on optical/infrared interferometry. The program is open for all levels of astronomers (Ph.D. students to tenured staff), with priority given to Ph.D. students and young postdocs. Non-EU based missions will only be funded if considered essential by the Fizeau Committee. Applicants are strongly encouraged to seek also partial support from their home or host institutions.

The deadline for applications is November 15.
Fellowships can be awarded for missions to be carried out between mid January 2019 and July 2019!

Note: the next call will be in May 2019!

Further informations and application forms can be found at http://www.european-interferometry.eu

The program is funded by OPTICON/H2020.

Please distribute this message also to potentially interested colleagues outside of your community!

Looking forward to your applications,
Josef Hron & Péter Ábrahám
(for the European Interferometry Initiative)

See also www.european-interferometry.eu

RAS specialist discussion meeting: the supernova–supernova remnant connection (11 Jan 2019)

We are pleased to announce the "supernova–supernova remnant connection" RAS specialist discussion meeting taking place on 11 January 2019 in London.

The supernova–supernova remnant connection
10:00am, 11 January 2019
Burlington House, London
Website: http://bit.ly/snsnr-ras
Contact: antonia.bevan.12@ucl.ac.uk

The aim of this conference is to bring together experts in supernovae at all stages of their evolution to discuss how our detailed observations of supernova remnants can inform our understanding of supernova physics. We will discuss a range of subjects including dust formation in SNe, SN morphologies and progenitor systems. The meeting will include a number of invited and contributed talks. Confirmed invited speakers include Dan Milisavljevic, Thomas Janka and Haley Gomez.

Abstract submission for contributed talks is currently open and abstracts are due by 30$^{\text{th}}$ November 2018.

It is not necessary to register to attend this event and it is free for RAS members. Further information can be found at our website (http://bit.ly/snsnr-ras) and on the RAS site (https://ras.ac.uk/events-and-meetings/ras-meetings/supernova-supernova-remnant-connection).

We look forward to welcoming you to London!

See also http://bit.ly/snsnr-ras