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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 254$^{\rm th}$ issue of the AGB Newsletter.

IAU Symposium 343, 'Why Galaxies Care About AGB Stars. A Continuing Challenge through Cosmic Time', was held at the General Assembly in Vienna last month. The advantage of a GA symposium is that there is a much wider audience. A disadvantage is that there is less time available. The oversubscription for speaking slots was high. The talks covered a wide range of topics: stellar structure and evolution, future observational perspectives, nucleosynthesis, atmospheres and dust formation, circumstellar envelopes of AGB stars and planetary nebulæ, binarity, cosmic matter cycle and galaxy evolution, and stellar populations. There were two major plenary talks for the entire GA: Eline Tolstoy spoke about the resolved extragalactic stellar populations with JWST and the ELT, and Amanda Karakas covered the origin of the elements, with emphasis on s-process elements (from AGB stars) and re-process elements (which are now known to come from neutron star mergers, at least in part).

A notable highlight was the observational detail that is now achievable using the VLTI, Sphere, and ALMA, and which resolve the stellar surface with the convective cells, and the dust formation region. ALMA was also used to measure the depletion of elements in the gas phase, showing that dust formation begins with aluminium oxide. Models of dust formation from the molecules have made significant progress, and point at silicon oxide and aluminium oxide as the first dust species. The evidence for binary companions to AGB stars is growing. The origin of the asymmetries seen in post-AGB stars and planetary nebulæ remains unsolved, with both binaries and magnetic fields in evidence, but more evidence now points at the AGB. Common envelopes remain problematic. The close binaries seen in planetary nebulæ have gone through a common envelope, but the models find it difficult to eject the envelopes, leaving the relation between the stellar interactions and the circumstellar nebulæ unclear. Abundances were discussed in several talks. High mass AGB stars are under suspicion for the abundance discrepancies in globular clusters. Stellar population models for galaxies now include evolved AGB and post-AGB stars. AGB stars form an important interface between stellar and galactic evolution. That link came through very well in the meeting, and in the GA.

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

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

Food for Thought

This month's thought-provoking statement is:

White dwarf pollution is due to post-AGB circumbinary discs

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

New full evolutionary sequences of H and He atmosphere massive white dwarf stars using MESA

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We explore the evolution of hydrogen-rich and hydrogen-deficient white dwarf stars with masses between 1.012 and 1.307 M$_o dot$, and initial metallicity of $Z = 0.02$. These sequences are the result of main sequence stars with masses between 8.8 and 11.8 M$_\odot$. The simulations were performed with MESA, starting at the zero-age main sequence, through thermally pulsing and mass-loss phases, ending at the white dwarf cooling sequence. We present reliable chemical profiles for the whole mass range considered, covering the different expected central compositions, i.e. C/O, O/Ne and Ne/O/Mg, and its dependence with the stellar mass. In addition, we present detailed chemical profiles of hybrid C/O–O/Ne core white dwarfs, found in the mass range between 1.024 and 1.15 M$_\odot$. We present the initial-to-final mass relation, mass–radius relation, and cooling times considering the effects of atmosphere and core composition.

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The first polluted white dwarf from Gaia DR2: the cool DAZ Gaia J1738−0826

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We present the first metal-polluted single white dwarf star identified through Gaia DR2. Gaia J1738−0826, selected from color and absolute magnitude cuts in the Gaia DR2 data, was discovered to have strong Ca II absorption in initial spectroscopic characterization at Lick Observatory. Notably, Gaia J1738−0826 resembles in many ways the first confirmed metal-polluted hydrogen atmosphere white dwarf, the DAZ G 74-7.

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The true luminosities of planetary nebulæ in M 31's bulge: massive central stars from an old stellar population

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We measure the Balmer decrements of 23 of the brightest planetary nebulæ (PNe) in the inner bulge ($r \lesssim 3'$) of M 31

and de-redden the bright end of the region's [O III] λ5007 planetary nebula luminosity function. We show that the most luminous PNe produce $\gtrsim$1,200 $L_\odot$ of power in their [O III] λ5007 line, implying central star luminosities of at least $\sim$ 11,000 $L_\odot$. Even with the most recent accelerated-evolution post-AGB models, such luminosities require central star masses in excess of 0.66 $M_\odot$, and main sequence progenitors of at least $\sim$ 2.5 $M_\odot$. Since M 31's bulge has very few intermediate-age stars, we conclude that conventional single-star evolution cannot be responsible for these extremely luminous objects. We also present the circumstellar extinctions for the region's bright PNe and demonstrate that the distribution is similar to that found for PNe in the Large Magellanic Cloud, with a median value of A_{5007} = 0.71 mag. Finally, we compare our results to extinction measurements made for PNe in the E6 elliptical NGC 4697 and the interacting lenticular NGC 5128. We show that such extinctions are not unusual, and that the existence of very high-mass PN central stars is a general feature of old stellar populations. Our results suggest that single-star population synthesis models significantly underestimate the maximum luminosities and total integrated light of AGB stars.

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High-resolution observations of the symbiotic system R Aqr. Direct imaging of the gravitational effects of the secondary on the stellar wind

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We have observed the symbiotic stellar system R Aqr, aiming to describe the gravitational interaction between the white dwarf (WD) and the wind from the Mira star, the key phenomenon driving the symbiotic activity and the formation of nebulae in such systems. We present high-resolution ALMA maps of the ^{12}CO and ^{13}CO J = 3–2 lines, the 0.9 mm continuum distribution, and some high-excitation molecular lines in R Aqr. The maps, which have resolutions ranging between 40 milliarcsecond (mas) and less than 20 mas, probe the circumstellar regions at suborbital scales as the distance between the stars is $\sim$ 40 mas. Our observations show the gravitational effects of the secondary on the stellar wind. The AGB star was identified in our maps from the continuum and molecular line data, and we estimated the probable position of the secondary from a new estimation of the orbital parameters. The (preliminary) comparison of our maps with theoretical predictions is surprisingly satisfactory and the main expected gravitational effects are directly mapped for the first time. We find a strong focusing in the equatorial plane of the resulting wind, which shows two plumes in opposite directions that have different velocities and very probably correspond to the expected double spiral due to the interaction. Our continuum maps show the very inner regions of the nascent bipolar jets, at scales of some au. Continuum maps obtained with the highest resolution show the presence of a clump that very probably corresponds to the emission of the ionized surroundings of the WD and of a bridge of material joining both stars, which is likely material flowing from the AGB primary to the accretion disk around the WD secondary.

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Heading Gaia to measure atmospheric dynamics in AGB stars

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Context: Asymptotic Giant Branch (AGB) stars are characterised by complex stellar surface dynamics that affect the

measurements and amplify the uncertainties on stellar parameters. As a matter of fact, the uncertainties in observed absolute magnitudes originate mainly from uncertainties in the parallaxes. The resulting motion of the stellar photo-center could have adverse effects on the parallax determination with Gaia.
Aims: We explore the impact of the convection-related surface structure in AGBs on the photocentric variability. We quantify these effects to characterise the observed parallax errors and estimate fundamental stellar parameters and dynamical properties.
Methods: We use 3D radiative-hydrodynamics simulations of convection with CO5BOLD and the post-processing radiative transfer code OPTIM3D to compute intensity maps in the Gaia G band [325–1030 nm]. From those maps, we calculate the intensity-weighted mean of all emitting points tiling the visible stellar surface (i.e. the photo-center) and evaluate its motion as a function of time. We extract the parallax error from Gaia DR2 for a sample of semiregular variables in the solar neighbourhood and compare it to the synthetic predictions of photo-center displacements.
Results: AGB stars show a complex surface morphology characterised by the presence of few large scale long-lived convective cells accompanied by short-lived and small scale structures. As a consequence, the position of the photo-center displays temporal excursions between 0.077 to 0.198 au (≈ 5 to $\approx 11\%$ of the corresponding stellar radius), depending on the simulation considered. We show that the convection-related variability accounts for a substantial part to the Gaia DR2 parallax error of our sample of semiregular variables. Finally, we put in evidence for a correlation between the mean photo-center displacement and the stellar fundamental parameters: surface gravity and pulsation. We denote that parallax variations could be exploited quantitatively using appropriate RHD simulations corresponding to the observed star.

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Through the magnifying glass: ALMA acute viewing of the intricate nebular architecture of OH 231.8+4.2

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We present continuum and molecular line emission ALMA observations of OH 231.8+4.2, a well studied bipolar nebula around an asymptotic giant branch (AGB) star. The high angular resolution (0.″2–0.″3) and sensitivity of our ALMA maps provide the most detailed and accurate description of the overall nebular structure and kinematics of this object to date. We have identified a number of outflow components previously unknown. Species studied in this work include ^{12}CO, ^{13}CO, CS, SO, SO_2, OCS, SiO, SiS, H_3O^+, Na^{37}Cl, and CH_3OH. The molecules Na^{37}Cl and CH_3OH are first detections in OH 231.8+4.2, with CH_3OH being also a first detection in an AGB star. Our ALMA maps bring to light the totally unexpected position of the mass-losing AGB star (QX Pup) relative to the large-scale outflow. QX Pup is enshrouded within a compact ($\lesssim$60 au) parcel of dust and gas (clump S) in expansion ($v_{\rm exp} \sim$ 5–7 km s^{-1}) that is displaced by $\sim$ 0.″6 to the south of the dense equatorial region (or waist) where the bipolar lobes join. Our SiO maps disclose a compact bipolar outflow that emerges from QX Pup's vicinity. This outflow is oriented similarly to the large-scale nebula but the expansion velocities are about ten times lower ($v_{\rm exp}\lesssim$35 km s^{-1}). We deduce short kinematical ages for the SiO outflow, ranging from $\sim$ 50–80 yr, in regions within $\sim$ 150 au, to $\sim$ 400–500 yr at the lobe tips ($\sim$ 3500 au). Adjacent to the SiO outflow, we identify a small-scale hourglass-shaped structure (mini-hourglass) that is probably made of compressed ambient material formed as the SiO outflow penetrates the dense, central regions of the nebula. The lobes and the equatorial waist of the mini-hourglass are both radially expanding with a constant velocity gradient ($v_{\rm exp} \propto r$). The mini-waist is characterized by extremely low velocities, down to $\sim$ 1 km s^{-1} at $\sim$ 150 au, which tentatively suggest the presence of a stable structure. The spatio-kinematics of the large-scale, high-velocity

lobes (HV lobes) and the dense equatorial waist (large waist) known from previous works are now precisely determined, indicating that both were shaped nearly simultaneously about 800–900 yr ago. We report the discovery of two large ($\sim 8'' \times 6''$), faint bubble-like structures (fish bowls) surrounding the central parts of the nebula. These are relatively old structures although probably slightly ($\sim$ 100–200 yr) younger than the large waist and the HV lobes. We discuss the series of events that may have resulted in the complex array of nebular components found in OH 231.8+4.2 as well as the properties and locus of the central binary system. The presence of $\lesssim$80 yr bipolar ejections indicate that the collimated fast wind engine is still active at the core of this outstanding object.

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Discovery of two bright DO-type white dwarfs

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We discovered two bright DO-type white dwarfs, GALEX J053628.3+544854 (J0536+5448) and GALEX 231128.0 +292935 (J2311+2929), which rank among the eight brightest DO-type white dwarfs known. Our non-LTE model atmosphere analysis reveals effective temperatures and surface gravities of $T_{\rm eff} = 80000 \pm 4600$ K and $\log g = 8.25 \pm 0.15$ for J0536+5448 and $T_{\rm eff} = 69400 \pm 900$ K and $\log g = 7.80 \pm 0.06$ for J2311+2929. The latter shows a significant amount of carbon in its atmosphere ($C = 0.003^{+0.005}_{-0.002}$, by mass), while for J0536+5448 we could derive only an upper limit of $C < 0.003$. Furthermore, we calculated spectroscopic distances for the two stars and found a good agreement with the distances derived from the Gaia parallaxes.

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ALMA imaging of the nascent planetary nebula IRAS 15103−5754

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We present continuum and molecular line (CO, $C^{18}O$, HCO^+) observations carried out with the Atacama Large Millimeter/submillimeter Array toward the "water fountain" star IRAS 15103−5754, an object that could be the youngest PN known. We detect two continuum sources, separated by 0.39 ± 0.03 arcsec. The emission from the brighter source seems to arise mainly from ionized gas, thus confirming the PN nature of the object. The molecular line emission is dominated by a circumstellar torus with a diameter of $\simeq 0.6$ arcsec (2000 au) and expanding at $\simeq 23$ km s^{-1}. We see at least two gas outflows. The highest-velocity outflow (deprojected velocities up to 250 km s^{-1}), traced by the CO lines, shows a biconical morphology, whose axis is misaligned $\simeq 14°$ with respect to the symmetry axis of the torus, and with a different central velocity (by $\simeq 8$ km s^{-1}). An additional high-density outflow (traced by HCO^+) is oriented nearly perpendicular to the torus. We speculate that IRAS 15103−5754 was a triple stellar system

that went through a common envelope phase, and one of the components was ejected in this process. A subsequent low-collimation wind from the remaining binary stripped out gas from the torus, creating the conical outflow. The high velocity of the outflow suggests that the momentum transfer from the wind was extremely efficient, or that we are witnessing a very energetic mass-loss event.

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Near-infrared spectroscopy of SN 2017eaw in 2017: carbon monoxide and dust formation in a Type II-P supernova

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The origin of dust in the early Universe has been the subject of considerable debate. Core-collapse supernovae (ccSNe), which occur several million years after their massive progenitors form, could be a major source of that dust, as in the local universe several ccSNe have been observed to be copious dust producers. Here we report nine near-infrared (0.8–2.5 μm) spectra of the Type II-P SN 2017eaw in NGC 6946, spanning the time interval 22–205 days after discovery. The spectra show the onset of CO formation and continuum emission at wavelengths greater than 2.1 μm from newly-formed hot dust, in addition to numerous lines of hydrogen and metals, which reveal the change in ionization as the density of much of the ejecta decreases. The observed CO masses estimated from an LTE model are typically 10^{-4} $M_\odot$ during days 124–205, but could be an order of magnitude larger if non-LTE conditions are present in the emitting region. The timing of the appearance of CO is remarkably consistent with chemically controlled dust models of Sarangi & Cherchneff.

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Early formation of carbon monoxide in the Centaurus A supernova SN 2016adj

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We present near-infrared spectroscopy of the NGC 5128 supernova SN 2016adj in the first 2 months following discovery. We report the detection of first overtone carbon monoxide emission at $\sim$ 58.2 d after discovery, one of the earliest detections of CO in an erupting supernova. We model the CO emission to derive the CO mass, temperature and

velocity, assuming both pure ^{12}CO and a composition that includes ^{13}CO; the case for the latter is the isotopic analyses of meteoritic grains, which suggest that core collapse supernovæ can synthesise significant amounts of ^{13}C. Our models show that, while the CO data are adequately explained by pure ^{12}CO, they do not preclude the presence of ^{13}CO, to a limit of ^{12}C/^{13}C > 3, the first constraint on the ^{12}C/^{13}C ratio determined from near-infrared observations. We estimate the reddening to the object, and the effective temperature from the energy distribution at outburst. We discuss whether the ejecta of SN 2016adj may be carbon-rich, what the infrared data tell us about the classification of this supernova, and what implications the early formation of CO in supernovæ may have for CO formation in supernovæ in general.

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The short orbital period binary star at the heart of the planetary nebula M 3-1

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We present the discovery of a $3^{\rm h}5^{\rm m}$ orbital-period binary star at the heart of the planetary nebula M 3-1 – the shortest period photometrically variable central star known and second only to V458 Vul, in general. Combined modelling of light and radial velocity curves reveals both components to be close to Roche lobe filling, strongly indicating that the central star will rapidly evolve to become a cataclysmic variable, perhaps experiencing a similar evolution to V458 Vul resulting in a nova eruption before the planetary nebula has fully dissipated. While the short orbital period and near Roche lobe filling natures of both components make the central binary of M 3-1 an important test case with which to constrain the formation processes of cataclysmic variables, novæ, and perhaps even supernovæ type Ia.

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Period spacings in red giants IV. Toward a complete description of the mixed-mode pattern

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Oscillation modes with a mixed character, as observed in evolved low-mass stars, are highly sensitive to the physical properties of the innermost regions. Measuring their properties is therefore extremely important to probe the core, but requires some care, due to the complexity of the mixed-mode pattern.
The aim of this work is to provide a consistent description of the mixed-mode pattern of low-mass stars, based on the asymptotic expansion. We also study the variation of the gravity offset ϵ_g with stellar evolution.
We revisit previous works about mixed modes in red giants and empirically test how period spacings, rotational

splittings, mixed-mode widths, and heights can be estimated in a consistent view, based on the properties of the mode inertia ratios.
From the asymptotic fit of the mixed-mode pattern of a large set of red giants at various evolutionary stages, we derive unbiased and precise asymptotic parameters. As the asymptotic expansion of gravity modes is verified with a precision close to the frequency resolution for stars on the red giant branch (10^{-4} in relative values), we can derive accurate values of the asymptotic parameters. We decipher the complex pattern in a rapidly rotating star, and explain how asymmetrical splittings can be inferred. We also revisit the stellar inclinations in two open clusters, NGC 6819 and NGC 6791: our results show that the stellar inclinations in these clusters do not have privileged orientation in the sky. The variation of the asymptotic gravity offset with stellar evolution is investigated in detail. We also derive generic properties that explain under which conditions mixed modes can be observed.

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The hot white dwarf in the peculiar binary nucleus of the planetary nebula EGB 6

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EGB 6 is an extended, faint old planetary nebula (PN) with an enigmatic nucleus. The central star (PG 0950+139) is a hot DAOZ-type white dwarf (WD). An unresolved, compact emission knot was discovered to be located $0\farcs166$ away from the WD and it was shown to be centered around a dust-enshrouded low-luminosity star. It was argued that the dust disk and evaporated gas (photoionized by the hot WD) around the companion are remnants of a disk formed by wind material captured from the WD progenitor when it was an asymptotic giant branch (AGB) star. In this paper, we assess the hot WD to determine its atmospheric and stellar parameters. We performed a model-atmosphere analysis of ultraviolet (UV) and optical spectra. We found $T_{\rm eff} = 105,000 \pm 5000$ K, $\log g = 7.4 \pm 0.4$, and a solar helium abundance (He $= 0.25 \pm 0.1$, mass fraction). We measured the abundances of ten more species (C, N, O, F, Si, P, S, Ar, Fe, Ni) and found essentially solar abundance values, indicating that radiation-driven wind mass-loss, with a theoretical rate of $\log(\dot{M}/{\rm M}_\odot/{\rm yr}) = -11.0^{+1.1}_{-0.8}$ prevents the gravitational separation of elements in the photosphere. The WD has a mass of $M/{\rm M}_\odot = 0.58^{+0.12}_{-0.04}$ and its post-AGB age ($\log(t_{\rm evol}/{\rm yr}) = 3.60^{+1.26}_{-0.09}$) is compatible with the PN kinematical age of $\log(t_{\rm PN}/{\rm yr}) = 4.2$. In addition, we examined the UV spectrum of the hot nucleus of a similar object with a compact emission region, TOL 26 (PN G298.0+34.8), and found that it is a slightly cooler DAOZ WD ($T_{\rm eff} \approx 85,000$ K), but this WD shows signatures of gravitational settling of heavy elements.

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Chemistry in the dIrr galaxy Leo A

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We present chemical abundance determinations of two H II regions in the dIrr galaxy Leo A, from GTC OSIRIS long-slit

spectra. Both H II regions are of low excitation and seem to be ionised by stars later than O8V spectral type. In one of the H II regions we used the direct method: O^{+2} ionic abundance was calculated using an electronic temperature determined from the [O III] $\lambda\lambda$4363/5007 line ratio; ionic abundances of O^+, N^+, and S^+ were calculated using a temperature derived from a parameterised formula. O, N and S total abundances were calculated using Ionisation Correction Factors from the literature for each element. Chemical abundances using strong-line methods were also determined, with similar results. For the second H II region, no electron temperature was determined thus the direct method cannot be used. We computed photoionisation structure models for both H II regions in order to determine their chemical composition from the best-fitted models. It is confirmed that Leo A in a very low metallicity galaxy, with $12 + \log(O/H) = 7.4 \pm 0.2$, $\log(N/O) = -1.6$, and $\log(S/O) = -1.1$. Emission lines of the only PN detected in Leo A were reanalysed and a photo-ionisation model was computed. This PN shows $12 + \log(O/H)$ very similar to the ones of the H II regions and a low N abundance, although its $\log(N/O)$ ratio is much larger than the values of the H II regions. Its central star seems to have had an initial mass lower than 2 $M_\odot$.

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The coordinated radio and infrared survey for high-mass star formation. IV: A new radio selected sample of compact Galactic planetary nebulæ

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We present a new radio-selected sample of PNe from the CORNISH survey. This is a radio continuum survey of the inner Galactic plane covering Galactic longitude, $10^\circ < l < 65^\circ$ and latitude, $|b| < 1^\circ$ with a resolution of $1\farcs5$ and sensitivity better than 0.4 mJy beam^{-1}. The radio regime, being unbiased by dust extinction, allows for a more complete sample selection, especially towards the Galactic mid-plane. Visual inspection of the CORNISH data, in combination with data from multi-wavelength surveys of the Galactic plane, allowed the CORNISH team to identify 169 candidate PNe. Here, we explore the use of multi-wavelength diagnostic plots and analysis to verify and classify the candidate PNe. We present the multi-wavelength properties of this new PNe sample. We find 90 new PNe, of which 12 are newly discovered and 78 are newly classified as PN. A further 47 previously suspected PNe are confirmed as such from the analysis presented here and 24 known PNe are detected. Eight sources are classified as possible PNe or other source types. Our sample includes a young sub-sample, with physical diameters < 0.12 pc, brightness temperatures (> 1000 K) and located closer than 7 kpc. Within this sample is a water-maser PN with a spectral index of -0.55 ± 0.08, which indicates non-thermal radio emission. Such a radio-selected sample, unaffected by extinction, will be particularly useful to compare with population synthesis models and should contribute to the understanding of the formation and evolution of PNe.

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Massive star population of the Virgo Cluster galaxy NGC 4535

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We analyzed the massive star population of the Virgo Cluster galaxy NGC 4535 using archival *Hubble* Space Telescope Wide Field Planetary Camera 2 images in filters F555W and F814W, equivalent to Johnson V and Kron–Cousins I. We performed high precision point spread function fitting photometry of 24 353 sources including 3762 candidate blue supergiants, 841 candidate yellow supergiants, and 370 candidate red supergiants. We estimated the ratio of blue to red supergiants as a decreasing function of galactocentric radius. Using Modules for Experiments in Stellar Astrophysics (MESA) isochrones at solar metallicity, we defined the luminosity function and estimated the star formation history of the galaxy over the last 60 Myrs. We conducted a variability search in the V and I filters using three variability indexes: the median absolute deviation, the interquartile range, and the inverse von-Neumann ratio. This analysis yielded 120 new variable candidates with absolute magnitudes ranging from $M_V = -4$ to -11 mag. We used the MESA evolutionary tracks at solar metallicity to classify the variables based on their absolute magnitude and their position on the color–magnitude diagram. Among the new candidate variable sources are eight candidate variable red supergiants, three candidate variable yellow supergiants and one candidate luminous blue variable, which we suggest for follow-up observations.

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New Galactic planetary nebulæ selected by radio and multi-wavelength characteristics

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We have used the Cornish radio catalogue combined with the use of multi-wavelength data to identify 62 new planetary nebula (PN) candidates close to the Galactic mid-plane. Of this sample 11 have weak optical counterparts in deep narrow band Hα imaging that allows their spectroscopic follow-up. We have observed eight of these candidates spectroscopically, leading to the confirmation of 7 out of 8 as PNe. All but one of our sample of newly detected PNe appear to be of Type I chemistry with very large [N II]/Hα ratios. This indicates that our selection method heavily favours detection of this kind of PN. Cornish is a low Galactic latitude survey where young objects and Type I PNe (thought to derive from higher mass progenitors) are more plentiful, but where optical extinction is large. The very high success rate in correctly identifying PNe in this zone proves the efficacy of our radio and multiple multi-wavelength diagnostic tools used to successfully predict and then confirm their PN nature, at least in the cases where an optical counterpart is found and has been observed. The study reinforces the effective use of a combination of multi-wavelength and optical data in the identification of new Galactic PNe and especially those of Type I chemistries

whose dusty environments often prevents their easy detection in the optical regime alone.

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Ensemble properties of the white dwarf population of the old, solar metallicity open star cluster Messier 67

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White dwarfs are excellent forensic tools for studying end-of-life issues surrounding low- and intermediate-mass stars, and the old, solar-metallicity open star cluster Messier 67 is a proven laboratory for the study of stellar evolution for solar-type stars. In this paper, we present a detailed spectroscopic study of brighter ($M_g < 12.4$ mag) white dwarfs in Messier 67, and, in combination with previously-published proper motion membership determinations, we identify a clean, representative sample of cluster white dwarfs, including 13 members with hydrogen-dominated atmospheres, at least one of which is a candidate double degenerate, and 5 members with helium-dominated atmospheres. Using this sample we test multiple predictions surrounding the final stages of stellar evolution in solar type stars. In particular, the stochasticity of the integrated mass lost by ~ 1.5-$M_\odot$ stars is less than 7% of the white dwarf remnant mass. We identify white dwarfs likely resulting from binary evolution, including at least one blue straggler remnant and two helium core white dwarfs. We observe no evidence of a significant population of helium core white dwarfs formed by enhanced mass loss on the red giant branch of the cluster. The distribution of white dwarf atmospheric compositions is fully consistent with that in the field, limiting proposed mechanisms for the suppression of helium atmosphere white dwarf formation in star clusters. In short, the white dwarf population of Messier 67 is fully consistent with basic predictions of single- and multiple-star stellar evolution theories for solar-metallicity stars.

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A new method to identify subclasses among AGB stars using Gaia and 2MASS photometry

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Aims: We explore the wealth of high-quality photometric data provided by data release 2 (DR2) of the Gaia mission for long-period variables (LPVs) in the Large Magellanic Cloud (LMC). Our goal is to identify stars of various types and masses along the asymptotic giant branch.
Methods: For this endeavour, we developed a new multi-band approach combining Wesenheit functions $W_{RP;BP-RP}$ and $W_{Ks;J-Ks}$ in the Gaia BP, RP, and 2MASS J, K_s spectral ranges, respectively, and use a new diagram, $(W_{RP;BP-RP} - W_{Ks;J-Ks})$ versus K_s to distinguish between different kinds of stars in our sample of LPVs. We used stellar population synthesis models to validate our approach.

Results: We demonstrate the ability of the new diagram to discriminate between O- and C-rich objects, and to identify low-mass, intermediate-mass, and massive O-rich red giants, as well as extreme C-rich stars. Stellar evolution and population synthesis models guide the interpretation of the results, highlighting the diagnostic power of the new tool to discriminate between stellar initial masses, chemical properties, and evolutionary stages.

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Post-common envelope binary systems experiencing helium-shell driven stable mass transfer

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We evolve stellar models to study the common envelope (CE) interaction of an early asymptotic giant branch star of initial mass 5 $M_\odot$ with a companion star of mass ranging from 0.1 to 2 $M_\odot$. We model the CE as a fast stripping phase in which the primary experiences rapid mass loss and loses about 80 per cent of its mass. The post-CE remnant is then allowed to thermally readjust during a Roche-lobe overflow (RLOF) phase and the final binary system and its orbital period are investigated. We find that the post-CE RLOF phase is long enough to allow nuclear burning to proceed in the helium shell. By the end of this phase, the donor is stripped of both its hydrogen and helium and ends up as carbon-oxygen white dwarf of mass ~ 0.8 $M_\odot$. We study the sensitivity of our results to initial conditions of different companion masses and orbital separations at which the stripping phase begins. We find that the companion mass affects the final binary separation and that helium-shell burning causes the star to refill its Roche lobe leading to post-CE RLOF. Our results show that double mass transfer in such a binary interaction is able to strip the helium and hydrogen layers from the donor star without the need for any special conditions or fine tuning of the binary parameters.

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When nature tries to trick us. An eclipsing eccentric close binary superposed on the central star of the planetary nebula M 3-2

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Bipolar planetary nebulae (PNe) are thought to result from binary star interactions and, indeed, tens of binary central stars of PNe have been found, in particular using photometric time-series that allow detecting post-common envelope systems. Using photometry at the NTT in La Silla we have studied the bright object close to the centre of PN M 3-2 and found it to be an eclipsing binary with an orbital period of 1.88 days. However, the components of the binary appear to be two A or F stars, of almost equal masses, and are thus too cold to be the source of ionisation of the nebula. Using deep images of the central star obtained in good seeing, we confirm a previous result that the central star is more likely a much fainter star, located $2''$ away from the bright star. The eclipsing binary is thus a chance alignment on top of the planetary nebula. We also studied the nebular abundance and confirm it to be a Type I PN.

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Quasi-simultaneous 43 and 86 GHz SiO maser observations and potential bias in the BAaDE survey are resolved

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We observed the 43 GHz $v = 1$, 2, and 3 and 86 GHz $v = 1$ SiO maser transitions quasi-simultaneously for a Mira-variable-dominated sample of over 80 sources from the Bulge Asymmetries and Dynamical Evolution (BAaDE) project, using ATCA, and statistically compared the relative line strengths. On average, the 43 GHz $v = 1$ line is brighter than the 86 GHz $v = 1$ line by a factor of 1.36 ± 0.15. As a result, an 86 GHz $v = 1$ observed sample can be observed to 85.9% of the distance of a 43 GHz $v = 1$ observed sample using the same sensitivity. We discuss what impact this may have on the BAaDE Galactic plane survey using the VLA and ALMA. Despite fewer $v = 3$ detections, specific trends are discerned or strengthened when the 43 GHz $v = 3$ line is detected. In particular the 43 and 86 GHz $v = 1$ lines are on average equal for sources with no detectable 43 GHz $v = 3$ emission, but the 43 GHz $v = 1$ line strength is on average about twice as bright as the 86 GHz $v = 1$ line for sources with detectable 43 GHz $v = 3$ emission. Some weak correlations are found between line strengths and Midcourse Space Experiment flux densities and colors, which are tightened when considering only sources with detectable 43 GHz $v = 3$ emission. We discuss these trends in the context of a radiative pumping model to highlight how the 43 GHz $v = 3$ line, when coupled with the $v = 1$ and $v = 2$ lines, can further our understanding of variable conditions like density in the circumstellar envelopes.

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The inside-out planetary nebula around a born-again star

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Planetary nebulæ are ionized clouds of gas formed by the hydrogen-rich envelopes of low- and intermediate-mass stars ejected at late evolutionary stages. The strong UV flux from their central stars causes a highly stratified ionization structure, with species of higher ionization potential closer to the star. Here, we report on the exceptional case of HuBi 1, a double-shell planetary nebula whose inner shell presents emission from low-ionization species close to the star and emission from high-ionization species farther away. Spectral analysis demonstrates that the inner shell of HuBi 1 is excited by shocks, whereas its outer shell is recombining. The anomalous excitation of these shells can be traced to its low-temperature [WC10] central star whose optical brightness has declined continuously by 10 magnitudes in a period of 46 years. Evolutionary models reveal that this star is the descendant of a low-mass star (≈ 1.1 $M_\odot$) that has experienced a "born-again" event whose ejecta shock-excite the inner shell. HuBi 1 represents the missing link in the formation of metal-rich central stars of planetary nebulæ from low-mass progenitors, offering unique insight regarding the future evolution of the born-again Sakurai's object. Coming from a solar-mass progenitor, HuBi 1 represents a potential end-state for our Sun.

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The excitation mechanisms and evolutionary stages of UWISH$_2$ planetary nebula candidates

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We present medium-resolution K-band long-slit spectroscopy of 29 true, likely, possible and candidate Galactic Plane planetary nebulæ (PNe) from the UWISH$_2$ survey – many of which have only been recently discovered. These objects are bright in molecular hydrogen (H_2) emission, and many have bipolar morphologies. Through the detection of the Brγ emission line, which traces ionized hydrogen, we find that the majority of the candidate PNe are indeed likely to be PNe, while 2 of the targets are more likely young stellar objects (YSOs) or pre-planetary nebulæ (pPNe). We detect Brγ in 13 objects which have no detection in IPHAS or SHS Hα surveys. This implies they are potential members of the little-known optically-obscured PN population, hidden from wide-field optical surveys. We use the spatial extent of the H_2 1–0 S(1) and Brγ lines to estimate the evolutionary stage of our targets, and find that W-BPNe (bipolar PNe with pinched waist morphologies) are likely to be younger objects, while R-BPNe (bipolar PNe with large ring structures) are more evolved. We use line ratios to trace the excitation mechanism of the H_2, and find the 1–0 S(1) / 2–1 S(1) and 1–0 S(1) / Brγ ratios are higher for R-BPNe, implying the H_2 is thermally excited. However, in W-BPNe, these ratios are lower, and so UV-fluorescence may be contributing to the excitation of H_2.

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Seismic characterization of red giants going through the helium-core flash

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First-ascent red giants in the approximate mass range $0.7 \lesssim M/\mathrm{M}_\odot \lesssim 2$ ignite helium in their degenerate core as a flash. Stellar evolution codes predict that the He flash consists of a series of consecutive subflashes. Observational evidence of the existence of the He flash and subflashes is lacking. The detection of mixed modes in red giants from space missions CoRoT and *Kepler* has opened new opportunities to search for such evidence. During a subflash, the He burning shell is convective, which splits the cavity of gravity modes in two. We here investigate how this additional cavity modifies the oscillation spectrum of the star. We also address the question of the detectability of the modes, to determine whether they could be used to seismically identify red giants passing through the He flash. We calculate the asymptotic mode frequencies of stellar models going through a He subflash using the JWKB approximation. To predict the detectability of the modes, we estimate their expected heights, taking into account the effects of radiative damping in the core. Our results are then compared to the oscillation spectra obtained by calculating numerically the mode frequencies during a He subflash. We show that during a He subflash, the detectable oscillation spectrum mainly consists of modes trapped in the acoustic cavity and in the outer g-mode cavity. The spectrum should thus at first sight resemble that of a core-helium-burning giant. However, we find a list of clear, detectable features that could enable us to identify red giants passing through a He subflash. In particular, during a He subflash, several modes that are trapped in the innermost g-mode cavity are expected to be detectable. We show that these modes could be identified by their frequencies or by their rotational splittings. Other features, such as the measured period spacing of gravity modes or the location of the H-burning shell within the g-mode cavity could also be used to identify stars going through a He subflash. The features derived in this study can now be searched for in the large datasets provided by the CoRoT and *Kepler* missions.

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Conference Papers

Revealing the true nature of Hen 2-428

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The nucleus of Hen 2-428 is a short orbital period (4.2 h) spectroscopic binary, whose status as potential supernova type Ia progenitor has raised some controversy in the literature. We present preliminary results of a thorough analysis of this interesting system, which combines quantitative non-local thermodynamic (non-LTE) equilibrium spectral modelling, radial velocity analysis,multi-band light curve fitting, and state-of-the art stellar evolutionary calculations. Importantly, we find that the dynamical system mass that is derived by using all available He II lines does not exceed the Chandrasekhar mass limit. Furthermore, the individual masses of the two central stars are too small to lead to an SN Ia in case of a dynamical explosion during the merger process.

Oral contribution, published in "Asymmetrical Planetary Nebulæ VII", Galaxies special edition
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Constraining theories of SiO maser polarization: analysis of a $\pi/2$ EVPA change

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The full theory of polarized SiO maser emission from the near-circumstellar environment of Asymptotic Giant Branch stars has been the subject of debate, with theories ranging from classical Zeeman origins to predominantly non-Zeeman anisotropic excitation or propagation effects. Features with an internal electric vector position angle (EVPA) rotation of $\sim \pi/2$ offer unique constraints on theoretical models. In this work, results are presented for one such feature that persisted across five epochs of SiO $\nu = 1$, $J = 1$–0 VLBA observations of TX Cam. We examine the fit to the predicted dependence of linear polarization and EVPA on angle (θ) between the line of sight and the magnetic field against theoretical models. We also present results on the dependence of m_c on θ and their theoretical implications. Finally, we discuss potential causes of the observed differences, and continuing work.

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Review Paper

Population synthesis of binary stars

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Many aspects of the evolution of stars, and in particular the evolution of binary stars, remain beyond our ability to model them in detail. Instead, we rely on observations to guide our often phenomenological models and pin down uncertain model parameters. To do this statistically requires population synthesis. Populations of stars modelled on computers are compared to populations of stars observed with our best telescopes. The closest match between observations and models provides insight into unknown model parameters and hence the underlying astrophysics. In this brief review, we describe the impact that modern big-data surveys will have on population synthesis, the large parameter space problem that is rife for the application of modern data science algorithms, and some examples of how population synthesis is relevant to modern astrophysics.

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Available from https://arxiv.org/abs/1808.06883

Announcement

Fizeau exchange visitors program call for applications (deadline Sep. 15)

Dear colleagues!

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 September 15.
Fellowships can be awarded for missions to be carried out between November 2018 and May 2019!

Further informations and application forms can be found at 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