THE AGB NEWSLETTER

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Editorial

Dear Colleagues,

It is our pleasure to present you the 217$^{\rm th}$ issue of the AGB Newsletter. Two papers present high-resolution images of L_2 Puppis. There is a lot of work on nucleosynthesis, in particular of fluorine. And lots more.

We hope to see many of you at the IAU General Assembly in the coming fortnight!

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

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

Food for Thought

This month's thought-provoking statement is:

How can one distinguish a massive AGB star from a low-mass red supergiant?

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

Refereed Journal Papers

The dust disk and companion of the nearby AGB star L_2 Puppis

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The bright southern star L_2 Pup is a particularly prominent asymptotic giant branch (AGB) star, as its distance of 64 pc makes it the nearest of its type. We report new adaptive optics observations of L_2 Pup at visible wavelengths with the SPHERE/ZIMPOL instrument of the VLT that confirm the presence of the circumstellar dust disk at high inclination discovered recently by Kervella et al. (2014b). The signature of the three-dimensional structure of the disk is clearly observed in the map of the degree of linear polarization $p_{\rm L}$. We identify the inner rim of the disk through its polarimetric signature at a radius of 6 au from the AGB star. The ZIMPOL intensity images in the V and R bands also reveal a close-in secondary source at a projected separation of 2 au from the primary. The identification of the spectral type of this companion is uncertain due to the strong reddening from the disk, but its photometry suggests that it is a late K giant, of comparable mass to the AGB star. We present refined physical parameters for the dust disk derived using the RADMC-3D radiative transfer code. We also interpret the $p_{\rm L}$ map using a simple polarization model to infer the three-dimensional structure of the envelope. Interactions between the inner binary system and the disk apparently form spiral structures that propagate along the orthogonal axis to the disk to form streamers. Two dust plumes propagating orthogonally to the disk are also detected. They originate in the inner stellar system, and are possibly related to the interaction of the wind of the two stars with the material in the disk. Based on the morphology of the envelope of L_2 Pup, we propose that this star is at an early stage of the formation of a bipolar planetary nebula.

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Hu 1-2: a metal-poor bipolar planetary nebula with fast collimated outflows

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We present narrow-band optical and near-IR imaging and optical long-slit spectroscopic observations of Hu 1-2, a Galactic planetary nebula (PN) with a pair of [N II]-bright, fast-moving (> 340 km s^{-1}) bipolar knots. Intermediate-dispersion spectra are used to derive physical conditions and abundances across the nebula, and high-dispersion spectra to study the spatio-kinematical structure. Generally Hu 1-2 has high He/H (≈ 0.14) and N/O ratios (≈ 0.9), typical of Type I PNe. On the other hand, its abundances of O, Ne, S, and Ar are low as compared with the average abundances of Galactic Bulge and Disc PNe. The position-velocity maps can be generally described as an hour-glass shaped nebula with bipolar expansion, although the morphology and kinematics of the innermost regions cannot be satisfactorily

explained with a simple, tilted equatorial torus. The spatio-kinematical study confines the inclination angle of its major axis to be within 10° of the plane of sky. As in the irradiated bow-shocks of IC 4634 and NGC 7009, there is a clear stratification in the emission peaks of [O III], Hα, and [N II] in the northwest (NW) knot of Hu 1-2. Fast collimated outflows in PNe exhibit higher excitation than other low-ionization structures. This is particularly the case for the bipolar knots of Hu 1-2, with He II emission levels above those of collimated outflows in other Galactic PNe. The excitation of the knots in Hu 1-2 is consistent with the combined effects of shocks and UV radiation from the central star. The mechanical energy and luminosity of the knots are similar to those observed in the PNe known to harbor a post-common envelope (post-CE) close binary central star.

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An extreme high-velocity bipolar outflow in the pre-planetary nebula IRAS 08005−2356

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We report interferometric mapping of the bipolar pre-planetary nebula IRAS 08005−2356 with an angular-resolution of $\sim 1''$–$5''$, using the Submillimeter Array (SMA), in the ^{12}CO $J = 2$–1, 3–2, ^{13}CO $J = 2$–1 and SiO $J = 5$–4 ($v = 0$) lines. Single-dish observations, using the SMT 10-m, were made in these lines as well as in the CO $J = 4$–3 and SiO $J = 6$–5 ($v = 0$) lines. The lines profiles are very broad, showing the presence of a massive (> 0.1 M$_\odot$), extreme high-velocity outflow ($v \sim 200$ km s^{-1}) directed along the nebular symmetry axis derived from the HST imaging of this object. The outflow's scalar momentum far exceeds that available from radiation pressure of the central post-AGB star, and it may be launched from an accretion disk around a main-sequence companion. We provide indirect evidence for such a disk from its previously published, broad Hα emission profile, which we propose results from Lyβ emission generated in the disk followed by Raman scattering in the innermost regions of a fast, neutral wind.

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The origin of fluorine: abundances in AGB carbon stars revisited

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Revised spectroscopic parameters for the HF molecule and a new CN line list in the 2.3 μm region have been recently available, allowing a revision of the F content in AGB stars.AGB carbon stars are the only observationally confirmed sources of fluorine. Nowadays there is not a consensus on the relevance of AGB stars in its Galactic chemical evolution. The aim of this article is to better constrain the contribution of these stars with a more accurate estimate of their fluorine abundances. Using new spectroscopic tools and LTE spectral synthesis, we redetermine fluorine abundances from several HF lines in the K-band in a sample of Galactic and extragalactic AGB carbon stars of spectral types N, J and SC spanning a wide range of metallicities. On average, the new derived fluorine abundances are systematically lower by 0.33 dex with respect to previous determinations. This may derive from a combination of the lower excitation energies of the HF lines and the larger macroturbulence parameters used here as well as from the new adopted CN line list. Yet, theoretical nucleosynthesis models in AGB stars agree with the new fluorine determinations at solar metallicities. At low metallicities, an agreement between theory and observations can be found by handling in a different way the radiative/convective interface at the base of the convective envelope. New fluorine spectroscopic

measurements agree with theoretical models at low and at solar metallicity. Despite this, complementary sources are needed to explain its observed abundance in the solar neighbourhood.

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Formation of H_2–He substellar bodies in cold conditions: gravitational stability of binary mixtures in a phase transition

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Context: Molecular clouds consist typically of 3/4 H_2, 1/4 He and traces of heavier elements. In an earlier work we showed that at very low temperatures and high densities, H_2 can be in a phase transition leading to the formation of ice clumps as large as comets, or even planets. However, He has very different chemical properties and no phase transition is expected before H_2 in dense ISM conditions. The gravitational stability of fluid mixtures has been studied before, but not including a phase transition.
Aims: We study the gravitational stability of binary fluid mixtures with special emphasis if one component is in a phase transition. The results are aimed at applications in molecular cloud conditions.
Methods: First, we study the gravitational stability of van der Waals fluid mixtures using linearised analysis and examine virial equilibrium conditions using the Lennard-Jones inter-molecular potential. Then, combining the Lennard-Jones and gravitational potentials, the non-linear dynamics of fluid mixtures are studied by computer simulations using the molecular dynamics code LAMMPS.
Results: Besides the classical ideal-gas Jeans instability criterion, a fluid mixture is always gravitationally unstable if it is in a phase transition, because compression does not increase pressure, but the condensed phase fraction. In unstable situations the species can separate: in some conditions He precipitates faster than H_2, while in other conditions the converse occurs. Also, for an initial gas phase collapse the geometry is essential: contrary to spherical or filamentary collapses, sheet-like collapses starting below 15 K allow to easily reach H_2 condensation conditions because then it is the fastest, and both the increase of heating and opacity are limited.
Conclusions: Depending on density, temperature and mass, either rocky H_2 planetoids, or gaseous He planetoids form. H_2 planetoids are favoured by high density, low temperature and low mass, while He planetoids need more mass and can form at temperature well above the critical one.

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New observations and models of circumstellar CO line emission of AGB stars in the *Herschel* SUCCESS programme

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Context: Asymptotic giant branch (AGB) stars are in one of the latest evolutionary stages of low to intermediate-mass stars. Their vigorous mass loss has a significant effect on the stellar evolution, and is a significant source of heavy

elements and dust grains for the interstellar medium. The mass-loss rate can be well traced by carbon monoxide (CO) line emission.
Aims: We present new *Herschel* HIFI and IRAM 30-m telescope CO line data for a sample of 53 Galactic AGB stars. The lines cover a fairly large range of excitation energy from the $J = 1 \rightarrow 0$ line to the $J = 9 \rightarrow 8$ line, and even the $J = 14 \rightarrow 13$ line in a few cases. We perform radiative transfer modelling for 38 of these sources to estimate their mass-loss rates.
Methods: We used a radiative transfer code based on the Monte Carlo method to model the CO line emission. We assume spherically symmetric circumstellar envelopes that are formed by a constant mass-loss rate through a smoothly accelerating wind.
Results: We find models that are consistent across a broad range of CO lines for most of the stars in our sample, i.e. a large number of the circumstellar envelopes can be described with a constant mass-loss rate. We also find that an accelerating wind is required to fit, in particular, the higher-J lines and that a velocity law will have a significant effect on the model line intensities. The results cover a wide range of mass-loss rates ($\sim 10^{-8}$ to 2×10^{-5} M$_\odot$ yr^{-1}) and gas expansion velocities (2 to 21.5 km s^{-1}), and include M-, S-, and C-type AGB stars. Our results generally agree with those of earlier studies, although we tend to find slightly lower mass-loss rates by about 40%, on average. We also present "bonus" lines detected during our CO observations.

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Carbon-enhanced metal-poor stars: a window on AGB nucleosynthesis and binary evolution. I. Detailed analysis of 15 binary stars with known orbital periods

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AGB stars are responsible for producing a variety of elements, including carbon, nitrogen, and the heavy elements produced in the slow neutron-capture process (s-elements). There are many uncertainties involved in modelling the evolution and nucleosynthesis of AGB stars, and this is especially the case at low metallicity, where most of the stars with high enough masses to enter the AGB have evolved to become white dwarfs and can no longer be observed. The stellar population in the Galactic Halo is of low mass ($\lesssim$0.85 M$_\odot$) and only a few observed stars have evolved beyond the first giant branch. However, we have evidence that low-metallicity AGB stars in binary systems have interacted with their low-mass secondary companions in the past. The aim of this work is to investigate AGB nucleosynthesis at low metallicity by studying the surface abundances of chemically peculiar very metal-poor stars of the Halo observed in binary systems. To this end we select a sample of 15 carbon- and s-element-enhanced metal-poor (CEMP-s) Halo stars that are found in binary systems with measured orbital periods. With our model of binary evolution and AGB nucleosynthesis, we determine the binary configuration that best reproduces, at the same time, the observed orbital period and surface abundances of each star of the sample. The observed periods provide tight constraints on our model of wind mass transfer in binary stars, while the comparison with the observed abundances tests our model of AGB nucleosynthesis.

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Carbon-enhanced metal-poor stars: a window on AGB nucleosynthesis and binary evolution. II. Statistical analysis of a sample of 67 CEMP-s stars

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Many observed CEMP stars are found in binary systems and show enhanced abundances of s-elements. The origin of the chemical abundances of these CEMP-s stars is believed to be accretion in the past of enriched material from a primary star in the AGB phase. We investigate the mechanism of mass transfer and the process of nucleosynthesis in low-metallicity AGB stars by modelling the binary systems in which the observed CEMP-s stars were formed. For this purpose we compare a sample of 67 CEMP-s stars with a grid of binary stars generated by our binary evolution and nucleosynthesis model. We classify our sample CEMP-s stars in three groups based on the observed abundance of europium. In CEMP$-s/r$ stars the europium-to-iron ratio is more than ten times higher than in the Sun, whereas it is lower than this threshold in CEMP$-s/nr$ stars. No measurement of europium is currently available for CEMP-s/ur stars. On average our models reproduce well the abundances observed in CEMP-s/nr stars, whereas in CEMP-s/r stars and CEMP-s/ur stars the abundances of the light-s elements are systematically overpredicted by our models and in CEMP-s/r stars the abundances of the heavy-s elements are underestimated. In all stars our modelled abundances of sodium overestimate the observations. This discrepancy is reduced only in models that underestimate the abundances of most of the s-elements. Furthermore, the abundance of lead is underpredicted in most of our model stars. These results point to the limitations of our AGB nucleosynthesis model, particularly in the predictions of the element-to-element ratios. Finally, in our models CEMP-s stars are typically formed in wide systems with periods above 10 000 days, while most of the observed CEMP-s stars are found in relatively close orbits with periods below 5 000 days.

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Modelling the observed properties of carbon-enhanced metal-poor stars using binary population synthesis

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The stellar population in the Galactic Halo is characterised by a large fraction of CEMP stars. Most CEMP stars are enriched in s-elements (CEMP-s stars), and some of these are also enriched in r-elements (CEMP-s/r stars). One formation scenario proposed for CEMP stars invokes wind mass transfer in the past from a TP-AGB primary star to a less massive companion star which is presently observed. We generate low-metallicity populations of binary stars to reproduce the observed CEMP-star fraction. In addition, we aim to constrain our wind mass-transfer model and investigate under which conditions our synthetic populations reproduce observed abundance distributions. We compare the CEMP fractions and the abundance distributions determined from our synthetic populations with observations. Several physical parameters of the binary stellar population of the halo are uncertain, e.g., the initial mass function, the mass-ratio and orbital-period distributions, and the binary fraction. We vary the assumptions in our model about these parameters, as well as the wind mass-transfer process, and study the consequent variations of our synthetic CEMP population. The CEMP fractions calculated in our synthetic populations vary between 7% and 17%, a range

consistent with the CEMP fractions among very metal-poor stars recently derived from the SDSS/SEGUE data sample. The results of our comparison between the modelled and observed abundance distributions are different for CEMP-s/r stars and for CEMP-s stars. For the latter, our simulations qualitatively reproduce the observed distributions of C, Na, Sr, Ba, Eu, and Pb. Contrarily, for CEMP-s/r stars our model cannot reproduce the large abundances of neutron-rich elements such as Ba, Eu, and Pb. This result is consistent with previous studies, and suggests that CEMP-s/r stars experienced a different nucleosynthesis history to CEMP-s stars.

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Infrared studies of Nova Scorpii 2014: an outburst in a symbiotic system sans an accompanying blast wave

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Near-IR spectroscopy is presented for Nova Scorpii 2014. It is shown that the outburst occurred in a symbiotic binary system – an extremely rare configuration for a classical nova outburst to occur in but appropriate for the eruption of a recurrent nova of the T CrB class. We estimate the spectral class of secondary as M5 III ± (two sub-classes). The maximum magnitude versus rate of decline (MMRD) relations give an unacceptably large value of 37.5 kpc for the distance. The spectra are typical of the He/N class of novæ with strong He sc i and H lines. The profiles are broad and flat topped with full width at zero intensities (FWZIs) approaching 9 000–10 000 km s^{-1} and also have a sharp narrow component superposed which is attributable to emission from the giant's wind. Hot shocked gas, accompanied by X-rays and γ-rays, is expected to form when the high velocity ejecta from the nova plows into the surrounding giant wind. Although X-ray emission was observed no γ-ray emission was reported. It is also puzzling that no signature of a decelerating shock is seen in the near-infrared (NIR), seen in similar systems like RS Oph, V745 Sco and V407 Cyg, as rapid narrowing of the line profiles. The small outburst amplitude and the giant secondary strongly suggest that Nova Sco 2014 could be a recurrent nova.

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The abundance of fluorine in normal G and K stars of the Galactic thin disk

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The abundance of fluorine is determined from the (2–0) R9 2.3358 μm feature of the molecule HF for several dozen normal G and K stars in the Galactic thin disk from spectra obtained with the Phoenix IR spectrometer on the 2.1-m telescope at Kitt Peak. The abundances are analyzed in the context of Galactic chemical evolution to explore the contributions of supernovæ and asymptotic giant branch (AGB) stars to the abundance of fluorine in the thin disk. The average abundance of fluorine in the thin disk is found to be [F/Fe] $= +0.23 \pm 0.03$, and the [F/Fe] ratio is flat or declines slowly with metallicity in the range from $-0.6 <$ [Fe/H] $< +0.3$, within the limits of our estimated uncertainty. The measured abundance of fluorine and lack of variation with metallicity in Galactic thin disk stars suggest neutrino spallation in Type II supernovæ contributes significantly to the Galactic fluorine abundance, although contributions from AGB stars may also be important.

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A remarkable recurrent nova in M31: Discovery and optical/UV observations of the predicted 2014 eruption

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The Andromeda Galaxy recurrent nova M31N 2008-12a had been caught in eruption eight times. The inter-eruption period of M31N 2008-12a is ~ 1 year, making it the most rapidly recurring system known, and a strong single-degenerate Type Ia Supernova progenitor candidate. Following the 2013 eruption, a campaign was initiated to detect the predicted 2014 eruption and to then perform high cadence optical photometric and spectroscopic monitoring using ground-based telescopes, along with rapid UV and X-ray follow-up with the Swift satellite. Here we report the results of a high cadence multicolour optical monitoring campaign, the spectroscopic evolution, and the UV photometry. We also discuss tantalising evidence of a potentially related, vastly-extended, nebulosity. The 2014 eruption was discovered, before optical maximum, on October 2, 2014. We find that the optical properties of M31N 2008-12a evolve faster than all Galactic recurrent novæ known, and all its eruptions show remarkable similarity both photometrically and spectroscopically. Optical spectra were obtained as early as 0.26 days post maximum, and again confirm the nova nature of the eruption. A significant deceleration of the inferred ejecta expansion velocity is observed which may be caused by interaction of the ejecta with surrounding material, possibly a red giant wind. We find a low ejected mass and low ejection velocity, which are consistent with high mass-accretion rate, high mass white dwarf, and short recurrence time models of novæ. We encourage additional observations, especially around the predicted time of the next eruption, towards the end of 2015.

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Evolution and nucleosynthesis of helium-rich asymptotic giant branch models

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There is now strong evidence that some stars have been born with He mass fractions as high as $Y \approx 0.40$ (e.g., in

ω Centauri). However, the advanced evolution, chemical yields, and final fates of He-rich stars are largely unexplored. We investigate the consequences of He-enhancement on the evolution and nucleosynthesis of intermediate-mass asymptotic giant branch (AGB) models of 3, 4, 5, and 6 $M_\odot$ with a metallicity of $Z = 0.0006$ ([Fe/H] ≈ -1.4). We compare models with He-enhanced compositions ($Y = 0.30$, 0.35, 0.40) to those with primordial He ($Y = 0.24$). We find that the minimum initial mass for C burning and super-AGB stars with CO(Ne) or ONe cores decreases from above our highest mass of 6 $M_\odot$ to $\sim$ 4–5 $M_\odot$ with $Y = 0.40$. We also model the production of trans-Fe elements via the slow neutron-capture process (s-process). He-enhancement substantially reduces the third dredge-up efficiency and the stellar yields of s-process elements (e.g., 90% less Ba for 6 $M_\odot$, $Y = 0.40$). An exception occurs for 3 $M_\odot$, where the near-doubling in the number of thermal pulses with $Y = 0.40$ leads to $\sim$ 50% higher yields of Ba-peak elements and Pb if the ^{13}C neutron source is included. However, the thinner intershell and increased temperatures at the base of the convective envelope with $Y = 0.40$ probably inhibit the ^{13}C neutron source at this mass. Future chemical evolution models with our yields might explain the evolution of s-process elements among He-rich stars in ω Centauri.

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Oscillatory convective modes in red giants: a possible explanation of the long secondary periods

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We discuss properties of oscillatory convective modes in low-mass red giants, and compare them with observed properties of the long secondary periods (LSPs) of semi-regular red giant variables. Oscillatory convective modes are very nonadiabatic g^- modes and they are present in luminous stars, such as red giants with $\log L/L_\odot \gtrsim 3$. Finite amplitudes for these modes are confined to the outermost nonadiabatic layers, where the radiative energy flux is more important than the convective energy flux. The periods of oscillatory convection modes increase with luminosity, and the growth times are comparable to the oscillation periods. The LSPs of red giants in the Large Magellanic Cloud (LMC) are observed to lie on a distinct period–luminosity sequence called sequence D. This sequence D period–luminosity relation is roughly consistent with the predictions for dipole oscillatory convective modes in AGB models if we adopt a mixing length of 1.2 pressure scale height ($\alpha = 1.2$). However, the effective temperature of the red-giant sequence of the LMC is consistent to models with $\alpha = 1.9$, which predict periods too short by a factor of two.

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Kepler rapidly rotating giant stars

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Rapidly rotating giant stars are relatively rare and may represent important stages of stellar evolution, resulting from stellar coalescence of close binary systems or accretion of substellar companions by their hosting stars. In the present Letter, we report 17 giant stars observed in the scope of the *Kepler* space mission exhibiting rapid rotation behavior. For the first time, the abnormal rotational behavior for this puzzling family of stars is revealed by direct measurements of rotation, namely from photometric rotation period, exhibiting a very short rotation period with values ranging from 13 to 55 days. This finding points to remarkable surface rotation rates, up to 18 times the rotation of the Sun.

These giants are combined with six others recently listed in the literature for mid-infrared (IR) diagnostics based on Wide-field Infrared Survey Explorer information, from which a trend for an IR excess is revealed for at least one-half of the stars, but at a level far lower than the dust excess emission shown by planet-bearing main-sequence stars.

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On the red-giant luminosity bump

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The increase in luminosity as a star evolves on the red-giant branch is interrupted briefly when the hydrogen-burning shell reaches the vicinity of the composition discontinuity left behind from the first convective dredge-up. The non-monotonic variation of luminosity causes an accumulation of stars, known as the 'bump', in the distribution of stars in the colour–magnitude diagrams of stellar clusters, which has substantial diagnostic potential. Here I present numerical results on this behaviour and discuss the physical reason for the luminosity variation, with the goal of strengthening the understanding of origin of the phenomenon and hence of its diagnostic potential.

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Chemical abundances in the PN Wray 16-423 in the Sagittarius dwarf spheroidal galaxy: constraining the dust composition

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We performed a detailed analysis of elemental abundances, dust features, and polycyclic aromatic hydrocarbons (PAHs) in the C-rich planetary nebula (PN) Wray 16-423 in the Sagittarius dwarf spheroidal galaxy, based on a unique dataset taken from the Subaru/HDS, MPG/ESO FEROS, HST/WFPC2, and *Spitzer*/IRS. We performed the first measurements of Kr, Fe, and recombination O abundance in this PN. The extremely small [Fe/H] implies that most Fe atoms are in the solid phase, considering into account the abundance of [Ar/H]. The *Spitzer*/IRS spectrum displays broad 16–24-μm and 30-μm features, as well as PAH bands at 6–9 μm and 10–14 μm. The unidentified broad 16–24 μm feature may not be related to iron sulfide (FeS), amorphous silicate, or PAHs. Using the spectral energy distribution model, we derived the luminosity and effective temperature of the central star, and the gas and dust masses. The observed elemental abundances and derived gas mass are in good agreement with asymptotic giant branch nucleosynthesis models for an initial mass of 1.90 $M_{\odot}$ and a metallicity of $Z = 0.004$. We infer that respectively about 80%, 50%, and 90% of the Mg, S, and Fe atoms are in the solid phase. We also assessed the maximum possible magnesium sulfide (MgS) and iron-rich sulfide (Fe50S) masses and tested whether these species can produce the band flux of the observed 30-μm feature. Depending on what fraction of the sulfur is in sulfide molecules such as CS, we conclude that MgS and Fe50S could be possible carriers of the 30-μm feature in this PN.

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s-Process enrichment in the planetary nebula NGC 3918: results from deep échelle spectrophotometry

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The chemical content of the planetary nebula NGC 3918 is investigated through deep, high-resolution ($R \sim 40\,000$) UVES at VLT spectrophotometric data.We identify and measure more than 750 emission lines, making ours one of the deepest spectra ever taken for a planetary nebula. Among these lines we detect very faint lines of several neutron-capture elements (Se, Kr, Rb, and Xe), which enable us to compute their chemical abundances with unprecedented accuracy, thus constraining the efficiency of the s-process and convective dredge-up in NGC 3918's progenitor star. We find that Kr is strongly enriched in NGC 3918 and that Se is less enriched than Kr, in agreement with the results of previous papers and with predicted s-process nucleosynthesis. We also find that Xe is not as enriched by the s-process in NGC 3918 as is Kr and, therefore, that neutron exposure is typical of modestly sub-solar metallicity AGB stars. A clear correlation is found when representing [Kr/O] vs. log(C/O) for NGC 3918 and other objects with detection of multiple ions of Kr in optical data, confirming that carbon is brought to the surface of AGB stars along with s-processed material during third dredge-up episodes, as predicted by nucleosynthesis models. We also detect numerous refractory element lines (Ca, K, Cr, Mn, Fe, Co, Ni, and Cu) and a large number of metal recombination lines of C, N, O, and Ne. We compute physical conditions from a large number of diagnostics, which are highly consistent among themselves assuming a three-zone ionization scheme. Thanks to the high ionization of NGC 3918 we detect a large number of recombination lines of multiple ionization stages of C, N, O and Ne. The abundances obtained for these elements by using recently-determined state-of-the-art ICF schemes or simply adding ionic abundances are in very good agreement, demonstrating the quality of the recent ICF scheme for high ionization planetary nebulæ.

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On infrared excesses associated with Li-rich K giants

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Infrared (IR) excesses around K-type red giants (RGs) have previously been discovered using Infrared Astronomy Satellite (IRAS) data, and past studies have suggested a link between RGs with overabundant Li and IR excesses, implying the ejection of circumstellar shells or disks. We revisit the question of IR excesses around RGs using higher spatial resolution IR data, primarily from the Wide-field Infrared Survey Explorer (WISE). Our goal was to elucidate the link between three unusual RG properties: fast rotation, enriched Li, and IR excess. Our sample of RGs includes those with previous IR detections, a sample with well-defined rotation and Li abundance measurements with no previous IR measurements, and a large sample of RGs asserted to be Li-rich in the literature; we have 316 targets thought to be K giants, about 40% of which we take to be Li-rich. In 24 cases with previous detections of IR excess at low spatial resolution, we believe that source confusion is playing a role, in that either (a) the source that is bright in the optical is not responsible for the IR flux, or (b) there is more than one source responsible for the IR flux as

measured in IRAS. We looked for IR excesses in the remaining sources, identifying 28 that have significant IR excesses by $\sim 20\ \mu$m (with possible excesses for 2 additional sources). There appears to be an intriguing correlation in that the largest IR excesses are all in Li-rich K giants, though very few Li-rich K giants have IR excesses (large or small). These largest IR excesses also tend to be found in the fastest rotators. There is no correlation of IR excess with the carbon isotopic ratio, $^{12}C/^{13}C$. IR excesses by 20 μm, though relatively rare, are at least twice as common among our sample of Li-rich K giants. If dust shell production is a common by-product of Li enrichment mechanisms, these observations suggest that the IR excess stage is very short-lived, which is supported by theoretical calculations. Conversely, the Li-enrichment mechanism may only occasionally produce dust, and an additional parameter (e.g., rotation) may control whether or not a shell is ejected.

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The abundance of $^{28}Si^{32}S$, $^{29}Si^{32}S$, $^{28}Si^{34}S$, and $^{30}Si^{32}S$ in the inner layers of the envelope of IRC +10°216

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We present high spectral resolution mid-IR observations of SiS towards the C-rich AGB star IRC +10°216 carried out with the Texas Échelon-cross-Échelle Spectrograph mounted on the NASA Infrared Telescope Facility. We have identified 204 ro-vibrational lines of $^{28}Si^{32}S$, 26 of $^{29}Si^{32}S$, 20 of $^{28}Si^{34}S$, and 15 of $^{30}Si^{32}S$ in the frequency range 720–790 cm^{-1}. These lines belong to bands v = 1–0, 2–1, 3–2, 4–3, and 5–4, and involve rotational levels with $J_{\rm low} < 90$. About 30 per cent of these lines are unblended or weakly blended and can be partially or entirely fitted with a code developed to model the mid-IR emission of a spherically symmetric circumstellar envelope composed of expanding gas and dust. The observed lines trace the envelope at distances to the star < 35 R$_\star$ ($\simeq 0\farcs7$). The fits are compatible with an expansion velocity of $1 + 2.5(r/{\rm R}_\star - 1)$ km s^{-1} between 1 and 5 R$_\star$, 11 km s^{-1} between 5 and 20 R$_\star$, and 14.5 km s^{-1} outwards. The derived abundance profile of $^{28}Si^{32}S$ with respect to H_2 is 4.9×10^{-6} between the stellar photosphere and 5 R$_\star$, decreasing linearly down to 1.6×10^{-6} at 20 R$_\star$ and to 1.3×10^{-6} at 50 R$_\star$. $^{28}Si^{32}S$ seems to be rotationally under LTE in the region of the envelope probed with our observations and vibrationally out of LTE in most of it. There is a red-shifted emission excess in the $^{28}Si^{32}S$ lines of band v = 1–0 that cannot be found in the lines of bands v = 2–1, 3–2, 4–3, and 5–4. This excess could be explained by an enhancement of the vibrational temperature around 20 R$_\star$ behind the star. The derived isotopic ratios $^{28}Si/^{29}Si$, and $^{32}S/^{34}S$ are 17 and 14, compatible with previous estimates.

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A pilot deep survey for X-ray emission from fuvAGB stars

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We report the results of a pilot survey for X-ray emission from a newly discovered class of AGB stars with far-ultraviolet excesses (fuvAGB stars) using XMM–*Newton* and *Chandra*. We detected X-ray emission in 3 of 6 fuvAGB

stars observed – the X-ray fluxes are found to vary in a stochastic or quasi-periodic manner on roughly hour-long times-scales, and simultaneous UV observations using the Optical Monitor on XMM for these sources show similar variations in the UV flux. These data, together with previous studies, show that X-ray emission is found only in fuvAGB stars. From modeling the spectra, we find that the observed X-ray luminosities are $\sim$ (0.002–0.2) $L_\odot$, and the X-ray emitting plasma temperatures are $\sim$ (35–160) $\times 10^6$ K. The high X-ray temperatures argue against the emission arising in stellar coronæ, or directly in an accretion shock, unless it occurs on a WD companion. However, none of the detected objects is a known WD-symbiotic star, suggesting that if WD companions are present, they are relatively cool (< 20 000 K). In addition, the high X-ray luminosities specifically argue against emission originating in the coronæ of main-sequence companions. We discuss several models for the X-ray emission and its variability and find that the most likely scenario for the origin of the X-ray (and FUV) emission involves accretion activity around a companion star, with confinement by strong magnetic fields associated with the companion and/or an accretion disk around it.

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Identification of a class of low-mass Asymptotic Giant Branch stars struggling to become carbon stars in the Magellanic Clouds

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We have identified a new class of Asymptotic Giant Branch (AGB) stars in the Small and Large Magellanic Clouds (SMC/LMC) using optical to infrared photometry, light curves, and optical spectroscopy. The strong dust production and long-period pulsations of these stars indicate that they are at the very end of their AGB evolution. Period–mass–radius relations for the fundamental-mode pulsators give median current stellar masses of 1.14 $M_\odot$ in the LMC and 0.94 $M_\odot$ in the SMC (with dispersions of 0.21 and 0.18 $M_\odot$, respectively), and models suggest initial masses of < 1.5 $M_\odot$ and < 1.25 $M_\odot$, respectively. This new class of stars includes both O-rich and C-rich chemistries, placing the limit where dredge-up allows carbon star production below these masses. A high fraction of the brightest among them should show S star characteristics indicative of atmospheric C/O $\sim$ 1, and many will form O-rich dust prior to their C-rich phase. These stars can be separated from their less-evolved counterparts by their characteristically red J–[8] colors.

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Evolution, nucleosynthesis and yields of AGB stars at different metallicities. III: intermediate mass models, revised low mass models and the ph-FRUITY interface

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We present a new set of models for intermediate mass AGB stars (4.0, 5.0 and, 6.0 $M_\odot$) at different metallicities ($-2.15 \leq$ [Fe/H] $\leq +0.15$). This integrates the existing set of models for low mass AGB stars ($1.3 \leq M/M_\odot \leq 3.0$)

already included in the FRUITY database. We describe the physical and chemical evolution of the computed models from the Main Sequence up to the end of the AGB phase. Due to less efficient third dredge up episodes, models with large core masses show modest surface enhancements. The latter is due to the fact that the interpulse phases are short and, then, Thermal Pulses are weak. Moreover, the high temperature at the base of the convective envelope prevents it to deeply penetrate the radiative underlying layers. Depending on the initial stellar mass, the heavy elements nucleosynthesis is dominated by different neutron sources. In particular, the *s*-process distributions of the more massive models are dominated by the ^{22}Ne(α,n)^{25}Mg reaction, which is efficiently activated during Thermal Pulses. At low metallicities, our models undergo hot bottom burning and hot third dredge up. We compare our theoretical final core masses to available white dwarf observations. Moreover, we quantify the weight that intermediate mass models have on the carbon stars luminosity function. Finally, we present the upgrade of the FRUITY web interface, now also including the physical quantities of the TP-AGB phase of all the models included in the database (ph-FRUITY).

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The UWISH2 extended H_2 source catalogue

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We present the extended source catalogue for the UKIRT Widefield Infrared Survey for H_2 (UWISH2). The survey is unbiased along the inner Galactic Plane from $l \approx 357°$ to $l \approx 65°$ and $|b| \leq 1.^{\circ}5$ and covers 209 square degrees. A further 42.0 and 35.5 square degrees of high dust column density regions have been targeted in Cygnus and Auriga. We have identified 33200 individual extended H_2 features. They have been classified to be associated with about 700 groups of jets and outflows, 284 individual (candidate) Planetary Nebulæ, 30 Supernova Remnants and about 1300 Photo-Dissociation Regions. We find a clear decline of star formation activity (traced by H_2 emission from jets and photo-dissociation regions) with increasing distance from the Galactic Centre. More than 60% of the detected candidate Planetary Nebulæ have no known counterpart and 25% of all Supernova Remnants have detectable H_2 emission associated with them.

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Tracing the tidal streams of the Sagittarius dSph, and halo Milky Way features, with carbon-rich long-period variables

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We assemble 121 spectroscopically-confirmed halo carbon stars, drawn from the literature, exhibiting measurable variability in the Catalina Surveys. We present their periods and amplitudes, which are used to estimate distances from period–luminosity relationships. The location of the carbon stars – and their velocities when available – allow

us to trace the streams of the Sagittarius (Sgr) dwarf spheroidal galaxy. These are compared to a canonical numerical simulation of the accretion of Sgr. We find that the data match this model well for heliocentric distances of 15–50 kpc, except for a virtual lack of carbon stars in the trailing arm just north of the Galactic Plane, and there is only tentative evidence of the leading arm south of the Plane. The majority of the sample can be attributed to the Sgr accretion. We also find groups of carbon stars which are not part of Sgr; most of which are associated with known halo substructures. A few have no obvious attribution and may indicate new substructure. We find evidence that there may be a structure behind the Sgr leading stream apocentre, at $\sim$ 100 kpc, and a more distant extension to the Pisces Overdensity also at $\sim$ 100 kpc. We study a further 75 carbon stars for which no good period data could be obtained, and for which NIR magnitudes and colours are used to estimate distances. These data add support for the features found at distances beyond 100 kpc.

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A tale of three mysterious spectral features in carbon-rich evolved stars: the 21 μm, 30 μm, and "unidentified infrared" emission features

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The mysterious "21-μm" emission feature seen almost exclusively in the short-lived protoplanetary nebula (PPN) phase of stellar evolution remains unidentified since its discovery two decades ago. This feature is always accompanied by the equally mysterious, unidentified "30-μm" feature and the so-called "unidentified infrared" (UIR) features at 3.3, 6.2, 7.7, 8.6, and 11.3 μm which are generally attributed to polycyclic aromatic hydrocarbon (PAH) molecules. The 30-μm feature is commonly observed in all stages of stellar evolution from the asymptotic giant branch (AGB) through PPN to the planetary nebula phase. We explore the interrelations among the mysterious 21-μm, 30-μm, and UIR features of the 21-μm sources. We derive the fluxes emitted in the observed UIR, 21-μm, and 30-μm features from published ISO or *Spitzer*/IRS spectra. We find that none of these spectral features correlate with each other. This argues against a common carrier (e.g., thiourea) for both the 21-μm feature and the 30-μm feature. This also does not support large PAH clusters as a possible carrier for the 21-μm feature.

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AMBER-NACO aperture-synthesis imaging of the half-obscured central star and the edge-on disk of the red giant L_2 Pup

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The red giant L_2 Pup started a dimming event in 1994, which is considered to be caused by the ejection of dust clouds. We present near-IR aperture-synthesis imaging of L_2 Pup achieved by combining data from VLT/NACO speckle observations and long-baseline interferometric observations with the AMBER instrument of the Very Large Telescope Interferometer (VLTI). We also extracted an 8.7-μm image from the mid-IR VLTI instrument MIDI. Our aim is to spatially resolve the innermost region of the circumstellar environment. The diffraction-limited image at 2.27 μm obtained by bispectrum speckle interferometry with NACO with a spatial resolution of 57 mas shows an elongated component. The aperture-synthesis imaging combining the NACO speckle data and AMBER data (2.2–2.29 μm) with a spatial resolution of 5.6×7.3 mas further resolves not only this elongated component, but also the central star. The

reconstructed image reveals that the elongated component is a nearly edge-on disk with a size of $\sim 180 \times 50$ mas lying in the E–W direction, and furthermore, that the southern hemisphere of the central star is severely obscured by the equatorial dust lane of the disk. The angular size of the disk is consistent with the distance that the dust clouds that were ejected at the onset of the dimming event should have traveled by the time of our observations, if we assume that the dust clouds moved radially. This implies that the formation of the disk may be responsible for the dimming event. The 8.7-μm image with a spatial resolution of 220 mas extracted from the MIDI data taken in 2004 (seven years before the AMBER and NACO observations) shows an approximately spherical envelope without a signature of the disk. This suggests that the mass loss before the dimming event may have been spherical.

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Photometry of variable stars from THU-NAOC transient survey. I: The first 2 years

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In this paper, we report the detections of stellar variabilities from the first 2-year observations of sky area of about 1300 square degrees from the Tsinghua University-NAOC Transient Survey (TNTS). A total of 1237 variable stars (including 299 new ones) were detected with brightness < 18.0 mag and magnitude variation ≥ 0.1 mag on a timescale from a few hours to few hundred days. Among such detections, we tentatively identified 661 RR Lyræ stars, 431 binaries, 72 Semiregular pulsators, 29 Mira stars, 11 slow irregular variables, 11 RS Canum Venaticorum stars, 7 γ Doradus stars, 5 long period variables, 3 W Virginis stars, 3 δ Scuti stars, 2 Anomalous Cepheids, 1 Cepheid, and 1 nova-like star based on their time-series variability index J_s and their phased diagrams. Moreover, we found that 14 RR Lyræ stars show the Blazhko effect and 67 contact eclipsing binaries exhibit the O'Connell effect. Since the period and amplitude of light variations of RR Lyræ variables depend on their chemical compositions, their photometric observations can be used to investigate distribution of metallicity along the direction perpendicular to the Galactic disk. We find that the metallicity of RR Lyræ stars shows large scatter at regions closer to the Galactic plane (e.g., $-3.0 <$ [Fe/H] < 0) but tends to converge at [Fe/H] ~ -1.7 at larger Galactic latitudes. This variation may be related to that the RRAB Lyræ stars in the Galactic Halo come from globular clusters with different metallicity and vertical distances, i.e. OoI and OoII populations, favoring for the dual-halo model.

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Conference Papers

Planetary nebulæ: what can they tell us about close binary evolution?

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It is now clear that a binary pathway is responsible for a significant fraction of planetary nebulæ, and the continually increasing sample of known central binaries means that we are now in a position to begin to use these systems to further our understanding of binary evolution. Binary central stars of planetary nebulæ are key laboratories in understanding the formation processes of a wide-range of astrophysical phenomena – a point well-illustrated by the fact that the only known double-degenerate, super-Chandrasekhar mass binary which will merge in less than a Hubble time is found inside a planetary nebula. Here, I briefly outline our current understanding and avenues for future investigation.

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Stellar granulation and interferometry

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Stars are not smooth. Their photosphere is covered by a granulation pattern associated with the heat transport by convection. The convection-related surface structures have different size, depth, and temporal variations with respect to the stellar type. The related activity (in addition to other phenomena such as magnetic spots, rotation, dust, etc.) potentially causes bias in stellar parameters determination, radial velocity, chemical abundances determinations, and exoplanet transit detections. The rôle of long-baseline interferometric observations in this astrophysical context is crucial to characterize the stellar surface dynamics and correct the potential biases. In this Chapter, we present how the granulation pattern is expected for different kind of stellar types ranging from main sequence to extremely evolved stars of different masses and how interferometric techniques help to study their photospheric dynamics.

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The circumstellar dust of "Born-Again" stars

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We describe the evolution of the carbon dust shells around Very Late Thermal Pulse (VLTP) objects as seen at infrared wavelengths. This includes a 20-year overview of the evolution of the dust around Sakurai's object (to which Olivier made a seminal contribution) and FG Sge. VLTPs may occur during the endpoint of as many as 25% of solar

mass stars, and may therefore provide a glimpse of the possible fate of the Sun.

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The role of binarity in Wolf–Rayet central stars of planetary nebulæ

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Over a hundred planetary nebulæ (PNe) are known to have H-deficient central stars that mimic the spectroscopic appearance of massive Wolf–Rayet stars. The formation of these low-mass Wolf–Rayet stars, denoted [WR] stars, remains poorly understood. While several binary formation scenarios have been proposed, there are too few [WR] binaries known to determine their feasibility. Out of nearly 50 post-common-envelope (post-CE) binary central stars known, only PN G222.8−04.2 ([WC7], $P = 1.26$ d) and NGC 5189 ([WO1], $P = 4.05$ d) have a [WR] component. The available data suggests that post-CE central stars with [WR] components lack main sequence companions and have a wider orbital separation than typical post-CE binaries. There is also some indirect evidence for wide binaries that could potentially lead to the discovery of more [WR] binaries.

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Post-common-envelope Wolf–Rayet central stars of planetary nebulæ

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Nearly 50 post-common-envelope (post-CE) close binary central stars of planetary nebulæ (CSPNe) are now known. Most contain either main sequence or white dwarf (WD) companions that orbit the WD primary in around 0.1–1.0 days. Only PN G222.8−04.2 and NGC 5189 have post-CE CSPNe with a Wolf–Rayet star primary (denoted [WR]), the low-mass analogues of massive Wolf–Rayet stars. It is not well understood how H-deficient [WR] CSPNe form, even though they are relatively common, appearing in over 100 PNe. The discovery and characterisation of post-CE [WR] CSPNe is essential to determine whether proposed binary formation scenarios are feasible to explain this enigmatic class of stars. The existence of post-CE [WR] binaries alone suggests binary mergers are not necessarily a pathway to form [WR] stars. Here we give an overview of the initial results of a radial velocity monitoring programme of [WR] CSPNe to search for new binaries. We discuss the motivation for the survey and the associated strong selection effects. The mass functions determined for PN G222.8−04.2 and NGC 5189, together with literature photometric variability data of other [WR] CSPNe, suggest that of the post-CE [WR] CSPNe yet to be found, most will have WD or subdwarf O/B-type companions in wider orbits than typical post-CE CSPNe (several days or months c.f. less than a day).

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