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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 280$^{\rm th}$ issue of the AGB Newsletter, full of interesting new findings.

Don't miss the review by Conny Aerts on asteroseismology! This is becoming more and more relevant to luminous cool stars.

Due to migration from Google mail to Microsoft Outlook at the institution of the editorial office we have experienced a period of inaccessibility of our e-mail account. Apologies if you have written to us and we haven't responded yet. We hope the issues will be resolved within the coming week – things are just proceeding a lot more slowly at the moment due to complications arising from the Covid-19 restrictions.

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

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

Food for Thought

This month's thought-provoking statement is:

How is convective overshoot best described in a physically motivated way?

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

Three-component modelling of C-rich AGB star winds – V. Effects of frequency-dependent radiative transfer including drift

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Stellar winds of cool carbon stars enrich the interstellar medium with significant amounts of carbon and dust. We present a study of the influence of two-fluid flow on winds where we add descriptions of frequency-dependent radiative transfer (RT). Our radiation hydrodynamic models in addition include stellar pulsations, grain growth and ablation, gas-to-dust drift using one mean grain size, dust extinction based on both the small particle limit (SPL) and Mie scattering, and an accurate numerical scheme. We calculate models at high spatial resolution using 1024 gridpoints and solar metallicities at 319 frequencies, and we discern effects of drift by comparing drift models to non-drift models. Our results show differences of up to 1000 per cent in comparison to extant results. Mass-loss rates and wind velocities of drift models are typically, but not always, lower than in non-drift models. Differences are larger when Mie scattering is used instead of the SPL. Amongst other properties, the mass-loss rates of the gas and dust, dust-to-gas density ratio, and wind velocity show an exponential dependence on the dust-to-gas speed ratio. Yields of dust in the least massive winds increase by a factor 4 when drift is used. We find drift velocities in the range 10–67 km s^{-1}, which is drastically higher than in our earlier works that use grey RT. It is necessary to include an estimate of drift velocities to reproduce high yields of dust and low wind velocities.

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From solar-like to Mira stars: a unifying description of stellar pulsators in the presence of stochastic noise

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We discuss and characterise the power spectral density properties of a model aimed at describing pulsations in stars from the main-sequence to the asymptotic giant branch. We show that the predicted limit of the power spectral density for a pulsation mode in the presence of stochastic noise is always well approximated by a Lorentzian function. While in stars predominantly stochastically driven the width of the Lorentzian is defined by the mode lifetime, in stars where the driving is predominately coherent the width is defined by the amplitude of the stochastic perturbations. In stars where both drivings are comparable, the width is defined by both these parameters and is smaller than that expected from pure stochastic driving. We illustrate our model through numerical simulations and propose a well defined classification of stars into predominantly stochastic (solar-like) and predominately coherent (classic) pulsators. We apply the model to the study of the Mira variable U Per, and the semiregular variable L_2 Pup and, following our classification, conclude that they are both classical pulsators. Our model provides a natural explanation for the change in behaviour of the pulsation amplitude-period relation noted in several earlier works. Moreover, our study of L_2 Pup enables us to test the scaling relation between the mode line width and effective temperature, confirming that an exponential scaling reproduces well the data all the way from the main sequence to the asymptotic giant branch, down to temperatures about 1000 K below what has been tested in previous studies.

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Detection of Pb II in the ultraviolet spectra of three metal-poor stars

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We report the first detection of the Pb II line at 2203.534 Å in three metal-poor stars, using ultraviolet spectra obtained with the Space Telescope Imaging Spectrograph on board the *Hubble* Space Telescope. We perform a standard abundance analysis assuming local thermodynamic equilibrium (LTE) to derive lead (Pb, $Z = 82$) abundances. The Pb II line yields a higher abundance than Pb I lines by $+0.36 \pm 0.34$ dex and $+0.49 \pm 0.28$ dex in the stars HD 94028 and HD 196944, where Pb I lines had been detected previously. The Pb II line is likely formed in LTE, and these offsets affirm previous calculations showing that Pb I lines commonly used as abundance indicators underestimate the Pb abundance in LTE. Pb is enhanced in the *s*-process-enriched stars HD 94028 ([Pb/Fe] $= +0.95 \pm 0.14$) and HD 196944 ([Pb/Fe] $= +2.28 \pm 0.23$), and we show that ^{208}Pb is the dominant Pb isotope in these two stars. The $\log \epsilon$(Pb/Eu) ratio in the *r*-process-enhanced star HD 222925 is 0.76 ± 0.14, which matches the Solar System *r*-process ratio and indicates that the Solar System *r*-process residuals for Pb are, in aggregate, correct. The Th/Pb chronometer in HD 222925 yields an age of 8.2 ± 5.8 Gyr, and we highlight the potential of the Th/Pb chronometer as a relatively model-insensitive age indicator in *r*-process-enhanced stars.

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Discovery of a fast expanding shell in the inside-out born-again planetary nebula HuBi 1 through high-dispersion integral field spectroscopy

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HuBi 1 has been proposed to be member of the rare class of born-again planetary nebulæ (PNe), i.e. its central star

experienced a very late thermal pulse and ejected highly-processed material at high speeds inside the old hydrogen-rich PN. In this letter we present GTC MEGARA integral field spectroscopic observations of the innermost regions of HuBi 1 at high spectral resolution $\simeq$ 16 km s^{-1} and multi-epoch sub-arcsec images obtained $\simeq$ 12 yr apart. The analysis of these data indicates that the inner regions of HuBi 1 were ejected $\simeq$ 200 yr ago and expand at velocities $\simeq$ 300 km s^{-1}, in excellent agreement with the born-again scenario. The unprecedented tomographic capabilities of the GTC MEGARA high-dispersion observations used here reveal that the ejecta in HuBi 1 has a shell-like structure, in contrast to the disrupted disk and jet morphology of the ejecta in other born-again PNe.

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The M supergiant high mas X-ray binary 4U 1954+31

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The X-ray binary 4U 1954+31 has been classified as a Low Mass X-ray Binary (LMXB) containing a M giant and a neutron star (NS). It has also been included in the rare class of X-ray symbiotic binaries (SyXB). The Gaia parallax, infrared colors, spectral type, abundances, and orbital properties of the M star demonstrate that the cool star in this system is not a low mass giant but a high mass M supergiant. Thus, 4U 1954+31 is a High Mass X-ray Binary (HMXB) containing a late-type supergiant. It is the only known binary system of this type. The mass of the M I is 9^{+6}_{-2} M$_\odot$ giving an age of this system in the range 12–50 Myr with the NS no more than 43 Myr old. The spin period of the NS is one of the longest known, 5 hours. The existence of M I plus NS binary systems is in accord with stellar evolution theory, with this system a more evolved member of the HMXB population.

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Formation of sdB-stars via common envelope ejection by substellar companions

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Common envelope (CE) phases in binary systems where the primary star reaches the tip of the red giant branch are discussed as a formation scenario for hot subluminous B-type (sdB) stars. For some of these objects, observations point to very low-mass com- panions. In hydrodynamical CE simulations with the moving-mesh code AREPO, we test whether low-mass objects can successfully unbind the envelope. The success of envelope removal in our simulations critically depends on whether or not the ionization energy released by recombination processes in the expanding material is taken into account. If this energy is thermalized locally, envelope ejection eventually leading to the formation of an sdB star is possible with companion masses down to the brown dwarf range. For even lower companion masses approaching the regime of giant planets, however, envelope removal becomes increasingly difficult or impossible to achieve. Our results are consistent with current observational constraints on companion masses of sdB stars. Based on a semi-analytic model, we suggest a new criterion for the lowest companion mass that is capable of triggering a dynamical response of the primary star thus potentially facilitating the ejection of a CE. This gives an estimate consistent with the findings of our hydrodynamical simulations.

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Rapid evolution of [WC] stars in the Magellanic Clouds

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We obtained new spectra of fourteen Magellanic Cloud planetary nebulæ with the Southern African Large Telescope to determine heating rates of their central stars and to verify evolutionary models of post-asymptotic giant branch stars. We compared new spectra with observations made in previous years. Five planetary nebulæ showed an increase in excitation over time. Four of their central stars exhibit [WC] features in their spectra, including three new detections. This raises the total number of [WC] central stars of PNe in the Magellanic Clouds to ten. We compared determined heating rates of the four [WC] central stars with the He-burning post-asymptotic giant branch evolutionary tracks and the remaining star with the H-burning tracks. Determined heating rates are consistent with the evolutionary models for both H and He-burning post-asymptotic giant branch stars. The central stars of the PNe that show the fastest increase of excitation are also the most luminous in the sample. This indicates that [WC] central stars in the Magellanic Clouds evolve faster than H-burning central stars, and they originate from more massive progenitors.

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Constraining nucleosynthesis in two CEMP progenitors using fluorine

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We present new fluorine abundance estimations in two carbon enhanced metal-poor (CEMP) stars, HE 1429−0551 and HE 1305+0007. HE 1429−0551 is also enriched in slow neutron-capture process (s-process) elements, a CEMP-s, and HE 1305+0007 is enhanced in both, slow and rapid neutron-capture process elements, a CEMP-s/r. The F abundances estimates are derived from the vibration–rotation transition of the HF molecule at 23358.6 Å using high-resolution infrared spectra obtained with the Immersion Grating Infrared Spectrometer (IGRINS) at the 4-m class Lowell Discovery Telescope. Our results include an F abundance measurement in HE 1429−0551 of $A(\mathrm{F}) = +3.93$ ($[\mathrm{F/Fe}] = +1.90$) at $[\mathrm{Fe/H}] = -2.53$, and an F upper limit in HE 1305+0007 of $A(\mathrm{F}) < +3.28$ ($[\mathrm{F/Fe}] < +1.00$) at $[\mathrm{Fe/H}] = -2.28$. Our new derived F abundance in HE 1429−0551 makes this object the most metal-poor star where F has been detected. We carefully compare these results with literature values and state-of-the-art CEMP-s model predictions including detailed asymptotic giant branch (AGB) nucleosynthesis and binary evolution. The modelled fluorine abundance for HE 1429−0551 is within reasonable agreement with our observed abundance, although is slightly higher than our observed value. For HE 1429−0551, our findings support the scenario via mass transfer by a primary companion during its thermally pulsing phase. Our estimated upper limit in HE 1305+0007, along with data from the literature, shows large discrepancies compared with AGB models. The discrepancy is principally due to the simultaneous s- and r-process element enhancements which the model struggles to reproduce.

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Most EL CVn systems are inner binaries of hierarchical triples

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In spite of their importance for modern astronomy, we do not fully understand how close binary stars containing at least one white dwarf form from main sequence binary stars. The discovery of EL CVn binaries, close pre-white dwarfs with A/F main sequence star companions, offers now the unique possibility to test models of close compact binary star formation. Binary evolution theories predict that these EL CVn stars descend from very close main sequence binaries with orbital periods shorter than 3 days. If this is correct, nearly all EL CVn stars should be inner binaries of hierarchical triples because more than 95 per cent of very close main sequence binaries (the alleged progenitor systems) are found to be hierarchical triples. We here present SPHERE/IRDIS observations of five EL CVn binaries, finding in all of them tertiary objects, as predicted. We conclude that EL CVn systems are inner binaries of hierarchical triples and indeed descend from very close main sequence binaries that experience stable mass transfer.

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The Dusty Evolved Star Kit (DESK): A PYTHON package for fitting the spectral energy distribution of evolved stars

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One of the few ways that we can understand the environment around dusty stars and how much material they contribute back to the Universe, is by fitting their brightness at different wavelengths with models that account for how the energy transfers through the dust. The DESK is a python package designed to compare the best fits of different stellar samples and model grids for a better understanding of the results and their uncertainties. The package fits the Spectral Energy Distribution (SED) of evolved stars, using photometry or spectra, to grids of radiative transfer models using a least-squares method. The package includes newly created grids using a variety of different dust species, and state-of-the-art dust growth grids. A robust method for testing different model grids will be particularly important given the wealth of infrared data to come from the *James Webb* Space Telescope (JWST).

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Serendipitous discovery of nine white dwarfs with gaseous debris disks

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Optical spectroscopic observations of white dwarf stars selected from catalogs based on the Gaia DR2 database reveal nine new gaseous debris disks that orbit single white dwarf stars, about a factor of two increase over the previously known sample. For each source we present gas emission lines identified and basic stellar parameters, including abundances for lines seen with low-resolution spectroscopy. Principle discoveries include: (1) the coolest white dwarf ($T_{\rm eff} \approx 12,720$ K) with a gas disk; this star, WD 0145+234, has been reported to have undergone a recent infrared outburst; (2) co-location in velocity space of gaseous emission from multiple elements, suggesting that different elements are well-mixed; (3) highly asymmetric emission structures toward SDSS J0006+2858, and possibly asymmetric structures for two other systems; (4) an overall sample composed of approximately 25% DB and 75% DA white dwarfs, consistent with the overall distribution of primary atmospheric types found in the field population; and (5) never-before-seen emission lines from Na in the spectra of Gaia J0611−6931, semi-forbidden Mg, Ca, and Fe lines toward WD 0842+572, and Si in both stars. The currently known sample of gaseous debris disk systems is significantly skewed towards northern hemisphere stars, suggesting a dozen or so emission line stars are waiting to be found in the southern hemisphere.

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Atomium: a high-resolution view on the highly asymmetric wind of the AGB star π_1 Gruis I. First detection of a new companion and its effect on the inner wind

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The nebular circumstellar environments of cool evolved stars are known to harbour a rich morphological complexity of gaseous structures on different length scales. A large part of these density structures are thought to be brought about by the interaction of the stellar wind with a close companion. The S-type asymptotic giant branch star π_1 Gruis, which has a known companion at ~ 440 au and is thought to harbour a second, closer-by (< 10 au) companion, was observed with the Atacama Large Millimeter/submillimeter Array as part of the Atomium Large programme. In this work, the brightest CO, SiO, and HCN molecular line transitions are analysed. The continuum map shows two maxima, separated by $0\farcs04$ (6 au). The CO data unambiguously reveal that π_1 Gruis' circumstellar environment harbours an inclined, radially outflowing, equatorial density enhancement. It contains a spiral structure at an angle of $38° \pm 3°$ with the line-of-sight. The HCN emission in the inner wind reveals a clockwise spiral, with a dynamical crossing time of the spiral arms consistent with a companion at a distance of $0\farcs04$ from the asymptotic giant branch star, which is in agreement with the position of the secondary continuum peak. The inner wind dynamics imply a large acceleration region, consistent with a β-law power of ~ 6. The CO emission suggests that the spiral is approximately Archimedean within $5''$, beyond which this trend breaks down as the succession of the spiral arms becomes less periodic. The SiO emission at scales smaller than $0\farcs5$ exhibits signatures of gas in rotation, which is found to fit the expected behaviour of gas in the wind-companion interaction zone. An investigation of SiO maser emission reveals what could be a stream of gas accelerating from the surface of the AGB star to the companion. Using these dynamics, we have tentatively derived an upper limit on the companion mass to be ~ 1.1 $M_\odot$.

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Rotational spectra of vibrationally excited AlO and TiO in oxygen rich stars

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Rotational transitions in vibrationally excited AlO and TiO – two possible precursors of dust – were observed in the 300 GHz range (1 mm wavelength) towards the oxygen rich AGB stars R Dor and IK Tau with ALMA, and vibrationally excited AlO was observed towards the red supergiant VY CMa with the SMA. The $J = 11 \rightarrow 10$ transition of TiO in the $v = 1$ and 2 levels, and the $N = 9 \rightarrow 8$ transition in the $v = 2$ level of AlO were identified towards R Dor; the $J = 11 \rightarrow 10$ line of TiO was identified in the $v = 1$ level towards IK Tau; and two transitions in the $v = 1$ and 2 levels of AlO were identified towards VY CMa. The newly-derived high vibrational temperature of TiO and AlO in R Dor of 1800 ± 200 K, and prior measurements of the angular extent confirm that the majority of the emission is from a region within $\lesssim 2R_\star$ of the central star. A full radiative transfer analysis of AlO in R Dor yielded a fractional abundance of $\sim 3\%$ of the solar abundance of Al. From a similar analysis of TiO a fractional abundance of $\sim 78\%$ of the solar abundance of Ti was found. The observations provide indirect evidence that TiO is present in a rotating disk close to the star. Further observations in the ground and excited vibrational levels are needed to determine whether AlO, TiO, and TiO_2 are seeds of the Al_2O_3 dust in R Dor, and perhaps in the gravitationally bound dust shells in other AGB stars with low mass loss rates.

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Infrared Telescope Facility (IRTF) spectral library II: New indices in Y, J, H, and L atmospheric windows

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Context: Stellar population studies in the infrared (IR) wavelength range have two main advantages with respect to the optical regime: they probe different populations, because most of the light in the IR comes from redder and generally older stars, and they allow us to see through dust because IR light is less affected by extinction. Unfortunately, IR modeling work was halted by the lack of adequate stellar libraries, but this has changed in the recent years.
Aims: Our project investigates the sensitivity of various spectral features in the 1–5 μm wavelength range to the physical properties of stars ($T_{\rm eff}$, [Fe/H], $\log g$) and aims to objectively define spectral indices that can characterize the age and metallicity of unresolved stellar populations.
—it Methods: We implemented a method that uses derivatives of the indices as functions of $T_{\rm eff}$, [Fe/H] or $\log g$ across the entire available wavelength range to reveal the most sensitive indices to these parameters and the ranges in which these indices work.
Results: Here, we complement the previous work in the I and K bands, reporting a new system of 14, 12, 22, and 12 indices for Y, J, H, and L atmospheric windows, respectively, and describe their behavior. We list the equivalent widths of these indices for the Infrared Telescope Facility (IRTF) spectral library stars.

Conclusions: Our analysis indicates that features sensitive to the effective temperature are present and measurable in all the investigated atmospheric windows at the spectral resolution and in the metallicity range of the IRTF library for a signal-to-noise ratio greater than 20–30. The surface gravity is more challenging and only indices in the H and J windows are best suited for this. The metallicity range of the stars with available spectra is too narrow to search for suitable diagnostics. For the spectra of unresolved galaxies, the defined indices are valuable tools in tracing the properties of the stars in the IR-dominant stellar populations.

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On the mass and metallicity distribution of parent AGB stars of presolar SiC

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The vast majority ($\geq 90\%$) of presolar SiC grains identified in primitive meteorites are relics of ancient asymptotic giant branch(AGB) stars, whose ejecta were incorporated into the Solar System during its formation. Detailed characterization of these ancient stardust grains has revealed precious information on mixing processes in AGB interiors in great detail. However, the mass and metallicity distribution of their parent stars still remains ambiguous, although such information is crucial to investigating the slow neutron capture process, whose efficiency is mass- and metallicity-dependent. Using a well-known Milky Way chemo-dynamical model, we follow the evolution of the AGB stars that polluted the SolarSystem at 4.57 Gyr ago and weighted the stars based on their SiC dust productions. We find that presolar SiC in the Solar System predominantly originated from AGB stars with $M \sim 2$ $M_\odot$ and $Z \sim Z_\odot$.Our finding well explains the grain-size distribution of presolar SiC identified in situ in primitive meteorites. Moreover, it provides complementary results to very recent papers dealing with the characterization of parent stars of presolar SiC.

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Long-term photospheric instabilities and envelopes dynamics in the post-AGB binary system 89 Herculis

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We present a long-term optical spectroscopic study of the post-AGB binary system 89 Herculis, with the aim to characterize the relationship between photospheric instabilities and dynamics in the close circumstellar environment of the system. This study is based on spectra acquired with the high-resolution Catania Astrophysical Observatory

Spectropolarimeter and archive data, covering a time interval between 1978 and 2018. We find long-term changes in the radial velocity curve of the system, occurring mostly in amplitude, which correlate with the variability observed in the blue-shifted absorption component of the P Cygni like Hα profile. Two possible scenarios are discussed. We also find strong splitting in the s-process elements of Ba II 6141.713 Å and 6496.898 Å lines, with short-term morphological variations. A Gaussian decomposition of such profiles allows us to distinguish four shell components, two expanding and two in-falling toward the central star, which are subject to the orbital motion of the system and are not affected by the long-term instabilities. Finally, we find that the numerous metal lines in emission could originate in regions of a structured circumbinary disk that have sizes proportional to the energy of the corresponding upper level transition $E_{\rm up}$. This study demonstrates the potential of long-term high-resolution spectroscopy in linking together the instability processes occurring during the late evolutionary stages of post-AGBs and the subsequent phase of PNe.

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Molecular remnant of Nova 1670 (CK Vulpeculæ): I. Properties and enigmatic origin of the gas

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CK Vul erupted in 1670 and is considered a Galactic stellar-merger candidate. Its remnant, observed 350 yr after the eruption, contains a molecular component of surprisingly rich composition, including polyatomic molecules as complex as methylamine (CH_3NH_2). We present interferometric line surveys with subarcsec resolution with ALMA and SMA. The observations provide interferometric maps of molecular line emission at frequencies between 88 and 243 GHz that allow imaging spectroscopy of more than 180 transitions of 26 species. We present, classify, and analyze the different morphologies of the emission regions displayed by the molecules. We also perform a non-LTE radiative-transfer analysis of emission of most of the observed species, deriving the kinetic temperatures and column densities in five parts of the molecular nebula. Non-LTE effects are clearly seen in complex species including methanol absorption against the cosmic microwave background. The temperatures are about 17 K in the inner remnant and 14 K in the extended lobes, both higher than excitation temperatures estimated earlier in an LTE approach and based on single-dish spectra. We find total (hydrogen plus helium) densities in the range of 10^4–10^6 cm^{-3}. The column densities provide rough relative abundance patterns in the remnant which currently are not understood. Attempts to derive elemental abundances within the assumption of a chemical equilibrium give only loose constraints on the CNO elements. That the formation of many of the observed molecules requires a major involvement of circumstellar shocks remains the preferred possibility. The molecular gas could have formed 350 yr ago or more recently. The molecules are well shielded from the interstellar radiation field by the circumstellar dust. Their presence alone indicates that the unobservable central star cannot be a hot object such as a white dwarf. This excludes some of the proposed scenarios on the nature of CK Vul. The general characteristics of the molecular environment of CK Vul derived in this study resemble quite well those of some pre-planetary nebulæ and asymptotic giant branch stars, most notably that of OH 231.8+4.2.

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Molecular remnant of Nova 1670 (CK Vulpeculæ). II. A three-dimensional view on the gas distribution and velocity field

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CK Vul is the remnant of an energetic eruption known as Nova 1670 that is thought to be caused by a stellar merger. The remnant is composed of (1) a large hourglass nebula of recombining gas (of 71″ size), very similar to some classical planetary and pre-planetary nebulæ (PPNe), and (2) of a much smaller and cooler inner remnant prominent in millimeter-wave emission from molecules. We investigate the three-dimensional spatio-kinematic structure of both components. The analysis of the hourglass structure yields a revised distance to the object of > 2.6 kpc, at least 3.7 times greater than so far assumed. At this distance, the stellar remnant has a bolometric luminosity > 12 $L_\odot$ and is surrounded by molecular material of total mass > 0.8 $M_\odot$ (the latter value has a large systematic uncertainty). We also analyzed the architecture of the inner molecular nebula using ALMA observations of rotational emission lines obtained at subarcsecond resolution. We find that the distribution of neutral and ionized gas in the lobes can be reproduced by several nested and incomplete shells or jets with different velocity fields and varying orientations. The analysis indicates that the molecular remnant was created in several ejection episodes, possibly involving an interacting binary system. We calculated the linear momentum ($\approx 10^{40}$ g cm s^{-1}) and kinetic energy ($\approx 10^{47}$ erg) of the CK Vul outflows and find them within the limits typical for classical PPNe. Given the similarities of the CK Vul outflows to PPNe, we suggest there may CK Vul analogs among wrongly classified PPNe with low intrinsic luminosities, especially among PPNe with post-red-giant-branch central stars.

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High-resolution optical spectroscopy of the post-AGB supergiant V340 Ser (= IRAS 17279−1119)

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Evidences of wind variability and velocity stratification in the extended atmosphere has been found in the spectra of the supergiant V340 Ser (= IRAS 17279−1119) taken at the 6-m BTA telescope with a spectral resolving power $R \geq 60,000$. The Hα line has a P Cyg profile whose absorption component ($v = +34$ km s^{-1}) is formed in the upper layers of the expanding atmosphere close to the circumstellar environment. For four dates the mean velocity has been derived from the positions of 300–550 symmetric metal absorptions with an accuracy better than ± 0.1 km s^{-1}: $v_\odot = 59.30$, 60.09, 58.46, and 55.78 km s^{-1}. A lot of low-excitation metal lines have an inverse P Cyg profile. The mean positions of their emission components, $v_\odot = 46.3 \pm 0.4$ km s^{-1}, differ systematically from the velocity inferred from symmetric absorptions, suggesting the presence of a velocity gradient in the supergiant extended atmosphere. The multicomponent profile of the Na I D lines contains the interstellar, $v_\odot = -11.2$ km s^{-1}, and circumstellar, $v_\odot = +10$ km s^{-1}, components and the component forming in the upper atmospheric layers, $v_\odot = +34.0$ km s^{-1}. The mean velocity from 20–30 diffuse interstellar bands (DIBs) identified in the spectra, $v_\odot$(DIBs) $= -11.6 \pm 0.2$ km s^{-1}, agrees with the velocity from interstellar Na I and K I components. The equivalent width of the oxygen triplet W(O I 7774) = 1.25 Å corresponds to an absolute magnitude of the star $M_V \approx -4\overset{\mathrm{m}}{.}6$, which, taking into account the total (interstellar + circumstellar) extinction, leads to a distance to the star $d \approx 2.3$ kpc.

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Gaia DR2 data and the evolutionary status of eight high-velocity hot post-AGB candidates

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From Gaia DR2 data of eight high-velocity hot post-AGB candidates, LS 3593, LSE 148, LS 5107, HD 172324, HD 214539, LS IV −12°111, LS III +52°24, and LS 3099, we found that six of them have accurate parallaxes which made it possible to derive their distances, absolute visual magnitudes (M_V) and luminosity ($\log L/L_\odot$). All the stars except LS 5107 have an accurate effective temperature ($T_{\rm eff}$) in the literature. Some of these stars are metal poor, and some of them do not have circumstellar dust shells. In the past, the distances of some stars were estimated to be 6 kpc, which we find to be incorrect. The accurate Gaia DR2 parallaxes show that they are relatively nearby, post-AGB stars.When compared with post-AGB evolutionary tracks we find their initial masses to be in the range 1 $M_\odot$ to 2 $M_\odot$. We find the luminosity of LSE 148 to be significantly lower than that of post-AGB stars, suggesting that this is a post-horizontal-branch star or post-early-AGB star. LS 3593 and LS 5107 are new high-velocity hot post-AGB stars from Gaia DR2.

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Modelling long-period variables – II. Fundamental mode pulsation in the nonlinear regime

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Long-period variability in luminous red giants has several promising applications, all of which require models able to accurately predict pulsation periods. Linear pulsation models have proven successful in reproducing the observed periods of overtone modes in evolved red giants, but they fail to accurately predict their fundamental mode periods. Here, we use a 1D hydrodynamic code to investigate the long-period variability of M-type asymptotic giant branch stars in the nonlinear regime. We examine the period and stability of low-order radial pulsation modes as a function of mass and radius, and find overtone mode periods in complete agreement with predictions from linear pulsation models. In contrast, nonlinear models predict an earlier onset of dominant fundamental mode pulsation, and shorter periods at large radii. Both features lead to a substantially better agreement with observations, that we verify against OGLE and Gaia data for the Magellanic Clouds. We provide simple analytic relations describing the nonlinear fundamental mode period-mass-radius relation. Differences with respect to linear predictions originate from the readjustment of the envelope structure induced by large-amplitude pulsation. We investigate the impact of turbulent viscosity on linear and nonlinear pulsation, and probe possible effects of varying metallicity and carbon abundance.

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Detailed studies of IPHAS sources – I. The disrupted late bipolar IPHASX J193718.6+202102

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We present a detailed analysis of the new planetary nebula (PN) IPHASX J193718.6+202102 using deep imaging and intermediate and high resolution spectroscopy that are interpreted through morpho-kinematic and photoionisation modelling. The physical structure of the nebula consists of a fragmented torus and an extremely faint orthogonal bipolar outflow, contrary to the pinched waist PN morphology suggested by its optical image. Our kinematic analysis indicates that the torus is expanding at 25 ± 5 km s^{-1} and is gradually breaking up. At an estimated distance of $7.1^{+0.8}_{-0.3}$ kpc, the corresponding kinematic age of $\sim 26\,000$ years is consistent with a faint and disintegrating PN. The intermediate-resolution spectra reveal an excited PN with chemical abundances typical of Type II PNe. Based on the latter we also estimate an initial mass for the progenitor in the range 2–3 M$_\odot$ and a central star (CSPN) mass $M_{\rm CSPN} \sim 0.61$ M$_\odot$. The *Spitzer* MIPS 24 μm emission that closely follows the fragmented torus could be attributed to the emission of [O IV] at 25.9 μm rather than to dust emission. All the results coherently point towards an evolved moderately massive bipolar Type II PN on the brink of dissolving into the interstellar medium.

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Detailed Studies of IPHAS sources – II. Sab 19, a true planetary nebula and its mimic crossing the Perseus Arm

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The INT Photometric Hα Survey (IPHAS) has provided us with a number of new-emission line sources, among which planetary nebulæ (PNe) constitute an important fraction. Here we present a detailed analysis of the IPHAS nebula Sab 19 (IPHASX J055242.8+262116) based on radio, infrared, and optical images and intermediate- and high-dispersion longslit spectra. Sab 19 consists of a roundish 0.10 pc in radius double-shell nebula surrounded by a much larger 2.8 pc in radius external shell with a prominent H-shaped filament. We confirm the nature of the main nebula as a PN whose sub-solar N/O ratio abundances, low ionized mass, peculiar radial velocity, and low-mass central star allow us to catalog it as a type III PN. Apparently, the progenitor star of Sab 19 became a PN when crossing the Perseus Arm during a brief visit of a few Myr. The higher N/O ratio and velocity shift ~ 40 km s^{-1} of the external shell with respect to the main nebula and its large ionized mass suggest that it is not truly associated with Sab 19, but it is rather dominated by a Strömgren zone in the interstellar medium ionized by the PN central star.

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Detailed studies of IPHAS sources – III. The highly extinguished bipolar planetary nebula IPHASX J191104.8+ 060845

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We present the first detailed study of the bipolar planetary nebula (PN) IPHASX J191104.8+060845 (PN G040.6−01.5) discovered as part of the Isaac Newton Telescope Photometric Hα Survey of the Northern Galactic plane (IPHAS). We present Nordic Optical Telescope (NOT) narrow-band images to unveil its true morphology. This PN consists of a main cavity with two newly uncovered extended low-surface brightness lobes located towards the NW and SE directions. Using near-IR WISE images we unveiled the presence of a barrel like structure, which surrounds the main cavity, which would explain the dark lane towards the equatorial regions. We also use Gran Telescopio de Canarias (GTC) spectra to study the physical properties of this PN. We emphasise the potential of old PNe detected in IPHAS to study the final stages of the evolution of the circumstellar medium around solar-like stars.

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Low-mass low-metallicity AGB stars as an efficient i-process site explaining CEMP-rs stars

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Among Carbon-Enhanced Metal-Poor (CEMP) stars, some are found to be enriched in s-process elements (CEMP-s), in r-process elements (CEMP-r) or in both s- and r-process elements (CEMP-rs). The origin of the abundance differences between CEMP-s and CEMP-rs stars is presently unknown. It has been claimed that the i-process, whose site still remains to be identified, could better reproduce CEMP-rs abundances than the s-process. We analyze high-resolution spectra of 25 metal-poor stars, observed with the high-resolution HERMES spectrograph mounted on the Mercator telescope, La Palma, or with the UVES/VLT and HIRES/KECK spectrographs. We propose a new, robust classification method for CEMP-s and CEMP-rs stars using eight heavy element abundances. The abundance profiles of CEMP-s and CEMP-rs stars are derived and there appears to be an abundance continuum between the two stellar classes. CEMP-rs stars present most of the characteristics of extrinsic stars such as CEMP-s, CH, Barium

and extrinsic S stars, with an even larger binarity rate among CEMP-rs stars than among CEMP-s stars. Stellar evolutionary tracks of an enhanced carbon composition (consistent with our abundance determinations) are necessary to explain the position of CEMP-s and CEMP-rs stars in the HR diagram using Gaia DR2 parallaxes; they are found to lie mostly on the RGB. CEMP-rs stars can be explained as being polluted by a low-mass, low-metallicity TP-AGB companion experiencing i-process nucleosynthesis after proton ingestion during its first convective thermal pulses. The global fitting of our i-process models to CEMP-rs stars is as good as the one of our s-process models to CEMP-s stars. As such, CEMP-rs stars could be renamed as CEMP-sr stars, since they represent a particular manifestation of the s-process at low-metallicities. For these objects a call for an exotic i-process site may not necessarily be required anymore.

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Extended view on the dust shells around two carbon stars

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Stars on the asymptotic giant branch (AGB) lose considerable amounts of matter through their dust-driven stellar winds. A number of such sources have been imaged by *Herschel*/PACS, revealing a diverse sample of different morphological types. Among them are a few examples which show geometrically thin, spherically symmetric shells which can be used to probe the mass loss history of their host stars. We aim to determine the physical properties of the dust envelope around the two carbon stars U Hya and W Ori. With the much-improved spatial constraints from the new far-infrared maps, our primary goal is to measure the dust masses contained in the shells and see how they fit the proposed scenarios of shell formation. We calculated the radiative transfer of the circumstellar dust envelope using the 1D code More of DUSTY (MoD). Adopting a parametrised density profile, we obtained a best-fit model in terms of the photometric and spectroscopic data, as well as a radial intensity profile based on *Herschel*/PACS data. For the case of U Hya, we also computed a grid of circumstellar envelopes by means of a stationary wind code and compare the results of the two modelling approaches. The *Herschel*/PACS maps show U Hya surrounded by a detached shell of 114″ (0.12 pc) in radius, confirming the observations from previous space missions. The dust masses calculated for the shell by the two approaches are consistent with respect to the adopted dust grain properties. In addition, around W Ori, we detect for the first time a weak spherically symmetric structure with a radius of 92″ (0.17 pc) and a dust mass of $(3.5 \pm 0.3) \times 10^{-6}$ $M_\odot$.

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Review Paper

Probing the interior physics of stars through asteroseismology

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Years-long high-precision brightness measurements obtained with telescopes operating in space have become available for thousands of stars. Such data allowed us to measure the physics of stellar interiors via nonradial oscillations, opening a new avenue to study the stars in the Universe. Asteroseismology, the interpretation of the characteristics of oscillation modes in terms of the physical properties of the stellar interior, brought entirely new insights in how stars rotate and how they build up their chemistry throughout their evolution. We discuss how data-driven space asteroseismology delivered a drastic increase in the reliability of computer models mimicking the evolution of stars born with a variety of masses and metallicities. Such models are critical ingredients for modern physics as a whole, because they are used throughout various contemporary and multidisciplinary research fields in space science, including the search for life outside the solar system, archaeological studies of the Milky Way, and the study of single and binary supernova progenitors, among which future gravitational wave sources. We illustrate the specific role and potential of asteroseismology for those modern research fields. We end with current limitations of asteroseismology and highlight how they can be overcome with ongoing and future large infrastructures for survey astronomy combined with new theoretical research in the era of high-performance computing. This review presents results obtained thanks to major community efforts over the past decade. These breakthroughs were achieved in a collaborative and inclusive spirit so characteristic of the asteroseismology community. The aim was to write it so as to make this research field well accessible to graduate students and readers from other fields in physics, with incentives to enjoy and join future applications in this glorious domain of astrophysics.

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