THE AGB NEWSLETTER

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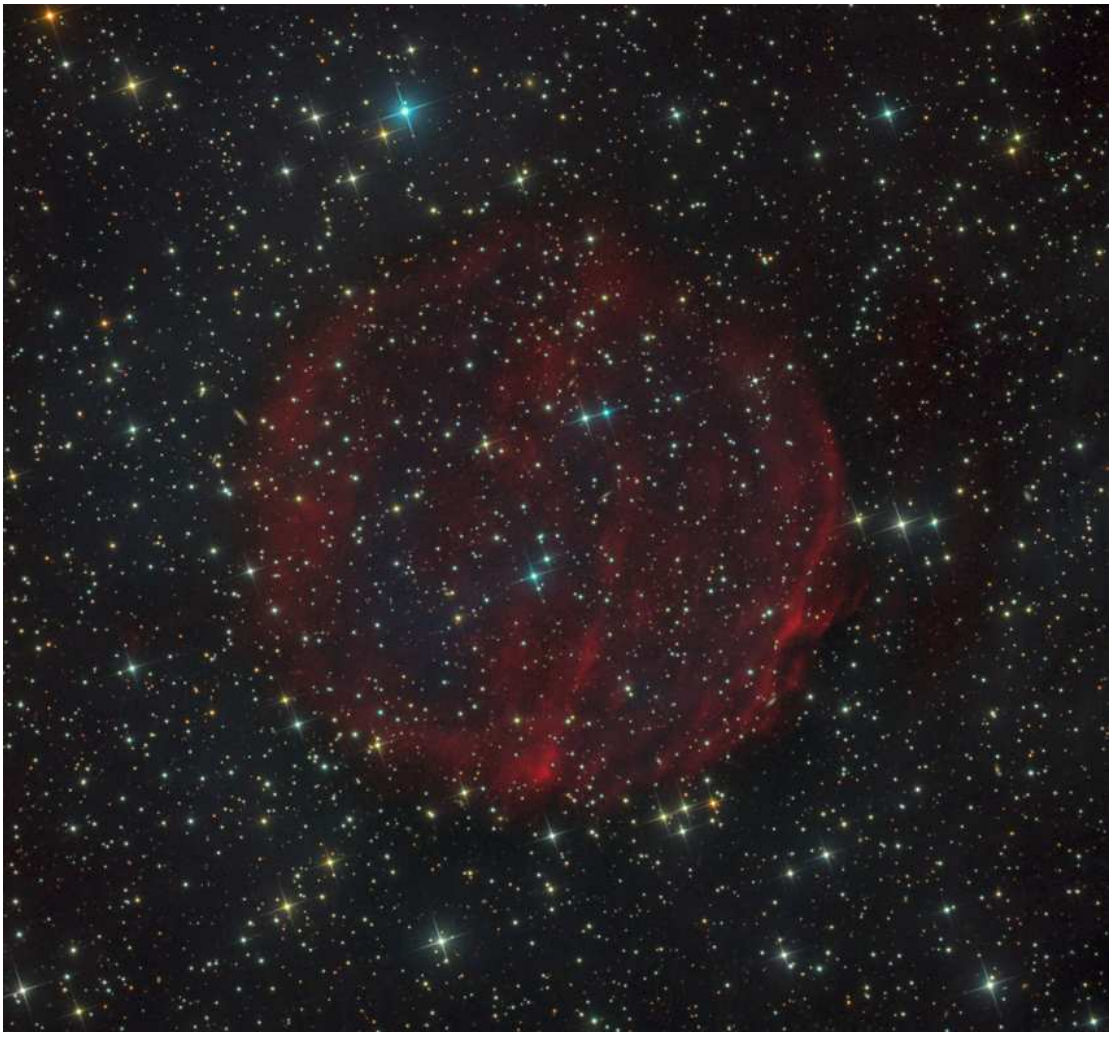

Figure 1: Planetary nebula PuWe 1, observed by Mark Hanson in New Mexico and suggested by Sakib Rasool. For more details see https://www.hansonastronomy.com/puwe1-png-1589178.

Editorial

Dear Colleagues,

It is a pleasure to present you the 269$^{\rm th}$ issue of the AGB Newsletter.

It is with sadness that we learnt of the death of Yervant Terzian. Bruce Balick has written a wonderful obituary for him, and Albert Zijlstra found a beautiful picture to go with it. You will find it on page 4.

On a more positive note, there is a faculty opening at the University of Georgia, USA, that you might be interested in...

...and a meeting on high-resolution astronomy next year, in Exeter in the UK.

Tomasz Kamiński has stepped into the footsteps of Maria Lugaro, to write the second opinion piece. So do turn the page and read it, and if you wish to comment just send us an e-mail at astro.agbnews@keele.ac.uk.

Meanwhile we are finishing writing a proposal for a Focus Meeting at the 2021 General Assembly of the International Astronomical Union, on unsolved problems in red giants and supergiants – and on how to solve them! So if you are not yet an IAU member, apply now, and start planning to join us in South Korea!

The next issue is planned to be distributed around the 4$^{\rm st}$ of January. We send you the Season's Greetings and wish you a Happy and Peaceful New Year!

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

Food for Thought

This month's thought-provoking statement is:

Are the numbers of white dwarf–white dwarf binaries, binary central stars of planetary nebulæ, and binaries with a red giant component consistent?

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)

What am I thinking?

Tomasz (Tomek) Kamiński

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Why are we getting less of the ALMA pie?

ALMA observations are transforming astrophysics. A recent ALMA meeting in Cagliari, Sardinia, demonstrated that this is indeed the case for all ALMA science categories, with really outstanding results coming from the world of protoplanetary disks. Talks about evolved stars were less numerous and had poorer attendance than the other science categories. This may be my very subjective perception on how our field is doing among other ALMA science topics but the submission and acceptance statistics clearly show that our share in the ALMA observing time is dropping.

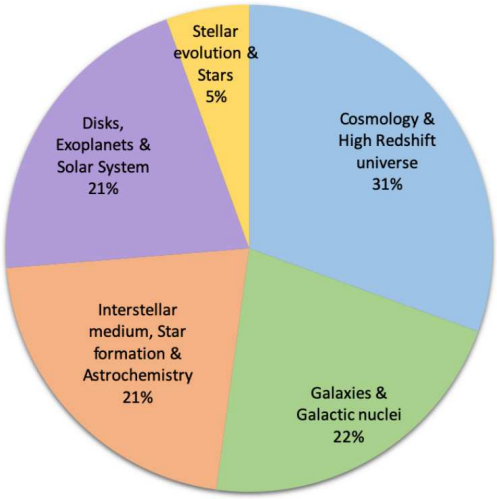

Figure on the left:

Time requested on the 12-m ALMA array in Cycle 7 by science categories The 5% representing stars is the lowest in years. Are we losing interest?

(https://almascience.eso.org/news/documents-and-tools/cycle7/cycle-7-proposal-submission-statistics)

In the last ALMA call, that is for Cycle 7 observations, our proposals for the 12-m array asked for only 5% of the total ALMA time. This is 2% less than in the previous year but that means that the drop in science time for stars (incl. the Sun) dropped by almost 30%. This is significant, even if one corrects these statistics for an increasing number of science hours that the observatory offered from Cycles 6 to 7. Have we saturated with the ALMA data? It is hard to believe it since for most observers there is never enough of good-quality data. Have we lost interest? Or have we got stuck faced with the complexity of circumstellar envelopes ALMA has revealed. Further drop in applications may actually endanger the "Stellar Evolution & Stars" being a separate science category at ALMA with the consequence that our proposals may be evaluated in the future by panels with less expertise in stellar evolution (if ALMA stays with the current proposal evaluation scheme). At the Submillimeter Array, the number of projects linked to evolved stars has also dropped dramatically so that in some semesters there are no evolved stars projects at all. I hear that the situation at NOEMA is no better.

I am sure there are many great ("stellar"!) ideas out there that can be tested with ALMA observations and spectacular discoveries around RGBs, AGBs, RSGs, PNe, or PPNe (etc.) are still to be made at millimeter/submillimeter wavelengths. While I am curious to hear from readers of the Newsletter on why it may be that the filed is shrinking, I am writing this to motivate more splendid proposals to be submitted in 2020. It is time now to start preparing a daring ALMA proposal that will transform our field. Do not be shy in asking for a lot of time. The next ALMA proposal deadline is foreseen for mid April 2020 and Cycle 8 pre-announcement can be expected as soon as this December.

Yervant Terzian
1939 – 2019

Prof. Yervant Terzian of Cornell University died peacefully in the early hours of Monday, November 25 after a series of long and difficult illnesses. Prof. Terzian (hereafter "Yervant") is best known to astronomers for his pioneering papers on the radio emission of H II regions, planetary nebulæ, and normal galaxies. His first refereed paper, "Radio Radiation from Normal Spiral Galaxies", appeared in the ApJ in 1967 and the last, "SIGGMA: A Survey of Ionized Gas in the Galaxy, Made with the Arecibo Telescope" was published in the AJ in 2013. (This is about the same time as the first of his major health problems blunted his career.) There were 300 other publications in between.

I view Yervant's career from my perspective as his first Ph.D. student (late 1960s) and as a close friend for over 50 years. Yervant was the ideal model of a passionate mentor. As Noam Soker very kindly reminded me, Yervant was a co-author on my first paper in 1969. We shared our love for our work and interest in one another ever since. I shall always treasure his sincere interest, thoughtfulness, and timely advice during our long friendship.

Yervant came to Cornell in 1965 after a post-doc at the National Radio Astronomy Observatory in Green Bank. He was active in the vortex of excitement of new discovery as new telescopes came on line during that time. Yervant wasted no time to make good use of his enthusiasm (always pronounced with a short 'e' at the end) and expertise from during from his years at NRAO. When we arrived at Cornell at about the same time he entrained me into his

studies of star formation and planetary nebulæ. That launched my career trajectory.

Yervant was an expert cajoler, as his long administrative career in the Astronomy Department so vividly illustrates. He was the Department Chair during a time of rapid and profound changes. His goals were pointedly altruistic and his sensitive leadership was deeply respected. Yervant gently but persistently bent people – his students, peers, and deans – to his will, followed by their gratitude and no lingering resentment. All during this time he raised millions of private dollars to re-ignite scientific research in Armenia, his ancestral nationhood. He must have learned the art of determined persuasion as he grew up in Egypt and Greece. He was also very active in NASA's Spacegrant Program to extend the reach of astronomy and science to new generations of well informed citizens in the U.S.

It was always a memorable pleasure to find my way to Ithaca where Yervant and his family would host a dinner, the last time just a year ago. Yervant is survived by a deeply loving wife, Patricia, and two children, the first of whom was born two hours before my firstborn (talk about intertwined world lines!) My world has a gaping hole in it.

Bruce Balick
Astronomy Department
University of Washington, USA

See also https://www.aras.am/FamousAstronomers/terzian.html

Refereed Journal Papers

An ancient double degenerate merger in the Milky Way halo

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We present an analysis and re-appraisal of the massive, carbon-enriched (DQ) white dwarf (WD) LP 93-21. Its high mass (≈ 1 $M_{\odot}$) and membership to the class of warm DQ WDs, combined with its peculiar halo kinematics suggest that this object is the product of an ancient stellar merger event, most likely that of two WDs. Furthermore, the kinematics places this object on a highly retrograde orbit driven by the accretion of a dwarf galaxy onto the Milky Way that occurred at a red shift greater than 1.5. As the product of a stellar merger LP 93-21 is probably representative of the whole class of warm/hot DQ WDs.

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Chemical evolution with rotating massive star yields II. A new assessment of the solar *s*- and *r*-process components

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The decomposition of the Solar system abundances of heavy isotopes into their *s*- and *r*-process components plays a key role in our understanding of the corresponding nuclear processes and the physics and evolution of their astrophysical sites. We present a new method for determining the *s*- and *r*-process components of the Solar system abundances, fully consistent with our current understanding of stellar nucleosynthesis and galactic chemical evolution. The method is based on a study of the evolution of the solar neighborhood with a state-of-the-art 1-zone model, using recent yields of low and intermediate mass stars as well as of massive rotating stars. We compare our results with previous studies and we provide tables with the isotopic and elemental contributions of the *s*- and *r*-processes to the Solar system composition.

Accepted for publication in MNRAS

The *Hubble* Catalog of Variables (HCV)

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Aims: Over its lifetime and despite not being a survey telescope, the *Hubble* Space Telescope (HST) has obtained multi-epoch observations by multiple, diverse observing programs, providing the opportunity for a comprehensive variability search aiming to uncover new variables. We have therefore undertaken the task of creating a catalog of variable sources based on archival HST photometry. In particular, we have used version 3 of the *Hubble* Source Catalog (HSC), which relies on publicly available images obtained with the WFPC2, ACS, and WFC3 instruments onboard the HST.

Methods: We adopted magnitude-dependent thresholding in median absolute deviation (a robust measure of light curve scatter) combined with sophisticated preprocessing techniques and visual quality control to identify and validate variable sources observed by *Hubble* with the same instrument and filter combination five or more times.

Results: The *Hubble* Catalog of Variables (HCV) includes 84 428 candidate variable sources (out of 3.7 million HSC sources that were searched for variability) with $V < 27$ mag; for 11 115 of them the variability is detected in more than one filter. The data points in the light curves of the variables in the HCV catalog range from five to 120 points (typically having less than ten points); the time baseline ranges from under a day to over 15 years; while $\sim 8\%$ of all variables have amplitudes in excess of 1 mag. Visual inspection performed on a subset of the candidate variables suggests that at least 80% of the candidate variables that passed our automated quality control are true variable sources rather than spurious detections resulting from blending, residual cosmic rays, and calibration errors.

Conclusion: The HCV is the first, homogeneous catalog of variable sources created from the highly diverse, archival HST data and currently is the deepest catalog of variables available. The catalog includes variable stars in our Galaxy and nearby galaxies, as well as transients and variable active galactic nuclei. We expect that the catalog will be a valuable resource for the community. Possible uses include searches for new variable objects of a particular type for population analysis, detection of unique objects worthy of follow-up studies, identification of sources observed at other wavelengths, and photometric characterization of candidate progenitors of supernovæ and other transients in nearby galaxies. The catalog is available to the community from the ESA *Hubble* Science Archive (eHST) at the European Space Astronomy Centre (ESAC) and the Mikulski Archive for Space Telescopes (MAST) at Space Telescope Science Institute (STScI).

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Precise radial velocities of giant stars XIII. A second Jupiter orbiting in 4:3 resonance in the 7 CMa system

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We report the discovery of a second planet orbiting the K giant star 7 CMa based on 166 high-precision radial velocities obtained with Lick, HARPS, UCLES, and SONG. The periodogram analysis reveals two periodic signals of approximately 745 and 980 d, associated with planetary companions. A double-Keplerian orbital fit of the data reveals two Jupiter-like planets with minimum masses $M_{\rm b} \sin i \sim 1.9$ $\rm M_{jup}$ and $M_{\rm c} \sin i \sim 0.9$ $\rm M_{jup}$, orbiting at semimajor axes of $a_{\rm b} \sim 1.75$ au and $a_{\rm c} \sim 2.15$ au, respectively. Given the small orbital separation and the large minimum masses of the planets, close encounters may occur within the time baseline of the observations; thus, a more accurate N-body dynamical modeling of the available data is performed. The dynamical best-fit solution leads to collision of the planets and we explore the long-term stable configuration of the system in a Bayesian framework, confirming that 13% of the posterior samples are stable for at least 10 Myr. The result from the stability analysis indicates that the two planets are trapped in a low eccentricity 4:3 mean motion resonance. This is only the third discovered system to be inside a 4:3 resonance, making this discovery very valuable for planet formation and orbital evolution models.

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A PSF-based Approach to TESS High quality data Of Stellar clusters (PATHOS) – I. Search for exoplanets and variable stars in the field of 47 Tuc

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TheTESSmission will survey $\sim$ 85 per cent of the sky, giving us the opportunity of extracting high-precision light curves of millions of stars, including stellar cluster members. In this work, we present our project "A PSF-based Approach to TESS High quality data Of Stellar clusters" (PATHOS), aimed at searching and characterize candidate exoplanets and variable stars in stellar clusters using our innovative method for the extraction of high-precision light curves of stars located in crowded environments. Our technique of light-curve extraction involves the use of empirical point spread functions (PSFs), an input catalogue and neighbour-subtraction.The PSF-based approach allows us to minimize the dilution effects in crowded environments and to extract high-precision photometry for stars in the faint regime ($G > 13$ mag). For this pilot project, we extracted, corrected, and analysed the light curves of 16 641 stars located in a dense region centred on the globular cluster 47 Tuc. We were able to reach the TESS magnitude $T \sim 16.5$ with a photometric precision of $\sim$ 1 per cent on the 6.5-h time-scale; in the bright regime we were able to detect transits with depth of $\sim$ 34 parts per million. We searched for variables and candidate transiting exoplanets. Our

pipeline detected one planetary candidate orbiting a main-sequence star in the Galactic field. We analysed the period–luminosity distribution for red-giant stars of 47 Tuc and the eclipsing binaries in the field. Light curves are uploaded on the Mikulski Archive for Space Telescopes under the project PATHOS.

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and from https://ui.adsabs.harvard.edu/abs/2019MNRAS.490.3806N/abstract

My companion is bigger than your companion!

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We provide an analysis of the mass ratio distribution as gathered from almost all of the 559 orbital solutions derived by Professor Roger Griffin in his long series in the Observatory Magazine about "Spectroscopic Binary Orbits from Photoelectric Radial Velocities". The total distribution we determine is close to a uniform one, with a dearth of the smallest companions and an excess of almost twins. When splitting our sample between main-sequence and red giant primaries, however, we discover a different picture: the excess of twins is limited to the main-sequence stars, for which it appears even more pronounced. The mass-ratio distributions of red giants is characterised by a decline of systems with mass ratio above 0.6 and an excess of systems with a mass ratio around 0.25, which we attribute to post-mass transfer systems. The difference between the two mass-ratio distributions is likely due to the different primary masses they sample.

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An ongoing mid-infrared outburst in the white dwarf 0145+234: catching in action the tidal disruption of an exoasteroid?

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We report the detection of a large-amplitude MIR outburst in the white dwarf (WD) 0145+234 in the NEOWISE Survey data. The source had a stable MIR flux before 2018, and was brightened by about 1.0 magnitude in the W1 and W2 bands within half a year and has been continuously brightening since then. No significant variations are found in the optical photometry data during the same period. This suggests that this MIR outburst is caused by recent replenishing or redistribution of dust, rather than intrinsic variations of the WD. Spectral energy distribution modeling of 0145+234 suggests that there was already a dust disk around the WD in the quiescent state, and both of

the temperature and surface area of the disk evolved rapidly since the outburst. The dust temperature was 1770 K in the initial rising phase, close to the sublimation temperature of silicate grains, and gradually cooled down to around 1150 K, while the surface area increased by a factor of about six during the same period. The inferred closest distance of dust to the WD is within the tidal disruption radius of a gravitationally bounded asteroid. We estimated the dust mass to be between 3×10^{15} and 3×10^{17} $\rho/(1$ g cm$^{-}3)$ kg for silicate grains of a power-law size distribution with a high cutoff size from 0.1 to 1000 μm. We interpret this as a possible tidal breakup of an exoasteroid by the WD. Further follow-up observations of this rare event may provide insights on the origin of dust disk and metal pollution in some WDs.

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Available from https://arxiv.org/abs/1910.04314

Carbon-deficient red giants

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Carbon-deficient red giants (CDRGs) are a rare class of peculiar red giants, also called "weak G-band" or "weak-CH" stars. Their atmospheric compositions show depleted carbon, a low ^{12}C/^{13}C isotopic ratio, and an overabundance of nitrogen, indicating that the material at the surface has undergone CN-cycle hydrogen-burning. I present Strömgren *uvby* photometry of nearly all known CDRGs. Barium stars, having an enhanced carbon abundance, exhibit the "Bond–Neff effect" – a broad depression in their energy distributions at $\sim$ 4000 Å, recently confirmed to be due to the CH molecule. This gives Ba II stars unusually low Strömgren c_1 photometric indices. I show that CDRGs, lacking CH absorption, exhibit an "anti-Bond–Neff effect": higher c_1 indices than normal red giants. Using precise parallaxes from Gaia DR2, I plot CDRGs in the color–magnitude diagram (CMD) and compare them with theoretical evolution tracks. Most CDRGs lie in a fairly tight clump in the CMD, indicating initial masses in the range $\sim$ 2 to 3.5 M$_\odot$, if they have evolved as single stars. It is unclear whether they are stars that have just reached the base of the red-giant branch and the first dredge-up of CN-processed material, or are more highly evolved helium-burning stars in the red-giant clump. About 10% of CDRGs have higher masses of $\sim$ 4 to 4.5 M$_\odot$, and exhibit unusually high rotational velocities. I show that CDRGs lie at systematically larger distances from the Galactic plane than normal giants, possibly indicating a role of binary mass-transfer and mergers. CDRGs continue to present a major puzzle for our understanding of stellar evolution.

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A carbon-rich hot bubble in the planetary nebula NGC 5189

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We present the discovery of extended X-ray emission from the planetary nebula (PN) NGC 5189 around the [WO1]-type WD 1330−657 with XMM–*Newton*. The X-ray-emitting gas fills the cavities detected in the *Hubble* Space Telescope [O III] narrow-band image and presents a limb-brightened morphology towards the outer edges of the east and west lobes. The bulk of the X-ray emission is detected in the soft (0.3–0.7 keV) band with the XMM–*Newton* EPIC spectra dominated by the C VI Lyα line at 0.37 keV (= 33.7 Å). Spectral analysis resulted in carbon and neon abundances 38 and 6 times their solar values, with a plasma temperature of $kT = 0.14 \pm 0.01$ keV ($T = 1.6 \times 10^6$ K) and X-ray luminosity of $L_{\rm X} = (2.8 \pm 0.8) \times 10^{32}$ erg s^{-1}. NGC 5189 is an evolved and extended PN ($\lesssim$0.70 pc in radius), thus, we suggest that the origin of its X-ray emission is consistent with the born-again scenario in which the central star

becomes carbon-rich through an eruptive very late thermal pulse, subsequently developing a fast, carbon-rich wind powering the X-ray emission as suggested for A 30 and A 78.

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A catalogue of stellar diameters and fluxes for mid-infrared interferometry

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We present the Mid-infrared stellar Diameters and Fluxes compilation Catalogue (MDFC) dedicated to long-baseline interferometry at mid-infrared wavelengths (3–13 μm). It gathers data for half a million stars, i.e. nearly all the stars of the *Hipparcos–Tycho* catalogue whose spectral type is reported in the SIMBAD data base. We cross-match 26 data bases to provide basic information, binarity elements, angular diameter, magnitude and flux in the near and mid-infrared, as well as flags that allow us to identify the potential calibrators. The catalogue covers the entire sky with 465 857 stars, mainly dwarfs and giants from B to M spectral types closer than 18 kpc. The smallest reported values reach 0.16 μJy in L and 0.1 μJy in N for the flux, and 2 microarcsec for the angular diameter. We build four lists of calibrator candidates for the L and N bands suitable with the Very Large Telescope Interferometer (VLTI) sub- and main arrays using the MATISSE instrument. We identify 1621 candidates for L and 44 candidates for N with the Auxiliary Telescopes (ATs), 375 candidates for both bands with the ATs, and 259 candidates for both bands with the Unit Telescopes (UTs). Predominantly cool giants, these sources are small and bright enough to belong to the primary lists of calibrator candidates. In the near future, we plan to measure their angular diameter with 1 per cent accuracy.

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Asteroseismological analysis of the ultra-massive ZZ Ceti stars BPM 37093, GD 518, and SDSS J0840+5222

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Ultra-massive ($\gtrsim 1$ M$_\odot$) hydrogen-rich (DA) white dwarfs are expected to have a substantial portion of their cores in a crystalline state at the effective temperatures characterizing the ZZ Ceti instability strip ($T_{\rm eff} \sim 12\,500$ K), as a result of Coulomb interactions in very dense plasmas. Asteroseismological analyses of these white dwarfs can provide valuable information related to the crystallization process, the core chemical composition and the evolutionary origin of these stars. We present a thorough asteroseismological analysis of the ultra-massive ZZ Ceti star BPM 37093, which exhibits a rich period spectrum, on the basis of a complete set of fully evolutionary models that represent ultra-massive oxygen/neon(ONe)-core DA white dwarf stars harbouring a range of hydrogen (H) envelope thicknesses.

We also carry out preliminary asteroseismological inferences on two other ultra-massive ZZ Ceti stars that exhibit fewer periods, GD 518, and SDSS J0840+5222. We considered g-mode adiabatic pulsation periods for ultra-massive ONe-core DA white dwarf models with stellar masses in the range $1.10 \lesssim M_\star/\mathrm{M}_\odot \lesssim 1.29$, effective temperatures in the range $10\,000 \lesssim T_{\rm eff} \lesssim 15\,000$ K, and H envelope thicknesses in the interval $-10 \lesssim \log(M_{\rm H}/M_\star) \lesssim -6$. We explore the effects of employing different H-envelope thicknesses on the mode-trapping properties of our ultra-massive ONe-core DA white dwarf models, and perform period-to-period fits to ultra-massive ZZ Ceti stars with the aim of finding an asteroseismological model for each target star. We found that the trapping cycle and trapping amplitude are larger for thinner H envelopes, and that the asymptotic period spacing is longer for thinner H envelopes. We found a mean period spacing of $\Delta\Pi \sim 17$ s in the data of BPM 37093, which is likely to be associated to $\ell = 2$ modes. However, we are not able to put constraints on the stellar mass of BPM 37093 using this mean period spacing due to the simultaneous sensitivity of $\Delta\Pi$ with $M_\star$, $T_{\rm eff}$, and $M_{\rm H}$, an intrinsic property of DAV stars. We found asteroseismological models for the three objects under analysis, two of them (BPM 37093 and GD 518) characterized by canonical (thick) H envelopes, and the third one (SDSS J0840+5222) with a thinner H envelope. The effective temperature and stellar mass of these models are in agreement with the spectroscopic determinations. The percentage of crystallized mass of these asteroseismological models is 92%, 97%, and 81% for BPM 37093, GD 518, and SDSS J0840+5222, respectively. We also derive asteroseismological distances which are in agreement with the astrometric measurements of Gaia for these stars. Asteroseismological analyses like the one presented in this paper could lead to a more complete knowledge of the processes occurring during crystallization inside white dwarfs. Also, they could make it possible to deduce the core chemical composition of ultra-massive white dwarfs, and in this way, to infer their evolutionary origin, i.e. if the star has an ONe core and then is the result of single-star evolution, or if it harbour a carbon/oxygen (CO) core and is the product of a merger of the two components of a binary system. However, to achieve these objectives it is necessary to find more pulsating ultra-massive WDs, and also to carry out additional observations of the already known pulsating stars to detect more pulsation periods. Space missions such as TESS can give a great boost in this direction.

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Compositions of planetary debris around dusty white dwarfs

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The photospheres of some white dwarfs are "polluted" by accretion of material from their surrounding planetary debris. White dwarfs with dust disks are often heavily polluted and high-resolution spectroscopic observations of these systems can be used to infer the chemical compositions of extrasolar planetary material. Here, we report spectroscopic observation and analysis of 19 white dwarfs with dust disks or candidate disks. The overall abundance pattern very much resembles that of bulk Earth and we are starting to build a large enough sample to probe a wide range of planetary compositions. We found evidence for accretion of Fe-rich material onto two white dwarfs as well as O-rich but H-poor planetary debris onto one white dwarf. In addition, there is a spread in Mg/Ca and Si/Ca ratios and it cannot be explained by differential settling or igneous differentiation. The ratios appear to follow an evaporation sequence. In this scenario, we can constrain the mass and number of evaporating bodies surrounding polluted white dwarfs.

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Overall variation of the H_2O masers around W Hydræ in 28 years

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In this paper, we present the distribution of H_2O masers associated with a semi-regular variable star W Hydræ (W Hya). We have collected the radio interferometric data of the maser distribution taken with the Very Large Array (VLA), the Kashima–Nobeyama InterFErometer (KNIFE), Multi-Element Radio Link Network (MERLIN), the VLBI Exploration of Radio Astrometry (VERA), and the combined array of Korean VLBI Network (KVN) and VERA (KaVA) in order to trace the maser distribution variation in two decades. Even though differences in the sensitivities and angular resolutions of the interferometric observations should be taken into account, we attempt to find possible correlation of the maser distribution with the stellar light curve. Our failure in measurement of the annual parallax of the masers with VERA is likely caused by the properties of the maser features, which have been spatially resolved by the synthesized beam and survived for only half year or shorter. No dependence of the maser spot flux density on its size is found in the KNIFE data, suggesting that maser spot size is determined by the physical boundary as expected for a clump affected by outward propagation of a stellar pulsation shock wave rather than the (spherical) geometry of maser beaming in the maser gas clump.

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Tomography of cool giant and supergiant star atmospheres II. Signature of convection in the atmosphere of the red supergiant star μ Cep

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Context: Red supergiants are cool massive stars and are the largest and the most luminous stars in the Universe. They are characterized by irregular or semi-regular photometric variations, the physics of which is not clearly understood.
Aims: The paper aims to derive the velocity field in the red supergiant star μ Cep and to relate it to the photometric variability with the help of the tomographic method.
Methods: The tomographic method allows one to recover the line-of-sight velocity distribution over the stellar disk and within different optical-depth slices. This method was applied to a series of high-resolution spectra of μ Cep, and these results are compared to those obtained from 3D radiative-hydrodynamics CO5BOLD simulations of red supergiants. Fluctuations in the velocity field are compared with photometric and spectroscopic variations, the latter were derived from the TiO band strength and serve, at least partly, as a proxy of the variations in effective temperature.
Results: The tomographic method reveals a phase shift between the velocity and spectroscopic and photometric variations. This phase shift results in a hysteresis loop in the temperature–velocity plane with a timescale of a few hundred days, which is similar to the photometric one. The similarity between the hysteresis loop timescale measured in μ Cep and the timescale of acoustic waves disturbing the convective pattern suggests that such waves play an important role in triggering the hysteresis loops.

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Properties of carbon stars in the Solar neighbourhood based on Gaia DR2 astrometry

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Stars evolving along the Asymptotic Giant Branch can become carbon-rich in the final part of their evolution. The detailed description of their spectra has led to the definition of several spectral types, namely: N, SC, J and R types. Up to now, differences among them have been partially established only on the basis of their chemical properties. An accurate determination of the luminosity function (LF) and kinematics together with their chemical properties is extremely important for testing the reliability of theoretical models and establishing on a solid basis the stellar population membership of the different carbon star types. Using Gaia Data Release 2 (Gaia DR2) astrometry, we determine the LF and kinematic properties of a sample of 210 carbon stars with different spectral types in the Solar neighbourhood, including some R-hot stars, with measured parallaxes better than 20%. Their spatial distribution and velocity components are also derived. Furthermore, the use of the infrared Wesenheit function allows us to identify the different spectral types in a Gaia–2MASS diagram. We find that the combined LF of N- and SC-type stars are consistent with a Gaussian distribution peaking at $M_{\rm bol} \sim -5.2$ mag. The resulting LF however shows two tails at lower and higher luminosities more extended than those previously found, indicating that AGB carbon stars with Solar metallicity may reach $M_{\rm bol} \sim -6.0$ mag. This contrasts with the narrower LF derived in Galactic carbon Miras from previous studies. We find that J-type stars are about half a magnitude fainter on average than N- and SC-type stars, while R-hot stars are half a magnitude brighter than previously found although, in any case, fainter by several magnitudes than the rest of carbon types. Part of these differences are due to systematically lower parallaxes measured by Gaia DR2 with respect to *Hipparcos* ones, in particular for sources with parallax $\pi < 1$ mas. The Galactic spatial distribution and velocity components of the N-, SC- and J-type stars are very similar, while about 30% of the R-hot stars in the sample are located at distances larger than ~ 500 pc from the Galactic Plane, and show a significant drift with respect to the local standard of rest. The LF derived for N- and SC-type in the Solar neighbourhood fully agrees with the expected luminosity of stars of 1.5–3 $M_\odot$ on the AGB. On a theoretical basis, the existence of an extended low luminosity tail would require a contribution of extrinsic low mass carbon stars, while the high luminosity one would imply that stars with mass up to ~ 5 $M_\odot$ may become carbon stars on the AGB. J-type stars not only differ significantly in their chemical composition with respect to the N- and SC-types but also in their LF, which reinforces the idea that these carbon stars belong to a different type whose origin is still unknown. The derived luminosities of R-hot stars make these stars unlikely to be in the red clump as previously claimed. On the other hand, the derived spatial distribution and kinematic properties, together with their metallicity, indicate that most of the N-, SC- and J-type stars belong to the thin disc population, while a significant fraction of R-hot stars show characteristics compatible with the thick disc.

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Ammonia in the circumstellar environment of V Cyg

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The HIFI instrument on board of the *Herschel* Space Observatory (HSO) has been very successful in detecting molecular lines from circumstellar envelopes around evolved stars, like massive red supergiants, Asymptotic Giant Branch (AGB) and post-AGB stars, as well as planetary nebulæ. Among others, ammonia has been found in circumstellar envelopes of C-rich AGB stars in amounts that significantly exceeded theoretical predictions for C-rich stars. Few scenarios have been proposed to resolve this problem: formation of ammonia behind the shock front, photochemical processes in the inner part of the envelope partly transparent to UV background radiation due to the clumpy structure of the gas, and formation of ammonia on dust grains. Careful analysis of observations may help to put constraints on one or another mechanism of ammonia formation. Here, we present results of the non-LTE radiative transfer modeling of ammonia

transitions including a crucial process of radiative pumping via $v_2 = 1$ vibrational band (at ~ 10 μm) for V Cyg. Only ground-based ammonia transition NH_3 $J = 1_0 - 0_0$ at 572.5 GHz has been observed by HIFI. Therefore, to determine abundance of ammonia we estimate a photodissociation radius of NH_3 using chemical model of the envelope consistent with dust grain properties concluded from the spectral energy distribution.

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Measurements of low temperature rate coefficients for the reaction of CH with CH_2O and application to dark cloud and AGB stellar wind models

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Rate coefficients have been measured for the reaction of CH radicals with formaldehyde, CH_2O, over the temperature range 31–133 K using a pulsed Laval nozzle apparatus combined with pulsed laser photolysis and laser induced fluorescence spectroscopy. The rate coefficients are very large and display a distinct decrease with decreasing temperature below 70 K, although classical collision rate theory fails to reproduce this temperature dependence. The measured rate coefficients have been parameterized and used as input for astrochemical models for both dark cloud and AGB stellar outflow scenarios. The models predict a distinct change (up to a factor of two) in the abundance of ketene, H_2CCO, which is the major expected molecular product of the CH + CH_2O reaction.

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The effect of pulsation on the near-ultraviolet spectrum of AGB stars

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Pulsating and non-pulsating AGB stars exhibit a variable near-UV spectrum, which suggest that mechanisms other than pulsation may affect their near-UV spectrum. In this work we analyse the near-UV spectra of two groups of AGB stars: (1) regularly pulsating and (2) irregular, small-amplitude stars. Near-UV and blue spectra were obtained for 27 stars distributed into these two groups with the INT telescope (La Palma, Spain). Additional near-UV spectra were taken from the IUE library. The occurrence of Fe II lines depends mainly on the intensity of the stellar continuum: as it increases, Fe II lines are gradually hampered. Balmer emission lines are pulsation driven, as they appear only among the large-amplitude pulsating stars of our sample, between $-0.10 < \phi < 0.50$. Among the regularly pulsating stars, the intensity of the Mg IIλ2800 doublet is driven by pulsation, with its maximum between $0.20 < \phi < 0.35$. On the other hand, this feature is also highly variable among small-amplitude, irregularly pulsating stars. This suggests that, besides pulsation, other mechanisms may participate in the formation of this line. The spectral slope between $3000 < \lambda(\text{Å}) < 3200$ is approximately constant among small-amplitude stars, but it shows a strong correlation with the phase of the pulsation in the other group, which indicates that the origin of the continuum is chromospheric. Different phase lags between the Mg IIλ2800 and the slope of the continuum suggests that this line and its neighbouring continuum might be formed in distinct places in the chromosphere or its surroundings.

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The central star of NGC 2346 as a clue to binary evolution through the common envelope phase

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We present an analysis of the binary central star of the planetary nebula NGC 2346 based on archival data from the International Ultraviolet Explorer, and new low- and high-resolution optical spectra (3700–7300 Å). By including in the spectral analysis the contribution of both stellar and nebular continuum, we reconciled long-time discrepant UV and optical diagnostics and derive $E(B-V) = 0.18 \pm 0.01$ mag. We reclassified the companion star as A5 IV by analyzing the wings of the Balmer absorption lines in the high-resolution ($R = 67\,000$) optical spectra. Using the distance to the nebula of 1400 pc from Gaia DR2, we constructed a photoionization model based on abundances and line intensities derived from the low-resolution optical spectra, and obtained a temperature of $T_{\rm eff} = 130\,000$ K and a luminosity of $L = 170$ L$_\odot$ for the ionizing star, consistent with the UV continuum. This analysis allows us to better characterize the binary system's evolution. We conclude that the progenitor star of NGC 2346 has experienced a common envelope phase, in which the companion star has accreted mass and evolved off the main-sequence.

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CO in the C1 globule of the Helix nebula with ALMA

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We present and analyse ^{12}CO, ^{13}CO, and C^{18}O(2–1) ALMA observations of the C1 globule inside the Helix nebula in order to determine its physical properties. Our findings confirm the molecular nature of the globule with a multipeak structure. The ^{12}CO line has a high optical depth $\tau \sim 10$. The derived ^{12}C/^{13}C ~ 10 and ^{16}O/^{18}O ~ 115 ratios are not in agreement with the expected isotopic ratios of carbon-rich AGB stars. Assuming that the ^{12}CO optical depth has been underestimated, we can find a consistent fit for an initial mass of 2 M$_\odot$. We obtain a molecular mass of $\sim 2 \times 10^{-4}$ M$_\odot$ for the C1 globule, which is much higher than its mass in the literature. Clumping could play a role in the high molecular mass of the knot. The origin of the tail is discussed. Our findings show that the most probable model appears to be shadowing. The kinematics and molecular morphology of the knot are not consistent with a wind-swept model and the photoevaporation model alone is not enough to explain the nature of the globule. We propose an integrated model where the effects of the photoevaporation, the stream, and shadowing models are all considered in the tail shaping process.

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Discovery of a rare late-type, low-mass Wolf–Rayet star in the LMC

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We report the serendipitous discovery of an object, UVQS J060819.93−715737.4, with a spectrum dominated by extremely intense, narrow C II emission lines. The spectrum is similar to those of the very rare, late-type [WC11] low-mass Wolf–Rayet stars. Despite the recognition of these stars as a distinct class decades ago, there remains barely a handful of Galactic members, all of which are also planetary-nebula central stars. Although no obvious surrounding nebulosity is present in J0608, [O II], [N II], and [S II] emission suggest the presence of an inconspicuous, low-excitation nebula. There is low-amplitude incoherent photometric variability on timescales of days to years, as well as numerous prominent P Cygni profiles, implying mass loss. There are indications of a binary companion. The star is located on the outskirts of the LMC, and the observed radial velocity ($\sim$ 250 km s^{-1}) and proper motion strongly suggest membership. If indeed an LMC member, this is the first extragalactic late [WC] star, and the first with an accurately determined luminosity, as the Galactic examples are too distant for precise parallax determinations. A high-quality, broad-coverage spectrum of the prototype of the late [WC] class, CPD −56°8032, is also presented. We discuss different excitation mechanisms capable of producing the great strength of the C II emission. Numerous autoionizing levels of C II are definitely populated by processes other than dielectronic recombination. Despite the spectacular emission spectra, observational selection makes objects such as these difficult to discover. Members of the [WC11] class may in fact be considerably more common than the handful of previously known late [WC] stars.

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The extended molecular envelope of the asymptotic giant branch star π^1 Gruis as seen by ALMA. II. The spiral-outflow observed at high-angular resolution

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This study follows up the previous analysis of lower-angular resolution data in which the kinematics and structure of the circumstellar envelope (CSE) around the S-type asymptotic giant branch (AGB) star π^1 Gruis were investigated. The AGB star has a known companion (at a separation of $\sim$ 400 au) which cannot explain the strong deviations from spherical symmetry of the CSE. Recently, hydrodynamic simulations of mass transfer in closer binary systems have successfully reproduced the spiral-shaped CSEs found around a handful of sources. There is growing evidence for an even closer, undetected companion complicating the case of π^1 Gruis further. The improved spatial resolution allows for the investigation of the complex circumstellar morphology and the search for imprints on the CSE of the third component. We have observed the ^{12}CO $J = 3$–2 line emission from π^1 Gruis using both the compact and extended array of Atacama Large Millimeter/submillimeter Array (ALMA). The interferometric data has furthermore been

combined with data from the ALMA total power (TP) array. The imaged brightness distribution has been used to constrain a non-local, non-LTE 3D radiative transfer model of the CSE. The high-angular resolution ALMA data have revealed the first example of a source on the AGB where both a faster bipolar outflow and a spiral pattern along the orbital plane can be seen in the gas envelope. The spiral can be traced in the low- to intermediate-velocity (13–25 km s^{-1}) equatorial torus. The largest spiral-arm separation is $\approx 5\farcs5$ and consistent with a companion with an orbital period of $\approx$ 330 yrs and a separation of less than 70 au. The kinematics of the bipolar outflow is consistent with it being created during a mass-loss eruption where the mass-loss rate from the system increased by at least a factor of five for 10–15 yrs. The spiral pattern is the result of an undetected companion. The bipolar outflow is the result of a rather recent mass-loss eruption event.

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Kinematical investigation of possible fast collimated outflows in twelve planetary nebulæ

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A significant fraction of planetary nebulæ (PNe) exhibit collimated outflows, distinct narrow kinematical components with notable velocity shifts with respect to the main nebular shells typically associated with low-ionization compact knots and linear or precessing jet-like features. We present here a spatio-kinematical investigation of a sample of twelve PNe with morphologies in emission lines of low-ionization species suggestive of collimated outflows. Using archival narrow-band images and our own high-dispersion long-slit échelle spectra, we confirm the presence of collimated outflows in Hen 2-429, J 320, M 1-66, M 2-40, M 3-1, and NGC 6210 and possibly in NGC 6741, for which the spatio-kinematical data can also be interpreted as a pair of bipolar lobes. The presence of collimated outflows is rejected in Hen 2-47, Hen 2-115, M 1-26, and M 1-37, but their morphology and kinematics are indicative of the action of supersonic outflows that have not been able to pierce through the nebular envelope. In this sense, M 1-66 appears to have experienced a similar interaction between the outflow and nebular envelope, but, as opposed to these four PNe, the outflow has been able to break through the nebular envelope. It is suggested that the PNe without collimated outflows in our sample are younger or descend from lower mass progenitors than those that exhibit unambiguous collimated outflows.

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Physical properties of the fluorine and neutron-capture element rich PN Jonckheere 900

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We performed detailed spectroscopic analyses of a young C-rich planetary nebula (PN) Jonckheere 900 (J 900) in order to characterise the properties of the central star and nebula. Of the derived 17 elemental abundances, we present the first determination of eight elemental abundances. We present the first detection of the [F IV] 4059.9 Å, [F V] 13.4 μm, and [Rb IV] 5759.6 Å lines in J900. J900 exhibits a large enhancement of F and neutron-capture elements Se, Kr, Rb, and Xe. We investigated the physical conditions of the H_2 zone using the newly detected mid-IR H_2 lines while also using the the previously measured near-IR H_2 lines, which indicate warm ($\sim$ 670 K) and hot ($\sim$ 3200 K) temperature regions. We built the spectral energy distribution (SED) model to be consistent with all the observed quantities. We found that about 67% of all dust and gas components (4.5×10^{-4} $M_\odot$ and 0.83 $M_\odot$, respectively) exists beyond the ionisation front, indicating critical importance of photodissociation regions in understanding stellar mass loss. The

best-fitting SED model indicates that the progenitor evolved from an initially ~ 2.0 $M_\odot$ star which had been in the course of the He-burning shell phase. Indeed, the derived elemental abundance pattern is consistent with that predicted by a asymptotic giant branch star nucleosynthesis model for a 2.0-$M_\odot$ star with $Z = 0.003$ and partial mixing zone mass of 6.0×10^{-3} $M_\odot$. Our study demonstrates how accurately determined abundances of C/F/Ne/neutron-capture elements and gas/dust masses help us understand the origin and the internal evolution of the PN progenitors.

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Variability in proto-planetary nebulæ: VI. Multi-telescope light curve studies of several medium-bright ($V = 13$–15 mag), carbon-rich objects

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We present ten years of new photometric monitoring of the light variability of five evolved stars with strong mid-infrared emission from surrounding dust. Three are known carbon-rich proto-planetary nebulæ (PPNe) with F–G spectral types; the nature of the other two was previously unknown. For the three PPNe, we determine or refine the pulsation periods of IRAS 04296+3429 (71 days), 06530−0213 (80 days), and 23304+6147 (84 days). A secondary period was found for each, with a period ratio P_2/P_1 of 0.9. The light variations are small, 0.1–0.2 mag. These are similar to values found in other PPNe. The other two are found to be giant stars. IRAS 09296+1159 pulsates with a period of only 47 days but reaches pulsational light variations of 0.5 mag. Supplemental spectroscopy reveals the spectrum of a CH carbon star. IRAS 08359-1644 is a G1 III star that does not display pulsational variability; rather, it shows non-periodic decreases of brightness of up to 0.5 mag over this ten-year interval. These drops in brightness are reminiscent of the light curves of R Corona Borealis variables, but with much smaller decreases in brightness, and are likely due to transient dust obscuration. Its SED is very similar to that of the unusual oxygen-rich giant star HDE 233517, which possesses mid-infrared hydrocarbon emission features. These two non-PPNe turn out to members of the rare group of giant stars with large mid-infrared excesses due to dust, objects which presumably have interesting evolutionary histories.

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High-resolution spectroscopy of the high velocity hot post-AGB star IRAS 18379−1707 (LS 5112)

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The high-resolution ($R \sim 48\,000$) optical spectrum of the B-type supergiant LS 5112, identified as the optical counterpart of the post-AGB candidate IRAS 18379−1707, is analysed. We report the detailed identifications of the observed absorption and emission features in the wavelength range 3700–9200 Å for the first time. The absorption line spectrum has been analysed using non-LTE model atmosphere techniques to determine stellar atmospheric parameters and chemical composition. We estimate $T_{\rm eff} = 18000 \pm 1000$ K, $\log g = 2.25 \pm 0.08$, $\xi_t = 10 \pm 4$ km s^{-1} and $v \sin i = 37 \pm 6$ km s^{-1}, and the derived abundances indicate a metal-deficient ([M/H] ≈ -0.6) post-AGB star. Chemical abundances of eight different elements were obtained. The estimates of the CNO abundances in IRAS 18379−1707 indicate that

these elements are overabundant with [(C+N+O)/S] = $+0.5 \pm 0.2$ suggesting that the products of helium burning have been brought to the surface as a result of third dredge-up on the AGB. From the absorption lines, we derived heliocentric radial velocity of $v_r = -124.0 \pm 0.4$ km s^{-1}. We have identified permitted emission lines of O I, N I, Na I, S II, Si II, C II, Mg II and Fe III. The nebula forbidden lines of [N I], [O I], [Fe II], [N II], [S II], [Ni II]and [Cr II] have also been identified. The Balmer lines Hα, Hβ and Hγ show P-Cygni behaviour clearly indicating post-AGB mass-loss process in the object with the wind velocity up to 170 km s^{-1}.

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Models of the mass-ejection histories of pre-planetary nebulæ. IV. Magnetized winds and the origins of jets, bullets, and FLIERs

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The influences and consequences of toroidal magnetic fields in shaping the visible lobes of pre-planetary nebulæ ("prePNe") are explored in this, the last of a series of papers of parameter studies of prePN evolution. To probe these influences we start with the steady, diverging, and field-free wind model of our previous papers and add weak to moderate toroidal fields to the winds in order to generate arrays of outcomes after 500 y, after which the structures grow almost homologously. As expected, toroidal fields in the stellar winds invariably form very thin and dense axial features whose structure is best described as a thin cold jet with an ultra-dense and neutral leading knot, or "bullet", at its tip. The speed of the leading knot depends only on the density contrast (the ratio of injected to ambient gas densities at the nozzle) and wind injection speed, but not on the field strength or opening angle. The lobes formed by the ram pressure of the winds take a variety of forms and sizes that depend primarily on the geometric structure of the injected gas and the density contrast. About 20% of the HST images of prePNe show the unique signatures of shaping by toroidal fields. Pairs of low-ionization knots seen along the major axis of fully ionized PNe, often called "FLIERs", are easily explained as the very dense, cold , and neutral remnants of magnetically formed knots.

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Conference Paper

Evolutionary timescales from the AGB to the CSPNe phase

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The transition from the asymptotic giant branch (AGB) to the final white dwarf (WD) stage is arguably the least understood phase in the evolution of single low- and intermediate-mass stars ($0.8 \lesssim M_{\rm ZAMS}/{\rm M}_\odot \lesssim 8...10$). Here we briefly review the progress in the last 50 years of the modeling of stars during the post-AGB phase. We show that although the main features, like the extreme mass dependency of post-AGB timescales were already present in the earliest post-AGB models, the quantitative values of the computed post-AGB timescales changed every time new physics was included in the modeling of post-AGB stars and their progenitors. Then we discuss the predictions and uncertainties of the latest available models regarding the evolutionary timescales of post-AGB stars.

Oral contribution, published in IAU Symposium No. 343 "Why Galaxies Care About AGB stars IV", Vienna (2018), invited review
Available from https://arxiv.org/abs/1910.01013

Review Paper

Semi-regular variable stars

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The studies of semi-regular variable stars by different authors are considered, and the main theoretical and observational problems associated with these stars are reviewed. Their evolutionary status and possible connection with long-period variables such as Mira Ceti are discussed. Individual objects belonging to different types of semi-regular variables are described in detail. The studies of the period were carried out for all the considered stars using periodogram and/or wavelet analysis. The study of phase portraits of smoothed light fluctuations was added to the previously developed additional photometric classification criteria. It is also noted that all methods of analysis of photometric behavior used for Mira-type stars can be applied to semi-regular variables. After leaving the main sequence, the stars pass through the region of instability of Cepheids, turning into radially pulsating variables of type δ Cephei. These stars can be associated with semi-regular variables giants and supergiants of spectral classes F–K, which are usually denoted by the symbol SRd. In the process of further evolution of the variables of high luminosity fall in the region of red supergiants, becoming the type variables SRc (or Lc), and the variables lower luminosity turn into a semi-regular variables SRab (or wrong Lb) of late spectral classes. Variables of the RV Tau type are a class of low-mass (with masses of the order of one solar) pulsating F–K-supergiants ($M_V = -3^{\rm m} \div 5^{\rm m}$), which may be at the short-term evolutionary stage of transition from the red giant to the proto-planetary nebula, which explains the small number of stars of this type of variability.

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Job Advert

University of Georgia, USA
Tenure-Track Faculty Position in Computational Astrophysics

The Department of Physics and Astronomy at the University of Georgia has an opening for a tenure-track assistant professor in Computational Astrophysics with an anticipated start date of August 2020. The Department is expanding into a number of the National Science Foundation's 10 Big Ideas for research areas, including Multi-Messenger Astronomy (MMA). We are particularly interested in candidates with expertise in neutron star merger/kilonova modeling, hydrodynamical simulations, and related areas. However, outstanding candidates in all fields of computational astrophysics will be considered. Currently the department has 24 faculty members, five of whom work in astronomy and astrophysics. Specialties include radio, UV, and X-ray observations of the interstellar medium, infrared observations of disks, hydrodynamical and spectral simulations of interstellar gas, and atomic and molecular laboratory astrophysics. UGA is uniquely located within short drives to Oak Ridge National Laboratory (NL), Savannah River NL, Marshall Space Flight Center, and Atlanta. The Department has a strong commitment to undergraduate and graduate education. The new hire will be expected to contribute effectively to our teaching effort and to develop a vigorous, externally funded research program. A Ph.D. in astronomy, physics, or related field with at least one year of postdoctoral experience is required.

To apply for this position, please upload a cover letter addressed to Prof. Robin Shelton, the Chair of the Search Committee, along with a CV, statements of research and teaching interests, and names and contact information of

three references, on http://www.ugajobsearch.com/postings/126115

Review of applications will begin on December 12, 2019 and all applications received by that date will receive full consideration. The Franklin College of Arts and Sciences, its many units, and UGA are committed to increasing the diversity of its faculty and students, and sustaining a work and learning environment that is inclusive. Women, minorities and people with disabilities are encouraged to apply. UGA is an Equal Opportunity/ Affirmative Action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, ethnicity, age, genetic information, disability, gender identity, sexual orientation, or protected veteran status. Persons needing accommodations or assistance with the accessibility of materials related to this search are encouraged to contact Central HR (hrweb@uga.edu). Please do not contact the Department or search committee with such requests.

See also http://www.ugajobsearch.com/postings/126115

Announcements

The Sharpest Eyes on the Sky: A 2020 vision for high angular resolution astronomy

Dear colleagues,

We invite you to join us at the University of Exeter, UK, between April 20–24$^{\text{th}}$ 2020 for our conference on high angular resolution astronomy.

The conference will focus on discussing the latest scientific results obtained with optical interferometry and other high angular resolution imaging techniques (ALMA, SPHERE, GPI, ...). There will be presentations on operational aspects, ongoing and future instrumentation development activities at CHARA and VLTI, and opportunities to discuss synergies between facilities.

We are charging a fee of GBP (£) 95 per delegate (with financial support from ERC project "ImagePlanetFormDiscs" and the University of Exeter). This cost covers all conference events for the delegate including a ticket for the conference dinner and attendance at one of two excursions we are offering for the Wednesday afternoon. For more information as well as details of how to register your attendance and submit a talk/poster abstract, please visit the conference website provided.

Please note that the deadline for registration and abstract submission is March 6$^{\text{th}}$ 2020.

Confirmed Invited Speakers:
Arnaud Cassan (IAP Paris, France), Mercedes Filho (University of Porto, Portugal), Violeta Games (University of Leiden, The Netherlands), Tyler Gardner (University of Michigan, USA), Doug Gies (Georgia State University, USA), Susanne Höfner (Uppsala University, Sweden), Evgenia Koumpia (University of Leeds, UK), Jacques Kluska (University of Leuven, Belgium), Sylvestre Lacour (Observatoire de Paris, France), Keiichi Ohnaka (University of Antofagasta, Chile).

Scientific Organisers:
Fabien Baron (Georgia State University, USA), Claire Davies (University of Exeter, UK), Sebastian Hönig (University of Southampton, UK), Stefan Kraus (University of Exeter, UK), Antoine Mérand (European Southern Observatory, Germany), Claudia Paladini (European Southern Observatory, Chile), Rachael Roettenbacher (Yale University, USA), Gail Schaefer (CHARA Array, USA).

See also http://sites.exeter.ac.uk/sharpesteyes2020/