# THE AGB NEWSLETTER

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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra




## *Editorial*

Dear Colleagues,

It is our pleasure to present you the 298$^{th}$ issue of the AGB Newsletter.

There's a fantastic opportunity for a postdoc to work with Keiichi Ohnaka, in Santiago de Chile.

Meanwhile, the Fizeau interferometry exchange programme continues.

Do consider the workshop on the links between atomic data and our understanding of the Milky Way system.

John Percy (University of Toronto) responds to last month's *Food for Thought* ("What is Betelgeuse going to do next"):

"I recently published a short, non-refereed article, addressed primarily to amateur astronomers, on 'What's Up With Betelgeuse?' (Percy 2020, JRASC, 114, 134). I pointed out that Betelgeuse had a pulsation period of $388 \pm 30$ d and a 'long secondary period' (LSP) of $2025 \pm 460$ d. Both have variable amplitude. At the time of the 'Great Dimming' in 2020, both were at their minimum phase, and their maximum amplitude, resulting in an unusually deep minimum. Other observations show that this minimum was enhanced by obscuring dust.

Assuming that these periods continue, and their amplitude variations continue, then we might expect similar 'great dimmings' in the future. They have occurred in the past, e.g., in 1925–26 (Goldberg 1984, PASP, 96, 366). Goldberg shows that Betelgeuse is a spectroscopic binary with a period of 2100 d – not statistically different from the LSP. The obscuring dust may therefore be associated with the companion, as is the case with RV Tauri stars and red giants with LSPs.

These various observations show the benefit of long-term data, including the visual data collected by the American Association of Variable Star Observers."

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

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

# *Food for Thought*

This month's thought-provoking statement is:

*How can we prove (close) binarity of red (super) giants in the presence of pulsation and convection?*

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)

## The white dwarf binary pathways survey – VII. Evidence for a bi-modal distribution of post mass transfer systems?

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Binary systems consisting of a white dwarf (WD) and a main-sequence companion with orbital periods up to $\approx 100$ d are often thought to be formed through common envelope evolution which is still poorly understood. To provide new observational constraints on the physical processes involved in the formation of these objects, we are conducting a large-scale survey of close binaries consisting of a WD and an A- to K-type companion. Here, we present three systems with eccentric orbits and orbital periods between $\approx 10$ and 42 d discovered by our survey. Based on *Hubble* Space Telescope spectroscopy and high-angular resolution images obtained with the Spectro-Polarimetric High-contrast Exoplanet REsearch (SPHERE), we find that two of these systems are most likely triple systems while the remaining one could be either a binary or a hierarchical triple but none of them is a post-common envelope binary (PCEB). The discovery of these systems shows that our survey is capable to detect systems with orbital periods of the order of weeks, but all six PCEBs we have previously discovered have periods $< 2.5$ d. We suggest that the fact that all of the systems we identify with periods of the order of weeks are not PCEBs indicates a transition between two different mechanisms responsible for the formation of very close ($\lesssim 10$ d) and somewhat wider WD + AFGK binaries: common envelope evolution and non-conservative stable mass transfer.

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*and from* https://academic.oup.com/mnras/article-abstract/512/2/2625/6547013?redirectedFrom=PDF

## What are the SRd stars?

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SRd variables are semiregular pulsating variable giants or supergiants of spectral type F, G, or K. But why are they not regular? This paper presents a detailed study, using light curve analysis, and Fourier and wavelet analysis, of data from the All-Sky Automated Survey for Supernovae (ASAS-SN), on 37 arbitrarily-selected SRd variables to examine the possible causes of their non-regularity. Of the 37 variables, 30 showed significant variations in pulsation amplitude, 11 showed significant "wandering" of the period, 6 showed abrupt period shifts, 7 showed a possible long secondary period (LSP), 8 showed possible bimodal pulsation, and 4 showed otherwise complicated behavior. Variable pulsation amplitude is therefore the most common of several phenomena which lead to their non-regularity. It also occurs in RV Tauri variables and pulsating red giants, but its physical cause is not known, nor is the cause of period wandering. Because there was some previous evidence that LSPs were rare among SRd variables, 13 SRd stars with the longest ASAS-SN periods were similarly analyzed. That analysis, and examination of the light curves of several dozen other SRd variables with long ASAS-SN periods showed clearly that LSPs are common in SRd variables. In longer-period SRd variables in the ASAS-SN variable star catalog, the catalog period is usually the LSP, rather than the pulsation period. LSPs in RV Tauri variables and in red giants have been ascribed to binarity; that may be the case in SRd

variables also. A dozen W Virginis variables and 30 RV Tauri variables were also analyzed to study the overlap and possible relationship between CW, RV, and SRd stars. There is considerable overlap between these types.

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## Molecules in the carbon-rich protoplanetary nebula CRL 2688

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We present observations of the carbon-rich protoplanetary nebula CRL 2688 made with the Institut de Radioastronomie Millimétrique 30 m telescope in the 3 and 2 mm bands. In total, 196 transition lines belonging to 38 molecular species and isotopologues are detected, among which, to the best of our knowledge, 153 transition lines and 13 species are the first reported for this object. Additionally, in order to contribute to future research, we have collected observational data on the molecular lines of CRL 2688 from the literature and compiled them into a single unified catalog. We find that the molecular abundance of CRL 2688 cannot be explained by the standard model of a circumstellar envelope. The implications of metal-bearing molecules on circumstellar chemistry are discussed.

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*and from* https://doi.org/10.3847/1538-4365/ac5180

## Mass matters: no evidence for ubiquitous lithium production in low-mass clump giants

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Spectroscopic surveys are providing large samples of lithium (Li) measurements in evolved stars. A seemingly unexpected result from this work has been the apparent detection of Li at a higher rate in core helium-burning stars than in luminous shell hydrogen-burning stars, which has been interpreted as evidence for ubiquitous Li production on the upper red giant branch or at helium ignition. This is distinct from the "Li-rich giant" problem and reflects bulk red clump star properties. We provide an analysis of the GALAH Li data that accounts for the distribution of progenitor masses of field red clump stars observed today. Using standard models of the post-main sequence evolution of low-mass stars, we show that the observed distribution of Li among the bulk of field clump giants is natural, and that observations of clump and red giants in the field should not be compared without correcting for population effects. For typical stellar population distributions, moderate Li abundances among the bulk of field clump giants are expected without the need for a new Li production mechanism. Our model predicts a large fraction of very low Li abundances from low mass progenitors, with higher Li abundances from higher mass ones. Moreover, there should be a large number of upper limits for red clump stars, and higher abundances should correspond to higher masses. The

most recent GALAH data indeed confirm the presence of large numbers of upper limits, and a much lower mean Li abundance in clump stars, which is concordant with our interpretation.

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## First detection of AlF line emission towards M-type AGB stars

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The nucleosynthesis production of fluorine (F) is still a matter of debate. Asymptotic giant branch (AGB) stars are one of the main candidates for F production. However, their contribution to the total F budget is not fully known due to the lack of observations. In this paper, we report the detection of aluminium monofluoride (AlF) line emission, one of the two main carriers of F in the gas-phase in the outflow of evolved stars, towards five nearby oxygen-rich (M-type) AGB stars. We studied the Atacama large millimetre/submillimetre array (ALMA) observations of AlF ($v = 0$, $J = 4$–3, 9–8, 10–9, and 15–14) and ($v = 1$, $J = 7$–6) line emission towards o Ceti, and ($v = 0$, $J = 7$–6 and 15–14) lines towards R Leo. We also report a tentative detection of AlF ($v = 0$, $J = 7$–6) line in IK Tau, ($v = 0$, $J = 15$–14) line towards R Dor, and ($v = 0$, $J = 7$–6 and $J = 15$–14) lines in W Hya. From spatially resolved observations, we estimated the AlF emitting region with a radius $\sim 11\ R_\star$ for o Ceti and $\sim 9\ R_\star$ for R Leo. From population diagram analysis, we report the AlF column densities of $\sim 5.8 \times 10^{15}$ cm$^{-2}$ and $\sim 3 \times 10^{15}$ cm$^{-2}$ for o Ceti and R Leo, respectively, within these regions. For o Ceti, we used the $C^{18}O$ ($v = 0$, $J = 3$–2) observations to estimate the $H_2$ column density of the emitting region. We found a fractional abundance of $f_{AlF/H_2} \sim (2.5 \pm 1.7) \times 10^{-8}$. This gives a lower limit on the F budget in o Ceti and is compatible with the solar F budget $f_{F/H_2} = (5 \pm 2) \times 10^{-8}$. For R Leo, a fractional abundance $f_{AlF/H_2} = (1.2 \pm 0.5) \times 10^{-8}$ is estimated. For other sources, we cannot precisely determine the emitting region based on the available data. Assuming an emitting region with a radius of $\sim 11\ R_\star$ and the rotational temperatures derived for o Ceti and R Leo, we crudely approximated the AlF column density to be $\sim (1.2$–$1.5) \times 10^{15}$ cm$^{-2}$ in W Hya, $\sim (2.5$–$3.0) \times 10^{14}$ cm$^{-2}$ in R Dor, and $\sim (0.6$–$1.0) \times 10^{16}$ cm$^{-2}$ in IK Tau. These result in fractional abundances within a range of $f_{AlF/H_2} \sim (0.1$–$4) \times 10^{-8}$ in W Hya, R Dor, and IK Tau.

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## Numerical experiments to help understand cause and effect in massive star evolution

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The evolution of massive stars is affected by a variety of physical processes including convection, rotation, mass loss and binary interaction. Because these processes modify the internal chemical abundance profiles in multiple ways simultaneously, it can be challenging to determine which properties of the stellar interior are primarily driving the overall evolution. Building on previous work, we develop a new modelling approach called snapshot that allows us to isolate the key features of the internal abundance profile that drive the evolution of massive stars. Using our approach, we compute numerical stellar structure models in thermal equilibrium covering key phases of stellar evolution. For the main sequence, we demonstrate that models with the same mass and very similar surface properties can have different internal distributions of hydrogen and convective core masses. We discuss why massive stars expand after the main sequence and the fundamental reasons for why they become red, blue or yellow supergiants. For the post-main sequence, we demonstrate that small changes in the abundance profile can cause very large effects on the surface properties. We also discuss the effects that produce blue supergiants and the cause of blue loops. Our models show that massive stars with lower metallicity tend to be more compact due to the combined effect of lower CNO abundances in the burning regions and lower opacity in the envelope.

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# The ultramassive white dwarfs of the $\alpha$ Persei cluster

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We searched through the entire Gaia EDR3 candidate white dwarf catalog for stars with proper motions and positions that are consistent with them having escaped from the $\alpha$ Persei cluster within the past 81 Myr, the age of the cluster. In this search we found five candidate white dwarf escapees from $\alpha$ Persei and obtained spectra for all of them. We confirm that three are massive white dwarfs sufficiently young to have originated in the cluster. All these are more massive than any white dwarf previously associated with a cluster using Gaia astrometry, and possess some of the most massive progenitors. In particular, the white dwarf Gaia EDR3 4395978097863572, which lies within 25 pc of the cluster center, has a mass of about 1.20 $M_\odot$ and evolved from an 8.5 $M_\odot$ star, pushing the upper limit for white dwarf formation from a single massive star, while still leaving a substantial gap between the resulting white dwarf mass and the Chandrasekhar mass.

**Published in The Astrophysical Journal Letters**
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*and from* https://iopscience.iop.org/article/10.3847/2041-8213/ac50a5

# Kinematic properties of white dwarfs. Galactic orbital parameters and age–velocity dispersion relation

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*Context:* Kinematic and chemical tagging of stellar populations have both revealed much information on the past and recent history of the Milky Way, including its formation history, merger events, and mixing of populations across the Galactic disk and halo.

*Aims:* We present the first detailed 3D kinematic analysis of a sample of 3133 white dwarfs that used Gaia astrometry plus radial velocities, which were measured either by Gaia or by ground-based spectroscopic observations. The sample includes either isolated white dwarfs that have direct radial velocity measurements, or white dwarfs that belong to common proper motion pairs that contain nondegenerate companions with available radial velocities. A subset of common proper motion pairs also have metal abundances that have been measured by large-scale spectroscopic surveys or by our own follow-up observations.
*Methods:* We used the white dwarfs as astrophysical clocks by determining their masses and total ages through interpolation with dedicated evolutionary models. We also used the nondegenerate companions in common proper motions to chemically tag the population. Combining accurate radial velocities with Gaia astrometry and proper motions, we derived the velocity components of our sample in the Galactic rest frame and their Galactic orbital parameters.
*Results:* The sample is mostly located within $\sim$ 300 pc from the Sun. It predominantly contains (90–95%) thin-disk stars with almost circular Galactic orbits, while the remaining 5–10% of stars have more eccentric trajectories and belong to the thick disk. We identified seven isolated white dwarfs and two common proper motion pairs as halo members. We determined the age–velocity dispersion relation for the thin disk members, which agrees with previous results that were achieved from different white dwarf samples without published radial velocities. The age–velocity dispersion relation shows signatures of dynamical heating and saturation after 4–6 Gyr. We observed a mild anticorrelation between [Fe/H] and the radial component of the average velocity dispersion, showing that dynamical mixing of populations takes place in the Galactic disk, as was detected through the analysis of other samples of FGK stars.
*Conclusions:* We have shown that a white dwarf sample with accurate 3D kinematics and well-measured chemical compositions enables a wider understanding of their population in the solar neighborhood and its connection with the Galactic chemodynamics. The legacy of existing spectroscopic surveys will be boosted by the availability of upcoming larger samples of white dwarfs and common proper motion pairs with more uniform high-quality data.

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## Neutron-capture elements record the ordered chemical evolution of the disc over time

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An ensemble of chemical abundances probing different nucleosynthetic channels can be leveraged to build a comprehensive understanding of the chemical and structural evolution of the Galaxy. Using GALAH DR3 data, we seek to trace the enrichment by the supernovae Ia, supernovae II, asymptotic giant branch stars, and neutron-star mergers and/or collapsars nucleosynthetic sources by studying the [Fe/H], [$\alpha$/Fe], [Ba/Fe], and [Eu/Fe] chemical compositions of $\sim 50,000$ red giant stars, respectively. Employing small [Fe/H]–[$\alpha$/Fe] cells, which serve as an effective reference-frame of supernovae contributions, we characterise the abundance–age profiles for [Ba/Fe] and [Eu/Fe]. Our results disclose that these age-abundance relations vary across the [Fe/H]–[$\alpha$/Fe] plane. Within cells, we find negative age–

[Ba/Fe] relations and flat age–[Eu/Fe] relations. Across cells, we see the slope of the age–[Ba/Fe] relations evolve smoothly and the [Eu/Fe] relations vary in amplitude. We subsequently model our empirical findings in a theoretical setting using the flexible Chempy Galactic chemical evolution (GCE) code, using the mean [Fe/H], [Mg/Fe], [Ba/Fe], and age values for stellar populations binned in [Fe/H], [Mg/Fe], and age space. We find that within a one-zone framework, an ensemble of GCE model parameters vary to explain the data. Using present day orbits from Gaia EDR3 measurements we infer that the GCE model parameters, which set the observed chemical abundance distributions, vary systematically across mean orbital radii. Under our modelling assumptions, the observed chemical abundances are consistent with a small gradient in the high mass end of the initial mass function (IMF) across the disc, where the IMF is more top heavy towards the inner disc and more bottom heavy in the outer disc.

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## Galactic chemical evolution of radioactive isotopes with an $s$-process contribution

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Analysis of inclusions in primitive meteorites reveals that several short-lived radionuclides (SLRs) with half-lives of 0.1–100 Myr existed in the early Solar System (ESS). We investigate the ESS origin of $^{107}$Pd, $^{135}$Cs, and $^{182}$Hf, which are produced by *slow* neutron captures (the $s$-process) in asymptotic giant branch (AGB) stars. We modeled the Galactic abundances of these SLRs using the omega+ galactic chemical evolution (GCE) code and two sets of mass- and metallicity-dependent AGB nucleosynthesis yields (Monash and FRUITY). Depending on the ratio of the mean life $\tau$ of the SLR to the average length of time between the formations of AGB progenitor $\gamma$, we calculate timescales relevant for the birth of the Sun. If $\tau/\gamma \gtrsim 2$, we predict self-consistent isolation times between 9 and 26 Myr by decaying the GCE predicted $^{107}$Pd/$^{108}$Pd, $^{135}$Cs/$^{133}$Cs, and $^{182}$Hf/$^{180}$Hf ratios to their respective ESS ratios. The predicted $^{107}$Pd/$^{182}$Hf ratio indicates that our GCE models are missing 9–73% of $^{107}$Pd and $^{108}$Pd in the ESS. This missing component may have come from AGB stars of higher metallicity than those that contributed to the ESS in our GCE code. If $\tau/\gamma \lesssim 0.3$, we calculate instead the time ($T_{\rm LE}$) from the last nucleosynthesis event that added the SLRs into the presolar matter to the formation of the oldest solids in the ESS. For the 2 M$_\odot$, $Z = 0.01$ Monash model we find a self-consistent solution of $T_{\rm LE} = 25.5$ Myr.

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# The X-shooter Spectral Library (XSL): Data Release 3

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We present the third data release (DR3) of the X-shooter Spectral Library (XSL). This moderate-to-high resolution, near-ultraviolet-to-near-infrared (350–2480 nm, $R \sim 10\,000$) spectral library is composed of 830 stellar spectra of 683 stars. DR3 improves upon the previous data release by providing the combined de-reddened spectra of the three X-shooter segments over the full 350–2480-nm wavelength range. It also includes additional 20 M-dwarf spectra from the ESO archive. We provide detailed comparisons between this library and Gaia EDR3, MILES, NGSL, CaT library, and (E-)IRTF. The normalised rms deviation is better than $D = 0.05$ or 5% for the majority of spectra in common between MILES (144 spectra of 180), NGSL (112/116), and (E-)IRTF (55/77) libraries. Comparing synthetic colours of those spectra reveals only negligible offsets and small rms scatter, such as the median offset(rms) $0.001 \pm 0.040$ mag in the (box1–box2) colour of the UVB arm, $-0.004 \pm 0.028$ mag in (box3–box4) of the VIS arm, and $-0.001 \pm 0.045$ mag in (box2–box3) colour between the UVB and VIS arms, when comparing stars in common with MILES. We also find an excellent agreement between the Gaia published (BP–RP) colours and those measured from the XSL DR3 spectra, with a zero median offset and an rms scatter of 0.037 mag for 449 non-variable stars. The unmatched characteristics of this library, which combine a relatively high resolution, a large number of stars, and an extended wavelength coverage, will help us to bridge the gap between the optical and the near-IR studies of intermediate and old stellar populations, and to probe low-mass stellar systems.

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*and from* http://xsl.astro.unistra.fr/ https://doi.org/10.1051/0004-6361/202142388

# Modelling simple stellar populations in the near-ultraviolet to near-infrared with the X-shooter Spectral Library (XSL)

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We present simple stellar population models based on the empirical X-shooter Spectral Library (XSL) from near-ultraviolet (NUV) to near-infrared (NIR) wavelengths. The unmatched characteristics of the relatively high resolution and extended wavelength coverage (350–2480 nm, $R \sim 10\,000$) of the XSL population models bring us closer to bridging optical and NIR studies of intermediate-age and old stellar populations. It is now common to find good agreement between observed and predicted NUV and optical properties of stellar clusters due to our good understanding of the main-sequence and early giant phases of stars. However, NIR spectra of intermediate-age and old stellar populations are sensitive to cool K and M giants. The asymptotic giant branch, especially the thermally pulsing asymptotic giant branch, shapes the NIR spectra of 0.5–2 Gyr old stellar populations; the tip of the red giant branch defines the NIR spectra of older populations. We therefore construct sequences of the average spectra of static giants, variable O-rich giants, and C-rich giants to be included in the models separately. The models span the metallicity range $-2.2 <$ [Fe/H] $< +0.2$ and ages above 50 Myr, a broader range in the NIR than in other models based on empirical spectral libraries. We focus on the behaviour of colours and absorption-line indices as a function of age and metallicity. Our models can reproduce the integrated optical colours of the Coma cluster galaxies at the same level as other semi-empirical models found in the literature. In the NIR, there are notable differences between the colours of the models and Coma cluster galaxies. Furthermore, the XSL models expand the range of predicted values of NIR indices compared to other models based on empirical libraries. Our models make it possible to perform in-depth studies of colours and spectral features consistently throughout the optical and the NIR range to clarify the role of evolved cool stars in stellar populations.

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# Common envelope to explosion delay time distribution (CEEDTD) of Type Ia supernovæ

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I use recent observations of circumstellar matter (CSM) around type Ia supernovæ (SNe Ia) to estimate the fraction of SNe Ia that explode into a planetary nebula (PN) and to suggest a new delay time distribution from the common envelope evolution (CEE) to the SN Ia explosion for SNe Ia that occur shortly after the CEE. Under the assumption that the CSM results from a CEE, I crudely estimate that about 50% of all SNe Ia are SNe Ia inside PNe (SNIPs), and that the explosions of most SNIPs occur within a CEE to explosion delay (CEED) time of less than about ten thousand years. I also estimate that the explosion rate of SNIPs, i.e. the CEED time distribution, is roughly constant

within this timescale of ten thousand years. The short CEED time suggests that a fraction of SNIPs come from the core-degenerate (CD) scenario where the merger of the core with the white dwarf takes place at the end of the CEE. I present my view that the majority of SNIPs come from the CD scenario. I list some further observations that might support or reject my claims, and describe the challenge to theoretical studies to find a process to explain a merger to explosion delay (MED) time of up to ten thousand years or so. A long MED will apply also to the double degenerate scenario.

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# Metallicity of the globular cluster NGC 6388 based on high-resolution spectra of more than 160 giant stars

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NGC 6388 is one of the most massive Galactic globular clusters (GC) and it is an old, metal-rich Galactic bulge cluster. By exploiting previous spectroscopic observations, we were able to bypass the uncertainties in membership related to the contamination from strong field stars. We present the abundance analysis of 12 new giant stars with UVES spectra and 150 giants with GIRAFFE spectra acquired at the ESO-VLT. We derived radial velocities, atmospheric parameters, and iron abundances for all the stars. When combined with the previous data, we obtained a grand total of 185 stars homogeneously analysed in NGC 6388 from high-resolution spectroscopy. The average radial velocity of the 185 stars is $81.2 \pm 0.7$, rms 9.4 km $s^{-1}$. We obtained an average metallicity [Fe/H] $= -0.480$ dex, rms $=$ 0.045 dex (35 stars), and [Fe/H] $= -0.488$ dex, rms $= 0.040$ dex (150 stars) from the UVES and GIRAFFE samples, respectively. Comparing these values to the internal errors in abundance, we excluded the presence of a significant intrinsic metallicity spread within the cluster. Since about a third of giants in NGC 6388 is claimed to belong to the 'anomalous red giants' in the HST pseudo-colour map defining the so-called type-II GCs, we conclude that either enhanced metallicity is not a necessary requisite to explain this classification (as also suggested by the null iron spread for NGC 362) or NGC 6388 is not a type-II globular cluster.

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# The acoustic resonant drag instability with a spectrum of grain sizes

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We study the linear growth and nonlinear saturation of the "acoustic resonant drag instability" (RDI) when the dust grains, which drive the instability, have a wide, continuous spectrum of different sizes. This physics is generally applicable to dusty winds driven by radiation pressure, such as occurs around red-giant stars, star-forming regions, or active galactic nuclei. Depending on the physical size of the grains compared to the wavelength of the radiation field that drives the wind, two qualitatively different regimes emerge. In the case of grains that are larger than the radiation's wavelength – termed the constant-drift regime – the grain's equilibrium drift velocity through the gas is approximately independent of grain size, leading to strong correlations between differently sized grains that persist well into the saturated nonlinear turbulence. For grains that are smaller than the radiation's wavelength – termed

the non-constant-drift regime – the linear instability grows more slowly than the single-grain-size RDI and only the larger grains exhibit RDI-like behaviour in the saturated state. A detailed study of grain clumping and grain–grain collisions shows that outflows in the constant-drift regime may be effective sites for grain growth through collisions, with large collision rates but low collision velocities.

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# Red supergiants in M 31: the Humphreys–Davidson limit at high metallicity

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The empirical upper limit to red supergiant (RSG) luminosity, known as the Humphreys–Davidson (HD) limit, has been commonly explained as being caused by the stripping of stellar envelopes by metallicity-dependent, line-driven winds. As such, the theoretical expectation is that the HD limit should be higher at lower metallicity, where weaker mass-loss rates mean that higher initial masses are required for an envelope to be stripped. In this paper, we test this prediction by measuring the luminosity function of RSGs in M 31 and comparing to those in the LMC and SMC. We find that $\log(L_{\rm max}/L_{\odot}) = 5.53 \pm 0.03$ in M 31 ($Z \gtrsim$ Z$_{\odot}$), consistent with the limit found for both the LMC ($Z \sim 0.5$ Z$_{\odot}$) and SMC ($Z \sim 0.25$ Z$_{\odot}$), while the RSG luminosity distributions in these three galaxies are consistent to within $1\sigma$. We therefore find no evidence for a metallicity dependence on both the HD limit and the RSG luminosity function, and conclude that line-driven winds on the main sequence are not the cause of the HD limit.

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# Multiple components in the molecular outflow of the red supergiant NML Cyg

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Despite their large impact on stellar and galactic evolution, the properties of outflows from red supergiants are not well characterized. We used the Onsala 20m telescope to perform a spectral survey at 3 and 4 mm (68–116 GHz) of the red supergiant NML Cyg, alongside the yellow hypergiant IRC +10°420. Our observations of NML Cyg were combined with complementary archival data to enable a search for signatures of morphological complexity in the circumstellar environment, using emission lines from 15 molecular species. The recovered parameters imply the presence of three distinct, coherent, and persistent components, comprised of blue-shifted and red-shifted components, in addition to an underlying outflow centred at the stellar systemic velocity. Furthermore, to reproduce $^{12}$CO emission with 3D radiative transfer models required a spherical outflow with three superposed conical outflows, one towards and one away from the observer, and one in the plane of the sky. These components are higher in density than the spherical outflow by up to an order of magnitude. We hence propose that NML Cyg's circumstellar environment consists of a small number of high-density large-scale coherent outflows embedded in a spherical wind. This would make the mass-loss history similar to that of VY CMa, and distinct from $\mu$ Cep, where the outflow contains many randomly distributed smaller clumps. A possible correlation between stellar properties, outflow structures, and content is critical

in understanding the evolution of massive stars and their environmental impact.

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# The in situ origin of the globular cluster NGC 6388 from abundances of Sc, V, and Zn of a large sample of stars

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Chemical tagging of globular clusters (GCs) is often done using abundances of alpha-elements. The iron-peak elements Sc, V, and in particular Zn were proposed as an alternative to $\alpha$-elements to tag accreted GCs in the metal-rich regime, where the dwarf galaxy Sagittarius and its GCs show peculiarly marked under-abundances of these heavier species with respect to Milky Way stars. A handful of stars in NGC 6388 was used to suggest an accreted origin for this GC, contradicting the results from dynamics. We tested the efficiency of the iron-peak method by using large samples of stars in NGC 6388, compared to thousands of field stars in the disc and the bulge of the Milky Way. Our abundance ratios of Sc (185 stars) and V (35 stars) for NGC 6388 are within about $1.5\sigma$ from the average for the field stars with a similar metallicity, and they are in perfect agreement for Zn (31 stars), claimed to be the most sensitive element concerning the accretion pattern. Moreover, the chemo-dynamical plots, coupled to the bifurcated age–metallicity relation of GCs in the Galaxy, clearly rule out any association of NGC 6388 to the groups of accreted GCs. Using a large set of GC abundances from the literature, we also show that the new method with Sc, V, and Zn seems to be efficient in picking up GCs related to the Sagittarius dwarf galaxy. Whether this is also generally true for accreted GCs seems to be less evident, and it should be verified with larger and homogeneous samples of stars both in the field and in GCs.

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# Dust in AGB wind–ISM interaction regions

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*Aims:* In this paper we aim to constrain the dust mass and grain sizes in the interaction regions between the stellar winds and the interstellar medium (ISM) around asymptotic giant branch stars. By describing the dust in these regions, we aim to shed light on the role of low mass evolved stars in the origin of dust in galaxies.
*Methods:* We use images in the far-infrared at 70 $\mu$m and 160 $\mu$m to derive dust temperatures and dust masses in the wind–ISM interaction regions around a sample of carbon-rich and oxygen-rich asymptotic giant branch (AGB) stars. The dust temperature and mass are determined in two ways. First directly from the data using the ratio of the measured fluxes and assuming opacities for dust with a constant grain size of 0.1 $\mu$m. We then perform 3-dimensional dust-radiative transfer models spatially constrained by the observations to consistently calculate the temperature and mass. For the radiative transfer models each model contains one constant grain size, which is varied between 0.01 $\mu$m to 5.0 $\mu$m.
*Results:* We find that the observed dust mass in the wind-ISM interaction regions is consistent with mass accumulated from the stellar winds. For the carbon-rich sources adding the spatial constraints in the radiative transfer models results in preferentially larger grain sizes ($\approx 2$ $\mu$m). For the oxygen-rich sources the spatial constraints result in too

high temperatures in the models, making it impossible to fit the observed far-infrared ratio irrespective of the grain size used, indicating a more complex interplay of grain properties and the stellar radiation field.
*Conclusions:* The results have implications for how likely it is for the grains to survive the transition into the ISM, and the properties of dust particles that later act as seeds for grain growth in the ISM. However, the results for the oxygen-rich sources show that the derivation of dust properties is not straight forward, requiring more complex modelling.

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## Instability in the system of the distant post-AGB star LS III+52°24 (IRAS 22023+5249)

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The optical spectra of the B-supergiant LS III +52°24 (IRAS 22023+5249) obtained at the 6-meter telescope with a resolution $R \geq 60\,000$ in 2010–2021 revealed signs of wind variability and velocity stratification in the extended atmosphere. The H$\alpha$ and H$\beta$ lines have a P Cyg type profile; their wind absorption changes position in the range from $v_{\rm r} = -270$ to $-290$ km s$^{-1}$. The intensity of the H$\alpha$ emission reaches record values with respect to the local continuum: $I/I_{\rm cont} \geq 70$. The stationary radial velocity according to the positions of symmetric forbidden emissions and permitted metal emissions was taken as the systemic velocity $v_{\rm sys} = -149.6 \pm 0.7$ km s$^{-1}$. Based on the positions of absorptions of $N^+$ and $O^+$ ions, a time variability of the radial velocity in the range from $-127.2$ to $-178.3$ km s$^{-1}$ was found for the first time for this star. This variability indicates the possible presence of a companion and/or atmospheric pulsations. The change of the oxygen triplet profile O I 7775Å due to the occurrence of unstable emission was registered. The set of interstellar absorptions of the Na I D-lines profile in the range from $-10.0$ to $-167.2$ km s$^{-1}$ is formed in the Local Arm and subsequent arms of the Galaxy. The distance to the star, $d > 5.3$ kpc, combined with the high systemic velocity indicates that the star is located in the interarm space of the Galaxy beyond the Scutum–Crux arm.

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## Red supergiant stars in binary systems – I. Identification and characterisation in the Small Magellanic Cloud from the UVIT ultraviolet imaging survey

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We aim to identify and characterise binary systems containing red supergiant (RSG) stars in the Small Magellanic Cloud (SMC) using a newly available ultraviolet (UV) point source catalogue obtained using the Ultraviolet Imaging Telescope (UVIT) on board AstroSat. We select a sample of 560 SMC RSGs based on photometric and spectroscopic observations at optical wavelengths and cross-match this with the far-UV point source catalogue using the UVIT F172M filter, finding 88 matches down to $m_{\rm F172M} = 20.3$ ABmag, which we interpret as hot companions to the RSGs. Stellar parameters (luminosities, effective temperatures and masses) for both components in all 88 binary systems are determined and we find mass distributions in the ranges 6.1 to 22.3 $M_\odot$ for RSGs and 3.7 to 15.6 $M_\odot$ for their companions. The most massive RSG binary system in the SMC has a combined mass of $32 \pm 4$ $M_\odot$, with a mass ratio ($q = 0.92$. By simulating observing biases, we find an intrinsic multipliciy fraction of $18.8 \pm 1.5\%$ for mass ratios in the range $0.3 < q < 1.0$ and orbital periods approximately in the range $3 < \log P[\text{days}] < 8$. By comparing our results with those of a similar mass on the main-sequence, we determine the fraction of single stars to be $\sim 20\%$ and argue that the orbital period distribution declines rapidly beyond $\log P \sim 3.5$. We study the mass-ratio distribution of RSG binary systems and find that a uniform distribution best describes the data below 14 $M_\odot$. Above 15 $M_\odot$, we find a lack of high mass-ratio systems.

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## 99 oscillating red-giant stars in binary systems with NASA/TESS and NASA/*Kepler* identified from the SB9-Catalogue

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Oscillating red-giant stars in binary systems are an ideal testbed for investigating the structure and evolution of stars in the advanced phases of evolution. With 83 known red giants in binary systems, of which only $\sim 40$ have determined global seismic parameters and orbital parameters, the sample is small compared to the numerous known oscillating stars. The detection of red-giant binary systems is typically obtained from the signature of stellar binarity in space photometry. The time base of such data biases the detection towards systems with shorter periods and orbits of insufficient size to allow a red giant to fully extend as it evolves up the red-giant branch. Consequently, the sample shows an excess of H-shell burning giants while containing very few stars in the He-core burning phase. From the ninth catalogue of spectroscopic binary orbits (SB9), we identified candidate systems hosting a red-giant primary component. Searching space photometry from the NASA missions *Kepler*, K2, and TESS (Transiting Exoplanet Survey Satellite) as well as the BRITE (BRIght Target Explorer) constellation mission, we find 99 systems, which were previously unknown to host an oscillating giant component. The revised search strategy allowed us to extend the range of orbital periods of systems hosting oscillating giants up to 26 000 d. Such wide orbits allow a rich population of He-core burning primaries, which are required for a complete view of stellar evolution from binary studies. Tripling the size of the sample of known oscillating red-giant stars in binary systems is an important step towards an ensemble approach for seismology and tidal studies. While for non-eclipsing binaries the inclination is unknown, such a seismically well-characterized sample will be a treasure trove in combination with Gaia astrometric orbits for binary systems.

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## Chemistry of nebulæ around binary post-AGB stars: a molecular survey of mm-wave lines

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*Context:* There is a class of binary post-asymptotic giant branch (post-AGB) stars that exhibit remarkable near-infrared excess. Such stars are surrounded by Keplerian or quasi-Keplerian disks, as well as extended outflows composed of gas escaping from the disk. This class can be subdivided into disk- and outflow-dominated sources, depending on whether it is the disk or the outflow that represents most of the nebular mass, respectively. The chemistry of this type of source has been practically unknown thus far.
*Aims:* Our objective is to study the molecular content of nebulae around binary post-AGB stars that show disks with Keplerian dynamics, including molecular line intensities, chemistry, and abundances.
*Methods:* We focused our observations on the 1.3, 2, 3 mm bands of the 30m IRAM telescope and on the 7 and 13 mm bands of the 40m Yebes telescope. Our observations add up $\sim$ 600 h of telescope time. We investigated the integrated intensities of pairs of molecular transitions for CO, other molecular species, and IRAS fluxes at 12, 25, and 60 $\mu$m. Additionally, we studied isotopic ratios, in particular $^{17}O/^{18}O$, to analyze the initial stellar mass, as well as $^{12}CO/^{13}CO$, to study the line and abundance ratios.
*Results:* We present the first single-dish molecular survey of mm-wave lines in nebulæ around binary post-AGB stars. We conclude that the molecular content is relatively low in nebulæ around binary post-AGB stars, as their molecular lines and abundances are especially weaker compared with AGB stars. This fact is very significant in those sources where the Keplerian disk is the dominant component of the nebula. The study of their chemistry allows us to classify nebulæ around AC Her, the Red Rectangle, AI CMi, R Sct, and IRAS 20056+1834 as O-rich, while that of 89 Her is probably C-rich. The calculated abundances of the detected species other than CO are particularly low compared with AGB stars. The initial stellar mass derived from the $^{17}O/^{18}O$ ratio for the Red Rectangle and 89 Her is compatible with the central total stellar mass derived from previous mm-wave interferometric maps. The very low $^{12}CO/^{13}CO$ ratios found in binary post-AGB stars reveal a high $^{13}CO$ abundance compared to AGB and other post-AGB stars.

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## Barium stars as tracers of s-process nucleosynthesis in AGB stars I. 28 stars with independently derived AGB mass

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*Context:* Barium (Ba) stars are polluted by material enriched in the slow neutron capture (s-process) elements synthesised in the interior of their former asymptotic giant branch (AGB) companion star, which is now a white dwarf.
*Aims:* We aim to compare individual Ba star abundance patterns to AGB nucleosynthesis model predictions to verify if the AGB model mass is compatible with independently derived AGB mass, which was previously estimated using

binary parameters and Gaia parallax data.
*Methods:* We selected a sample of 28 Ba stars for which both self-consistent spectroscopic observation and analysis were performed and, additionally, stellar mass determinations, via positioning the star on the Hertzsprung–Russell (HR) diagram and comparing with evolutionary tracks are available. For this sample of stars, we considered both previously (Y, Zr, Ce, and Nd) and recently derived (Rb, Sr, Nb, Mo, Ru, La, Sm, and Eu) elemental abundances. Then, we performed a detailed comparison of these s-process elemental abundances to different AGB nucleosynthesis models from the Monash and the FRUITY theoretical data sets. We simplified the binary mass transfer by calculating dilution factors to match the [Ce/Fe] value of each star when using different AGB nucleosynthesis models, and we then compared the diluted model abundances to the complete Ba-star abundance pattern.
*Results:* Our comparison confirms that low-mass (with initial masses roughly in the range 2–3 $M_{\odot}$), non-rotating AGB stellar models with $^{13}C$ as the main neutron source are the polluters of the vast majority of the considered Ba stars. Out of the 28 stars, in 21 cases the models are in good agreement with both the determined abundances and the independently derived AGB mass, although in 16 cases higher observed abundances of Nb, Ru, Mo, and/or Nd, Sm than predicted were present. For three stars, we obtain a match to the abundances only by considering models with masses lower than those independently determined. Finally, four stars show much higher first s-process peak abundance values than the model predictions, which may represent the signature of a physical (e.g., mixing) and/or nucleosynthetic process that is not represented in the set of models considered here.

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# *Job Advert*

## Postdoctoral position in high angular resolution stellar astrophysics

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*See also* https://jobregister.aas.org/ad/43e23e56

## Workshop ”Investigating the roots: How our perception of the Milky Way System is shaped by our knowledge of atomic data products”

Heidelberg (Germany) 03.10–07.10.2022

The aim of our workshop is to bring suppliers and users of atomic data together in a very open and relaxed format that stimulates discussions and ideas. The three main sessions will be:

1. Stellar Atmospheres and other astrophysical applications
2. Experiments and laboratory measurements of atomic data
3. Modelling and theoretical calculations of atomic data

The programme will leave room for asking questions not only after, but also during the presentations. By learning more about the demands of the users of atomic data and the requirements for their calculations and measurements, we aim at a better understanding of current caveats as well as identifying routes to move forward in this crucial field that underpins our astrophysical research.

Pre-registration is open until end of June 2022

*See also* https://wwwstaff.ari.uni-heidelberg.de/ansander/workshops/atomic-data/

## Fizeau exchange visitors program call open

Dear colleagues,

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

The deadline for applications is May 15. Fellowships can be awarded for missions to be carried out between mid-August 2022 and January 2023!

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

The program is funded by OPTICON/H2020.

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

Looking forward to your applications,
Claudia Paladini
(for the European Interferometry Initiative)

*See also* https://european-interferometry.eu/fizeau-program/