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 293$^{\rm rd}$ issue of the AGB Newsletter. This means we're heading for the 300$^{\rm th}$ by July 2022 – ideas (and contributions) for a "celebratory" issue are welcome.

See the announcement at the end of the newsletter for availability of data on silicate grain properties – we encourage you to share similar announcements on data availability (observational, experimental or computational) or other resources (research, teaching, outreach...) or invitations to collaborate.

Looking for a Ph.D. position? Consider applying for the one in Spain. Already got one? (And not yet tenure) Consider applying for a fellowship in Iowa (USA) or at Chalmers (Sweden).

The next issue is planned to be distributed around the 1$^{\rm st}$ of January. We wish you all a Happy New Year!

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

Food for Thought

This month's thought-provoking statement is:

Do stars with initial mass $\lesssim 2$ $M_\odot$ evolve differently from stars with initial mass $\gtrsim 2$ $M_\odot$?

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

Refereed Journal Papers

Magnetism and astronomical infrared spectrum of fullerene C_{60} and void induced graphene molecules

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Fullerene C_{60} shows astronomical four infrared bands (IR) of carbon rich planetary nebulæ. However, there remain many unidentified bands. Our previous paper revealed that single void-defect induced graphene molecule reproduce many astronomical bands. In this paper, we investigated a series of multiple-void induced graphene molecules. We tried spin dependent DFT calculation. Model molecules are C_{23} (one carbon pentagon ring among hexagon network), C_{22} (two), and C_{21} (three). Those were all magnetic molecules with spin state of $S_z = 2/2$, $2/2$ and $4/2$ respectively. Calculated IR was compared with astronomical observation. The largest astronomical band at 18.9 μm was found in C_{23}. Second largest band at 17.4 μm appeared both in C_{22} and C_{21}. Other major bands from 6 to 10 μm were reproduced well by a combination of C_{23}, C_{22} and C_{21}. Similarly, larger size graphene molecules of C_{53}, C_{52} and C_{51} were also magnetic and reproduced astronomical bands as well. Weighting sum IR of those molecules could successfully trace astronomical 12 bands from 6 to 20 μm. A series of multiple void induced graphene would be major component of astronomical carbon. Fullerene C_{60} would be one of them.

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Dynamic atmospheres and winds of cool luminous giants – II. Gradual Fe enrichment of wind-driving silicate grains

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The winds observed around asymptotic giant branch (AGB) stars are generally attributed to radiation pressure on dust formed in the extended dynamical atmospheres of these long-period variables. The composition of wind-driving grains is affected by a feedback between their optical properties and the resulting heating due to stellar radiation. We explore the gradual Fe enrichment of wind-driving silicate grains in M-type AGB stars to derive typical values for Fe/Mg and to test the effects on wind properties and synthetic spectra. We present new radiation-hydrodynamical DARWIN models that allow for the growth of silicate grains with a variable Fe/Mg ratio and predict mass-loss rates, wind velocities, and grain properties. Synthetic spectra and other observables are computed a posteriori with the COMA code. The self-regulating feedback between grain composition and radiative heating, in combination with quickly falling densities in the stellar wind, leads to low values of Fe/Mg, typically a few percent. Nevertheless, the new models show distinct silicate features around 10 and 18 μm. Fe enrichment affects visual and near-IR photometry moderately, and the new DARWIN models agree well with observations in $(J-K)$ versus $(V-K)$ and *Spitzer* color–color diagrams. The enrichment of the silicate dust with Fe is a secondary process, taking place in the stellar wind on the surface of large Fe-free grains that have initiated the outflow. Therefore, the mass-loss rates are basically unaffected, while the wind velocities tend to be slightly higher than in corresponding models with Fe-free silicate dust. The gradual Fe enrichment of silicate grains in the inner wind region should produce signatures observable in mid-IR spectro-interferometrical

measurements. Mass-loss rates derived from existing DARWIN models, based on Fe-free silicates, can be applied to stellar evolution models since the mass-loss rates are not significantly affected by the inclusion of Fe in the silicate grains.

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The most metal-rich asymptotic giant branch stars

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We present new stellar evolutionary sequences of very metal-rich stars evolved with the Monash Stellar Structure code and with MESA. The Monash models include masses of 1–8 $M_\odot$ with metallicities $Z = 0.04$ to $Z = 0.1$ and are evolved from the main sequence to the thermally-pulsing asymptotic giant branch (AGB). These are the first $Z = 0.1$ AGB models in the literature. The MESA models include intermediate-mass models with $Z = 0.06$ to $Z = 0.09$ evolved to the onset of the thermally-pulsing phase. Third dredge-up only occurs in intermediate-mass models $Z \leq 0.08$. Hot bottom burning (HBB) shows a weaker dependence on metallicity, with the minimum mass increasing from 4.5 $M_\odot$ for $Z = 0.014$ to ≈ 5.5 $M_\odot$ for $Z = 0.04$, 6 $M_\odot$ for $0.05 \leq Z \leq 0.07$ and above 6.5 $M_\odot$ for $Z \geq 0.08$. The behaviour of the $Z = 0.1$ models is unusual; most do not experience He-shell instabilities owing to rapid mass-loss on the early part of the AGB. Turning off mass-loss produces He-shell instabilities, however thermal pulses are weak and result in no third dredge-up. The minimum mass for carbon ignition is reduced from 8 $M_\odot$ for $Z = 0.04$ to 7 $M_\odot$ for $Z = 0.1$, which implies a reduction in the minimum mass for core-collapse supernovæ. MESA models of similarly high metallicity ($Z = 0.06$–0.09) show the same lowering of the minimum mass for carbon ignition: carbon burning is detected in a 6 $M_\odot$ model at the highest metallicity ($Z = 0.09$) and in all 7 $M_\odot$ models with $Z \geq 0.06$. This demonstrates robustness of the lowered carbon burning threshold across codes.

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The ionised and molecular mass of post-common-envelope planetary nebulæ. The missing mass problem

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Most planetary nebulæ (PNe) show beautiful, axisymmetric morphologies despite their progenitor stars being essentially spherical. Close binarity is widely invoked to help eject an axisymmetric nebula, after a brief phase of engulfment of the secondary within the envelope of the Asymptotic Giant Branch (AGB) star, known as the common envelope (CE). The evolution of the AGB would thus be interrupted abruptly, its envelope being rapidly ejected to form the PN, which a priori would be more massive than a PN coming from the same star, were it single. We aim at testing this hypothesis by investigating the mass of a sample of 21 post-CE PNe, $\sim 1/5^{\rm th}$ of the known total population, and comparing them to a large sample of ‘regular’ (i.e. not known to host close binaries) PNe. We have gathered data on the ionised and molecular content of our sample and carried out new molecular observations. We derive the ionised and molecular masses of the sample by means of a systematic approach, using tabulated, dereddened Hβ fluxes for finding the ionised mass, and CO 2–1 and 3–2 observations for the molecular mass. There is a general lack of molecular content in post-CE PNe, with few exceptions. Once we derive the ionised and molecular masses, we find that post-CE PNe arising from Single-Degenerate (SD) systems are just as massive, on average, as 'regular' PNe, whereas post-CE PNe arising from Double-Degenerate (DD) systems are considerably more massive, and show larger linear momenta and kinetic energy than SD systems and 'regular' PNe. Reconstruction of the CE of four objects suggests that the mass of SD nebulae actually amounts to a very small fraction of the envelope of their progenitor stars. This leads to the uncomfortable question of where the rest of the envelope is and why we cannot detect it in the stars' vicinity, thus raising serious doubts on our understanding of these intriguing objects.

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Where have all the interstellar silicon carbides gone?

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The detection of the 11.3-μm emission feature characteristic of the Si–C stretch in carbon-rich evolved stars reveals that silicon carbide (SiC) dust grains are condensed in the outflows of carbon stars. SiC dust could be a significant constituent of interstellar dust since it is generally believed that carbon stars inject a considerable amount of dust into the interstellar medium (ISM). The presence of SiC dust in the ISM is also supported by the identification of presolar SiC grains of stellar origin in primitive meteorites. However, the 11.3-μm absorption feature of SiC has never been seen in the ISM and oxidative destruction of SiC is often invoked. In this work we quantitatively explore the destruction of interstellar SiC dust through oxidation based on molecular dynamics simulations and density functional theory calculations. We find that the reaction of an oxygen atom with SiC molecules and clusters is exothermic and could cause CO-loss. Nevertheless, even if this is extrapolable to bulk SiC dust, the destruction rate of SiC dust through oxidation could still be considerably smaller than the (currently believed) injection rate from carbon stars. Therefore, the lack of the 11.3-μm absorption feature of SiC dust in the ISM remains a mystery. A possible solution may lie in the currently believed stellar injection rate of SiC (which may have been overestimated) and/or the size of SiC dust (which may actually be considerably smaller than submicron in size).

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Interstellar extinction and elemental abundances: individual sightlines

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While it is well recognized that both the Galactic interstellar extinction curves and the gas-phase abundances of dust-forming elements exhibit considerable variations from one sight line to another, as yet most of the dust extinction modeling efforts have been directed to the Galactic average extinction curve, which is obtained by averaging over many clouds of different gas and dust properties. Therefore, any details concerning the relationship between the dust properties and the interstellar environments are lost. Here we utilize the wealth of extinction and elemental abundance data obtained by space telescopes and explore the dust properties of a large number of individual sight lines. We

model the observed extinction curve of each sight line and derive the abundances of the major dust-forming elements (i.e. C, O, Si, Mg and Fe) required to be tied up in dust (i.e. dust depletion). We then confront the derived dust depletions with the observed gas-phase abundances of these elements and investigate the environmental effects on the dust properties and elemental depletions. It is found that for the majority of the sight lines the interstellar oxygen atoms are fully accommodated by gas and dust and therefore there does not appear to be a "missing oxygen" problem. For those sightlines with an extinction-to-hydrogen column density $A_V/N_{\rm H} \gtrsim 4.8 \times 10^{-22}$ mag cm^2 H^{-1} there are shortages of C, Si, Mg and Fe elements for making dust to account for the observed extinction, even if the interstellar C/H, Si/H, Mg/H and Fe/H abundances are assumed to be protosolar abundances augmented by Galactic chemical evolution.

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C_{60} cation as the carrier of the 9577 and 9632 Å diffuse interstellar bands: further support from the VLT/X-Shooter spectra

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Ever since their first detection over 100 years ago, the mysterious diffuse interstellar bands (DIBs), a set of several hundred broad absorption features seen against distant stars in the optical and near infrared wavelength range, largely remain unidentified. The close match both in wavelengths and in relative strengths recently found between the experimental absorption spectra of gas-phase buckminsterfullerene ions (C_{60}^+) and four DIBs at λ9632Å, λ9577Å, λ9428Å and λ9365Å (and, to a lesser degree, a weaker DIB at λ9348Å) suggests C_{60}^+ as a promising carrier for these DIBs. However, arguments against the C_{60}^+ identification remain and are mostly concerned with the large variation in the intensity ratios of the λ9632Å and λ9577Å DIBs. In this work, we search for these DIBs in the ESO VLT/X-shooter archival data and identify the λ9632Å, λ9577Å, λ9428Å, and λ9365Å DIBs in a sample of 25 stars. While the λ9428Å and λ9365Å DIBs are too noisy to allow any reliable analysis, the λ9632Å and λ9577Å DIBs are unambiguously detected and, after correcting for telluric water vapor absorption, their correlation can be used to probe their origin. To this end, we select a subsample of nine hot, O- or B0-type stars of which the stellar Mg II contamination to the λ9632Å DIB is negligibly small. We find that their equivalent widths, after normalized by reddening to eliminate their common correlation with the density of interstellar clouds, exhibit a tight, positive correlation, supporting C_{60}^+ as the carrier of the λ9632Å and λ9577Å DIBs.

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The impact of stellar companion UV photons on the chemistry of the circumstellar environments of AGB stars

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Spherical asymmetries are prevalent within the outflows of AGB stars. Since binary interaction with a stellar or planetary companion is thought to be the underlying mechanism behind large-scale structures, we included the effects of UV radiation originating from a stellar companion in our chemical kinetics model. The one-dimensional model provides a first approximation of its effects on the chemistry throughout the outflow. The presence of a close-by stellar companion can strongly influence the chemistry within the entire outflow. Its impact depends on the intensity of the radiation (set by the stellar radius and blackbody temperature) and on the extinction the UV radiation experiences (set by the outflow density, density structure, and assumed radius of dust formation). Parent species can be photodissociated by the companion, initiating a rich photon-driven chemistry in the inner parts of the outflow. The outcome depends on the balance between two-body reactions and photoreactions. If two-body reactions dominate, chemical complexity within the outflow increases. This can make the abundance profiles of daughters appear like those of parents, with a larger inner abundance and a gaussian decline. If photoreactions dominate, the outflow can appear molecule-poor. We model three stellar companions. The impact of a red dwarf companion is limited. Solar-like companions show the largest effect, followed by a white dwarf. A stellar companion can also lead to the formation of unexpected species. The outflow's molecular content, especially combined with abundance profiles, can indicate a stellar companion's presence. Our results pave the way for further outflow-specific (three-dimensional) model development.

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The sample of red supergiants in twelve low-mass galaxies of the Local Group

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This work establishes the most complete sample of red supergiants (RSGs) in 12 low-mass galaxies (WLM, IC 10, NGC 147, NGC 185, IC 1613, Leo A, Sextans B, Sextans A, NGC 6822, Pegasus Dwarf, SMC, and LMC) of the Local Group, which forms a solid basis to study the properties of RSGs as well as the star formation rate and initial mass function of the galaxies. After removing the foreground dwarf stars by their obvious branch in the near-infrared color–color diagram $((J-H)_0/(H-K)_0)$ with the UKIRT/WFCAM and 2MASS photometry as well as the Gaia/EDR3 measurements of proper motion and parallax, RSGs are identified from their location in the color–magnitude diagram $(J-K)_0/K_0$ of the member stars of the specific galaxy. A total of 2190 RSGs are found in 10 dwarf galaxies, and additionally, 4823 and 2138 RSGs are found in LMC and SMC, respectively. The locations of the tip of the red giant branch in the $(J-K)_0/K_0$ diagram are determined to serve as an indicator of the metallicity and distance modulus of the galaxies.

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A fresh look at AGB stars in Galactic open clusters with Gaia: impact on stellar models and the initial–final mass relation

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Benefiting from the GAIA second and early third releases of photometric and astrometric data we examine the population of asymptotic giant branch (AGB) stars that appear in the fields of intermediate-age and young open star clusters. We identify 49 AGB star candidates, brighter than the tip of the red giant branch, with a good-to-high cluster membership probability. Among them we find 19 TP-AGB stars with known spectral type: 4 M stars, 3 MS/S stars and 12 C stars. By combining observations, stellar models, and radiative transfer calculations that include the effect of circumstellar dust, we characterize each star in terms of initial mass, luminosity, mass-loss rate, core mass, period and mode of pulsation. The information collected helps us shed light on the TP-AGB evolution at solar-like metallicity, placing constraints on the third dredge-up process, the initial masses of carbon stars, stellar winds, and the initial-final mass relation (IFMR). In particular, we find that two bright carbon stars, MSB 75 and BM IV 90, members of the clusters NGC 7789 and NGC 2660 (with similar ages of $\simeq$ 1.2–1.6 Gyr and initial masses $2.1 \gtrsim M_{\rm i}/{\rm M}_{\odot} \gtrsim 1.9$) have unusually high core masses, $M_{\rm c} \approx 0.67$–$0.7\ {\rm M}_{\odot}$. These results support the findings of a recent work (Marigo et al. 2020) that identified a kink in the IFMR, which interrupts its monotonic trend just at the same initial masses. Finally, we investigate two competing scenarios to explain the $M_{\rm c}$ data: the role of stellar winds in single-star evolution, and binary interactions through the blue-straggler channel.

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Morpho-kinematics of the wind of AGB star L_2 Pup

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Single dish observations of AGB star L_2 Pup have revealed exceptionally low mass loss rate and expansion velocity, challenging interpretations in terms of standard wind models. Recent VLT and ALMA observations have drawn a detailed picture of the circumstellar envelope within $\sim$ 20 au from the centre of the star: a nearly edge-on rotating disc of gas and dust, probably hosting a planetary companion near the star. However, these observations provide no direct information on the wind escaping the gravity of the star. The present article uses ALMA observations of the ^{12,13}CO(3–2), ^{29}SiO(8–7), ^{12}CO(2–1) and ^{28}SiO(5–4) line emissions to shed new light on this issue. It shows the apparent normality of L_2 Pup in terms of the formation of the nascent wind, with important line broadening within 4 au from the centre of the star, but no evidence for a wind flowing along the disc axis. At larger distances, up to some 200 au from the centre of the star, the wind morpho-kinematics is dominated by a disc, or equatorial enhancement, expanding isotropically and radially with a velocity not exceeding some 5 km s^{-1}, inclined in the north–west/south–east direction with respect to the plane of the sky. In addition, outflows of lower density are observed on both sides of the disc, covering large solid angles about the disc axis, contributing about half the flux of the disc. Such morphology is at strong variance with the expectation of a pair of back-to-back outflows collimated by the central gas-and-dust disc.

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A search for distant, pulsating red giants in the southern halo

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To investigate the AGB population in the Galactic halo, we search for pulsating AGB stars at a heliocentric distance

$D > 50$ kpc. Our research is based on the Catalina Southern Survey (CSS) catalogue of variables, comprising 1286 long-period variables (LPV) with $\delta < 20°$. We first focus on the 77 stars in the cap $|b| > 30°$ for which spectral M-type or C-type classification can be derived from Hamburg–ESO objective prism spectra. Most of these are M-type and very few are carbon rich. The periods are in the range 100–500 days, and CSS amplitudes are up to 3 mag. In this small sample, no halo AGB star is fainter than $K = 12.5$ mag. This may be due to the scarcity of AGBs in the outer halo, or insufficient instrumental depth. Leaving aside spectral information, we then searched for even fainter pulsators ($K_s > 12.5$ mag) in the entire CSS catalogue. Gaia astrometry makes it possible to identify some contaminants. Our final result is the identification of ten candidate distant LPVs. If these ten stars obey the fundamental mode K-band period–luminosity relation used for Miras and small-amplitude Miras, their distances are between 50 and 120 kpc from the Sun. In a diagram showing distance versus Gaia tangential velocity, these ten stars have positions consistent with that of other objects in the halo, such as globular clusters and dwarf galaxies. We detect some underluminous AGBs that deserve further study. Finally, the halo LPVs resemble the slow redder variable of globular clusters when colour and periods are compared.

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Molecules, shocks, and disk in the axi-symmetric wind of the MS-type AGB star RS Cancri

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The latest evolutionary phases of low- and intermediate mass stars are characterized by complex physical processes like turbulence, convection, stellar pulsations, magnetic fields, condensation of solid particles, and the formation of massive outflows that inject freshly produced heavy elements and dust particles into the interstellar medium.
By investigating individual objects in detail we wish to analyze and disentangle the effects of the interrelated physical processes on the structure of the wind forming region around these objects.
We use the Northern Extended Millimeter Array (NOEMA) to obtain spatially and spectrally resolved observations of the semi-regular Asymptotic Giant Branch star RS Cancri to shed light on the morpho-kinematic structure of its inner, wind forming environment by applying detailed 3-D reconstruction modeling and LTE radiative transfer calculations.
We detect 32 lines of 13 molecules and isotopologs (CO, SiO, SO, SO_2, H_2O, HCN, PN), including several transitions from vibrationally excited states. HCN, $H^{13}CN$, millimeter vibrationally excited H_2O, SO, ^{34}SO, SO_2, and PN are detected for the first time in RS Cnc. Evidence for rotation is seen in HCN, SO, SO_2, and SiO($v = 1$). From CO and SiO channel maps, we find an inner, equatorial density enhancement, and a bipolar outflow structure with a mass loss rate of 1×10^{-7} $M_\odot$ yr^{-1} for the equatorial region and of 2×10^{-7} $M_\odot$ yr^{-1} for the polar outflows. The $^{12}CO/^{13}CO$ ratio is measured to be ~ 20 on average, 24 ± 2 in the polar outflows and 19 ± 3 in the equatorial region. We do not find direct evidence of a companion that might explain this kind of kinematic structure, and explore the possibility that a magnetic field might be the cause of it. The innermost molecular gas is influenced by stellar pulsation and possibly by convective cells that leave their imprint on broad wings of certain molecular lines, such as SiO and SO.
RS Cnc is one of the few nearby, low mass-loss-rate, oxygen-rich AGB stars with a wind displaying both an equatorial disk and bipolar outflows. Its orientation with respect to the line of sight is particularly favorable for a reliable study of its morpho-kinematics. The mechanism causing early spherical symmetry breaking remains however uncertain, calling for additional high spatial and spectral resolution observations of the emission of different molecules in different transitions, along with a deeper investigation of the coupling among the different physical processes at play.

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MUSE spectroscopy of planetary nebulæ with high abundance discrepancies

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We present MUSE deep integral-field unit spectroscopy of three planetary nebulæ (PNe) with high abundance discrepancy factors (ADF > 20): NGC 6778, M 1-42 and Hf 2-2. We have constructed flux maps for more than 40 emission lines, and use them to build extinction, electron temperature (Te), electron density (n_e), and ionic abundances maps of a number of ionic species. The effects of the contribution of recombination to the auroral [N II] and [O II] lines on T_e and the abundance maps of low-ionization species are evaluated using recombination diagnostics. As a result, low T_e values and a downward gradient of T_e are found toward the inner zones of each PN. Spatially, this nearly coincides with the increase of abundances of heavy elements measured using recombination lines in the inner regions of PNe, and strongly supports the presence of two distinct gas phases: a cold and metal-rich and a warm one with "normal" metal content. We have simultaneously constructed, for the first time, the ADF maps of O^+ and O^{2+} and found that they centrally peak for all three PNe under study. We show that the main issue when trying to compute realistic abundances from either ORLs or CELs is to estimate the relative contribution of each gas component to the H I emission, and we present a method to evaluate it. It is also found that, for the studied high-ADF PNe, the amount of oxygen in the cold and warm regions is of the same order.

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Oxygen and aluminum–magnesium isotopic systematics of presolar nanospinel grains from CI chondrite Orgueil

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Presolar oxide grains have been previously divided into several groups (Group 1 to 4) based on their isotopic compositions, which can be tied to several stellar sources. Much of available data was acquired on large grains, which may not be fully representative of the presolar grain population present in meteorites. We present here new O isotopic data for 74 small presolar oxide grains ($\sim$ 200 nm in diameter on average) from Orgueil and Al–Mg isotopic systematics for 25 of the grains. Based on data-model comparisons, we show that (i) Group 1 and Group 2 grains more likely originated in low-mass first-ascent (red giant branch; RGB) and/or second-ascent (asymptotic giant branch; AGB) red giant stars and (ii) Group 1 grains with $(^{26}Al/^{27}Al)_0 \gtrsim 5 \times 10^{-3}$ and Group 2 grains with $(^{26}Al/^{27}Al)_0 \lesssim 1 \times 10^{-2}$ all likely experienced extra circulation processes in their parent low-mass stars but under different conditions, resulting in proton-capture reactions occurring at enhanced temperatures. We do not find any large ^{25}Mg excess in Group 1 oxide grains with large ^{17}O enrichments, which provides evidence that ^{25}Mg is not abundantly produced in low-mass stars. We also find that our samples contain a larger proportion of Group 4 grains than so far suggested in the literature for larger presolar oxide grains ($\sim$ 400 nm). We also discuss our observations in the light of stellar dust production mechanisms.

Accepted for publication in Geochimica et Cosmochimica Acta

Available from https://arxiv.org/abs/2112.00512

and from https://www.sciencedirect.com/science/article/abs/pii/S0016703721006773

Hydrodynamic model of decaying radial oscillations in RU Cam

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Calculations of stellar evolution up to the early white dwarf stage were carried out for stars with mass on the main sequence $M_0 = 0.82\ \mathrm{M}_\odot$, $0.85\ \mathrm{M}_\odot$, $0.9\ \mathrm{M}_\odot$ and with initial abundances of helium and heavier elements $Y = 0.25$ and $Z = 10^{-3}$, respectively. For each value of M_0 the AGB and post-AGB evolutionary phases were computed with three values of the mass loss parameter in the Blöcker formula: $\eta_B = 0.02$, 0.05 and 0.1. The variable star RU Cam with pulsation period $P \approx 22$ day is shown to be in the post-AGB stage and the pulsation amplitude decrease in years 1962–1963 is due to movement of the star across the HR diagram beyond the pulsation instability region. Theoretical estimates of the mass and the luminosity of RU Cam are $0.524\ \mathrm{M}_\odot \le M \le 0.532\ \mathrm{M}_\odot$ and $2.20\times10^3\ \mathrm{L}_\odot \le L \le 2.33\times10^3\ \mathrm{L}_\odot$, respectively. Hydrodynamic calculations of nonlinear stellar pulsations show that while the star approaches the instability boundary a significant reduction ($\approx 90\%$) in the pulsation amplitude occurs for nearly two years with subsequent slow decay of low-amplitude oscillations. Solution of the equations of hydrodynamics with time-dependent inner boundary conditions describing evolutionary changes in the radius and the luminosity at the bottom of the pulsating envelope allows us to conclude that decay of radial oscillations in RU Cam is accompanied by the effect of oscillation hysteresis. In particular, the stage of large-amplitude limit cycle oscillations extends by ≈ 12 years and the subsequent stage of decaying small-amplitude oscillations spreads beyond the formal boundary of pulsation instability.

Accepted for publication in Astronomy Letters
Available from https://arxiv.org/abs/2111.14194

Conference Papers

Evidence for dynamical changes in Betelgeuse using multi-wavelength data

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The reasons behind the Great Dimming and subsequent rising in the brightness of Betelgeuse between October 2019 and March 2020 still continue to baffle astronomers. It has been shown by George et. al. (2020) that critical slowing down preceded the dimming event. This suggested that the dimming was a result of the change in the nature of the nonlinear dynamics of the star. In this work we present additional evidence for dynamical changes in Betelgeuse prior to the Great Dimming event, using nonlinear time series analysis. We study the relations between the different bands in the photometry data collected from the Wing photometry (IR/near-IR) and Wasatonic observatory (V-band). We also analyse how the early warning signals studied previously changed during and after the Great Dimming.

Oral contribution, published in Proceedings of the Sixteenth Marcel Grossmann Meeting (MG16), July 5–10, 2021
Available from https://arxiv.org/abs/2111.09218

Tracing wind motion in the H_2O maser shell of VX Sgr

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Masers provide accurate velocity information on the movement of matter in the circumstellar shells of late-type stars. We show here for the case of the red supergiant VX Sgr, evidence for the radially outward movement of an H_2O maser cloud traversing in 28 years a distance of $\sim$ 90 au. The maser cloud (VXSgr-H2O-1987/14) was detected in 1987 at a distance of $\sim$ 140 au from the central star moving with a velocity of $v = 14$ km s^{-1} relative to the stellar velocity away from the observer. The cloud was followed for decades during a 22 GHz H_2O maser monitoring program at Medicina and Effelsberg until 2015, when the cloud was at a distance of $\sim$ 230 au and had increased its velocity to $v = 19$ km s^{-1}. VXSgr-H2O-1987/14 was identified in MERLIN maps from 1994 and 1999 (Murakawa et al. 2003; Richards et al. 2012), and its location in the shell suggests an angle of 16 ± 1 degrees between the line-of sight and the outflow direction. This shows the ability of well-designed H_2O maser monitoring programs to map wind motions in circumstellar shells of red supergiants at typical radial distances of 100–200 au.

Poster contribution, published in IAUS 366: "The origin of outflows in evolved stars", Leuven, Belgium (2021)

Available from https://doi.org/10.5281/zenodo.5702619

Job Adverts

Astronomy and Astrophysics Prize Fellowship

The Physics and Astronomy Department at Iowa State University invites applications to its inaugural Astronomy and Astrophysics Prize Fellowship. This 3-year fellowship supports independent research by an early-career scientist in astronomy and astrophysics. The fellow is expected to move to Ames at the start of appointment (summer 2022) and actively participate to the scientific life of the department.

Astronomy research at ISU spans both observation and theory in a variety of disciplines, from stellar astronomy, to interstellar medium physics, high energy astrophysics, galaxy evolution, and planetary systems. The new Fellow will be free to carry their own research program, although research interests intersecting with current A&A faculty (including research in evolved stars and pulsating variables) are preferred. Applicants must have completed all requirements for a Ph.D. in astronomy, astrophysics or related fields prior to appointment.

The fellow will receive an annual salary of $65,000 with competitive benefits package, relocation reimbursement up to $2,500 and annual research funds of $10,000. The application deadline is December 15, 2021, but late applications may be considered until the position is filled.

For more information, see http://jobregister.aas.org/ad/a6e7ca3b.
Inquiries: Attn. to Massimo Marengo, mmarengo@iastate.edu.
Apply through the Iowa State online application form linked below.

See also https://isu.wd1.myworkdayjobs.com/IowaStateJobs/job/Ames-IA/Postdoc-Research-Associate_R6505

Ph.D. position on "PN Genesis: outflows, mass-loss and jet-launching" within the INPhINIT "la Caixa" Foundation Fellowship Programme

The doctoral fellowship programme INPhINIT "la Caixa" is devoted to attracting talented Early-Stage Researchers – of any nationality – who wish to pursue doctoral studies in Spanish or Portuguese territory. Sponsored by "la Caixa" Foundation, it is aimed at supporting the best scientific talent and fostering innovative and high-quality research in Spain and Portugal by recruiting outstanding international students and offering them an attractive and competitive environment for conducting research of excellence.

INPhINIT will select 35 young researchers of all nationalities for a three year program to complete a Ph.D. in one of the centers that has received a Severo Ochoa or María de Maeztu award, a quality seal given by the Spanish Agencia Estatal de Investigación. The salaries and other benefits are very competitive.

The Center for Astrobiology (CAB, CSIC–INTA) a is a research centre accredited with the Spanish Seal of Excellence María de Maeztu, the perfect place to carry out your Ph.D. project through an INPhINIT Incoming fellowship. CAB is a multidisciplinary institute hosting about 150 scientists devoted to astrobiological research, astrophysics, technology development for space missions and exploration of the Solar System.

Project title: "PN Genesis: outflows, mass-loss and jet-launching"

Advisers: Carmen Sanchez Contreras (csanchez@cab.inta-csic.es)

Research Project / Research Group Description:

This project focuses on the study of the physical and chemical properties of envelopes around low and intermediate mass stars in the latest stages of their evolution: in the Asymptotic Giant Branch (AGB), in the planetary nebula (PN) stage, and in the transitional post-AGB (pAGB) or pre-PN (pPN) phase. Our main goal is to make progress in the identification of the processes responsible for the morphological, dynamic and chemical transformation during the short AGB-to-PN transition. Our team has multi-wavelength, high-quality data obtained with first-line telescopes such as ALMA, HST, *Herschel*, GTC, etc. In the next years, we will continue with the scientific exploitation of these data, and of future observations, to address one of the key issues in AGB-to-PN evolution: understanding how AGB winds, roughly spherical and slow, become PN displaying a large variety of complex morphologies.

We will use different observational approaches in our studies. We will use new tracers that, combined with more classic diagnostic tools, will allow us to reach a complete and global view of the processes that govern the death of most stars in the Universe. As new tracers, barely exploited to date, we will use recombination lines in the mm-wavelength domain (observed with ALMA) that are optimal for estimating the mass-loss rate in the pAGB phase, a fundamental but empirically unconstrained parameter, and for penetrating into the enigmatic central regions of pPNs where jet launching mechanisms operate. We will also use high angular resolution observations of molecular lines to characterize the nebular structure and dynamics at different spatial scales, to recreate the history of mass loss and to study the physical and chemical effects of the interaction between fast collimated pAGB winds and the slow and predominantly round AGB envelope. We will carry out a comprehensive analysis of these data, for which we will update and upgrade our modeling tools (e.g., radiative transfer codes).

Job position description:

The Ph.D. researcher will be introduced in the study of gas and dust envelopes around AGB and pAGB stars through multi-wavelength observations. Large amounts of data from a variety of top facilities (ALMA, HST, GTC10.4m, IRAM30m, *Herschel*, etc.) and of various characteristics (radio interferometry, high-resolution optical imaging, high-sensitivity data, etc.) have been already obtained by our team and we expect to continue in our line of successful observations over the next years. The Ph.D. researcher will focus on the analysis of interferometric continuum and mm-RRLs emission maps obtained with ALMA for a sample of pPNs and young PNs to characterize the emerging ionized regions at their cores, concealed to date, where some of the most critical processes that drive the evolution of late-stage stars occur (e.g., the formation of fast, collimated winds). The student will also work with ALMA maps of the molecular outflows of pPNs, bridging the central ionized regions with the more distant envelope layers that are predominantly molecular. ALMA based studies will be complemented with observations from other ground-based and space borne platforms at shorter wavelengths, including optical spectroscopy with HST/STIS and MEGARA/GTC, optical/NIR imaging, and FIR-to-mm spectroscopy (*Herschel* and IRAM30m), to gain a wide perspective on the complex phenomenology of pPNs and young PNs.

The student will be formed in a broad range of observational techniques across the electromagnetic spectrum, from radioastronomy and FIR techniques to optical spectroscopy. The Ph.D. student will develop a very specialized knowledge of complex techniques, under the supervision of high-level experts in our group, including radiative transfer modelling, mm-wave interferometry data calibration and reduction, reduction of optical spectroscopic cubes, etc. To complete his/her formation, the Ph.D. researcher will also attend the IRAM International Schools on both single-dish and interferometry at mm-wavelengths.

Highlights of the call:

- 35 fellowships to pursue Ph.D. studies in research centres accredited with the Spanish Seal of Excellence Severo Ochoa, María de Maeztu or Health Institute Carlos III and Portuguese units accredited as "excellent" according to the evaluation of the Fundação de Ciência e Tecnologia.
- STEM disciplines (life sciences and health, experimental sciences, physics, chemistry and mathematics).
- Maximum duration: 3 years.
- Total maximum allocation: 122,592 euros.
- Training programme in transversal skills.

Key dates:

- 27 January 2022: Deadline for submitting applications.
- 10 February 2022: Deadline for submitting the language certificate.
- 11 April 2022: Notification of the shortlist results and arrangement of interviews.
- 24, 25 and 26 May 2022: Face-to-face interviews in Barcelona.
- 8 June 2022: Communication of the final results.
- From 8 to 30 June 2022: Matching host institution – fellow.

Requirements for candidates:

In order to be accepted, candidates must meet the following eligibility requirements:

- Research experience: Candidates must be in the first four years of their research career and must not have previously obtained a Ph.D. degree or be in a position to apply for one.
- Academic records: Applicants must hold a higher education degree that makes them eligible to enrol in a doctoral programme in Spain/Portugal when starting at their host institutions. The verification of the level of studies equivalent to those mentioned above will be carried out by the host university during the admission procedure.
- Mobility: Candidates must not have resided or carried out their main activity (work, studies, etc.) in Spain/Portugal for more than twelve months in the three years immediately prior to the deadline for applications.
- Level of English: Candidates must accredit an advanced level of English (B2 or higher).
- Complete applications: Only candidates whose applications meet all the requirements of the call may be accepted.

Applications and further information:

All applications must be completed online at the following link, where additional information on the application process is also provided:

https://fundacionlacaixa.org/en/inphinit-doctoral-fellowships-incoming

The link for the Ph.D. position on "PN Genesis: outflows, mass-loss and jet-launching" is:
https://finder.lacaixafellowships.org/finder?position=5139

The deadline for the applications is 27 January 2022

See also https://finder.lacaixafellowships.org/finder?position=5139

Chalmers Astronomy and Plasma Physics Fellow

There is an opening for a postdoc fellowship in Astronomy and Plasma Physics at the Department of Space, Earth and Environment at Chalmers University of Technology in Gothenburg, Sweden. The successful candidate is expected to lead a creative, cross-field research program that establishes new collaborations between the division's research topics. In addition to an active evolved stars group, the department does research in the fields of active galactic nuclei, exoplanets, star formation and the ISM, galaxy clusters and galaxy evolution, astrochemistry, and plasma physics. Find the full job advertisement and links to the department under the link provided. The deadline for applications is January 14, 2022.

See also https://www.chalmers.se/sv/om-chalmers/Arbeta-pa-Chalmers/lediga-tjanster/Sidor/default.aspx?rmpage=job&rmjob=9962&rmlang=SE

Announcement

Infrared spectra of pyroxenes (crystalline chain silicates) at room temperature: data available online

Bowey, J.E., Hofmeister, A., Keppel, E. 2020, MNRAS, 497, 3658
Infrared Spectra of Pyroxenes (Crystalline Chain Silicates) at Room Temperature
https://doi.org/10.1093/mnras/staa2227

We present quantitative room-temperature spectra of 17 Mg-, Fe-, and Ca-bearing ortho- and clinopyroxenes, and a Ca-pyroxenoid in order to discern trends indicative of crystal structure and a wide range of composition. Data are produced using a diamond anvil cell: our band strengths are up to six times higher than those measured in KBr or polyethylene dispersions, which include variations in path length (from grain size) and surface reflections that are not addressed in data processing.

Data doi is : 10.5281/zenodo.5564539

Complete spectra are in Figure 4 and compositions are listed in Table 1.
Wavelength range is 8.5 to 90 μm.

See also https://zenodo.org/communities/mineralspectra/