# THE AGB NEWSLETTER

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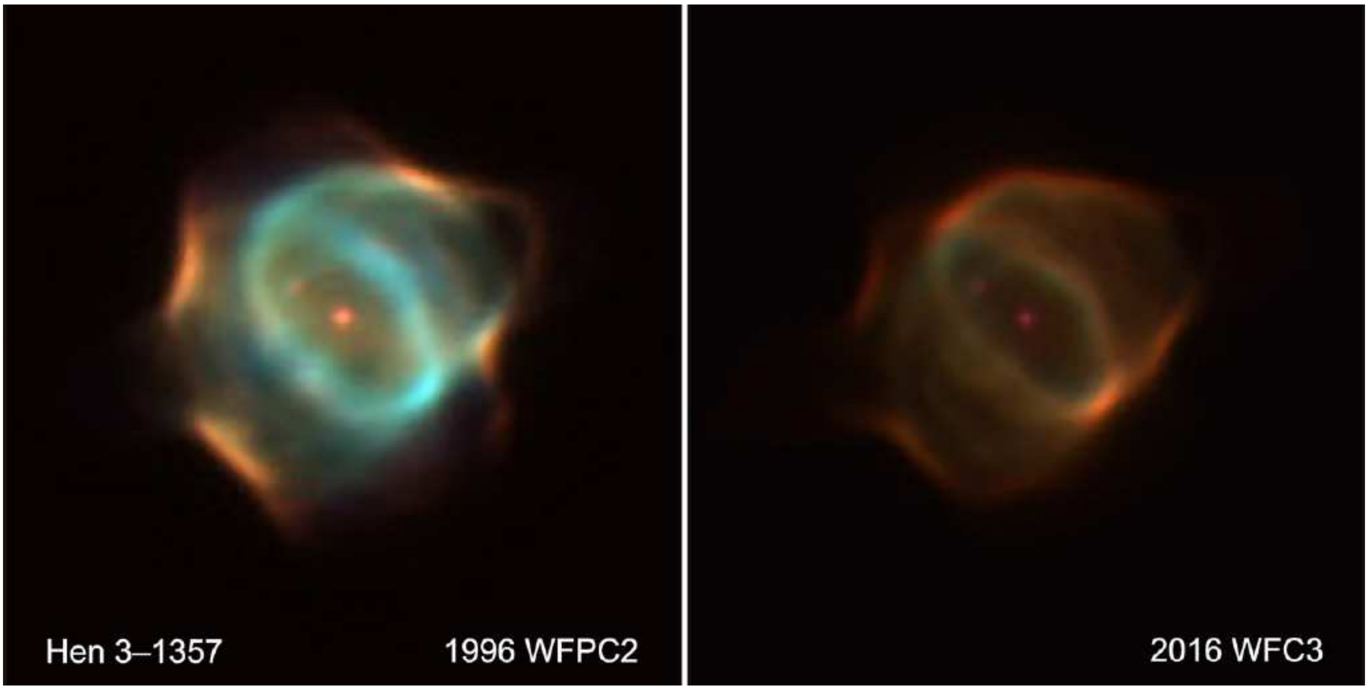


Figure 1: The Rapid Fading of the Youngest Planetary Nebula, Hen 3-1357. Two composite *Hubble* images of the Sting Ray Nebula taken in 1996 and 2016 in (R:G:B) = (F658N,F656N,F502N) = the emission lines of ([N II], H$\alpha$, [O III]). Both images are shown with the same absolute intensities in each filter. Nebular emission from Hen 3-1357, the youngest planetary nebula (Bobrowsky, 1994, ApJ, 426, L47), unexpectedly appeared sometime during the 1980s (Parthasarathy et al. 1993, A&A, 267, 19). Since then the central star has rapidly faded (e.g., Schaefer & Edwards, 2015, ApJ, 812, 133). The integrated emission fluxes of these three lines in the images above decreased by factors of 0.20, 0.37, and 0.6, respectively, over 20 years. As expected, the rates of fading are much higher in regions of highest emission measure as $N^+$, $H^+$, and $O^{++}$ recombine. See Balick et al. in this issue.

# *Editorial*

Dear Colleagues,

It is a pleasure to present you the 279$^{\text{th}}$ issue of the AGB Newsletter. There's a lot of interest for everyone – if not, then why not write a contribution?

This month, risen (and still rising) star Emily Levesque treats us to her insight into the behaviour of Betelgeuse.

Near the back of the newsletter, Claudia Palladini invites junior scientists to consider a Ph.D. or Fellowship at ESO – one of the best choices you can ever make.

Interferometry is also becoming more accessible, thanks in part to the Fizeau programme (see announcements) which continues to help novices become acquainted with the techniques.

Last month's Food for Thought ("What will Betelgeuse do next?") remains highly topical, with a couple of related papers in this very issue, and unsurprisingly provoked a few reactions. Elizabeth Griffin wrote:

"We might start with a simpler case and get that right first. Read Observatory 116,404, 1996 (only 2 pages) and see if you can predict what Arcturus will do next."

...while Lee Patrick offered to following thoughts:

"I imagine you will be flooded with responses predicting all sorts of really interesting next steps, but I think probably the best answer to that question is: nothing. We all know Betelgeuse is very likely to explode as a type II supernova at some point within the next few Myr, but at the minute I believe we do not know enough about the normal lives of RSGs and their intrinsic variations to make any meaningful predictions. Because of this, any answer about what an individual RSG will do next is almost certainly doomed to failure. What we really need to do to move forward on this question is assess how rare are these kinds of photometric and spectroscopic variations in RSGs in general. It is important to keep in mind that it is only really because Betelgeuse is a famous RSG that we are giving this recent dimming so much attention."

Indeed. Why would Betelgeuse be anything but a middle-of-the-road supergiant? Well, it's speeding, for one thing. And possibly *rotating* "fast" as well. How normal is that? What will its supernova (and remnant) really look like?

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

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

# *Food for Thought*

This month's thought-provoking statement is:

*How much of our bodies was once inside an AGB star?*

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

# *What am I thinking?*

**Emily Levesque**

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**A Year of Betelgeuse**

This month marks a year since Betelgeuse began its unusual and precipitous plunge in brightness. The drop sparked a flurry of interest from professional and amateur astronomers like, along with the curiosity from the press that inevitably accompanies any odd behavior from a favorite progenitor candidate for the next Galactic supernova! The end result was a fresh surge of attention focused on potential sources of variability in red supergiants (RSGs) and other luminous cool stars.

A burst of timely observations – everything from speckle polarimetry and high-contract imaging to ground-based spectrophotometry and monitoring by the *Hubble* Space Telescope in the UV – were aimed at disentangling several known sources of variability in red supergiants as a whole and Betelgeuse in particular. These included the effects of large-scale surface convection, mass loss and the associated production of circumstellar dust, and pulsations. In Betelgeuses case, the explanation for its sudden and extreme dimming last year seems to have now solidly coalesced around dust (Levesque & Massey 2020), with material shed during a possibly-pulsation-aided mass loss event earlier in 2019 observed by Dupree et al. (2020) condensing into the large-grain gray dust typical of RSGs. However, the aftermath of this excitement raises new and compelling questions for the study of RSG variability as a whole.

To begin, how typical is this kind of photometric behavior? We noticed the substantial dip in Betelgeuses light curve because the star is so nearby and so closely monitored, but there are many hundreds of easily-observed red supergiants in the Milky Way and the Local Group. We know that episodic mass loss and the associated production of asymmetrically-distributed circumstellar dust is common in RSGs, so one might expect to see similar sudden sharp drops in brightness from other RSGs. Betelgeuses drop in brightness happened on a timescale of months; this suggests that long-term and well-sampled light curves of more RSGs would go a long way towards identifying similar behavior across a larger population and offer us a sizable sample for probing the specific quirks of RSG mass loss and dust production.

Theres also the question of how mass loss, pulsations, and surface convection cells are intertwined. This is a thorny problem and broaches incredibly challenging topics such as asteroseismology of cool massive stars. When we move from AGB stars to the high-mass realm of RSGs, convection speeds in these stars envelopes become sonic or even supersonic, introducing new potential sources of variability and preventing us from learning much about their deep interiors. Still, applying the techniques that have proved so successful in the study of red giants to their higher-mass cousins could still shed new light on the behavior of their outer layers. Trying to quantify the distinct contributions from convective variations, mass loss events, changes in circumstellar dust content, pulsations, and other crucial effects such as contributions from binary companions sounds daunting. However, this is a challenge we should be equipped to tackle today given the renaissance currently occurring in the fields of time-domain astronomy and computational astrophysics.

Finally, the study of Betelgeuse highlighted the importance of studying luminous cool stars across the full breadth of wavelengths and observational techniques available to us as astronomers. The initial discovery of its variability came from optical light curves, but its behavior in the IR and UV later proved crucial for understanding what the star was doing. Observations that contributed to this burst of research on Betelgeuse ranged from optical spectrophotometry taken with 4.3-meter Lowell Discovery Telescope (Levesque & Massey 2020) to mid-IR spectra taken with SOFIA (Harper et al. 2020), long-term monitoring in the sub-millimeter (Dharmawardena et al. 2020), and spatially-resolved images of Betelgeuse and its circumstellar environment in the optical and IR (Montargès et al. 2020; Kervella et al. 2020). More papers are undoubtedly still working their way through the publishing queue, presenting still more data on Betelgeuses behavior last year, and what its doing now.

Looking toward the coming years of cool star research, Betelgeuse serves as an excellent example of why we want to continue leveraging the full might of our observational resources in our study of luminous cool stars, and why we should be poised to immediately harness the capabilities offered by new observatories. Time-domain resources now include current missions like NASA TESS and the *Zwicky* Transient Facility in the optical and WISE in the IR, and the coming years will see first light from the *Rubin* Observatory: taken together, the light curves amassed by these facilities will be invaluable for building well-monitored and long-term samples of RSGs and AGB stars. Future space telescope facilities concentrated in the IR regime – JWST and the *Roman* Observatory – will extend our reach of how many resolved RSG populations we can survey and study in detail but will demand a shift to primarily studying these stars physical properties using IR rather than optical data. Next-generation coronagraphs, including the Coronagraph Instrument on *Roman* and coronagraphs used with NIRCam and MIRI on JWST, will give us an unprecedented view of the circumstellar environments and dust production of these stars. Finally, studying these stars will also require continued support for the invaluable contributions of classical ground-based astronomy. In particular, developing and maintaining high-quality optical and IR spectrographs and high-contrast imaging capabilities on telescopes large and small will give us data that can place our future research in context with the studies of cool stars that have gone on for decades.

The past years focus on Betelgeuse has helped us learn more about this nearby and well-studied cool star and revealed the many compelling questions that we still want to explore in the study in RSGs. In the coming years we should continue to apply this same enthusiasm to the cool massive star population as a whole, improving our understanding of their interior physics, photometric evolution, and mass loss behavior... and we should continue to keep some eyes on Betelgeuse in the coming months as well!

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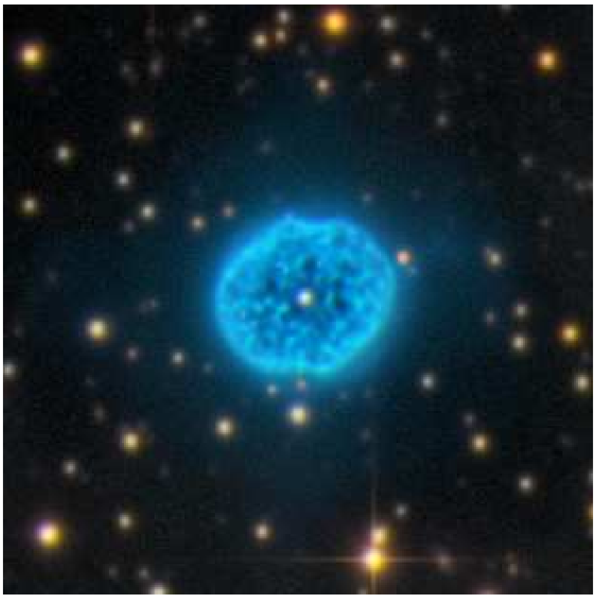

Figure 2: Planetary Nebula NGC 1501 imaged by Mark Hanson at Stan Watson Observatory with a 24″ f6.7 telescope. For more details see https://www.hansonastronomy.com/ngc1501 (Suggestion by Sakib Rasool.)

## WD 1032+011, an inflated brown dwarf in an old eclipsing binary with a white dwarf

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We present the discovery of only the third brown dwarf known to eclipse a non-accreting white dwarf. Gaia parallax information and multi-colour photometry confirm that the white dwarf is cool ($9950 \pm 150$ K) and has a low mass ($0.45 \pm 0.05$ $M_\odot$), and spectra and lightcurves suggest the brown dwarf has a mass of $0.067 \pm 0.006$ $M_\odot$ (70 $M_{Jup}$) and a spectral type of L5±1. The kinematics of the system show that the binary is likely to be a member of the thick disk and therefore at least 5 Gyr old. The high cadence lightcurves show that the brown dwarf is inflated, making it the first brown dwarf in an eclipsing white dwarf–brown dwarf binary to be so.

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## The effect of the slit configuration on the $H_2$ 1–0 S(1) to Br$\gamma$ line ratio of spatially resolved planetary nebulæ

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The $H_2$ 1–0 S(1) / Br$\gamma$ ratio ($R$(Br$\gamma$)) is used in many studies of the molecular content in planetary nebulæ (PNe). As these lines are produced in different regions, the slit configuration used in spectroscopic observations may have an important effect on their ratio. In this work, observations and numerical simulations are used to demonstrate and quantify such effect in PNe. The study aims to assist the interpretation of observations and their comparison to models. The analysis shows that observed $R$(Br$\gamma$) ratios reach only values up to 0.3 when the slit encompasses the entire nebula. Values higher than that are only obtained when the slit covers a limited region around the $H_2$ peak emission and the Br$\gamma$ emission is then minimized. The numerical simulations presented show that, when the effect of the slit configuration is taken into account, photo-ionization models can reproduce the whole range of observed $R$(Br$\gamma$) in PNe, as well as the behaviour described above. The argument that shocks are needed to explain the higher values of $R$(Br$\gamma$) is thus not valid. Therefore, this ratio is not a good indicator of the $H_2$ excitation mechanism as suggested in the literature.

**Published in MNRAS**
*Available from* https://arxiv.org/abs/2007.12310
*and from* https://ui.adsabs.harvard.edu/abs/2020MNRAS.497.3180A/abstract

# The fall of the "youngest planetary nebula", Hen 3-1357

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The Stingray Nebula, aka Hen 3-1357, went undetected until 1990 when bright nebular lines and radio emission were unexpectedly discovered. We report changes in shape and rapid and secular decreases in its nebular emission-line fluxes based on well calibrated images obtained by the *Hubble* Space Telescope in 1996, 2000, and 2016. Hen 3-1357 is now a "recombination nebula".

**Submitted to Science**
*Available from* please send email request to balick@uw.edu

# A study of extragalactic planetary nebulæ populations based on spectroscopy – I. Data compilation and first findings

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We compile published spectroscopic data and [O III] magnitudes of almost 500 extragalactic planetary nebulæ (PNe) in 13 galaxies of various masses and morphological types. This is the first paper of a series that aims to analyze the PN populations and their progenitors in these galaxies. Although the samples are not complete or homogeneous we obtain some first findings through the comparison of a few intensity line ratios and nebular parameters. We find that the ionized masses and the luminosities in H$\beta$, $L_{\mathrm{H}\beta}$, of around 30 objects previously identified as PNe indicate that they are most likely compact H II regions. We find an anti-correlation between the electron densities and the ionized masses in M 31, M 33, and NGC 300 which suggests that most of the PNe observed in these galaxies are probably ionization bounded. This trend is absent in LMC and SMC suggesting that many of their PNe are density bounded. The He II $\lambda$4686 / H$\beta$ values found in many PNe in LMC and some in M 33 and SMC are higher than in the other galaxies. Photo-ionization models predict that these high values can only be reached in density bounded PNe. We also find that the brightest PNe in the sample are not necessarily the youngest since there is no correlation between electron densities and the H$\beta$ luminosities. The strong correlation found between $L_{\mathrm{H}\beta}$–$L_{[\mathrm{O\,III}]}$ implies that the so far not understood cut off of the planetary luminosity function (PNLF) based on [O III] magnitudes can be investigated using $L_{\mathrm{H}\beta}$, a parameter much easier to study.

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# Carbon star CGCS 673 identified as a semi-regular variable star

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This study shows that the carbon star CGCS 673 is a semi-regular (SR) variable star with a period of 135 d and an amplitude of 0.18 magnitudes in the $V$-band. The light curve obtained by this study correlates well with the SR classification as the photometric data obtained shows noticeable periodicity in the light changes of CGCS 673 that is occasionally interrupted by a period of irregular variability. The derived period and colour index obtained from our data and those from professional databases indicate that the attributes of this star fall within the parameters of the semi-regular class of variable stars. Following our notification of the discovery that this star is a variable source, CGCS 673 has received the AAVSO Unique Identifier as (AAVSO UID) 000-BMZ-492.

**Published in Research in Astron. Astrophys.**
*Available from* https://arxiv.org/abs/2006.07289

# The CARMENES search for exoplanets around M dwarfs: Rubidium abundances in nearby cool stars

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In this study, abundances of the neutron-capture elements Rb, Sr, and Zr are derived, for the first time, in a sample of nearby M dwarfs. We focus on stars in the metallicity range $-0.5 < [Fe/H] < +0.3$, an interval poorly explored for Rb abundances in previous analyses. To do this we use high-resolution, high-signal-to-noise-ratio, optical and near-infrared spectra of 57 M dwarfs observed with CARMENES. The resulting [Sr/Fe] and [Zr/Fe] ratios for most M dwarfs are almost constant at about the solar value, and are identical to those found in GK dwarfs of the same metallicity. However, for Rb we find systematic underabundances ($[Rb/Fe] < 0.0$) by a factor two on average. Furthermore, a tendency is found for Rb – but not for other heavy elements (Sr, Zr) – to increase with increasing metallicity such that $[Rb/Fe] > 0.0$ is attained at metallicities higher than solar. These are surprising results, never seen for any other heavy element, and are difficult to understand within the formulation of the s- and r-processes, both contributing sources to the Galactic Rb abundance. We discuss the reliability of these findings for Rb in terms of non-LTE effects, stellar activity, or an anomalous Rb abundance in the Solar System, but no explanation is found. We then interpret the full observed [Rb/Fe] versus [Fe/H] trend within the framework of theoretical predictions from state-of-the-art chemical evolution models for heavy elements, but a simple interpretation is not found either. In particular, the possible secondary behaviour of the [Rb/Fe] ratio at super-solar metallicities would require a much larger production of Rb than currently predicted in AGB stars through the s-process without overproducing Sr and Zr.

**Accepted for publication in Astronomy & Astrophysics**
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# The Gaia–ESO Survey: an extremely Li-rich giant in globular cluster NGC 1261

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Lithium-rich stars in globular clusters are rare. Only 14 have been found so far, in different evolutionary phases from dwarfs to giants. Different mechanisms have been proposed to explain this enhancement, but it is still an open problem. Using spectra collected within the Gaia–ESO Survey, obtained with the GIRAFFE spectrograph at the ESO Very Large Telescope, we present the discovery of the first Li-rich star in the cluster NGC 1261, the second star known in the red giant branch bump phase. The star shows an extreme Li overabundance of $A(\mathrm{Li})_{\mathrm{LTE}} = 3.92 \pm 0.14$, corresponding to $A(\mathrm{Li})_{\mathrm{NLTE}} = 3.40$ dex. We propose that the Li enhancement is caused by fresh Li production through an extra mixing process (sometimes referred to as cool bottom burning). Alternatively, it could be a preexisting Li overabundance caused by mass-transfer from a red giant star; this mechanism does not enhance the barium abundance and thus we observe low barium. To unambiguously explain the Li enhancement in globular cluster stars, however, a reliable determination of the abundance of key species like Be, $^{6}$Li, $^{12}$C/$^{13}$C, and several s-process elements is required, as well as detailed modelling of chromospheric activity indicators.

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*and from* https://www.aanda.org/articles/aa/pdf/2020/07/aa38435-20.pdf

# Spatially resolved ultraviolet spectroscopy of the "Great Dimming" of Betelgeuse

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The bright supergiant, Betelgeuse ($\alpha$ Orionis, HD 39801) experienced a visual dimming during 2019 December and the first quarter of 2020 reaching an historic minimum 2020 February 7–13. During 2019 September to 2019 November, prior to the optical dimming event, the photosphere was expanding. At the same time, spatially resolved ultraviolet spectra using HST/STIS revealed a substantial increase in the ultraviolet spectrum and Mg II line emission from the chromosphere over the southern hemisphere of the star. Moreover, the temperature and electron density inferred from the spectrum and C II diagnostics also increased in this hemisphere. These changes happened prior to the "Great Dimming" event. Variations in the Mg II k-line profiles suggest material moved outwards in response to the passage of a pulse or acoustic shock from 2019 September through 2019 November. It appears that this extraordinary outflow of material from the star, likely initiated by convective photospheric elements, was enhanced by the coincidence with the outward motions in this phase of the $\sim 400$ day pulsation cycle. These ultraviolet observations appear to provide the connecting link between the known large convective cells in the photosphere and the mass ejection event that cooled to form the dust cloud in the southern hemisphere imaged in 2019 December, and led to the exceptional optical dimming of Betelgeuse in 2020 February.

**Published in Astrophysical Journal, 899, 68 (2020)**

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*and from* doi:10.3847/1538-4357/aba516

# Infrared color separation between thin-shelled oxygen-rich and carbon-rich AGB stars

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We present 43 GHz VLA spectra for 51 AGB sources with the goal of verifying an infrared (IR) color cut intended to separate Carbon-rich (C) and Oxygen-rich (O) AGB sources throughout the Galaxy. The color cut is a simple line in the [$K_s$]–[A] versus [A]–[E] color–color diagram based on 2MASS and MSX photometry, and was originally derived from SiO detection rates in the Bulge Asymmetries and Dynamical Evolution (BAaDE) sample. The division is fully supported by the spectra presented here, which show that SiO maser detections lie on the O-rich side, and SiO non-detections and a single $HC_3N$ detection are found on the C-rich side of the division. We further compare the color cut with classifications of the sources based on Low-Resolution Spectra (LRS) from the Infrared Astronomical Satellite (IRAS), and find good agreement, verifying that the division is a reliable and efficient method for differentiating O- and C-rich AGB sources. These observations also demonstrate that single lines detected in the BAaDE survey around 42.9 GHz are almost certainly the $^{29}$SiO $v = 0$ line. SiO maser sources where this rare isotopologue transition is brighter than the dominant $^{28}$SiO lines have not been reported before, and our observations show that these sources can reverse their behavior such that the typical ratios of $^{28}$SiO and $^{29}$SiO are restored within a few years.

**Accepted for publication in ApJ**

*Available from* https://arxiv.org/abs/2008.06535

# Evidence for coupling of evolved star atmospheres and spiral arms of the Milky Way

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It is imperative to map the strength and distribution of feedback in galaxies to understand how feedback affects galactic ecosystems. $H_2O$ masers act as indicators of energy injection into the interstellar medium. Our goal is to measure the strength and distribution of feedback traced by water masers in the Milky Way. We identify optical counterparts to $H_2O$ masers discovered by the HOPS survey. The distribution and luminosities of $H_2O$ masers in the Milky Way are determined using parallax measurements derived from the second Gaia Data Release. We provide evidence of a correlation between evolved stars, as traced by $H_2O$ masers, and the spiral structure of the Milky Way, suggesting a link between evolved stars and the Galactic environment.

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# A rapidly varying red supergiant X-ray binary in the Galactic center

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We analyzed multiwavelength observations of the previously identified Galactic center X-ray binary CXO 174528.79−290942.8 (XID 6592) and determine that the near-infrared counterpart is a red supergiant based on its spectrum and luminosity. Scutum X-1 is the only previously known X-ray binary with a red supergiant donor star and closely resembles XID 6592 in terms of X-ray luminosity ($LX$), absolute magnitude, and IR variability ($L_{\mathrm{IR,\ var}}$), supporting the conclusion that XID 6592 contains a red supergiant donor star. The XID 6592 infrared counterpart shows variability of $\sim 0.5$ mag in the Wide-field Infrared Survey Explorer-1 band (3.4 $\mu$m) on timescales of a few hours. Other infrared data sets also show large-amplitude variability from this source at earlier epochs but do not show significant variability in recent data. We do not expect red supergiants to vary by $\sim 50\%$ in luminosity over these short timescales, indicating that the variability should be powered by the compact object. However, the X-ray luminosity of this system is typically $\sim 1000\times$ less than the variable luminosity in the infrared and falls below the *Chandra* detection limit. While X-ray reprocessing can produce large-amplitude fast infrared variability, it typically requires $L_{\mathrm{X}} \gg L_{\mathrm{IR,\,var}}$ to do so, indicating that another process must be at work. We suggest that this system may be a supergiant fast X-ray transient (SFXT), and that a large ($\sim 10^{38}$ ergs s$^{-1}$), fast ($10^{2-4}$ s) X-ray flare could explain the rapid IR variability and lack of a long-lasting X-ray outburst detection. SFXTs are normally associated with blue supergiant companions, so if confirmed, XID 6592 would be the first red supergiant SFXT, as well as the second X-ray red supergiant binary.

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# Tomography of cool giant and supergiant star atmospheres – III. Validation of the method on VLTI/AMBER observations of the Mira star S Ori

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The knowledge of the structure and dynamics of AGB-star atmospheres is crucial to better understand the mass loss. The tomographic method, that relies on the design of spectral masks containing lines forming in given ranges of optical depths in the stellar atmosphere, is an ideal technique for this purpose. It is applied to high-resolution spectro-interferometric VLTI/AMBER observations of the Mira-type AGB star S Ori. First, the interferometric visibilities are extracted at wavelengths contributing to the tomographic masks and fitted to those computed from a uniform disk model. This allows the measurement of the geometrical extent of the atmospheric layer probed by the corresponding mask. Then, we compare the observed atmospheric extension with those measured from available 1D pulsation CODEX models and 3D radiative-hydrodynamics CO5BOLD simulations. We found that while the average optical depths probed by the tomographic masks in S Ori decrease (with $\langle \log \tau_0 \rangle = -0.45$, $-1.45$, and $-2.45$ from the innermost to the central and outermost layers), the angular diameters of these layers increase, from $10.59 \pm 0.09$ mas through $11.84 \pm 0.17$ mas, up to $14.08 \pm 0.15$ mas. A similar behavior is observed when the tomographic method is applied to 1D and 3D dynamical models. Thus, this study derives, for the first time, a quantitative relation between optical- and geometrical-depth scales when applied to the Mira star S Ori, or to 1D and 3D dynamical models. In the context of Mira-type stars, the knowledge of the link between the optical and geometrical depths opens the way to derive the shock-wave propagation velocity, which can not be directly observed in these stars.

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# Betelgeuse – a century and more of variation

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The mean light curve of Betelgeuse is constructed from the visual data in BAA VSS and AAVSO archives. Period analysis reveals clusters of periods around 2000 and 400 days but these are swamped by the long-term trends. No identifiable periods emerge but the feature near 400 days is the most persistent and survives even when the range of variation is low. Herschel's data from 1836–40 and early data from the BAA VSS around 1900 show a range of $V$ 0–1, so the star was brighter and more active than recently. Historically it shows a wide range of behaviour.

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# Deuterated polycyclic aromatic hydrocarbons in the interstellar medium: the C–D band strengths of mono-deuterated species

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Deuterium (D) is one of the light elements created in the big bang. As the Galaxy evolves, the D/H abundance in the interstellar medium (ISM) decreases from its primordial value due to “astration”. However, the observed gas-phase D/H abundances of some sightlines in the local Galactic ISM are substantially lower than the expected reduction by astration. The missing D could have been depleted onto polycyclic aromatic hydrocarbon (PAH) molecules which are ubiquitous and abundant in interstellar regions. To quantitatively explore the hypothesis of PAHs as a possible reservoir of interstellar D, we compute quantum-chemically the infrared vibrational spectra of mono-deuterated PAHs (and their cations) of various sizes. We find that, as expected, when H in PAHs is replaced by D, the C–H stretching and bending modes at 3.3, 8.6 and 11.3 $\mu$m shift to longer wavelengths at $\sim$ 4.4, 11.4 and 15.4 $\mu$m, respectively, by a factor of $\sim \sqrt{13/7}$, the difference in reduced mass between the C–H and C–D oscillators. We derive from the computed spectra the mean intrinsic band strengths of the 3.3-$\mu$m C–H stretch and 4.4-$\mu$m C–D stretch to be $\langle A_{3.3} \rangle \approx 13.4$ km mol$^{-1}$ and $\langle A_{4.4} \rangle \approx 7.4$ km mol$^{-1}$ for neutral deuterated PAHs which would dominate the interstellar emission at 3.3 and 4.4 $\mu$m. By comparing the computationally-derived mean band-strength ratio of $\langle A_{4.4}/A_{3.3} \rangle \approx 0.56$ for neutral PAHs with the mean ratio of the observed intensities of $\langle (L_{4.4}/L_{3.3})_{\rm obs} \rangle \approx 0.019$, we find that the degree of deuteration (i.e. the fraction of peripheral atoms attached to C atoms in the form of D) is $\sim$ 2.4%, corresponding to a D-enrichment of a factor of $\sim$ 1200 with respect to the interstellar D/H abundance.

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# On the absorption properties of metallic needles

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Needle-like metallic particles have been suggested to explain a wide variety of astrophysical phenomena, ranging from the mid-infrared interstellar extinction to the thermalization of starlight to generate the cosmic microwave background. These suggestions rely on the amplitude and the wavelength dependence of the absorption cross sections of metallic needles. On the absence of an exact solution to the absorption properties of metallic needles, their absorption cross sections are often derived from the antenna approximation. However, it is shown here that the antenna approximation is not an appropriate representation since it violates the Kramers–Kronig relation. Stimulated by the recent discovery of iron whiskers in asteroid Itokawa and graphite whiskers in carbonaceous chondrites, we call for rigorous calculations of the absorption cross sections of metallic needle-like particles, presumably with the discrete dipole approximation. We also call for experimental studies of the formation and growth mechanisms of metallic needle-like particles as well as experimental measurements of the absorption cross sections of metallic needles of various aspect ratios over a wide wavelength range to bound theoretical calculations.

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# A search for light hydrides in the envelopes of evolved stars

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We report a search for the diatomic hydrides SiH, PH, and FeH along the line of sight toward the chemically rich circumstellar envelopes of IRC +10°216 and VY Canis Majoris. These molecules are thought to form in high-temperature regions near the photospheres of those stars, and may then further react via gas-phase and dust–grain interactions leading to more complex species, but have yet to be constrained by observation. We used the German Receiver for Astronomy at Terahertz Frequencies spectrometer on the Stratospheric Observatory for Infrared Astronomy to search for rotational emission lines of these molecules in four spectral windows ranging from 600 to 1500 GHz. Although none of the targeted species was detected in our search, we report their upper limit abundances in each source and discuss how they influence the current understanding of hydride chemistry in dense circumstellar media. We attribute the non-detections of these hydrides to their compact source sizes, high barriers of formation, and proclivity to react with other molecules in the winds.

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# DEATHSTAR: nearby AGB stars with the Atacama Compact Array – I. CO envelop sizes and asymmetries: A new hope for accurate mass-loss-rate estimates

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This is the first publication from the DEATHSTAR project. The overall goal of the project is to reduce the uncertainties of the observational estimates of mass-loss rates from evolved stars on the Asymptotic Giant Branch (AGB). The aim in this first publication is to constrain the sizes of the $^{12}$CO emitting region from the circumstellar envelopes around 42 mostly southern AGB stars, of which 21 are M-type and 21 are C-type, using the Atacama Compact Array (ACA) at the Atacama Large Millimeter/submillimeter Array (ALMA). The symmetry of the outflows is also investigated. Line

emission from $^{12}$CO $J = 2 \to 1$ and $3 \to 2$ from all of the sources were mapped using the ACA. In this initial analysis, the emission distribution was fit to a Gaussian distribution in the $uv$-plane. A detailed radiative transfer analysis will be presented in a future publication. The major and minor axis of the best-fit Gaussian at the line center velocity of the $^{12}$CO $J = 2 \to 1$ emission gives a first indication of the size of the emitting region. Furthermore, the fitting results, such as the Gaußian major and minor axis, center position, and the goodness of fit across both lines, constrain the symmetry of the emission distribution. For a subsample of sources, the measured emission distribution is compared to predictions from previous best-fit radiative transfer modeling results. We find that the CO envelope sizes are, in general, larger for C-type than for M-type AGB stars, which is as expected if the CO/$H_2$ ratio is larger in C-type stars. Furthermore, the measurements show a relation between the measured (Gaußian) $^{12}$CO $J = 2 \to 1$ size and circumstellar density that, while in broad agreement with photo-dissociation calculations, reveals large scatter and some systematic differences between the different stellar types. For lower mass-loss-rate irregular and semi-regular variables of both M- and C-type AGB stars, the $^{12}$CO $J = 2 \to 1$ size appears to be independent of the ratio of the mass-loss rate to outflow velocity, which is a measure of circumstellar density. For the higher mass-loss-rate Mira stars, the $^{12}$CO $J = 2 \to 1$ size clearly increases with circumstellar density, with larger sizes for the higher CO-abundance C-type stars. The M-type stars appear to be consistently smaller than predicted from photo-dissociation theory. The majority of the sources have CO envelope sizes that are consistent with a spherically symmetric, smooth outflow, at least on larger scales. For about a third of the sources, indications of strong asymmetries are detected. This is consistent with what was found in previous interferometric investigations of northern sources. Smaller scale asymmetries are found in a larger fraction of sources. These results for CO envelope radii and shapes can be used to constrain detailed radiative transfer modeling of the same stars so as to determine mass-loss rates that are independent of photo-dissociation models. For a large fraction of the sources, observations at higher spatial resolution will be necessary to deduce the nature and origin of the complex circumstellar dynamics revealed by our ACA observations.

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# FLASHING: new high-velocity $H_2O$ masers in IRAS 18286−0959

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We discovered new high-velocity components of $H_2O$ maser emission in one of the "water fountain" sources, IRAS 18286 −0959, which has been monitored using the Nobeyama 45 m telescope in the new FLASHING (Finest Legacy Acquisitions of SiO- and $H_2O$-maser Ignitions by Nobeyama Generation) project since 2018 December. The maser spectra show new, extremely high expansion velocities ($>$ 200 km s$^{-1}$ projected in the line of sight) components, some of which are located symmetrically in the spectrum with respect to the systemic velocity. They were also mapped with KaVA (KVN and VERA Combined Array) in 2019 March. We located some of these maser components closer to the central stellar system than other high velocity components (50–200 km s$^{-1}$) that have been confirmed to be associated with the known bipolar outflow. The new components would flash in the fast collimated jet at a speed over 300 km s$^{-1}$ (soon) after 2011 when they had not been detected. The fastest of the new components seem to indicate rapid

deceleration in these spectra, however our present monitoring is still too sparse to unambiguously confirm it (up to 50 km s$^{-1}$ yr$^{-1}$) and too short to reveal their terminal expansion velocity, which will be equal to the expansion velocity that has been observed ($v_{\rm exp} \sim 120$ km s$^{-1}$). Future occurrences of such extreme velocity components may provide a good opportunity to investigate possible recurrent outflow ignitions. Thus sculpture of the parental envelope will be traced by the dense gas that is entrained by the fast jet and exhibits spectacular distributions of the relatively stable maser features.

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# (Sub)stellar companions shape the winds of evolved stars

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Binary interactions dominate the evolution of massive stars, but their role is less clear for low- and intermediate-mass stars. The evolution of a spherical wind from an asymptotic giant branch (AGB) star into a non-spherical planetary nebula (PN) could be due to binary interactions. We observed a sample of AGB stars with the Atacama Large Millimeter/submillimeter Array (ALMA) and found that their winds exhibit distinct nonspherical geometries with morphological similarities to planetary nebulæ (PNe). We infer that the same physics shapes both AGB winds and PNe; additionally, the morphology and AGB mass-loss rate are correlated. These characteristics can be explained by binary interaction. We propose an evolutionary scenario for AGB morphologies that is consistent with observed phenomena in AGB stars and PNe.

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# Constraining the thermally pulsing asymptotic giant branch phase with resolved stellar populations in the Large Magellanic Cloud

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Reliable models of the thermally pulsing asymptotic giant branch (TP-AGB) phase are of critical importance across astrophysics, including our interpretation of the spectral energy distribution of galaxies, cosmic dust production, and enrichment of the interstellar medium. With the aim of improving sets of stellar isochrones that include a detailed description of the TP-AGB phase, we extend our recent calibration of the AGB population in the Small Magellanic Cloud (SMC) to the more metal-rich Large Magellanic Cloud (LMC). We model the LMC stellar populations with the TRILEGAL code, using the spatially resolved star formation history derived from the VISTA survey. We characterize the efficiency of the third dredge-up by matching the star counts and the $K_{\rm s}$-band luminosity functions of the AGB stars identified in the LMC. In line with previous findings, we confirm that, compared to the SMC, the third dredge-up in AGB stars of the LMC is somewhat less efficient, as a consequence of the higher metallicity. The predicted range of initial mass of C-rich stars is between $M_{\rm i} \approx 1.7$ and 3 $\mathrm{M}_\odot$ at $Z_{\rm i} = 0.008$. We show how the inclusion of new opacity data in the carbon star spectra will improve the performance of our models. We discuss the predicted lifetimes, integrated luminosities, and mass-loss rate distributions of the calibrated models. The results of our calibration are included in updated stellar isochrones publicly available.

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# Characterizing the evolved stellar population in the Galactic foreground – I: bolometric magnitudes, spatial distribution and P–L relations

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Radio campaigns using maser stellar beacons have provided crucial information to characterize Galactic stellar populations. Currently, the Bulge Asymmetries and Dynamical Evolution (BAaDE) project is surveying infrared (IR) color-selected targets for SiO masers. This provides a sample of evolved stars that can be used to study the inner, optically obscured Galaxy using line of sight velocities and possibly VLBI proper motions. In order to use the BAaDE sample for kinematic studies, the stellar population should be characterized. In this study, the BAaDE targets have been cross-matched with IR (2MASS) and optical Gaia samples. By exploring the synergies of this cross-match together with Gaia parallaxes and extinction maps, the local ($d < 2$ kpc) AGB stars can be characterized. We have defined a BAaDE–Gaia sample of 20,111 sources resulting from cross-matching BAaDE targets with IR and optical surveys. From this sample, a local sample of 1,812 evolved stars with accurate parallax measurements, confirmed evolved stellar evolution stage, and within 2 kpc distance around the Sun was selected, for which absolute (bolometric) magnitudes are estimated. The evolved stellar population with Gaia counterparts that are variable seems to be predominantly associated with AGB stars with moderate luminosity (1,500 $L_\odot$) and periods between 250 and 1,250 days.

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# Three open clusters containing Cepheids: NGC 6649, NGC 6664 & Berkeley 55

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Classical Cepheids in open clusters play an important role in benchmarking stellar evolution models, anchoring the cosmic distance scale, and invariably securing the Hubble constant. NGC 6649, NGC 6664 and Berkeley 55 are three pertinent clusters that host classical Cepheids and red (super)giants, and an analysis was consequently initiated to assess newly acquired spectra ($\approx$ 50), archival photometry, and Gaia DR2 data. Importantly, for the first time chemical abundances are determined for the evolved members of NGC 6649 and NGC 6664. We find that they are slightly metal-poor relative to the mean Galactic gradient, and an overabundance of Ba is observed. Those clusters likely belong to the thin disc, and the latter finding supports D'Orazi et al. (2009) "s-enhanced" scenario. NGC 6664 and Berkeley 55 exhibit radial velocities consistent with Galactic rotation, while NGC 6649 displays a peculiar velocity. The resulting age estimates for the clusters ($\sim$ 70 Ma) imply masses for the (super)giant demographic of $\sim 6\ M_\odot$. Lastly, the observed yellow-to-red (super)giant ratio is lower than expected, and the overall differences relative to models reflect outstanding theoretical uncertainties.

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## The cooling-down central star of the planetary nebula SwSt 1: a late thermal pulse in a massive post-AGB star?

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SwSt 1 (PN G001.5−06.7) is a bright and compact planetary nebula containing a late [WC]-type central star. Previous studies suggested that the nebular and stellar lines are slowly changing with time. We studied new and archival optical and ultraviolet spectra of the object. The [O III] 4959 and 5007Å to H$\beta$ line flux ratios decreased between about 1976 and 1997/2015. The stellar spectrum also shows changes between these epochs. We modeled the stellar and nebular spectra observed at different epochs. The analyses indicate a drop of the stellar temperature from about 42 kK to 40.5 kK between 1976 and 1993. We do not detect significant changes between 1993 and 2015. The observations show that the star performed a loop in the H–R diagram. This is possible when a shell source is activated during its post-AGB evolution. We infer that a late thermal pulse (LTP) experienced by a massive post-AGB star can explain the evolution of the central star. Such a star does not expand significantly as the result of the LTP and does not became a born-again red giant. However, the released energy can remove the tiny H envelope of the star.

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# *Review Paper*

## Neutron-capture element abundances in planetary nebulæ

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Nebular spectroscopy is a valuable tool for assessing the production of heavy elements by slow neutron (n-)capture nucleosynthesis (the s-process). Several transitions of n-capture elements have been identified in planetary nebulæ (PNe) in the last few years, with the aid of sensitive, high-resolution, near-infrared spectrometers. Combined with optical spectroscopy, the newly discovered near-infrared lines enable more accurate abundance determinations than previously possible, and provide access to elements that had not previously been studied in PNe or their progenitors. Neutron-capture elements have also been detected in PNe in the Sagittarius Dwarf galaxy and in the Magellanic Clouds. In this brief review, I discuss developments in observational studies of s-process enrichments in PNe, with an emphasis on the last five years, and note some open questions and preliminary trends.

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*and from* https://www.mdpi.com/2075-4434/8/2/50/htm

## *Job Adverts*

# European Southern Observatory ESO studentship program

Dear colleagues,

we would like to advertise the ESO studentship (Santiago–Chile and Garching–Germany) programs. The programs fund students already enrolled in a University Ph.D. program in astronomy or a related field. The students have the possibility to spend part of their Ph.D. project under the formal supervision of their home institute, in one of the ESO premises (Chile or Germany) under co-supervision of an ESO staff member for a period up to two years, with funding provided. The call for the second semester is open with application deadline November 30$^{st}$. At the following link http://www.eso.org/sci/activities/FeSt-overview/ESOstudentship/PhDThesisTopics.html you will be able to find available topics covering the aspects of the field of evolved stars (watch out for updates from time to time!). Of course additional topics can be discussed, just remember: for a successful application, you and your supervisor need to contact in advance a co-supervisor from ESO to define the project. Looking forward to increasing the ESO/AGB team!

Claudia Paladini on behalf of the ESO/AGB team

*See also* https://recruitment.eso.org

# European Southern Observatory ESO Fellowship

Dear colleagues,

ESO invite applications for the ESO Fellowship Programme 2020/2021 in Chile and Germany. The Programme is designed to help young scientists to develop their independent research programmes and successfully reach the next step of their scientific careers. The deadline to apply is 15 October 2020.
Details at http://www.eso.org/sci/activities/FeSt-overview/fellowship_programme.html

Best Regards
Claudia Paladini

*See also* https://recruitment.eso.org

## *Announcement*

# Fizeau exchange visitors program in optical interferometry call for applications

Dear colleagues!

The Fizeau exchange visitors program in optical interferometry funds (travel and accommodation) visits of researchers to an institute of their 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. From January 2021 onwards, applications to travel to VLTI Expertise Centres are priority, given the new financial rules applying to the programme. Applicants are strongly encouraged to seek also partial support from their home or host institutions.

The deadline for applications is November 15. Fellowships can be awarded for missions to be carried out between January 2021 and July 2021!

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,
Josef Hron & Péter Ábrahám
(for the European Interferometry Initiative)

*See also* www.european-interferometry.eu