# 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 228$^{\rm th}$ issue of the AGB Newsletter.

Many thanks to Ben Tatton, Tom Marsh and Karin Sandstrom for not just suggesting, but also explaining how, to add hyperlinks to the PDF. It seems to work, but do let us know if you notice something awry.

There are two very interesting jobs on offer: a fellowship in Melbourne and a Ph.D. position in Brussels.

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

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

## *Food for Thought*

This month's thought-provoking statement is:

*Much more laboratory work is needed on the formation and optical and physical properties of circumstellar grains.*

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*

## Galactic planetary nebulæ with precise nebular abundances as a tool to understand the evolution of asymptotic giant branch stars

*D.A. García-Hernández*[1], *P. Ventura*[2], *G. Delgado-Inglada*[3], *F. Dell'Agli*[2], *M. Di Criscienzo*[2] *and A. Yagüe*[2,1]

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We present nucleosynthesis predictions (HeCNOCl) from asymptotic giant branch (AGB) models, with diffusive overshooting from all the convective borders, in the metallicity range $Z_{\odot}/4 < Z < 2\ Z_{\odot}$. They are compared to recent precise nebular abundances in a sample of Galactic planetary nebulæ (PNe) that is divided among double-dust chemistry (DC) and oxygen-dust chemistry (OC) according to the infrared dust features. Unlike the similar subsample of Galactic carbon-dust chemistry PNe recently analysed by us, here the individual abundance errors, the higher metallicity spread, and the uncertain dust types/subtypes in some PNe do not allow a clear determination of the AGB progenitor masses (and formation epochs) for both PNe samples; the comparison is thus more focussed on a object-by-object basis. The lowest metallicity OC PNe evolve from low-mass ($\sim 1\ M_{\odot}$) O-rich AGBs, while the higher metallicity ones (all with uncertain dust classifications) display a chemical pattern similar to the DC PNe. In agreement with recent literature, the DC PNe mostly descend from high-mass ($M \geq 3.5\ M_{\odot}$) solar/supersolar metallicity AGBs that experience hot bottom burning (HBB), but other formation channels in low-mass AGBs like extra mixing, stellar rotation, binary interaction, or He pre-enrichment cannot be disregarded until more accurate C/O ratios would be obtained. Two objects among the DC PNe show the imprint of advanced CNO processing and deep second dredge-up, suggesting progenitors masses close to the limit to evolve as core collapse supernovae (above 6 $M_{\odot}$). Their actual C/O ratio, if confirmed, indicate contamination from the third dredge-up, rejecting the hypothesis that the chemical composition of such high-metallicity massive AGBs is modified exclusively by HBB.

**Accepted for publication in MNRAS**
*Available from* http://arxiv.org/abs/1606.00356
*and from* http://www.iac.es/preprints/?c=view&pre_id=16036

## The red supergiant content of M 31

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We investigate the red supergiant (RSG) population of M 31, obtaining radial velocities of 255 stars. These data substantiate membership of our photometrically-selected sample, demonstrating that Galactic foreground stars and extragalactic RSGs can be distinguished on the basis of $B-V, V-R$ two-color diagrams. In addition, we use these spectra to measure effective temperatures and assign spectral types, deriving physical properties for 192 RSGs. Comparison with the solar-metallicity Geneva evolutionary tracks indicates astonishingly good agreement. The most luminous RSGs in M 31 are likely evolved from 25–30 $M_{\odot}$ stars, while the vast majority evolved from stars with initial masses of 20 $M_{\odot}$ or less. There is an interesting bifurcation in the distribution of RSGs with effective temperatures that increases with higher luminosities, with one sequence consisting of early K-type supergiants, and with the other consisting of M-type supergiants that become later (cooler) with increasing luminosities. This separation is only partially reflected in the evolutionary tracks, although that might be due to the mis-match in metallicities between the solar Geneva models and the higher-than-solar metallicity of M 31. As the luminosities increase the median spectral type also increases; i.e., the higher mass RSGs spend more time at cooler temperatures than do those of lower luminosities, a result which is new to this study. Finally we discuss what would be needed observationally to successfully build a luminosity function that could be used to constrain the mass-loss rates of RSGs as our Geneva colleagues have suggested.

**Accepted for publication in Astronomical Journal**
*Available from* http://arxiv.org/abs/1605.07900

# NGC 2440 : A morpho-kinematical model

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This work describes the modelling of the 3D structure and position–velocity ($P$–$V$) diagrams of NGC 2440, a well known planetary nebula, aiming to describe the morphology of this object, specially its core. We have used high resolution spectra and $P$–$V$ diagrams to reproduce the 3D structure of the nebula using SHAPE, a software that allows 3D modelling. HST high angular resolution images were used as reference to the model. The observational data point to a segmented core, and the simulations confirm this assumption; the best model for the nebula is a torus segmented in three pieces. The simulated $P$–$V$ diagrams agree with the observations. We suggest that the torus was torn apart by interaction with the surrounding medium, either as winds or the radiation field. For the two bipolar lobes, orientation angles to the plane of the sky of $27 \pm 5$ and $-5 \pm 3$ degrees, respectively for the bipolar components with PA of 85 and 35 degrees, were derived. No additional bipolar lobes were required to model the observed features of NGC 2440. A distance of $1.8 \pm 0.5$ kpc was derived for the nebula using our velocity field for the toroidal structure. These results are the first derived for NGC 2440 from modelling in a 3D environment.

**Accepted for publication in RMxAA**
*Available from* http://arxiv.org/abs/1606.01234

# Very Large Telescope deep échelle spectroscopy of Galactic planetary nebulæ NGC 6153, M 1-42 and Hf 2-2

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We present deep spectroscopy of three Galactic planetary nebulæ (PNe) with large abundance discrepancy factors (ADFs): NGC6 153, M 1-42 and Hf 2-2. The spectra were obtained with VLT/UVES and cover the whole optical range (3040–11,000 Å) with a spectral resolution of ∼20,000. For all three PNe, several hundred emission lines were detected and identified, with more than 70 per cent of them as permitted lines. Most of these permitted lines are excited by recombination. Numerous weak optical recombination lines (ORLs) of O II, C II, N II and Ne II were detected in the spectra and accurate fluxes measured. Line flux tables were compiled and ready for use by the community of nebular astrophysics. These ORLs were critically analyzed using the effective recombination coefficients recently calculated for the optical recombination spectrum of N II and O II under the physical conditions of photo ionized gaseous nebulæ. Plasma diagnostics based on the heavy element ORLs were carried out using the new atomic data. Elemental abundances derived from the ORLs were systematically higher than those derived from the collisionally excited lines (CELs) by a factor of ∼ 11, 22 and 80 for NGC 6153, M 1-42 and Hf 2-2, respectively. The electron temperatures derived from the heavy element ORLs are systematically lower than those derived from the CELs. These ORL versus CEL abundance and temperature discrepancies, previously observed in the three PNe through deep spectroscopy with medium to low spectral resolution, are thus confirmed by our analysis of the deep échelle spectra using the new atomic data.

**Accepted for publication in Monthly Notices of the Royal Astronomical Society**
*Available from* http://arxiv.org/abs/1606.02925

# *Herschel*/HIFI observations of the circumstellar ammonia lines in IRC +10°216

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New high-resolution far-infrared (FIR) observations of both ortho- and para-$NH_3$ transitions toward IRC +10°216 were obtained with *Herschel*, with the goal of determining the ammonia abundance and constraining the distribution of $NH_3$ in the envelope of IRC +10°216. We used the Heterodyne Instrument for the Far Infrared (HIFI) on board *Herschel* to observe all rotational transitions up to the $J = 3$ level (three ortho- and six para-$NH_3$ lines). We conducted non-LTE multilevel radiative transfer modelling, including the effects of near-infrared (NIR) radiative pumping through vibrational transitions. We found that NIR pumping is of key importance for understanding the excitation of rotational levels of $NH_3$. The derived $NH_3$ abundances relative to molecular hydrogen were $(2.8 \pm 0.5) \times 10^{-8}$ for ortho-$NH_3$ and $(3.2^{+0.7}_{-0.6}) \times 10^{-8}$ for para-$NH_3$, consistent with an ortho/para ratio of 1. These values are in a rough agreement with abundances derived from the inversion transitions, as well as with the total abundance of $NH_3$ inferred from the MIR absorption lines. To explain the observed rotational transitions, ammonia must be formed near to the central star at a radius close to the end of the wind acceleration region, but no larger than about 20 stellar radii (1 $\sigma$ confidence level).

**Accepted for publication in A&A**
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# Imaging the elusive H-poor gas in the high ADF planetary nebula NGC 6778

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We present the first direct image of the high-metallicity gas component in a planetary nebula (NGC 6778), taken with the OSIRIS Blue Tunable Filter centered on the O II $\lambda$4649+50 Å optical recombination lines (ORLs) at the 10.4m Gran Telescopio Canarias. We show that the emission of these faint O II ORLs is concentrated in the central parts of the planetary nebula and is not spatially coincident either with emission coming from the bright [O III] $\lambda$5007 Å collisionally excited line (CEL) or the bright H$\alpha$ recombination line. From monochromatic emission line maps taken with VIMOS at the 8.2m Very Large Telescope, we find that the spatial distribution of the emission from the auroral [O III] $\lambda$4363 line resembles that of the O II ORLs but differs from nebular [O III] $\lambda$5007 CEL distribution, implying a temperature gradient inside the planetary nebula. The centrally peaked distribution of the O II emission and the

differences with the [O III] and H I emission profiles are consistent with the presence of an H-poor gas whose origin may be linked to the binarity of the central star. However, determination of the spatial distribution of the ORLs and CELs in other PNe, and a comparison of their dynamics is needed to further constrain the geometry and ejection mechanism of the metal-rich (H-poor) component and hence, understand the origin of the abundance discrepancy problem in PNe.

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## Sodium abundances of AGB and RGB stars in Galactic globular clusters I. Analysis and results of NGC 2808

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Galactic globular clusters (GC) are known to have multiple stellar populations and be characterised by similar chemical features, e.g., O–Na anti-correlation. While second-population stars, identified by their Na overabundance, have been found from the main sequence turn-off up to the tip of the red giant branch in various Galactic GCs, asymptotic giant branch (AGB) stars have rarely been targeted. The recent finding that NGC 6752 lacks an Na-rich AGB star has thus triggered new studies on AGB stars in GCs, since this result questions our basic understanding of GC formation and stellar evolution theory. In order to compare the Na abundance distributions of AGB and RGB stars in Galactic GCs and investigate whether the presence of Na-rich stars on the AGB is metallicity-dependent, we obtained the high-resolution spectra with the multi-object high-resolution spectrograph FLAMES on ESO/VLT for a sample of AGB and RGB stars in the Galactic GC NGC 2808. The accurate Na abundances were derived for 31 AGB and 40 RGB stars. We find that NGC 2808 has a mean metallicity of $-1.11 \pm 0.08$ dex, in good agreement with earlier analyses. Comparable Na abundance dispersions are derived for our AGB and RGB samples, with the AGB stars being slightly more concentrated than the RGB stars. The ratios of Na-poor first-population to Na-rich second-population stars are 45:55 in the AGB sample and 48:52 in the RGB sample. NGC 2808 has Na-rich second-population AGB stars, which turn out to be even more numerous – in relative terms – than their Na-poor AGB counterparts and the Na-rich stars on the RGB. Our findings are well reproduced by the fast rotating massive stars scenario and they do not contradict the recent results that there is not an Na-rich AGB star in NGC 6752. NGC 2808 thus joins the larger group of Galactic GCs for which Na-rich second-population stars on the AGB have recently been found.

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## Synthesis of C-rich dust in CO nova outbursts

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Classical novæ are thermonuclear explosions that take place in the envelopes of accreting white dwarfs in stellar binary systems. The material transferred onto the white dwarf piles up under degenerate conditions, driving a thermonuclear

runaway. In those outbursts, about $10^{-7}$–$10^{-3}$ $M_\odot$, enriched in CNO and, sometimes, other intermediate-mass elements (e.g., Ne, Na, Mg, or Al, for ONe novæ) are ejected into the interstellar medium. The large concentrations of metals spectroscopically inferred in the nova ejecta reveal that the (solar-like) material transferred from the secondary mixes with the outermost layers of the underlying white dwarf. Most theoretical models of nova outbursts reported to date yield, on average, outflows characterized by O > C, from which only oxidized condensates (e.g., O-rich grains) would be expected, in principle. To specifically address whether CO novæ can actually produce C-rich dust, six different hydrodynamic nova models have been evolved, from accretion to the expansion and ejection stages, with different choices for the composition of the substrate with which the solar-like accreted material mixes. Updated chemical profiles inside the H-exhausted core have been used, based on stellar evolution calculations for a progenitor of 8 $M_\odot$ through H and He-burning phases. We show that these profiles lead to C-rich ejecta after the nova outburst. This extends the possible contribution of novæ to the inventory of presolar grains identified in meteorites, particularly in a number of carbonaceous phases (i.e., nanodiamonds, silicon carbides and graphites). Results: We show that these profiles lead to C-rich ejecta after the nova outburst. This extends the possible contribution of novae to the inventory of presolar grains identified in meteorites, particularly in a number of carbonaceous phases (i.e., nanodiamonds, silicon carbides and graphites).

**Accepted for publication in A&A**
*Available from* http://arxiv.org/abs/1606.05438

# Dynamic atmospheres and winds of cool luminous giants, I. $Al_2O_3$ and silicate dust in the close vicinity of M-type AGB stars

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High spatial resolution techniques have given valuable insights into the mass loss mechanism of AGB stars, which presumably involves a combination of atmospheric levitation by pulsation-induced shock waves and radiation pressure on dust. Observations indicate that $Al_2O_3$ condenses at distances of about 2 stellar radii or less, prior to the formation of silicates. $Al_2O_3$ grains are therefore prime candidates for producing the scattered light observed in the close vicinity of several M-type AGB stars, and they may be seed particles for the condensation of silicates at lower temperatures. We have constructed a new generation of Dynamic Atmosphere & Radiation-driven Wind models based on Implicit Numerics (DARWIN), including a time-dependent treatment of grain growth & evaporation for both $Al_2O_3$ and Fe-free silicates ($Mg_2SiO_4$). The equations describing these dust species are solved in the framework of a frequency-dependent radiation-hydrodynamical model for the atmosphere & wind structure, taking pulsation-induced shock waves and periodic luminosity variations into account. Condensation of $Al_2O_3$ at the close distances and in the high concentrations implied by observations requires high transparency of the grains in the visual and near-IR region to avoid destruction by radiative heating. For solar abundances, radiation pressure due to $Al_2O_3$ is too low to drive a wind. Nevertheless, this dust species may have indirect effects on mass loss. The formation of composite grains with an $Al_2O_3$ core and a silicate mantle can give grain growth a head start, increasing both mass loss rates and wind velocities. Furthermore, our experimental core-mantle grain models lead to variations of visual and near-IR colors during a pulsation cycle which are in excellent agreement with observations.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* http://arxiv.org/abs/1605.09730

## Polarisation properties of OH emission in planetary nebulæ

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We present the interferometric, full-polarisation observations of the four ground-state transitions of OH, toward five confirmed and one candidate OH-emitting planetary nebulæ (OHPNe). OHPNe are believed to be very young PNe, and information on their magnetic fields (provided by their polarisation) could be key to understand the early evolution of PNe. We detect significant circular and linear polarisation in four and two objects, respectively. Possible Zeeman pairs are seen in JaSt 23 and IRAS 17393−2727, resulting in estimates of magnetic field strengths between 0.8 and 24 mG. We also report the new detection of OH emission at 1720 MHz toward Vy 2-2, making it the third known PN with this type of emission. We suggest that younger PNe have spectra dominated by narrow maser features and higher degrees of polarisation. Shock-excited emission at 1720 MHz seems to be more common in PNe than in early evolutionary phases, and could be related to equatorial ejections during the early PN phase.

**Accepted for publication in Monthy Notices of the Royal Astronomical Society**
*Available from* http://arxiv.org/abs/1606.07004

## The infrared spectral properties of Magellanic carbon stars

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The Infrared Spectrograph on the *Spitzer* Space Telescope observed 184 carbon stars in the Magellanic Clouds. This sample reveals that the dust-production rate (DPR) from carbon stars generally increases with the pulsation period of the star. The composition of the dust grains follows two condensation sequences, with more SiC condensing before amorphous carbon in metal-rich stars, and the order reversed in metal-poor stars. MgS dust condenses in optically thicker dust shells, and its condensation is delayed in more metal-poor stars. Metal-poor carbon stars also tend to have stronger absorption from acetylene ($C_2H_2$) at 7.5 um. The relation between DPR and pulsation period shows significant apparent scatter, which results from the initial mass of the star, with more massive stars occupying a sequence parallel to lower-mass stars, but shifted to longer periods. Accounting for differences in the mass distribution between the carbon stars observed in the Small and Large Magellanic Clouds reveals a hint of a subtle decrease in the DPR at lower metallicities, but it is not statistically significant. The most deeply embedded carbon stars have lower variability amplitudes and show SiC in absorption. In some cases they have bluer colors at shorter wavelengths, suggesting that the central star is becoming visible. These deeply embedded stars may be evolving off of the AGB

and/or they may have non-spherical dust geometries.

**Accepted for publication in ApJ**
*Available from* http://arxiv.org/abs/1604.06464
*and from* http://isc.astro.cornell.edu/∼sloan/library/2016/mcc/

# *Conference Paper*

## Uncertainties in AGB evolution and nucleosynthesis

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We summarise the evolution and nucleosynthesis in AGB and Super-AGB stars. We then examine the major sources of uncertainty, especially mass-loss.

**Oral contribution, published in the 11$^{\text{th}}$ Pacific Rim Conference on Stellar Astrophysics "Physics and Chemistry of the Late Stages of Stellar Evolution" (invited review)**
*Available from* http://arxiv.org/abs/1605.06163

# *Job Adverts*

## Monash Centre for Astrophysics, School of Physics and Astronomy, Monash University, Melbourne, Australia
## Research Fellow in Statistical Inference for Astronomical Data

We seek to fill a 2.5 year post-doctoral fellowship dedicated to extensions and applications of the Minimum Message Length (MML) technique to the analysis of spectroscopic data from recent large surveys, such as GALAH. The position is based jointly within the Monash Centre for Astrophysics (MoCA, in the School of Physics and Astronomy) and the Faculty of Information Technology (FIT).

The successful applicant will develop and extend the MML method as needed, applying it to spectroscopic data from the GALAH project, with an aim to understanding nucleosynthesis in stars as well as the formation and evolution of our Galaxy ("galactic archæology").

The position is based at the main campus of Monash University which hosts approximately 56,000 equivalent full-time students and approximately 3500 academic staff spread across its Australian and off-shore campuses. Monash is committed to growing its already established excellence in astrophysics as well as machine learning and statistical inference. The successful applicant will work with world experts in both the Bayesian information-theoretic MML method as well as nuclear astrophysics. The immediate supervisors will be Professor John Lattanzio (MoCA), Associate Professor David Dowe (FIT) and Dr. Aldeida Aleti (FIT).

Salary will be in the range $86,209 – $92,541 (which includes a 9.5% employer contribution to superannuation).

Monash University is based in Melbourne, named the World's most livable city in each of the last 5 years. It is a highly multi-cultural cosmopolitan city providing extensive cultural and lifestyle opportunities, is situated on the coast with

excellent beaches readily accessible, many fine restaurants and world-leading vineyards are less than 60 minutes away.

Applications due by 1 August 2016

Further Information:
Position Description:
http://www.jobs-monash.jxt.net.au/academic-jobs/research-fellow-in-statistics-and-astrophysics/706686
Monash University: http://www.monash.edu
Monash Centre for Astrophysics: http://moca.monash.edu/
School of Physics and Astronomy: http://www.monash.edu/science/schools/physics
Faculty of Information Technology: http://www.infotech.monash.edu.au/
Minimum Message Length: http://www.csse.monash.edu.au/ dld/CSWallacePublications/#Wallace2005
City of Melbourne: http://www.melbourne.vic.gov.au/Pages/Home.aspx & http://www.thatsmelbourne.com.au

*See also* http://www.jobs-monash.jxt.net.au/academic-jobs/research-fellow-in-statistics-and-astrophysics/706686

## Royal Observatory of Belgium Ph.D. position

The Royal Observatory of Belgium and the Astronomical Institute of the Leuven University have a position open for a Ph.D. position starting this fall. The topics are Galactic Type-II Cepheids and the relation to post-AGB and post-RGB stars. For details and applications see http://homepage.oma.be/marting/

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