# THE AGB NEWSLETTER

*An electronic publication dedicated to Asymptotic Giant Branch stars and related phenomena*

Official publication of the IAU Working Group on Abundances in Red Giants

No. 202 — 1 May 2014

http://www.astro.keele.ac.uk/AGBnews

Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra


## *Editorial*

Dear Colleagues,

It is our pleasure to present you the 202$^{nd}$ issue of the AGB Newsletter. After an apparent lull in activity, it seems to have picked up again! The variety in presented work is impressive, with quite a bit on symbiotic systems, masers, planetary nebulæ, seismology, elemental abundances and dust production including that in the early Universe, but also computational techniques and reference works including a medium-resolution broadband spectral library.

Don't miss the advertisement for a Ph.D. opportunity in Leuven.

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

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

## *Food for Thought*

This month's thought-provoking statement is:

*Super-AGB stars do not explode.*

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

# *Refereed Journal Papers*

## A super lithium-rich red-clump star in the open cluster Trumpler 5

*L. Monaco*[1], *H.M.J. Boffin*[1], *P. Bonifacio*[2], *S. Villanova*[3], *G. Carraro*[1], *E. Caffau*[2,4], *M. Steffen*[5,2], *J.A. Ahumada*[6], *Y. Beletsky*[7] *and G. Beccari*[1]

[1]European Southern Observatory, Casilla 19001, Santiago, Chile

[2]GEPI, Observatoire de Paris, CNRS, Université Paris Diderot, Place Jules Janssen, 92195 Meudon, France

[3]Universidad de Concepción, Casilla 160-C, Concepción, Chile

[4]Zentrum für Astronomie der Universität Heidelberg, Landessternwarte, Königstuhl 12, 69117 Heidelberg, Germany

[5]Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany

[6]Observatorio Astronómico, Universidad Nacional de Córdoba, Laprida 854, 5000 Córdoba, Argentina

[7]Las Campanas Observatory, Carnegie Institution of Washington, Colina el Pino, Casilla 601, La Serena, Chile

*Context:* The existence of lithium-rich low-mass red giant stars still represents a challenge for stellar evolution models. Stellar clusters are privileged environments for this kind of investigation.
*Aims:* To investigate the chemical abundance pattern of the old open cluster Trumpler 5, we observed a sample of four red-clump stars with high-resolution optical spectrographs. One of them (#3416) reveals extremely strong lithium lines in its spectrum.
*Methods:* One-dimensional, local thermodynamic equilibrium analysis was performed on the spectra of the observed stars. A 3D-NLTE analysis was performed to derive the lithium abundance of star #3416.
*Results:* Star #3416 is super Li-rich with $A(\mathrm{Li}) = 3.75$ dex. The lack of $^6$Li enrichment ($^6$Li/$^7$Li$< 2\%$), the low carbon isotopic ratio ($^{12}\mathrm{C}/^{13}\mathrm{C} = 14 \pm 3$), and the lack of evidence for radial velocity variation or enhanced rotational velocity ($v \sin i = 2.8$ km s$^{-1}$) all suggest that lithium production has occurred in this star through the Cameron & Fowler mechanism.
*Conclusions:* We identified a super Li-rich core helium-burning, red-clump star in an open cluster. Internal production is the most likely cause of the observed enrichment. Given the expected short duration of a star's Li-rich phase, enrichment is likely to have occurred at the red clump or in the immediately preceding phases, namely during the He-flash at the tip of the red giant branch (RGB) or while ascending the brightest portion of the RGB.

**Accepted for publication in Astronomy & Astrophysics Letters**
*Available from* arXiv:1403.6461

## Super and massive AGB stars. III. Nucleosynthesis in metal-poor and very metal-poor stars: $Z = 0.001$ and 0.0001

*Carolyn L. Doherty*[1], *Pilar Gil-Pons*[2], *Herbert H.B. Lau*[3], *John C. Lattanzio*[1], *Lionel Siess*[4] *and Simon W. Campbell*[1]

[1]Monash Centre for Astrophysics (MoCA), School of Mathematical Sciences, Monash University, Victoria 3800, Australia

[2]Department of Applied Physics, Polytechnical University of Catalonia, 08860 Barcelona, Spain

[3]Argelander Institute for Astronomy, University of Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany

[4]Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles (ULB), CP 226, B-1050 Brussels, Belgium

We present a new grid of stellar models and nucleosynthetic yields for super-AGB stars with metallicities $Z = 0.001$ and 0.0001, applicable for use within galactic chemical evolution models. Contrary to more metal rich stars where hot bottom burning is the main driver of the surface composition, in these lower metallicity models the effect of third dredge-up and corrosive second dredge-up also have a strong impact on the yields. These metal-poor and very metal-poor super-AGB stars create large amounts of $^4$He, $^{13}$C and $^{14}$N, as well as the heavy magnesium isotopes $^{25}$Mg and $^{26}$Mg. There is a transition in yield trends at metallicity $Z \approx 0.001$, below which we find positive yields of $^{12}$C, $^{16}$O, $^{15}$N, $^{27}$Al and $^{28}$Si, which is not the case for higher metallicities. We explore the large uncertainties derived

from wind prescriptions in super-AGB stars, finding approximately 2 orders of magnitude difference in yields of $^{22}$Ne, $^{23}$Na, $^{24,25,26}$Mg, $^{27}$Al and our *s*-process proxy isotope $g$. We find inclusion of variable composition low temperature molecular opacities is only critical for super-AGB stars of metallicities below $Z \approx 0.001$. We analyze our results, and those in the literature, to address the question: Are super-AGB stars the polluters responsible for extreme population in the globular cluster NGC 2808? Our results, as well as those from previous studies, seem unable to satisfactorily match the extreme population in this globular cluster.

**Accepted for publication in MNRAS**
*Available from* arXiv:1403.5054

# PAH formation in O-rich planetary nebulæ

*L. Guzman-Ramirez[1,2], E. Lagadec[3], D. Jones[1,4], A.A. Zijlstra[2] and K. Gesicki[5]*

[1]European Southern Observatory, Alonso de Córdova 3107, Casilla 19001, Santiago, Chile
[2]Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, Manchester M13 9PL, UK
[3]Astronomy department, Cornell University, Ithaca, NY 14853-6801, USA
[4]Universidad de Atacama, Departamento de Física, Copayapu 485, Copiapó, Chile
[5]Centre for Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, PL-87-100 Toruń, Poland

Polycyclic aromatic hydrocarbons (PAHs) have been observed in O-rich planetary nebulæ towards the Galactic Bulge. This combination of oxygen-rich and carbon-rich material, known as dual-dust or mixed chemistry, is not expected to be seen around such objects. We recently proposed that PAHs could be formed from the photodissociation of CO in dense tori. In this work, using VISIR/VLT, we spatially resolved the emission of the PAH bands and ionized emission from the [S IV] line, confirming the presence of dense central tori in all the observed O-rich objects. Furthermore, we show that for most of the objects, PAHs are located at the outer edge of these dense/compact tori, while the ionized material is mostly present in the inner parts of these tori, consistent with our hypothesis for the formation of PAHs in these systems. The presence of a dense torus has been strongly associated with the action of a central binary star and, as such, the rich chemistry seen in these regions may also be related to the formation of exoplanets in post-common-envelope binary systems.

**Published in MNRAS, 441, 364 (2014)**
*Available from* arXiv:1403.1856

# A fast and accurate method to compute the mass return from multiple stellar populations

*Francesco Calura[1], Luca Ciotti[2] and Carlo Nipoti[2]*

[1]INAF – Osservatorio di Bologna, Italy
[2]Bologna University, Italy

The mass returned to the ambient medium by aging stellar populations over cosmological times sums up to a significant fraction (20–30% or more) of their initial mass. This continuous mass injection plays a fundamental role in phenomena such as galaxy formation and evolution, fueling of supermassive black holes in galaxies and the consequent (negative and positive) feedback phenomena, and the origin of multiple stellar populations in globular clusters. In numerical simulations the calculation of the mass return can be time consuming, since it requires at each time step the evaluation of a convolution integral over the whole star formation history, so the computational time increases quadratically with the number of time-steps. The situation can be especially critical in hydrodynamical simulations, where different grid points are characterized by different star formation histories, and the gas cooling and heating times are shorter by orders of magnitude than the characteristic stellar lifetimes. In this paper we present a fast and accurate method

to compute the mass return from stellar populations undergoing arbitrarily complicated star formation histories. At each time-step the mass return is calculated from its value at the previous time, and the star formation rate over the last time-step only. Therefore in the new scheme there is no need to store the whole star formation history, and the computational time increases linearly with the number of time-steps.

**Published in MNRAS**
*Available from* arXiv:1312.1090

# MHD and deep mixing in evolved stars. I. 2D and 3D analytical models for the AGB

*M.C. Nucci*[1,2] *and M. Busso*[2,3]

[1]Department of Mathematics & Informatics, University of Perugia, Italy
[2]INFN, Section of Perugia, Italy
[3]Department of Physics and Geology, University of Perugia, Italy

The advection of thermonuclear ashes by magnetized domains emerging from near the H-shell was suggested to explain AGB star abundances. Here we verify this idea quantitatively through exact MHD models. Starting with a simple 2D geometry and in an inertia frame, we study plasma equilibria avoiding the complications of numerical simulations. We show that, below the convective envelope of an AGB star, variable magnetic fields induce a natural expansion, permitted by the almost ideal MHD conditions, in which the radial velocity grows as the second power of the radius. We then study the convective envelope, where the complexity of macro-turbulence allows only for a schematic analytical treatment. Here the radial velocity depends on the square root of the radius. We then verify the robustness of our results with 3D calculations for the velocity, showing that, for both the studied regions, the solution previously found can be seen as a planar section of a more complex behavior, in which anyway the average radial velocity retains the same dependency on radius found in 2D. As a final check, we compare our results to approximate descriptions of buoyant magnetic structures. For realistic boundary conditions the envelope crossing times are sufficient to disperse in the huge convective zone any material transported, suggesting magnetic advection as a promising mechanism for deep mixing. The mixing velocities are smaller than for convection, but larger than for diffusion and adequate to extra-mixing in red giants.

**Accepted for publication in The Astrophysical Journal**
*Available from* arXiv:1404.2503

# Dissecting the *Spitzer* color–magnitude diagrams of extreme LMC AGB stars

*F. Dell'Agli*[1,2]*, P. Ventura*[1]*, D.A. García-Hernández*[3,4]*, R. Schneider*[1]*, M. Di Criscienzo*[1]*, E. Brocato*[1]*, F. D'Antona*[1] *and C. Rossi*[2]

[1]INAF – Osservatorio Astronomico di Roma, Via Frascati 33, 00040, Monte Porzio Catone (RM), Italy
[2]Dipartimento di Fisica, Università di Roma "La Sapienza", P.le Aldo Moro 5, 00143, Roma, Italy
[3]Instituto de Astrofísica de Canarias, Vía Láctea s/n, E-38200 La Laguna, Tenerife, Spain
[4]Dept. Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Tenerife, Spain

We trace the full evolution of low- and intermediate-mass stars ($1\ M_\odot \leq M \leq 8\ M_\odot$) during the Asymptotic Giant Branch (AGB) phase in the *Spitzer* two-color and color–magnitude diagrams. We follow the formation and growth of dust particles in the circumstellar envelope with an isotropically expanding wind, in which gas molecules impinge upon pre-existing seed nuclei, favour their growth. These models are the first able to identify the main regions in the *Spitzer* data occupied by AGB stars in the Large Magellanic Cloud (LMC). The main diagonal sequence traced by LMC extreme stars in the [3.6]–[4.5] vs. [5.8]–[8.0] and [3.6]–[8.0] vs. [8.0] planes are nicely fit by carbon stars models;

it results to be an evolutionary sequence with the reddest objects being at the final stages of their AGB evolution. The most extreme stars, with $[3.6]-[4.5]>1.5$ mag and $[3.6]-[8.0]>3$ mag, are 2.5–3 $M_\odot$ stars surrounded by solid carbon grains. In higher mass ($>3$ $M_\odot$) models dust formation is driven by the extent of Hot Bottom Burning (HBB) – most of the dust formed is in the form of silicates and the maximum obscuration phase by dust particles occurs when the HBB experienced is strongest, before the mass of the envelope is considerably reduced.

**Accepted for publication in Monthly Notices of the Royal Astronomical Society**
*Available from* arXiv:1403.7340

## On the alumina dust production in the winds of O-rich Asymptotic Giant Branch stars

*F. Dell'Agli[1,2], D.A. García-Hernández[3,4], C. Rossi[2], P. Ventura[1], M. Di Criscienzo[1] and R. Schneider[1]*

[1]INAF – Osservatorio Astronomico di Roma, Via Frascati 33, 00040, Monte Porzio Catone (RM), Italy
[2]Dipartimento di Fisica, Università di Roma "La Sapienza", P.le Aldo Moro 5, 00143, Roma, Italy
[3]Instituto de Astrofísica de Canarias, Vía Láctea s/n, E-38200 La Laguna, Tenerife, Spain
[4]Departamento de Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Spain

The O-rich Asymptotic Giant Branch (AGB) stars experience strong mass loss with efficient dust condensation and they are major sources of dust in the interstellar medium. Alumina dust ($Al_2O_3$) is an important dust component in O-rich circumstellar shells and it is expected to be fairly abundant in the winds of the more massive and O-rich AGB stars. By coupling AGB stellar nucleosynthesis and dust formation, we present a self-consistent exploration on the $Al_2O_3$ production in the winds of AGB stars with progenitor masses between $\sim 3$ and 7 $M_\odot$ and metallicities in the range $0.0003 \leq Z \leq 0.018$. We find that $Al_2O_3$ particles form at radial distances from the centre between $\sim 2$ and 4 $R_\star$ (depending on metallicity), which is in agreement with recent interferometric observations of Galactic O-rich AGB stars. The mass of $Al_2O_3$ dust is found to scale almost linearly with metallicity, with solar metallicity AGBs producing the highest amount (about $10^{-3}$ $M_\odot$) of alumina dust. The $Al_2O_3$ grain size decreases with decreasing metallicity (and initial stellar mass) and the maximum size of the $Al_2O_3$ grains is $\sim 0.075$ $\mu$m for the solar metallicity models. Interestingly, the strong depletion of gaseous Al observed in the low-metallicity HBB AGB star HV 2576 seems to be consistent with the formation of $Al_2O_3$ dust as predicted by our models. We suggest that the content of Al may be used as a mass (and evolutionary stage) indicator in AGB stars experiencing HBB.

**Accepted for publication in Monthly Notices of the Royal Astronomical Society**
*Available from* arXiv:1404.0507

## The formation of long-period eccentric binaries with a helium white dwarf

*Lionel Siess[1], Philip J. Davis[1] and Alain Jorissen[1]*

[1]Institut d'Astronomie et d'Astrophysique, ULB, Belgium

The recent discovery of long-period eccentric binaries hosting a He-WD or a sdB star has been challenging binary-star modelling. Based on accurate determinations of the stellar and orbital parameters for IP Eri, a K0 + He-WD system, we propose an evolutionary path that is able to explain the observational properties of this system and, in particular, to account for its high eccentricity (0.25). Our scenario invokes an enhanced-wind mass loss on the first red giant branch (RGB) in order to avoid mass transfer by Roche-lobe overflow, where tides systematically circularize the orbit. We explore how the evolution of the orbital parameters depends on the initial conditions and show that eccentricity can be preserved and even increased if the initial separation is large enough. The low spin velocity of the K0 giant implies that accretion of angular momentum from a (tidally-enhanced) RGB wind should not be efficient.

**Accepted for publication in A&A**
*Available from* http://www.astro.ulb.ac.be/∼siess/pmwiki/pmwiki.php/Main/News

# IPHAS and the symbiotic stars. III. New discoveries and their IR spectral energy distributions

*E.R. Rodríguez-Flores*[1,2,3], *R.L.M. Corradi*[2,3], *A. Mampaso*[2,3], *D. García-Alvarez*[2,3,4], *U. Munari*[5], *R. Greimel*[6], *M.M. Rubio-Díez*[7] *and M. Santander-García*[8,7]

[1]Instituto de Geofísica y Astronomía, Calle 212, N. 2906, CP 11600, La Habana, Cuba

[2]Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

[3]Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain

[4]Grantecan S.A., Centro de Astrofísica de La Palma, E-38712 Breña Baja, La Palma, Spain

[5]INAF, Osservatorio Astronomico di Padova, 36012 Asiago (VI), Italy

[6]IGAM, Institut für Physik, Universität Graz, A-8010 Graz, Austria

[7]Centro de Astrobiología, CSIC–INTA, E-28850 Torrejón de Ardoz, Spain

[8]Observatorio Astronómico Nacional (OAN–IGN), E-28014 Madrid, Spain

The IPHAS H$\alpha$ survey provides a rich database to search for emission-line sources in the northern Galactic Plane. We are performing a systematic search for symbiotic stars in the Milky Way using IPHAS. Our final goal, a complete census of this class of objects in the Galaxy, is a fundamental figure to discuss their overall properties and relevance to other classes of stars. Candidate symbiotic stars are selected using a refined combination of IPHAS and 2MASS photometric colours. Optical spectroscopy, together with the analysis of their spectral energy distribution in the IR, are obtained to confirm their nature and determine their main properties.

Five new symbiotic stars are confirmed from spectroscopy at the 10.4m GTC telescope. In one case, the confirmation of the presence of a red giant star required NIR spectroscopy. In another case, its symbiotic nature is adopted based on the strong similarity of its optical spectrum and spectral energy distribution with those of other genuine symbiotic stars. The spectral energy distribution of the two S-types found is well fittted by red-giant model atmospheres up to 22 $\mu$m without evidence of IR excesses due to dust. On the contrary, the three D-types mostly show emission from hot dust with a temperature around 1000 K. We also present the spectroscopic and photometric monitoring of the symbiotic star IPHAS J 190832.31+051226.6, that was originally discovered in outburst, and has now returned to a lower luminosity status. The spectra of thirteen other sources, all classified as young stellar objects except for a new compact planetary nebula, are also presented.

The refinement of our discovery method, the completion of the IPHAS survey and photometric calibration, and the start of the twin survey in the South, VPHAS+, provide excellent perspectives to complete, in the next few years, a reliable census of symbiotic stars in the Galaxy.

**Accepted for publication in Astronomy & Astrophysics**

# A hydrodynamical study of multiple-shell planetary nebulæ. III. Expansion properties and internal kinematics: Theory versus observation

*D. Schönberner*[1], *R. Jacob*[1], *H. Lehmann*[2], *G. Hildebrandt*[1], *M. Steffen*[1], *A. Zwanzig*[1], *C. Sandin*[1] *and R.L.M. Corradi*[3,4]

[1]Leibniz-Institut für Astrophysik Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany

[2]Thüringer Landessternwarte Tautenburg, Karl-Schwarzschild-Observatorium, D-07778 Tautenburg, Germany

[3]Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

[4]Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain

We present the result of a study on the expansion properties and internal kinematics of round/elliptical planetary nebulæ of the Milky Way disk, the halo, and of the globular cluster M 15. The purpose of this study is to considerably enlarge the small sample of nebulæ with precisely determined expansion properties. To this aim, we selected a representative sample of objects with different evolutionary stages and metallicities and conducted high-resolution échelle spectroscopy. In most cases, we succeeded in detecting the weak signals from the outer nebular shell which are attached to the main line emission from the bright nebular rim. Next to the measurement of the motion of the rim gas by decomposition of the main line components into Gaussians, we were able to measure separately, for most objects for the first time, the gas velocity immediately behind the leading shock of the shell, i.e. the post-shock velocity. We more than doubled the number of objects for which the velocities of both rim and shell are known and confirm that the overall expansion of planetary nebulæ is accelerating with time. There are, however, differences between the expansion behaviour of the shell and the rim. This observed distinct velocity evolution of both rim and shell is explained by radiation-hydrodynamics simulations, at least qualitatively. Because of the time-dependent boundary conditions, a planetary nebula will never evolve into a simple self-similar expansion. Also the metal-poor objects behave as theory predicts: The post-shock velocities are higher and the rim flow velocities are equal or even lower compared to disk objects at similar evolutionary stage. We detected, for the first time, in some objects an asymmetric expansion behaviour: The relative expansions between rim and shell appear to be different for the receding and approaching parts of the nebular envelope.

**Accepted for publication in Astron.Nachr.**
*Available from* arXiv:1404.0391

# VLBI astrometry of AGB variables with VERA – A Mira type variable T Lepus

*Akiharu Nakagawa*[1], *Toshihiro Omodaka*[1], *Toshihiro Handa*[1], *Mareki Honma*[2], *Noriyuki Kawaguchi*[3], *Hideyuki Kobayashi*[2], *Tomoaki Oyama*[2], *Katsuhisa Sato*[3], *Katsunori M. Shibata*[2], *Makoto Shizugami*[3], *Yoshiaki Tamura*[3] *and Yuji Ueno*[3]

[1]Graduate School of Science and Engineering, Kagoshima University, 1-21-35 Korimoto, Kagoshima-shi, Kagoshima 890-0065, Japan
[2]Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[3]Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, 2-12 Hoshi-ga-oka, Mizusawa-ku, Oshu-shi, Iwate 023-0861, Japan

We conducted phase referencing VLBI observations of the Mira variable T Lepus (T Lep) using VERA, from 2003 to 2006. The distance to the source was determined from its annual parallax which was measured to be $3.06 \pm 0.04$ mas, corresponding to a distance of $327 \pm 4$ pc. Our observations revealed the distribution and internal kinematics of $H_2O$ masers in T Lep, and we derived a source systemic motions of $14.60 \pm 0.50$ mas yr$^{-1}$ and $-35.43 \pm 0.79$ mas yr$^{-1}$ in right ascension and declination, respectively. We also determined a LSR velocity of $v^{\star}_{\rm LSR} = -27.63$ km s$^{-1}$. Comparison of our result with an image recently obtained from the VLTI infrared interferometer reveals a linear scale picture of the circumstellar structure of T Lep. Analysis of the source systemic motion in the Galacto-centric coordinate frame indicates a large peculiar motion, which is consistent with the general characteristics of AGB stars. This source makes a contribution to the calibration of the period-luminosity relation of Galactic Mira variables. From the compilation of data for nearby Mira variables found in the literature, whose distances were derived from astrometric VLBI observations, we have calibrated the Galactic Mira period–luminosity relation to a high degree of accuracy.

**Accepted for publication in Publications of the Astronomical Society of Japan**
*Available from* arXiv:1404.4463

# SiO masers from AGB stars in the vibrationally excited $v = 1$, $v = 2$, and $v = 3$ states

*J.-F. Desmurs*[1], *V. Bujarrabal*[2], *M. Lindqvist*[3], *J. Alcolea*[1], *R. Soria-Ruiz*[1] *and P. Bergman*[3]

[1]Observatorio Astronómico Nacional (OAN–IGN), C/ Alfonso XII, 3, E-28014 Madrid, Spain
[2]Observatorio Astronómico Nacional (OAN–IGN), Apartado 112, E-28803 Alcalá de Henares, Spain
[3]Onsala Space Observatory, Dept. of Earth and Space Sciences, Chalmers University of Technology, 43992 Onsala, Sweden

The $v = 1$ and $v = 2$ $J = 1$–0 (43 GHz), and $v = 1$ $J = 2$–1 (86 GHz) SiO masers are intense in AGB stars and have been mapped using VLBI showing ring-like distributions. Those of the $v = 1$, $v = 2$ $J = 1$–0 masers are similar, but

the spots are rarely coincident, while the $v = 1$ $J = 2$–1 maser arises from a well separated region farther out. These relative locations can be explained by models tools that include the overlap of two IR lines of SiO and $H_2O$. The $v = 3$ $J = 1$–0 line is not directly affected by any line overlap and its spot structure and position, relative to the other lines, is a good test to the standard pumping models. We present single-dish and simultaneous VLBI observations of the $v = 1$, $v = 2$, and $v = 3$ $J = 1$–0 maser transitions of $^{28}$SiO in several AGB stars. The spatial distribution of the SiO maser emission in the $v = 3$ $J = 1$–0 transition from AGB stars is systematically composed of a series of spots that occupy a ring-like structure. The overall ring structure is extremely similar to that found in the other 43 GHz transitions and is very different from the structure of the $v = 1$ $J = 2$–1 maser. The positions of the individual spots of the different 43 GHz lines are, however, very rarely coincident, which in general is separated by about 0.3 au (between 1 and 5 mas). These results are very difficult to reconcile with standard pumping models, which predict that the masers of rotational transitions within a given vibrational state require very similar excitation conditions, while the transitions of different vibrational states should appear in different positions. However, models including line overlap tend to predict $v = 1$, $v = 2$, $v = 3$ $J = 1$–0 population inversion to occur under very similar conditions, while the requirements for $v = 1$ $J = 2$–1 appear clearly different, and are compatible with the observational results.

**Accepted for publication in A&A**
*Available from* arXiv:1404.4182

# Chemical abundances in Galactic planetary nebulæ with *Spitzer* spectra

*D.A. García-Hernández*[1,2] *and S.K. Górny*[3]

[1]Instituto de Astrofísica de Canarias, C/ Via Láctea s/n, E-38205 La Laguna, Spain
[2]Departamento de Astrofísica, Universidad de La Laguna (ULL), E-38206 La Laguna, Spain
[3]N. Copernicus Astronomical Center, Rabiańska 8, 87-100 Toruń, Poland

We present new low-resolution ($R \sim 800$) optical spectra of 22 Galactic PNe with *Spitzer* spectra. These data are combined with recent optical spectroscopic data available in the literature to contstruct representative samples of compact (and presumably young) Galactic disc and bulge PNe with *Spitzer* spectra. Attending to the nature of the dust features – C-rich, O-rich and both C- and O-rich dust features (or double chemistry) – seen in their *Spitzer* spectra, Galactic disc and bulge PNe are classified according to four major dust types (oxygen chemistry or OC, carbon chemistry or CC, double chemistry or DC, featureless or F) and subtypes (amorphous and crystalline, and aliphatic and aromatic) and their Galactic distributions are presented. Nebular gas abundances of He, N, O, Ne, S, Cl and Ar, as well as plasma parameters (e.g., $N_e$, $T_e$) are homogeneously derived by using the classical empirical method. We study the median chemical abundances and nebular properties in Galactic disc and bulge PNe depending on their *Spitzer* dust types and subtypes. Differences/similarities between PNe in the Galactic disc and bulge are reported. In particular, the median abundances for the major *Spitzer* dust types CC and OC are representative of the dominant dust subtype (which are different in both Galactic environments) while these values in DC PNe are representative of the two DC subtypes. A comparison of the derived median abundance patterns with AGB nucleosynthesis predictions show mainly that: i) DC PNe, both with amorphous and crystalline silicates, display high-metallicity (solar/supra-solar) and the highest He abundances and N/O abundance ratios, suggesting relatively massive ($\sim$ 3–5 $M_\odot$) hot bottom burning AGB stars as progenitors; ii) PNe with O-rich and C-rich unevolved dust (amorphous and aliphatic) seem to evolve from sub-solar metallicity ($Z \sim 0.008$) and lower mass ($< 3$ $M_\odot$) AGB stars; iii) a few O-rich PNe and a significant fraction of C-rich PNe with more evolved dust (crystalline and aromatic, respectively) display chemical abundances similar to DC PNe, suggesting that they are related objects. A comparison of the derived nebular properties with predictions from models combining the theoretical central star evolution with a simple nebular model is also presented. Finally, a possible link between the *Spitzer* dust properties, chemical abundances and evolutionary status is discussed.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1404.5158
*and from* http://www.iac.es/preprints/files/PP14041.pdf

# Symbiotic stars in X-rays. II. Faint sources detected with XMM–*Newton* and *Chandra*

*N.E. Nuñez[1], G.J.M. Luna[2], I. Pillitteri[3] and K. Mukai[4,5]*

[1]Instituto de Ciencias Astronómicas de la Tierra y el Espacio (ICATE–UNSJ), Av. España (sur) 1512, San Juan, Argentina
[2]Instituto de Astronomía y Física del Espacio (IAFE), CC 67, Suc. 28 (C1428ZAA) CABA, Argentina
[3]Osservatorio Astronomico di Palermo (INAF), Piazza del Parlamento 1, 90 134 Palermo, Italy
[4]CRESST and X-ray Astrophysics Laboratory, NASA/GCFC, Greenbelt, MD 20 771, USA
[5]Department of Physics, University of Maryland, Baltimore County, 1 000 Hilltop Circle, Baltimore, MD 21 250, USA

We report the detection, with *Chandra* and XMM–*Newton*, of faint, soft X-ray emission from four symbiotics stars that were not known to be X-ray sources. These four object show a $\beta$-type X-ray spectrum, i.e. their spectra can be modeled with an absorbed optically thin thermal emission with temperatures of a few million degrees. Photometric series obtained with the Optical Monitor on board XMM–*Newton* from V2416 Sgr and NSV 25735 support the proposed scenario where the X-ray emission is produced in a shock-heated region inside the symbiotic nebulæ.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1402.6790

# The present and future of planetary nebula research. A White Paper by the IAU Planetary Nebula Working Group

*K.B. Kwitter[1], R.H. Méndez[2], M. Peña[3], L. Stanghellini[4], R.L.M. Corradi[5,6], O. De Marco[7], X. Fang[8,9], R.B.C. Henry[10], A.I. Karakas[11], X.-W. Liu[8,9], J.A. López[12], A. Manchado[5,6] and Q.A. Parker[7]*

[1]Department of Astronomy, Williams College, 33 Lab Campus Drive, Williamstown, MA 01267, USA
[2]Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[3]Instituto de Astronomía, Universidad Nacional Autónoma de México, 04510 México, D.F., México
[4]National Optical Astronomy Observatory, 950 N. Cherry Ave., Tucson, AZ 85719, USA
[5]Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain
[6]Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain
[7]Department of Physics & Astronomy, Macquarie University, Sydney, NSW 2109, Australia
[8]Department of Astronomy, School of Physics, Peking University, Beijing 100871, China
[9]Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing 100871, China
[10]H.L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA
[11]Research School of Astronomy & Astrophysics, Mt. Stromlo Observatory, Weston Creek ACT 2611, Australia
[12]Instituto de Astronomía, Universidad Nacional Autónoma de México, Campus Ensenada, Ensenada, B.C., México

We present a summary of current research on planetary nebulæ and their central stars, and related subjects such as atomic processes in ionized nebulæ, AGB and post-AGB evolution. Future advances are discussed that will be essential to substantial improvements in our knowledge in the field.

**Accepted for publication in RMxAA**
*Available from* arXiv:1403.2246

# Abundances of the high-latitude Herbig Ae star PDS 2

*C.R. Cowley[1], S. Hubrig[2] and N. Przybilla[3]*

[1]University of Michigan, USA
[2]AIP, Potsdam, Germany
[3]Institute for Astro- and Particle Physics, Innsbruck, Austria

The Herbig Ae star PDS 2 (CD −53°251) is unusual in several ways. It has a high Galactic latitude, unrelated to any known star-forming region. It is at the cool end of the Herbig Ae sequence, where favorable circumstances facilitate the

determination of stellar parameters and chemical abundances. We find $T_{\text{eff}} = 6500$ K, and $\log g = 3.5$. The relatively low $v \sin i = 12 \pm 2$ km s$^{-1}$ made it possible to use mostly weak lines for the abundances. PDS 2 appears to belong to the class of Herbig Ae stars with normal volatile and depleted involatile elements. This pattern is seen not only in $\lambda$ Boo stars, but in some post AGB and RV Tauri stars. The appearance of the same abundance pattern in young stars and highly evolved giants strengthens the hypothesis of gas-grain separation for its origin. The intermediate volatile zinc can violate the pattern of depleted volatiles.

**Published in MNRAS, 440, 2457 (2014)**
*Available from* arXiv:1403.0918

# On calibration of some distance scales in astrophysics

*B. Vukotić[1], M. Jurković[1], D. Urošević[2,3] and B. Arbutina[2]*

[1]Astronomical Observatory, Volgina 7, 11060, Belgrade 38, Serbia
[2]Department of Astronomy, Faculty of Mathematics, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia
[3]Isaac Newton Institute of Chile, Yugoslavia Branch

We present a method for distance calibration without using standard fitting procedures. Instead, we use random resampling to reconstruct the probability density function (PDF) of calibration data points in the fitting plane. The resulting PDF is then used to estimate distance-related properties. The method is applied to samples of radio surface brightness to diameter ($\Sigma$–$D$) data for the Galactic supernova remnants (SNRs) and planetary nebulæ (PNe), and period–luminosity (PL) data for the Large Magellanic Cloud (LMC) fundamental mode classical Cepheids. We argue that resulting density maps can provide more accurate and more reliable calibrations than those obtained by standard linear fitting procedures. For the selected sample of the Galactic SNRs, the presented PDF method of distance calibration results in a smaller average distance fractional error of up to $\approx 16$ percentage points. Similarly, the fractional error is smaller for up to $\approx 8$ and $\approx 0.5$ percentage points, for the samples of Galactic PNe and LMC Cepheids, respectively. In addition, we provide a PDF-based calibration data for each of the samples.

**Published in MNRAS, 440, 2026 (2014)**
*Available from* arXiv:1403.1368

# A phase dependent comparison of the velocity parameters of SiO $v = 1$, $J = 1$–0 and $J = 2$–1 maser emission in long period variables

*Balthasar Indermühle[1] and Gordon McIntosh[2]*

[1]CSIRO Astronomy and Space Science, P.O. Box 76, Epping 1710 NSW, Australia
[2]Division of Science and Mathematics, University of Minnesota, Morris, 600 East 4th Street, Morris, MN 56267, USA

We have examined the relationship between the velocity parameters of SiO masers and the phase of the long period variable stars (LPVs) from which the masers originate. The SiO spectra from the $v = 1$, $J = 1$–0 (43.122 GHz; hereafter $J_{1\rightarrow 0}$) and the $v = 1$, $J = 2$–1 (86.2434 GHz; hereafter $J_{2\rightarrow 1}$) transitions have been measured using the Mopra Telescope of the Australia Telescope National Facility. One hundred twenty one sources have been observed including 47 LPVs contained in the American Association of Variable Star Observer Bulletin (2011). The epoch of maxima and the periods of the LPVs are well studied. This database of spectra allows for phase dependent comparisons and analysis not previously possible with such a large number of sources observed almost simultaneously in the two transitions over a time span of several years. The velocity centroids ($VC$s) and velocity ranges of emission ($VR$s) have been determined and compared for the two transitions as a function of phase. No obvious phase dependence has been determined for the $VC$ or $VR$. The results of this analysis are compared with past observations and existing SiO maser theory.

**Accepted for publication in MNRAS**
*Available from* arXiv:1403.4697

# Dusty disks around central stars of planetary nebulæ

*G.C. Clayton*[1], *O. De Marco*[2,3], *J. Nordhaus*[4], *J. Green*[5], *T. Rauch*[6], *K. Werner*[6] *and Y.-H. Chu*[7]

[1]Department of Physics & Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA; gclayton@fenway.phys.lsu.edu
[2]Department of Physics & Astronomy, Macquarie University, Sydney, NSW 2109, Australia
[3]Astronomy, Astrophysics, and Astrophotonics Research Centre, Macquarie University, Sydney, NSW 2109, Australia
[4]NSF Fellow, Center for Computational Relativity and Gravitation, and National Technical Institute for the Deaf, Rochester Institute of Technology, Rochester, NY 14623, USA
[5]The University of Texas, Department of Astronomy, 1 University Station, C1400, Austin, TX 78712-0259, USA
[6]Institute for Astronomy & Astrophysics, Kepler Center for Astro and Particle Physics, Eberhard Karls University, Sand 1, 72076, Tübingen, Germany
[7]Department of Astronomy, University of Illinois at Urbana-Champaign, 1002 West Green Street, Urbana, IL 61801, USA

Only a few percent of cool, old white dwarfs (WDs) have infrared excesses interpreted as originating in small hot disks due to the infall and destruction of single asteroids that come within the star's Roche limit. Infrared excesses at 24 $\mu$m were also found to derive from the immediate vicinity of younger, hot WDs, most of which are still central stars of planetary nebulae (CSPN). The incidence of CSPN with this excess is 18%. The Helix CSPN, with a 24 $\mu$m excess, has been suggested to have a disk formed from collisions of Kuiper belt-like objects (KBOs). In this paper, we have analyzed an additional sample of CSPN to look for similar infrared excesses. These CSPN are all members of the PG 1159 class and were chosen because their immediate progenitors are known to often have dusty environments consistent with large dusty disks. We find that, overall, PG 1159 stars do not present such disks more often than other CSPN, although the statistics (5 objects) are poor. We then consider the entire sample of CSPN with infrared excesses, and compare it to the infrared properties of old WDs, as well as cooler post-AGB stars. We conclude with the suggestion that the infrared properties of CSPN more plausibly derive from AGB-formed disks rather than disks formed via the collision of KBOs, although the latter scenario cannot be ruled out. We finally remark that there seems to be an association between CSPN with a 24-$\mu$m excess and confirmed or possible binarity of the central star.

**Accepted for publication in AJ**
*Available from* arXiv:1403.5795

# Observations and three-dimensional photoionization modelling of the Wolf–Rayet planetary nebula Abell 48

*A. Danehkar*[1], *H. Todt*[2], *B. Ercolano*[3,4] *and A.Y. Kniazev*[5,6,7]

[1]Department of Physics and Astronomy, Macquarie University, Sydney, NSW 2109, Australia
[2]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Straße 24/25, D-14476 Potsdam, Germany
[3]Universitäts-Sternwarte München, Ludwig-Maxmilians Universität München, Scheinerstraße 1, D-81679 München, Germany
[4]Exzellenzcluster Universe, Technische Universität München, Boltzmannstraße 2, D-85748 Garching bei München, Germany
[5]South African Astronomical Observatory, P.O. Box 9, 7935 Observatory, Cape Town, South Africa
[6]Southern African Large Telescope Foundation, P.O. Box 9, 7935 Observatory, Cape Town, South Africa
[7]Sternberg Astronomical Institute, Lomonosov Moscow State University, 119992 Moscow, Russia

Recent observations reveal that the central star of the planetary nebula Abell 48 exhibits spectral features similar to massive nitrogen-sequence Wolf–Rayet stars. This raises a pertinent question, whether it is still a planetary nebula or rather a ring nebula of a massive star. In this study, we have constructed a three-dimensional photoionization model of Abell 48, constrained by our new optical integral field spectroscopy. An analysis of the spatially resolved velocity distributions allowed us to constrain the geometry of Abell 48. We used the collisionally excited lines to obtain the nebular physical conditions and ionic abundances of nitrogen, oxygen, neon, sulphur and argon, relative to hydrogen. We also determined helium temperatures and ionic abundances of helium and carbon from the optical recombination lines. We obtained a good fit to the observations for most of the emission-line fluxes in our photoionization model.

The ionic abundances deduced from our model are in decent agreement with those derived by the empirical analysis. However, we notice obvious discrepancies between helium temperatures derived from the model and the empirical analysis, as overestimated by our model. This could be due to the presence of a small fraction of cold metal-rich structures, which were not included in our model. It is found that the observed nebular line fluxes were best reproduced by using a hydrogen-deficient expanding model atmosphere as the ionizing source with an effective temperature of 70 kK and a stellar luminosity of 5500 $L_\odot$, which corresponds to a relatively low-mass progenitor star ($\sim 3\ M_\odot$) rather than a massive Pop I star.

**Published in Mon.Not.Roy.Astron.Soc.,439, 3605 (2014)**
*Available from* arXiv:1403.0567
*and from* http://dx.doi.org/10.1093/mnras/stu203

## Barium isotopic composition of mainstream silicon carbides from Murchison: Constraints for *s*-process nucleosynthesis in asymptotic giant branch stars

*Nan Liu*[1,2,3], *Michael R. Savina*[2,3], *Andrew M. Davis*[1,2,4], *Roberto Gallino*[5], *Oscar Straniero*[6], *Frank Gyngard*[7], *Michael J. Pellin*[1,2,3], *David G. Willingham*[3], *Nicolas Dauphas*[1,2,4], *Marco Pignatari*[8,9], *Sara Bisterzo*[5,10], *Sergio Cristallo*[6] *and Falk Herwig*[9,10]

[1]Department of the Geophysical Sciences, The University of Chicago, Chicago, IL 60637, USA

[2]Chicago Center for Cosmochemistry, Chicago, IL 60637, USA

[3]Materials Science Division, Argonne National Laboratory, Argonne, IL 60439, USA

[4]Enrico Fermi Institute, The University of Chicago, Chicago, IL, 60637, USA

[5]Dipartimento di Fisica, Università di Torino, I-10125 Torino, Italy

[6]INAF–Osservatorio Astronomico di Collurnia, via Maggini snc, I-64100 Teramo, Italy

[7]Laboratory for Space Sciences, Washington University, St. Louis, Mo 63130, USA

[8]Department of Physics, University of Basel, Basel CH-4056, Switzerland

[9]Department of Physics & Astronomy, University of Victoria, Victoria, BC V8P5C2, Canada

[10]INAF–Osservatorio Astrofisico di Torino, Strada Osservatorio 20, I-10025 Pino Torinese, Italy

We present barium, carbon, and silicon isotopic compositions of 38 acid-cleaned presolar SiC grains from Murchison. Comparison with previous data shows that acid washing is highly effective in removing barium contamination. Strong depletions in $\delta(^{138}Ba/^{136}Ba)$ values are found, down to $-400$‰, which can only be modeled with a flatter $^{13}C$ profile within the $^{13}C$ pocket than is normally used. The dependence of $\delta(^{138}Ba/^{136}Ba)$ predictions on the distribution of $^{13}C$ within the pocket in asymptotic giant branch (AGB) models allows us to probe the $^{13}C$ profile within the $^{13}C$ pocket and the pocket mass in AGB stars. In addition, we provide constraints on the $^{22}Ne(\alpha,n)^{25}Mg$ rate in the stellar temperature regime relevant to AGB stars, based on $\delta(^{134}Ba/^{136}Ba)$ values of mainstream grains. We found two nominally mainstream grains with strongly negative $\delta(^{134}Ba/^{136}Ba)$ values that cannot be explained by any of the current AGB model calculations. Instead, such negative values are consistent with the intermediate neutron capture process (*i* process), which is activated by the very late thermal pulse during the post-AGB phase and characterized by a neutron density much higher than the *s* process. These two grains may have condensed around post-AGB stars. Finally, we report abundances of two *p*-process isotopes, $^{130}Ba$ and $^{132}Ba$, in single SiC grains. These isotopes are destroyed in the *s* process in AGB stars. By comparing their abundances with respect to that of $^{135}Ba$, we conclude that there is no measurable decay of $^{135}Cs$ ($t_{1/2} = 2.3$ Ma) to $^{135}Ba$ in individual SiC grains, indicating condensation of barium, but not cesium into SiC grains before $^{135}Cs$ decayed.

**Published in The Astrophysical Journal**
*Available from* arXiv:1403.4336

# Near-IR studies of recurrent nova V745 Scorpii during its 2014 outburst

*D.P.K. Banerjee*[1], *Vishal Joshi*[1], *V. Venkataraman*[1], *N.M. Ashok* [1], *G.H. Marion*[2,3], *E.Y. Hsiao*[4] *and A. Raj*[1]

[1]Physical Research Laboratory, Navrangpura, Ahmedabad, Gujarat 380009, India

[2]University of Texas at Austin, 1 University Station C1400, Austin, TX, 78712-0259, USA

[3]Harvard–Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

[4]Carnegie Observatories, Las Campanas Observatory, Colina El Pino, Casilla 601, Chile

The recurrent nova (RN) V745 Scorpii underwent its third known outburst on 2014 January 6. Infrared monitoring of the eruption on an almost daily basis, starting from 1.3 days after discovery, shows the emergence of a powerful blast wave generated by the high velocity nova ejecta exceeding 4000 km $s^{-1}$ plowing into its surrounding environment. The temperature of the shocked gas is raised to a high value exceeding $10^8$ K immediately after outburst commencement. The energetics of the outburst clearly surpass those of similar symbiotic systems like RS Oph and V407 Cyg which have giant secondaries. The shock does not show a free-expansion stage but rather shows a decelerative Sedov–Taylor phase from the beginning. Such strong shockfronts are known to be sites for $\gamma$-ray generation. V745 Sco is the latest nova, apart from five other known novæ, to show $\gamma$-ray emission. It may be an important testbed to resolve the crucial question of whether or not all novæ are generically $\gamma$-ray emitters by virtue of having a circumbinary reservoir of material that is shocked by the ejecta rather than $\gamma$-ray generation being restricted to only symbiotic systems with a shocked red giant (RG) wind. The lack of a free-expansion stage favors V745 Sco to have a density enhancement around the white dwarf (WD), above that contributed by a RG wind. Our analysis also suggests that the WD in V745 Sco is very massive and a potential progenitor for a future SN Ia explosion.

**Published in The Astrophysical Journal, 785, L11 (2014)**
*Available from* arXiv:1403.0651

# Chemical abundance analysis of symbiotic giants. I. RW Hya and SY Mus

*J. Mikołajewska*[1], *C. Gałan*[1], *K.H. Hinkle*[2], *M. Gromadzki*[3] *and M.R. Schmidt*[4]

[1]N. Copernicus Astronomical Center, Bartycka 18, PL-00-716 Warsaw, Poland

[2]National Optical Astronomy Observatory, P.O. Box 26732, Tucson, AZ 85726, USA

[3]Departamento de Física y Astronomía, Universidad de Valparaíso, Av. Gran Bretaña 1111, Playa Ancha, Casilla 5030, Chile

[4]N. Copernicus Astronomical Center, Rabiańska 8, PL-87-100 Toruń, Poland

The study of symbiotic systems is of considerable importance in our understanding of binary system stellar evolution in systems where mass loss or transfer takes place. Elemental abundances are of special significance since they can be used to track mass exchange. However, there are few symbiotic giants for which the abundances are fairly well determined. Here, we present for the first time a detailed analysis of the chemical composition for the giants in the RW Hya and SY Mus systems. The analysis is based on high-resolution ($R \sim 50\,000$), high signal-to-noise (S/N), near-IR spectra. Spectrum synthesis employing standard local thermal equilibrium (LTE) analysis and atmosphere models was used to obtain photospheric abundances of CNO and elements around the iron peak (Sc, Ti, Fe, and Ni). Our analysis reveals a significantly sub-solar metallicity, [Fe/H] $\sim -0.75$, for the RW Hya giant confirming its membership in the Galactic Halo population and a near-solar metallicity for the SY Mus giant. The very low $^{12}C/^{13}C$ isotopic ratios, $\sim$ 6–10, derived for both objects indicate that the giants have experienced the first dredge-up.

**Published in MNRAS**
*Available from* arXiv:1403.2659
*and from* http://mnras.oxfordjournals.org/content/440/4/3016.full.pdf+html

# Strange pulsation modes in luminous red giants

*Peter R. Wood*[1] *and Enrico A. Olivier*[2]

[1]RSAA, Australian National University, Australia

[2]Physics Department, University of Western Cape, South Africa

We show that the spectrum of radial pulsation modes in luminous red giants consists of both normal modes and a second set of modes with periods similar to those of the normal modes. These additional modes are the red giant analogues of the strange modes found in classical Cepheids and RR Lyræ variables. Here, we describe the behaviour of strange and normal modes in luminous red giants and discuss the dependence of both the strange and normal modes on the outer boundary conditions. The strange modes always appear to be damped, much more so than the normal modes. They should never be observed as self-excited modes in real red giants, but they may be detected in the spectrum of solar-like oscillations. A strange mode with a period close to that of a normal mode can influence both the period and growth rate of the normal mode.

**Published in MNRAS, 440, 2576 (2014)**
*Available from* arXiv:1403.1607

# Dusty gas with one fluid

*Guillaume Laibe*[1,2] *and Daniel J. Price*[1]

[1]Monash Centre for Astrophysics and School of Mathematical Sciences, Monash University, Clayton, Vic 3800, Australia

[2]School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews, Fife KY16 9SS, UK

In this paper, we show how the two-fluid equations describing the evolution of a dust and gas mixture can be reformulated to describe a single fluid moving with the barycentric velocity of the mixture. This leads to evolution equations for the total density, momentum, the differential velocity between the dust and the gas phases and either the dust-to-gas ratio or the dust fraction. The equations are similar to the usual equations of gas dynamics, providing a convenient way to extend existing codes to simulate two-fluid mixtures without modifying the code architecture.
Our approach avoids the inherent difficulties related to the standard approach where the two phases are separate and coupled via a drag term. In particular, the requirements of infinite spatial and temporal resolution as the stopping time tends to zero are no longer necessary. This means that both small and large grains can be straightforwardly treated with the same method, with no need for complicated implicit schemes. Since there is only one resolution scale the method also avoids the problem of unphysical trapping of one fluid (e.g., dust) below the resolution of the other.
We also derive a simplified set of equations applicable to the case of strong drag/small grains, consisting of the standard fluid equations with a modified sound speed, plus an advection–diffusion equation for the dust-to-gas ratio.
This provides a simple and fast way to evolve the mixture when the stopping time is smaller than the Courant timestep.
We present a Smoothed Particle Hydrodynamics implementation in a companion paper.

**Published in MNRAS**
*Available from* arXiv:1402.5248

# Dusty gas with one fluid in smoothed particle hydrodynamics

*Guillaume Laibe*[1,2] *and Daniel J. Price*[1]

[1]Monash Centre for Astrophysics and School of Mathematical Sciences, Monash University, Clayton, Vic 3800, Australia

[2]School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews, Fife KY16 9SS, UK

In a companion paper we have shown how the equations describing gas and dust as two fluids coupled by a drag term can be re-formulated to describe the system as a single fluid mixture. Here we present a numerical implementation of the one-fluid dusty gas algorithm using Smoothed Particle Hydrodynamics (SPH).
The algorithm preserves the conservation properties of the SPH formalism. In particular, the total gas and dust mass, momentum, angular momentum and energy are all exactly conserved. Shock viscosity and conductivity terms are generalised to handle the two-phase mixture accordingly. The algorithm is benchmarked against a comprehensive suit of problems: DUSTYBOX, DUSTYWAVE, DUSTYSHOCK and DUSTYOSCILL, each of them addressing different properties of the method. We compare the performance of the one-fluid algorithm to the standard two-fluid approach.
The one-fluid algorithm is found to solve both of the fundamental limitations of the two-fluid algorithm: it is no longer possible to concentrate dust below the resolution of the gas (they have the same resolution by definition), and the spatial resolution criterion $h < c_s t_s$, required in two-fluid codes to avoid over-damping of kinetic energy, is unnecessary. Implicit time stepping is straightforward. As a result, the algorithm is up to ten billion times more efficient for 3D simulations of small grains. Additional benefits include the use of half as many particles, a single kernel and fewer SPH interpolations. The only limitation is that it does not capture multi-streaming of dust in the limit of zero coupling, suggesting that in this case a hybrid approach may be required.

**Published in MNRAS**
*Available from* arXiv:1402.5249

# Accelerated post-AGB evolution, initial–final mass relations, and the star-formation history of the Galactic Bulge

*K. Gesicki*[1], *A.A. Zijlstra*[2], *M. Hajduk*[1,3] *and C. Szyszka*[1,2]

[1]Centre for Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, PL-87-100 Toruń, Poland

[2]Jodrell Bank Centre for Astrophysics, School of Physics & Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

[3]Nicolaus Copernicus Astronomical Center, ul. Rabiańska 8, 87-100 Toruń, Poland

We study the star-formation history of the Galactic Bulge, as derived from the age distribution of the central stars of planetary nebulae that belong to this stellar population. The high resolution imaging and spectroscopic observations of 31 compact planetary nebulæ are used to derive their central star masses. The Blöcker tracks with the cluster IFMR result in ages, which are unexpectedly young. We find that the Blöcker post-AGB tracks need to be accelerated by a factor of three to fit the local white dwarf masses. This acceleration extends the age distribution. We adjust the IFMR as a free parameter to map the central star ages on the full age range of Bulge stellar populations. This fit requires a steeper IFMR than the cluster relation. We find a star-formation rate in the Galactic Bulge, which is approximately constant between 3 and 10 Gyr ago. The result indicates that planetary nebulæ are mainly associated with the younger and more metal-rich Bulge populations. The constant rate of star-formation between 3 and 10 Gyr agrees with suggestions that the metal-rich component of the Bulge is formed during an extended process, such as a bar interaction.

**Accepted for publication in A&A**
*Available from* arXiv:1404.6353

## The X-shooter Spectral Library (XSL). I. DR1: near-ultraviolet through optical spectra from the first year of the survey

*Yan-Ping Chen[1], S.C. Trager[1], R.F. Peletier[1], A. Lançon[2], A. Vazdekis[3,4], Ph. Prugniel[5], D.R. Silva[6] and A. Gonneau[2]*

[1]Kapteyn Astronomical Institute, University of Groningen, P.O. Box 800, 9700 AV Groningen, The Netherlands

[2]Observatoire Astronomique, 11, rue de l'Université, F-67000 Strasbourg, France

[3]Instituto de Astrofísica de Canarias (IAC), E-38200 La Laguna, Tenerife, Spain

[4]Departamento de Astrofísica, Universidad de La Laguna, E-38205, Tenerife, Spain

[5]Université de Lyon, Université Lyon 1, 69622 Villeurbanne, France; CRAL, Observatoire de Lyon, CNRS UMR 5574, 69561 Saint-Genis Laval, France

[6]National Optical Astronomy Observatory, 950 North Cherry Avenue, Tucson, AZ, 85719 USA

We present the first release of XSL, the X-shooter Spectral Library. This release contains 237 stars. The spectra in this release span a wavelength range of 3000–10200 Å and have been observed at a resolving power of $R \equiv \lambda/\Delta\lambda \sim 10\,000$. The spectra were obtained at ESO's 8-m Very Large Telescope (VLT). The sample contains O–M, long-period variable (LPV), C and S stars. The spectra are flux-calibrated and telluric-corrected. We describe a new technique for the telluric correction. The wavelength coverage, spectral resolution, and spectral type of this library make it well suited to stellar population synthesis of galaxies and clusters, kinematical investigation of stellar systems, and the study of the physics of cool stars.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1403.7009
*and from* http://xsl.u-strasbg.fr/

## Synthetic photometry for carbon-rich giants. IV. An extensive grid of dynamic atmosphere and wind models

*Kjell Eriksson[1], Walter Nowotny[2], Susanne Höfner[1], Bernhard Aringer[2] and Astrid Wachter[3]*

[1]Department of Physics and Astronomy, Division of Astronomy and Space Physics, Uppsala university, Uppsala, Sweden

[2]Department of Astrophysics, University of Vienna, Wien, Austria

[3]Departamento de Astronomía de la Universidad de Guanajuato, Guanajuato, GTO, México

*Context:* The evolution and spectral properties of stars on the asymptotic giant branch (AGB) are significantly affected by mass loss through dusty stellar winds. Dynamic atmosphere and wind models are an essential tool for studying these evolved stars, both individually and as members of stellar populations, to understand their contribution to the integrated light and chemical evolution of galaxies.
*Aims:* This paper is part of a series with the purpose of testing state-of-the-art atmosphere and wind models of C-type AGB stars against observations, and making them available to the community for use in various theoretical and observational studies.
*Methods:* We have computed low-resolution spectra and photometry (in the wavelength range 0.35–25 $\mu$m) for a grid of 540 dynamic models with stellar parameters typical of solar-metallicity C-rich AGB stars and with a range of pulsation amplitudes. The models cover the dynamic atmosphere and dusty outflow (if present), assuming spherical symmetry, and taking opacities of gas-phase species and dust grains consistently into account. To characterize the time-dependent dynamic and photometric behaviour of the models in a concise way we defined a number of classes for models with and without winds.
*Results:* Comparisons with observed data in general show a quite satisfactory agreement for example regarding mass-loss rates vs. J–K colours or K magnitudes vs. J–K colours. Some exceptions from the good overall agreement, however, are found and attributed to the range of input parameters (e.g., relatively high carbon excesses) or intrinsic model assumptions (e.g., small particle limit for grain opacities).
*Conclusions:* While current results indicate that some changes in model assumptions and parameter ranges should be made in the future to bring certain synthetic observables into better agreement with observations, it seems unlikely that these pending improvements will significantly affect the mass-loss rates of the models.

**Accepted for publication in Astronomy and Astrophysics**
*Available from* arXiv:1404.7515

# Atmospheric parameters and chemical properties of red giants in the CoRoT asteroseismology fields

*T. Morel*[1], *A. Miglio*[2,3], *N. Lagarde*[2,3], *J. Montalbán*[1], *M. Rainer*[4], *E. Poretti*[4], *P. Eggenberger*[5], *S. Hekker*[6,7], *T. Kallinger*[8,9], *B. Mosser*[10], *M. Valentini*[1,11], *F. Carrier*[8], *M. Hareter*[9] *and L. Mantegazza*[4]

[1]Institut d'Astrophysique et de Géophysique, Université de Liège, Allée du 6 Août, Bât. B5c, 4000 Liège, Belgium

[2]School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

[3]Stellar Astrophysics Centre (SAC), Department of Physics and Astronomy, Århus University, Ny Munkegade 120, DK-8000, Århus C, Denmark

[4]INAF – Osservatorio Astronomico di Brera, via E. Bianchi 46, 23807 Merate (LC), Italy

[5]Geneva Observatory, University of Geneva, Chemin des Maillettes 51, 1290, Versoix, Switzerland

[6]Astronomical Institute 'Anton Pannekoek', University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

[7]Max-Planck-Institut für Sonnensystemforschung, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany

[8]Katholieke Universiteit Leuven, Departement Natuurkunde en Sterrenkunde, Instituut voor Sterrenkunde, Celestijnenlaan 200D, B-3001 Leuven, Belgium

[9]Institute for Astrophysics, University of Vienna, Türkenschanzstraße 17, 1180 Vienna, Austria

[10]LESIA, CNRS, Université Pierre et Marie Curie, Université Denis Diderot, Observatoire de Paris, 92195 Meudon Cedex, France

[11]Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482, Potsdam, Germany

A precise characterisation of the red giants in the seismology fields of the CoRoT satellite is a prerequisite for further in-depth seismic modelling. High-resolution FEROS and HARPS spectra were obtained as part of the ground-based follow-up campaigns for 19 targets holding great asteroseismic potential. These data are used to accurately estimate their fundamental parameters and the abundances of 16 chemical species in a self-consistent manner. Some powerful probes of mixing are investigated (the Li and CNO abundances, as well as the carbon isotopic ratio in a few cases). The information provided by the spectroscopic and seismic data is combined to provide more accurate physical parameters and abundances. The stars in our sample follow the general abundance trends as a function of the metallicity observed in stars of the Galactic disk. After an allowance is made for the chemical evolution of the interstellar medium, the observational signature of internal mixing phenomena is revealed through the detection at the stellar surface of the products of the CN cycle. A contamination by NeNa-cycled material in the most massive stars is also discussed. With the asteroseismic constraints, these data will pave the way for a detailed theoretical investigation of the physical processes responsible for the transport of chemical elements in evolved, low- and intermediate-mass stars.

**Published in A&A, 564, A119 (2014)**
*Available from* arXiv:1403.4373
*and from* http://www.astro.ulg.ac.be/∼morel/articles/AA_564_A119.pdf

# Prospects for asteroseismic inference on the envelope helium abundance in red giant stars

*A.-M. Broomhall*[1,2,3], *A. Miglio*[3,4], *J. Montalbán*[5], *P. Eggenberger*[6], *W.J. Chaplin*[3,4], *Y. Elsworth*[3,4], *R. Scuflaire*[5], *P. Ventura*[7] *and G.A. Verner*[3]

[1]Institute of Advanced Studies, University of Warwick, Coventry, CV4 7HS, UK

[2]Centre for Fusion, Space, and Astrophysics, Department of Physics, University of Warwick, Coventry CV4 7AL, UK

[3]School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

[4]Stellar Astrophysics Centre (SAC), Department of Physics and Astronomy, Århus University, Ny Munkegade 120, DK-8000, Århus C, Denmark

[5]Institut d'Astrophysique et de Géophysique de l'Université de Liège, 17 allée du 6 Août, 4000 Liège, Belgium

[6]Observatoire de Genève, Université de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland

[7]Osservatorio Astronomico di Roma – INAF, via Frascati 33, I-00040 Monteporzio Catone, Rome, Italy

Regions of rapid variation in the internal structure of a star are often referred to as acoustic glitches since they create a characteristic periodic signature in the frequencies of p modes. Here we examine the localized disturbance arising

from the helium second ionization zone in red giant branch and clump stars. More specifically, we determine how accurately and precisely the parameters of the ionization zone can be obtained from the oscillation frequencies of stellar models. We use models produced by three different generation codes that not only cover a wide range of stages of evolution along the red giant phase but also incorporate different initial helium abundances. To study the acoustic glitch caused by the second ionization zone of helium we have determined the second differences in frequencies of modes with the same angular degree, $l$, and then we fit the periodic function described by Houdek & Gough to the second differences. We discuss the conditions under which such fits robustly and accurately determine the acoustic radius of the second ionization zone of helium. When the frequency of maximum amplitude of the p-mode oscillations was greater than 40 $\mu$Hz a robust value for the radius of the ionization zone was recovered for the majority of models. The determined radii of the ionization zones as inferred from the mode frequencies were found to be coincident with the local maximum in the first adiabatic exponent described by the models, which is associated with the outer edge of the second ionization zone of helium. Finally, we consider whether this method can be used to distinguish stars with different helium abundances. Although a definite trend in the amplitude of the signal is observed any distinction would be difficult unless the stars come from populations with vastly different helium abundances or the uncertainties associated with the fitted parameters can be reduced. However, application of our methodology could be useful for distinguishing between different populations of red giant stars in globular clusters, where distinct populations with very different helium abundances have been observed.

**Accepted for publication in MNRAS**
*Available from* arXiv:1403.7045

# The dust budget crisis in high-redshift submillimetre galaxies

*K. Rowlands[1,2], H.L. Gomez[3], L. Dunne[4], A. Aragón-Salamanca[2], S. Dye[2], S. Maddox[4], E. da Cunha[5] and P. van der Werf[6]*

[1]School of Physics & Astronomy, University of St. Andrews, North Haugh, St. Andrews, KY16 9SS, UK
[2]School of Physics & Astronomy, The University of Nottingham, University Park Campus, Nottingham, NG7 2RD, UK
[3]School of Physics & Astronomy, Cardiff University, Queens Buildings, The Parade, Cardiff, CF24 3AA, UK
[4]Department of Physics and Astronomy, University of Canterbury, Private Bag 4800, Christchurch, New Zealand
[5]Max Planck Institute for Astronomy, Königstuhl 17, 69117, Heidelberg, Germany
[6]Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands

We apply a chemical evolution model to investigate the sources and evolution of dust in a sample of 26 high-redshift ($z > 1$) submillimetre galaxies (SMGs) from the literature, with complete photometry from ultraviolet to the submillimetre. We show that dust produced only by low–intermediate mass stars falls a factor 240 short of the observed dust masses of SMGs, the well-known 'dust-budget crisis'. Adding an extra source of dust from supernovæ can account for the dust mass in 19 per cent of the SMG sample. Even after accounting for dust produced by supernovae the remaining deficit in the dust mass budget provides support for higher supernova yields, substantial grain growth in the interstellar medium or a top-heavy IMF. Including efficient destruction of dust by supernova shocks increases the tension between our model and observed SMG dust masses. The models which best reproduce the physical properties of SMGs have a rapid build-up of dust from both stellar and interstellar sources and minimal dust destruction. Alternatively, invoking a top-heavy IMF or significant changes in the dust grain properties can solve the dust budget crisis only if dust is produced by both low mass stars and supernovæ and is not efficiently destroyed by supernova shocks.

**Accepted for publication in MNRAS**
*Available from* arXiv:1403.2995

# An edge-on translucent dust disk around the nearest AGB star $L_2$ Puppis – VLT/NACO spectro-imaging from 1.04 to 4.05 $\mu$m and VLTI interferometry

*P. Kervella*[1], *M. Montargès*[1], *S. T. Ridgway*[2], *G. Perrin*[1], *O. Chesneau*[3], *S. Lacour*[1], *A. Chiavassa*[3], *X. Haubois*[1] *and A. Gallenne*[4]

[1]LESIA, Observatoire de Paris, France
[2]NOAO, Tucson, AZ, USA
[3]Observatoire de la Côte d'Azur, France
[4]Universidad de Concepción, Chile

As the nearest known AGB star ($d$ = 64 pc) and one of the brightest ($m_{\rm K} \sim -2$ mag), $L_2$ Pup is a particularly interesting benchmark object to monitor the final stages of stellar evolution. We report new lucky imaging observations of this star with the VLT/NACO adaptive optics system in twelve narrow band filters covering the 1.0–4.0 $\mu$m wavelength range. These diffraction limited images reveal an extended circumstellar dust lane in front of the star, that exhibits a high opacity in the J band and becomes translucent in the H and K bands. In the L band, extended thermal emission from the dust is detected. We reproduce these observations using Monte-Carlo radiative transfer modeling of a dust disk with the RADMC-3D code. We also present new interferometric observations with the VLTI/VINCI and MIDI instruments. We measure in the K band an upper limit to the limb-darkened angular diameter of $\theta_{\rm LD} = 17.9 \pm 1.6$ mas, converting to a maximum linear radius of $R = 123 \pm 14$ $R_\odot$. Considering the geometry of the extended K band emission in the NACO images, this upper limit is probably close to the actual angular diameter of the star. The position of $L_2$ Pup in the Herzsprung–Russell diagram indicates that this star has a mass around 2 $M_\odot$ and is probably experiencing an early stage of the asymptotic giant branch. We do not detect any stellar companion of $L_2$ Pup in our adaptive optics and interferometric observations, and we attribute its apparent astrometric wobble in the *Hipparcos* data to variable lighting effects on its circumstellar material. We however do not exclude the presence of a binary companion, as the large loop structure extending to more than 10 au to the North–East of the disk in our L band images may be the result of interaction between the stellar wind of $L_2$ Pup and a hidden secondary object. The geometric configuration that we propose, with a large dust disk seen almost edge-on, appears particularly favorable to test and develop our understanding of the formation of bipolar nebulæ.

**Published in Astronomy & Astrophysics, 564, A88 (2014)**
*Available from* arXiv:1404.3189
*and from* http://www.obspm.fr/the-future-of-the-sun.html?lang=en

# Planet transit and stellar granulation detection with interferometry

*A. Chiavassa*[1], *R. Ligi*[1], *Z. Magic*[2], *R. Collet*[3], *M. Asplund*[3] *and D. Mourard*[1]

[1]Laboratoire Lagrange, UMR 7293, CNRS, Observatoire de la Côte d'Azur, Université de Nice Sophia-Antipolis, Nice, France
[2]Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, 85741 Garching bei München, Germany
[3]Research School of Astronomy and Astrophysics, Australian National University, Cotter Road, Weston ACT 2611, Australia

*Context:* Stellar activity, and in particular convection-related surface structures, potentially cause bias in the planet detection and characterisation. In the latter, interferometry can help to disentangle the signal of the transiting planet.
*Aims:* We used realistic three-dimensional (3D) radiative hydrodynamical (RHD) simulations from the STAGGER-grid and synthetic images computed with the radiative transfer code OPTIM3D to provide interferometric observables to extract the signature of stellar granulation and transiting planets.
*Methods:* We computed intensity maps from RHD simulations and produced synthetic stellar disk images as a nearby observer would see accounting for the centre-to-limb variations. We did this for twelve interferometric instruments covering wavelengths ranging from optical to infrared. We chose an arbitrary date and arbitrary star with coordinates that ensures observability throughout the night. This optimization of observability allows for a broad coverage of spatial frequencies. The stellar surface asymmetries in the brightness distribution, either due to convection-related structures or a faint companion mostly affect closure phases. We then computed closure phases for all images and compared the system star with a transiting planet and the star alone. We considered the impact of magnetic spots constructing a hypothetical starspots image and compared the resulting closure phases with the system star with a transiting planet.

*Results:* We analyzed the impact of convection at different wavelengths. All the simulations show departure from the axisymmetric case (closure phases not equal to 0 or $\pm\pi$) at all wavelengths. The levels of asymmetry and inhomogeneity of stellar disk images reach high values with stronger effects from $3^{\rm rd}$ visibility lobe on. We presented two possible targets ($\beta$ Com and Procyon) either in the visible and in the infrared and found that departures up to 16° can be detected on the $3^{\rm rd}$ lobe and higher. In particular, MIRC is the most appropriate instrument because it combines good UV coverage and long baselines. Moreover, we explored the impact of convection on interferometric planet signature for three prototypes of planets with sizes corresponding to one hot Jupiter, one hot Neptune, and a terrestrial planet. The signature of the transiting planet on closure phase is mixed with the signal due to the convection-related surface structures, but it is possible to disentangle it at particular wavelengths (either in the infrared or in the optical) by comparing the closure phases of the star at difference phases of the planetary transit. It must be noted that starspots caused by the magnetic field may pollute the granulation and the transiting planet signals. However, it is possible to differentiate the transiting planet signal because the time-scale of a planet crossing the stellar disk is much smaller than the typical rotational modulation of a star.
*Conclusions:* The detection and characterisation of planets must be based on a comprehensive knowledge of the host star; this includes the detailed study of the stellar surface convection with interferometric techniques. In this context, RHD simulations are crucial to reach this aim. We emphasize that interferometric observations should be pushed at high spatial frequencies by accumulating observations on closure phases at short and long baselines.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1404.7049

## Upper limits to the magnetic field in central stars of planetary nebulæ

*A. Asensio Ramos[1,2], M.J. Martínez González[1,2], R. Manso Sainz[1,2], R.L.M. Corradi[1,2] and F. Leone[3]*

[1]Instituto de Astrofísica de Canarias, E-38205, La Laguna, Tenerife, Spain

[2]Departamento de Astrofísica, Universidad de La Laguna, E-38205, La Laguna, Tenerife, Spain

[3]Dipartimento di Fisica e Astronomia, Università di Catania, Sezione Astrofisica, Via S. Sofia 78, I-9512, Catania, Italy

More than about twenty central stars of planetary nebulæ (CSPN) have been observed spectropolarimetrically, yet no clear, unambiguous signal of the presence of a magnetic field in these objects has been found. We perform a statistical (Bayesian) analysis of all the available spectropolarimetric observations of CSPN to constrain the magnetic fields on these objects. Assuming that the stellar field is dipolar and that the dipole axis of the objects are oriented randomly (isotropically), we find that the dipole magnetic field strength is smaller than 400 G with 95% probability using all available observations. The analysis introduced allows integration of future observations to further constrain the parameters of the distribution, and it is general, so that it can be easily applied to other classes of magnetic objects. We propose several ways to improve the upper limits found here.

**Accepted for publication in The Astrophysical Journal**
*Available from* arXiv:1404.2718

## Spectral and timing nature of the symbiotic X-ray binary 4U 1954+319: The slowest rotating neutron star in an X-ray binary system

*Teruaki Enoto[1,2], Makoto Sasano[3], Shin'ya Yamada[2], Toru Tamagawa[2], Kazuo Makishima[2,3], Katja Pottschmidt[4,5], Diana Marcu[4,5], Robin H.D. Corbet[1,5], Felix Fuerst[6] and Jörn Wilms[7]*

[1]NASA Goddard Space Flight Center, Astrophysics Science Division, Code 662, Greenbelt, MD 20771, USA

[2]High Energy Astrophysics Laboratory, RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

[3]Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan

[4]NASA Goddard Space Flight Center, Astrophysics Science Division, Code 661, Greenbelt, MD 20771, USA

[5]CRESST & University of Maryland Baltimore County, Baltimore, MD 21250, USA

[6]Cahill Center for Astronomy and Astrophysics, California Institute of Technology, Pasadena, CA 91125, USA

[7]Dr. Remeis Sternwarte and Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Sternwartstraße 7, 96049 Bamberg, Germany

The symbiotic X-ray binary 4U 1954+319 is a rare system hosting a peculiar neutron star (NS) and an M-type optical

companion. Its $\sim$ 5.4-h NS spin period is the longest among all known accretion-powered pulsars and exhibited large ($\sim$ 7%) fluctuations over 8 years. A spin trend transition was detected with *Swift*/BAT around an X-ray brightening in 2012. The source was in quiescent and bright states before and after this outburst based on 60 ks *Suzaku* observations in 2011 and 2012. The observed continuum is well described by a Comptonized model with the addition of a narrow 6.4-keV Fe K$\alpha$ line during the outburst. Spectral similarities to slowly rotating pulsars in high-mass X-ray binaries, its high pulsed fraction ($\sim$ 60–80%), and the location in the Corbet diagram favor high B-field ($\gtrsim 10^{12}$ G) over a weak field as in low-mass X-ray binaries. The observed low X-ray luminosity ($10^{33}$–$10^{35}$ erg s$^{-1}$), probable wide orbit, and a slow stellar wind of this SyXB make quasi-spherical accretion in the subsonic settling regime a plausible model. Assuming a $\sim 10^{13}$-G NS, this scheme can explain the $\sim$ 5.4-h equilibrium rotation without employing the magnetar-like field ($\sim 10^{16}$ G) required in the disk accretion case. The time-scales of multiple irregular flares ($\sim$ 50 s) can also be attributed to the free-fall time from the Alfvén shell for a $\sim 10^{13}$-G field. A physical interpretation of SyXBs beyond the canonical binary classifications is discussed.

**Accepted for publication in The Astrophysical Journal**
*Available from* arXiv:1404.0134

## *Herschel* Planetary Nebula Survey (HerPlaNS): First detection of $OH^+$ in planetary nebulæ

*Isabel Aleman[1], T. Ueta[2,3], D. Ladjal[2], K.M. Exter[4], J.H. Kastner[5], R. Montez[6], A.G.G.M. Tielens[1], Y.-H. Chu[7], H. Izumiura[8], I. McDonald[9], R. Sahai[10], N. Siódmiak[11], R. Szczerba[11], P.A.M. van Hoof[12], E. Villaver[13], W. Vlemmings[14], M. Wittkowski[15] and A.A. Zijlstra[9]*

[1]Leiden Observatory, The Netherlands
[2]University of Denver, USA
[3]JAXA, Japan
[4]KU Leuven, Belgium
[5]Rochester Institute of Technology, USA
[6]Vanderbilt University, USA
[7]University of Illinois, USA
[8]National Astronomical Observatory of Japan, Japan
[9]The University of Manchester, UK
[10]JPL/Caltech, USA
[11]N. Copernicus Astronomical Center, Poland
[12]Royal Observatory of Belgium, Belgium
[13]Universidad Autónoma de Madrid, Spain
[14]Onsala Space Observatory, Sweden
[15]ESO, Germany

We report the first detections of $OH^+$ emission in planetary nebulæ (PNe). As part of an imaging and spectroscopy survey of 11 PNe in the far-IR using the PACS and SPIRE instruments aboard the *Herschel* Space Observatory, we performed a line survey in these PNe over the entire spectral range between 51 $\mu$m and 672 $\mu$m to look for new detections. The rotational emission lines of $OH^+$ at 152.99, 290.20, 308.48, and 329.77 $\mu$m were detected in the spectra of three planetary nebulæ: NGC 6445, NGC 6720, and NGC 6781. Excitation temperatures and column densities derived from these lines are in the range of 27–47 K and $2 \times 10^{10}$–$4 \times 10^{11}$ cm$^{-2}$, respectively. In PNe, the $OH^+$ rotational line emission appears to be produced in the photodissociation region (PDR) in these objects. The emission of $OH^+$ is observed only in PNe with hot central stars ($T_{\rm eff} > 100\,000$ K), suggesting that high-energy photons may play a role in the $OH^+$ formation and its line excitation in these objects, as seems to be the case for ultraluminous galaxies.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1404.2431

# *Herschel* spectral mapping of the Helix Nebula (NGC 7293): Extended CO photodissociation and $OH^+$ emission

*M. Etxaluze[1,2], J. Cernicharo[1,2], J.R. Goicoechea[1,2], P.A.M. van Hoof[3], B.M. Swinyard[4,5], M.J. Barlow[4], G.C. van de Steen[3], M.A.T. Groenewegen[3], F. Kerschbaum[6], T.L. Lim[5], F. Lique[7], M. Matsuura[4], C. Pearson[5,8], E.T. Polehampton[5,9], P. Royer[10] and T. Ueta[11,12]*

[1]Departamento de Astrofísica. Centro de Astrobiología. CSIC–INTA, Torrejón de Ardoz, 28850 Madrid, Spain

[2]Grupo de Astrofísica Molecular, Instituto de Ciencias de Materiales de Madrid, Cantoblanco, 28049 Madrid, Spain

[3]Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium

[4]Department of Physics & Astronomy, University College London, London WC1E 6BT, UK

[5]RAL Space, Rutherford Appleton Laboratory, Oxfordshire, OX11 0QX, UK

[6]University of Vienna, Department of Astrophysics, Türkenschanzstraße 17, 1180 Wien, Austria

[7]LOMC–UMR 6294, CNRS–Université du Havre, 25 rue Philippe Lebon, BP 540 76058 Le Havre France

[8]Department of Physics and Astronomy, The Open University, Milton Keynes, MK7 6AA, UK

[9]Institute for Space Imaging Science, Dept. of Physics & Astronomy, University of Lethbridge, Lethbridge, AB T1K3M4, Canada

[10]Institute of Astrophysics, K.U. Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium

[11]Department of Physics and Astronomy, University of Denver, 2112 E. Wesley Ave., Denver, CO 80210, USA

[12]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yosinodai, Chuo-ku, Sagamihara, Kanagawa, 252-5210, Japan

The Helix Nebula (NGC 7293) is our closest planetary nebula. Therefore, it is an ideal template for photochemical studies at small spatial scales in planetary nebulae. We aim to study the spatial distribution of the atomic and the molecular gas, and the structure of the photodissociation region along the western rims of the Helix Nebula as seen in the submillimeter range with *Herschel*. We used five SPIRE FTS pointing observations to make atomic and molecular spectral maps. We analyzed the molecular gas by modeling the CO rotational lines using a non-local thermodynamic equilibrium (non-LTE) radiative transfer model. For the first time, we have detected extended $OH^+$ emission in a planetary nebula. The spectra towards the Helix Nebula also show CO emission lines (from $J = 4$ to 8), [N II] at 1461 GHz from ionized gas, and [C I] ($^3P_2$–$^3P_1$), which together with the $OH^+$ lines trace extended CO photodissociation regions along the rims. The estimated $OH^+$ column density is $\sim 10^{12}$–$10^{13}$ cm$^{-2}$. The $CH^+$ (1–0) line was not detected at the sensitivity of our observations. Non-LTE models of the CO excitation were used to constrain the average gas density ($n(H_2) \sim (1\text{–}5) \times 10^5$ cm$^{-3}$) and the gas temperature ($T_k \sim 20$–40 K). The SPIRE spectral-maps suggest that CO arises from dense and shielded clumps in the western rims of the Helix Nebula, whereas $OH^+$ and [C I] lines trace the diffuse gas and the UV and X-ray illuminated clumps surfaces where molecules reform after CO photodissociation. The [N II] line traces a more diffuse ionized gas component in the interclump medium.

**Accepted for publication in Astronomy and Astrophysics**
*Available from* arXiv:1404.2177

# Dust production factories in the early Universe: Formation of carbon grains in red-supergiant winds of very massive Population III stars

*Takaya Nozawa[1,2], Sung-Chul Yoon[3], Keiichi Maeda[4,2], Takashi Kozasa[5], Ken'ichi Nomoto[2,7] and Norbert Langer[6]*

[1]National Astronomical Observatory of Japan, Japan

[2]Kavli IPMU, The University of Tokyo, Japan

[3]Seoul National University, South Korea

[4]Kyoto University, Japan

[5]Hokkaido University, Japan

[6]Argelander-Institut für Astronomie der Universität Bonn, Germany

[7]Hamamatsu Professor

We investigate the formation of dust in a stellar wind during the red-supergiant (RSG) phase of a very massive Population III star with the zero-age main sequence mass of 500 $M_\odot$. We show that, in a carbon-rich wind with a

constant velocity, carbon grains can form with a lognormal-like size distribution, and that all of the carbon available for dust formation finally condense into dust for wide ranges of the mass-loss rate ($(0.1–3) \times 10^{-3}$ $M_\odot$ $yr^{-1}$) and wind velocity (1–100 km $s^{-1}$). We also find that the acceleration of the wind driven by newly formed dust suppresses the grain growth but still allows more than half of gas-phase carbon to be finally locked up in dust grains. These results indicate that at most 1.7 $M_\odot$ of carbon grains can form in total during the RSG phase of 500 $M_\odot$ Population III stars. Such a high dust yield could place very massive primordial stars as important sources of dust at the very early epoch of the universe if the initial mass function of Population III stars was top-heavy. We also briefly discuss a new formation scenario of carbon-rich ultra-metal-poor stars considering the feedback from very massive Population III stars.

**Accepted for publication in The Astrophysical Journal Letters**
*Available from* arXiv:1404.5391

# VLTI/AMBER observations of cold giant stars: atmospheric structures and fundamental parameters

*B. Arroyo-Torres*[1], *I. Martí-Vidal*[2], *J.M. Marcaide*[1,3], *M. Wittkowski*[4], *J.C. Guirado*[1,5], *P.H. Hauschildt*[6], *A. Quirrenbach*[7] *and J. Fabregat*[5]

[1]Dpt. Astronomia i Astrofísica, Universitat de València, C/ Dr. Moliner 50, 46100, Burjassot (València), Spain
[2]Onsala Space Observatory, Chalmers University of Technology, Observatorievågen 90, 43992 Onsala, Sweden
[3]Donostia International Physics Center, Paseo de Manuel Lardizabal 4, 20018 Donostia-San Sebastián, Spain
[4]ESO, Karl-Schwarzschild-Straße 2, 85748, Garching bei München, Germany
[5]Observatori Astronòmic, Universitat de València, C/ Catedrático José Beltrán 2, 46980 Paterna (València), Spain
[6]Hamburger Sternwarte, Gojenbergsweg 112, 21029, Hamburg, Germany
[7]Landessternwarte, Zentrum für Astronomie der Universität Heidelberg, Königstuhl 12, 69117 Heidelberg, Germany

The main goal of this research is to determine the angular size and the atmospheric structures of cool giant stars ($\epsilon$ Oct, $\beta$ Peg, NU Pav, $\psi$ Peg, and $\gamma$ Hya) and to compare them with hydrostatic stellar model atmospheres, to estimate the fundamental parameters, and to obtain a better understanding of the circumstellar environment.
We conducted spectro-interferometric observations of $\epsilon$ Oct, $\beta$ Peg, NU Pav, and $\psi$ Peg in the near-infrared K band (2.13–2.47 $\mu$m), and $\gamma$ Hya (1.9–2.47 $\mu$m) with the VLTI/AMBER instrument at medium spectral resolution ($\sim$ 1500). To obtain the fundamental parameters, we compared our data with hydrostatic atmosphere models (PHOENIX).
We estimated the Rosseland angular diameters of $\epsilon$ Oct, $\beta$ Peg, NU Pav, $\psi$ Peg, and $\gamma$ Hya to be $11.66 \pm 1.50$ mas, $16.87 \pm 1.00$ mas, $13.03 \pm 1.75$ mas, $6.31 \pm 0.35$ mas, and $3.78 \pm 0.65$ mas, respectively. Together with distances and bolometric fluxes (obtained from the literature), we estimated radii, effective temperatures, and luminosities of our targets. In the $\beta$ Peg visibility, we observed a molecular layer of CO with a size similar to that modeled with PHOENIX. However, there is an additional slope in absorption starting around 2.3 $\mu$m. This slope is possibly due to a shell of $H_2O$ that is not modeled with PHOENIX (the size of the layer increases to about 5% with respect to the near-continuum level). The visibility of $\psi$ Peg shows a low increase in the CO bands, compatible with the modeling of the PHOENIX model. The visibility data of $\epsilon$ Oct, NU Pav, and $\gamma$ Hya show no increase in molecular bands.
The spectra and visibilities predicted by the PHOENIX atmospheres agree with the spectra and the visibilities observed in our stars (except for $\beta$ Peg). This indicates that the opacity of the molecular bands is adequately included in the model, and the atmospheres of our targets have an extension similar to the modeled atmospheres. The atmosphere of $\beta$ Peg is more extended than that predicted by the model. The role of pulsations, if relevant in other cases and unmodeled by PHOENIX, therefore seems negligible for the atmospheric structures of our sample. The targets are located close to the red limits of the evolutionary tracks of the STAREVOL model, corresponding to masses between 1 $M_\odot$ and 3 $M_\odot$. The STAREVOL model fits the position of our stars in the Hertzsprung–Russell (HR) diagram better than the Ekström model does. STAREVOL includes thermohaline mixing, unlike the Ekström model, and complements the latter for intermediate-mass stars.

**Accepted for publication in Astronomy & Astrophysics**
*Available from* arXiv:1404.7384

# *Review Papers*

## The status of spectroscopic data for the exoplanet characterisation missions

*J. Tennyson*[1] *and S.N. Yurchenko*[1]

[1]Department of Physics and Astronomy, University College London, London WC1E 6BT, UK

The status of laboratory spectroscopic data for exoplanet characterisation missions such as EChO is reviewed. For many molecules (e.g., $H_2O$, CO, $CO_2$, $H_3^+$, $O_2$, $O_3$) the data are already available. For the other species work is actively in progress constructing this data. Much of the is work is being undertaken by ExoMol project (www.exomol.com). This information can be used to construct a mission-specific spectroscopic database.

**Published in Experimental Astronomy**
*Available from* arXiv:1401.4212

## Challenges in nucleosynthesis of trans-iron elements

*T. Rauscher*[1,2]

[1]Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, University of Hertfordshire, UK
[2]Department of Physics, University of Basel, Switzerland

Nucleosynthesis beyond Fe poses additional challenges not encountered when studying astrophysical processes involving light nuclei. Astrophysical sites and conditions are not well known for some of the processes involved. On the nuclear physics side, different approaches are required, both in theory and experiment. The main differences and most important considerations are presented for a selection of nucleosynthesis processes and reactions, specifically the $s$-, $r$-, $\gamma$-, and $\nu p$-processes. Among the discussed issues are uncertainties in sites and production conditions, the difference between laboratory and stellar rates, reaction mechanisms, important transitions, thermal population of excited states, and uncertainty estimates for stellar rates. The utility and limitations of indirect experimental approaches are also addressed. The presentation should not be viewed as confining the discussed problems to the specific processes. The intention is to generally introduce the concepts and possible pitfalls along with some examples. Similar problems may apply to further astrophysical processes involving nuclei from the Fe region upward and/or at high plasma temperatures. The framework and strategies presented here are intended to aid the conception of future experimental and theoretical approaches.

**Published in AIP Advances 4 (2014) 041012**
*Available from* arXiv:1403.2015
*and from* http://dx.doi.org/10.1063/1.4868239

## *Job Advert*

# PhD-position in Leuven (Belgium): Post-AGB stars as tracers of stellar evolution

The late stages of evolution for low- to intermediate-mass single stars is a rapid transition from the Asymptotic Giant Branch (AGB) phase through the transient post-AGB phase and towards the Planetary Nebula Phase (PNe) before the stellar remnant cools down as a White Dwarf (WD). During the AGB phase, stars eject most of their initial mass and the enriched ejecta forms a major source of C, N, heavy elements and dust grains for their host galaxy. Although this evolution scheme is in every textbook on stellar evolution, there is little understanding from first principles of the different important physical processes that govern these evolutionary phases. More importantly, the evolution of any star, especially during the giant phases will be strongly affected if the star is in a binary system.

This PhD project is embedded into this large research theme of the IoA and will specifically focus on post-AGB stars in wide binary systems. It is fair to say that the current orbital characteristics of these systems are not understood and the whole sample is a challenge to binary evolution theory. The aim of this PhD project is to study in detail the circumstellar structure of post-AGB binaries and more specifically the structure and evolution of the dusty circumbinary discs which surround them. Our research shows that the discs must play a lead role in the evolution of the systems and the aim of this PhD project is to study the interplay between the disc and the central binary.

This project will involve detailed radiative transfer modelling with strong observational constraints coming from optical spectroscopy, high spatial resolution interferometric data (VLTI) and information on the gas dynamics obtained with ALMA. Thanks to our own HERMES spectrograph installed on the Flemish Mercator telescope, we obtained time series of high-resolution spectra which extends now over a period of five years. Apart from the obvious orbital motion, the spectra also trace circumstellar gas motions within the systems. This PhD project will exploit these unique data sets to study the ongoing interaction processes in these binaries.

In addition to the research task, you must also register and comply with the requirements of the Leuven Arenberg Doctoral School (ADS). This implies a teaching assistance task in physics of maximum 4 hours per week, as well as at least one observing run per year at the Mercator telescope at La Palma to contribute to the long-term monitoring programmes of IoA. Application to the vacancy implies an implicit commitment to these tasks.

The PhD supervisor is Professor Hans Van Winckel. Further inquiries about the PhD position can be addressed to Hans.VanWinckel@ster.kuleuven.be

*See also* https://icts.kuleuven.be/apps/jobsite/vacatures/52918297