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# THE AGB NEWSLETTER

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Editors: Jacco van Loon and Albert Zijlstra

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## *Editorial*

Dear Colleagues,

It is our pleasure to present you the 144<sup>th</sup> issue of the AGB Newsletter. A great number of papers dealt with post-AGB and symbiotic systems, and planetary nebulae were used to learn more about the nearby galaxies IC10 and NGC 6822 — the latter works also yielded interesting results about the planetary nebula progenitors. Don't miss the announcement of a new release of the POLLUX database of synthetic spectra.

A Big Hurray for Sofia Ramstedt, who defended her Ph.D. thesis on the circumstellar envelopes of S stars. Well done!

We received the following response to last month's Food for Thought (and note that several papers occurred recently on the topic of non-radial pulsation in red giants): *p-modes excited in the deep envelope can develop to large amplitudes on the surface. Noam Soker writes in the abstract of his paper "Excitation of pressure modes in common envelopes" (1992, ApJ, 386, 190): "A secondary of mass about 1 percent of the primary mass excites modes with relative surface amplitudes of a few  $\times$  10 percent. Even a Jupiter-like brown dwarf, when it is very deep in the envelope of an asymptotic giant branch star, can cause perturbations of relative surface amplitudes of about 10 percent near the equatorial plane" [See eq. 5.7 inside the paper]. Namely, non-radial p-waves excited by a companion (even a planet) deep in the envelope can be amplified on the surface, and influence mass loss rate. In a subsequent paper, Noam Soker (1993, ApJ, 417, 347) showed that the convection will not dump much these oscillations. The bottom line is that, YES, depending on the excitation mechanism, non-radial pulsation (p-waves, as g-waves do not expand in the convective envelope of AGB stars) can be very large on the surface (probably it is what you call tsunami).*

The next issue will be distributed on the 1<sup>st</sup> of August 2009; the deadline for contributions is the 31<sup>st</sup> of July.

Editorially Yours,

Jacco van Loon and Albert Zijlstra

## *Food for Thought*

This month's thought-provoking statement is:

*Which is the most massive white dwarf resulting from single-star evolution? (Both with and without a PN.)*

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

## Numerical Simulations of Wind Accretion in Symbiotic Binaries

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About half of the binary systems are close enough to each other for mass to be exchanged between them at some point in their evolution, yet the accretion mechanism in wind accreting binaries is not well understood. We study the dynamical effects of gravitational focusing by a binary companion on winds from late-type stars. In particular, we investigate the mass transfer and formation of accretion disks around the secondary in detached systems consisting of an asymptotic giant branch (AGB) mass-losing star and an accreting companion. The presence of mass outflows is studied as a function of mass loss rate, wind temperature and binary orbital parameters. A two-dimensional hydrodynamical model is used to study the stability of mass transfer in wind accreting symbiotic binary systems. In our simulations we use an adiabatic equation of state and a modified version of the isothermal approximation, where the temperature depends on the distance from the mass losing star and its companion. The code uses a block-structured adaptive mesh refinement method that allows us to have high resolution at the position of the secondary and resolve the formation of bow shocks and accretion disks. We explore the accretion flow between the components and formation of accretion disks for a range of orbital separations and wind parameters. Our results show the formation of stream flow between the stars and accretion disks of various sizes for certain orbital configurations. For a typical slow and massive wind from an AGB star the flow pattern is similar to a Roche lobe overflow with accretion rates of 10% of the mass loss from the primary. Stable disks with exponentially decreasing density profiles and masses of the order  $10^{-4} M_{\odot}$  are formed when wind acceleration occurs at several stellar radii. The disks are geometrically thin with eccentric streamlines and close to Keplerian velocity profiles. The formation of tidal streams and accretion disks is found to be weakly dependent on the mass loss from the AGB star. Our simulations of gravitationally focused wind accretion in symbiotic binaries show the formation of stream flows and enhanced accretion rates onto the compact component. We conclude that mass transfer through a focused wind is an important mechanism in wind accreting interacting binaries and can have a significant impact on the evolution of the binary itself and the individual components.

**Accepted for publication in ApJ**

*Available from* arXiv:0905.3542

## PopStar I: Evolutionary synthesis models description

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We present new evolutionary synthesis models for Simple Stellar Populations for a wide range of ages and metallicities. The models are based on the Padova isochrones. The core of the spectral library is provided by the medium resolution Lejeune et al. atmosphere models. These spectra are complemented by NLTE atmosphere models for hot stars that have an important impact in the stellar cluster's ionizing spectra: O, B and WR stellar spectra at the early ages, and spectra of post-AGB stars and planetary nebulae, at intermediate and old ages. At young ages, our models compare well with other existing models but we find that, the inclusion of the nebular continuum, not considered in several other models, reddens significantly the integrated colours of very young stellar populations. This is consistent with the results of spectral synthesis codes particularly devised for the study of starburst galaxies. At intermediate and old ages, the agreement with literature model is good and, in particular, we reproduce well the observed colours of star clusters in LMC. Given the ability to produce good integrated spectra from the far-UV to the infrared at any age, we

consider that our models are particularly suited for the study of high redshift galaxies. These models are available on the web site (<http://www.fractal-es.com/SEDmod.htm>) and also through the Virtual Observatory Tools on the PopStar server.

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*and from* <http://www.fractal-es.com>

## Gas phase mean opacities for varying $[M/H]$ , $N/O$ , and $C/O$

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We present a set of gas-phase Planck mean and Rosseland mean opacity tables applicable for simulations of star and planet formation, stellar evolution, disk modelling at various metallicities in hydrogen-rich environments. The tables are calculated for gas temperatures between 1000 K and 10000 K and total hydrogen number densities between  $10^2 \text{ cm}^{-3}$  and  $10^{17} \text{ cm}^{-3}$ . The carbon-to-oxygen ratio is varied from 0.43 to well above 2.0, the nitrogen-to-oxygen ratio between 0.14 and 100.0. The tables are calculated for a range of metallicities down to  $[M/H]' = \log N_M/N_H = -7.0$ . We demonstrate how the mean opacities and the abundances of the opacity species vary with  $C/O$ ,  $N/O$ , and  $[M/H]'$ . We use the element abundances from Grevesse, Asplund & Sauval (2007), and we provide additional tables for the oxygen-abundance value from Caffau et al. (2008). All tables will be available online under <http://star-www.st-and.ac.uk/~ch80/datasources.html>

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## IC 10: the history of the nearest starburst galaxy through its Planetary Nebula and H II region populations

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We report the results of spectroscopic observations, obtained with the Gemini North Multi-Object Spectrograph, of 9 planetary nebulae (PNe) and 15 H II regions located in the  $5.5' \times 5.5'$  inner region of the nearby starburst galaxy IC 10. Twelve new candidate PNe have been discovered during our pre-imaging phase. Nine of them have been spectroscopically confirmed. The direct availability of the electron temperature diagnostics in several nebulae allowed an accurate determination of the metallicity map of IC 10 at two epochs: the present-time from H II regions and the old/intermediate-age from PNe. We found a non-homogeneous distribution of metals at both epochs, but similar average abundances were found for the two populations. The derived age-metallicity relation shows a little global enrichment interpreted as the loss of metals by SN winds and to differential gas outflows. Finally, we analyzed the production of oxygen — through the third dredge-up — in the chemical abundance patterns of the PN populations belonging to several dwarf irregular galaxies. We found that the third dredge-up of oxygen is a metallicity dependent phenomenon occurring mainly for  $12 + \log(O/H) \leq 7.7$  and substantially absent in IC 10 PNe.

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# Circumstellar molecular line emission from S-type AGB stars: mass-loss rates and SiO abundances

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**Aims.** The main aim is to derive reliable mass-loss rates and circumstellar SiO abundances for a sample of 40 S-type AGB stars based on new multi-transitional CO and SiO radio line observations. In addition, the results are compared to previous results for M-type AGB stars and carbon stars to look for trends with chemical type. **Methods:** The circumstellar envelopes are assumed to be spherically symmetric and formed by a constant mass-loss rate. The mass-loss rates are estimated from fitting the CO observations using a non-local, non-LTE radiative transfer code based on the Monte Carlo method. In the excitation analysis, the energy balance equation is solved self-consistently simultaneously as the radiative transfer and the temperature structure of the gas is derived. Effects of dust grains are also included in the molecular excitation analysis. Once the physical properties of the circumstellar envelopes are determined, the same radiative transfer code is used to model the observed SiO lines in order to derive circumstellar abundances and the sizes of the SiO line-emitting regions. **Results:** We have estimated mass-loss rates of 40 S-type AGB stars and find that the derived mass-loss rates have a distribution that resembles those previously derived for similar samples of M-type AGB stars and carbon stars. The estimated mass-loss rates also correlate well with the corresponding expansion velocity of the envelope, in accordance with results for M-type AGB stars and carbon stars. In all, this indicates that the mass loss is driven by the same mechanism in all three chemical types of AGB stars. In addition, we have estimated the circumstellar fractional abundance of SiO relative to H<sub>2</sub> in 26 of the sample S-type AGB stars. The derived SiO abundances are, on average, about an order of magnitude higher than predicted by stellar atmosphere thermal equilibrium chemistry, indicating that non-equilibrium chemical processes determines the abundance of SiO in the circumstellar envelope. Moreover, a comparison with the results for M-type AGB stars and carbon stars show that for a certain mass-loss rate, the circumstellar SiO abundance seems independent (although with a large scatter) of the C/O-ratio. **Conclusions:** In our comparison of S-type AGB stars with carbon stars and M-type AGB stars, we find no large differences in circumstellar physical properties or SiO abundances depending on the chemical type of the star.

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## Morphological effects on IR band profiles: Experimental spectroscopic analysis with application to observed spectra of oxygen-rich AGB stars

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To trace the source of the unique 13, 19.5, and 28  $\mu\text{m}$  emission features in the spectra of oxygen-rich circumstellar shells around AGB stars, we have compared dust extinction spectra obtained by aerosol measurements. We have measured the extinction spectra for 19 oxide powder samples of eight different types, such as Ti-compounds (TiO, TiO<sub>2</sub>, Ti<sub>2</sub>O<sub>3</sub>, Ti<sub>3</sub>O<sub>5</sub>, Al<sub>2</sub>TiO<sub>5</sub>, CaTiO<sub>3</sub>),  $\alpha$ -,  $\gamma$ -,  $\chi$ - $\delta$ - $\kappa$ -Al<sub>2</sub>O<sub>3</sub>, and MgAl<sub>2</sub>O<sub>4</sub> in the infrared region (10–50  $\mu\text{m}$ ) paying special attention to the morphological (size, shape, and agglomeration) effects and the differences in crystal structure. Anatase (TiO<sub>2</sub>) particles with rounded edges are the possible 13, 19.5 and 28  $\mu\text{m}$  band carriers as the main contributor

in the spectra of AGB stars, and spherically shaped nano-sized spinel and  $\text{Al}_2\text{TiO}_5$  dust grains are possibly associated with the anatase, enhancing the prominence of the  $13\ \mu\text{m}$  feature and providing additional features at  $28\ \mu\text{m}$ . The extinction data sets obtained by the aerosol and CsI pellet measurements have been made available for public use at <http://elbe.astro.uni-jena.de>.

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## A "firework" of $\text{H}_2$ knots in the Planetary Nebula NGC 7293 (the Helix Nebula)

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We present a deep and wide field-of-view ( $4' \times 7'$ ) image of the planetary nebula (PN) NGC 7293 (the Helix Nebula) in the  $2.12\ \mu\text{m}$   $\text{H}_2\ v = 1-0\ \text{S}(1)$  line. The excellent seeing ( $0.4''$ ) at the Subaru Telescope, allows the details of cometary knots to be examined. The knots are found at distances of  $2.2'-6.4'$  from the central star (CS). At the inner edge and in the inner ring (up to  $4.5'$  from the CS), the knot often show a "tadpole" shape, an elliptical head with a bright crescent inside and a long tail opposite to the CS. In detail, there are variations in the tadpole shapes, such as narrowing tails, widening tails, meandering tails, or multi-peaks within a tail. In the outer ring ( $4.5'-6.4'$  from the CS), the shapes are more fractured, and the tails do not collimate into a single direction. The transition in knot morphology from the inner edge to the outer ring is clearly seen. The number density of knots governs the  $\text{H}_2$  surface brightness in the inner ring:  $\text{H}_2$  exists only within the knots. Possible mechanisms which contribute to the shaping of the knots are discussed, including photo-ionization and streaming motions. A plausible interpretation of our images is that inner knots are being overrun by a faster wind, but that this has not (yet) reached the outer knots. Based on  $\text{H}_2$  formation and destruction rates,  $\text{H}_2$  gas can survive in knots from formation during the late asymptotic giant branch (AGB) phase throughout the PN phase. These observations provide new constraints on the formation and evolution of knots, and on the physics of molecular gas embedded within ionized gas.

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*Available from arXiv:0906.2870*

*and from [http://zuserver2.star.ucl.ac.uk/~mikako/helix\\_figure.eps](http://zuserver2.star.ucl.ac.uk/~mikako/helix_figure.eps)*

*and [http://zuserver2.star.ucl.ac.uk/~mikako/helix\\_maintext.pdf](http://zuserver2.star.ucl.ac.uk/~mikako/helix_maintext.pdf)*

## Near-Infrared H and K band studies of the 2006 outburst of the recurrent nova RS Ophiuchi

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We present near-infrared photo-spectroscopy in the H and K bands of the 2006 outburst of the recurrent nova

RS Ophiuchi (RS Oph). The observations cover the period between 1 to 94 days after the eruption. The near infrared light curve is presented. An extensive set of spectra are presented, lines identified and the general characteristics of the spectra discussed. Analysis of the H I line profiles show the presence of broad wings on both flanks of a strong central component indicating the presence of a bipolar velocity flow in the ejecta. Such a flow is kinematically consistent with the bipolar structure that the object displays in high-resolution spatial images. We discuss the behaviour and origin of the Fe II lines at 1.6872 and 1.7414  $\mu\text{m}$  that are prominently seen throughout the span of the observations. It is examined and shown that Lyman- $\alpha$  and Lyman continuum fluorescence are viable mechanisms to excite these lines. We draw upon the result, that collisional excitation can also contribute in exciting and significantly enhancing the strength of these Fe II lines, to propose that these lines originate from a site of high particle density. Such a likely site could be the high-density, low temperature contact surface that should exist in the shockfront in between the shocked ejecta and red giant wind. Recombination analysis of the H I lines indicate deviations from Case B conditions during most of the span of our observations indicating optical depth effects. It appears likely that the breakout of the shockfront had not yet occurred till the end of our observations. An analysis is made of the temporal evolution of the [Si VI] 1.9641  $\mu\text{m}$  coronal line and another coronal line at 2.0894  $\mu\text{m}$  which is attributed to [Mn XIV]. Assuming collisional effects to dominate in the hot coronal gas, estimates are made of the ion temperature in the gas.

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## On the possible existence of short-period $g$ -mode instabilities powered by nuclear burning shells in post-AGB H-deficient (PG 1159-type) stars

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We present a pulsational stability analysis of hot post-AGB H-deficient pre-white dwarf stars with active He-burning shells. The stellar models employed are state-of-the-art equilibrium structures representative of PG 1159 stars derived from the complete evolution of the progenitor stars, through the thermally pulsing AGB phase and born-again episode. On the basis of fully nonadiabatic pulsation computations, we confirmed theoretical evidence for the existence of a separate PG 1159 instability strip in the  $\log T_{\text{eff}} - \log g$  diagram characterized by short-period  $g$ -modes excited by the  $\epsilon$ -mechanism. This instability strip partially overlaps the already known GW Vir instability strip of intermediate/long period  $g$ -modes destabilized by the classical  $\kappa$ -mechanism acting on the partial ionization of C and/or O in the envelope of PG 1159 stars. We found that PG 1159 stars characterized by thick He-rich envelopes and located inside this overlapping region could exhibit both short and intermediate/long periods simultaneously. As a natural application of our results, we study the particular case of VV 47, a pulsating planetary nebula nucleus (PG 1159-type) particularly interesting because it has been reported to exhibit a rich and complex pulsation spectrum including a series of unusually short pulsation periods. We found that the long periods exhibited by VV 47 can be readily explained by the classical  $\kappa$ -mechanism, while the observed short-period branch below  $\approx 300$  s could correspond to modes triggered by the He-burning shell through the  $\epsilon$ -mechanism, although more observational work is needed to confirm the reality of these short-period modes. Were the existence of short-period  $g$ -modes in this star convincingly confirmed by future observations, VV 47 could be the first known pulsating star in which both the  $\kappa$ -mechanism and the  $\epsilon$ -mechanism of mode driving are *simultaneously* operating.

**Accepted for publication in The Astrophysical Journal**

*Available from arXiv:0906.2387*

# Light-curves of symbiotic stars in massive photometric surveys I: D-type systems

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ASAS, MACHO, OGLE and SAAO *JHKL* light curves of 13 stars, that have at some time been classified as D-type symbiotics, are analysed. Most of the near-IR light-curves that have been monitored over many years show long-term changes due to variable dust obscuration, in addition to the stellar pulsation. The distances to these objects are derived from the period-luminosity relation and estimates of the mass-loss rates made from the  $K_0 - [12]$  colour. We reclassify AS 245 as an S-type symbiotic, with a semi-regular cool component with a pulsation period of about one year. The periods of the large amplitude pulsations of SS 73 38 (463 days), AS 210 (423 days) and H 2-38 (395 days) are estimated for the first time, confirming that they are symbiotic Miras. A comparison of the symbiotic Miras with normal Miras of similar pulsation period shows that the symbiotic stars have on average higher values of  $K_0 - [12]$ . This may indicate that they have higher mass-loss rates, or more likely that the dust which is being lost by the Mira is trapped within the binary system.

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# Low-ionization pairs of knots in planetary nebulae: physical properties and excitation

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We obtained optical long-slit spectra of four planetary nebulae (PNe) with low-ionization pair of knots, namely He 1-1, IC 2149, KJpN 8 and NGC 7662. These data allow us to derive the physical parameters and excitation of the pairs of knots, and those of higher ionization inner components of the nebulae, separately. Our results are as follows. 1) The electron temperatures of the knots are within the range 9500 to 14500 K, similar to the temperatures of the higher ionization rims/shells. 2) Typical knots' densities are 500 to 2000  $\text{cm}^{-3}$ . 3) Empirical densities of the inner rims/shells are higher than those of the pairs of knots, by up to a factor of 10. Theoretical predictions, at variance with the empirical results, suggest that knots should be denser than the inner regions, by at least a factor of 10. 4) Empirical and theoretical density contrasts can be reconciled if we assume that at least 90% of the knots' gas is neutral (likely composed of dust and molecules). 5) By using Raga et al. (2008) shock modeling and diagnostic diagrams appropriated for spatially resolved PNe, we suggest that high-velocity shocked knots traveling in the photoionized outer regions of PNe can explain the emission of the pairs of knots analysed in this paper.

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*Available from arXiv:0906.4134*

# Sculpting an AGB Mass-Loss Envelope into a Bipolar Planetary Nebula: High-Velocity Outflows in V Hydrae

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We have carried out high-resolution spectroscopic observations of the carbon star V Hya, covering the 4.6- $\mu$ m band of CO. These data, taken over 7 epochs, show that the circumstellar environment of V Hya consists of a complex high-velocity (HV) outflow containing at least six kinematic components with expansion velocities ranging between 70 and 120 km s<sup>-1</sup>, together with a slow-moving normal outflow at about 10 km s<sup>-1</sup>. Physical changes occur in the HV outflow regions on a time-scale as short as two days, limiting their extent to be  $\lesssim 10^{16}$  cm. The intrinsic line-width for each HV component is quite large (6–8 km s<sup>-1</sup>) compared to the typical values ( $\sim 1$  km s<sup>-1</sup>) appropriate for normal AGB circumstellar envelopes (CSEs), due to excess turbulence and/or large velocity gradients resulting from the energetic interaction of the HV outflow with the V Hya CSE. We have modelled the absorption features to set constraints on the temperature distribution in, and the mass ejection-rates for gas in the main HV components.

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*Available from arXiv:0905.0460*

## Post-AGB stars with hot circumstellar dust: binarity of the low-amplitude pulsators

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While the first binary post-AGB stars were serendipitously discovered, the distinct characteristics of their Spectral Energy Distribution (SED) allowed us to launch a more systematic search for binaries. We selected post-AGB objects which show a broad dust excess often starting already at H or K, pointing to the presence of a gravitationally bound dusty disc in the system. We started a very extensive multi-wavelength study of those systems and here we report on our radial velocity and photometric monitoring results for six stars of early F type, which are pulsators of small amplitude. To determine the radial velocity of low signal-to-noise time-series, we constructed dedicated auto-correlation masks. The radial velocity variations were subjected to detailed analysis to differentiate between pulsational variability and variability due to orbital motion. Finally orbital minimalisation was performed to constrain the orbital elements. All of the six objects are binaries, with orbital periods ranging from 120 to 1800 days. Five systems have non-circular orbits. The mass functions range from 0.004 to 0.57 M<sub>⊙</sub> and the companions are likely unevolved objects of (very) low initial mass. We argue that these binaries must have been subject to severe binary interaction when the primary was a cool supergiant. Although the origin of the circumstellar disc is not well understood, the disc is generally believed to be formed during this strong interaction phase. The eccentric orbits of these highly evolved objects remain poorly understood. With the measured orbits and mass functions we conclude that the circumbinary discs seem to have a major impact on the evolution of a significant fraction of binary systems.

**Accepted for publication in Astronomy and Astrophysics**

*Available from arXiv:0906.4482*

# Analysis of the infrared spectra of the peculiar post-AGB stars EP Lyr and HD 52961

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**Aim:** We aim to study in detail the peculiar mineralogy and structure of the circumstellar environment of two binary post-AGB stars, EP Lyr and HD 52961. Both stars were selected from a larger sample of evolved disc sources observed with Spitzer and show unique solid-state and gas features in their infrared spectra. Moreover, they show a very small infrared excess in comparison with the other sample stars. **Methods:** The different dust and gas species are identified on the basis of high-resolution Spitzer-IRS spectra. We fit the full spectrum to constrain grain sizes and temperature distributions in the discs. This, combined with our broad-band spectral energy distribution and interferometric measurements, allows us to study the physical structure of the disc, using a self-consistent 2D radiative-transfer disc model. **Results:** We find that both stars have strong emission features due to CO<sub>2</sub> gas, dominated by <sup>12</sup>C<sup>16</sup>O<sub>2</sub>, but with clear <sup>13</sup>C<sup>16</sup>O<sub>2</sub> and even <sup>16</sup>O<sup>12</sup>C<sup>18</sup>O isotopic signatures. Crystalline silicates are apparent in both sources but proved very hard to model. EP Lyr also shows evidence of mixed chemistry, with emission features of the rare class-C PAHs. Whether these PAHs reside in the oxygen-rich disc or in a carbon-rich outflow is still unclear. With the strongly processed silicates, the mixed chemistry and the low <sup>12</sup>C/<sup>13</sup>C ratio, EP Lyr resembles some silicate J-type stars, although the depleted photosphere makes nucleosynthetic signatures difficult to probe. We find that the disc environment of both sources is, to a first approximation, well modelled with a passive disc, but additional physics such as grain settling, radial dust distributions, and an outflow component must be included to explain the details of the observed spectral energy distributions in both stars.

**Accepted for publication in A&A**

*Available from arXiv:0906.4718*

# High Resolution Optical Spectroscopy of a Newly Discovered Post-AGB Star in the Globular Cluster M 79

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An abundance analysis based on a high-resolution spectrum is presented for a newly discovered post-AGB star in the globular cluster M 79. The surprising result is that the iron abundance of the star is apparently about 0.6 dex less than that of the cluster's red giants as reported by published studies including a recent high-resolution spectroscopic analysis by Carretta and colleagues. Abundances relative to iron appear to be the same for the post-AGB star and the red giants for the 15 common elements. It is suggested that the explanation for the lower abundances of the post-AGB star may be that its atmospheric structure differs from that of a classical atmosphere; the temperature gradient may be flatter than predicted by a classical atmosphere.

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# Comparing Symbiotic Nebulae and Planetary Nebulae Luminosity Functions

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We compare the observed symbiotic nebulae (SyN) luminosity function (SyNLF) in the [O III] 5007 Å line to the planetary nebulae (PN) luminosity function (PNLF) and find that the intrinsic SyNLF (ISyNLF) of galactic SyNs has very similar cutoff luminosity and general shape to those of the PNLF. The [O III]/(H $\alpha$ + [N II]) line ratios of SyNs and PNs are shown to be also related. Possible implications of these results for the universality of the PNLF are briefly outlined.

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# Oxygen And Light Element Synthesis by Neutron-Capture Reactions in Metal-Free And Extremely Metal-Poor AGB Stars

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The metal-free (Pop. III) and extremely metal-poor (EMP) stars of low- and intermediate-masses experience mixing of hydrogen into the helium convection during the early TP-AGB phase, differently from the metal-rich stars. We study the nucleosynthesis in the helium convective zone with <sup>13</sup>C formed from mixed protons as neutron source by using a nuclear network from H through S. In the absence or scarcity of the pristine metals, the neutron-recycling reactions, <sup>12</sup>C(n, $\gamma$ )<sup>13</sup>C( $\alpha$ ,n)<sup>16</sup>O and also <sup>16</sup>O(n, $\gamma$ )<sup>17</sup>O( $\alpha$ ,n)<sup>20</sup>Ne promote the synthesis of O and light elements, including their neutron-rich isotopes and the odd atomic number elements. Based on the results, we demonstrate that the peculiar abundance patterns of C through Al observed for the three most iron-deficient, carbon-rich stars can be reproduced in terms of the nucleosynthesis in Pop. III, AGB stars in the different mass range. We argue that these three stars were born as the low-mass members of Pop. III binaries and later subject to the surface pollution by the mass transfer in the binary systems. It is also shown that the AGB nucleosynthesis with hydrogen mixing explains the abundances of C, O, Na, Mg and Al observed for most of carbon-enhanced EMP (CEMP) stars, including all CEMP-s stars with s-process elements. In addition the present 1 results are used to single out other nucleosynthetic signatures of early generations of stars.

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# Chemical behavior of the Dwarf Irregular NGC 6822. Its PN and H II region abundances.

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We derive the chemical behavior of a significant sample of PNe and H II regions in the irregular galaxy NGC 6822. The selected objects are distributed in different zones of the galaxy. Our purpose is to obtain the chemical abundances of

the present interstellar medium (represented by H II regions) and the corresponding values at the time of formation of PNe. With these data the chemical homogeneity of NGC 6822 is tested and the abundance pattern given by H II regions and PNe is used as an observational constrain for computing chemical evolution models to infer the chemical history of NGC 6822.

We obtained a well suited sample of spectra by employing VLT-FORS2 and Gemini-GMOS spectrographs. Ionic and total abundances are calculated for 11 PNe and 1 H II region where electron temperatures can be determined through the detection of [O III]4363 or/and [N II]5755 lines. Determinations of He, O, N, Ne, S and Ar abundances were obtained. A "simple" chemical evolution model has been developed and the observed data are used to compute a model for NGC 6822 in order to infer a preliminary chemical history in this galaxy.

Our results are: We confirm that the present ISM is chemically homogeneous, at least in the central 2 kpc of the galaxy, showing a value  $12 + \log O/H = 8.06 \pm 0.04$ . From the abundance pattern of PNe, we identified two populations: a group of young PNe with abundances similar to H II regions and a group of older objects with abundances a factor of two lower. A couple of extreme Type I PNe were found. No third dredge-up O enrichment was detected in PNe of this galaxy. The abundance determinations allow us to discuss the chemical behavior of the present and past ISM in NGC 6822. Our preliminary chemical evolution model predicts that an important gas-mass lost occurred during the first 5.3 Gyr, that no star higher than  $40 M_{\odot}$  was formed, and that 1% of all 3–15  $M_{\odot}$  stars became binary systems progenitors to SN Ia.

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## Water maser detections in southern candidates to post-AGB stars and Planetary Nebulae

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We intended to study the incidence and characteristics of water masers in the envelopes of stars in the post-AGB and PN evolutionary stages. We have used the 64-m antenna in Parkes (Australia) to search for water maser emission at 22 GHz, towards a sample of 74 sources with IRAS colours characteristic of post-AGB stars and PNe, at declination  $< -32^{\circ}$ . In our sample, 39% of the sources are PNe or PNe candidates, and 50% are post-AGB stars or post-AGB candidates. We have detected four new water masers, all of them in optically obscured sources: three in PNe candidates (IRAS 12405–6219, IRAS 15103–5754, and IRAS 16333–4807); and one in a post-AGB star (IRAS 13500–6106). The PN candidate IRAS 15103–5754 has water fountain characteristics, and it could be the first PN of this class found. We confirm the tendency suggested in Paper I that the presence of water masers in the post-AGB phase is favoured in obscured sources with massive envelopes. We propose an evolutionary scenario for water masers in the post-AGB and PNe stages, in which "water fountain" masers could develop during post-AGB and early PN stages. Later PNe would show lower velocity maser emission, both along jets and close to the central objects, with only the central masers remaining in more evolved PNe.

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## Analysis of the spectral energy distribution of the coolest R CrB type carbon star DY Per

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We analyse the spectral energy distribution of the evolved carbon giant DY Per with a spectral synthesis technique. The red giant shows the photometric features of R CrB type stars. We derive the atmospheric parameters of DY Per using three variants of molecular line lists. We estimate  $T_{\text{eff}}$  to be in the range  $2900 < T_{\text{eff}} < 3300$  K. We adopted  $\log g = 0$ . The star may be metal deficient and hydrogen deficient. The maximum possible carbon abundance in the star,  $[C] = 0.94$ , provides the following atmospheric parameters:  $T_{\text{eff}} = 3100$  K,  $[Fe/H] = 0$ ,  $\log(C/O) = 0.6$ ,  $[N/Fe] = 0$ ,  $[H/He] = 0$ , with Jørgensen's line lists for the molecules  $C_2$  and CN.

**Oral contribution, published in Publication of Odessa Astronomical Observatory**

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## IR imaging surveys of AGB stars in the Magellanic Clouds

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AGB stars are ideal IR targets because they are cool and bright. Most of them escaped detection in optical or shallow IR surveys in the eighties contributing to the puzzling missing number of AGB stars with respect to theoretical predictions and former stages of evolution. Observations and AGB models have advanced steadily in the following decades providing us with an almost complete view of the AGB stars in the Magellanic Clouds. Their properties are tracers of structure and chemistry across galaxies. New surveys will be able to fill-in the gaps, in terms of sensitivity and monitoring, providing new constraints for the formation and evolution of the Magellanic Clouds.

**Oral contribution, published in "An astronomical Observatory at Concordia (Dome C, Antarctica) for the next decade", 11–15 May, Rome (Italy)**

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## Understanding Mass-Loss and the Late Evolution of Intermediate Mass Stars: Jets, Disks, Binarity, Dust, and Magnetic Fields

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Almost all stars in the  $1\text{--}8 M_{\odot}$  range evolve through the Asymptotic Giant Branch (AGB), preplanetary nebula (PPN)

and planetary nebula (PN) evolutionary phases. Most stars that leave the main sequence in a Hubble time will end their lives in this way. The heavy mass loss which occurs during the AGB phase is important across astrophysics, and the particulate matter crucial for the birth of new solar systems is made and ejected by AGB stars. Yet stellar evolution from the beginning of the AGB phase to the PN phase remains poorly understood. We do not understand how the mass-loss (rate, geometry, temporal history) depends on fundamental stellar parameters or the presence of a binary companion. While the study of evolved non-massive stars has maintained a relatively modest profile in recent decades, we are nonetheless in the midst of a quiet but exciting revolution in this area, driven by new observational results, such as the discovery of jets and disks in stellar environments where these were never expected, and by the recognition of new symmetries such as multipolarity and point-symmetry occurring frequently in the nebulae resulting from the outflows. In this paper we summarise the major unsolved problems in this field, and specify the areas where allocation of effort and resources is most likely to help make significant progress.

**Published as a White Paper, National Academy of Sciences Astro2010 Decadal Survey Committee**  
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## *Thesis*

# **Molecules and dust around AGB stars Mass-loss rates and molecular abundances**

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All stars with a stellar mass of about 0.8–8  $M_{\odot}$  will end their lives as asymptotic giant branch (AGB) stars. Through their extensive mass loss the AGB stars constitutes an important source of nuclear processed material. They also provide us with fascinating systems where an interchange of different physical and chemical processes occur, making them excellent astrophysical laboratories. Being the most important process for the evolution of an AGB star, the mass loss is well established, but its details are less well known. On the AGB, the mass-loss rate can span several orders of magnitude, reaching  $10^{-4} M_{\odot} \text{ yr}^{-1}$  toward the end of the AGB. It is challenging to find reliable methods to estimate the mass-loss rates of individual objects. Nevertheless, it is important, since the mass-loss rate affects the derived abundances of other molecules in the circumstellar envelope, and therefore the estimates of the amount and composition of the recycled material. In the first part of the thesis the reliability of mass-loss rate estimates is evaluated using two main methods; the observations and radiative transfer analysis of CO radio line emission, and dust radiative transfer combined with a dynamical model. The second part of the thesis focuses on a particular chemical type of AGB stars; the S-type. The S-stars are believed to have approximately the same amount of carbon as oxygen in the photosphere, and to be an intermediate evolutionary stage as the star evolves from an oxygen-rich M-star into a carbon star. As possible transition objects the S-stars might give important clues to the mass-loss mechanisms and to the chemical evolution along the AGB. Using observations of circumstellar radio line emission in combination with detailed radiative transfer analysis, we have estimated mass-loss rates and abundances of chemically important molecules for a sample of 40 S-stars. The results are compared to previous results for M- and carbon stars.

**Defended on the 4<sup>th</sup> of June, 2009, at Stockholm University, Sweden.**

## *Announcement*

### **Third release of the POLLUX database within the Virtual Observatory**

The third release of the POLLUX database for high resolution synthetic spectra and spectral energy distributions is available through this webpage:

<http://pollux.graal.univ-montp2.fr>

and through some services of the Virtual observatory such as VOSpec or Aladin.

This release contains new data based on stellar atmosphere models from CMFGEN (O to B spectral types), ATLAS12 (A and F spectral types) and MARCS (G to M spectral types). Both high resolution synthetic spectra and spectral energy distributions may be retrieved in various formats, including VOTable and FITS compatible with the standards of the virtual observatory.

The query via the above quoted webpage also allows simultaneous plotting of up to three spectra (raw or normalised to the continuum).

We invite you to visit this database and to send us your remarks/suggestions.

With best regards

The POLLUX team

*See also* <http://pollux.graal.univ-montp2.fr>