
THE AGB NEWSLETTER

*An electronic publication dedicated to stellar evolution
on the asymptotic giant branch and beyond*

No. 52 — 01 September 1998

Editors: Thierry Forveille and Claudine Kahane (agbnews@obs.ujf-grenoble.fr)

From the editors

Some of you had recently troubles to access AGB Newsletter back issues and LaTeX forms through the WEB. We apologize for these problems caused by some subtle changes in the ftp zone architecture. In principle, disturbances should be now under control and you should be able to access your favourite electronic Newsletter at

<http://www-laog.obs.ujf-grenoble.fr/liens/agbnews/agbnews.html>

Abstracts of recently accepted papers

The binary RV Tauri star AC Her and evidence for a long-lived dust-disc.

H. Van Winckel¹, C. Waelkens², L.B.F.M. Waters², F.J. Molster², S. Udry³, E.J. Bakker⁴

¹ Instituut voor Sterrenkunde, K.U.Leuven, Celestijnenlaan 200B, 3001 Heverlee, Belgium

² Astronomical institute "Anton Pannekoek", University of Amsterdam, Kruislaan 403, NL-1098 SJ Amsterdam, The Netherlands

³ Observatoire de Genève, CH-1290 Sauverny, Switzerland

⁴ TNO Physics and Electronics Lab., P.O. Box 96864, 2509 JG The Hague, The Netherlands

We present in this letter a homogeneous set of CORAVEL radial velocity measurements of the well studied RV Tauri star ACHer showing it to be a binary with a period of 1196 ± 6 days. The photospheric abundances are deduced using high resolution, high signal-to-noise optical spectra and prove that ACHer is another RV Tauri star displaying depletion of refractory elements, strengthening the relation between binarity and the depletion process. Our full ISO-SWS spectrum shows that the unusual broad emission feature at $8-12 \mu\text{m}$, is due to a high crystallisation fraction of the circumstellar silicates. We review all observational evidence that the circumstellar material is trapped in a long-lived disc in the system similar to what is observed in the Red Rectangle nebula.

Accepted by A&A Letter to the Editor. 19 june 1998.

Preprints can be obtained by contacting Hans.VanWinckel@ster.kuleuven.ac.be
or via WWW on <http://www.ster.kuleuven.ac.be/homepage/publications.html>

The Abundance Pattern of the Yellow Symbiotic Star He2-467

C.B. Pereira¹, V.V. Smith^{2,3} & K. Cunha^{1,2}

¹ CNPq/Observatório Nacional, Departamento de Astronomia Galáctica. Rua Gen. José Cristino, 77, 20921-400, São Cristóvão, Rio de Janeiro, Brazil

² Department of Physics, University of Texas, El Paso, TX 79912, USA

³ McDonald Observatory, University of Texas, Austin, TX 78712, USA

We report on the analysis of high-resolution optical spectra of the yellow component of the symbiotic star He2-467. The chemical composition of its atmosphere reveals He2-467 to be a metal-poor K-giant with $[\text{Fe}/\text{H}]=-1.1$. From a set of 14 Fe I lines, its radial velocity is found to be -106.9 ± 0.5 km/s. This high velocity plus low metallicity points to He2-467 being a halo star. The K-giant in He2-467 is also enriched in the heavy s-process elements. As its luminosity is below that for an asymptotic giant branch (AGB) star which could have commenced shell helium-burning (via thermal pulses) and become self-enriched in the neutron-capture elements, we ascribe its heavy-element excess to the barium star phenomenon. In this scenario, the secondary component accreted matter from the primary (now the white dwarf) when it was a thermally pulsing AGB star overabundant in s-process elements. The heavy-element abundance distribution of He2-467, as well as its atmospheric parameters, is almost identical to two yellow symbiotics analyzed previously, AG Dra and BD-21°3873. In particular, its neutron exposure parameter, τ , which characterizes the s-process abundance distribution is larger than for solar metallicities (with a single-exposure $\tau = 1.1$ mb⁻¹). Also, analysis of the rubidium abundance in He2-467 reveals that the s-process ratio of $N(\text{Rb})/N(\text{Zr})$ is much larger than for solar metallicity s-process material, indicating that the s-process neutron density is considerably larger at lower metallicities, in agreement with the $^{13}\text{C}(\alpha, n)^{16}\text{O}$ neutron source.

Accepted by The Astronomical Journal

Preprints can be obtained by contacting claudio@on.br

High-resolution bispectrum speckle interferometry and two-dimensional radiative transfer modeling of the Red Rectangle

G. Weigelt¹, Y.Y. Balega², A.B. Men'shchikov¹, and R. Osterbart¹

¹ Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

² Special Astrophysical Observatory, Nizhnij Arkhыз, Zelenchukskaya, Karachaevo-Cherkesia, 357147 Russia

We present the first diffraction-limited K -band image of the Red Rectangle with 76 mas resolution, an H -band image with 75 mas resolution, and an RG 715 filter image (~ 800 nm wavelength) with 78 mas resolution (corresponding to 25 AU for a distance of 330 pc). The H and K images were reconstructed from 6 m telescope speckle data and the RG 715 image from 2.2 m telescope data using the speckle masking bispectrum method. At all wavelengths the images show a compact, highly symmetric bipolar nebula, suggesting a toroidal density distribution of the circumstellar material. No direct light from the central binary can be seen as it is obscured by a dust disk or circumbinary torus. Our first high-resolution $H - K$ color image of the nebula shows a broad red plateau of $H - K \approx 2^m$ in the bright inner regions.

The optical and near-infrared images and the available photometric continuum observations in a wide range of ultraviolet to centimeter wavelengths enabled us to model the Red Rectangle in detail using a two-dimensional radiative transfer code. Our model matches both the high-resolution images and the spectral energy distribution of this object very well, making the following picture much more certain. The central close binary system with a total luminosity of $3000 L_{\odot}$ is embedded in a very dense, compact circumbinary torus which has an average number density $\langle n_{\text{H}} \rangle \approx 5 \times 10^{12} \text{ cm}^{-3}$, an outer radius of the dense inner region of $R \approx 30$ AU (91 mas), and a $\rho \propto r^{-2}$ density distribution. The full opening angle of the bipolar outflow cavities in our model is 70° . By comparing the observed and theoretical images, we derived an inclination angle of the torus to the line of sight of $7^{\circ} \pm 1^{\circ}$.

The radiative transfer calculations show that the dust properties in the Red Rectangle are spatially inhomogeneous. Our modeling confirms that the idea of large grains in the long-lived disk around the Red Rectangle (Jura, Turner, & Balm 1997) is quantitatively consistent with the observations. The best model fit has been found for very large, on average at least millimeter-sized particles in the compact massive torus, although it is clear that a size distribution of dust grains must exist in reality. Assuming a dust-to-gas ratio ρ_d/ρ_g of 0.005, the dense torus mass is $0.25 M_\odot$. The model gives a lower limit of $0.0018 M_\odot$ for the mass of the large particles with an average radius of 2 mm, which produce a gray extinction of $A \approx 28^m$ towards the center. A much smaller mass of submicron-sized dust grains is presumably located in the polar outflow cavities, their conical surface layers, and in the outer low-density parts of the torus (where $\rho \propto r^{-4}$, in the region of $30 \text{ AU} \lesssim r \lesssim 2000 \text{ AU}$ corresponding to $0''.09\text{--}6''$) containing low-density material.

Accepted by New Astronomy.

Preprints can be obtained by contacting meshchikov@mpifr-bonn.mpg.de
or via WWW on <http://www.speckle.mpifr-bonn.mpg.de/publications.html>
or via anonymous ftp on <ftp://speckle.mpifr-bonn.mpg.de/incoming/RedRectangle/redrec.ps>

Are low-order resonances observed in Mira pulsation ?

D. Barthès¹, M. O. Mennessier¹, J. L. Vidal¹ and J.A. Mattei²

¹ Groupe de Recherche en Astronomie et Astrophysique du Languedoc (UPRESA 5024 CNRS), Université Montpellier II, F-34095 Montpellier Cedex 05, France

² American Association of Variable Star Observers, 25 Birch Street, Cambridge MA 02138-1205, USA

The possibility of a low-order, two-mode resonance in the pulsation of LPVs is investigated by means of Fourier analysis of lightcurves, supplemented by spectral types and by kinematic population analysis based on HIP-PARCOs astrometric data. The question might be positively answered.

Letter published in *Astronomy and Astrophysics* 334 with erroneous figure 1. Erratum to be published very soon.

Preprints can be obtained by contacting barthes@pchpc4.am.ub.es

Galactic planetary nebulae with Wolf-Rayet nuclei. I. Objects with [WC]-early type stars

M. Peña¹, G. Stasińska², C. Esteban³, L. Koesterke⁴, S. Medina¹, R. Kingsburgh⁵

¹ Instituto de Astronomía, UNAM, Apdo. Postal 70 264, México D.F. 04510, México

² DAEC, Observatoire de Paris-Meudon, 92195 Meudon Cedex, France

³ Instituto de Astrofísica de Canarias, Spain

⁴ Lehrstuhl Astrophysik der Universität Potsdam, Germany

⁵ Department of Physics and Astronomy, York University, Canada

Spatially resolved long-slit spectrophotometric data for the planetary nebulae PB 6, NGC 2452, NGC 2867, NGC 6905 and He 2-55 are presented. Different knots were observed in each nebula. All the nebulae are ionized by [WC 2–3] type nuclei. For the five objects, we calculated photoionization models using the ionizing radiation field from models of expanding atmospheres. The photoionization models, built with the condition that the predicted stellar visual magnitude is equal to the observed one, were rather successful in reproducing at the

same time the ionization structure and the electron temperature of the nebulae, using model atmospheres that were close (± 20000 K) to the best fit for reproducing the stellar features, as presented by Koesterke & Hamann (1997a). The constraints for the modelling procedure were to reproduce the observed intensity ratios of important lines of different ionization stages, and to be roughly consistent with the observed $H\beta$ flux, angular diameter and morphology of the nebulae. We found that, for some objects, only two-density models with an inner zone of lower density can meet all these requirements. These density structures are consistent with the morphology showed by the nebulae. In a couple of cases, our photoionization modelling seems to indicate that the models of expanding atmospheres used could be lacking ionizing photons with respect to their emission in the V band.

Chemical abundances in the nebulae were derived from the ionic abundances observed and ionization correction factors obtained from the models. We found that, while the five nebulae of our program have very similar exciting stars (similar stellar temperatures, mass loss rates, chemical compositions), the nebular chemical compositions are different. PB 6 and NGC 2452 are He-, N-, and probably C-rich nebulae, indicating massive progenitors ($M_{\text{initial}} \geq 2.8M_{\odot}$). In particular, abundances in PB 6 are consistent with a scenario of C produced via the triple- α process, being brought to the surface by the third dredge-up event and partially converted into N through envelope-burning. The other nebulae present typical disk-PNe abundances, showing only C enrichment ($C/O \geq 1$). Therefore their progenitors were not massive, but all underwent the third dredge-up. Thus, clearly, post-AGB stars of quite different initial masses can pass through a [WC] stage with similar atmospheric parameters. We did not find evidence for abundance variations inside any of the nebulae. In PB 6 and NGC 2867, we found that the C/O ratios derived from the $[C_{iii}] 1909/[O_{iii}] 5007$ line ratios would induce electron temperatures significantly lower than observed. The discrepancy would be larger if carbon abundances derived from the optical $C_{ii} 4267$ recombination lines are considered.

Accepted by Astronomy & Astrophysics

*Preprints can be obtained by contacting miriam@astroscu.unam.mx
or via anonymous ftp on ftp://132.248.1.7/incoming/miriam/WRPN.ps.gz*

Abundance Analyses of Field RV Tauri Stars. IV: AD Aquilae, DS Aquarii, V360 Cygni, AC Herculis, and V453 Ophiuchi

S. Giridhar¹, D.L. Lambert², and G. Gonzalez³

¹ Indian Institute of Astrophysics, Bangalore, 560034 India

² Department of Astronomy, University of Texas, Austin, TX 78712 USA

³ Department of Astronomy, University of Washington, Seattle, WA 98195 USA

Abundance analyses are presented and discussed for five RV Tauri variables. Three stars - DS Aqr, V360 Cyg, and V453 Oph - are RV C stars by spectroscopic classification, i.e., metal lines are weak. They are shown to be metal-poor with $[Fe/H]$ from -1.0 to -2.2 with normal relative abundances of other elements. By contrast, AD Aql and AC Her are RV B stars with an odd abundance pattern: elements that condense into grains at a high temperature are underabundant (i.e., $[Fe/H] = -2.1$ for AD Aql) but elements with a low condensation temperature are much less underabundant (i.e., $[S/H] 0.0$ and $[Zn/H] = -0.1$ for AD Aql). This abundance pattern is ascribed to a separation of dust and gas in the upper atmosphere of the star. The present analyses with previously published results are used to investigate the systematics of the dust-gas separation in RV Tauri variables. The process is apparently inoperative in stars with an initial metallicity of about $[Fe/H] \lesssim -1.0$; RV C stars and similar variables in globular clusters are immune to the dust-gas separation. The process achieves more severe effects in RV B than in RV A stars. The strength of the abundance anomalies attributed to dust-gas separation is not correlated with reported infrared excesses. After correction for the effects of the dust-gas separation, there is no strong evidence from the abundances that evolution along the AGB and experience of the third dredge-up preceded the formation of the majority of the RV Tauri variables.

Accepted by ApJ.

Preprints can be obtained by contacting dll@astro.as.utexas.edu

A Mysterious Dust Clump in a Disk Around an Evolved Binary Star System

M. Jura¹, J. Turner¹

¹ Astronomy Department, UCLA, USA

We report high-angular-resolution observations at millimeter and submillimeter wavelengths of the dust disk associated with the Red Rectangle. We find a dust clump with an estimated mass near that of Jupiter in the outer region of the disk. The clump is larger than our Solar System, and far beyond where planet formation would normally be expected, so its nature is at present unclear.

Accepted by Nature

Preprints can be obtained by contacting jura@clotho.astro.ucla.edu

HST Imaging of IRAS 17441–2411: A Case Study of a Bipolar Nebula with a Circumstellar Disk

Kate Y.L. Su¹, Kevin Volk¹, Sun Kwok¹ Bruce J. Hrivnak²

¹ Department of Physics and Astronomy, University of Calgary, Calgary, Canada T2N 1N4

² Department of Physics and Astronomy, Valparaiso University, Valparaiso, IN 46383

The bipolar proto-planetary nebula IRAS 17441–2411 (the “Silkworm Nebula”) was observed with the Hubble Space Telescope. By fitting the observed spectral energy distribution and the V-band image by a 2-D radiation transfer model, we derive the properties of the circumstellar wind and a proposed circumstellar “disk”. We suggest that bipolar structures are probably more common than actually observed, because objects with similar intrinsic structures may simply appear stellar due to their orientation in the sky.

To appear in the Dec 1 issue of the Astrophysical Journal

Preprints can be obtained by contacting kwok@iras.ucalgary.ca

The CNO Isotopes: Deep Circulation in Red Giants and First and Second Dredge-up

A.I. Boothroyd¹ and I.-J. Sackmann¹

¹ W. K. Kellogg Radiation Laboratory 106-38, California Institute of Technology, Pasadena, CA 91125

It is demonstrated that *deep circulation mixing* below the base of the standard convective envelope, and the consequent “*cool bottom processing*” (CBP) of the CNO isotopes, can reproduce the trend with stellar mass of the $^{12}\text{C}/^{13}\text{C}$ observations in low mass red giants. (This trend is opposite to what is expected from standard first dredge-up.) Our models assume that extra mixing always reaches to the same distance in temperature from the H-burning shell, and that CBP begins when the H-burning shell erases the molecular weight discontinuity (“ μ -barrier”) established by first dredge-up. For Population I stars, none of the other CNO isotopes except ^{15}N are expected to be altered by CBP. (If ^{18}O depletion occurs on the AGB, as some observations suggest, it would require that extra mixing reach closer to the H-burning shell on the AGB than on the RGB — and should also result in a much lower $^{12}\text{C}/^{13}\text{C}$ ratio than is observed in the relevant AGB stars.)

CBP increases dramatically as one *reduces* the stellar mass or metallicity — roughly as M^{-2} on the RGB, due to the longer RGB of low mass stars, and roughly as Z^{-1} , due to the higher H-shell burning temperatures of low metallicity stars. In low mass Population II stars, *all* the CNO isotopes are expected to be significantly

altered by CBP. Field Population II stars exhibit RGB abundances consistent with the predictions of our CBP models that have been normalized to reproduce the Population I RGB abundances. On the other hand, globular cluster stars are observed to encounter much more extensive processing; additionally, CBP is observed to start near the base of the globular cluster RGB (overcoming any “ μ -barrier”).

For the CNO isotopes ^{12}C , ^{13}C , ^{14}N , ^{16}O , ^{17}O , and ^{18}O , we also present self-consistent calculations of the consequences of both first and second dredge-up, i.e., of standard convection during the RGB and AGB stages, over a wide range of stellar masses (0.8 to $9 M_{\odot}$) and metallicities ($Z = 0.02$ to 0.0001). We demonstrate that the common low and intermediate mass stars are a prime source of ^{13}C , ^{14}N , and ^{17}O in the universe.

The light elements (^3He , ^4He , ^7Li , ^9Be , ^{10}B , and ^{11}B) are discussed in Sackmann & Boothroyd (1998).

Accepted by The Astrophysical Journal.

*Preprints can be obtained by contacting aib@krl.caltech.edu
or via WWW on <http://www.krl.caltech.edu/aib/> (i.e., <http://www.krl.caltech.edu/~aib/>),
or as astro-ph/9512121 at the LANL archive <http://xxx.lanl.gov/>*

Creation of ^7Li and Destruction of ^3He , ^9Be , ^{10}B , and ^{11}B in Low Mass Red Giants, Due to Deep Circulation

I.-J. Sackmann¹ and A.I. Boothroyd¹

¹ W. K. Kellogg Radiation Laboratory 106-38, California Institute of Technology, Pasadena, CA 91125

It has been demonstrated that ^7Li can be created in low mass red giant stars via the Cameron-Fowler mechanism, due to extra deep mixing and the associated “cool bottom processing”. Under certain conditions, this ^7Li creation can take the place of the ^7Li destruction normally expected. Note that such extra mixing on the red giant branch (RGB) has previously been invoked to explain the observed ^{13}C enhancement. This new ^7Li production can account for the recent discovery of surprisingly high lithium abundances in some low mass red giants (a few of which are super-rich lithium stars, with abundances higher than that in the interstellar medium). The amount of ^7Li produced can exceed $\log \varepsilon(^7\text{Li}) \sim 4$, but depends critically on the details of the extra mixing mechanism (mixing speeds, geometry, episodicity). If the deep circulation is a relatively long-lived, continuous process, lithium-rich RGB stars should be completely devoid of beryllium and boron.

Cool bottom processing leads to ^3He destruction in low mass stars; in contrast to the ^7Li creation, the extent of ^3He depletion is largely independent of the details of the extra mixing mechanism. The overall contribution from solar-metallicity stars (from 1 to $40 M_{\odot}$) is expected to be a net destruction of ^3He , with an overall ^3He survival fraction $g_3 \approx 0.9 \pm 0.2$ (weighted average over all stellar masses); this is in contrast to the conclusion from standard dredge-up theory, which would predict that stars are net producers of ^3He (with $g_3^{\text{dr}} \sim 2.4 \pm 0.5$). Population II stars experience even more severe ^3He depletion, with $0.3 \lesssim g_3 \lesssim 0.7$. Destruction of ^3He in low mass stars is consistent with the requirements of galactic chemical evolution models; it would also result in some relaxation of the upper bound on the primordial $(\text{D}+^3\text{He})/\text{H}$ abundance, thus relaxing the lower bound on the cosmic baryon density Ω_b from Big Bang nucleosynthesis calculations.

For reference, we also present the effects of standard first and second dredge-up on the helium, lithium, beryllium, and boron isotopes.

Accepted by The Astrophysical Journal.

*Preprints can be obtained by contacting aib@krl.caltech.edu
or via WWW on <http://www.krl.caltech.edu/aib/> (i.e., <http://www.krl.caltech.edu/~aib/>),
or as astro-ph/9512122 at the LANL archive <http://xxx.lanl.gov/>*

ROSAT X-ray Observations of Two Planetary Nebulae: NGC 1535 and NGC 3587

Y.-H. Chu¹, R.A. Gruendl¹, G.M. Conway¹

¹ Astronomy Department, University of Illinois, 1002 W. Green Street, Urbana, USA

X-ray emission from planetary nebulae (PNs) may originate from the central stars or from the shocked fast stellar winds. These two origins may be distinguished by the spatial extent and the spectral properties of the X-ray emission. Using ROSAT Position Sensitive Proportional Counter (PSPC) observations, Leahy et al. (1996) reported X-ray emission from the PNe NGC 1535 and NGC 3587. However, a careful comparison between optical and X-ray images of NGC 1535 shows that the X-ray emission is coincident with a star outside the optical boundary of the nebula. Previous reports of X-ray emission from NGC 1535 are therefore spurious. The PSPC image of NGC 3587 shows three peaks, two projected within and one outside the optical shell boundary. To improve the spatial resolution, we have obtained a 35 ks ROSAT High Resolution Imager (HRI) observation of NGC 3587. The HRI image shows clearly that the three peaks are point sources: RX J111447.9+550106, RX J111450.9+550208, and RX J111504.9+550141. RX J111447.9+550106 is projected at the position of the central star and its PSPC energy distribution shows a very soft X-ray spectrum; therefore, RX J111447.9+550106 most likely represents the photospheric emission from the 110,000 K central star. RX J111450.9+550208 and RX J111504.9+550141 have spectral properties different from that of RX J111447.9+550106, and are probably unrelated background sources.

Accepted by the Astronomical Journal

Preprints can be obtained by contacting chu@astro.uiuc.edu or via WWW on <http://www.astro.uiuc.edu/~chu/publications/preprints/preprints.html>

Monitoring of dust-enshrouded AGB stars in the LMC

P.R. Wood¹

¹ Mount Stromlo and Siding Spring Observatories, Private Bag, Weston Creek PO, ACT 2611, Australia

Twelve IRAS sources in the LMC with colours similar to those expected for dust-enshrouded AGB stars have been monitored in the infrared for 1880 days. The objects come from the list of Reid 1991, ApJ 382, 143. Nine of these objects are large amplitude variables with periods in the range 530 to 1295 days. The variability confirms their status as dust-enshrouded AGB stars. Combined with the results of Wood et al. 1992, ApJ 397, 552, a total of 15 large amplitude, dust-enshrouded AGB stars are now known in the LMC but it is estimated that many hundreds more await discovery. The objects studied in this paper are ~ 2 magnitudes fainter in M_{bol} than the previously known variables. The low luminosities of six of the new objects suggest that they are evolving from the tip of the AGB of the dominant intermediate-age LMC population which has an initial mass $\sim 1.5M_{\odot}$ and age $\sim 2-3 \times 10^9$ years. It is suggested that these stars should be carbon-rich although several of them have been tentatively classified as oxygen-rich. The period range of the objects is consistent with that expected from theoretical models of AGB evolution with mass loss. The observations presented here clearly demonstrate that once significant mass loss and dust formation occurs, large amplitude LPVs no longer fall on the tight ($M_{\text{bol}}, \log P$) or ($K, \log P$) relation found for the Mira variables with $P \lesssim 450$ days.

Accepted by A&A

Preprints can be obtained by contacting wood@mso.anu.edu.au or via anonymous ftp on ftp://merlin.anu.edu.au/pub/wood/papers/lmc_paper.ps.Z

The Density and Shock Characteristics of NGC 2818

J.P. Phillips¹ and L. Cuesta²

¹ Instituto de Astronomía y Meteorología, Avenida Vallarta, 2602, Col. Arcos Vallarta, C.P. 44130 Guadalajara, Jalisco, Mexico

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

We report the results of narrow band imaging of the bipolar outflow source NGC 2818 in transitions of [NII], [OIII], [SII], and HI. As a consequence, we are able to assess the overall excitation properties of the shell, and determine that line ratios towards the nebular periphery are anomalous, and characteristic of planar shocks with velocity $V_s \geq 110 \text{ km s}^{-1}$. Pre-shock densities are likely to be modest, and of order $10^2 < n_p < 10^3 \text{ cm}^{-3}$.

The [SII] imaging is further used to derive a fully-sampled map of electron density, whence it is clear that the density structure is rather complex, and related to various features within the excitation maps. Peak values $n_e \sim 1.5 \cdot 10^3 \text{ cm}^{-3}$ occur close to the nucleus, although densities subsequently decline for major axis displacements $> 7 \text{ arcsec}$. The minor axis distribution, on the other hand, appears to be somewhat more extended and bilobal.

It is probable that complexities in the density mapping reflect the presence of condensations and filaments within the primary shell structure, and that these are also responsible for apparent variations in density as a function of forbidden and permitted line transition.

Accepted by Astronomy and Astrophysics. May 1998.

Preprints can be obtained by contacting lcc@ll.iac.es

IRC +10 216 revisited II: the circumstellar CO shell

M.A.T. Groenewegen¹, W.E.C.J. van der Veen² & H.E. Matthews³

¹Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, D-85740 Garching, Germany

²Department of Astronomy, Columbia University, 538 West 120th Street, New York, NY 10027, U.S.A. ³Joint Astronomy Centre, 660 N. A'ohōkū Place, University Park, Hilo, Hawaii 96720, U.S.A., and Herzberg Institute of Astrophysics, NRC of Canada, 5071 W. Saanich Road, Victoria, B.C. V8X 4M6, Canada

¹²CO and ¹³CO J = 6-5 observations of IRC +10 216 with the JCMT are presented. A spherically symmetric radiative transfer code is used to model these and other CO observations of the carbon star IRC +10 216/CW Leo. Compared to previously published model calculations a much larger set of observational data is used as constraints; on-source ¹²CO and ¹³CO J = 1-0 up to J = 6-5 and mapping data taken with various telescopes, most of which are obtained from the literature.

The gas temperature in the envelope is calculated taking into account heating and cooling. The heating by dust-gas collisions and various other parameters (such as luminosity over distance squared) are constrained from our previous modeling of the circumstellar dust shell. Photoelectric heating is taken into account.

A grid of models is calculated with the following parameters: luminosity (in the range 10 000 – 30 000, in steps of 5 000 L_{\odot}), mass loss rate, dust-to-gas ratio, dust opacity and CO abundance. For each of the considered luminosities a good fit to the on-source data can be obtained. A comparison with CO J = 1-0 data obtained from the literature points towards a preferred luminosity of 10-15 000 L_{\odot} .

Notwithstanding the overall good agreement, there remain discrepancies. The different observed ¹²CO J = 3-2 observations appear to be always larger than the model predictions. The observed ¹³CO J = 6-5 is almost flat-topped, while the model gives a slight double-peaked profile. There is a large discrepancy with the single existing ¹²CO J = 7-6 observation.

The best fitting models (for each of the considered luminosities) cannot accommodate the more extended emission seen in the mapping data. This is not due to an underestimate of the photoelectric effect. To fit the data for radial offsets $> 50''$ the mass loss rate must be a factor of 5 higher in the outer envelope. Because the various sets of data for offsets $\gtrsim 150''$ are not consistent with each other it is unclear if the enhancement in the mass loss rate extends beyond that radius.

Visibility curves are calculated for comparison with future interferometric observations. These appear to be insensitive to luminosity and mass loss variations but should be good tracers of the geometry of the CO shell.

A comparison is made between the mass loss rates and dust-to-gas ratios derived from the CO modelling and those derived from our previous dust modelling. To do this we make use of the relation $\dot{M} v_\infty = \tau_F \frac{L}{c} \left(1 - \frac{1}{F}\right)$, which is valid for radiation pressure driven outflows. The best agreement is obtained for the model with 15 000 L_\odot . This agrees well with the luminosity range 7 700–12 500 L_\odot based on the period-luminosity relation for carbon miras.

In summary, we conclude that the likely luminosity of IRC +10 216 is between 10 000 and 15 000 L_\odot and that its distance is between 110 and 135 pc. The present-day mass loss rate is $(1.5 \pm 0.3) \times 10^{-5} M_\odot \text{ yr}^{-1}$ and the gas-to-dust ratio is a 700 ± 100 . The dust opacity at 60 μm is found to be of order of 250 $\text{cm}^2 \text{gr}^{-1}$. The CO abundance is 1.1×10^{-3} relative to H_2 .

Accepted by A&A

For preprints, contact groen@mpa-garching.mpg.de, *or look at*
<http://www.mpa-garching.mpg.de/~groen/groen.html>

New peculiar CO data of the shell around IRC +10 216

M.A.T. Groenewegen¹, H.-G. Ludwig²

¹Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, D-85740 Garching, Germany

²Astronomical Observatory, Niels Bohr Institute, Juliane Maries Vej 30, DK-2100 Copenhagen, Denmark

A CO(1-0) on-source spectrum of the well-known carbon star IRC +10 216 taken with the IRAM 30m telescope in June 1996 shows excess emission between -18.3 and -14.3 km s^{-1} at the red wing of the underlying profile. The excess emission is confirmed in January 1997 but is absent in April 1997 and June 1998 IRAM spectra. Such a transient feature has not been seen before in this star or any other AGB star. In April 1997 we mapped the circumstellar shell out to $110''$. Both the $J = 1-0$ and $J = 2-1$ spectra show “spikes” or components which vary in strength with position in the envelope. One of these components corresponds to the velocity interval mentioned above. An immediate conclusion is that the circumstellar shell is not spherically symmetric, contrary to what was believed based on lower spectral resolution data. We are probably seeing emission from a complex geometrical structure. Neither a disk structure nor a double-wind structure seem to be able to explain the observations. The on-source transient behaviour of the red excess emission can reasonably well be explained by a single large ($\sim 5 \times 10^{13} \text{ cm}$) blob, that expands due to internal motion.

Accepted by A&A

For preprints, contact groen@mpa-garching.mpg.de, *or look at*
<http://www.mpa-garching.mpg.de/~groen/groen.html>

The variable central star of PN G 243.8–37.1

M. Peñã¹ and M. T. Ruiz²

¹ Instituto de Astronomía, UNAM, Apdo. Postal 70 264, México D.F. 04510, México

² Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

Spectroscopic and photometric variations of the central star of the planetary nebula PRTM 1 (PN G 243.8–37.1) have been detected from optical spectrophotometric data. The photometric variations can be as large as $\delta V \sim 1 \text{ mag}$, but most of the time are within 0.2 mag. The phenomenon seems to be cyclic. These optical changes confirm the *UV* variations reported by Feibelman (1998) from *IUE* archived data. The star presents a highly

ionized spectrum, showing absorption lines of H β and HeII. The stellar features also change becoming deeper when the star is brighter, while at the same time the C IV λ 5808 doublet appears in emission. The star cannot be classified as an “OVI” star, as proposed by Feibelman (1998), because the optical OVI lines are absent from the spectrum. The nebular lines show no sign of variation. The possible origin of the stellar changes is discussed.

Astrophysical Journal Letters, September 10 issue, in press

*Preprints can be obtained by contacting miriam@astroscu.unam.mx
or via anonymous ftp on ftp://132.248.1.7/incoming/miriam/PN242.ps*

Mass Loss Histories of Three Carbon Rich Evolved Stars as Revealed by ^{12}CO Emission

M. Meixner¹, M. T. Campbell¹, W.J. Welch² and L. Likke³

¹ Dept. of Astronomy, MC-221, University of Illinois, Urbana, IL 61801, meixner@astro.uiuc.edu, mtcampbe@astro.uiuc.edu

² Dept. of Astronomy, Univ. of California, Berkeley, CA, 94720, welch@astro.berkeley.edu

³ Dept. of Physics and Astronomy, University of Wisconsin–Eau Claire, Eau Claire, WI 54702-4004, likke1@uwec.edu

We investigate the history and geometry of mass loss in three carbon rich evolved stars, CIT 6, AFGL 618 and IRAS 21282+5050, using observations of the ^{12}CO J=1–0 line emission and a simple radiative transfer code to model these observations. Combining data from the Berkeley–Illinois–Maryland–Association millimeter array and the NRAO 12m, we have constructed full synthesis data cubes of the ^{12}CO J=1–0 line emission from CIT 6, AFGL 618 and IRAS 21282+5050 with angular resolutions of approximately 8", 3" and 4", respectively. We find clumpy envelopes with zeroth–order structures of bright cores, surrounded by lower surface brightness halos in all three sources; however, the contrast between the core and halo is greater for AFGL 618 than for IRAS 21282+5050 and CIT 6. The total flux line profile for CIT 6 has a parabolic shape, in contrast to the flat-topped shape found by all previous single dish observations which have resolved the envelope that we measure to be at least 100" in diameter. The ^{12}CO emission in AFGL 618 has a similar east–west bipolar morphology as its optical reflection nebulosity, although on a much larger scale (90" \times 60"). The bulk of molecular gas in AFGL 618 participates in a spherically symmetric expansion; however, a significant east–west bipolar outflow appears at the heart of the core with detected velocities upto ~ 70 km s $^{-1}$. A blue–shifted component (~ -40 km s $^{-1}$) of the this bipolar outflow is observed in absorption against the continuum source in AFGL 618. We resolve a central hole in IRAS 21282+5050 with a size, 6", slightly larger than its HII region. A bright ring of ^{12}CO emission surrounds this central hole and a ~ 70 " diameter halo surrounds this ring. The ring appears broken in position–velocity cuts due to a significant blue-shifted self-absorption of the gas. We develop a simple radiative transfer code, that assumes spherically symmetric expansion, to model the zeroth–order cored–halo structures observed in these sources. We assume a temperature power law profile with respect to radius and fit a power law index between -0.7 and -0.8 for all three sources. The fitted density profiles with respect to radius reflect the observed differences in the core–halo structures and suggest differences in the mass loss histories of the three sources. The models of both CIT 6 and IRAS 21282+5050 are consistent with constant mass loss rates of $6 \pm 2 \times 10^{-6}$ and $6 \pm 4 \times 10^{-5}$ M_{\odot} yr $^{-1}$, respectively. The model of AFGL 618 suggests two phases of mass loss: an older asymptotic giant branch (AGB) wind lasting ~ 8000 years when the mass loss rate decreased from $2 \pm 1 \times 10^{-4}$ – $3 \pm 1 \times 10^{-5}$ M_{\odot} yr $^{-1}$ and a more recent superwind lasting ~ 4000 years when the mass loss rate increased to $2 \pm 1 \times 10^{-4}$ M_{\odot} yr $^{-1}$.

Accepted by Astrophysical Journal; Dec. 10th issue

*Preprints can be obtained by contacting meixner@astro.uiuc.edu
or via WWW on http://www.astro.uiuc.edu/meixner/meixner.html*

Molecular line observations of southern S stars

J.H. Bieging¹, L.B.G. Kneec², W.B. Latter³, and H. Olofsson⁴

¹ Steward Observatory, University of Arizona, Tucson AZ 85721, USA

² Dominion Radio Astrophysical Observatory, P.O. Box 248, Penticton, BC, V2A 6K3, Canada

³ IPAC, Caltech, MS 100-22, Pasadena CA 91125, USA

⁴ Stockholm Observatory, S-133 36 Saltsjöbaden, Sweden

We observed a sample of southern S stars with the SEST telescope, in the SiO ($v=0$, $J=3-2$) transition at 130.3 GHz, and the HCN ($J=1-0$) transition at 88.6 GHz. SiO emission was detected in all seven stars observed, while HCN was detected in two. We employed a statistical equilibrium/radiative transfer model to estimate the SiO abundance for an assumed molecular distribution. The inferred SiO abundances are consistent with formation of the molecule under thermodynamic equilibrium (TE) conditions near the stellar photosphere, for reasonable physical conditions. We also model the HCN emission by a similar analysis, and find that if HCN is produced near the stellar photosphere, our model abundances are much higher than predicted by TE chemistry, unless the gas temperature is <1300 K and the gas density $n(\text{H}_2) \sim 10^{12} \text{ cm}^{-3}$. Under such conditions, condensation of silicate grains may enhance production of HCN for $\text{C/O} \approx 1$. Alternatively, HCN may be formed by photochemical reactions in the outer circumstellar envelope, as has been proposed for O-rich giants.

Accepted by Astronomy and Astrophysics.

Preprints can be obtained by contacting jbieging@as.arizona.edu

or via anonymous ftp on <ftp://sirius.as.arizona.edu/pub/jbieging/Sstars.ps.gz>

Mode switching in the nearby Mira-like variable R Doradus

T.R. Bedding¹, Albert A. Zijlstra², A. Jones³ and G. Foster⁴

¹ School of Physics, University of Sydney 2006, Australia

² UMIST, Department of Physics, P.O. Box 88, Manchester M60 1QD, U.K.

³ Carter Observatory, P.O. Box 2909, Wellington, New Zealand

⁴ AAVSO, 25 Birch St., Cambridge, MA 02138, U.S.A.

We discuss visual observations spanning nearly 70 years of the nearby semiregular variable R Doradus. Using wavelet analysis, we show that the star switches back and forth between two pulsation modes having periods of 332 days and about 175 days, the latter with much smaller amplitude. Comparison with model calculations suggests that the two modes are the first and third radial overtone, with the physical diameter of the star making fundamental mode pulsation unlikely. The mode changes occur on a timescale of about 1000 d, which is too rapid to be related to a change in the overall thermal structure of the star and may instead be related to weak chaos.

The Hipparcos distance to R Dor is 62.4 ± 2.8 pc which, taken with its dominant 332-day period, places it exactly on the period-luminosity relation of Miras in the Large Magellanic Cloud. Our results imply first overtone pulsation for all Miras which fall on the P-L relation. We argue that semiregular variables with long periods may largely be a subset of Miras and should be included in studies of Mira behaviour. The semiregulars may contain the immediate evolutionary Mira progenitors, or stars may alternate between periods of semiregular and Mira behaviour.

Accepted by MNRAS

Preprints can be obtained by contacting bedding@physics.usyd.edu.au

or via WWW on <http://xxx.lanl.gov/abs/astro-ph/9808322>

Hipparcos period-luminosity relations for Mira and semiregular variables

T.R. Bedding¹ and Albert A. Zijlstra²

¹ School of Physics, University of Sydney 2006, Australia

² UMIST, Department of Physics, P.O. Box 88, Manchester M60 1QD, U.K.

We present period-luminosity diagrams for nearby Miras and semiregulars, selecting stars with parallaxes better than 20 per cent and well-determined periods. Using *K*-band magnitudes, we find two well-defined P-L sequences, one corresponding to the standard Mira P-L relation and the second shifted to shorter periods by a factor of about 1.9. The second sequence only contains semiregular variables, while the Mira sequence contains both Miras and semiregulars. Several semiregular stars show double periods in agreement with both relations. The Whitelock evolutionary track is shown to fit the data, indicating that the semiregulars are Mira progenitors. The transition between the two sequences may correspond to a change in pulsation mode or to a change in the stellar structure. Large amplitude pulsations leading to classical Mira classification occur mainly near the tip of the local AGB luminosity function.

Accepted by ApJ Letters

Preprints can be obtained by contacting bedding@physics.usyd.edu.au
or via WWW on <http://xxx.lanl.gov/abs/astro-ph/9808173>

Modelling the Dust and Gas Outflows from IRC+10 216. I: Ground-Based and Airborne Observations

C.J. Skinner,¹ K. Justtanont,² A.G.G.M. Tielens,^{3,2} A.L. Betz^A, R.T. Boreiko,⁴ F. Baas⁵

¹ Space Telescope Science Institute, 3700 San Martin Drive, Baltimore MD 21218, U.S.A.; on assignment from the Space Sciences Department of the European Space Agency.

²SRON, P.O.Box 800, 9700 AV Groningen, The Netherlands.

³NASA Ames Research Center, Mail Stop 245-3, Moffett Field, CA 94035-1000, U.S.A.

⁴Center for Astrophysics & Space Astronomy, University of Colorado, Boulder, CO 80309, U.S.A.

⁵Joint Astronomy Center, 660 N. A'ohoku Place, University Park, Hilo, HI 96720, U.S.A.

We have developed a model for the dust and gas envelope of the C-star IRC+10 216. Spherical symmetry is assumed, and the model consistently solves the full radiative transfer problem for the rotationally excited far-IR and sub-mm wavelength CO lines and for the dust continuum. New observations of the CO J=9-8 and J=12-11 lines, made with the Kuiper Airborne Observatory, are presented. The model accounts for the first 32 rotational states in the lowest two vibrational levels of CO, and is shown to yield satisfactory fits to both line profiles and spatial maps of the CO J=1-0, 2-1, 3-2, 4-3, 6-5, 7-6, 9-8 and 12-11 lines. The dust model yields a good fit to the spectral energy distribution from the near-IR to mm wavelengths, assuming a distance to the star of 170 pc. From the CO model we are able to confirm previous findings that the gas in the outer envelope is heated by photoelectric effect, and we also find that the mass-loss rate must be of order $5 \times 10^{-5} M_{\odot} \text{ yr}^{-1}$, with a gas-to-dust ratio of approximately 220, in order to simultaneously fit all the CO observations and the spectral energy distribution, and to accurately predict the observed wind terminal velocity via radiative acceleration of the dust grains which are momentum coupled to the gas. The gas temperature distribution is found to be lower than predicted by a simple three-level molecule approach which has been found to work for the envelopes of O-rich AGB stars, but is in good agreement with some previously published models for this source. In contrast with some previously published models, we find no evidence for a recent change in mass-loss rate.

Accepted by MNRAS

Preprints can be obtained by contacting kay@astro.su.se

Stellar Evolution in Real Time: Single Star Evolution

N. Mowlavi

Observatoire de Genève, CH-1290 Versoix, Switzerland

The evolution of single stars is reviewed for those objects which evolve fast enough to be witnessed in real time (i.e. by observations performed during a human life-time). It concerns principally stars in their late phases of evolution. The objects presented in this paper belong to the asymptotic giant branch phase, the post-asymptotic giant branch phase, the planetary nebulae and the luminous blue variables class of stars. Attention is given to the physical mechanisms at the origin of their fast evolution, and to the unique opportunity that those stars offer to test our understanding of stellar evolution.

Invited review (JD8, IAU General Assembly) to be published in ‘Stellar Evolution on Human Time Scales’, eds. Ed. Guinan, B. Koch, New Astronomy, Elsevier

Preprints can be obtained by contacting Nami.Mowlavi@obs.unige.ch

or via WWW on <http://obswww.unige.ch/~mowlavi/publications>

or via anonymous ftp on [obsftp.unige.ch](ftp://obsftp.unige.ch), *file* /pub/mowlavi/realtime.ps.gz