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Abstracts of recently accepted papers

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

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We present in this letter a homogeneous set of CORAVEL radial velocity measurements of the well studied RV Tauri star AC Her showing it to be a binary with a period of 1196 $\pm$ 6 days. The photospheric abundances are deduced using high resolution, high signal-to-noise optical spectra and prove that AC Her 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 μm, 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.

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or via WWW on http://www.ster.kuleuven.ac.be/homepage/publications.html

The Abundance Pattern of the Yellow Symbiotic Star He2-467

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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 [Fe/H]=-1.1. From a set of 14 Fe I lines, its radial velocity is found to be -106.9$\pm$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(Rb)/N(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}C(α,n)^{16}O neutron source.

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Are low–order resonances observed in Mira pulsation ?

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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 HIPPARCOS 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

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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 (±20 000 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 Hβ 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 ($M_{\rm initial} \geq 2.8 M_{\odot}$). 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.

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

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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 up preceded the formation of the majority of the RV Tauri variables.

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A Mysterious Dust Clump in a Disk Around an Evolved Binary

Star System

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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.

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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

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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.

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

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

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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 $^{12}C/^{13}C$ 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 $^{12}C/^{13}C$ 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 (^{3}He, ^{4}He, ^{7}Li, ^{9}Be, ^{10}B, and ^{11}B) are discussed in Sackmann & Boothroyd (1998).

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or via WWW on http://www.krl.caltech.edu/ aib/ (*i.e.*, http://www.krl.caltech.edu/~aib/),
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Creation of ^{7}Li and Destruction of ^{3}He, ^{9}Be, ^{10}B, and ^{11}B in Low Mass Red Giants, Due to Deep Circulation

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It has been demonstrated that ^{7}Li *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 ^{7}Li creation can take the place of the ^{7}Li 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 ^{7}Li 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 ^{7}Li produced can exceed $\log \varepsilon(^{7}\mathrm{Li}) \sim 4$, 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 ^{3}He destruction in low mass stars; in contrast to the ^{7}Li creation, the extent of ^{3}He 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 ^{3}He, with an overall ^{3}He 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 ^{3}He (with $g_3^{\mathrm{dr}} \sim 2.4 \pm 0.5$). Population II stars experience even more severe ^{3}He depletion, with $0.3 \lesssim g_3 \lesssim 0.7$. Destruction of ^{3}He 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 (D+^{3}He)/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.

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

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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.

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Monitoring of dust-enshrouded AGB stars in the LMC

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Twelve IRAS sources in the LMC with colours similar to those expected for dust-enshrounded 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 $M_{\rm bol}$ 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$1.5$M_{\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 ($M_{\rm bol}$, $\log P$) or (K, $\log P$) relation found for the Mira variables with $P \lesssim$ 450 days.

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The Density and Shock Characteristics of NGC 2818

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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 asses 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 $V_s \geq 110$ km s^{-1}. Pre-shock densities are likely to be modest, and of order $10^2 < n_p < 10^3$ 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 $n_e \sim 1.5\ 10^3$ cm^{-3} occur close to the nucleus, although densities subsequently decline for major axis displacements> 7 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 permited line transition.

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

IRC +10 216 revisited II: the circumstellar CO shell

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^{12}CO and ^{13}CO 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 ^{12}CO and ^{13}CO 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 ^{12}CO J = 3-2 observations appear to be always larger than the model predictions. The observed ^{13}CO 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 ^{12}CO 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" y 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 $\dot{M}\, v_\infty = \tau_{\rm F}\, \frac{L}{c}\, \left(1 - \frac{1}{\Gamma}\right)$, 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) $\times 10^{-5}$ $M_\odot$ yr^{-1} and the gas-to-dust ratio is a 700 $\pm$ 100. The dust opacity at 60 μm is found to be of order of 250 cm^{2}gr^{-1}. The CO abundance is 1.1 $\times$ 10^{-3} relative to H_2.

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