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*Abstract of recently accepted papers*

## The galactic mass injection from cool stellar winds of the 1 to 2.5 $M_\odot$ stars in the solar neighbourhood

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We have computed synthetic stellar samples and HR diagrams on the basis of a fine-meshed, consistent grid of evolution tracks for given IMF and SFR(t). In order to model the galactic disk stellar component (single stars only) and to derive its IMF and apparent SFR(t), we selected the synthetic sample which is the best fit to the observed distribution of single stars in the solar neighbourhood HR diagram (complete for $d < 50$pc, $M_V \leq 4$, based on *Hipparcos* data). Most giants of this synthetic sample fall in the range of $M_i = 1$ to 2.5 $M_\odot$.

Stellar evolution on the tip-AGB has been computed by adopting, time-step by time-step, the mass-loss rates predicted by very detailed dust-driven, pulsating wind models for carbon-rich stars. This mass-loss description causes the natural development of superwinds. Their properties are in agreement with the range of measured masses and expansion velocities of PNe, i.e. a total mass of between 0.25 $M_\odot$ and 0.65 $M_\odot$ has been ejected over the final 30 thousand years. For the preceeding mass-loss on the AGB and RGB, we use a semi-empirical approach, i.e., a re-calibrated Reimers mass-loss which yields an RGB mass-loss (for $M_* \leq 1M_\odot$) consistent with the formation of horizontal branch stars. Combining these approaches, we obtain a consistent grid of mass-loss histories in the mass range of $M_i = 1$ to $2.5M_\odot$.

By increasing the number of stars in our synthetic solar neighbourhood stellar sample by a factor of thousand, we have been able to compute a detailed, present-day, synthetic reference sample of galactic disk RGB and AGB giant stars, together with their mass-loss. The results are in good agreement with observations of cool giant stellar mass-loss, as well as with the estimated space density of carbon stars. Finally, we discuss the relative collective yields of the RGB, AGB and tip-AGB stellar mass-loss as contributions to the galactic disk mass re-injection.

**Accepted by Astronomy & Astrophysics**

*Preprints can be obtained via WWW on*

http://star-www.cpes.susx.ac.uk/ kps/GalMassinj.ps

# Circumstellar masers in the Magellanic Clouds

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Results are presented of a search for 22 GHz $H_2O$ $6_{16} \rightarrow 5_{23}$, 43 GHz $SiO_{v=1}(J = 1 \rightarrow 0)$, 86 GHz $SiO_{v=1}(J = 2 \rightarrow 1)$ and 129 GHz $SiO_{v=1}(J = 3 \rightarrow 2)$ maser emission from bright IRAS point sources in the Small and Large Magellanic Clouds — mostly circumstellar envelopes around obscured red supergiants and Asymptotic Giant Branch stars (OH/IR stars). The aim of this effort was to test whether the kinematics of the mass loss from these stars depends on metallicity.

$H_2O$ maser emission was detected in the red supergiants IRAS04553−6825 and IRAS05280−6910, and tentatively in the luminous IR object IRAS05216−6753 and the AGB star IRAS05329−6708, all in the LMC. $SiO_{v=1}(J = 2 \rightarrow 1)$ maser emission was detected in IRAS04553−6825.

The double-peaked $H_2O$ maser line profiles of IRAS04553−6825 and IRAS05280−6910, in combination with the OH (and SiO) maser line profiles, yield the acceleration of the outflows from these stars. The outflow velocity increases between the $H_2O$ masing zône near the dust-formation region and the more distant OH masing zône from $v \sim 18$ to 26 km for IRAS04553−6825 and from $v \sim 6$ to 17 km s$^{-1}$ for IRAS05280−6910.

The total sample of LMC targets is analysed in comparison with circumstellar masers in the Galactic Centre. The photon fluxes of circumstellar masers in the LMC are found to be very similar to those in the Galactic Centre. The expansion velocities in the LMC appear to be $\sim 20\%$ lower than for similarly bright OH masers in the Galactic Centre, but the data are still consistent with no difference in expansion velocity. OH/IR stars in the LMC appear to have slower accelerating envelopes than OH/IR stars in the Galactic Centre.

The masers in the LMC have blue-asymmetric emission profiles. This may be due to the amplification of stellar and/or free-free radiation, rather than the amplification of dust emission, and may be more pronounced in low metallicity envelopes.

The SiO maser strength increases with the photometric amplitude at 2.2 $\mu$m but is independent of the photometric amplitude at 10 $\mu$m. This suggests a strong connection between shocks in the dust-free SiO masing zône and the dust formation process. The LMC masers obey the same trend as the Galactic Centre masers.

Appendices describe $H_2O$ maser emission from the moderately mass-losing AGB star R Dor in the Milky Way, optical echelle spectroscopy of IRAS04553−6825, and the properties of circumstellar masers in the Galactic Centre.

**Accepted by Astronomy & Astrophysics**

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# The peculiar cluster HS 327 in the Large Magellanic Cloud: can OH/IR stars and carbon stars be twins?

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The obscured OH/IR star IRAS05298−6957 in the LMC was recently noticed to be member of the small double cluster HS 327 that also contains a carbon star (van Loon et al., 1998, A&A 329, 169). Hence they are coeval and have (nearly) the same progenitor mass, which can only be understood if Hot Bottom Burning (HBB) has prevented IRAS05298−6957 from being a carbon star.

We present extensive visual and near-IR photometric data for $> 10^4$ stars in and around HS 327, and spectroscopic data for some of the brightest AGB stars amongst these. Colour-magnitude diagrams are used to estimate the age for the cluster and its members, and luminosities are derived for the stars for which spectra have been obtained. The age for IRAS05298−6957 and the carbon star is estimated to be $\sim$ 200 Myr. This corresponds to a Main-Sequence progenitor mass $\sim 4.0$ $M_\odot$ — the first direct measurement of the lower mass threshold for HBB. This agrees with stellar evolution models that, however, fail to reproduce the low luminosity of the carbon star.

**Accepted by Astronomy & Astrophysics**

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# The Galactic Disk Distribution of Planetary Nebulae With Warm Dust Emission Features: I

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We investigate the galactic disk distribution of a sample of planetary nebulae characterised in terms of their mid-infrared spectral features. The total number of galactic disk PNe with 8–13$\mu$m spectra is brought up to 74 with the inclusion of 24 new objects, whose spectra we present for the first time. 54 PNe have clearly identified warm dust emission features, and form a sample which we use to construct the distribution of the C/O chemical balance in galactic disk PNe. The dust emission features complement the information on the progenitor masses brought by the gas-phase N/O ratios: PNe with unidentified infrared emission bands have the highest N/O ratios, while PNe with the silicate signature have either very high N enrichment or close to none, and SiC emission features coincide with a range of moderate N-enrichments. We find a trend for a decreasing proportion of O-rich PNe towards the third and fourth galactic quadrants. Two independent distance scales confirmed that the proportion of O-rich PNe decreases from 30±9% inside the solar circle, to 14±7% outside. PNe with warm dust are also the youngest. PNe with no warm dust are uniformly distributed in C/O and N/O ratios, and do not appear to be confined to C/O$\sim$1. They also have higher 6 cm fluxes, as expected from more evolved PNe. We show that the *IRAS* fluxes are a good representation of the bolometric flux for warm-dust PNe. The requirement $F(12\mu\mathrm{m}) > 0.5$ Jy should probe a good portion of the galactic disk, and the dominant selection effects are rooted in the PN catalogues.

**Accepted by MNRAS**

*Preprints can be obtained by contacting* simon@das.uchile.cl *or via WWW on* http://arXiv.org/abs/astro-ph/0009399

# The Galactic Disk Distribution of Planetary Nebulae with Warm Dust Emission Features: II

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We address the question of whether the distribution of warm-dust compositions in IR-bright galactic disk PNe (paper I, Casassus et al. 2000), can be linked to the underlying stellar population. The PNe with warm dust emission represent a homogeneous population, which is presumably young and minimally affected by a possible dependence of PN lifetime on progenitor mass. The sample in paper I thus allows testing the predictions of single star evolution, through a comparison with synthetic distributions and under the assumption that tip-of-the-AGB and PN statistics are similar. We construct a schematic model for AGB evolution (adapted from Groenewegen & de Jong 1993), whose free-parameters are calibrated with the luminosity function (LF) of C stars in the LMC, the initial-final mass relation, and the range of PN compositions. The observed metallicity gradient and distribution of star forming regions with galactocentric radius (Bronfman et al. 2000) allow us to synthesise the galactic disk PN progenitor population. We find the fraction of O-rich PNe, f(O), is a tight constraint on AGB parameters. For our best model, a minimum PN progenitor mass $M^{\rm min} = 1\ {\rm M}_\odot$ predicts that about 50% of all young PNe should be O-rich, compared to an observed fraction of 22%; thus $M^{\rm min} = 1.2\ {\rm M}_\odot$, at a $2\sigma$ confidence level ($M^{\rm min} = 1.3\ {\rm M}_\odot$ at $1\sigma$). By contrast, current AGB models for single stars can account neither for the continuous range of N enrichment (Leisy & Dennefeld 1996), nor for the observation that the majority of very C-rich PNe have Peimbert type I (paper I). f(O) is thus an observable much easier to model. The decrease in f(O) with galactocentric radius, as reported in paper I, is a strong property of the synthetic distribution, independent of $M^{\rm min}$. This trend reflects the sensitivity of the surface temperature of AGB stars and of the core mass at the first thermal pulse to the galactic metallicity gradient.

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*Preprints can be obtained by contacting* simon@das.uchile.cl *or via WWW on* http://arXiv.org/abs/astro-ph/0009400

# Galactic planetary nebulae with Wolf-Rayet nuclei. II. A consistent data set

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We present high resolution spectrophotometric data for a sample of 34 planetary nebulae with [WC] spectral type central stars (WRPNe) in our Galaxy. The observed objects cover a wide range in stellar characteristics: early and late [WC] type stars, as well as weak-emission line stars (WELS). Physical conditions in the nebulae (electron density and temperatures) have been obtained from various diagnostic line ratios, and chemical abundances have been derived with the usual empirical scheme. Expansion velocities were estimated in a consistent manner from the line profiles for most objects of the sample. A statistical study was developed for the derived data in order to find fundamental relationships casting some light on the evolutionary status of WRPNe.

We found evidence for a strong electron temperature gradient in WRPNe which is related to nebular excitation. Such a gradient is not predicted in simple photoionization models.

Abundance ratios indicate that there seems to be no preferential stellar mass for the Wolf-Rayet phenomenon to occur in the nucleus of a planetary nebula. Two objects, M 1-25 and M 1-32, were found to have a very small Ne/O ratio, a property difficult to understand.

We reexamined the relation between the nebular properties of the WRPNe and the spectral types of the central stars. Our data confirm the trend found by other authors of the electron density decreasing with decreasing

spectral type, which was interpreted as evidence that [WC] stars evolve from late to early [WC] types. On the other hand, our data on the expansion velocities do not show the increase of expansion velocity with decreasing spectral type, that one might expect in such a scenario.

Two objects with very late [WC] type central stars, K 2-16 and PM 1-188, do not follow the general density sequence, being of very low density for their spectral types. We suggest that the stars either underwent a late helium flash (the "born again" scenario) or that they have had a particularly slow evolution from the AGB.

The 6 WELS of our sample follow the same density vs. [WC]-type relation as the bona fide WRPNe, but they tend to have smaller expansion velocities. Considerations about the evolutionary status of WELS must await the constitution of a larger observational sample.

The analysis of the differences between the WRPNe in the Magellanic Clouds (distribution of [WC] spectral types, N/O ratios) and in the Galaxy indicates that metallicity affects the [WR] phenomenon in central stars of planetary nebulae.

**Accepted by Astronomy & Astrophysics**

*Preprints can be obtained by contacting* miriam@astroscu.unam.mx

*or via anonymous ftp on* ftp://ftp.astroscu.unam.mx/pub/temporal/miriam/WRPNII.ps.gz

## Mass-Losing Semiregular Variable Stars in Baade's Windows

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By cross-correlating the results of two recent large-scale surveys, the general properties of a well defined sample of semi-regular variable stars have been determined. ISOGAL mid-infrared photometry (7 and 15 $\mu$m) and MACHO $V$ and $R$ lightcurves are assembled for approximately 300 stars in the Baade's Windows of low extinction towards the Galactic bulge. These stars are mainly giants of late M spectral type, evolving along the asymptotic giant branch. They are found to possess a wide and continuous distribution of pulsation periods and to obey an approximate log period - bolometric magnitude ($\log P$ - $M_{\rm bol}$) relation or set of such relations.

Approximate mass-loss rates $\dot{M}$ in the range of $\sim 3 \times 10^{-8}$ to $5 \times 10^{-7}$ $M_\odot$ year$^{-1}$ are derived from ISOGAL mid-infrared photometry and models of stellar spectra adjusted for the presence of optically-thin circumstellar silicate dust. Mass loss rates depend on luminosity and pulsation period. Some stars lose mass as rapidly as short-period Miras but do not show Mira-like amplitudes. A period of 70 days or longer is a necessary but not a sufficient condition for mass loss to occur.

For AGB stars in the mass-loss ranges that we observe, the functional dependence of mass-loss rate on temperature and luminosity can be expressed as $\dot{M} \propto T^\alpha L^\beta$, where $\alpha = -8.80^{+0.96}_{-0.24}$ and $\beta = +1.74^{+0.16}_{-0.24}$, in agreement with recent theoretical predictions.

If we include our mass-loss rates with a sample of extreme mass-losing asymptotic giant branch (AGB) stars in the Large Magellanic Cloud (LMC), and ignore $T$ as a variable, we get the general result for AGB stars that

$$\dot{M} \propto L^{2.7},$$

valid for AGB stars with $10^{-8} < \dot{M} < 10^{-4}$ $M_\odot$ yr$^{-1}$.

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# Discovery of Two New HCN Maser Lines in Five Carbon Stars

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A survey with the Heinrich Hertz Submillimeter Telescope of HCN emission from mass-losing carbon stars has revealed masers in the J=3–2 and 4–3 transitions of the ($01^{1}c0$) vibrational bending mode. These lines have not previously been known to show maser action. Five stars—R Scl, V384 Per, R Lep, Y CVn, and V Cyg—out of 12 observed were detected as masers. Allowing for evidence of variability, this detection rate suggests that these HCN lines are masers at least some of the time in the majority of mass-losing carbon stars. The line widths and velocities imply that the maser action occurs in gas close to the star where the circumstellar envelope is just being accelerated outward.

**Accepted by The Astrophysical Journal (Letters)**

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# Crystallinity versus mass-loss rate in Asymptotic Giant Branch stars

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Infrared Space Observatory (ISO) observations have shown that O-rich Asymptotic Giant Branch (AGB) stars exhibit crystalline silicate features in their spectra only if their mass-loss rate is higher than a certain threshold value. Usually, this is interpreted as evidence that crystalline silicates are not present in the dust shells of low mass-loss rate objects. In this study, radiative transfer calculations have been performed to search for an alternative explanation to the lack of crystalline silicate features in the spectrum of low mass-loss rate AGB stars. It is shown that due to a temperature difference between amorphous and crystalline silicates it is possible to include up to 40% of crystalline silicate material in the circumstellar dust shell, without the spectra showing the characteristic spectral features. Since this implies that low mass-loss rate AGB stars might also form crystalline silicates and deposit them into the Interstellar Medium (ISM), the described observational selection effect may put the process of dust formation around AGB stars and the composition of the predominantly amorphous dust in the Interstellar Medium in a different light. Our model calculations result in a diagnostic tool to determine the crystallinity of an AGB star with a known mass-loss rate.

**Accepted by A&A**

*Preprints can be obtained by contacting* ciska@astro.uva.nl *or via anonymous ftp on*
ftp://zon.wins.uva.nl/users/ciska/xsil_vs_mdot.ps.gz

## Probing the post-AGB nature of HD 179821. A new radio study of its circumstellar envelope.

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In spite of recent detailed studies, the nature of HD 179821 is still puzzling. It is classified either as an intermediate-mass post-AGB star or as a massive supergiant. We present here new high sensitivity radio observations of HD 179821 in the circumstellar $^{12}CO$ and $^{13}CO$ lines. We also report the new detection of $HCO^+$ in this object. The $^{12}CO$ line intensities allow estimations of the mass-loss rate of HD 179821 and of the dynamical age of its circumstellar envelope. The comparison between $^{12}CO$ and $^{13}CO$ lines indicates an isotopic ratio for carbon of at most 5. Such a low value is characteristic of (post-)AGB stars with low-mass progenitors. Furthermore, the $HCO^+$ molecular ion indicates that an active photochemistry occurs in the envelope of HD 179821, probably induced by UV photons emitted as the central post-AGB star warms up and/or by shocks generated by interacting winds.

**Accepted by Astron. Astrophys.**

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## Discovery of anomalous oxygen isotopic ratios in HR 4049

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We report the discovery in the ISO/SWS spectrum of the post-AGB star HR 4049 of emission bands due to $^{17}O$ and $^{18}O$ isotopes locked up in $CO_2$ molecules. It is the first time these isotopomers are detected outside the solar system. Isotopic ratios derived in the optically thin limit are as low as $^{16}O/^{17}O = 8.3\pm 2.3$ and $^{16}O/^{18}O = 6.9 \pm 0.9$. These values are at least one order of magnitude lower than any previously determined isotopic ratio in any type of evolved star.

**Accepted by A&A Letters**

*Preprints can be obtained by contacting* cami@astro.rug.nl WWW

## Planetary Nebulae with Double Shells and Haloes: Insights from Hydrodynamical Simulations

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We combined hydrodynamical simulations with stellar evolutionary calculations based on prescribed mass-loss rates in order to get a better understanding of how structure and kinematics of circumstellar matter develop with time during the late AGB and the following post-AGB and Planetary Nebula (PN) evolution.

**Proceedings "Ionized Gaseous Nebulae", Mexico City, in press**

*Preprints can be obtained by contacting* DeSchoenberner@aip.de *or via WWW on*
http://www.aip.de/groups/sternphysik/stp/PSFILES/2001/RevMex2001.ps.gz

## Chandra Reveals the X-ray Glint in the Cat's Eye

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We have obtained *Chandra* ACIS-S observations of NGC 6543, the Cat's Eye Nebula. The X-ray emission from NGC 6543 is clearly resolved into a point source at the central star and diffuse emission confined within the central elliptical shell and two extensions along the major axis. Spectral analysis of the diffuse component shows that the abundances of the X-ray-emitting gas are similar to those of the fast (1,750 km $s^{-1}$) stellar wind but not those of the nebula. Furthermore, the temperature of this gas is $\sim 1.7\times10^6$ K, which is 100 times lower than the expected post-shock temperature of the fast stellar wind. The combination of low temperature and wind abundances is puzzling. The thermal pressure of this hot gas is about twice the pressure in the cool nebular shell; thus, the hot gas plays an essential role in the ongoing evolution of the nebula.

**Accepted by the ApJL**

*Preprints can be obtained by contacting* chu@astro.uiuc.edu *or via WWW on*
http://xxx.lanl.gov/abs/astro-ph/0101444

## The evolution of AGB stars towards planetary nebulae

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[2] Astrophysikalisches Institut Potsdam We combined hydrodynamical simulations with stellar evolutionary calculations based on prescribed mass-loss rates in order to get a better understanding of how structure and kinematics of circumstellar matter develop with time during the late AGB and the following post-AGB evolution. We show (i) that the final density profile of the circumstellar shells produced by AGB mass loss falls off steeper than $\rho \sim r^{-2}$, (ii) that stages of high mass-loss rates are periodically interrupted by shorter phases of much lower outflow rates and speeds due to the luminosity dips associated with thermal pulses, and (iii) that during the post-AGB evolution ionization destroys the initial density and velocity distribution set up at the end of the AGB.

**Proceedinga "Post-AGB stars as a phase of stellar evolution, Torun, Poland, in press**

*Preprints can be obtained by contacting* DeSchoenberner@aip.de *or via WWW on*
http://www.aip.de/groups/sternphysik/stp/PSFILES/2000/ppn2000_1.ps.gz

## Evolution of thin gas shells along the AGB and beyond

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Based on numerical simulations with two different computer codes, we have studied the time-dependent hydrodynamics of circumstellar gas/dust shells of AGB stars in their final stages of evolution. We discuss two different mechanisms capable of producing very thin shells of greatly enhanced gas density in the dusty outflows from these stars and illustrate their observable signatures. Our model calculations demonstrate that the thin shells produced on the AGB survive the transition to the post-AGB phase and can still be detected in the haloes of some Planetary Nebulae.

**Proceedings "Post-AGB stars as a phase of stellar evolution", Torun, Poland, in press**

*Preprints can be obtained by contacting* MSteffen@aip.de *or via WWW on*
http://www.aip.de/groups/sternphysik/stp/PSFILES/2000/ppn2000_2.ps.gz

# Dynamos in AGB Stars and Magnetic Shaping of Planetary Nebulae

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The formation of a planetary nebula is usually described by an interacting-stellar-winds model, in which a slow wind from the progenitor star is overtaken by a subsequent fast wind from the star entering its white-dwarf stage, forming a shock that creates the dense shell that forms the planetary nebula. Magnetic shaping of the wind from the progenitor star has been shown to be an effective mechanism for producing elliptical or bipolar planetary nebulae. A question that naturally arises then is, what is the origin of the magnetic field that does the shaping? We suggest that the field is generated by an alpha-omega dynamo in the central star during its AGB phase. Contraction of the star's core and expansion of its envelope during this stage of evolution naturally produce strong differential rotation, while convection (or magnetic instabilities) in the deep convective envelope provide the alpha effect. Using a simple nonlinear interface dynamo model and evolutionary models for a typical AGB star (of mass $3M_{Sun}$), we find an oscillatory dynamo with period of order 0.4 yr and toroidal field strength of order $5 \times 10^4$ G at the base of the convection zone. From this we estimate surface magnetic field strengths of order 400 G, which could produce coronal mass ejections (by analogy with the Sun) that might be responsible for the ejected knots or bullets seen in some planetary nebulae. The post-AGB wind, produced when the AGB star sheds its outer layers and exposes the rapidly rotating, magnetized core, may be strongly collimated by magneto-centrifugal processes. Magnetic braking of the dense core of the progenitor star will eventually shut down the dynamo but could also explain why the white dwarf stars that develop from the AGB cores following the planetary nebula phase are generally slow rotators. Our model offers the possibility of a self-consistent paradigm for planetary nebula formation, beginning with the AGB stage and ending with slowly rotating white dwarfs

**Accepted by Nature**

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# Structure and Physical Properties of the Rapidly Evolving Dusty Envelope of IRC +10 216 Reconstructed by Detailed Two-Dimensional Radiative Transfer Modeling

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We present the first detailed, two-dimensional radiative transfer model of the dusty envelope around the carbon star IRC +10 216. Our goal was to find a self-consistent model of the star and its envelope which takes into account as many observational constraints as possible. The model reproduces very well the entire beam-matched spectral energy distribution of IRC +10 216 from optical to centimeter wavelengths (at several phases of stellar luminosity), observed intensity profiles of the object at 1.25, 2.2, 10.5, 50, 100 $\mu$m, and 1.3 mm, a 10.5 $\mu$m lunar occultation intensity profile, our high-resolution $J, H$, $K$, and $H-K$ bispectrum speckle-interferometry images, and visibilities in $J, H, K, L, M$, and $N$ bands.

For the adopted distance of 130 pc, the model of IRC +10 216 implies that the object changes its luminosity between 13000 and 5200 $L_{\odot}$, its effective temperature between 2800 and 2500 K, and its radius between 500 and 390 $R_{\odot}$. There is a dense non-spherical dust shell around the star, with outflow cavities at position angle

PA $\approx 20°$. The southern cavity with a full opening angle of 36° is tilted toward us by 40° from the plane of sky, causing the observed bipolar appearance of the object on a subarcsecond scale. If the envelope's outflow velocity of $15\,\mathrm{km\,s^{-1}}$ applies to the material making up the dense core, then just $\sim 15$ years ago the star was losing mass at a rate of $9\times10^{-5}\,M_\odot\,\mathrm{yr}^{-1}$.

Dust exists in the envelope of IRC +10 216 everywhere from the stellar photosphere up to a distance of 3 pc from the star. The total mass of the envelope lost by the central star is $3\,M_\odot$ and the dust-to-gas mass ratio is 0.004. The total optical depth $\tau_V$ toward the star in the visual is 40, in the polar cavities it is 10. The innermost parts of the envelope are optically thick even at 10.7 $\mu$m due to a strong resonance absorption of silicon carbide grains at that wavelength. In addition to SiC dust, the model contains inhomogeneous grains made of a mixture of SiC and incompletely amorphous carbon with thin $[Mg_{0.5}Fe_{0.5}]S$ mantles. This is the simplest dust mixture required to fit all observations of IRC +10 216 and to correctly interpret the well-known 11.3 $\mu$m and 27 $\mu$m emission bands. The dust model found in this study can also be successfully applied to many other carbon stars exhibiting broad emission features in the 10.3–12.6 $\mu$m and 25–37 $\mu$m wavelength regions.

An important and firm result of our modeling is that the brightest compact peak observed in IRC +10 216 *is not* the direct light from the underlying central star. In contrast to previous suggestions, the brightest southern component, labeled A in our high-resolution near-infrared images (Weigelt et al. 1998a, Weigelt et al. 1998b, Osterbart et al. 2000), is only the radiation emitted and scattered in the optically thinner southern cavity of the bipolar dense shell moving away from the central star. The carbon star is at the position of the fainter component B in our $H$ and $K$ images, which is $0\farcs21$ away from A along the symmetry axis. Direct stellar light (component B) is not seen at all in the Hubble Space Telescope 0.8 $\mu$m and 1.1 $\mu$m images, being absorbed by the dense dusty material. The even fainter components C and D in the $H$ and $K$ images are probably due to smaller deviations of the dense shell from the spherical shape. IRC +10 216 seems to have entered a phase immediately before moving off the asymptotic giant branch and started developing asymmetries in its envelope.

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# A census of AGB stars in Local Group galaxies I. Photometry of a field in M31

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We present four colour CCD photometry of a field in M31. Observations were carried out in two broad band filters ($V$ and $i$) and two special narrow band "Wing" filters centered on a TiO and a CN molecular band. Colour-magnitude diagrams constructed from broad band photometry show the sequence of RGB/AGB stars. Three known Cepheid variables could be identified on our frames. We used colour-colour diagrams to identify the M- and C-type AGB stars and to investigate e.g. the luminosity function of the AGB population. We found 61 new extragalactic C-stars in this field of M31.

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# Low-excitation atomic gas around evolved stars I: ISO observations of C-rich nebulae

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We present ISO LWS and SWS spectra of far-infrared (FIR) atomic fine structure lines in 12 carbon-rich evolved stars including asymptotic giant branch (AGB) stars, proto-planetary nebulae (PPNe) and planetary nebulae (PNe). The spectra include grating and Fabry-Perot measurements of the line emission of [O I], [C II], [Si I], [Si II], [S I], [Fe I], [Fe II], [Ne II] and [N II]. Only 5 out of our 12 object sample have been detected in at least one of these FIR lines. When we include the 12 oxygen-rich evolved stars from Castro-Carrizo et al.(2000, Paper II), we find that atomic line emission is observed only in those sources in which the central star's $T_{eff} \geq 10000$ K. Above this cutoff, the number of detectable lines and the intensity of the line emission increase as $T_{eff}$ increases. These trends suggest that the atomic lines originate from photodissociation regions (PDRs). In general, the kinematics of the atomic gas, derived from line fits to the Fabry-Perot data, are comparable to the molecular expansion velocities. These kinematics are expected for atomic cooling lines associated with circumstellar PDRs. AFGL 618, however, appears exceptional with dual velocity components: a narrow component (<20 km/s) that may be associated with a PDR, and a broad component (∼66 km/s) that may be produced in post-shocked, accelerated gas. A new PDR code which properly treats enhanced carbon abundances was used to model the observations of our carbon-rich objects. The predicted line intensities agree reasonably well with the observations. Shock models, however, do not compare well with the observed line intensities. PDR mass estimates ranging from $\sim 0.01 - 0.2$ $M_\odot$ were derived from the [C II] 158 $\mu$m line emission. The atomic gas constitutes only a small fraction of the total mass for young planetary nebulae, but its importance grows significantly as the nebulae evolve. Our overall analysis shows that photodissociation, and not shocks, dominates the evolution of the circumstellar envelope by transforming the initially molecular asymptotic giant branch envelopes into the atomic gas found in proto-planetary and planetary nebulae.

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# Low-excitation atomic gas around evolved stars II: ISO observations of O-rich nebulae

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We have observed atomic fine-structure lines in the far-infrared (FIR) from 12 oxygen-rich evolved stars. The sample is composed of mostly proto-planetary nebulae (PPNe) and some planetary nebulae (PNe) and asymptotic giant branch (AGB) stars. ISO LWS and SWS observations of [O I], [C II], [N II], [Si I], [Si II], [S I], [Fe I], and [Fe II] lines were obtained. Taking into account also the sample presented by Fong et al. (Paper I) of carbon-rich evolved stars, we find that PPNe emit in these low-excitation atomic transitions only when the central star is hotter than $\sim$ 10000 K. This result suggests that such lines predominantly arise from photodissociation regions (PDRs), and not from shocked regions. The line widths determined from our Fabry-Perot data also suggest that the FIR lines arise from relatively quiescent PDR gas, as opposed to shocked gas. Our results are in reasonable agreement with predictions from PDR emission models, allowing the estimation of the density of the emitting layers by comparison with the model results. On the other hand, the comparison with predictions of the emission from J-type and C-type shocked regions suggests that detected lines do not come from shocks. The [C II] line flux has been used to measure the mass of the low-excitation atomic component in PPNe, since this transition has been found to be a useful model-independent probe to estimate the total mass of these PDRs. The derivation of the mass formula and assumptions made are also discussed.

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## The Southern Crab from a new perspective

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New HST images and CTIO echelle spectra of the nebula around the symbiotic Mira He 2-104 are presented. The nebula consists of two nested hourglass-shaped structures, and a collimated polar jet. Spatiokinematical modelling shows that all three outflows have been ejected at approximately the same epoch, namely about 5700 yr ago with the adopted distance of 4.4 kpc, in a mass loss event which is not related to the present ongoing outburst. We present a tentative model in which the outer pair of lobes and jets are produced by a high velocity outflow from the white dwarf companion to the Mira, while the inner, slowly expanding lobes are produced by the Mira wind itself.

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## Models of circumstellar molecular radio line emission: Mass loss rates for a sample of bright carbon stars

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Using a detailed radiative transfer analysis, combined with an energy balance equation for the gas, we have performed extensive modelling of circumstellar CO radio line emission from a large sample of optically bright carbon stars, originally observed by Olofsson et al. (ApJS, 87, 267). Some new observational results are presented here. We determine some of the basic parameters that characterize circumstellar envelopes (CSEs),

e.g., the stellar mass loss rate, the gas expansion velocity, and the kinetic temperature structure of the gas. Assuming a spherically symmetric CSE with a smooth gas density distribution, created by a continuous mass loss, which expands with a constant velocity we are able to model reasonably well 61 of our 69 sample stars. The derived mass loss rates depend crucially on the assumptions in the circumstellar model, of which some can be constrained if enough observational data exist. Therefore, a reliable mass loss rate determination for an individual star requires, in addition to a detailed radiative transfer analysis, good observational constraints in the form of multi-line observations and radial brightness distributions. In our analysis we use the results of a model for the photodissociation of circumstellar CO by Mamon et al. (1988). This leads to model fits to observed radial brightness profiles that are, in general, very good, but there are also a few cases with clear deviations, which suggest departures from a simple $r^{-2}$ density law.

The derived mass loss rates span almost four orders of magnitude, from $\sim 5\times10^{-9}\,M_\odot\,yr^{-1}$ up to $\sim 2\times10^{-5}\,M_\odot\,yr^{-1}$, with the median mass loss rate being $\sim 3\times10^{-7}\,M_\odot\,yr^{-1}$. We estimate that the mass loss rates are typically accurate to $\sim$50% within the adopted circumstellar model. The physical conditions prevailing in the CSEs vary considerably over such a large range of mass loss rates. Among other things, it appears that the dust-to-gas mass ratio and/or the dust properties change with the mass loss rate. We find that the mass loss rate and the gas expansion velocity are well correlated, and that both of them clearly depend on the pulsational period and (with larger scatter) the stellar luminosity. Moreover, the mass loss rate correlates weakly with the stellar effective temperature, in the sense that the cooler stars tend to have higher mass loss rates, but there seems to be no correlation with the stellar C/O-ratio. We conclude that the mass loss rate increases with increased regular pulsation and/or luminosity, and that the expansion velocity increases as an effect of increasing mass loss rate (for low mass loss rates) and luminosity.

Five, of the remaining eight, sample stars have detached CSEs in the form of geometrically thin CO shells. The present mass loss rates and shell masses of these sources are estimated. Finally, in three cases we encounter problems using our model. For two of these sources there are indications of significant departures from overall spherical symmetry of the CSEs.

Carbon stars on the AGB are probably important in returning processed gas to the ISM. We estimate that carbon stars of the type considered here annually return $\sim 0.05\,M_\odot$ of gas to the Galaxy, but more extreme carbon stars may contribute an order of magnitude more. However, as for the total carbon budget of the Galaxy, carbon stars appear to be of only minor importance.

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# The discovery of circumstellar arcs around two bipolar proto-planetary nebulae

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Circumstellar arcs have been discovered using the *HST* in two proto-planetary nebulae (PPNs), IRAS 16594−4656 and IRAS 20028+3910. This raises to five the number of PPNs in which such arcs have been detected, and suggests that they are not rare and may even be common features. All five of these PPNs display a bipolar morphology, but this correlation may be the result of a selection effect in which deeper images are taken of bipolar PPNs in which the central star is obscured. Two pairs of oppositely-directed "searchlight beams" are seen in IRAS 20028+3910, similar to those seen in the AFGL 2688 and IRAS 17150−3224. The presence of circular arcs and rings in PPNs and planetary nebulae with a variety of viewing orientations implies that they are illuminated portions of spherical shells, viewed in scattered light. This suggests that the mass loss process is spherically symmetric over most of the lifetime of the progenitor AGB star, and the transition to a bipolar morphology occurs over a short period at the end of the AGB evolution.

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# Properties of OH/IR stars with IRAS LRS spectra

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1858 OH satellite line (1612 MHz) maser sources associated with the IRAS counterparts were assembled from the literature. Cross-correlation between collected OH/IR – IRAS sources and the recent catalogue of the IRAS LRS spectra (Kwok et al.1997, ApJS 112, 557) allows us to subdivide 1024 of them (after excluding OH sources with uncertain IRAS associations) into 10 groups according to the Volk & Cohen (1989, AJ 98, 931) classification scheme. We have found that sources with silicate emission form the largest group (about 57%), followed by the group with silicate absorption (only about 16%). For more sensitive individual OH maser surveys these numbers differentiate even more and the ratio between silicate emission and absorption sources reaches a value close to 6. Surprisingly, we found an association of OH maser emission with a small number of stars with carbon–rich atmospheres. The distribution of these subgroups of OH/IR stars in the IRAS colour–colour and the period–colour diagrams as well as histograms of some physical properties are presented. The galactic distribution of important parameters (periods, IRAS colours, expansion and stellar velocities) for different classes of OH/IR sources is analyzed from the point of view of the stars' evolutionary status. The correlations among the periods, colours, expansion and star velocities and the pumping efficiencies for selected subgroups of OH/IR stars are also investigated. These analyses allow us to demonstrate that a significant fraction of silicate emission group sources do not form an evolutionary sequence with the silicate absorption objects — as is suggested e.g. by the IRAS colour–colour diagram, but rather form a lower initial mass sequence, i.e. these sources will never develop sufficient mass loss to manifest silicate absorption.

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## *Conference announcement*

In commemoration of the 50th anniversary of the paper by Chamberlain and Aller that showed that the subdwarfs are metal-poor, and the discovery of technetium in stars. The Astronomy department of the University of Washington is pleased to announce a conference on the CHEMICAL COMPOSITION OF STARS to be held in SEATTLE on SEPTEMBER 19, 20, 21, 22, 2001. Specific subtopics that we would like covered include: Li, Be, B, in stars C, N, O, Na, Al, alphas Hot Stars (types O, B, A) Supernova Nucleosynthesis Extremely metal-poor stars AGB and post-AGB stars Stars with planets L and T stars Atmospheric modeling and NLTE

Specific social events will include a salmon bake and a Seattle Mariners baseball game.

To receive further information and to help us estimate the number of attendees please send an email to WALL@ASTRO.WASHINGTON.EDU if it is likely that you will attend.

A web site will be created within a month or so.

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