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Abstract of recently accepted papers

Low and intermediate-mass close binary evolution and the initial – final mass relation

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Using Eggleton's stellar evolution code, we carry out 150 runs of Pop I binary evolution calculations, with the primary's initial-mass between 1 and $8M_{\odot}$, the initial mass ratio $q = M_1/M_2$ between 1.1 and 4, and the onset of Roche lobe overflow (RLOF) at early, middle, or late Hertzsprung gap. We assume that the RLOF is conservative in the calculations and find that the remnant mass of primary may change over 40 per cent over the range of initial mass ratio or orbital period for a given primary mass. This is contrary to the, often held, belief that remnant mass depends only on progenitor mass if mass transfer begins in the Hertzsprung gap. We fit a formula, with an error less than 3.6 per cent, for remnant (white dwarf actually) mass as a function of the initial mass $M_{1\rm i}$ of primary, the initial mass ratio $q_{\rm i}$, and the radius of primary at the onset of RLOF. We also find that a carbon-oxygen white dwarf with mass as low as $0.33M_{\odot}$ may be formed if the primary's initial mass is around $2.5M_{\odot}$.

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A systematic investigation of the mass loss mechanism in dust forming long–period variable stars

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In order to investigate the relations between the mass loss from pulsating red giants and quantities which can be obtained from observations, we have explored the behavior of theoretical models which treat the time-dependent hydrodynamics of circumstellar outflows, including a detailed treatment of the dust formation process. This approach, while ignoring effects such as a possible non-sphericity of the stellar atmospheres which are difficult to assess, accounts correctly for factors such as the grain formation and destruction which are crucial to the

mass-loss mechanism.
We built a grid of $\sim$ 150 models covering a wide range of physical situations. This grid allows us to characterize the effects of different parameters, such as the stellar luminosity and temperature, the period and the amplitude of the pulsation, and the C/O element abundance ratio, on the behavior of AGB winds and on the rates of mass loss.
We find two regimes for the stellar outflows. The first one (A) is characterized by stable winds with a layered structure of the circumstellar dust shell, outflow velocities in excess of $5\,\mathrm{km\,s^{-1}}$, and a large rate of mass loss. These outflows are dominated by radiation pressure on dust. For these models we find good correlations between near-infrared colors and the mass loss rates. In the second regime (B), the winds are slow and do not present a layered structure. The outflows displaying the second behavior come, e.g., from red giants with low luminosity, high temperature, or short period. For them there is no correlation between color and mass loss rate. The mass loss rates are low and never exceed $3\,10^{-7} M_{\odot}\mathrm{yr}^{-1}$. Radiation pressure on dust plays only a minor role in this regime.
We have explored the effect of different parameters on the behavior of the stellar winds. We find that, in general, all other parameters been kept identical, there is a narrow range of values for each parameter within which the models abruptly change from B to A, and that once a model is stabilized in the A mode the changes in the values of each parameter have only a smooth effect on the wind characteristics.

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Presolar SiC grains of type Y: origin from low-metallicity AGB stars

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We report isotopic data for 27 presolar SiC grains of the rare sub-type Y in an acid-resistant residue of the Murchison (CM2) meteorite. Presolar SiC grains of type Y constitute only ~1% of Murchison SiC grains larger than ~2 μm and are defined as having ^{12}C/^{13}C>100 (solar = 89) and ^{14}N/^{15}N>272 (solar). In a Si 3-isotope plot, their Si isotopic compositions plot to the right of the correlation line defined by the majority of presolar SiC grains (the mainstream population), whose isotopic compositions indicate an origin in C-rich Asymptotic Giant Branch (AGB) stars of near-Solar metallicity. Because of their low abundance, the new Y grains were identified by automatic isotopic imaging of the ^{12}C/^{13}C ratio in the ion microprobe. We report C, N, and Si isotopic ratios of all 27 grains, inferred initial ^{26}Al/^{27}Al ratios of 18, and Ti isotopic ratios of 20 grains. Whereas ^{14}N/^{15}N and ^{26}Al/^{27}Al ratios exhibit the same range as mainstream grains, the C, Si, and Ti isotopic ratios are distinct. Carbon-12/Carbon-13 ratios range up to 295 and ^{30}Si/^{28}Si excesses up to 183$^{o}/_{oo}$ relative to Solar. The average ^{29}Si/^{28}Si ratio of Y grains is by 59$^{o}/_{oo}$ smaller than that of mainstream grains. Ti isotopic ratios relative to ^{48}Ti are somewhat similar to those of mainstream grains, but extend to more extreme anomalous compositions. One grain has ^{46}Ti/^{48}Ti, ^{49}Ti/^{48}Ti, and ^{50}Ti/^{48}Ti excesses of 183, 365, and 990$^{o}/_{oo}$, respectively, relative to Solar. These features exhibited by Y grains point to an origin in AGB stars of somewhat lower-than-Solar metallicity. In the envelope of such stars the proportion of ^{12}C and s-processed material dredged up from deep zones that experienced partial He burning and was mixed with original material is higher than in stars of Solar metallicity. Their envelopes are therefore expected to have larger ^{12}C/^{13}C, ^{30}Si/^{28}Si, and ^{49}Ti/^{48}Ti and ^{50}Ti/^{48}Ti ratios than mainstream grains. We compare the C, Si and Ti isotopic compositions of Y grains with the results of theoretical models of AGB stars with 1.5, 3, and 5 $M_{\odot}$ and Z = 0.006, 0.01 and 0.02. While Solar-metallicity (Z = 0.02) AGB models cannot account for the Y grain data, the models with Z = 0.01 can reproduce the measured isotopic compositions reasonably well. A range of stellar masses (from 1.5 $M_{\odot}$ possibly

up to 5 $M_{\odot}$) is indicated by the grain data. The present study together with additional data on SiC grains of type Z furthermore indicate that the rate of change of the ratios of the secondary Si isotopes (^{29}Si and ^{30}Si) relative to ^{28}Si prior to Solar System formation was lower than has been generally assumed, implying larger contributions of ^{28}Si from Type Ia supernovae compared to those from Type II supernovae. The Si isotopic ratios of Galactic cosmic rays also suggest such an evolution.

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Mira's wind explored in scattering infrared CO lines

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We have observed the intermediate regions of the circumstellar envelope of Mira (o Ceti) in photospheric light scattered by three vibration-rotation transitions of the fundamental band of CO, from low-excited rotational levels of the ground vibrational state, at an angular distance of $\beta \sim 2" - 7"$, away from the star. The data were obtained with the Phoenix spectrometer mounted on the 4 m Mayall telescope at Kitt Peak. The spatial resolution is approximately 0.5" and seeing limited. Our observations provide absolute fluxes, leading to an independent new estimate of the mass-loss rate of approximately $3 \times 10^{-7}\,\mathrm{M}_{\odot}\ \mathrm{yr}^{-1}$, as derived from a simple analytic wind model. We find that the scattered intensity from the wind of Mira for $2" \lesssim \beta \lesssim 7"$ decreases as β^{-3}, which suggests a time constant mass-loss rate, when averaged over 100 years, over the past 1200 years.

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Dust features in the 10-μm infrared spectra of oxygen-rich evolved stars

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We have analyzed the $8-13.5\mu$m UKIRT CGS3 spectra of 142 M-type stars including 80 oxygen-rich AGB stars and 62 red supergiants, with a view to understanding the differences and similarities between the dust features of these stars. We have classified the spectra into groups according to the observed appearance of the infrared features. In each case the normalized continuum-subtracted spectrum has been compared to those of the other stars to find similarities and form groups. The dust features of the AGB stars are classified into six groups: *broad AGB*, where the feature extends from 8μm to about 12.5μm with little structure; *broad+sil AGB*, which consists of a broad feature with an emerging 9.7μm silicate bump; and four *silicate AGB* groups in which a "classic" 9.7μm silicate feature gets progressively narrower. Likewise, the supergiant spectra have also been classified into groups, however these do not all coincide with the AGB star groups. In the supergiant case we again have six groups: *featureless*, where there is little or no emission above the continuum; *broad Super*, where the feature extends from about 9μm to about 13μm; and four *silicate Super* groups, which again show a progression towards the narrowest "classic" 9.7μm silicate feature. We compare the mean spectrum for each group, which yields two main results. Firstly, while the "classic" silicate feature is essentially identical for both AGB stars and red supergiants, the *broad* features observed for these two stellar types are quite different. We suggest that the dust

in these two environments follows different evolutionary paths, with the dust around Mira stars, whose broad feature spectra can be fit by a combination of alumina (Al_2O_3) and magnesium silicate, progressing from this composition to dust dominated by magnesium silicate only, while the dust around supergiants, whose broad feature can be fit by a combination of Ca-Al-rich silicate and Al_2O_3, progresses from this initial composition to one eventually also dominated by magnesium silicate. The reason for the difference in the respective broad features is not clear as yet, but could be influenced by lower C/O ratios and chromospheric UV radiation fields in supergiant outflow environments. The second result concerns the $12.5-13.0\mu$m feature discovered in IRAS LRS spectra and widely attributed to Al_2O_3. This feature is seen predominantly in the spectra of semiregular variables, sometime in Miras and only once (so far) in supergiant spectra. We argue that it is unlikely that this feature is due to Al_2O_3 or, as has more recently been suggested, spinel ($MgAl_2O_4$), but could be associated with silicon dioxide or highly polymerized silicates (not pyroxenes or olivines).

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Strong asymmetries in the neutral envelope of Mira

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We present high-resolution observations of the neutral envelope of *o* Ceti. The molecular component has been mapped in the CO(2–1) radio line and the atomic component is studied through long-slit spectroscopy of the optical KI line. These observations reveal strong asymmetries in the gas distribution, which can be interpreted as a spherical envelope disrupted by a bipolar outflow.
These data, combined with other observations of this object as well as similar observations of other AGB stars, suggest that asymmetrical mass loss processes occur early during the AGB stage, well before the proto-planetary nebula phase.

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ISO Observations of the Planetary Nebula Lindsay 305 in the Small Magellanic Cloud

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We present ISO (Infrared Space Observatory) observations of the planetary nebula Lindsay 305 (L 305) in the Small Magellanic Cloud. L 305 is well prominent in the ISOCAM frames at 6.75 and 11.5 μm, although it is under the detection limit at 4.5 μm. The obtained spectral energy distribution shows a strong mid-IR excess, which, depending on the amount of energy radiated at wavelengths longer than 11.5 μm, may be as large as $\sim 1500 L_\odot$. However, since an accurate estimate of the total nebular luminosity is not available to date, the evolutionary status of L 305 can not yet be constrained precisely.

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Third-dredge-up oxygen in planetary nebulae

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The planetary nebulae He 2-436 and Wray 16-423 in the Sagittarius dwarf galaxy appear to result from nearly twin stars, except that third-dredge-up carbon is more abundant in He 2-436. A thorough photoionization-model analysis implies that ratios Ne/O, S/O and Ar/O are significantly smaller in He 2-436, indicative of third-dredge-up oxygen enrichment. The enrichment of oxygen with respect to carbon is (7±4)%. Excess nitrogen in Wray 16-423 suggests third dredge-up of late-CN-cycle products even in these low-mass, intermediate-metallicity stars.

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Molecular envelopes around carbon stars Interferometric observations and models of HCN and CN emission

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We have observed four carbon stars (W Ori, RW LMi [CIT6], Y CVn, and LP And [IRC+40540]) in the HCN($J = 1 \rightarrow 0$) line and three of them (RW LMi, Y CVn, and LP And) also in the CN($N = 1 \rightarrow 0$) line using the IRAM interferometer on Plateau de Bure. The HCN brightness distributions are centred on the stellar positions suggesting a photospheric origin of this molecule. We see the expected structure of a hollow CN brightness distribution outside that of the HCN emitting region (in particular, for RW LMi and LP And).

We have used a non-LTE radiative transfer code, based on the Monte Carlo method, to model the circumstellar HCN and CN line emissions. We have, in addition to the interferometer data, used also multi-transition single dish data as constraints. The results are qualitatively, and in most cases also quantitatively, consistent with a simple photodissociation model, in which HCN is produced in the stellar atmosphere, while the observed CN is formed in the circumstellar envelope due to the photodissociation of HCN. The most notable discrepancy is the low CN/HCN peak abundance ratios, ≈0.16, obtained for those objects with the best observational constraints. These are lower by at least a factor of two compared to the results of also more elaborate chemical models. Some of our modelling discrepancies, e.g., the weakness of the model HCN($J = 1 \rightarrow 0$) intensities, are attributed to a too crude treatment of the radiative excitation in the inner region of a circumstellar envelope, and to a lack of knowledge of the density structure and kinematics in the same region. We find it particularly difficult to model the circumstellar line emissions towards RW LMi, and suspect that this is due to, e.g., a mass loss rate that has varied with time and/or a non-spherical envelope. The HCN and CN brightness maps suggest the latter.

Furthermore, we have obtained interferometric data towards RW LMi in also the HNC($J = 1 \rightarrow 0$), HC_3N($J = 10 \rightarrow 9$), HC_5N($J = 34 \rightarrow 33$) and SiS($J = 5 \rightarrow 4$) lines. The HNC, HC_3N, and HC_5N molecules appear to be distributed in a shell, while the SiS emission is clearly confined to regions close to the star. The HCN($J = 1 \rightarrow 0$), HNC($J = 1 \rightarrow 0$), and HC_3N($J = 10 \rightarrow 9$) lines show the effect that the peak brightness position varies systematically with the velocity. We attribute this to a large-scale asymmetry in the envelope. We also find that

some of the spectra obtained towards the map centre are highly asymmetric, with the redshifted emission being significantly stronger than the blueshifted emission.

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Excitation of HCN in the circumstellar envelope of carbon stars. Maser emission and hyperfine line interaction

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We have investigated the excitation of the molecule HCN in the circumstellar envelopes of carbon stars, particularly the HCN(J=1-0) maser emission using a model which takes into account the collisional and radiative excitation, as well as the effect of the overlap of hyperfine lines.
We calculate consistently both the gas temperature and the mass loss rate based on the energy balance equation and the fitting of CO observations. In this way we can obtain more realistic data of the envelope.
In optically thin envelopes such as that around Y CVn, our results suggest that the HCN(J=1-0) transition is inverted by the absorption of 3 μm stellar photons which transfers the population to the (001) vibrational state and by subsequent cascades down to the fundamental state. Mutual amplification of hyperfine components results in HCN line profiles containing several strong maser spikes.
In thicker envelopes, such as IRC+10216, we find that HCN and $H^{13}CN$ are excited mainly by the absorption of infrared photons emitted by the warm dust at 14 μm. The HCN(J=1-0) and $H^{13}CN$(J=1-0) line profiles calculated by our model contain several features as observed. We also discuss the implication of our results on the mass loss history of IRC+10216.

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Cyclic and secular variation in the temperatures and radii of extreme helium stars

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The ultraviolet properties of seventeen extreme helium stars have been examined using 150 IUE spectra. Combining short-wave and long-wave image pairs and using a grid of hydrogen-deficient model atmospheres and a χ^2-minimization procedure, seventy measurements of effective temperature ($T_{\rm eff}$), angular diameters (θ) and interstellar extinction ($E_{\rm B-V}$) were obtained. In most cases, these were in good agreement with previous measurements, but there are some ambiguities in the case of the hotter stars, where the solutions for $T_{\rm eff}$ and $E_{\rm B-V}$ become degenerate, and in the case of the cooler stars with large $E_{\rm B-V}$, where the total flux is no longer dominated by the ultraviolet.

The behaviour of twelve helium stars was examined over an interval exceeding ten years. The surfaces of four stars (HD168476, HD160641, BD–9°4395 and BD–1°3438) were found to be heating at rates between 20 and 120 $\rm Kyr^{-1}$, in remarkable agreement with theoretical predictions. This result provides the first direct evidence

that extreme helium stars are helium shell-burning stars of up to $\sim 0.9 M_{\odot}$ *contracting* towards the white dwarf sequence. Low-luminosity helium stars do not show a detectable contraction, also in agreement with theory, although one, BD+10°2179, may be expanding.

The short-term behaviour of three variable helium stars (PV Tel variables: HD168476, BD+1°4381, LS IV–1°2) was examined over a short interval in 1995. All three showed changes in $T_{\rm eff}$ and θ on periods consistent with previous observations. Near-simultaneous radial velocity (v) measurements were used to establish the total change in radius, with some reservations concerning the adopted periods.

Subsequently, measurements of the stellar radii and distances could be derived. With $T_{\rm eff}$ and surface gravities established previously, stellar luminosities and masses were thus obtained directly from observation. In the case of HD168476 the mass is $0.94 \pm 0.68 M_{\odot}$. Assuming a similar gravity for LS IV–1°2 based on its neutral helium line profiles, its mass becomes $0.79 \pm 0.46 M_{\odot}$. The θ amplitude for BD+1°4381 appears to be overestimated by the IUE measurements and leads to a nonsense result. These first direct measurements of luminous extreme helium star masses agree well with previous estimates from stellar structure and pulsation theory.

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Envelope tomography of long-period variable stars: I. The Schwarzschild mechanism and the Balmer emission lines

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This paper is the first one in a series devoted to the study of the dynamics of the atmospheres of long-period variable stars. Results from a two-month-long monitoring of the Mira variables RT Cyg and X Oph around maximum light with the ELODIE spectrograph at the Haute-Provence Observatory are presented. The monitoring covers phases 0.80 to 1.16 for RT Cyg and phases 0.83 to 1.04 for X Oph. The cross-correlation profile of the spectrum of RT Cyg with a K0 III mask confirms that the absorption lines of RT Cyg in the optical domain appear double around maximum light. No line doubling was found in the optical spectrum of X Oph around maximum light, indicating that this feature is not common to all long-period variables.
This paper also presents the application to RT Cyg of a new tomographic technique deriving the velocity field across the atmosphere by cross-correlating the optical spectrum with numerical masks constructed from synthetic spectra and probing layers of increasing depths. This technique reveals that both the temporal evolution of the line doubling, and its variation with depth in the atmosphere of RT Cyg, are consistent with the "Schwarzschild scenario". This scenario relates the temporal evolution of the red and blue peaks of the double absorption lines to the progression of a shock wave in the atmosphere.
The temporal evolution of the Balmer Hα, Hβ, Hγ and Hδ emission lines around maximum light is also presented for RT Cyg and X Oph. The velocity variations of Hα and of the absorption lines are discussed in the framework of two competing models for the formation of Balmer emission lines in long-period variable stars.

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Large amplitude variables near the Galactic Centre

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We report here the results of a four-year K-band (2.2 μm) survey for large-amplitude variable stars in a 24 × 24 arcmin^2 area centered on the Galactic Centre. A total of 409 likely long-period variables (LPVs) were detected, for which positions, amplitudes, average magnitudes and periods were obtained whenever possible. The surface density of LPVs is more than ten times greater than in the Sgr I Baade's window at $l = 1.37°$, $b = -2.63°$.
The limits of completeness arising from interstellar and circumstellar absorption are discussed. Most of the area suffers interstellar extinction of $20 < A_V < 40$ mag. The shorter-period LPVs are less luminous than the longer-period ones and may be slightly under-represented in the data. Extremely heavy extinction ($A_V > 40$ mag), which affects the probability of detecting variables, occurs in less than 25% of the area.
Almost all of the LPVs are Miras or OH/IR stars, with periods ranging from 150 days to about 800 days. K-band counterparts have been found for 59% of the 109 known OH sources in the field. The average period of the variables found is 427 days, while that of the OH/IR stars is 524 days. For comparison, the average period in the Sgr I window, which contains no known OH/IR stars, is 333 days and only two stars are detected with $P > 600$ days. The survey field also contains a number of long-period, large-amplitude variables which are not OH emitters.

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An electronic version can be obtained from ftp.saao.ac.za in /pub/isg/survey.ps.gz

On 2MASS identifications for OH/IR stars

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Most OH/IR stars discovered by color-selection from the IRAS Point Source Catalog have 5-15″ quality positions, whereas the density of 2MASS sources around them is typically 0.005 per arcsecond^2. About 40% of positional associations within 5″ are thus false. This confusion can be reduced by a factor of 8 by discarding potential associations with inappropriate $J - K_s$ colors. It is further reduced for OH/IR stars within 4.5° of the Galactic Plane by the availability of ≈ 2″ quality positions from the MSX mission. We use a sample of IRAS-derived OH/IR stars with radio positions from the VLA and extant 2MASS data to assess the likelihood of finding valid near-IR identifications for stars with thick circumstellar shells, and the residual probability of making a false 2MASS identification. Two noteworthy results are (i) 19440+2251 cannot be associated with a 2MASS source satisfying $J - K_s > 2$; (ii) the candidate-hypergiant star 19566+3423, alias MSX5C_G070.7763+02.6837, which has an LRS 36 type, has a positional association with 2MASSI 1958322+343133 and a $K_s = 14.2 \pm 0.1$.

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Modelling CO emission from Mira's wind

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We have modelled the circumstellar envelope of *o* Ceti (Mira) using new observational constraints. These are obtained from photospheric light scattered in near-IR vibrational-rotational lines of circumstellar CO molecules

at 4.6 μm: absolute fluxes, the radial dependence of the scattered intensity, and two line ratios. Further observational constraints are provided by ISO observations of far-IR emission lines from highly excited rotational states of the ground vibrational state of CO, and radio observations of lines from rotational levels of low excitation of CO. A code based on the Monte-Carlo technique is used to model the circumstellar line emission. The vibrational-rotational lines are sensitive to the radiation field, whereas the pure rotational lines, such as the rotational lines of low excitation measured at radio wavelengths and the rotational lines from highly excited states observed with ISO, are usually more sensitive to the temperature structure. These rotational lines have been the prime probe in most earlier investigations.
We find that it is possible to model the radio and ISO fluxes, as well as the highly asymmetric radio-line profiles, reasonably well with a spherically symmetric and smooth stellar wind model. However, it is not possible to reproduce the observed NIR line fluxes consistently with a 'standard model' of the stellar wind. This is probably due to incorrectly specified conditions of the inner regions of the wind model, since the stellar flux needs to be larger than what is obtained from the standard model at the point of scattering, i.e., the intermediate regions at approximately 100$-$400 R_* (2"$-$7") away from the star. Thus, the optical depth in the vibrational-rotational lines from the star to the point of scattering has to be decreased. This can be accomplished in several ways. For instance, the gas close to the star (within approximately 2") could be in such a form that light is able to pass through, either due to the medium being clumpy or by the matter being in radial structures (which, further out, developes into more smooth or shell-like structures). Further observations of the gas in the stellar wind close to Mira are required to resolve this problem.
The model circumstellar envelope, which reproduces the observables reasonably well, has a mass-loss rate of $2.5\times10^{-7}\,M_\odot\,yr^{-1}$, and a turbulent velocity of $1.5\,km\,s^{-1}$, given a terminal expansion velocity of the wind of $2.5\,km\,s^{-1}$.

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Morphological and kinematic signatures of a binary central star in the planetary nebula Hu 2-1

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We present Hα, [NII] and [OIII] ground-based and HST archive images, VLA–A 3.6 cm continuum and H92α emission line data and high resolution long-slit [NII] spectra of the planetary nebula Hu 2-1. A large number of structural components are identified in the nebula: an outer bipolar and an inner shell, two pairs of collimated bipolar structures at different directions, monopolar bow-shock-like structures and an extended equatorial structure within a halo. The formation of Hu 2-1 appears dominated by anisotropic mass ejection during the late AGB stage of the progenitor and by variable, "precessing" collimated bipolar outflows during the proto-planetary nebula and/or early planetary nebula phases. Different observational results strongly support the existence of a binary central star in Hu 2-1, among them: (1) the observed point-symmetry of the bipolar lobes and inner shell, and the departures from axial symmetry of the bipolar lobes, (2) the off-center position of the central star, (3) the detection of mass ejection towards the equatorial plane, and (4) the presence of "precessing" collimated outflows. In addition, (5) an analysis of the kinematics shows that the systemic velocity of the bipolar outflows does not coincide with the systemic velocity of the bipolar shell. We propose that this velocity difference is a direct evidence of orbital motion of the ejection source in a binary system. From a deduced orbital velocity of $\sim$ 10 km s^{-1}, a semi-major axis of $\sim$ 9–27 AU and period of $\sim$ 25–80 yr are obtained, assuming a reasonable range

of masses. These parameters are used to analyze the formation of Hu 2-1 within current scenarios of planetary nebula with binary central stars.

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Water and Dust Emission from W Hydrae

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We construct a self-consistent model for the wind around W Hya by solving the coupled equations describing the hydrodynamics and dust radiative transfer problems. The model matches simultaneously the observed continuum radiation and wind velocity profile. The water line emission is calculated next using the water abundance as the only free parameter, fitted from the ISO observations of Neufeld et al. (1996) and Barlow et al. (1996). The gas temperature is determined from a thermal balance calculation that includes water as one of its main components. Our model successfully fits all the observed water lines, resolving a major discrepancy between the modeling results of the two observing teams. The mass loss rate is 2.3×10^{-6} $M_\odot$ yr^{-1}, the water abundance is 1.0×10^{-4} and the ortho:para ratio is 1:1.3.

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The Shaping of Planetary Nebulae by Bipolar Outflows: the Case of M1-16

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We report high resolution ($2.7'' \times 1.9''$) CO $J = 2 - 1$ line imaging of the young planetary nebula M1-16 that reveals the shaping of its neutral envelope by collimated outflows or jets. An extended ($\sim 50''$) envelope of molecular gas surrounds the compact ($3''$) ionized nebula, and dominates the mass of circumstellar material (~ 0.12 $M_\odot$). Multiple bipolar outflows, prominent at optical wavelengths, have pierced the envelope from the center, disrupting a significant fraction of the molecular gas. The outflows have excavated cavities along the bipolar axes, with CO velocities up to ~ 30 $km\,s^{-1}$ in the cavity walls, and have produced point-symmetric lobes of molecular gas by entrainment. These features, imprinted by the outflows on the neutral gas, will appear as characteristics of the ionized nebula as the envelope becomes more fully ionized. The outflow-envelope interactions seen in M1-16 exemplify the shaping mechanism of a wide class of planetary nebulae at early stages of their formation.

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Axisymmetry in proto-planetary nebulae: using imaging polarimetry to investigate envelope structure

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We use ground-based imaging polarimetry to detect and image the dusty circumstellar envelopes of a sample of proto-planetary nebulae (PPNe) at near-infrared wavelengths. This technique allows the scattered light from the faint envelope to be separated from the glare of the bright central star and is particularly well suited to this class of object. We detect extended (up to 9 arcsec diameter) circumstellar envelopes around 15 out of 16 sources with a range of morphologies including bipolars and shells. The distribution of scattered light in combination with its polarization (up to 40 per cent) provides unambiguous evidence for axisymmetry in 14 objects showing this to be a common trait of PPNe. We suggest that the range of observed envelope morphologies results from the development of an axisymmetric dust distribution during the superwind phase at the end of the AGB. We identify shells seen in polarized light with scattering from these superwind dust distributions which allows us to provide constraints on the duration of the superwind phase. In one object (IRAS 19475+3119) the circumstellar envelope has a two-armed spiral structure which we suggest results from the interaction of the mass losing star with a binary companion.

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High resolution spectroscopic study of Abell 78

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High resolution spectroscopic data of the central knots and the outer shell of the planetary nebula Abell 78 are analyzed. Chemical abundances and kinematics were derived for each region. The inner knots appear to be denser and slightly cooler than the outer shell, and they are constituted by an extremely H-deficient material. These knots are receding from the central star with velocities in the range from +40 to −60 km s^{-1} and present cometary structures probably caused by the stellar wind. The outer shell appears to have very low metallicity but we conclude that abundance determinations are probably affected by large temperature fluctuations in the gas, caused by additional heating mechanisms such as shocks by high speed ejecta ans photo-electrons from dust grains, etc. Our kinematical analysis clearly demonstrate that H lines are not emitted in the inner knots but in the outer shell. In the outer zone we have detected a high-velocity compact structure, with veloc! it! ies from −40 to 90 km s^{-1}. This *spike* emits in collisionally excited lines (mainly [O III]), but it is not detected in H or He lines. Therefore, it should consist of a "bullet" of H-deficient material that is colliding with the outer shell.

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