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Abstracts of recently accepted papers

Narrow-band images and spatially-resolved spectroscopy of hydrogen-poor planetary nebulae

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We present new CCD narrow-band images and spatially-resolved intermediate-dispersion spectroscopy of the hydrogen-poor nebulae A 30 and A 58. These data have allowed us to obtain information on the physical properties and chemical abundances of the inner knots and outer envelopes of A 30 and A 58 as a basis for the discussion of their implications in the evolutionary theories. In particular, hydrogen emission from the central knots has been carefully measured and, consequently, the rates of conversion of hydrogen into helium have been established with accuracy.

The rates found indicate that almost all the original hydrogen (between 75% and 95%) has been burnt into helium. The chemical segregation among the knots of A 30 previously suggested by Jacoby & Ford (1983) is confirmed. The A 58 inner knot, which is spatially resolved in two different components, shows evidence of excitation by shocks. Helium abundances and the N/O ratio in the outer envelope of this nebula are very high, therefore indicating that it corresponds to the evolution of an intermediate-mass stars.

An analysis of the chemical abundances, including other objects of the same class, gives some hints that He/H and O/H are anti-correlated. The time elapsed between the formation of the outer envelopes and the ejection of the central knots also seems to be related with the central knots chemical abundances.

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K I emission from envelopes around N-type stars – Spectroscopic observations and interpretations.

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Circumstellar envelopes around three bright N-type stars, R Scl, X TrA, and V Aql have been detected in emission in resonance lines from K I. This radiation, which is most probably scattered photospheric radiation, was first found spectroscopically, but has later been imaged with coronographic and polarimetric techniques. In the present paper, which is the first in a series, the spectroscopic K I observations are discussed.

From the observations of the K I 769.9 nm emission we find systemic and expansion velocities in fair agreement with those obtained from the CO millimetre lines. We find a decline of the emission with distance from the star, in rough agreement with the assumption of a constant expansion velocity, mass-loss rate and K I abundance. Our mass loss rate estimates from the K I line observations agree rather well with those obtained from CO (ranging from 1/4 to 1/1 of the CO mass loss), which suggests that a considerable fraction of the potassium stays neutral through the envelope. This puts strong upper limits on the photoionizing chromospheric UV emission from the stars. Some indirect indications that the envelopes have inhomogeneous structures, clumps, are discussed.

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Circumstellar Hα from SN 1994D and future Type Ia supernovae: an observational test of progenitor models

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Searching for the presence of circumstellar material is currently the only direct way to discriminate between the different types of possible progenitor systems for Type Ia supernovae. We have therefore looked for narrow Hα in a high-resolution spectrum of the normal Type Ia supernova 1994D taken 10 days before maximum and only 6.5 days after explosion. We derive an upper limit of 2.0×10^{-16} erg s^{-1} cm^{-2} for an unresolved emission line at the local H II region velocity. To estimate the limit this puts on wind density, we have made time-dependent photoionization calculations. Assuming spherical symmetry we find an upper limit of $\dot{M} \sim 1.5 \times 10^{-5}$ M$_\odot$ yr^{-1} for a wind speed of 10 km s^{-1}. This limit can exclude only the highest-mass-loss-rate symbiotic systems as progenitors. We discuss the effect of asymmetry and assess the relative merits of early optical, radio and X-ray limits in constraining mass loss from Type Ia progenitors. We find that X-ray observations can probably provide the most useful limits on the progenitor mass loss, while high-resolution optical spectroscopy offers our only chance of actually identifying circumstellar hydrogen.

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Preprints can be obtained by contacting robert@astro.su.se *or via WWW on*
http://www.astro.su.se/~robert/Paper/94D.html *or via anonymous ftp on*
ftp://www.astro.su.se/pub/supernova/clspk96_94D_MN/clspk96_94D_MN.ps.gz

Spectroscopic investigation of the PPN candidate AI CMi = IRAS 07331+0021

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Chemical composition (26 elements) of the cool supergiant AI CMi was studied by the model atmosphere method using echelle spectra taken with the 6 m telescope in 1993–95. Metallicity of the star turns to be by an order of magnitude lower than solar, the abundance of α–process elements (Na, Mg, Al, Si) is on the average $[\alpha/Fe] = 0.33$, the mean abundance of heavy s–process elements (La, Ce, Pr, Nd) is $[s/Fe] = -0.35$.

Together with the radial velocity determination results this permits us to classify AI CMi with halo population or with population of the old (thick) disk. The spectra obtained in 1994 and 1995 contain titanium oxide bands which allowed the outermost AI CMi atmosphere layer characteristics to be estimated. The presence of emission components in hydrogen lines of Balmer and Paschen series is indicative of mass loss with varying rate.

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The evolved central star of the planetary nebula ESO 166−PN 21

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Optical and UV spectrophotometric data of the nebula and the central star of the planetary nebula ESO 166−PN 21 are presented. The analysis of the nebular lines confirms that it is a He- and N-rich PN, with He/H = 0.138 ± 0.005 and N/O = 0.58 ± 0.08. The oxygen abundance is 12 + log O/H = 8.60 ± 0.10. A distance of 1.2 ± 0.2 kpc is derived for the nebula. The central star is very faint and blue, with an apparent magnitude $V = 17.94 \pm 0.03$ mag and a dereddened color index $(B-V)_0 = -0.38$ mag. It shows faint wide H and He absorption lines typical of a DAO star. By modeling the line profiles we derived $T_{eff} = 69\,200 \pm 8\,700$ K, log g = 7.14 ± 0.39 and log He/H = −1.50 ± 0.49 for the star. The position of the star in a HR diagram compared with evolutionary tracks indicates a stellar mass of ~ 0.55 $M_\odot$. The bolometric correction derived from the model atmosphere is −5.6 mag which, combined with the mass, yields an absolute visual magnitude $M_V = 6.95$, a luminosity of 22 $L_\odot$ and a distance of 1 185 ± 700 pc, in good agreement with the nebular distance. Therefore, ESO 166−PN 21 central star is among the hottest and most helium-rich DAO stars and it is one of the most evolved PN nuclei known, similar to the central stars of S 216 and NGC 7293. A kinematical age of 16 100 yr is deduced for the nebula which is lower by about two orders of magnitude than the age of the central star. The possibility that this object is a member of a close binary system is suggested.

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Infrared Light Curves of Carbon-Rich Variables

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Long-term trends in the infrared, JHKL, light curves of various carbon variables are described. Some stars show multiple periodicities, e.g. the semi-regular variables R Scl and GM CMa; others, particularly the Miras with moderately thick dust-shells, show more erratic long-term changes. The light curves for R For, which have been intensively monitored over 20 years, show a pattern which is reminiscent of that seen for R CrB stars. This pattern is superimposed on regular large-amplitude Mira pulsations. The multi-periodic and erratic behaviour of these stars is compared with the predictions from various models.
keywords: Mira variables; Semi-regular variables; mass-loss; dust; infrared.

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Long-term UBV(RI)$_c$ monitoring of 12 southern hemisphere Long Period Variables

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A program of UBV(RI)$_c$ photometric observations of twelve southern hemisphere Long Period Variables (LPV or Miras) has been carried out at the European Southern Observatory. Each star was observed on at least 11 occasions up to 29 over a 4-year period. A determination of their spectral types from the (V-R) and (R-I) colours was also performed using the method described by Celis (1986b). We therefore present for the first time spectral type variations together with visible and colour light-curves for at least three successive cycles. New photometric parameters as visible and spectral type extrema are given. Spectral type variations are found in the range 1.3 - 4.5 subclasses. The variations during a cycle and from cycle-to-cycle are discussed and short-term declines with large amplitude are reported for R Oct and RY Hyi. We finally estimate the distance of these stars using a (M_V^{max},P, Spectral type) relation. It is shown that rather good distances (mean error less than 30 %) can be determined if the period of the stars is known and good UBVRI data are collected at the maximum of luminosity.

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From the tip of the AGB towards a planetary: a hydrodynamical simulation

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Based on the mass-loss description developed by Blöcker (1995, A&A, 297, 727) we present the first attempt to compute the dynamical response of a stellar wind envelope for the last 10^5 years of the AGB evolution and the following 5 000 years of post-AGB evolution for an initially 3 $M_\odot$ stellar model. For the cool envelope we used a two-component 1D hydrodynamical code which computes the radiation pressure on the dust grains and takes the variable coupling between these grains and the gas explicitly into account. The grains are either carbon or oxygen based and of single, spherical shape. At the end of the AGB evolution the density and velocity structure of the wind envelope reflects the previous mass-loss history and differs considerably from that of stationary outflows. No significant differences between carbon and oxygen-rich envelopes are found.

The post-AGB phase has been modelled with a newly developed code that computes the radiation hydrodynamics of interacting winds with fully time-dependent heating and cooling processes, using our previously gained final AGB wind envelope as initial structure. The development of observationally well-known structures of planetaries are the natural consequences of the temporal changes of the surface and wind parameters of the now 0.6 $M_\odot$ central star. We show in particular that the often found double-shell structures are entirely formed by hydrodynamical effects and have nothing to do with the mass-loss history along the upper AGB, contrary to what is often stated in the literature.

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Mid-Infrared Imaging of the Bipolar Nebulae AFGL 618, AFGL 2688, and AFGL 915

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We have obtained nearly diffraction-limited images of three bipolar proto-planetary nebulae: AFGL 618, AFGL 2688 (the "Egg nebula"), and AFGL 915 (the "Red Rectangle"). Images were taken at unidentified infrared (UIR) emission feature wavelengths and at several continuum wavelengths in the 10 and 20 μm atmospheric windows. In all three nebulae the emission is dominated by a central point source. In AFGL 618, evidence for a slight (0.1 – 0.2 arcsec) extension of the core in the E–W direction is seen. In AFGL 2688 and AFGL 915, the cores are extended and fainter emission is detected several arcsec from the central peaks. In AFGL 2688, the mid-IR emission is extended in the same direction as the main optical and near-IR lobes. In AFGL 915, the nebula is seen to follow the optical and near-IR bicone morphology. The "spikes" that have been observed at 2 μm and give the nebula its rectangular appearance are also visible at 10 μm. The UIR feature emission is spatially separate from the central source and is enhanced along the walls of the bicone. In all three nebulae, the direction of largest spatial extension is along the major axis as defined by the optical and near-infrared morphology. Therefore the mid-infrared emission appears to be tracing material in the bipolar outflow regions, rather than detecting structure related to an equatorial density enhancement that presumably is collimating the flow.

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On the Numerical Treatment and Dependence of the Third Dredge-Up Phenomenon

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We present results of an investigation into the behaviour of the base of the convective envelope of models of AGB stars during third dredge-up. We find that the extent, and even presence, of third dredge-up depends critically on the treatment of convection within a stellar structure calculation.

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On the pulsation mode of Mira variables: Evidence from the LMC

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Recent angular diameter measurements for Mira variables suggest that the radii of these stars are very large and consistent with pulsation in the first overtone mode rather than the fundamental mode (Haniff et al. 1995). On the other hand, nonlinear pulsation models of Mira variables suggest that the observed pulsation velocity

amplitudes can only be achieved during fundamental mode pulsation, at least for stellar masses $\leq 2.0 M_{\odot}$. Here, we present some new observations of long period variables (LPVs) in the LMC which show that the LPVs lie on two (K,log$P$) sequences, one sequence being the well-known Mira sequence and the other being a sequence parallel to the Mira sequence but separated from it by $\Delta \log P \sim 0.35$. The LPVs on the Mira sequence have a wide range of amplitudes ($0.1 < \Delta I < 3$) while those on the second sequence have relatively small amplitudes ($\Delta I < 0.5$). The previously known LPVs of large amplitude ($\Delta I > 0.5$) in the LMC lie almost always on the Mira sequence. Theoretical models of LPVs predict a ratio of fundamental to first or second overtone period of $\Delta \log P \sim 0.3$-0.4, and overtone pulsators are expected to have smaller limiting amplitudes than fundamental mode pulsators. Hence, the above observations can be easily understood if the LPVs on the Mira sequence are fundamental mode pulsators while LPVs on the second sequence are overtone pulsators. A second test of the pulsation mode is obtained by computing pulsation periods for model stars on the LMC old giant branch and comparing these periods with those of observed Mira variables. Once again, the fundamental mode pulsators have periods consistent with those seen in the LMC Miras while the overtone periods are too short. The above results strongly suggest that Mira variables are fundamental mode pulsators.

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Big grains in the Red Rectangle?

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We report VLA observations at 3.6 cm, 2 cm and 1.3 cm of the Red Rectangle and Hα spectroscopy of HD 44179, the central binary star in the nebulosity. Emission is detected and all three radio wavelengths, and the source is resolved at 2 cm and 1.3 cm. Convolved to the same beam, the radio spectrum of the inner 0".76 $\times$ 0".49 is characteristic of thermal emission from ionized gas which becomes optically thin near 2 cm. The diameter of the bulk of the ionized gas producing this radio emission is between 1.3×10^{14} cm ($\sim$10 AU) and 2×10^{15} cm ($\sim$100 AU); in this region we estimate that 10^6 cm$^{-3} \leq n_e \leq 4 \times 10^6$ cm^{-3}. The Hα profile has both a wide (200 km s^{-1} full width zero intensity) plateau which is probably associated with a small circumstellar region ($< 10^{13}$ cm or $\sim$1 AU) and a spike (FWHM $\approx$ 20 km s^{-1}) which we suggest is produced in the extended ionized gas ($\geq 10^{14}$ cm) detected at radio wavelengths.

We also detect low surface brightness radio emission at 2 cm and 1.3 cm, but not at 3.6 cm, that is extended well beyond 1" from the source. This extended radio emission has a spectral index between 1.3 cm and 3.6 cm greater than 3.2, and is therefore produced by grains. Our VLA data also indicate that the previously-observed mm-continuum flux cannot result from ionized gas and therefore is emitted by dust. Although uncertain, it is possible that the cm and mm wavelength continuum arise from the same dust in which case there is probably little frequency variation in the emissivity of the dust between 1.3 cm and 0.13 cm. We propose that there is a an orbiting, long-lived gravitationally bound disk of dust grains with radii $\geq$ 0.02 cm.

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The mass and temperature distribution in the protoplanetary nebula M1–92: ^{13}CO interferometric observations

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We present high-resolution ^{13}CO J=1-0 maps of the protoplanetary nebula M1–92, Minkowski's Footprint, obtained with the IRAM interferometer at Plateau de Bure. Previous ^{12}CO J=1-0 maps and single dish observations of the J=1-0, J=2-1, and J=3-2 transitions in both isotopic substitutions are also discussed. The

cartography confirms the axial symmetry and complex structure already found from ^{12}CO data. The gas velocity presents a dominant axial component that increases in absolute value from the center, up to a (deprojected) velocity of 70 km s^{-1}. Most of the observed emission is at velocities clearly above the expected AGB expansion kinematics. This fact, together with a remarkable continuity found along the axis in the structure and velocity of the nebula, is interpreted as showing that the present CO nebula has been shaped by momentum transport from the fast post-AGB flow to the rest of the (AGB) envelope, probably by means of a bow-like shock.

The comparison of the different transitions is used to deduce the physical conditions in the molecular gas. Most of the observed (post-shock) material is found to have a low temperature of about 15 K, indicating that the cooling processes are efficient after the passage of the shock. Typical densities of 3 10^4 – 2 10^5 cm^{-3} are deduced, corresponding to a total gas mass of about 1 solar mass. This high value shows that most of the nebular material is molecular and probed by the CO observations. Therefore, our maps effectively represent the disruption of the AGB envelope by the passage of a shock, allowing a description of the physical conditions present in the nebula during this evolutionary phase.

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Is UU Herculis a post-AGB star?

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In order to understand the evolutionary status of the anomalous supergiant UU Her, the prototype of the class of variable supergiants located at high galactic latitudes, we obtained several high-resolution spectra of this star, with the 6m telescope, over 5 years. This material was used for a search of possible temporal variations of the radial velocity at the different depths in the photosphere and for studying the chemical composition. The average radial velocity $V_r \approx 130\,km/s$ suggests that UU Her belongs to the old population of the Galaxy. No systematic dependence of the velocity on depth of the line formation layer or on ionization and excitation potential is observed. The radial velocity of the Hα absorption differs strongly from the average photospheric velocity.

The iron abundance in the photosphere of UU Her is significantly lower than that of the Sun: $[Fe/H] = -1.32$. The enhancement of nitrogen relatively to iron content $[N/Fe]_\odot = 0.40$ in combination with the carbon underabundance $[C/Fe]_\odot = -0.30$ suggests that only a first dredge-up episode occurred. The Na content is normal relatively to iron, therefore there is no evidence for dredging-up of Ne-Na cycle products. The heavy s-process metals Y, Ba are depleted relative to H and Fe, which again implies that the third dredge-up did not occur.

From the high luminosity ($log\, g \approx 1$), the large radial velocity and the chemical abundance pattern, we conclude that UU Her is a low-mass halo star, but not a post-AGB star.

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Spectrophotometry of Planetary Nebulae. III. IIDS Observations of Compact Nebulae

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We give spectral line intensities, electron temperatures, electron densities, and chemical compositions for 25 compact planetary nebulae observed with the IIDS at Kitt Peak. Several (Ha 3-75, He 2-15, K 3-89, M 1-16, M 2-52, and M 3-28) are found to be especially rich in helium and/or nitrogen (He/H ¿ 0.15; N/O ¿ 1). The results minimally confirm the correlation between N/O and He/H, but also confirm the intrinsic scatter in the relation, as N-rich nebulae can be unenriched in He and vice versa.

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Nucleosynthesis of light elements inside thermally pulsing AGB stars. I: the case of intermediate-mass stars

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The structural and nucleosynthetic evolution of 3, 4, 5, 6 and 7 $M_\odot$ stars with two metallicities ($Z = 0.005$ and 0.02) has been computed in detail, from the early pre-main sequence phase up to the thermally pulsing (TP) AGB phase or the onset of off-center carbon burning. Typically 10 to 20 thermal pulses have been followed for each TP-AGB object. This homogeneous and quite large set of models allows us to present an overview of the thermal pulse properties as well as of the nucleosynthesis accompanying the TP-AGB phase of intermediate-mass stars.

More specifically, after a brief description of the previous evolutionary stages, predictions are given for the isotopic ratios involving C, N, O, Ne, Mg, Al and Si. Also the surface abundances of ^{7}Li, ^{19}F and ^{23}Na are reported. As the asymptotic phase of the thermal pulses has been reached for each star, we also indicate how these abundances will probably evolve until the stars completely loose their envelope, by including the evolution of the nucleosynthesis itself.

This article, in its paper form, has been shortened at a level of roughly 60 % as required by directives coming from the A&A editors. The complete article (50 pages containing 37 figures) is only available in electronic form.

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Chemical composition of optically bright post-AGB stars

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We present a detailed LTE chemical analysis of 10 optically bright F-type post-AGB objects on the basis of the analysis of high-resolution optical spectra and compare the results with similar objects discussed in the literature.

The iron content is low on average, and so confirms the old and hence low-mass nature of the supergiants, with a noticable exception of HD 95767.

We emphasize the fact that the chemical patterns observed are very diverse: several different classes can be distinguished. Only a minor fraction of the objects are conform to standard post third dregde-up theory. Only in HD 187885 (Van Winckel et al., 1996), HD 56126 (Klochkova, 1995) and HD 158616 (this paper) is there conclusive *chemical* evidence that they occur in a post-AGB evolutionary phase : a high total CNO abundance, for HD 187885 a supersolar He content and—above all—a large overabundance of s-process elements.

The other objects, together with other well studied high galactic latitude F-supergiants, display no s-process enhancement but even depletion in some cases. The high N abondance and the mildly enhanced total CNO abundance indicate that the atmospheres of these objects contain a mixture of CNO-cycled material and He-burning products. For some sources, however, this enhancement of the total CNO abundance is barely significant.

HD 107369, the only object in our sample with neither H_α, emission nor observed IR excess, displays also unique chemical patterns among our sample stars (a C deficiency coupled with a moderate Fe depletion of [Fe/H] = $-$ 1.1). This star is the only object in our sample showing similar chemical patterns to the metal poor B stars at high galactic latitude (Conlon et al., 1993). Our chemical analysis does therefore not point to an evolutionary connection between the dusty high-latitude supergiants and the metal-poor B stars, but rather suggests that the latter evolve from stars such as HD 107369.

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Really Cool Stars at the Galactic Center

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New and existing $K-$band spectra for 19 Galactic center late–type stars have been analyzed along with representative spectra of disk and bulge M giants and supergiants. Absorption strengths for strong atomic and molecular features have been measured. The Galactic center stars generally exhibit stronger absorption features centered near Na I (2.206 microns) and Ca I (2.264 microns) than representative disk M stars at the same CO absorption strength.

Based on the absolute $K-$band magnitudes and CO and h2o absorption strengths for the Galactic center stars and known M supergiants and asymptotic giant branch (AGB) stars, we conclude that only IRS 7 must be a supergiant. Two other bright stars in our Galactic center sample are likely supergiants as well. The remaining bright, cool stars in the Galactic center that we have observed are most consistent with being intermediate mass/age AGB stars. We identify five of the Galactic center stars as long period variables based on their $K-$band spectral properties and associated photometric variability. Estimates of initial masses and ages for the GC stars suggest multiple epochs of star formation have occurred in the Galactic center over the last 7–100 Myr.

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Dust formation in winds of long-period variables IV. Atmospheric dynamics and mass loss

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We have calculated radiation-hydrodynamical models of the atmosphere and circumstellar dust shell of C-rich long-period variables which include a detailed description of the dust formation process. We discuss the time-dependent behaviour of the circumstellar envelope (e.g. multiperiodicity) and its relevance for observational properties like near-IR light curves and investigate the time-averaged mass loss characteristics of a sample of models satisfying radius–luminosity–mass and period–luminosity relations. The results can be summarized as follows: The dependence of the mass loss rate on stellar parameters predicts a strong increase of mass loss as stars evolve along the AGB. The models presented agree reasonably well with mean mass loss–period relations deduced from observations of Mira stars and the observed scatter of mass loss rates for a given period can be

understood in terms of pulsation amplitude or non-linearities of the wind mechanism. The wind velocities show a good correlation with the quantity $(\rho_d/\rho_g)\, L_\star/M_\star$ which characterizes the strength of radiation pressure on dust relative to gravitation.

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Meetings

First Announcement

A UMIST/CCP7 Workshop on

DUST AND MOLECULES IN EVOLVED STARS

24-27 March 1997

UMIST, Manchester - UK

(Organisers: I. Cherchneff & T.J. Millar)

Aim of the workshop: ——————-

Late stages of evolution of low- and high-mass stars are characterized by very different circumstellar environments, but observations of these objects at optical, infrared and millimetre wavelengths often reveal the presence of the same type of solid compounds and molecular species. The aim of this workshop is to gather scientists working on late stages of stellar evolution to discuss the nature and the role of dust and molecules in evolved objects and to address and answer fundamental questions such as how the same type of solid compounds and molecular species can form in very different astrophysical environments.

A large fraction of the Infrared Space Observatory ISO mission is dedicated to the study of evolved objects and the workshop will be an opportunity to present new and exciting ISO results on circumstellar matter related to late stages of stellar evolution.

Invited reviews: ——————

- R. Bachiller (OAN, Spain) Chemical Evolution from the AGB to the Planetary Nebula Phase
- M. Barlow (UCL, UK) ISO LWS Observations of Molecules and Dust in Evolved Stars and Nebulae
- I. Cherchneff (UMIST, UK) Forming Dust in Hydrogen-Deficient Stellar Winds
- D.D. Clayton (Clemson, USA) Isotopically Anomalous Dust from Supernovae
- A. Dalgarno (CfA, USA) Molecules and Dust in Supernovae
- A. Evans (Keele, UK) Dust and Molecules in Novae Environments
- D. Field (Bristol, UK) To be confirmed
- M. Jura (UCLA, USA) Dust in Discs and Outflows around Mass-Losing Stars
- H. Olofosson (Stockholm, Sweden) Molecular Line Observations of Envelopes around AGB stars
- P. Sarre (Nottingham, UK) Optical and IR Spectroscopy of Molecules in Circumstellar Environments
- E. Sedlmayr (Berlin, Germany) Dust Formation in LPVs

- M. Steffen (Potsdam, Germany) To be confirmed
- X. Tielens (NASA/Ames, USA) Circumstellar Dust
- K. van der Hucht (SRON, Physical Properties of Wolf-Rayet Winds as The Netherlands) Observed from Gamma to Radio Wavelengths
- P.M. Williams (ROE, UK) Formation of Dust in Hostile Environments - What We Learn from Wolf-Rayet Stars

If you are interested in participating, please contact :

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