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Abstracts of recently accepted papers

A Mid-Infrared Imaging Survey of Proto-Planetary Nebula Candidates

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We present the data from a mid-infrared imaging survey of 66 proto-planetary nebula candidates using two mid-IR cameras (MIRAC2 and Berkcam) at the NASA Infrared Telescope Facility and the United Kingdom Infrared Telescope. The goal of this survey is to determine the size, flux, and morphology of the mid-IR emission regions, which sample the inner regions of the circumstellar dust shells of proto-planetary nebulae. We imaged these proto-planetary nebulae with narrow-band filters ($\Delta\lambda/\lambda \sim 10\%$) at wavelengths of notable dust features. With our typical angular resolution of 1", we resolve 17 sources, find 48 objects unresolved, and do not detect 1 source. For several sources, we checked optical and infrared associations and positions of the sources. In table format, we list the size and flux measurements for all the detected objects and show figures of all the resolved sources. Images for all the detected objects are available on line in FITS format from the Astronomy Digital Image Library at the National Center for Supercomputing Application. The proto-planetary nebula candidate sample includes, in addition to the predominant proto-planetary nebulae, extreme asymptotic giant branch stars, young planetary nebulae, a supergiant, and a luminous blue variable. We find that dust shells which are cooler (T $\sim$ 150 K) and brighter in the infrared are more easily resolved. Eleven of the seventeen resolved sources are extended and fall into one of two types of mid-IR morphological classes: core/elliptical or toroidal. Core/elliptical structures show unresolved cores with lower surface brightness elliptical nebulae. Toroidal structures show limb-brightened peaks suggesting equatorial density enhancements. We argue that core/ellipticals have denser dust shells than toroidals.

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

AGB circumstellar envelopes: molecular observations

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Due to the low excitation requirements and easy observation from the ground, molecular line observations probably constitute our main source of empirical knowledge on circumstellar envelopes (CSEs) around AGB stars. The CO rotational transitions, the most intense 'thermal' lines, are efficiently used to determine the total gas content and its spatial distribution in wide samples of objects. Thermal emission from other molecules is mainly useful in order to study their abundances and the chemical reactions taking place in CSEs. Maser lines are easily observed due to their high intensity and the flux distribution in very compact spatial spots and narrow profile spikes, characteristic of the exponential amplification; however the data interpretation is difficult due to the intricate pumping processes. The most important maser lines (of SiO, H_2O and OH) arise from very different regions, which allows the study of various components of the CSEs. We will focus here on SiO masers.

Invited review presented at IAU Symp. 191, 'AGB Stars'; edited by T. Le Bertre, A. Lèbre and C. Waelkens and published in the IAU Symp. Series by the Astronomical Soc. of the Pacific
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The nature of the circumstellar CO_2 emission from M giants

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The $13-16\mu$m region observed by the Infrared Space Observatory (ISO) of several ABG stars are discussed. We present and analyse spectra of seven M giants which show carbon dioxide features. To explain the features of the bands, we suggest they originate from two different circumstellar layers, one being a warm and high density layer close to the star, possibly making the 15μm band optically thick, and the other being a large, cold and optically thin layer extending far out in the wind. This could explain the difference in temperatures of the different bands found in the analysis of the spectra and the number of molecules needed for the emission.

It is demonstrated that in spite of the bands probably not being formed in vibrational LTE, the temperatures can be estimated from the widths of the bands.

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Radio Continuum and Recombination Line Observations of the Polypolar Planetary Nebula NGC 2440

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H92α and He92α recombination lines and λ3.6 cm continuum observations have been carried out with the Very Large Array (synthesized beam $6.8'' \times 4.2''$, PA 74deg) toward the polypolar planetary nebula NGC 2440. The H92α and He92α lines have been detected, for the first time in this nebula, over a region of $\theta \simeq 14''$ around its geometric center. The λ3.6 cm continuum emission is detected over a region of $\simeq 65'' \times 40''$, similar in extent to the optical emission. Physical parameters of the nebula have been derived for the region where the recombination lines were detected. From the line to continuum ratio an electron temperature of $\sim$ 14000 K and a single ionized helium abundance $Y^+ \simeq 0.14$ are obtained. A relative extinction map of NGC 2440 has also been obtained from the ratio of the λ3.6 cm continuum and Hα images. A higher relative extinction in the central region traces the dense and dusty environment of a central 'toroid'. The velocity field obtained from the H92α line indicates that the central toroidal structure has a disrupted, non-circular shape. The polypolar characteristics of this nebula are discussed and compared with those of similar objects.

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Multi-wavelength imaging and long-slit spectroscopy of the planetary nebula NGC 6884: the discovery of a fast precessing, bipolar collimated outflow

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We present Hα, [N II]λ6583, [O III]λ5007 ground-based images, HST (V-band) archival images, VLA-A 3.6 cm continuum data, and high-resolution long-slit spectra of the planetary nebula NGC 6884. The VLA and HST images show an extremely knotty and filamentary nebula with an elliptical central structure also recognizable in Hα and [O III]. The [N II] image is different and is dominated by two bright arc-like structures. The image ratio maps indicate a complex ionization structure within the nebula with low-excitation filaments surrounded by high excitation regions.

The spectra allow to distinguish three basic structural components in NGC 6884: (1) a compact (3.8"×2.8", PA $\simeq 32°$), high excitation ([N II]λ6583/H$\alpha \leq 0.15$) ellipsoidal shell seen almost pole-on with polar and equatorial expansion velocities in the Hα line of $\simeq 25$ and $\simeq 19$ km s^{-1}, respectively; (2) two point-symmetric, low-excitation ([N II]/H$\alpha \simeq 0.6$–1) spirals in which the distance to the central star and the radial velocity exhibit systematic variations; (3) two compact, apparently isolated, low-excitation bipolar knots. All data agree that the spirals represent precessing bipolar jet-like outflows. The observational properties of these precessing outflows can satisfactorily be explained with an approximately constant ejection velocity ($\simeq 55$ km s^{-1}) and a large precession angle ($2\phi \simeq 120°$). The deduced precession period ($\simeq 500\times$[D(kpc)/2] yr) is the shortest one measured so far in this kind of structures in planetary nebulae. The image ratio maps and the [N II]/Hα intensity ratio suggest shock-excitation in the precessing jets. A general discussion of NGC 6884 is presented within the context of planetary nebulae with jet-like components.

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Late-type giants with infrared excess I.: Lithium abundances

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de la Reza et al. (1997) suggested that all K giants become Li-rich for a short time. During this period the giants are associated with an expanding thin circumstellar shell supposedly triggered by an abrupt internal mixing mechanism resulting in the surface Li enrichment. In order to test this hypothesis twenty nine late-type

giants with far-infrared excess from the list of Zuckerman et al. (1995) were observed in the Li-region to study the connection between the circumstellar shells and Li abundance. Eight giants have been found to have log ϵ(Li) > 1.0. In the remaining giants the Li abundance is found to be much lower.

HD 219025 is found to be a rapidly rotating (projected rotational velocity of 23 ± 3 km s^{-1}), dusty and Li-rich (log ϵ(Li) $= 3.0 \pm 0.2$) K giant. Absolute magnitude derived from the Hipparcos parallax reveals that it is a giant and not a pre-main-sequence star. The evolutionary status of HD 219025 seems to be similar to that of HDE 233517 which is also a rapidly rotating, dusty and Li-rich K giant.

The Hipparcos parallaxes of all the well studied Li-rich K giants show that most of them are brighter than the "clump" giants. Their position in the H-R diagram indicates that they have gone through mixing and the initial abundance of Li is not preserved. There seems to be no correlations between Li abundances, rotational velocities and carbon isotope ratios. The only satisfactory explanation for the overabundance of lithium in these giants is the creation of Li by the extra deep mixing and the associated "cool bottom processing".

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The rapid evolution of the born-again giant Sakurai's object

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The extraordinarily rapid evolution of the born-again giant Sakurai's object following discovery in 1996 has been investigated. The evolution can be traced both in a continued cooling of the stellar surface and dramatic changes in chemical composition on a timescale of a mere few months. The abundance alterations are the results of the mixing and nuclear reactions which have ensued due to the final He-shell flash which occurred during the descent along the white dwarf cooling track. The observed changes in the H and Li abundances can be explained by ingestion and burning of the H-rich envelope and Li-production through the Cameron-Fowler mechanism. The rapidly increasing abundances of the light *s*-elements (including Sc) is consistent with current *s*-processing by neutrons released from the concomitantly produced ^{13}C. However, the possibility that the *s*-elements have previously been synthesized during the AGB-phase and only mixed to the surface in connection with the final He-shell flash in the pre-white dwarf cannot be convincingly ruled out either. Since Sakurai's object shows substantial abundance similarities with the R CrB stars and has recently undergone R CrB-like visual fading events, the "birth" of an R CrB star may have been witnessed for the first time ever. Sakurai's object thus lends strong support for the suggestion that at least some of the R CrB stars have been formed through a final He-shell flash in a post-AGB star.

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or via WWW on http://xxx.soton.ac.uk/abs/astro-ph/9811208

Long-term evolution of AGB wind envelopes: Insights from hydrodynamical models

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Up to now, *hydrodynamical* models of dust-driven AGB winds do *not* generally take into account the 'long-term' changes of the stellar parameters (on stellar evolution time scales of 10^3 to 10^5 yrs), although it is well known that the luminosity and (very likely) the *mass loss rate* undergo significant variations when so called 'thermal pulses' occur on the upper AGB. In this review we demonstrate that time-dependent radiation hydrodynamics calculations are needed to understand the formation, structure, and spectral energy distribution of detached *dust* shells detected by IRAS and ISO. Combined with appropriate models, these observations can reveal part of the previous mass loss history on the AGB and allow an empirical check of presently adopted mass loss laws.

Based on insights from hydrodynamical simulations, we discuss the two competing scenarios that have been put forward to explain the origin of the very thin molecular shells recently discovered around some carbon stars. We find that the signature of a short *mass loss 'eruption'* broadens quickly with time due to the related velocity gradient across the shell. Hence, this scenario is not considered a likely explanation of detached CO shells. On the other hand, the alternative mechanism, *interaction of winds*, is shown to be capable of producing very thin shells of greatly enhanced gas density in the dusty outflows from AGB stars by sweeping up matter at the interface between both type of winds.

Invited review, IAU Symp. No. 191 on AGB stars (Montpellier 1998)
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Unravelling the structure of aspherical protoplanetary nebulae. I. *HST* imaging and OH maser-line observations of Roberts 22.

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We have obtained high-resolution wide-band, narrow-band and polarimetric images of the bipolar protoplanetary nebula Roberts 22 with the Wide-Field & Planetary Camera 2 on HST. OH maser-line emission has also been observed using the Australia Telescope Compact Array. The wide-band images at 0.6 μm show bright bipolar lobes shaped like a butterfly's "wings", separated by a dark equatorial "body" of dense dust which completely obscures the central star. The material within each lobe appears to be organized into an amazingly complex pattern of a very large number of intersecting loops and filaments. The bright lobes are surrounded by a fainter halo whose inner region contains multiple thin shell structures, reminiscent of those seen in the prototype protoplanetary nebula, CRL2688 (Egg Nebula). The halo can be traced to a distance of about 25$''$ from the nebular center. The radial surface brightness of the halo is inconsistent with that expected for time-invariant mass-loss at a constant expansion velocity. A simple model of the radial scattered light distribution supports the hypothesis that the bright lobes are cavities with thin ($<0''.5$), dense walls which are optically-thick in scattered light. The amount of mass in the cavity walls is quite large ($0.3 M_\odot$) and the dynamical time-scale for their formation is short ($\lesssim$440 yr). The bright lobes show high fractional polarisation (40-50%) and a centro-symmetric polarisation pattern, typical of a singly-scattering reflection nebula. In contrast, the polarisation in the dark equatorial region is small, and the polarisation vectors do not show a simple orientation pattern. The polarisation data has been compared with published models to set rough constraints on the dust albedo and

scattering phase function and the nebular optical depths. The OH maser-line emission at 1665 and 1667 MHz is found to be concentrated in the the dark equatorial region; the kinematics of the OH features indicates that they arise in low-latitudes outflows. The nebular morphology in Roberts 22 is characterised by a high degree of point-symmetry, which may result from the interaction of collimated bipolar outflows with the progenitor AGB envelope.

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Spectroscopic Observations of the Planetary Nebula NGC 6818

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NGC 6818 is a bright, high excitation, fairly regular, planetary nebula with a rather rich spectrum. Its rather unusual kinematical structure, studied by Wilson, Weedman, and particularly by Sabbadin are of special interest. We are here primarily concerned with its high resolution spectrum as revealed by the Hamilton Echelle Spectrograph at Lick Observatory (resolution $\sim$0.2Å) and supplemented by UV and IR data. These extensive data permit a determination of interstellar extinction, plasma diagnostics, and ionic concentrations.

Establishing the chemical composition requires finding the ionization correction factors which may be estimated empirically for only a few elements. In general we rely on a composite theoretical model. The chemical composition appears to be unremarkable. C and N appear to be more abundant than in the sun. Most other elements seem to have roughly a solar abundance except for those depleted by grain formation. NGC 6818 may have originated from a star resembling the sun at least in chemical composition.

The central star is rather faint and possibly of the Wolf-Rayet type. Comparisons with model predictions suggest a L($\star$) of about 3,500 L($\star$) and T($\star$) of at least 140,000 K. Comparison with theoretical tracks suggests an age of about 9000 years. Spectroscopic studies show that the bright shell appears to consist of tangentially moving filaments of differing excitation, a complication that may explain why theoretical nebular models have difficulties.

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Preprints can be obtained by contacting hyung@astro.ucla.edu or hyung@hanul.issa.re.kr *or via anonymous ftp on* ftp://eggneb.astro.ucla.edu/pub/submit/hyung/

Carbon molecules in the inner wind of the oxygen-rich Mira IK Tauri

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The gas-phase non-equilibrium chemistry of the inner wind of the oxygen-rich Mira variable IK Tau (NML Tau) is investigated using a physio-chemical model describing the periodically shocked gas close to the stellar photosphere. We predict the formation in large amounts of a few carbon species in the inner envelope, in particular CO_2, which has been recently detected with ISO in the spectra of several oxygen-rich semi-regular and Mira stars. The theoretical abundances are also in excellent agreement with values derived from millimeter

and sub-millimeter observations, pointing to the fact that some carbon species in oxygen stars do form from shock chemistry in the inner layers and travel the envelope as "parent" species.

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The chemistry of carbon dust formation

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We shall review the various types of chemistry involved in the formation of carbonaceous material present in carbon-rich AGB stars, mainly amorphous carbon, silicon carbide and other metal carbides discovered in pre-solar stardust extracted from meteorites. The chemistry is discussed in the context of laboratory experiments and their application to circumstellar AGB winds. Emphasis is put on polycyclic aromatic hydrocarbons (PAHs), titanium carbide clusters and silicon carbide grains. Attempt to explain the condensation sequences derived from the study of pre-solar grains of meteoretical origin is made on the basis of physio-chemical models which describe the periodically shocked gas close to the photosphere of AGB stars.

A review presented at the IAU Symp. 191: AGB Stars, August 1998

Preprints can be obtained by contacting imc@europa.phy.umist.ac.uk

Thesis Abstracts

Evolution of late stages of intermediate mass stars: Mixing processes and their consequence for stellar evolution and nucleosynthesis

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Thesis work conducted at: Astrophysical Institute Potsdam (AIP) and University of Kiel (Germany)

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The structure, nucleosynthesis and evolution of intermediate and low mass stars is studied from the main sequence to the thermal pulse (TP) AGB phase by means of numerical stellar evolution computations. In particular three main uncertainties of current models have been addressed: (1) The conditions under which material of the intershell region (between hydrogen- and helium-burning shell) can reach the surface by convective mixing (third dredge-up), (2) the nature of the neutron source for the s-process nucleosynthesis in AGB stars of lower core mass and (3) the origin of the observed abundance patterns of hydrogen deficient post-AGB stars (PG1159 and [WC]-CSPN) which may be related to the abundances in their progenitors (AGB star) intershell.

For the purpose of stellar modeling convectively unstable regions can be described conveniently by the mixing length theory. However, the discontinuities of the isotope abundance profiles which follow from the application of the Schwarzschild criterion are both for theoretical as well as for observational reasons questionable. Hydrodynamic simulations, e.g. of shallow surface convection zones, show that characteristic downdrafts and plumes extend into the stable region which evolve from turbulent structures in the unstable region. The mixing of material due to these downdrafts can be described by a diffusion process. The velocity field of the turbulent motions decays exponentially beyond the convective boundary. These findings have motivated to extend mixing beyond the convective boundary according to a parameterized exponentially declining diffusion coefficient. In practise this treatment leads to overshoot where the mixing efficiency in the stable region decreases with geometrical distance from the convective boundary.

This new treatment of mixing at convective boundaries has been applied to all convectively unstable regions for new stellar evolution model sequences. The structural and chemical model evolution during the stages which precede the AGB are overall very similar compared to existing computations which include instantaneous overshoot (e.g. prolonged main-sequence evolution). However, the application of exponential diffusive overshooting to TP-AGB models leads to clear improvements with respect to the above mentioned uncertainties. Overshoot at the bottom boundary of the envelope convection zone causes a continuous (although still sharp) transition of the abundance distribution from the envelope to the core. Thus, the opacity discontinuity, which often prohibits effective third dredge-up, is removed. Overshoot below the pulse-driven convection zone which forms during a TP leads to an enrichment of this region with ^{12}C and ^{16}O while the ^{4}He abundance is reduced [(^{4}He/^{12}C/^{16}O)=(0.40/0.40/0.16) in mass fractions compared to (^{4}He/^{12}C/^{16}O)=(0.70/0.26/0.01) for calculations without overshoot]. These new intershell abundances are in agreement with the observed surface abundances of above mentioned post-AGB stars. Therefore, these models may be a significant step towards the final modeling of such stars. It has also been found that the changes of the intershell abundances lead to an enhancement of the third dredge-up because the opacity is increased as a result of the smaller ^{4}He abundance. E.g. for the $M_{\rm ZAMS} = 3{\rm M}_{\odot}$ TP-AGB sequence third dredge-up starts at the third TP with steadily increasing efficiency until $\lambda \approx 1$ is reached at the tenth TP where the efficiency levels. At this TP the stellar model also becomes carbon rich.

Another consequence of the new treatment of mixing at convective boundaries is the formation of a so-called ^{13}C pocket at the interface of the hydrogen rich convective envelope and the stable ^{12}C rich intershell region. When the bottom of the envelope convection has reached its deepest extend during the dredge-up, the partial mixing in the overshoot region, leads to a zone where protons and ^{12}C coexist. In the further course of the pulse cycle the ^{13}C that has formed via the nuclear reactions $^{12}{\rm C}({\rm p},\gamma)^{13}{\rm N}({\rm e}^{+}\nu)^{13}{\rm C}$ can release a neutron as a result of an α-capture ($^{13}{\rm C}(\alpha,{\rm n})^{16}{\rm O}$). These neutrons are a crucial prerequisite for the production of trans-iron elements in AGB stars.

The different treatment of mixing at the convective boundaries has also consequences for the structural evolution. Models sequences with efficient third dredge-up do not follow the well known linear Paczyński core mass - luminosity relation. This refers to the range of core masses which are usually not associated with hot bottom burning, like the $M_{\rm ZAMS} = 3{\rm M}_{\odot}$ case.

Finally, some comparison between observed and model isotopic abundance ratios is given which also demonstrates the differences of the new models compared to models without overshoot during the AGB stage.

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