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Abstracts of recently accepted papers

Detection by *ISO* of the far-infrared OH maser pumping lines in IRC+10° 420

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The population inversions which lead to circumstellar hydroxyl (OH) maser emission from cool stars have long been thought to be radiatively pumped (Elitzur, Goldreich & Scoville 1976). However, the proposed pumping mechanism has not been directly observed before now, because the spectral lines which correspond to the rotational transitions of the pumping cycle lie in the far-IR, and are unobservable from the ground.

We present *iso* observations of IRC+10420, obtained with its Short and Long Wavelength Spectrometers (SWS and LWS, respectively). This object is an F-type hypergiant and a strong OH maser source. The SWS spectrum clearly shows the 34.6-μm doublet in absorption, and the ensuing rotational cascade lines at 98.7, 163 and 79 μm are clearly detected in emission in the LWS spectrum. These spectra provide the first direct confirmation of the radiative pumping cycle for circumstellar OH masers.

Accepted by MNRAS

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Chemical Evolution from the AGB to the Planetary Nebula Phase

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An overview is given on the wealth of data recently provided by large mm-wave radiotelescopes on AGB stars, planetary nebulae (PNe), and transition objects. The observations reveal that there is an observable chemical evolution in the neutral gas as a star evolves beyond the AGB, through the proto-PN and PN phases. Significant changes in the abundances of some key molecules (such as CS, CN, HCO^+, HCN, and HC_3N) take place during the fast evolution of the envelopes. Chemistry can thus be used as a rough clock to date the evolutionary stage of post-AGB envelopes and proto-PN objects. However, once the PN is formed, the observed abundances in the molecular clumps of the envelope remain relatively constant. The chemical evolution of the molecular envelopes likely occurs through the development of photon-dominated regions produced by the ultraviolet field of the central star. The main chemical processes which likely control the evolution are also reviewed.

Symposium on "Dust and molecules in evolved stars", Manchester, 1997 (Invited review).

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IRAS 06562−0337, the Iron-clad Nebula: a young star embedded in a molecular cloud

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We present millimeter and sub-millimeter observations of IRAS 06562−0337, the so-called Iron-clad Nebula. It had been suggested previously that this object could be an evolved star in the transitional phase between the AGB and a planetary nebula. However, our observations show that this IRAS source lies at the center of a dense massive molecular cloud which exhibits strong lines of CO, ^{13}CO, CS, and CI. The close association of the source with this molecular cloud, the proximity to other molecular complexes, the infrared spectral energy distribution, and the main characteristics of the previously observed optical spectra, imply that IRAS 06562−0337 is a young stellar object (or a small cluster) still associated to its parent molecular cloud. IRAS 06562 is placed at 7±3 kpc from the Sun, in the anticenter direction. Its location in the Galaxy, at about 15 kpc from the galactic center, makes the object particularly interesting for studies of galactic structure.

Accepted by Astronomy and Astrophysics.

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Hubble Space Telescope Observations of Planetary Nebulae in the Magellanic Clouds VI: Cycles Four and Five Ultraviolet Spectroscopy Using the Faint Object Spectrograph

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The Faint Object Spectrograph on board the Hubble Space Telescope is used to obtain spectra in the wavelength range $\lambda\lambda$1150–4800 of 3 planetary nebulae in the Small Magellanic Cloud and 10 planetary nebulae in the Large

Magellanic Cloud. This sample extends the sample of 12 objects previously observed with HST and reported in Paper III of this series. Observed and dereddened emission line fluxes are presented. Reddening estimates from the He II λ1640/λ4686 flux ratio are generally up to 0.2 dex lower than the reddening derived from the Balmer decrement. Nebular temperatures are estimated from the N^+ $\lambda\lambda$2138, 2142/$\lambda\lambda$6548, 6583 flux ratio. Nebular densities are calculated from the O IV] complex at λ1400, the N IV] $\lambda\lambda$1483, 1487 doublet, and the Si III] $\lambda\lambda$1883, 1892 doublet. Densities calculated using the oxygen lines are comparable to those determined from the optical lines. Densities calculated from the nitrogen lines show a scatter of over 3 dex, which is relatively large compared to the optically derived densities. Three of the five densities derived from the silicon lines are greater than 10000 cm^{-3}. The C^{+2}/O^{+2}, Si^{+2}/C^{+2}, and N^{+2}/O^{+2} ionic abundance ratios are calculated using the available ultraviolet emission features. The C/O and N/O ratios are anticorrelated, which supports the premise that third dredge-up has taken place during the asymptotic giant branch phase. In contrast to Paper III, Type I classification does not imply the presence of Si III] emission. Three objects show P-Cygni-like line profiles at C IV $\lambda\lambda$1548, 1551, indicative of stellar winds.

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Infrared Identification of SiO Maser Sources toward the Sgr B2 Molecular Cloud

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J, H, and K imaging observations have been made in order to identify infrared counterparts for 6 new SiO maser sources toward the Sgr B2 molecular cloud. Only two of these 6 new sources were previously identified with known objects in other catalogues: one with an OH/IR object, another with an IRAS point source. With the imaging observations, we find infrared counterparts for four of the objects: #1, #2, #4, and #7. These are late-type stars either nearby or near to the galactic center. The remaining two sources of which we could not find counterparts can be candidates of young stellar objects with SiO masers. However, it is highly possible that these two are late-type stars located behind the galactic-center molecular cloud, suffering from very high dust extinction. **Accepted by PASJ (Vol. 49, No. 5, 1997 in press)**

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Detection of short–term variations in Mira–type variables from Hipparcos photometry

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The Hipparcos photometric observations carried out over 37 months have been investigated in detail for ∼250 Miras. This leads to an unexpected by–product of the mission that we already suspected from ESOC real–time reductions: the first detection from space of photometric short–term brightness variations in Mira–type variables. Altogether, 51 events in 39 M–type Miras are detected and no similar variations are found for S and C–type Miras. Their amplitude ranges from 0.23 mag up to 1.11 mag and their duration extends from 2 hours up to almost 6 days. These events seem to occur preferentially in late spectral types. We suggest that they might be related to molecular opacity effects.

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Spectral analyses of late-type [WC] central stars of planetary nebulae: more empirical constraints for their evolutionary status

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The optical spectra of the five recently observed late-type Wolf-Rayet central stars He 2–459 ([WC8]), M 2–43 ([WC8]), SwSt 1 ([WC9]), PM 1–188 and IRAS 21282+5050 (both [WC11]) are analyzed by means of spherically expanding model atmospheres. The stellar parameters T_* (effective temperature), v_∞ (final velocity of the wind), R_* (stellar radius) and $\dot{M}$ (mass loss rate) are determined by NLTE simulations which account for the elements hydrogen, helium, carbon and oxygen. With two exceptions (SwSt 1 and IRAS 21282) the results presented here fit into the sample of already examined [WCL]-type objects. Altogether 13 out of 17 known [WCL]-CSPN have been analyzed so far. The presence of hydrogen in the atmospheres of [WC11] and [WC12] stars becomes more and more evident. In five out of seven analyzed objects of these subtypes hydrogen emission features of stellar origin can be identified.

The spectra of the latest subtypes ([WC11], [WC12]) show rather narrow lines and thus allow to detect features of nitrogen (N II, N III), neon (Ne I) and silicon (Si III, Si IV). For the first time we present model calculations accounting for these elements and perform abundance estimates for the eight narrow-lined stars (all [WC11] and [WC12] plus SwSt 1). The obtained surface compositions are discussed in the light of recent evolutionary calculations which account for diffuse mixing during thermal pulses at the Asymptotic Giant Branch.

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The survival of ^{205}Pb in intermediate-mass AGB stars

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The now extinct ^{205}Pb is a pure s-process radionuclide ($t_{1/2} = 1.5\ 10^7$ y) of possible substantial cosmochemical interest. As a necessary complement to the detailed theoretical study of the nuclear physics and astrophysics aspects of the ^{205}Pb - ^{205}Tl pair carried out by Yokoi et al. (1985), and to the recent calculation of the ^{205}Pb production in Wolf-Rayet stars by Arnould et al. (1997), this paper addresses for the first time in some detail the question of the survival of this radionuclide in thermally pulsing AGB stars. This problem is made difficult by the high sensitivity to temperature and density of the rates of the weak interaction processes that are able to produce or destroy ^{205}Pb. In view of this sensitivity, a recourse to detailed stellar models is mandatory. With the help of some simplifying assumptions concerning in particular the third dredge-up characteristics, some of which (like its depth) being considered as free parameters, predictions are made for the ^{205}Pb contamination of the stellar surface at the end of a pulse-interpulse cycle following a series of a dozen of pulses in three different intermediate-mass stars ($M = 3\,M_\odot, Z = 0.02$; $M = 6\,M_\odot, Z = 0.02$; $M = 3\,M_\odot, Z = 0.001$). It is concluded that the chances for a significant ^{205}Pb surface enrichment are likely to increase with M for a given Z, or to increase with decreasing Z for a given M. More specifically, following the considered pulses at least, the enrichment appears to be rather unlikely in the $3\,M_\odot$ star with $Z = 0.02$, while it seems to be much more probable in the other two considered stars. It is also speculated that the ($3\,M_\odot, Z = 0.02$) star could possibly experience some ^{205}Pb enrichment following later pulses than the ones considered in this paper.

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The shock structure in the protoplanetary nebula M1–92: imaging of atomic and H_2 line emission

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We present *HST* imaging of continuum (5500 Å) and atomic line (Hα, [OI] 6300 Å, [SII] 6717 and 6731 Å, and [OIII] 5007 Å) emissions in the protoplanetary nebula M1–92. Ground based imaging of 2μm continuum and H_2 ro-vibrational (S(1) v=1-0 and v=2-1 lines) emission has been also performed. The 5500 Å continuum is due to scattering of the stellar light by grains in a double-lobed structure comparable in extent and total density with the molecular envelope detected at mm wavelengths, which consists of two empty shells with a clear axis of symmetry. On the other hand, the optical line emission comes mainly from two chains of shocked knots placed along the symmetry axis of the nebula and inside those cavities, for which relatively high excitation is deduced (shock velocities of about 200 km/s). The H_2 emission probably comes from more extended regions with representative temperature and density of 1600 K and 6 10^3 cm^{-3}, intermediate in location and excitation between the atomic line knots and the very cold region detected in CO emission. We argue that the chains of knots emitting in atomic lines correspond to shocks taking place in the post-AGB bipolar flow. The models

for interstellar Herbig-Haro objects seem to agree with the observations, at least qualitatively, explaining in particular that the atomic emission from the bipolar flow dominates over that from shocks propagating in the AGB shell. Models developed for protoplanetary nebula dynamics fail, however, to explain the strong concentration of the atomic emission along the symmetry axis.

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Near-infrared narrow-band photometry of M–giant and Mira stars: models meet observations

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From near-infrared, narrow-band photometry of 256 oxygen-rich Mira variables we obtain evidence about the loops that these stars follow in colour–colour diagrams. We also find a phase lag between indices related to molecular band-strength of titanium oxide and vanadium oxide. We compute colours for normal M–giants and Miras using hydrostatic and hydrodynamic model atmospheres and very extensive up-to-date line lists. Normal M–giants colours are well reproduced, reaching a high quantitative agreement with observations for spectral types earlier than M7. The out-of-phase variations of the various spectral features of Miras are also acceptably reproduced, despite limitations in the modelling. This enables us to confirm that the phase lag phenomenon results from the propagation of perturbations in the extended atmosphere. It opens new perspectives in the spectral modelling of Miras.

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Photo-evaporation of clumps in Planetary Nebulae

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We study the evolution of dense neutral clumps located in the outer parts of planetary nebulae. These clumps will be photo-ionized by the ionizing radiation from the central star and change their structure in the process. The main effect of the ionization process is the setting up of a photo-evaporation flow and a shock running through the clump. Once this shock has moved through the entire clump it starts to accelerate because of the 'rocket effect'. This continues until the entire clump has been photo-ionized. We present an analytic model for the shock and accelerating phases and also the results of numerical simulations which include detailed microphysics. We find a good match between the analytic description and the numerical results and use the numerical results to produce some of the clump's observational characteristics at different phases of its evolution. We compare the results with the properties of the fast moving low ionization knots (ansae or FLIERs) seen in

a number of planetary nebulae. We find that the models match many of the kinematic and emission properties of FLIERs.

Accepted by A&A

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The Brightest Carbon Stars

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It is currently accepted that Hot-Bottom-Burning (HBB) in intermediate-mass asymptotic giant branch (AGB) stars prevents the formation of C stars. Nevertheless, we present the results of some detailed evolutionary calculations which show that even with HBB we obtain C stars at the highest luminosities reached on the AGB. This is due to mass-loss reducing the envelope mass so that HBB ceases but dredge-up continues. The high mass-loss rate produces an optically thick wind before the star reaches C/O> 1. This is consistent with the recent results of van Loon et al. (1997a,b) who find obscured C stars in the Magellanic Clouds at luminosities up to $M_{bol} = 3D - 6.8$.

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The High Excitation Planetary Nebula, NGC 6741

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The compact, bright Peimbert type I planetary nebula NGC 6741 shows an unusually rich spectrum which is studied here from 3700Å to 10370Å with the Hamilton Echelle spectrograph at Lick Observatory. By combining Hamilton Echelle observations with archive UV data secured with the *International Ultraviolet Explorer* (IUE), and with available IR data, we can obtain improved diagnostics and chemical composition of this high excitation planetary nebula. The diagnostic diagram gives T_ϵ = 12,500 K, N_ϵ = 6,300 cm^{-3} for most ions. An improved 'composite' theoretical nebular model is employed. The stellar temperature quoted in the earlier literature seems too high; the highest likely temperature appears to be 140,000 K.

Elemental abundances are estimated from ionic concentrations using an ionization correction factor in the usual way and also from a theoretical model. These different methods show large discordances, implying that one must use great caution in choosing T_ϵ for the determination of the ionic concentrations. Per 10,000 H atoms, there appear to be 8.0 atoms of C, 2.4 of N, 5.4 of O, 1.3 of Ne, 0.068 of S, 0.0023 of Cl, and 0.035 of Ar. NGC 6741 is rich in He, C, & N, compared with the Solar abundance. O is depleted probably by 'hot bottom'

burning. It may be also depleted in metals like Ca, Mg, Si, and Fe which may be tied up in grains. The progenitor star may have been an object in which C, N, & Ne had essentially solar abundances, while heavier elements were less plentiful than the Sun.

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The High Excitation Planetary Nebula, NGC 7662

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Wavelengths and identifications have been provided for approximately 300 lines between 3,660Å and 10,125Å in the spectrum of the arch type of bright, high excitation, planetary nebula NGC 7662. These lines measured with the Hamilton Echelle spectrograph at Lick Observatory and supplemented by image tube data and published results are used to construct diagnostic diagrams and derive ionic concentrations. The electron temperature indicated by [O III] is about 12,500 K; the density regimes consist of N_ϵ = 5,000 $\sim$ 17,000 cm^{-1}. Derivation of precise abundances will require appropriate model calculations but with the aid of a homogeneous spherical model procedures we find C to be enhanced, N marginally so if at all, and heavier elements depleted with respect to the sun, conclusions in harmony with those of Barker.

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Circumstellar molecular radio line intensity ratios

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We have observed a sample of 61 AGB-stars (39 M-stars and 22 C-stars) in circumstellar CO, CS, HCN, SiO, SiS, and SO radio line emission. The main results presented are based on the use of line intensity ratios, a well defined observational quantity that can be used to infer important conclusions as well as to provide constraints on models. Taken together the data are fully consistent with the facts that for this sample the circumstellar envelopes have the same basic chemistry (i.e., C/O<1 or >1) as the central stars, and that the mass loss rates have not changed drastically over periods between 10^2–10^3 years. The HCN(J=1–0)/SiO(J=2–1) intensity ratio discriminates unambiguously between "normal" circumstellar envelopes with C/O<1 (O-CSEs) and >1 (C-CSEs), while the CS(J=2–1), HCN(J=1–0), SiO(J=2-1), and SiS(J=5-4) intensity ratios with respect to CO(J=1–0) are not perfect for this purpose, and neither is the SiS(J=5–4)/SiO(J=2–1) intensity ratio. The data further shows that SO and the C-bearing molecule HCN are ubiquitously present in O-CSEs, and that their line intensities in O-CSEs are qualitatively consistent with the fact that the molecules are formed in a photo-induced circumstellar chemistry in a quantity that depends on the mass loss rate. Hence, both species can in principle be used to estimate the mass loss rate, and the tight relation between the SO($J_K = 3_2 \rightarrow 2_1$) and CO(J=1–0) intensities in O-CSEs shows that SO line emission may even be a good mass loss rate estimator. On the contrary, the SiO(J=2–1) luminosity appears to be essentially independent of the mass loss rate in O-CSEs, possibly due to a larger influence from molecular adhesion onto grains. These results explain why the

HCN(J=1–0)/SiO(J=2–1) intensity ratio increases with the mass loss rate in O-CSEs, and there is no need to invoke e.g. a spread in C/O-ratios for the M-stars to explain the large range of this ratio.

Maser emission is very likely present in the HCN(J=1–0) line in C-CSEs, and it seems to be sensitively dependent on the mass loss rate, i.e., it appears only for $\dot{M} \leq 5 \times 10^{-7}\,M_{\odot}\,yr^{-1}$. Based on time monitoring of this emission towards the C-stars W Ori and X TrA, we suggest that the strongest maser features are due to radial amplification in the F=2–1 transition. The predominance of redshifted maser emission could be caused by an additional amplification in the F=1-1 transition. We find no evidence for a similar maser in O-CSEs.

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Molecules in Envelopes around AGB-stars

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A large number of different molecular species have been found in the gas/dust envelopes that surround asymptotic giant branch stars. The relative simplicity of their geometry and kinematics, and the large variety in their physical and chemical (C/O<1 as well as >1) characteristics, make them excellent targets for the study of molecular formation processes. This review presents a compilation of estimated molecular abundances, discusses the uncertainties involved in their estimate, and makes some comparisons with theoretical predictions.

Invited paper at "Dust and Molecules in Evolved Stars", Manchester, United Kingdom, Mars 24–27, 1997

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Dust Formation in Carbon-Rich AGB Stars

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Dust is a crucial component of circumstellar envelopes surrounding late-type stars as it participates both to the dynamics and chemistry of stellar winds. This chapter reviews the composition and properties of dust grains formed in carbon-rich outflows, and the various mechanisms responsible for mass loss. AGB wind chemical and hydrodynamical models as well as dust formation processes are discussed. We also describe models based on a chemical kinetic approach and the nucleation stages of dust formation. **To be published in The molecular astrophysics of stars and galaxies - a volume honouring Alexander Dalgarno, 1998, (eds. T.W. Hartquist and D.A. Williams), (Oxford University Press: Oxford).**

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

PROFESSOR POSITION AT MONTPELLIER

(for information and circulation)

A professor position is likely to be published at Univ. Montpellier II with the profile "Stellar Physics". The teaching (astronomy and general physics) is to be given in french.

Here are more details (in french):

Le Conseil d'Administration de l'Université Montpellier II a décidé de proposer au Ministère l'affichage d'un poste de professeur en 34 ème section (Astronomie, Astrophysique).
Le profil de ce poste est "Physique stellaire".
Le candidat recruté sera affecté au GRAAL (Groupe de Recherche en Astronomie et Astrophysique du Languedoc) où il effectuera ses activités de recherche. L'enseignement sera à faire au sein du Département de Physique (astronomie et physique générale en 1er et 2ème cycle).
Si le Ministère agrée cette demande, il n'y aura que 3 à 4 semaines entre l'ouverture du concours au JO (fin 97-début 98) et la date limite de dépôt des candidatures.
Tout message ou appel téléphonique demandant des renseignements complémentaires sera accueilli avec plaisir (et discrétion le cas échéant!).

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