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Abstracts of recently accepted papers

Theoretical models of the planetary nebula populations in galaxies: The ISM oxygen abundance when star formation stops

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Using theoretical models of the planetary nebula populations in galaxies, we investigate whether the current oxygen abundances in bright planetary nebulae can be used to predict the oxygen abundance in the interstellar medium when star formation stopped. These models successfully reproduce a constant planetary nebula luminosity function (PNLF) peak luminosity, the PNLF shape in galaxies with and without star formation, and the mean densities and oxygen abundances observed in bright planetary nebulae in the Magellanic Clouds. To accomplish this, we had to couple the evolution of the nebular shell and the central star, and impose a mass-dependent nebular covering factor. In all galaxies, these models predict that a gap develops between the abundances observed in bright planetary nebulae and those in the interstellar medium when star formation stopped. This abundance gap depends primarily upon the oxygen abundance achieved in the interstellar medium when star formation stopped, though it also has some sensitivity to the history of star formation. The abundance gap is always less than 0.35 dex in these models. For the Milky Way, the predicted abundance gap, 0.14 dex, is identical to that observed.

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or via anonnymous ftp on ftp://ftp.obspm.fr/transit/richer/compact5.ps.Z

NaI/KI scattering observations in circumstellar envelopes: contraints on ionization and mass-loss rates

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We investigate KI or NaI fluorescent emission in circumstellar shells to study their ionization and mass-loss rates. First-time KI detections around the mira-type stars W Hya and R Hya are presented. Together with the previously analysed cases of α Ori, α Her and o Cet (Mauron and Caux 1992) and other observations, this gives an extended sample of 10 envelopes which includes μ Cep, CE Tau, β Peg, ρ Per and g Her. A few non-detections are also considered.

In order to compare observed with expected values of KI intensities, the ionization model of Glassgold and Huggins (1986) is used, and the relevant parameters such as distance d, mass-loss rate $\dot{M}$, gas temperature, fractional electron abundance x_e and stellar photoionizing rates $G_\oplus$ have to be known. Using data found in the literature, we estimate these parameters in detail for each case. The values of x_e are obtained with a hypothesized simple rule based on the circumstellar abundance of molecules and grains which could lock electron donors, giving either $x_e \sim 3\ 10^{-4}$ or $\sim 2\ 10^{-5}$. The $G_\oplus$ values depend on the rare ultraviolet spectrophotometric data available for red giants. The kinetic temperature was assumed to be 30 K at the probed impact parameters $r_{obs} \sim 0.5$ to $5\ 10^{16}$ cm.

Despite real uncertainties, the predicted KI intensities with our best estimates of the parameters are in very reasonable agreement with observations in 8 cases in 10. The largest discrepancy concerns the red supergiant μ Cep (M2Ia): our KI data suggest that, similar to α Ori, CO and dust are incompletely formed; for this object we favour $\dot{M}=5\ 10^{-6}$ $M_\odot\,yr^{-1}$. The wind of β Peg is the second case for which a larger mass-loss and/or a larger x_e than primarily believed is suggested, but confirming observations are needed. Finally there is no indication that K or Na might be depleted in silicate grains.

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A survey of CN in circumstellar envelopes

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We have conducted a survey of CN N=2–1 and N=1–0 line emission in the envelopes of evolved stars. The sample consists of 42 objects, including C-rich and O-rich envelopes, S-stars, detached envelopes, and proto-planetary nebulae. Confident detections have been achieved in 30 objects. Both CN lines are bright in C-rich envelopes, and the 2–1 line has been detected in 5 O-rich objects (previously, CN had been detected in only one O-rich envelope). The excitation temperature T_{rot}, evaluated from the 2–1/1–0 intensity ratio, is $\sim$ 3–6 K in most carbon stars, and $\geq$ 10–20 K in O-rich envelopes.

We find that the CN spectra display anomalies in the rotational, fine, and hyperfine line ratios. Anomalies in the rotational excitation appear in W Ori and UU Aur, two stars which are known to present HCN v=0 J=1–0 masers. The excitation of the CN 2–1 line is unusually high in both objects, and UU Aur may present a weak maser effect in this line. Anomalies are also observed in the intensity ratios of the fine and hyperfine components. If such anomalies were due to the envelope thickness, the required line opacities would be excessively high, in particular for low mass-loss rate objects. We thus suggest that the observed anomalies are the result of an anomalous excitation. Pumping through the optical and near-IR bands seems to play a dominant role in the CN excitation.

A comparison with previously published HCN data shows that the CN/HCN ratio of the total numbers of molecules in C-rich stars tends to be larger in the objects with lower mass-loss rate, supporting the idea that CN is mainly formed from the photodissociation of HCN. The average peak abundance of CN is $\sim 1.9\,10^{-5}$ in C-rich objects, and is about 300 times smaller ($\sim 6.6\,10^{-8}$) in O-rich envelopes. The CN/HCN peak abundance ratio is $\sim$0.45 in C-rich stars, in agreement with photodissociation chemical models, and $\sim$0.04 in O-rich objects. This last value is about two orders of magnitude smaller than the predictions of standard chemical models, and suggest that CN is destroyed by additional mechanisms than photodissociation in O-rich envelopes.

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Preprints can be obtained by contacting Rafael Bachiller (bachiller@oan.es)
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CS chemistry in the bipolar nebula CRL 2688

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High spatial-resolution observations of the protoplanetary nebula CRL2688 were made by the CS J =1–0 and J =2–1 lines with the Nobeyama Millimeter Array with angular resolutions of 6" × 6" and 3" ×3" , respectively. The mapping observations reveal that strong CS peaks in the J =2–1 line are located symmetrically at both sides of the optical dark lane at the center, though the CS J =1–0 distribution is rather round. These CS peaks seem to be slightly misaligned from the optical bipolar axis. A modeling of the CRL 2688 envelope results that the density distribution is nearly spherically symmetric but the abundance of CS is enhanced near the polar regions. The increase of the CS abundance near the poles can be explained by the chemistry of sulfur containing molecules in the postshocked region in the high-velocity flow.

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Superwind in evolved OH/IR stars

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We report observations of ^{13}CO (J=1–0) and (J=2–1) emission towards 5 evolved OH/IR envelopes. Four of them are known to have very weak CO emission compared to their infrared flux, and an anomalously high (J=2–1)/(J=1–0) intensity ratio. Modeling of their ^{12}CO and ^{13}CO lines is used to test several possible explanations of this behaviour. We conclude that it is most likely due to the recent onset of a superwind phase. Another interesting result of the modeling is the very low ^{12}C/^{13}C isotopic ratios we derive in these envelopes, of the order of 3.5 and close to the equilibrium value of the CNO cycle. We interpret this as the signature of massive stars at the end of their AGB phase. The sixth envelope, which shows a much lower (J=2–1)/(J=1–0) intensity ratio, also has a low, marginally larger, ^{12}C/^{13}C isotopic ratio. We conclude that it also is a massive object, but in a slightly less evolved stage, just before the superwind phase.

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Measurement of the ^{12}C/^{13}C ratio in Planetary Nebulae

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The ^{12}C/^{13}C isotope ratio in the *ionized* gas in three planetary nebulae has been measured using a new method based on transitions caused by hyperfine effects. The C III] multiplet near 1908Å has an F=$\frac{1}{2}$ - $\frac{1}{2}$ transition at 1909.6Å completely forbidden in ^{12}C, but allowed as a result of the non-zero nuclear spin of ^{13}C. The transition

probability for the ^{13}C $^3_{\frac{1}{2}}P^o_0 - ^1_{\frac{1}{2}}S_0$ transition was calculated in a multi-configuration basis and found to be 6.87×10^{-4}s^{-1}. The Goddard High Resolution Spectrograph aboard the Hubble Space Telescope was used to observe this transition in three nebulae. The ^{13}C line was detected in two C rich nebulae: NGC 3918 and SMC N2. The wavelength of the ^{13}C $^3_{\frac{1}{2}}P^o_0 - ^1_{\frac{1}{2}}S_0$ transition in NGC 3918 was found to be displaced by 7.3 ± 1.6 km s^{-1} from that determined from the experimental energies of the ^{12}C $^3P^o_0$ and $^1S_0$ states; this displacement is attributed to an isotope shift. The ^{12}C/^{13}C abundance ratio was determined to be 15 ± 3 in NGC 3918 and 21±11 in SMC N2. In the Type I nebula LMC N122, which was found to have C III] $^3P^o - ^1S$ velocity components over a range of 230 kms^{-1}, a tentative detection of ^{13}C was made, indicating a low value of the ^{12}C/^{13}C ratio. The ^{12}C/^{13}C ratio in these nebulae is lower than the typical range of values in carbon stars, excepting the very ^{13}C-rich stars. The implications of these new ^{12}C/^{13}C determinations for models of AGB evolution and dredge-up are discussed.

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The evolution of ultraviolet emission lines from circumstellar material surrounding SN 1987A

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The presence of narrow high-temperature emission lines from nitrogen-rich gas close to SN 1987A has been a principal observational constraint on the evolutionary status of the supernova's progenitor. A new analysis of the complete five-year set of low and high resolution IUE ultraviolet spectra of SN 1987A (1987.2–1992.3) provide fluxes for the N V 1240, N IV] 1486, He II 1640, O III] 1665, N III] 1751, and C III] 1908 lines with significantly reduced random and systematic errors and reveals significant short-term fluctuations in the light curves. The N V, N IV], and N III] lines turn on sequentially over 15 to 20 days and show a progression from high to low ionization potential, implying an ionization gradient in the emitting region. The line emission turns on suddenly at 83 ± 4 days after the explosion, as defined by N IV]. The N III] line reaches peak luminosity at 399 ± 15 days. A ring radius of $(6.24 \pm 0.20) \times 10^{17}$ *cm* and inclination of 41.0 ± 3.9 degrees is derived from these times, assuming a circular ring. The probable role of resonant scattering in the N V light curve introduces systematic errors that leads us to exclude this line from the timing analysis. A new nebular analysis yields improved CNO abundance ratios of N/C= 6.1 ± 1.1 and N/O= 1.7 ± 0.5, confirming the nitrogen enrichment found in our previous paper. From the late-time behavior of the light curves we find that the emission originates from progressively lower density gas and that the emitting region has a multi-component density structure. We estimate the emitting mass near maximum ($\sim$ 400 days) to be $\sim$ 0.047 solar masses, assuming a filling factor of unity and an electron density of $2.6 \times 10^4 cm^{-3}$. These results are discussed in the context of current models for the emission and hydrodynamics of the ring.

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The ISO LWS grating spectrum of NGC 7027

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We present a high signal-to-noise ISO Long Wavelength Spectrometer (LWS) grating spectrum of the planetary nebula NGC 7027 from 43–194μm. In total 40 emission lines have been detected, with 30 identified. From the ionized region, we observe fine-structure lines from [N II], [N III] and [O III]. The [O I] and [C II] fine-structure lines from the photodissociation region are the strongest features observed in this spectral region. Amongst the molecular lines, 11 pure rotation CO lines from J=14–13 up to J=24–23 have been detected. The most striking result, however, is the detection in this carbon-rich nebula of the o-H_2O 179.53μm and the OH 119.3μm fundamental lines. Astrophysical implications are briefly discussed.

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Wind fluctuations observed for the [WC9] nucleus of the planetary nebula BD+30^{o}3639

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The CIII and CIV lines in the [WC9] spectrum of BD+30^{o}3639 show variable features, interpreted in terms of radiative acceleration of "blobs" forming in the wind. The variations are like those observed for the WC9 massive stars, and the blobs accceleration appears smaller than for the [WC8] nucleus of NGC 40.

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Preprints can be obtained by contacting acker@cdsxb6.u-strasbg.fr

Variability and nature of the binary in the Red Rectangle Nebula

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We present new observations of the central binary inside the Red Rectangle nebula. The detection of zinc in the optical spectrum confirms that the peculiar photospheric abundances are due to accretion of circumstellar gas. Grey brightness variations with the orbital period are observed. They are interpreted as being due to the variation of the scattering angle with orbital phase. The small orbital separation of the system is not compatible with previous normal evolution of the primary on the AGB. We point out the similarity of the orbital history of this and other similar systems with those of some close Barium stars and suggest that the nonzero eccentricity of the orbit is the result of tidal interaction with the circumbinary disk.

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Preprints can be obtained by contacting hans@ster.kuleuven.ac.be

A detached dust shell surrounding the J-type carbon star Y Canum Venaticorum

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This paper reports the first clear detection of a detached dust shell surrounding the prototypical J-type carbon star Y CVn in 90 μm and 160 μm maps taken with the ISO/ISOPHOT* The projected inner radius of the shell is $180''$–$190''$, corresponding to (6.4–7.1) 10^{17} cm at a distance of 250 pc. The shell thickness is obtained to be (2–5) 10^{17} cm. The mass-loss rate at the formation of the shell is estimated to be in the range (7–20) 10^{-6} $M_\odot$ yr^{-1}, about two orders of magnitude higher than the present-day mass-loss rate derived from CO gas observations. The obtained mass in the shell is (4–14) 10^{-2} $M_\odot$. It is concluded that the mass-loss rate decreased by two orders of magnitude on a short time scale $1.4\,10^4$ years ago assuming an average shell expansion velocity of 15 km s^{-1}, and that Y CVn has been staying at the low mass-loss state. The duration of the previous higher mass-loss phase would be at most $2\,10^4$ years even if the asymmetry in the shell geometry is taken into account. The evolutionary status of Y CVn is also discussed.

* Based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA.

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Preprints can be obtained by contacting izumiura@oao.nao.ac.jp
or via WWW on http://isowww.estec.esa.nl:80/ISO/AandA/

Detection of a new linear carbon chain radical: C_7H

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Following our discovery of C_8H in IRC+10216 (Cernicharo & Guelin 1996), we report the detection in this circumstellar envelope of another linear carbon chain radical, C_7H. The microwave spectrum of C_7H has been recently observed in the laboratory and its rotational line frequencies are precisely known.

With this new detection, the family of acetylenic chain radicals (C_nH) observed in space is complete up to $n = 8$. The members with even numbers of carbon atoms are consistently more abundant than the odd number members; C_7H is found to be a factor of 4 less abundant than C_8H and a factor of 20 less abundant than C_5H.

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Preprints can be obtained by contacting guelin@iram.fr

The rich far-infrared water vapour spectrum of W Hya

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We present an ISO Long Wavelength Spectrometer (LWS) grating spectrum of the oxygen-rich AGB star W Hya from 43–197μm. The spectrum is dominated by a forest of water vapour emission lines, confirming that H_2O molecules are the dominant coolants of the winds of these stars. We have constructed an outflow model for the H_2O spectrum of W Hya, which successfully matches the fluxes of most of the observed H_2O lines, using an adopted wind temperature profile. These fits are sensitive to the mass loss rate, to the H_2O abundance and to the inner radius of the H_2O emitting region. The best fit parameters correspond to a mass loss rate of 6×10^{-7} $M_\odot$ yr^{-1}, inner and outer radii for the emitting region of 1.5×10^{14} and 1×10^{16} cm, and a H_2O/H_2 abundance of 8×10^{-4} for $r \leq 4.5 \times 10^{14}$ cm and 3×10^{-4} at large radii. A decrease of the H_2O/H_2 abundance in the outer envelope is consistent with the predictions of photochemical models. The availability for the first time of observations of the line fluxes from the dominant coolant species should enable improved models of the wind temperature distribution to be produced.

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